DWLBC REPORT

SA Land Condition Monitoring Review

2007/03

Government of South Australia
Department of Water, Land and Biodiversity Conservation

SA Land Condition Monitoring Review

Renata Rix and Karen Parry

Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

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Government of South Australia
Department of Water, Land and Biodiversity Conservation

Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
25 Grenfell Street, Adelaide
GPO Box 2834, Adelaide SA 5001
Telephone National (08) 8463 6946
International +61 8 8463 6946
Fax National (08) 8463 6999
International +61 8 8463 6999
Website www.dwlbc.sa.gov.au

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the state. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources, it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continue to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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The purpose of the *Land Condition Monitoring Review* is to review the needs of stakeholders with interests in land condition monitoring (LCM) data and information, and the adequacy of existing monitoring programs to meet these needs. The review aims to provide an 'ideal' model of LCM in South Australia as foundation for the development of a *State Monitoring, Evaluation and Reporting Operational Plan* (MER-OP). The MER-OP will further develop this model by generating and implementing collaborative monitoring agreements between stakeholders.

In this report, 'land condition' is the combined term for 'land salinity' and 'soil condition' which are both 'Matters for Target' as identified in the *National Monitoring, Evaluation and Reporting Framework* (NMERF). It is envisaged that separate reviews for biodiversity (including revegetation, and pest plant and animal control) and water (surface and ground) will occur and be collated into the integrated MER-OP.

The review has been collated from a wide range of relevant documents and discussions held with various technicians, scientific experts and program managers.

There are multiple drivers for monitoring land condition in South Australia including legislated mandates, formal agreements between states and governments and funding authorities, and an array of strategic and guideline documents designed to facilitate NRM practices and processes. Many of the documents and organisations reviewed do not have clear information needs specified. Some assumptions will have to be made to correlate broad information needs with those organisations already specifically requiring certain datasets and presume the same information will be useful.

The regional NRM Boards are required under the *NRM Act 2004* to monitor the state, condition, and related trends of natural resources. This review has focused on each region's currently endorsed resource condition targets (RCTs) as a means to determine the data and information needs. In many cases there are too many possible indicators identified, and these need to be rationalised in light of state and national monitoring protocols and directions. A review of regional NRM Board RCTs may be necessary for several regions. Creating RCTs has been difficult for regions given the recent changes to NRM in South Australia and the requirement for collaborative arrangements at national, state and regional levels. A project commissioned by the Joint South Australia and Commonwealth Natural Resources Management Committee will hopefully provide clearer direction to this process.

In addition to meeting their own needs, the state and regions also have responsibilities with respect to the NMERF as outlined in the *National Framework for Natural Resource Management Standards and Targets* (Natural Resource Management Ministerial Council 2002a).

The existing land condition monitoring activity identified in this report were reviewed and the following recommendations made:

Land Condition Monitoring Program

Recommendation 1: If the Land Condition Monitoring Program (LCMP) undertakes to produce regional land condition reports within new NRM boundaries, part of the process of

producing the report should be to enable local and regional data and knowledge to be incorporated into the report to support regional interpretation.

Recommendation 2: DWLBC, in conjunction with the regional NRM Boards, considers development of a communication strategy for the LCMP reports and information, which includes consideration of the most suitable format for a variety of audiences.

Recommendation 3: DWLBC and the regional NRM Boards incorporate the LCMP into a long-term strategic monitoring plan for South Australia, such as the MER-OP.

Recommendation 4: DWLBC implement succession planning and mentoring activities to ensure experienced and trained staff continue to manage the LCMP.

Recommendation 5: DWLBC provides expert help to work with the LCMP Manager to update software and processes used to manage the LCM data.

Field Survey Program for Wind and Water Erosion

Recommendation 6: DWLBC considers integrating remote sensing monitoring to expand current coverage of the LCMP and to provide a further level of confidence in the erosion indexes.

Land Manager Surveys

Recommendation 7: State agencies and regional NRM Boards investigate the potential for additional Land Manager Surveys to expand the current understanding of land management trends.

SASPAS data

Recommendation 8: DWLBC investigates potential stakeholder interest in additional Land Manager Surveys for possible resource assistance.

Recommendation 9: DWLBC investigates opportunities for creating an access agreement to soil analysis data from commercial fertiliser retailers.

Recommendation 10: DWLBC (and regional NRM Boards) investigates other potential users of soil analysis data and what kind of contribution they may make to the agreement.

Land and Soil Information Framework

Recommendation 11: DWLBC considers the value of conducting additional soil surveys to enhance the SaLI database and mapping products.

Recommendation 12: DWLBC (and potential collaborative organisations) considers conducting repeat soil surveys for a select number of sites and parameters to trial the possibilities of repeat site sampling for monitoring.

Recommendation 13: DWLBC edits and adds to the SaLI database all the paper-based point soil survey data to ensure maximum information availability and that knowledge is not lost.

Dryland Salinity Program

Recommendation 14: DWLBC (and potential collaborative organisations) review the current groundwater monitoring programs and considers whether areas currently at moderate risk of salinisation should be included in a monitoring program.

Pastoral Areas Land Monitoring System

Recommendation 15: The Pastoral Program, in cooperation with ACRIS and other rangeland monitoring bodies, continues to collaborate on data collecting methods to meet pastoral assessment and future monitoring requirements for land condition and biodiversity.

Recommendation 16: DWLBC hastens the development of ALIS to ensure the effective operation of the pastoral assessment and monitoring programs.

Recommendation 17: The Pastoral Program or DWLBC investigates means to fund and attract new staff to the program as a matter of priority to assist with the current backlog of data processing.

Recommendation 18: Further investigation of the options for remote sensing monitoring in the rangelands in combination with the ground-based assessment and potential collaborative relationships with landholders.

The 'ideal' LCM model is the result of discussions with technical experts and stakeholders throughout the development of this report. The model is the current best fit of data needs and programs that can meet those needs in the most practical, efficient and effective manner. It was felt by technical staff that a practical, realistic and affordable approach was far more useful to develop than an 'ideal' that will never be achievable.

Many new programs are proposed in the 'ideal' monitoring model in Chapter 4, including:

- Repeat pH and soil nutrient sampling sites.
- Commercial laboratory soil analysis results.
- Inland acid sulfate soils mapping (already underway and funded externally).
- Inland acid sulfate environments water quality monitoring.
- DustWatch.
- Land cover and/or vegetation cover.
- Gully, mass and riparian zone erosion surveys in water erosion risk zones.
- Gully, mass and riparian zone erosion monitoring.
- Soil carbon analysis and modelling (RothC).
- CRCGA calculator modelling.
- Clay spreading contractor surveys.

Significant further discussion and endorsement of this 'ideal' model should occur during the development of the MER-OP.

The report is not intended to make judgement of the science or technical components of the presented monitoring programs. Further work will be required to develop data collection, storage and interpretation protocols for new programs.

There is significant research being conducted utilising satellite imagery. The use of spatial imagery technology should compliment ground-based programs and not be considered appropriate as a stand-alone monitoring tool.

Land degradation issues associated with, and restricted to, irrigation industries have not been addressed in detail in this report.

A draft report titled 'Monitoring soil condition across Australia: recommendations from the expert panels' (McKenzie & Dixon 2006) was released in July 2006. The regions and states will need to keep informed of the expert panel's work and trial results.

This report should be considered a 'working' document and not an end-of-line agreement given the anticipated continual interpretation of the new *State Natural Resources Management Plan* (NRM Plan), monitoring and evaluation development at the national, state and regional level.

1. INTRODUCTION

1.1 PURPOSE OF REVIEW

The purpose of the *Land Condition Monitoring Review* is to review the needs of stakeholders with interests in LCM data and information, and the adequacy of existing monitoring programs to meet these needs.

The review aims to provide an 'ideal' model of LCM in South Australia as foundation for the development of a *State Monitoring, Evaluation and Reporting Operational Plan* (MER-OP). The MER-OP will further develop this model by generating and implementing collaborative monitoring agreements between stakeholders.

This report should be considered a 'working' document and not an end-of-line agreement given the anticipated continual interpretation of the new *State Natural Resources Management Plan* (NRM Plan), and monitoring and evaluation development at the national, state and regional level.

1.2 BACKGROUND

Monitoring and evaluation plays an important role in the delivery and reporting of natural resource management (NRM) activities. It is vital for accountability, adaptive management, and program improvement at all levels (Government of South Australia 2006).

Monitoring provides a reference point to:

- assess the health of natural resources
- identify the condition of natural resources to better target future investments
- measure progress towards agreed outcomes and goals
- evaluate the appropriateness and effectiveness of policies, strategies and programs
- assist the development of land management knowledge and the impact of sustainable land management practices.

The *Land Condition Monitoring Review* was initiated as part of a broader natural resource condition and capacity building monitoring review of South Australian NRM regions. Regional NRM bodies, state agencies, and State Assessment Panels recognised the need to optimise resource use and develop a coordinated approach to natural resource condition monitoring, evaluation and reporting systems.

There is considerable discussion and development work for resource condition monitoring occurring in South Australia. Some of the activities include:

- development of regional NRM plans and investment strategies
- implementation of new state NRM legislation
- rolling out of the State NRM Plan
- development of state and regional monitoring, evaluation, and reporting frameworks (MERFs).

In addition to meeting their own needs, the state and regions also have responsibilities with respect to the *National Monitoring and Evaluation Framework* (NMEF) as outlined in the *National Framework for Natural Resource Management Standards and Targets* (NFNRMST).

Despite plenty of discussion and activity at national, state and regional level with respect to resource condition monitoring, evaluation and reporting, all stakeholders must continue to progress developing their monitoring, evaluation and reporting processes and data needs.

Undoubtedly, stakeholders will need to reconsider their position due to their possibly unrealistic data needs or critical progress (e.g. finalisation of key documents) made by other stakeholders.

This review will endeavour to look broadly at data and information requirements with respect to land condition, as business needs, roles and responsibilities may identify a need for data but without a responsibility to monitor or collect data.

1.3 METHODOLOGY

The stages of developing an integrated monitoring system or strategy are outlined in Figure 1. This review encompasses steps 1 to 6 and a portion of 7 and will provide foundation information for steps 7, 8 and 9 that will be detailed in the *State Monitoring, Evaluation, and Reporting Operational Plan*.

The review has been collated from a wide range of relevant documents and discussions held with various technicians, scientific experts and program managers.

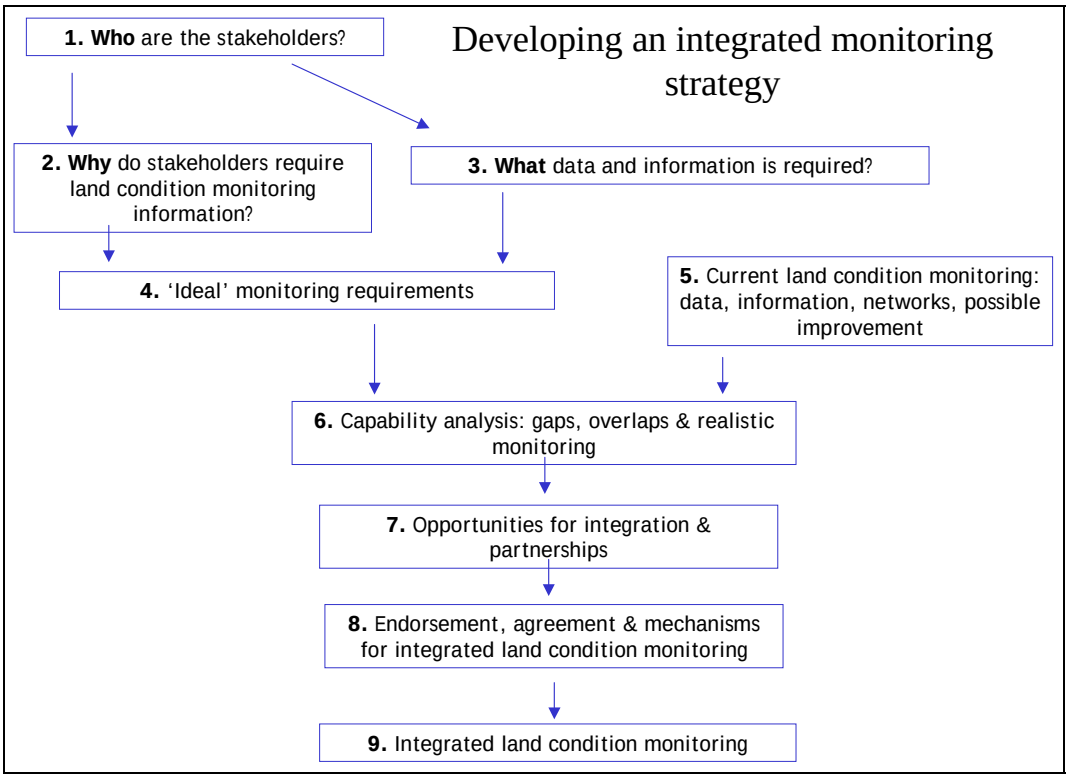

Figure 1. Developing an integrated monitoring strategy (adapted from SKM 2002)

The stakeholders identified in this review have been determined predominantly through the review of land condition related legislative and strategic documents. Additional stakeholder groups may exist but are expected to have pre-existing relationships with those stakeholders who have been identified.

Given that the term 'land condition' may encompass a large range of issues, some limitation on the scope was considered necessary.

In this report, 'land condition' is the combined term for 'land salinity' and 'soil condition' which are both 'Matters for Target' as identified in the NMEF. This LCMR will encompass features of land most relevant to agricultural production and sustainable land management, and pays limited attention to the rangelands region and land reserved for conservation purposes.

The land condition themes discussed in this review include:

- soil erosion — wind and water
- soil acidity
- soil salinity
- soil physical condition — structure, surface crusting, sodicity, compaction, hardpans
- soil fertility
- water-repellent soils
- soil carbon
- additional specific land condition requirements of the regional NRM Boards not covered above.

In reality, land condition encompasses many more potential themes of information including climate, biodiversity, revegetation, land management practices, pest plant and animal control, surface water and groundwater. It is envisaged that separate reviews for biodiversity (including revegetation and pest plant and animal control) and water (surface and ground) will occur and be collated into the integrated MER-OP. Monitoring programs with similar data capture requirements will be integrated in the MER-OP to ensure an effective and efficient process for all stakeholders involved.

The review details information on land management indicators including land use, landholder knowledge and awareness, and changes in land management practices. This information is sometimes referred to as 'surrogate' indicator data since it is not a direct measurement of the resource; however, it is considered crucial to understanding land condition change.

The review will also capture key state contextual data needs that are seen to be crucial to understanding LCM data.

Chapter 4 presents a proposed 'ideal' LCM model that identifies:

- priority land condition themes
- existing programs required by stakeholders
- new programs required by stakeholders
- lead, collaborative and interested agencies
- monitoring data collection and reporting time frames
- regional NRM Boards priority data needs.

The capability analysis provided in Chapter 5 summarises the monitoring data needs at national, state and regional level; describes existing monitoring programs; and compares those to the 'ideal' monitoring programs in order to identify gaps, overlaps or program deficiencies. A table containing the priority programs for improvement or development is included.

Chapter 6 discusses additional considerations, which may impact on the future of LCM in South Australia.

The concluding recommendations for the review are summarised in Chapter 7.

NOTE: Information included in this report was current at the time of writing. The following have changed since the original draft was prepared:

- A new State Strategic Plan was released in January 2007 and now includes a Land Condition Target based on the wind erosion index.
- A National SoE report was released in 2006.
- VivaSa (see section 2.2.12) has now been disbanded.
- The Joint Steering Committee 'Evaluation of Regional Target Setting in South Australia' project (see section 6) is now complete.

2. ROLES, RESPONSIBILITIES, AND STAKEHOLDER BUSINESS AND INFORMATION NEEDS

This chapter aims to answer parts 2 and 3 of the strategy detailed in Figure 1 — to identify 'why' stakeholders require LCM information and 'what' data and information are required.

Stakeholders may have multiple purposes and drivers for collecting or utilising land condition related monitoring data and information. Purposes may include statutory obligations, partnership agreements, and business needs (information necessary for a business to conduct its work).

Some organisations, such as DWLBC, will have a complex hierarchy of drivers and multiple purposes for monitoring and evaluation information.

The following sections summarise each stakeholder's LCM interests or needs as researched through key documents and discussions with individuals.

It is important to note that at this stage the roles and responsibilities have not been formally acknowledged by each organisation. Endorsing these responsibilities is an important step in the process of identifying which organisation should take a lead or collaborative role in both monitoring and evaluation as a whole or for a specific land condition theme. This process will occur during the development of the MER-OP.

The anticipated desired end point for this chapter would be to determine the specific data needs that enable the stakeholder to meet their monitoring requirements. In reality, many of the documents guiding the determination of monitoring responsibilities are vague and interpretation is an ongoing process. This report endeavours to provide a current interpretation of roles, responsibilities and data needs where they can be determined. Undoubtedly this interpretation will be subject to change in the future, especially given the recent adoption of the State NRM Plan.

In the following sections, business and information needs have been divided into national, state, and regional level.

2.1 NATIONAL REQUIREMENTS

This section summarises and takes extracts of national agreements, strategies and legislation with land condition related monitoring, evaluation and reporting requirements. The aim is to provide an information source of LCM requirements at the national level. Interpretation of the requirements in these documents is provided where possible.

2.1.1 MURRAY DARLING BASIN AGREEMENT 1992

The purpose of the *Murray Darling Basin Agreement 1992* is *' …to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of water, land and other environmental resources of the Murray-Darling Basin'.*

Whilst 'land' features as a resource of concern within the agreement, the prime concerns discussed at most length are water quality and quantity.

The agreement makes a broad statement regarding monitoring of natural resources within the MDB as follows:

40. 'The Commission:

(a) must, from time to time, advise the Ministerial Council on the adequacy and effectiveness of the arrangements for monitoring: and

(b) subject to Clause 42, may establish, maintain and operate effective means for monitoring:

the quality, extent, diversity and representativeness of water, land and other environmental resources of the Murray-Darling Basin, including but not limited to:

(i) aquatic and riverine environments, and

(ii) the effect of groundwater on water, land and other environmental resources.'

2.1.2 NATIONAL STRATEGY FOR ECOLOGICALLY SUSTAINABLE DEVELOPMENT

The purpose of the *National Strategy for Ecologically Sustainable Development* (NSESD) is to facilitate a coordinated and cooperative approach to ecologically sustainable development which encourages long-term benefits for Australia over short-term gains (Ecologically Sustainable Development Steering Committee 1992).

The NSESD indicates that governments will need to monitor and assess whether the actions and initiatives in the policy are being implemented and effective in achieving the goals of the Strategy:

- Objective 33.1 — to monitor and review the implementation and effectiveness of actions contained in this strategy at the program, sectoral and national levels.
- Objective 14.2 in the NSESD of December 1992 also called for national State of the Environment (SoE) reporting which led in part to the production of the first SoE report in 1996. Following this reporting requirement driven by the pursuit of ecologically sustainable development, the Australian Government formalised the reporting need in the 1999 *Environment Protection and Biodiversity Conservation Act.*

2.1.3 ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

The *Environment Protection and Biodiversity Conservation Act 1999* aims to protect the environment, particularly through those issues identified as matters of National Environmental Significance. The Act was designed to streamline national environmental assessment and approval processes, protect Australian biodiversity, and integrate the management of important natural and cultural places.

The EPBC Act also mandates the preparation of a National SoE Report to be tabled through parliament:

'Section 516B — State of the Environment reports

a) The Minister must cause a report on the environment in the Australian jurisdiction to be prepared in accordance with the regulations (if any) every 5 years. The first report must be prepared by 31 December 2001.

b) The report must deal with the matters prescribed by the regulations.

c) The Minister must cause a copy of the report to be laid before each House of the Parliament within 15 sitting days of that House after the day on which he or she receives the report.'

2.1.3.1 National SoE Report

A National SoE Report has been delivered in 1996 and 2001 (Australian Government 2001) and the next report is due in 2006. The objectives of this report are to provide accurate, up-to-date and accessible information about environmental and heritage conditions, trends and pressures for the Australian continent, surrounding seas, and Australia's external territories.

The National SoE Report is also driven by Australia's membership with international organisations that have specific reporting obligations for various aspects of the Australian environment. These organisations include:

- Organisation for Economic Cooperation and Development
- United Nations Environment Programme
- United Nations Economic and Social Commission for Asia and the Pacific
- Convention on Biological Diversity
- Framework on Climate Change Convention
- Montreal Process for forestry reporting
- World Meteorological Organization.

Since 1996, there has been significant investment by governments to improve data and information quality for SoE reporting. Some of the programs developed include the Cooperative Research Centres, the National Land and Water Resources Audit, and the Australian Greenhouse Office. The states remain the major custodians for much of the natural resource management data in Australia.

The report is structured around eight environment and heritage themes including atmosphere, inland waters, coasts and oceans, land, biodiversity, human settlements, natural and cultural heritage, Antarctica, and other external territories.

In 1998, the Australian and New Zealand Environment and Conservation Council (now partially replaced by the Natural Resource Management Ministerial Council) State of the Environment Reporting Task Force produced a discussion paper on a draft set of core indicators. The core set of environmental indicators was endorsed by ANZECC in December 1999 and published in 2000 in a document titled *'Core environmental indicators for reporting on the state of the environment'* (ANZECC 2000). The indicators are based on the Organisation for Economic Co-operation and Development's (OECD's) 'pressure-state-response' (PSR) model as the basis to examine the six major issues for Australian ecosystems. The core indicators were reported in the 2001 National SoE Report are listed in Table 1.

Table 1. 2001 National SoE Report 'land' theme core indicators

Land theme or issue	Core indicator	Actual indicator
Erosion	Potential for erosion	The area of soil that is bare or lacks vegetation cover to prevent accelerated wind or water erosion, classified by land-use type, soil type, climate and slope of land.
	Wind erosion from high wind events	Changes in the frequency of dust storms relative to high wind events.
Land use and management	Changes in land use	Area of each land use, described under a standard classification.
Acidity	Area affected by acidity	Area of land that is reported as having acidity within the top metre in regions of Australia with greater than 250 mm annual rainfall.
Contamination	Exceedance of the maximum residue levels in food and produce	Number of samples of rural produce and food that exceed the Maximum Residue Levels for contaminants are a surrogate for land and/or water contamination.
Salinity	Area of rising watertables	Area underlain by shallow watertables and areas where watertables are rising.
	Area affected by salinity	The area of land that is reported as having saline soils within the top metre in regions of Australia with greater than 250 mm annual rainfall. This indicator covers areas affected by dryland and irrigation salinity.

Additional environmental indicators were reported in the 2001 National SoE Report. These are listed in Appendix E. Not all jurisdictions were able to report on all indicators. The environmental indicators used in the 2001 SoE Theme Reports have been reviewed, and revised sets of environmental indicators were recommended to the National State of the Environment Reporting Coordinating Committee for use in the 2006 report (Department of the Environment and Heritage 2005). The committee has sought the advice of experts in the various themes to ensure that the indicators are robust and relevant. The indicators have not yet been endorsed by the committee nor made publicly available.

2.1.4 NATURAL HERITAGE TRUST ACT 1997

The *Natural Heritage Trust Act 1997* was established to manage the Natural Heritage Trust of Australia Account. The account was sourced with a total of $1.35 billion predominantly from the partial sale of Telstra. The purpose of establishing the account was to conserve, repair, and replenish Australia's natural capital infrastructure. In terms of land condition, the National Land and Water Resources Audit (NLWRA) project funded by the account is directed at monitoring (Australian Government 2005b).

2.1.5 NATIONAL ACTION PLAN FOR SALINITY AND WATER QUALITY AND NATURAL HERITAGE TRUST BILATERAL AGREEMENTS

In order to streamline planning and implementation of natural resource management, the Natural Heritage Trust (NHT) and National Action Plan for Salinity and Water Quality (NAP) have been integrated through bilateral agreements involving state and Australian governments (Australian Government 2006a,h).

Under the NAP agreement, the Australian and South Australian Governments have committed to an action plan to motivate and enable regional communities to use coordinated and targeted action to:

- prevent, stabilise and reverse trends in salinity, particularly dryland salinity, affecting the sustainability of production, the conservation of biological diversity, and viability of infrastructure
- improve water quality and secure reliable allocations for human uses, industry, and the environment.

The NHT was set up by the Australian Government in 1997. Since then, thousands of community groups and organisations have received funding for environmental and natural resource management projects. The NHT provides funding for environmental activities at a community, regional, state and national level.

The objectives of the NHT are:

- *Biodiversity conservation* — the conservation of Australia's biodiversity through the protection and restoration of terrestrial, freshwater, estuarine and marine ecosystems and habitat for native plants and animals.
- *Sustainable use of natural resources* — the sustainable use and management of Australia's land, water and marine resources to maintain and improve the productivity and profitability of resource-based industries.
- *Community capacity building and institutional change* — support for individuals, landholders, industry and communities with skills, knowledge, information and institutional frameworks to promote biodiversity conservation and sustainable resource use and management.

Under the bilateral agreements, South Australia must develop a monitoring, evaluation and reporting strategy with clear and transparent roles and responsibilities, and fund its implementation. The strategy must be consistent with the NFNRMST (see Section 2.1.6). The agreement also stipulates that indicators and baselines will be developed at regional, state and national scales consistent with other natural resource management policy initiatives at state and federal level. The monitoring will, amongst other reasons, be used to evaluate NHT and NAP programs. At the regional level, a single accredited NRM plan (see Section 2.3.2) and a single investment strategy per region will be used as the basis for investment for both programs. Plans will consider all environmental, social and economic impacts of natural resource management decisions on a regional basis.

In South Australia, NAP and NHT are jointly delivered through the Natural Resource Management Support Division of DWLBC and the Departments of Agriculture, Fisheries and Forestry and Environment and Heritage through the Australian Government's Natural Resources Management Team. A Joint Steering Committee (JSC) has been established to oversee the development and implementation of NAP and NHT in South Australia. The JSC is responsible for:

- Developing principles and criteria to guide NHT and NAP investment.
- Developing and implementing communication and monitoring and evaluation strategies.
- Assisting the regional bodies in developing regional plans and investment strategies.
- Consideration of the INRM Plans (now replaced by Regional NRM Plans) and making recommendations to Australian Government and South Australian Ministers for accreditation.

- Recommending NHT and NAP investment programs to Australian Government and South Australian Ministers.
- Reviewing quarterly and six-monthly reports for activities funded under NAP and NHT.
- Agreeing to the release of funding to proponents from the joint Australian Government and South Australia account for the NHT and NAP.

2.1.6 NATIONAL FRAMEWORK FOR NATURAL RESOURCE MANAGEMENT STANDARDS AND TARGETS

The key driving forces for monitoring programs at the national level comes from the (NFNRMST) documents (Natural Resource Management Ministerial Council 2002a). The NFNRMST was developed to assist and create consistency for NRM target setting, monitoring, evaluating and reporting across Australia. It was endorsed by the Natural Resource Management Ministerial Council, which comprises representatives from Australian, state and territory governments.

The NFNRMST outlines the principles and requirements for NRM standards and targets. It identifies a number of key 'Matters for Target' to help prioritise and focus NRM investment. The framework comprises:

- **national natural resource outcomes** — and a minimum set of matters for which regional targets are required, with associated national guidelines and protocols for regional target-setting, monitoring and reporting
- **national standards defining best practice management** of natural resources, applying principally to legislative, policy, process and institutional systems that, when adopted, will assist in the achievement of national outcomes.

2.1.7 NATIONAL (NATURAL RESOURCE) MONITORING AND EVALUATION FRAMEWORK

The National (Natural Resource) Monitoring and Evaluation Framework (NMEF) was developed by the Australian, state and territory governments and endorsed by the Natural Resource Management Ministerial Council to help monitor and report on the impact of the NAP and NHT (Natural Resource Management Ministerial Council 2002b).

The NMEF expands on the broad 'Matters for Target' determined in the NFNRMST using a range of indicators. The NMEF aims to promote consistency in measuring progress towards targets and to allow monitoring and progress reporting to be aggregated up to a national level. A key mechanism for this to occur is the development of a core set of resource condition indicators that can be applied nationally at regional and local levels. The indicators (and protocols for monitoring) are still in development. A table listing the 'Matters for Target' and present indicator and protocol status is provided in Appendix B.

2.1.8 NATIONAL LAND AND WATER RESOURCES AUDIT

The National Land and Water Resources Audit (NLWRA) is an initiative of the NHT (Natural Heritage Trust 2006). Its mission is to 'provide data, information and nationwide assessments of Australia's land, water and biological resources to support sustainable development'.

The primary objectives of the audit are:

- to estimate the direct and indirect causes and effects of land and water degradation on the quality of the Australian environment and to estimate the effects of land and water degradation on Australia's economy
- to provide a baseline for the purposes of carrying out assessments of the effectiveness of land and water degradation policies and programs.

A strategic plan for audit activity until 2007 has been developed in consultation with members of the Audit Advisory Council. The six key areas of activity, all of which involve coordination of data and information, are:

1. Developing a consistent national reporting mechanism for collating natural resource information collected under the NMEF.
2. Collating information to support the National SoE Report (Australian Government 2006g).
3. Developing nationally consistent, but regionally relevant, integrated resource condition reports.
4. Facilitating reporting on the ongoing collection of natural resource information for key theme areas including those related to the NMEF.
5. Reporting on National Data and Information Management (in collaboration with ANZLIC — the Spatial Information Council).
6. Developing national resource assessment (as requested by clients).

The audit completed its first series of national natural resource reports in 2002 and has the responsibility to report again by 2006–07, this time using the National Natural Resource Indicators as outlined in the NMEF.

The NLWRA has undertaken several projects to ascertain the availability and adequacy of data at the regional level that could be used to report on the national resource condition indicators. Through this process, the NLWRA has realised that there is very little monitoring data available and that in many cases the regions will be accessing state data. The NLWRA's current approach is to gather as much information on 'information products' available within state and territory agencies, which can be used to report on the national indicators.

Whilst, there is agreement that the 'Matters for Target' and many of the indicators are relevant, the accompanying protocols (methodologies) are not all fully developed. The NLWRA formed expert panels to develop and advise on recommended monitoring protocols. The 'land salinity' protocols have been agreed and accepted. The 'soil condition' protocols have just been released (July 2006) in a report titled '*Monitoring soil condition across Australia: Recommendations from the Expert Panels'* (McKenzie & Dixon 2006). These indicators and protocols are likely to be accepted in the near future following some trial projects. The results and recommendations from this report have been considered and adapted in developing the 'ideal' monitoring model in Chapter 4. Table 2 shows the current status of the national land condition related indicators and protocols.

At this stage, the protocols listed 'for advice' are unlikely to change significantly. However, the state and regions will still need to develop monitoring plans with their own needs and limitations accounted for.

Table 2. Status of National Resource Condition Indicators

Matter for target	Indicator heading	Recommended indicators	Indicator (and protocol) status
Land salinity	Area of land threatened by shallow or rising watertables	Depth to groundwater	Agreed
		Groundwater salinity	Agreed
		Location, size and severity of salt affected areas	Agreed
Soil condition	Soil condition	Soil acidification	For advice
		Soil erosion — water	For advice
		Soil erosion — wind	For advice
		Soil carbon content	For advice

(Natural Resources Management Ministerial Council 2006c)

2.2 STATE REQUIREMENTS

This section will consider LCM requirements and business needs at a state level. The main driver for monitoring in South Australia is the recently established *State Natural Resources Management Plan 2006* (NRM Plan). The NRM Plan includes South Australia's Monitoring and Evaluation Framework that identifies the role of regional NRM Boards and state agencies in monitoring natural resources condition. The NRM Plan contains a number of broad Resource Condition Targets (RCTs). Details regarding indicators, specific data requirements and monitoring programs have not yet been documented, and will be confirmed and endorsed in the state's MER-OP which is currently under development. A Monitoring Evaluation and Reporting Policy Group (MER-PG) has recently been formed to coordinate the state government agencies and regional boards at a policy level to assist in progressing the MER-OP. The agencies involved include PIRSA, Forestry SA, DEH, EPA, and DWLBC as chair.

This section will collate and attempt to clarify monitoring needs as described by key strategic documents and agency business needs; and will contribute to the development of the state MER-OP.

2.2.1 NATURAL RESOURCES MANAGEMENT ACT 2004

The purpose of the *Natural Resources Management Act 2004* is to 'assist in the achievement of ecologically sustainable development in the state by establishing an integrated scheme to promote the use and management of natural resources'.

The NRM Act has formulated a management structure for the state's natural resources, which includes a NRM Council, regional NRM Boards, and sub-regional NRM groups. Each level of management has the following stated functions relative to LCM:

The functions of the Minister under this Act are:

- s.10(1) a to keep the state and condition of the natural resources of the state under review; and
- s.10(1) e to compile, maintain and update information in relation to the state's natural resources; and
- s.10(1) f to promote public awareness of the importance of the state's natural resources and to encourage the conservation of those resources.

The functions of the NRM Council are:

s.17(1) b to audit, monitor and evaluate the state and condition of natural resources across the state, and to evaluate and report on:

(i) the performance of the NRM authorities established under this Act; and

(ii) the integration of natural resources management practices on account of this Act.

s.17(1) d to monitor and evaluate the effectiveness of:

(i) this Act; and

(ii) the State NRM Plan; and

(iii) other natural resources management policies initiated by the government.

Under the NRM Act, the NRM Council must also prepare and maintain a State NRM Plan that must:

s.74 (3) a (i) assess the state and condition of the natural resources of the state; and

(ii) identify existing and future risks of damage to, or degradation of, the natural resources of the state; and

(iii) provide for monitoring and evaluating the state and condition of the natural resources of the state on an ongoing basis.

s.74 (6) The NRM Council must review the State NRM Plan at least once in every 5 years.

The functions of the regional boards are:

s.29 (1) b (i) to prepare a Regional NRM Plan in accordance with this Act; and

(ii) to implement that plan; and

(iii) to keep the plan under review to ensure that the objects of this Act are being achieved.

The Regional NRM Plan must:

s.75 (3) e set out the method or methods that the board will use:

(i) to monitor the state and condition of natural resources for the purposes of this Act, and related trends; and

(ii) to assess the extent to which it has succeeded in implementing the plan, with particular reference to the monitoring and evaluation of the effectiveness of natural resources management programs and policies implemented at the regional and local level; and

(iii) to assess the extent to which the board has succeeded in achieving its goals.

See Section 2.3 for further details regarding the regional NRM Boards and plans.

The NRM Council must also provide a report on its activities for the financial year, accompanied by annual reports from the regional NRM Boards and NRM groups.

DWLBC, DEH and the EPA answer to the needs of the Minister for Environment and Conservation, who has charge of the NRM Act and has determined that DWLBC is the lead agency administering the Act. However, there still needs to be cross-agency agreement on

achieving objects of the Act, and DWLBC's roles and responsibilities require further clarification.

2.2.2 STATE NATURAL RESOURCES MANAGEMENT PLAN

The State Natural Resources Management Plan (NRM Plan; endorsed in February 2006; Government of South Australia 2006) is required under the state NRM Act. The NRM Plan contains the strategic policy for managing the state's natural resources and provides a framework for all state NRM initiatives. The plan has developed 10 resource condition targets (RCTs; including one for land) to describe the desired condition of natural resources within specific time frames. The RCT for 'land' is: 'By 2011, land condition will have improved compared to 2006'.

Land condition is described as '…an aggregated assessment of multiple land and soil parameters that in total describe the condition of land…'. Tables 3 and 4 show the break down of RCTs, goals, milestones and strategies that LCM can contribute to in some way.

The NRM Plan adopts the former Soil Conservation Council's (SCC) Soil Conservation and Land Management: Directions for South Australia (Morgan et al. 2005) document as identifying key directions for soils and land in South Australia. This document identifies a number of soil and land targets for South Australia (detailed in Section 2.2.9). The NRM Plan also endorses South Australia's Dryland Salinity Strategy (PIRSA 2001) to provide guidance for soils and land management. It is assumed that the comment 'The assessment methodology has been developed by state government and will be refined' (Government of South Australia 2006) infers the methods used by the former SCC (Morgan et al. 2005), the LCMP, the Dryland Salinity Strategy (PIRSA 2001), and possibly the Audit (Natural Heritage Trust 2001), are the basis for the future LCMPs in South Australia, which this report intends to build upon.

An additional key focus of the Plan is Goal 3 which is about involving communities to build capacity and connections for a more integrated NRM approach. Many community groups are already involved in on-ground works and perhaps community involvement in the direct monitoring of land condition could be investigated further.

Monitoring and evaluation plays a large role in the NRM Plan. The plan contains the first *South Australian Monitoring and Evaluation Framework* described in the following section (Government of South Australia 2006).

2.2.3 SOUTH AUSTRALIA'S MONITORING AND EVALUATION FRAMEWORK

The *South Australia's Monitoring and Evaluation Framework* (SAMEF) applies to all relevant agencies, boards and groups that deliver NRM. The aim of the framework is to ensure that monitoring and evaluation across the state is coordinated, integrated, effective and efficient.

The SAMEF stipulates that an 'Operational Plan' (MER-OP) will be developed collaboratively between the relevant bodies to implement the framework. The SAMEF clearly states that no duplication of data collection or reporting should occur and that these tasks should be coordinated. Any shared interests in data and reporting should be identified and explored, including identifying indicators to report overall condition of ecosystems and landscapes.

Table 3. RCTs, goals and milestones relevant to land condition identified in the state NRM Plan

Natural resources	Resource condition target	Explanation	NRM goals	Milestones
Land	By 2011, land condition will have improved compared to 2006.	Land condition is an aggregated assessment of multiple land and soil parameters that in total describe the condition of land. The assessment methodology has been developed by the state government and will be refined.	2: Prosperous communities and industries using and managing natural resources within ecologically sustainable limits (Principal goals and milestones)	2.1 By 2020, sustainable natural-resources-based industries will deliver multiple outcomes. 2.2 By 2010, land capability assessments will take into account climate change risks, and will be a key element of planning for all land-based industries. 2.5 By 2018, the River Murray will be managed within ecologically sustainable limits.
			1: Landscape-scale management that maintains healthy natural systems and is adaptive to climate change (Secondary goals and milestones)	1.1 By 2010, the NRM sector will have an increased understanding of the impacts of climate change on natural resources compared to 2006. 1.2 By 2010, the mechanisms and instruments will be in place to respond to the natural resource impacts of key threats (including climate change). 1.3 By 2010, the capacity of terrestrial and aquatic ecosystems to adapt to climate change (and other threats) will be greater than in 2006. 1.4 By 2010, natural-resource-based industries will have a greater capacity to adapt to climate change than in 2006. 1.5 By 2020, reduce the NRM sector's net contribution to greenhouse gas emissions compared to 2006 levels.
			4: Integrated management of biological threats to minimise risks to natural systems, communities and industry (Secondary goals and milestones)	4.1 No new pest species become established in South Australia from 2010. 4.2 There is a net reduction in the impact of established pest species and over-abundant native species on natural and productive systems and the community by 2010.

Table 4. State NRM Plan strategies contributed to by LCM in South Australia

Strategies	Contribution of LCMPs
2.1.1 Investigate the investment arrangements, rights and responsibilities relating to the legacy of natural resource degradation and private/public benefits to inform the next State NRM Plan.	Land condition (LC) monitoring and the trends that can be documented are collated from various information sources including the changing behaviours and practices of land managers who have direct impact on the degradation of land.
2.1.5 Investigate and develop more effective compliance approaches to reduce the risks of wind and water erosion in traditional broadacre agriculture.	LC monitoring trends may indicate preferred methods of broadacre agriculture with decreased risks of erosion.
2.1.6 Establish regional targets for reducing natural resource degradation.	LC monitoring programs will help to establish appropriate regional targets.
2.1.7 Develop strategies to reduce the risk of natural resource degradation during extreme climatic events.	Data from the LC monitoring programs will inform the development of appropriate strategies.

Strategies	Contribution of LCMPs
2.1.8 Promote to rural and urban communities the importance of using our soil, land and water resources within sustainable limits.	A communication strategy including broad public distribution of monitoring trend information will assist achieve this strategy.
2.1.10 Develop new, and strengthen existing, links between sustainable production groups, government and regional NRM Boards.	Increased sharing of monitoring information and communication with various groups will help to strengthen these links and ensure that ESD principles are relevant and appropriate.
2.1.11 Encourage all relevant industries to develop plans and strategies that reflect the ESD object of the Act and that align with the policy contained in relevant NRM plans under the Act.	
2.2.1 Develop and implement strategies to achieve targets in the Soil Conservation and Land Management: Directions for South Australia.	The LC monitoring programs will clearly be guided by this document and help to evaluate the targets in time.
2.2.2 Promote and further refine systems, types and intensities of land use that are compatible with land capability.	Monitoring trends may help to indicate which land uses are more appropriate than others in a given land capability.
2.2.3 Maintain the South Australian Dryland Salinity Strategy.	The LC monitoring programs will clearly be guided by this document.
2.5.1 Implement the Murray–Darling Basin Intergovernmental Agreement 2004 (including the recovery of 500 gigalitres of new water per year (long-term average) by 2009 for environmental flows).	LC monitoring will endeavour to contribute to the management of land-based natural resources as the agreement requires.
1.1.1 Develop regional sustainable landscapes pilot projects.	LC monitoring trends for regions may help to identify pilot projects and monitor any changes.
1.1.2 Develop and trial market-based instruments that provide incentives for private investment in activities that provide environmental benefits.	LC monitoring trends and expansion of current programs may be able to indicate which instruments can provide environmental benefits.
1.2.7 Investigate the investment arrangements, rights and responsibilities relating to the legacy of natural resource degradation and private/public benefits.	LC monitoring and the trends that can be documented are collated from various information sources including the changing behaviours and practices of land managers who have direct impact on the degradation of land.
1.2.8 Develop mechanisms that provide private landholders and other natural resource users and managers with greater certainty about long-term investments in NRM activities.	A communication strategy including broad public distribution of monitoring trend information will assist achieve this strategy.
1.2.9 Develop and use integrated modelling for NRM decision making at a landscape scale.	Monitoring information may contribute to landscape level modelling used for decision making.
1.3.1 Refine state and regional targets for healthy ecosystems and ecosystem services to be delivered by NRM planning and investment.	LC monitoring programs will help to establish appropriate regional and state level targets.
1.3.7 Minimise the impacts of key threatening processes (e.g. impact of invasive species).	LC monitoring may identify threatening processes that can then be included in the planning to reduce impacts. This may include observations such as pest invasions or climate change impacts.
1.4.1 Protect areas of productive agricultural land (and aquaculture sites) for primary production and other natural resource uses.	Clearly LC is key to this strategy by identifying land at risk of degradation and land requiring protection to maintain productivity.
1.5.2 Identify opportunities to reduce greenhouse gas emissions across current NRM sector activities wherever practicable.	Strategies identified to reduce degradation risk to land need to incorporate reducing greenhouse gas emissions.
4.1.1 Contribute to the implementation of the Biosecurity Strategy for South Australia and provide input to the development and implementation of the National Biosecurity System.	Whilst LC monitoring programs are being conducted on ground, it may be possible for field officers to record information on pest plant outbreaks. Degraded land identified during monitoring may also point out land at risk to invasive species.
4.2.2 Develop best practice control strategies, based on research, experience, animal welfare and off-target considerations.	LC monitoring can contribute to this strategy by providing data on changing practices and observed impacts on landscapes.

The NRM Council intends to work with all other bodies that collect and/or report monitoring data to '… avoid unnecessary duplication and to coordinate appropriate data collection … on the state and condition of natural resources …' in the State NRM Plan and the SoE Report.

The SAMEF delegates tasks to the state government, the state government in partnership with regional NRM Boards, and regional NRM Boards alone.

In terms of monitoring:

'Regional NRM Boards will:
- take responsibility for data collection in their region in accordance with priorities and protocols developed as part of the Operational Plan and at scales needed to inform their regional NRM Plan and component programs and projects …'

'The State Government in partnership with regional NRM Boards will:
- encourage regional data collection and management systems that integrate with the agreed natural resources information system
- develop an Operational Plan for South Australia's Monitoring and Evaluation Framework ...'

'The State Government will:
- be responsible for evaluating and reporting at a state scale and, as necessary, on scales appropriate to NRM programs and projects delivered by agencies.'

In order for the state government and the regional NRM Boards to define what they will monitor, they need to identify a number of RCTs. The State NRM Plan contains a set of RCTs for the state and is envisaged (in the NRM Plan) to provide direction for the development of regional RCTs. Beneath the RCTs at state and regional level are resource condition indicators. These indicators are to be 'identified and negotiated' through the development of the operational plan (MER-OP; Government of South Australia 2006). It is likely (and hoped for practical purposes) that the indicators developed for the regions will be the same or similar to the state indicators to facilitate data collation, evaluation and reporting. Figure 2 shows the relationship between regional and state-level goals, RCTs, indicators and processes.

2.2.4 PASTORAL LAND MANAGEMENT AND CONSERVATION ACT 1989

The objects of the *Pastoral Land Management and Conservation Act 1989* (Pastoral Act) are as follows:

(a) to ensure that all pastoral land in the state is well managed and utilised prudently so that its renewable resources are maintained and its yield sustained; and

(b) to provide for —

(i) the effective monitoring of the condition of pastoral land; and

(ii) the prevention of degradation of the land and its indigenous plant and animal life; and

(iii) the rehabilitation of the land in cases of damage; and

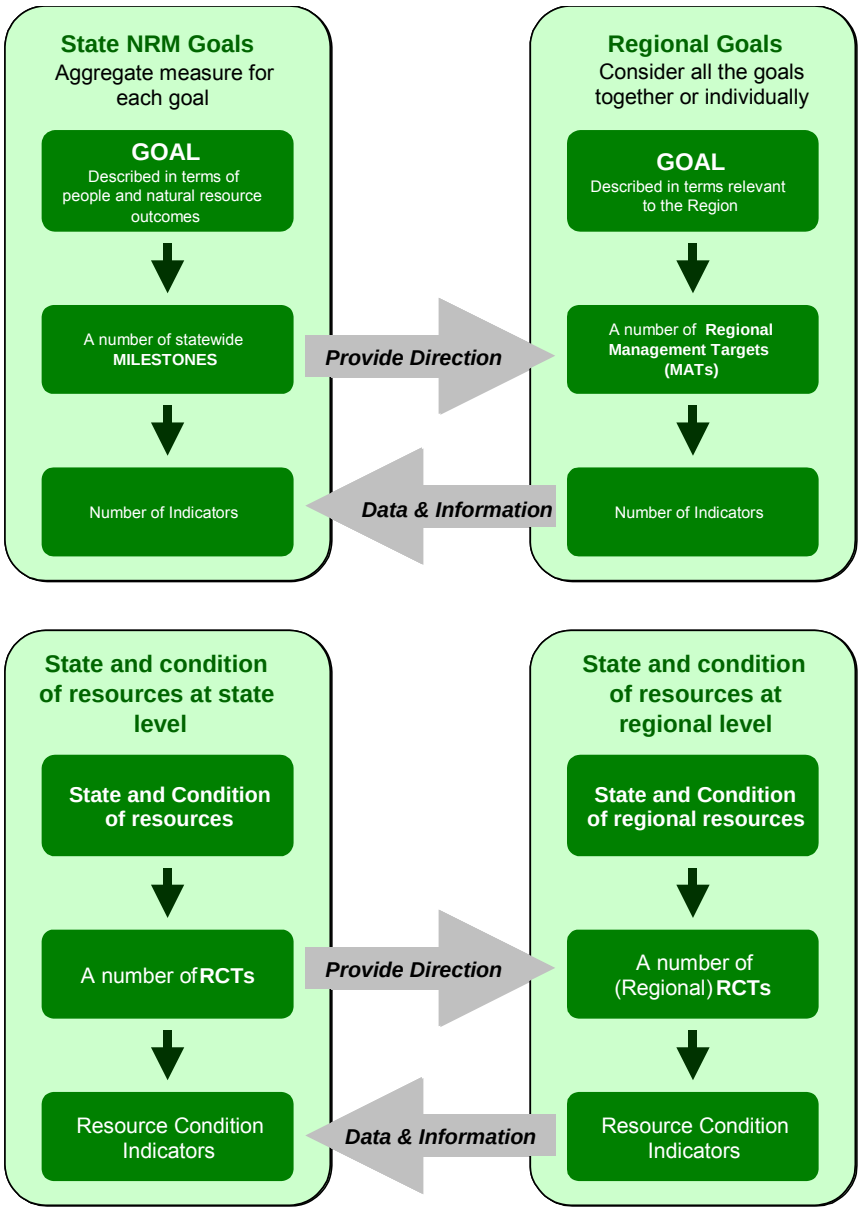

Figure 2. Relationships between the State NRM Plan and regional NRM Plans (Government of South Australia 2006)

(c) to provide a form of tenure of Crown Land for pastoral purposes that is conducive to the economic viability of the pastoral industry; and

(d) to recognise the right of Aboriginal persons to follow traditional pursuits on pastoral land; and

(e) to provide the community with a system of access to and through pastoral land that finds a proper balance between the interests of the pastoral industry and the interests of the community in enjoying the unique environment of the land.

It is of interest to note that the aim of rehabilitation is to return land to the condition it was in before degradation occurred '… having particular regard to its capacity to carry stock and its level of soil stability …'. This view may have impact on determining and implementing a landscape scale or ecological function monitoring approach. See Table 20 for further discussion.

To effectively monitor pastoral land, the Pastoral Act has put into place specific requirements for land assessments to be made as follows:

Section 25—Assessment of land

(1) The Board must cause an assessment of the condition of the land comprised in each pastoral lease to be completed at intervals of not more than 14 years.

(2) An assessment of the condition of land pursuant to this Act —

(a) must be thorough; and

(b) must include an assessment of the capacity of the land to carry stock; and

(c) must be conducted in accordance with recognised scientific principles; and

(d) must be carried out by persons who are qualified and experienced in land assessment techniques; and

(e) must take into account any matter prescribed by the regulations.

The Pastoral Areas Land Monitoring System (see Table 20) has been developed to meet the monitoring and assessment requirements of the Pastoral Act.

2.2.5 ENVIRONMENT PROTECTION ACT 1993

The objects of the *Environment Protection Act 1993* are basically to promote the principles of ecologically sustainable development and '… to ensure that all reasonable and practicable measures are taken to protect, restore and enhance the quality of the environment having regard to the principles of ecologically sustainable development …'. The Act stipulates the 'Authority' (known as the EPA) must prepare and publish a South Australian 'State of the Environment' report (SoE) at least every five years to be delivered to the Minister.

2.2.6 SOUTH AUSTRALIA'S STATE OF THE ENVIRONMENT REPORT

Under the Environment Protection Act, the State SoE Report must:

112 (3) (a) include an assessment of the condition of the major environmental resources of South Australia; and

(b) include a specific assessment of the state of the River Murray, especially taking into account the *Objectives for a Healthy River Murray* under the *River Murray Act 2003*; and

(b) identify significant trends in environmental quality based on an analysis of indicators of environmental quality; and

(c) review significant programs, activities and achievements of public authorities relating to the protection, restoration or enhancement of the environment; and

(d) review the progress made towards achieving the objects of this Act; and

(e) identify any significant issues and make any recommendations that, in the opinion of the Authority, should be drawn to the attention of the Minister.

The report is structured around seven environment themes including atmosphere, inland waters, coasts and the sea, land resources, biodiversity, human settlements, and heritage. Within these themes are 22 chapters focusing on various environmental issues.

The land resources section of the 2003 SoE Report includes soil acidity, soil erosion (wind and water), land-use and dryland salinity information. The EPA is responsible for collating the entire report but only contributes data on soil contamination (relative to land condition). The other state agencies are required to provide the remaining land and soils data.

An outline of the land resources indicators, data collected, and data sources from the 2003 State SoE Report has been collated in Appendix C. It is likely that indicators will be reviewed and amended again by the next State SoE Report (due 2008).

The 2003 report included recommendations with respect to land condition and also broader issues relating to monitoring, evaluation and reporting. The South Australian Government has responded to these recommendations in the Office of Sustainability (2005b) document *Action for the environment: Government's response to the State of the Environment Report for South Australia 2003*. The recommendations and responses are listed in Table 5.

The government's response noted above clearly suggests that the existing range of government indicator-based reports will align with the State Strategic Plan. It should also be noted that the current State Strategic Plan (see Section 2.2.10) does not include any land condition related indicators.

Table 5. 2003 SoE recommendations and South Australian Government's response

EPA's SoE 2003 recommendations	South Australian Government response (Office of Sustainability 2005b)
Develop a consistent and integrated approach to gathering, managing and sharing environmental information across governments and key research institutions, with an emphasis on the information that strategically addresses South Australia's environmental priorities.	Further work is needed and possible directions include the development of an SoE Information Plan.
Take into account the SoE report and government's response when developing performance measures and benchmarks for the state.	State Strategic Plan will be monitored every two years and it contains many of the performance measures and benchmarks in the SoE report.
Make sure that there is clarity of purpose and efficiency of effort in government indicator-based reporting.	State Strategic Plan will be South Australia's leading indicator-based report and it is expected that all other government plans and documents will align with directions and strategies in the state plan.
Ongoing and adequate funding and technical support for coordinated on-ground works, beyond the lifespan of the National Action Plan and Natural Heritage Trust, is provided. This should include provision for long-term monitoring and evaluation.	NRM Act provides for long-term management. Regional NRM Boards will play a key role in implementing monitoring and evaluation of results beyond the lifespan of the NAP and NHT.
There should be improved understanding of the underlying technical, economic and social reasons why adoption of improved land management practices remains inadequate in many areas, together with the development of methodologies and investment strategies that address the key issues identified.	Action plan for EMS in agriculture and other EMS activities to feed into National EMS Implementation Plan. Possible: State capacity building framework will assist. More research into economic and social barriers to uptake.
Monitoring of soil and land condition should be conducted on an ongoing basis to assess the impact of land management practices on soil erosion risk and the condition of acid soils.	Government runs an LCMP.

Note: This table does not include all recommendations, only those considered of most relevance to LCM (Government of South Australia 2005a; Office of Sustainability 2005b)

The government's response noted above clearly suggests that the existing range of government indicator-based reports will align with the State Strategic Plan. It should also be noted that the current State Strategic Plan (see Section 2.2.10) does not include any land condition related indicators.

2.2.7 MONITORING AND EVALUATION IMPLEMENTATION PLAN FOR SOUTH AUSTRALIA FOR THE NAP AND NHT

The *Monitoring and Evaluation Implementation Plan for South Australia for the NAP and NHT* (Government of South Australia 2005b) was completed in May 2005. Its purpose was to:

- guide the establishment of arrangements to monitor progress and achievements of NAP and NHT
- evaluate NAP and NHT effectiveness against the stated objectives
- clarify the relative roles and responsibilities of each stakeholder (Australian and state governments and regional NRM Boards) for monitoring, evaluating, and reporting on NAP and NHT investments.

The Implementation Plan provides useful clarification of the role of the NRM Boards and NAP and NHT reporting arrangements. The Implementation Plan contains examples and templates for monitoring, evaluating and reporting processes. The State MER-OP will incorporate and build on this plan. The Implementation Plan will require updating approximately annually to ensure its usefulness is maintained.

2.2.8 SOUTH AUSTRALIAN DRYLAND SALINITY STRATEGY

The *South Australian Dryland Salinity Strategy* (SADSS; PIRSA 2001) presents a strategy for the effective management of dryland salinity in South Australia. It follows the policy statement that the government is committed to 'reverse the trend' of rising salinity documented in the *Directions for Managing Salinity in South Australia* in August 2000 (PIRSA 2000).

SADSS outlines a range of actions and the responsible agencies or groups to work towards achieving the goals and objectives of the strategy. Some of the actions specified are related to monitoring needs and programs. Those most relevant are listed in Table 6.

One of the actions in the strategy is to establish a South Australian Dryland Salinity Committee (SADSC). This has been accomplished, and the committee meets four times a year to progress dryland salinity issues in South Australia. The committee was acting under, and reporting to, DWLBC but with the introduction of the State NRM Plan, now reports to the NRM Council. The NRM council approved the SADSC's terms of reference in March 2006, under which the SADSC must:

- advise the NRM Council on dryland salinity issues
- maintain the SADSS
- oversee, review and report on the implementation of the SADSS, including progress.

Table 6. Dryland salinity monitoring actions and responsibilities from the 2001 SADSS

Actions	Responsibility
Survey farmer awareness of dryland salinity and its causes, and identify the steps needed to raise farmer awareness where necessary.	Regional groups, SAFF
Use airborne geophysics and digital elevation models, where appropriate, to identify key catchments for targeted intervention.	PIRSA, DEH
Map areas affected by, and at risk to, salinity, use local knowledge to ground-truth salinity maps, and establish long-term monitoring sites.	PIRSA, catchment groups
Increase monitoring frequency of existing gauging stations in areas affected by, or at risk to, dryland salinity, and establish further gauging stations at key locations.	DWR (now DWLBC)
Monitor groundwater levels at all demonstration sites and establish paired sites to monitor effectiveness of recharge reduction strategies.	DWR (now DWLBC), regional groups, catchment groups, landholders
Maintain an accessible database of groundwater levels and salt loads, ensuring that data are shared between agencies and within regions.	DWR (now DWLBC), regional groups, PIRSA
Use indicators of catchment health to monitor impact of salinity and response intervention.	PIRSA, CSIRO, catchment groups
Survey the level of adoption of recommended land management practices for salinity control and identify impediments.	SADSC, regional groups
Evaluate and, where feasible, implement remote sensing technologies.	PIRSA, CRC, CSIRO

2.2.9 SOIL CONSERVATION COUNCIL (FORMER) — SOIL CONSERVATION AND LAND MANAGEMENT; DIRECTIONS FOR THE AGRICULTURAL LANDS OF SOUTH AUSTRALIA (2005)

The *Soil Conservation Council (former) — Soil Conservation and Land Management; Directions for the Agricultural Lands of South Australia* paper (Morgan et al. 2005) (Directions Paper) was produced to provide a summary of the current status of soil and land condition in South Australia, and identify critical issues for the future. The paper proposes several targets for the next 15 years for the critical issues identified.

The Directions Paper has been utilised by the State NRM Plan to inform and guide policy development. Strategy 2.2.1 in the plan stipulates the state will '… develop and implement strategies to achieve targets …' in the Directions Paper. Given this strategy, the targets identified in the Directions Paper will significantly dictate the LCM requirements at the state level.

2.2.10 SOUTH AUSTRALIA'S STRATEGIC PLAN

South Australia's State Strategic Plan 2004 (Government of South Australia 2004a) is a South Australian Government plan setting targets and benchmarks relating to the state's environmental, economic and social health. Quantifiable indicators are reported by the state government every two years to measure the state's development and progress, with the first report being due in 2006. The plan overview states '… it is expected that over time, all government plans will align with South Australia's Strategic Plan. All government agencies will be required to base their plans, budgets and programs on the key directions and strategies laid out in the plan …'. The plan does not include any indicators, targets or

Table 7. Proposed land condition targets from the Soil Conservation Council's Directions Paper

Land condition theme	Target
Erosion (wind and water)	For all regions, by 2010, the water and wind erosion risk indices are reduced to 35 days or less.
Soil acidity	By 2008, the annual application of lime used on medium and high-risk agricultural land equals or exceeds that required to balance acidification rates.
Dryland salinity	For whole of state, no net increase in salinised land beyond year 2000 levels.
Soil fertility Water repellence Soil physical condition	By 2010, water-use efficiency of agricultural crops and pastures are improved by at least 20% due mainly to improvements in soil physical and nutritional condition.
Irrigated soils	By 2020, all irrigation drainage in South Australia is managed sustainably. There is no net increase in area of land lost to irrigation salinity.
Returning perennial vegetation to the regional landscape	By 2006, regional priority plans for large-scale habitat re-establishment prepared. Rates of revegetation are increased substantially from 2005 levels.

'measuring tools' directly relevant to land condition. This is of concern as without specific land condition targets in the State Plan it reduces the likelihood of other government agencies incorporating land condition targets in subsequent plans and strategies.

The focus in the plan is protecting our biodiversity, securing sustainable water and energy supplies, and minimising waste. The 'Attaining Sustainability' objective includes '… reduce our ecological footprint to reduce the impact of human settlements and activities within 10 years …'. Specific actions, however, are focused on energy consumption and tree planting.

In line with the intent to improve and refine the State Plan, the Premier's Round Table on Sustainability has made recommendations on various aspects of the plan in its report titled *Three Four Five: 3 Challenges, 4 Principles, 5 Actions for a Sustainable Future*. Under the action theme of 'Managing Natural Systems', the report notes that the State Strategic Plan needs to include targets relating to soils and the state's agriculture and rangelands ecosystems, and that these targets should also be 'reflected in individual industry plans' (Government of South Australia 2004b).

2.2.11 GREEN PRINT SA

Green Print SA is a document produced by the Office of Sustainability for the Government of South Australia. It outlines plans for the environment and reports on South Australia's progress in achieving environmental goals. It is used as a tool to inform policy and strategy. Green Print reports on eight major topic areas including a section called 'Protecting our Land', within which several indicators and targets have been identified to monitor progress towards the environmental goals.

The Office of Sustainability states that the targets and indicators will be in '… agreement with those used in South Australia's Strategic Plan, State of the Environment Reporting and other government strategic planning documents …' (Office of Sustainability 2003).

The Office of Sustainability has the responsibility to coordinate the production of Green Print. Green Print has been described as being distinct from SoE and the State Strategic Plan in that it addresses the state government business need to report progress towards achieving

environmental targets. It does not appear to be linked to a statutory obligation or government policy but rather a tool to inform policy and strategy.

The land condition indicators and targets included in Green Print under the 'Protecting our Land' theme are outlined in Table 8. In the 2003 report (Office of Sustainability 2003), dryland salinity was the only land theme indicator and target. The indicators were expanded in 2004 and remained the same for 2005.

Table 8. Green Print's indicators, targets and data sources (Office of Sustainability 2003, 2004, 2005a)

Protecting Our Land Theme	Indicator	Target	Year: Data or information source
Dryland salinity	Area of land affected by dryland salinity	Minimise the area of land affected by dryland salinity beyond the current 336 000 hectares (2003 target). Minimise the area of land affected by human-induced salinity beyond the current estimate of 332 000 hectares.	2003: DWLBC 2004, 2005: SaLI, DWLBC from March 2004 GIS calculations
Soil acidity	Soil acidity balance	The amount of lime used on medium and high-risk agricultural land equals or exceeds that required to balance acidification rates by 2008.	2004, 2005: DWLBC LCMP
Soil erosion	Wind and water erosion risk indices	The erosion risk indices for both wind and water erosion are reduced to 35 days or less by 2010.	2004, 2005: DWLBC's LCMP risk index data
Revegetation	Area of land revegetated	Significantly increase the amount of revegetation.	2004, 2005: DWLBC — John Bourne

2.2.12 VivaSA

VivaSA is a collaborative organisation involving community, business and government. It operates independently with a vision to achieve a vibrant, prosperous and viable economy in South Australia. The organisation has developed a number of indicators on which to base future discussions and actions to improve the social, economic and environmental aspects of the state. VivaSA has a number of environmental indicators including:

- loss of seagrass
- revegetation
- energy, greenhouse, and climate change, and
- waste disposal.

The revegetation indicator is broadly used as a surrogate for dryland salinity, soil stability, and erosion since the establishment of perennial native vegetation assists with these land condition issues. The rate of revegetation of indigenous species is compared to the rate of vegetation clearance to determine a net increase or decrease (VivaSA 2005).

2.2.13 KEY STATE DOCUMENTS SUMMARY

Table 9 provides a summary of the land condition themes represented in the key natural resource documentation, either as targets, indicators or reported trends. In addition to the information in the table, it should be noted that the NRM Act and State NRM Plan also

Table 9. Summary of LCM data requirements from key state documents

Land condition theme	State Strategic Plan	State NRM Plan (Soil Conservation Council Directions document — Targets)	SA SoE 2003 indicators	National SoE 2003 indicators	Green Print indicators and targets	VivaSA indicators	National Monitoring and Evaluation Framework
Erosion — wind and water		✓	✓	✓	✓		✓
Acidity		✓	✓	✓	✓		✓
Dryland salinity		✓	✓	✓	✓		✓
Physical condition		✓					
Fertility		✓		✓			
Water repellent soils		✓ (WUE surrogate)					
Soil carbon				✓			✓
Land management indicators			✓	✓			✓
Revegetation	✓	✓			✓	✓	
Land use			✓	✓			✓
Site contamination			✓	✓			
Other		Irrigation induced salinity					

require reporting on state and condition, which may require additional data and information to that suggested below. The table includes the National SoE and NMEF reporting requirements since they clearly state the information required.

2.2.14 STATE AGENCIES

2.2.14.1 Department of Water, Land and Biodiversity Conservation

The Department of Water, Land and Biodiversity Conservation (DWLBC 2006) lies within the portfolios of two Ministers — the Minister for Environment and Conservation and the Minister for the River Murray.

DWLBC's vision is:

'Natural resources used sustainably to enhance quality of life.'

DWLBC has a number of business functions, some of which will be contributed to by LCM. DWLBC is required to provide NRM policy advice to government, to advise and support land managers on sustainable land management practices, and to advise on salinity management.

DWLBC has a corporate plan (for the period 2005–10) which is heavily driven by targets in South Australia's Strategic Plan (see Fig. 3). The corporate plan details a number of strategic priorities to meet the organisation's vision, mission, and State Strategic Plan, and includes to '… deliver effective reporting on the state and condition of the state's natural resources …'. The strategic priorities are supported by a number of initiatives with given time frames, and in terms of monitoring include:

- Develop a state-wide resource condition monitoring and reporting framework and obtain sign off from the NRM Steering Committee. June 2006 (this is complete and is detailed in the State NRM Plan).
- In conjunction with other agencies and the NRM Council, develop the key principles and elements of the framework, to better understand resource condition in general and the relationship between management action and changes to resource condition. June 2006 (this is complete and is detailed in the State NRM Plan).
- Based on the agreed framework, conduct an audit on a regional basis to determine what monitoring information is currently available, how it is collected, and identify gaps. December 2006 (a number of regional monitoring reviews have been undertaken, some completed).
- Finalise the resource monitoring and reporting framework and develop an implementation plan to address the identified gaps. June 2007 (in progress).

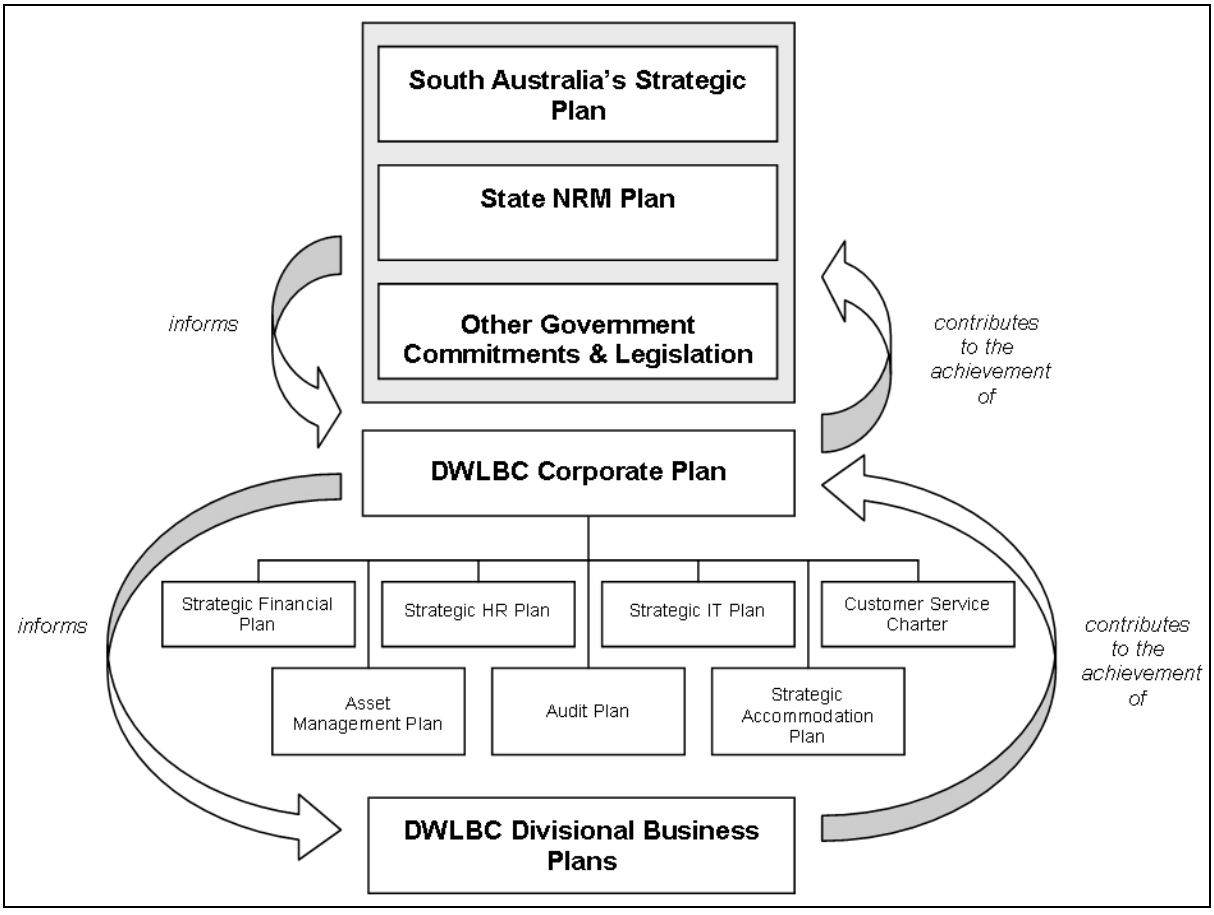

Figure 3. The DWLBC planning framework (DWLBC 2006)

The corporate plan provides direction and guidance to the various divisions and groups within the organisation. Each Division of DWLBC must produce a business plan that describes the activities to be undertaken during the year in order to achieve the vision, mission and strategies. To identify the activities to be included in the divisional business plans, priorities for determining the activities must be as follows:

- statutory requirements
- published commitments by the Premier, Minister and Government
- other strategic priorities identified in the DWLBC Corporate Plan.

DWLBC has the lead role in supporting delivery of the NRM Act, which is the key piece of NRM legislation and aims to promote sustainable and integrated NRM in South Australia. DWLBC is answerable to the two key natural resource Ministers so there are a number of monitoring, evaluation, and reporting responsibilities for state and condition of natural resources identified in the NRM Act. Further details on the Act are contained in Section 2.2.1. In summary, DWLBC has responsibility to operate, administer, and enforce the NRM Act. In assisting the functions of the Minister, DWLBC will keep the state and condition of natural resources under review and compile, maintain, and update information on the state's natural resources.

Under the SAMEF, which is in the NRM Plan, DWLBC, as part of the state government, will be responsible for:

- coordinating and managing a natural resources information system
- evaluating and reporting on natural resources at a state scale and, as necessary, on scales appropriate to NRM programs or projects delivered by the agencies.

Also under the SAMEF, the state government (DWLBC predominantly) and the regional NRM Boards must work together to develop the natural resource information system and the State MER-OP.

2.2.14.2 Department for Environment and Heritage

The Department for Environment and Heritage (DEH; Department for Environment and Heritage 2006) governs a wide range of environmental legislation and is responsible for environment policy, biodiversity conservation, heritage conservation, environmental sustainability, and animal welfare. It is also the custodian of most of the information on South Australia's environment. DEH has an extensive website where much of this information and reports can be sourced. It also manages the state's public land, crown land, national parks and conservation land.

DEH is duty-bound by various requirements and administers a wide array of legislation. Australia is a signatory to various international treaties on environmental conservation and DEH is responsible for ensuring these are being adhered to in South Australia.

The State Strategic Plan plays a major role in the development of DEH's corporate plan and drives many of its goals and strategies. DEH's central objective is predominantly related to the State Strategic Plan Objective 3 — 'Attaining Sustainability'.

DEH manages its business through the following seven programs:

- Attaining Sustainability — The promotion of sustainable and eco-efficient human endeavour with minimal impact on essential life systems.

- Nature Conservation — The management, science and education contributing to conserving the state's biodiversity.
- Public Land Management — The conservation, maintenance, and stewardship of the state's public lands.
- Coast and Marine Conservation — The conservation, management, and protection of the state's coast and marine environments.
- Heritage Conservation — The understanding, conservation, and protection of the state's rich heritage.
- Animal Welfare — The promotion and regulation of the humane treatment of animals.
- Environmental Information — The provision of information to support the state's environmental needs.

In terms of monitoring, under DEH's nature conservation program, one of its sub-programs is to survey and monitor South Australia's ecosystems, habitats, species and populations. In DEH's corporate plan, the only monitoring related strategy is to '… Develop a methodology to better assess and report on ecological trends …'. DEH has no LCMP or requirements as such.

DEH is divided into several business areas (to achieve the above work programs), one of which formally existed as the Office of Sustainability (OoS). The OoS was introduced in 2002 to increase the development and implementation of sustainability policies within government. Various programs relevant to monitoring and evaluation were contributed to and supported by the OoS. These included:

- The South Australian State Strategic Plan (see Section 2.2.10)
- State of Environment Reporting (see Sections 2.1.3.1 and 2.2.6)
- Green Print SA (see Section 2.2.11)

Other programs without defined monitoring components include:

- Ecological footprint
- Greening of Government Operations Framework and Scorecard
- The Premier's Round Table on Sustainability.

2.2.14.3 Environment Protection Authority

The responsibilities of the Environment Protection Authority (EPA 2006) are outlined in the *Environment Protection Act 1993* (see Section 2.2.5 for further details). The EPA administers a number of environment protection regulations and policies. The EPA is responsible for preparing and publishing the SoE report (see Section 2.2.6) but, as with Green Print, the SoE reports to date have drawn on existing data and information. The statutory responsibilities do not state that the EPA must resource the collection of appropriate data.

In addition to SoE reporting requirements, the Act requires the EPA to provide for monitoring and reporting on environmental quality on a regular basis to ensure compliance with statutory requirements and the maintenance of a record of trends in environmental quality. With respect to these additional requirements the EPA monitors air, soil and water quality, and supports various community monitoring activities such as Water, Frog, Air and Saltwatch.

2.2.14.4 Primary Industries and Resources SA

Primary Industries and Resources SA (PIRSA) is a state government agency that contributes to the sustainable planning and development of South Australia's natural, industrial and community assets. Targets in the State Strategic Plan also drive PIRSA's goals, one of which is to foster environmentally sustainable and internationally competitive industries (PIRSA 2006a).

PIRSA's strategic directions document for 2003–06 (PIRSA 2004) notes five strategic focus priorities, and includes:

> 'Sustainability: using, conserving and enhancing the communities resources so that ecological processes on which wealth generation depends are maintained, and the total quality of life, now and in the future, can be enhanced. Encouraging the application of sustainable development principles, for both ethical and market purposes, that industries have successfully adopted those principles, whilst also remedying the problems created by past use of resources.'

PIRSA has a number of initiatives in place to achieve sustainability, very few of which include monitoring. In 1999, PIRSA produced a document titled *Agricultural Sustainability Indicators for regions of South Australia* (Duncombe-Wall et al. 1999). This publication was driven by a Commonwealth group called the Standing Committee for Agriculture and Resource Management, which developed an initial set of indicators that were piloted and finalised by the National Collaborative Project on Indicators for Sustainable Agriculture. The indicators report was not reproduced but has been to some extent replaced by the LCMP.

PIRSA's Grains Industry Development Team is presently developing a grains industry strategy for the period 2005 to 2025 called *Single Vision*. The strategy will incorporate a triple bottom line (TBL) system to measure and monitor the performance and sustainability of the grains industry, and the achievement of defined goals (Olessya Karamysheva, PIRSA, pers. comm., 2006). The strategy and TBL system is envisaged to be introduced across the state to NRM and grains industry groups. Many proposed indicators for use in the TBL system are derived from DWLBC's LCMP including the Land Manager Surveys and the Field Survey Program for wind and water erosion. It is crucial to the TBL system to be able to access long-term data generated by the LCMP to ensure its success.

PIRSA operates a soil and plant analysis service (SASPAS) in Loxton. The laboratory provides the service to landholders and the LCMP accesses the data for monitoring purposes (PIRSA 2006b).

The 'business arm' of PIRSA, which is Rural Solutions SA, is a team of specialist consultants working independently on sustainability and NRM issues. DWLBC contracts various activities to Rural Solutions (Rural Solutions SA 2006). Rural Solutions conducts a significant amount of work consulting on salinity issues, and works collaboratively with DWLBC (and other agencies and groups) to provide expertise, monitoring, and data supply services. It has produced several sub-regional salinity benchmarking and monitoring strategies and also a *Dryland Salinity Monitoring Action Plan* (Dooley & Liddicoat 2004). Rural Solutions also collects lime sales data for DWLBC and for its own use.

2.2.14.5 Australian Bureau of Statistics

The Australian Bureau of Statistics (ABS) is Australia's central statistical authority, having responsibility to provide statistical services to all levels of Australian Government and the community under the *Australian Bureau of Statistics Act 1975*. This legislation dictates the following functions for the ABS:

Sect 6 (1)

a) to constitute the central statistical authority for the Australian Government and, by arrangements with the Governments of the States, provide statistical services for those Governments;

b) to collect, compile, analyse and disseminate statistics and related information;

c) to ensure co-ordination of the operations of official bodies in the collection, compilation and dissemination of statistics and related information, with particular regard to:

   (i) the avoidance of duplication in the collection by official bodies of information for statistical purposes;

   (ii) the attainment of compatibility between, and the integration of, statistics compiled by official bodies; and

   (iii) the maximum possible utilisation, for statistical purposes, of information, and means of collection of information, available to official bodies;

d) to formulate, and ensure compliance with, standards for the carrying out by official bodies of operations for statistical purposes;

e) to provide advice and assistance to official bodies in relation to statistics; and

f) to provide liaison between Australia, on the one hand, and other countries and international organisations, on the other hand, in relation to statistical matters.

ABS (2006a,b) conducts surveys on various themes that include 'Agriculture' and the 'Environment'. The environment surveys focus on energy and resource use and not land management issues. The agricultural surveys collect data on area and production of crops, livestock numbers, livestock products, land management, and environmental issues that are relevant to LCM.

The LCMP also utilises ABS crop yield data (see Table 17). In June 2006, 190 000 farm businesses will be involved in the 2005–06 Agricultural Census. This census will also collect information on land-use practices, including water usage and sources, tree planting, and fencing to prevent land degradation. Data from this census are not expected to be available until at least December 2007 and most likely at a statistical division scale. In 2008, it is expected that these data will be released at the Statistical Local Area scale and in other forms including National Action Plan regions and NRM Board regions.

2.3 REGIONAL REQUIREMENTS

Under the NRM Act, the recently formed regional NRM Boards have overtaken INRM Groups. This has increased the resource condition monitoring obligations and business needs for regional NRM Boards in addition to existing obligations with respect to funding

received from NAP and NHT. Section 2.2.1 contains extracts from the NRM Act regarding obligations of NRM Boards.

Essentially, NRM Boards are required to develop a comprehensive NRM Plan that (in terms of monitoring and evaluation):

- Is consistent with the State NRM Plan and any intergovernmental agreements specified by the Minister.
- Includes the state and condition of natural resources in the region and related trends.
- Includes the methods that will be used to:
  - '…monitor the state and condition of natural resources…and the related trends…'
  - monitor and evaluate the effectiveness of the boards NRM programs and policies at regional and local level
  - '…assess the extent to which…the board…has succeeded in implementing the plan…'
  - '…assess the extent to which the board has succeeded in achieving its goals…'.

For the majority of regional NRM Boards, their new plans will be in place by July 2008.

The regional comprehensive NRM Plan must be reviewed at least once every five years. The plan must also contain a strategic plan for a 10-year period and a business plan for the next three years. The business plan includes an implementation plan for the first year of the three-year business plan. The business plan must be reviewed annually and specify activities for the ensuing three years.

The board is also required to report annually to the NRM Council on:

- activities undertaken during the year;
- the extent to which the board has succeeded in implementing its plan; and
- include annual reports from the NRM Groups, financial statements etc.

Under the State NRM Plan, the regional NRM Boards are responsible for:

- data collection in their region as per the Monitoring, Evaluation and Reporting Operational Plan (MER-OP)
- '…evaluation and reporting at a regional scale and scales appropriate to individual programs and projects...'

The State NRM Plan outlines resource condition targets, which 'provide direction' for regional RCTs. The practical interpretation of this is still to be determined.

The boards are required to work with state government to develop the MER-OP. Considerable negotiation between the regions and the state government will be required to develop the MER-OP given the immense number of complicated drivers for all parties and the true cost of long-term monitoring. The aspect of most relevance for this review is the need for collaborative development of state and regional indicators, and subsequent data collection, to support evaluation of RCTs.

Current regional NRM Plans have RCTs that link with the national 'Matters for Target' (where relevant) as set out in the National Framework for NRM Standards and Targets. Each year, as part of the NAP and NHT Bilateral and Regional Partnership Agreements, the boards must report progress towards achieving the RCTs and Management Action Targets (MATs). With respect to RCTs, the reporting takes the form of categorising the status of progress and the type of evidence used to determine the category. The ideal situation would be to have

RCT assessment supported by a resource condition monitoring program. However, at this stage only a small number of RCTs across the regions have evidence of progress backed by a resource condition monitoring program. This type of assessment is also dependent on the quality and consistency of targets and it is well recognised across Australia that there is scope to improve the target setting process and the NAP and NHT RCT reporting process. In most cases, the data collated to report on MATs have less relevance for a resource condition monitoring review.

Given all of this, in terms of board's monitoring and evaluation requirements, the boards need to develop monitoring programs to assess the state and condition of natural resources for the long term in their own regions for the purpose of meeting obligations under the NRM Act.

Interpretation of the timing of reporting on the state and condition and trends is still to be clarified. However, following a review of the documentation and discussions held with key policy staff, it would appear that the results of these monitoring programs are only required to be evaluated and reported every five years when the regional NRM Plan is up for review. It was found that only at this time is information on state and condition and trends of natural resources required to be reported by the regional NRM Boards. The NRM Boards will also need to consider the resource condition monitoring requirements of key investors for example the annual RCT reporting requirements for current NAP and NHT arrangements.

In order to facilitate monitoring natural resources and formalising RCTs and MATs, most boards are likely to develop or modify their existing MERF. All regions already have RCTs and MATs, but the development of new comprehensive NRM Plans presents an opportunity for reviewing or developing new targets to meet the multiple target requirements.

Each region is slowly working through the complexities of collaborative arrangements, resource condition monitoring and their data and information needs. This review has focused on each region's currently endorsed RCTs as a means to determine the data and information required to report against the RCTs. This is presently the most tangible way to identify a region's data needs. A list of the currently endorsed RCTs for each region is contained in Appendix D. In order to prioritise data and information needs, the approach used by Beaten Track Group Pty Ltd (2004; and modified slightly by the SAMDB Board in their MERF) was used as a tool to identify data requirements and gaps for each of the regions. This approach separates data into three categories:

- RCT critical — critical for assessment of the RCT.
- Context critical — information vital to interpreting the RCT critical data.
- Context useful — information that is useful to interpret the RCT critical data.

The NRM monitoring and evaluation officers from each of the regions were asked to collate as far as possible the known data requirements and the known existing data sources for each of their land condition related RCTs. A table containing the collated results of this task is in Appendix E. Table 10 is a broad summary of each region's land condition information needs derived from their RCTs only. This summary does not consider other land condition information needs that might otherwise be presumed.

Undertaking this exercise highlighted several issues encountered by the regions. On many occasions, regions highlighted that they had no information available to them for a particular resource, and in several of those instances information was available unbeknown to them. On many occasions, data collection was occurring in their region and they had no knowledge

of this. The lack of knowledge of data availability makes it very difficult to develop appropriate RCTs and, as a result, in many cases the RCTs are simply not measurable. In some cases, regions reported that a data set provided enough detail to assess an RCT but the same dataset was not considered adequate for another region, purely due to the wording of the RCT.

Contextual datasets such as climate, land use and soil type were also considered with varying levels of suitability depending on the region's use for them. The arid regions of the state quite apparently have less data available to them.

The varying data needs expressed during this exercise perhaps more represents the lack of communication and collaboration that has occurred between the agencies and the NRM regions. No significant patterns of common data and information need could be ascertained.

In consideration of the region's data needs and knowledge of what data do exist, the following information, datasets and monitoring programs require development to meet the region's current RCT needs:

- soil pH and possible fixed-point surveys
- length and area of erosion (river, sand, dune and lake edge)
- stability condition (location of unstable versus stable river, sand, dune and lake edge)
- soil erosion severity (satellite imagery assessment)
- soil organic carbon content
- extent and severity of salt-affected land
- vegetation cover, area and changes
- area of perennial vegetation established
- depth to groundwater and groundwater salinity (some localities only)
- climate (some localities only)
- remedial works sites
- changing land practices (adoption of best practice, etc.).

This list does not consider which issues are considered to be of real importance to each region based on any scientific or technical advice collected elsewhere in this report.

The findings of this exercise have been incorporated into the following chapter in developing an 'ideal' state LCM framework. Table 10 summarises land condition theme (or issue) data needs captured by each region in their RCTs.

2.4 INTERESTED AGENCIES AND INDUSTRY GROUPS

2.4.1 AUSTRALIAN COLLABORATIVE RANGELAND INFORMATION SYSTEM

The Australian Collaborative Rangeland Information System (ACRIS; Australian Government 2005a) is an Australian Government initiative to coordinate and collate information on rangelands across Australia. The rangelands cover approximately 75% of Australia and are

Table 10. Summary of land condition information needs relative to each NRM Board region's RCTs

Land condition theme	EP	NYAD	SAMDB	SE	AMLR	KI	AW	AL
Water erosion	✓	✓	✓		✓		✓	✓
Wind erosion	✓	✓	✓	✓			✓	✓
Soil acidity	✓	✓		✓ (alkalinity)	✓	✓		
Soil salinity	✓	✓	✓	✓	✓	✓	✓	✓
Soil physical condition	✓	✓	✓		✓	✓		
Soil fertility		✓	✓	✓	✓	✓		
Soil carbon		✓	✓	✓	✓	✓		
Water repellence	✓	✓						
Productivity or WUE	✓	✓	✓					
Other			Stability of river bank, dunes, lake edges and cliffs	Waterlogging Soil diseases and contaminants	Land capability	Water-logging	Vegetation indicators for land condition	Vegetation indicators for land condition

NRM Board regions are defined in the list of abbreviations

difficult to monitor. ACRIS conducted a pilot project to test the information base and potential for merging data to establish national trends in five trial bioregions. In South Australia, the Gawler bioregion was selected for the pilot and the following information sources were utilised:

- pastoral monitoring sites
  - change in density of perennial species
  - change in species present
  - Richards-Green Functionality Index based on pastoral monitoring sites
  - cover change based on step-point method
- total stock numbers
- cover change based on LandSat imagery interpretation.

Following the pilot, ACRIS is working with the National Land and Water Resources Audit to report on the rangelands again in 2007, this time on seven broad themes. Two of the seven themes relate to the land condition information discussed earlier in this report. The themes are:

- Indicators of landscape or ecosystem change:

  Reporting products to be based on monitoring data describing change in landscape function by formal landscape function analysis or appropriate alternative indices, vegetation cover, plant density, and frequency, etc. In some jurisdictions, repeat regional resource condition assessments will complement site-based monitoring data.
- Indicators of sustainable management:

  Data from pastoral monitoring programs and other sources will be collated and analysed to report change in longer term forage quality and availability. Contributions to a national

photographic sequence will also illustrate change. Although more difficult to obtain comprehensive and accurate data, our hope is to report change in components of total grazing pressure. We also plan to report changes in the extent, frequency, and timing of larger fires.

Much of the data for the 2007 reporting will be extracted from the Pastoral Areas Land Monitoring System that has been described in Table 20. ACRIS has an interest in the data South Australia can contribute for reporting and may provide guidance in developing improved rangelands monitoring techniques. ACRIS has no authority to dictate what programs should be conducted, but a collaborative relationship between the state agencies (particularly DWLBC), the regional NRM Boards and ACRIS is likely to be mutually beneficial into the future.

2.4.2 GRAINS RESEARCH AND DEVELOPMENT CORPORATION

'GRDC is a national organisation with a mandate to plan and invest in research and development for the Australian grain industry. Its primary business activity is the allocation and management of investment in R&D' (GRDC 2002).

GRDC's Development Plan sets out five programs of work including sustainable farming systems. The objectives of this program include:

- protect and enhance the natural resource base
- actively contribute to the achievement of catchment management targets.

There are several strategies in place to achieve the program including developing new technology and practices that use the beneficial effects of soil flora and fauna and assist in overcoming soil constraints; develop and promote integrated farm management practices to assist overcoming subsoil constraints; provide opportunities for nutrient input; allow for weather and climate variability; integrate NRM practices to lead to efficient use of water and reduced recharge; provide for efficient nutrient uptake and minimise nutrient loss; contribute to outcomes for salinity and water quality.

GRDC has in place a number of economic, social and environmental performance indicators related to land condition. The following land condition related indicators are not direct measures of the natural resource but could be interpreted as surrogate measures. They are collected by GRDC through annual surveys of grain growers:

- Specific farming practice changes in accordance with targeted trends.
- Measures of uptake of targeted sustainable on-farm practices and technologies. These include: soil testing for nutrients, nutrient budgeting, testing of leaf and root, gypsum, lime, monitoring depth to watertable, etc.
- Grower perceptions of contribution of R&D to farm sustainability.

There may be potential collaborative arrangements or data sharing opportunities between GRDC and the LCMP of DWLBC.

2.4.3 GRAIN & GRAZE

Grain & Graze is a four-year national research program aimed at boosting the profitability of mixed cropping and livestock enterprises while managing natural resources and building social capital by working directly with landholders and catchment groups (Australian

Government 2006f). It is a partnership between Meat & Livestock Australia, Australian Wool Innovation Ltd, Grains Research and Development Corporation, and Land & Water Australia.

Grain & Graze has three key objectives:

- more profit for mixed farmers (especially from the pasture phase of rotations)
- better water quality (e.g. reduced recharge via incorporation of deep-rooted pastures)
- enhanced condition and diversity of plants and wildlife (on farms and across catchments).

Grain & Graze conducted a project to collate information from surveys of landholders across the project areas to establish a benchmarking tool to assess demographic, natural capital, financial capital and productivity, and social capital. Information and data collected included:

- Amount of land showing signs of salinity by area, by farming industry, irrigated or non-irrigated land, proportion of farm area, and proportion of total farms.
- Signs of dryland salinity, loss of soil structure, poor water quality, soil acidity, water and wind erosion, water logging, and weed infestation.
- Use of sustainable practices, including direct drilling, cultivation methods, tree planting, contour banking, crop rotation, soil testing, and controlled grazing.
- Use of salinity management strategies, including tree planting, fencing, and planting alternative crops on irrigated and non-irrigated farms.
- Area of pastures with lucerne, other fodder plants, other deep rooted perennials, salt tolerant pastures and crops, salt bush and bluebush, and other crop types.
- Types of earthworks used for salinity management, including length of levees and banks, subsurface drains, shallow and deep open drains.
- Irrigation methods used, including total area irrigated, spray or sprinkler, drip or micro-spray, and flood.
- Reasons for changing land management practices, including farm sustainability, improved environment protection, improved risk assessment, increased land value, and increased productivity.

Some of the information collected by the project was derived from the Land Manager Survey conducted by DWLBC (formerly conducted by PIRSA). There is potential for a collaborative arrangement to re-survey landholders and share this information.

2.4.4 MALLEE SUSTAINABLE FARMING INC.

Mallee Sustainable Farming Inc. (2006) is an incorporated association of Mallee farmers across the three Mallee states of South Australia, New South Wales and Victoria (Fig. 4). MSF aims to improve the knowledge and skill of farming in the Mallee by sharing knowledge, skills and resources across professional disciplines and state borders. MSF has secured funds from NHT through a Tri-State Extension Agreement with a number of other parties including:

- NSW Agriculture
- Department of Sustainable Natural Resources NSW
- Department of Primary Industries Victoria
- Primary Industries and Resources South Australia

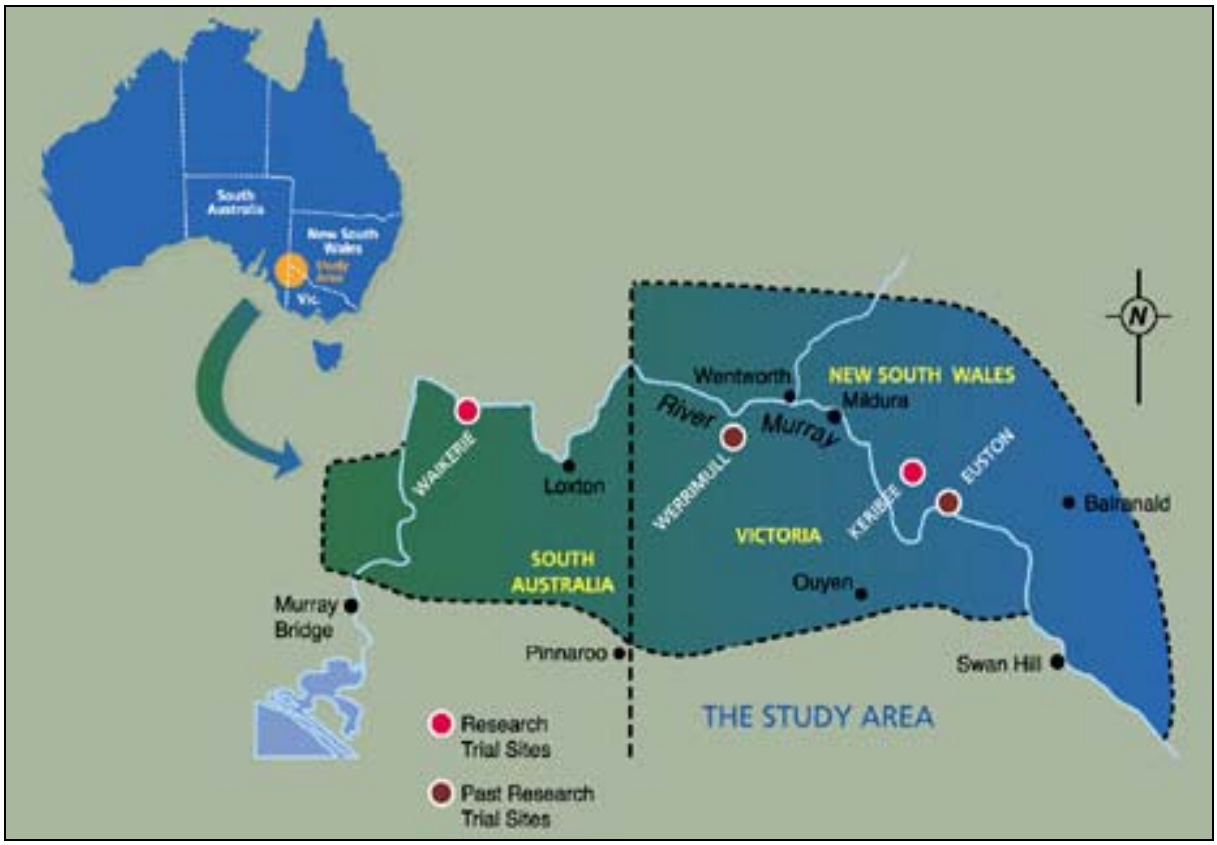

Figure 4. Geographic range of Mallee Sustainable Farming Inc. (2006)

- CSIRO Land and Water
- University of South Australia, Agricultural Machinery Research and Design Centre.

Issues related to land condition that are being specifically investigated by MSF include:

- assessment of soil microbial activity in low rainfall Mallee soils
- soil water management options and potential risk for recharge
- crop nutrition and targeted input options
- fallow management and erosion risk potential.

MSF has conducted a number of research projects and trials on cropping and grazing techniques, one of which included a wind erosion assessment on selected 'focus paddocks'. It is quite apparent that this association may also benefit from a collaborative relationship with the regional NRM Boards and the LCMP conducted by DWLBC.

2.4.5 SOUTH AUSTRALIAN WINE INDUSTRY ASSOCIATION

The South Australian Wine Industry Association (SAWIA) is a not-for-profit incorporated association representing the interests of the South Australian wine industry. In 2002, the Australian Wine Industry released its environmental strategy called Sustaining success (SAWIA 2002). One of the actions required in the strategy was for each state to produce a SoE report. SAWIA released its first report in 2004 for the year 2003. The report states that its aim is to address a key action of the Australian Wine Industry's Environment Strategy, and

the 2003 report is seen as assisting with the establishment of benchmarks to guide the wine industry's environmental programs and priorities. Various input, output, and management indicators are presented but there are no specific soil or land condition indicators. The report contains data from industry surveys on water use per unit of production, uptake of soil moisture monitoring and water-use efficiency practice, irrigation application method, area of native vegetation per unit of production, and area of revegetation versus clearance.

SAWIA may benefit from a collaborative monitoring arrangement with the state agencies and regional NRM Boards to undertake future resource monitoring.

2.4.6 NATIONAL CARBON ACCOUNTING SYSTEM

The National Carbon Accounting System (NCAS) collects information to determine projected carbon emissions and sinks to meet National Greenhouse Gas Inventory reporting requirements in order to assess progress towards meeting Australia's emissions target (Australian Greenhouse Office 2006).

The NCAS has developed a highly integrated digital map based information system, which when combined with remotely sensed images of land cover change, land use and management change, climate and soils data, greenhouse accounting, and a modelling system can model changes in carbon stocks.

The NCAS undertakes the following activities to map landscape change to inform the modelling process:

- biomass — plant growth and life cycle analysis
- climate — soil moisture and forest productivity mapping
- land cover — mapping clearing and revegetation
- land use — mapping use and management
- soil — carbon measurement and modelling
- modelling — carbon stocks and flows.

The NCAS modelling process has been developed using data already available. There are currently no concrete drivers or requirements to report to NCAS, but it may benefit or be interested in data derived from any monitoring programs implemented in South Australia.

2.4.7 SUMMARY OF INTERESTED ORGANISATIONS

This section has documented a small portion of the organisations that may be interested in, benefit from, or produce land condition information and data products generated through monitoring. There are many other organisations in South Australia with potentially similar objectives and interests as those presented in the previous sections. However, reporting on all organisations at this scale is not within the scope of this review. Those organisations documented in previous sections were accessible, and represent the likely range of organisations that could benefit from collaborative monitoring arrangements with the state agencies or regional NRM Boards.

It is apparent that the data produced by the current LCMP and other programs is not being distributed or utilised to its potential by other interested organisations. DWLBC must consider the importance of a communication strategy for the information and products it produces and

establish improved working links with interested organisations. There also appears to be a number of potential opportunities for landholder surveys to be conducted collaboratively by several organisations. At this stage it is not known what intervals and future plans some organisations have for surveying landholders but this opportunity should be considered and discussed.

It is presumed that many interested organisations or groups will be connected in one way or another to their regional NRM Board. Through the regional NRM Boards, appropriate links for future collaborative arrangements for data sharing and monitoring may be made.

2.5 CONCLUDING DISCUSSION

There are multiple drivers for monitoring land condition in South Australia including legislated mandates, formal agreements between state governments and funding authorities, and an array of strategic and guideline documents designed to facilitate NRM practices and processes. LCM data provide a basis for planning future programs, identifying gaps in current programs, prioritising investments, and understanding the sustainability of current land practices.

Many of the documents and organisations reviewed in this section do not have clear information needs specified. Some assumptions will have to be made to correlate broad information needs with those organisations already specifically requiring certain datasets and presume the same information will be useful. SoE reporting for example is always under review and improvements made to the information gathered. SoE reporting does not necessarily monitor the same things over time, so care must be taken to differentiate between monitoring and the state of the environment at a given time.

This chapter has collated specific monitoring requirements where possible. These are collated into several summary tables including:

- National SoE Report 'land' theme core indicators reported in 2001 (Table 1)
- current status of National Resource Condition Indicators (Table 2)
- summary of LCM data requirements from key state documents (Table 9)
- summary of land condition information needs relative to each NRM Board region's RCTs (Table 10).

Table 11 on the following pages captures the types of actions, processes and data requirements for LCM and information.

Table 11. Summary of LCM requirements

Who	Why and What				
	Legislation	*Formal agreement*	*Strategy*	*Guidelines*	*Report*
Murray–Darling Basin Agreement	To provide for monitoring land (and other resources).				
National Strategy for Ecologically Sustainable Development			Development of EPBC Act (see below).		
Environment Protection and Biodiversity Conservation Act 1999	National SoE reporting (environmental assessment, indicators developed).				
National State of Environment					Indicators developed, reported, and under review.
Natural Heritage Trust Act 1997	Funds NLWRA (and other projects).				
Natural Heritage Trust and National Action Plan for Salinity and Water Quality		Requires state MER framework; NFNRMST and NMEF.			
National (Natural Resource) Monitoring and Evaluation Framework and Standards and Targets (NFNRMST)				Identifies 'Matters for Target' for NAP and NHT reporting and investment focus.	
National (Natural Resource) Monitoring and Evaluation Framework (NMEF)				Provides indicators under 'Matters for Target' to assist monitoring and reporting on NHT and NAP investment.	
National Land and Water Resources Audit			Collate info for environmental reporting and assessment.		

Who	Why and What				
	Legislation	*Formal agreement*	*Strategy*	*Guidelines*	*Report*
Natural Resources Management Act 2004	Create state and regional NRM Plans; requirement to monitor and assess state and condition and trends.				
State Natural Resources Management Plan			Contains state ME Framework; state-level RCTs for monitoring and reporting.		
South Australia's Monitoring and Evaluation Framework				Develop state MER Operational Plan; monitoring roles.	
Pastoral Land Management and Conservation Act 1989	Monitor and assess pastoral land condition.				
Environment Protection Act 1993	Monitoring and reporting on environmental quality and state-level SoE reporting.				
State level State of the Environment					Indicators developed, reported, and under review.
South Australian Dryland Salinity Strategy			Map, monitor and use indicators for dryland salinity.		
Soil Conservation Council (former) — Soil Conservation and Land Management; Directions for the Agricultural Lands of South Australia				Targets for land condition to be monitored.	
Green Print SA					Reports various land condition indicators and targets.
VivaSA					Revegetation only indicator as surrogate for land condition themes.

Who	Why and What				
	Legislation	*Formal agreement*	*Strategy*	*Guidelines*	*Report*
Department of Water, Land and Biodiversity Conservation	Responsible for various Acts, in particular state NRM Act.		In particular state NRM Plan.	In particular State M&E Framework, and development of state MER-OP.	
Department for Environment and Heritage	Various.	Conservation and biodiversity responsibilities.	Contributes to various.		Produced Green Print SA (OoS).
Environment Protection Authority	Predominantly *Environment Protection Act 1993*, includes state SoE.				
Primary Industries and Resources SA			State Strategic Plan, no land condition targets.		
Australian Bureau of Statistics	Provide statistical advice and information for decision makers.				
Regional NRM Boards	State NRM Act, must monitor and report state, condition and trends.	With NAP and/or NHT.	Produce a regional NRM Plan including RCTs and monitoring plan.	State MER-OP (when produced).	

3. EXISTING MONITORING PROGRAMS, DATA AND INFORMATION

The purpose of this chapter is to provide an overview of existing LCM activities, datasets, and information. The aim of discussing existing programs and information is to learn enough about each program to assess its adequacy to meet the current needs of stakeholders. This is a timely exercise for South Australia following the endorsement of the NRM Act and State NRM Plan. The Act and plan generate new land condition data and information needs for the state and regions, and it is important to determine whether existing programs meet these new needs.

An assessment of adequacy requires an understanding of the data collected by each program and a cross-match of this data with each region's data needs and the state's needs. Chapter 5 of this review aligns data needs with existing monitoring programs and proposed new programs to determine gaps and possible overlaps.

Adequacy is also related to issues such as source data, availability, coverage, format, frequency, reporting time frames, etc. This chapter aims to provide a thorough understanding of existing programs and identify where improvements may be made to create a more suitable dataset for assessment of land condition for a broader range of users, or determine that a program is no longer suitable.

This chapter has collated as many monitoring programs as possible that are relevant on at least a regional scale up to a national scale. Some of the programs generate information covering large parts of the state but not the whole of the state. Many of the indicators for land condition do not apply in some areas of the state; it is therefore likely that there will be a need for variable monitoring programs and datasets to be maintained to accurately monitor and evaluate the state's overall land condition.

Table 12 provides a summary of all existing monitoring programs reviewed in this chapter. A summarised discussion and recommendations for each of the key state LCMPs is contained in Sections 3.1–3.5. These summary sections are followed by the key state LCMP discussed in further detail in Tables 14–21.

It should be noted that for the purposes of this report, revegetation as an indicator of land condition has not been discussed and is considered better discussed in a biodiversity monitoring context. Given this, re-vegetation and native vegetation cover provides critical contextual information for LCM in most parts of the state.

Table 12. Summary of available monitoring data and adequacy for RCT reporting

Dataset	Custodian and purpose	Coverage	Frequency	Currency	Brief comment
'Windscreen' Field Surveys (wind and water erosion). (Further detail in Table 14)	DWLBC: derive an erosion risk index — how many days per year is soil exposed and susceptible to erosion.	Eyre Peninsula, Lower, Mid and Upper Northern and Yorke Agricultural Districts, Murraylands, Upper and Mid South-East.	Surveys conducted 4 times yearly. Have been conducted annually since 1999.	Index and associated products are available for 99–00, 00–01, 01–02, 02–03, 03–04 and 04–05.	Method not appropriate to use in Mt Lofty Ranges, Kangaroo Island and Lower South-East.
Land Manager Survey. (Further detail in Table 15)	DWLBC: to monitor landholders' changing practices — may increase or decrease the risk of degradation of land.	Eyre Peninsula, Mt Lofty Ranges, Kangaroo Island, South-East, Murraylands, Northern and Yorke.	Surveys have been conducted in 2000, 2002 and 2005.	2000 and 2002 are published, 2005 recorded but not yet published.	Survey only includes agricultural areas and does not include pastoral grazing regions.
South Australian Soil and Plant Analysis Service — Soil Testing Data. (SASPAS) (Further detail in Table 16)	PIRSA, Loxton: Analytical Crop Management Laboratory.	State wide.	DWLBC has accessed data annually since 1976.	The most recent set of data has been collected from 2004. Last report was generated in 2004.	No. of samples decreasing. Service being taken over by commercial soil testing labs and fertiliser companies.
Agricultural census and annual survey data. (Further detail in Table 17)	ABS: LCM Project utilises data from ABS to generate a water-use efficiency (WUE) indicator.	State wide.	Census is every 5 years; smaller surveys conducted annually with additional topic areas of interest.	Last census conducted in 2001, next planned for 2005–06.	Census includes information on the distribution and application of gypsum, lime, fertilisers and various land management and conservation activities.
Pastoral Areas Land Monitoring System. (Further detail in Table 20)	DWLBC: required under the Pastoral Land Management and Conservation Act 1989. Provides LCM data.	Pastoral and rangeland areas which includes the Arid Lands, Alinytjara Wilurara (Aboriginal Lands) and small portions of Eyre, Murraylands and Northern and Yorke regions.	Assessments required on each station at least every 8 years. Monitoring is conducted continuously to keep up with the 40 million hectares to be covered.	Information is being produced continuously.	Given the massive area to be covered, the supply of data is slow, and the assessment or monitoring of one site may only occur every eight years.
Land and Soil Information Framework (formerly SaLI). (Further detail in Table 18)	DWLBC: framework provides soil information for the dominant agricultural soils of South Australia.	Point data for South Australia Agricultural Region. Soil landscapes available for Eyre Peninsula, Yorke Peninsula, Murray Mallee, Northern	Point data collected once only. Collation of point data is continuous and updated almost every 6 months.	Point data collection commenced 1976 to present.	This information is intended to be baseline data and is not monitored repeatedly.

Dataset	Custodian and purpose	Coverage	Frequency	Currency	Brief comment
		Agricultural Districts, South-East, Kangaroo Island and Mt Lofty Ranges.			
Dryland Salinity Program — depth to groundwater monitoring. (Further detail in Table 19)	DWLBC: (monitoring often conducted by Landcare groups, Catchment Boards or LAP groups). Regional and local groundwater flow systems monitored in most of the regions.	Murray–Darling Basin, South-East (includes drainage scheme monitoring), Mt Lofty Ranges, Northern and Yorke Agricultural Regions, Kangaroo Island, Eyre Peninsula.	At least annually in most cases, some monitoring is a bit discontinuous where conducted by Landcare groups.	Generally at least annually.	Specific catchments have been selected for monitoring, not all regions are well covered by the monitoring networks — dependant on priority sites.
Dryland Salinity Program — ground-based electromagnetic (EM) surveys. (Further detail in Table 19)	DWLBC: to identify extent and severity of salinity at specific locations that can be monitored over time. Rural Solutions SA also conducts this work at other sites for its clients.	Northern and Yorke Agricultural Regions (Jamestown and Minlaton), Kangaroo Island (Narroonda), Eyre Peninsula (Wanilla and Darke Peak).	A program for re-surveying the sites is currently underway.	1991 for all but Narroonda (re-surveyed in 2004).	Limited sites have been selected for this level of monitoring. Other locations may well have been surveyed but the information is not captured or reported by DWLBC. EM survey areas need to be large to provide appropriate level of information.
Dryland Salinity Program–Groundwater Salinity. (Further detail in Table 19)	DWLBC: (samples often collected by a range of groups, individuals or agencies).	Murray–Darling Basin, South-East, Mt Lofty Ranges, Northern and Yorke Agricultural Regions, Kangaroo Island, Eyre Peninsula.	Usually annually where necessary; some monitoring is somewhat discontinuous.	Annually for most areas.	Specific catchments have been selected for monitoring; not all regions are well covered by the monitoring networks — dependant on priority sites.
Balancing Acidity in SA Soils Program. (B. Hughes, PIRSA, pers. comm., 2006)	DWLBC: – NHT funded. 3-year program aimed at increasing acidity awareness and lime usage across SA soils.	State wide (acid-prone areas of the State).	Landholder survey conducted twice only (1999 and 2002), somewhat replaced by LCMP Land Manager Survey. No repeat intended.	1999 — 400 farmers surveyed across the state.	Only a 3-year program focused on raising landholder awareness and knowledge, and monitoring the change between 1999 and 2002.
Survey of commercial lime suppliers. (B. Hughes, PIRSA, pers.	Rural Solutions SA and DWLBC: used as an indicator of soil acidity in SA.	Eyre Peninsula, Northern Agricultural Districts, Mt Lofty Ranges, South-East, Kangaroo	Annually. Data collected for last 7 years for the LCMP.	2004–05 season.	No real agreement to continue to collect data. Information not widely

Dataset	Custodian and purpose	Coverage	Frequency	Currency	Brief comment
comm., 2006)		Island, Southern Mallee (regions excluded do not have soil acidity issues).			distributed. Some difficulty recently with lime being purchased and sold between states and not being recorded.
Inland Acid Sulfate Soils Mapping (National Atlas of Acid Sulfate Soils (NAASS)). (Further detail in Table 22)	CSIRO Land and Water, CRC for Landscape Environments and Mineral Exploration: coastal acid sulfate soils (ASS) have already been mapped around Australia; this is the second stage.	Australia wide.	Once only at this stage.	In progress.	Will identify distribution and properties of inland ASS sites and level of risk of land degradation. Includes development of better field identification methods and modelling.
AussieGRASS (Australian Grassland and Rangeland Assessment by Spatial Simulation). (Further detail in Table 24)	QLD Department of Natural Resources, Mines & Water: (DWLBC Pastoral Program for SA data). Monitors condition and productivity of grazing lands, models potential consequences under weather and management scenarios.	National (grazing (pastoral) lands). In SA used for Rangeland regions.	Annual trends and other info as required.	Commenced in 1997; no data collected since 2005 by DWLBC but AussieGRASS still in operation.	DWLBC has ceased funding this project as of 2005. Cost is $50 000/y to access and download information. Info was used in a report titled 'Land Condition in the Rangelands Region of South Australia' in 2003 compiled by the Pastoral Program and the Soil and Land Information Divisions of DWLBC.
Vegetation Cover Monitoring in the Perpetual Lease Rangelands. (See Figure 8 for location) (Lay et al. 2003)	DWLBC: land originally cleared for cropping; climate found to not be suitable and was heavily grazed instead. Massive decline in perennial vegetation populations. Perennial vegetation provides soil cover and fodder, and is key indicator of condition.	Area of land between cropping and pastoral lease rangelands, not covered by other monitoring programs. Monitoring zones include: Tent Hill, Middleback, Parachilna, Flinders, Willochra, West Yunta, East Yunta, Murkaby, Morgan, Mt Remarkable.	Conducted annually between 1999 and 2004.	Not conducted in 2005 or 2006. Last survey conducted in 2004 but no analysis of data conducted since 2003.	The survey takes approx. 2 weeks to conduct and costs approx. $10 000 in expenses. The program ceased due to lack of funds and suitably qualified staff. Without the program there is a significant gap in monitoring land condition for the state.

Dataset	Custodian and purpose	Coverage	Frequency	Currency	Brief comment
Land management regional market intelligence monthly report.	DWLBC (Land Management Group) (produced by Rural Solutions): Provide contextual information from the regions on seasonal conditions and events, land management practices, NRM Board or community group land issues, risks, achievements and/or highlights.	Northern Agricultural Districts, Yorke Peninsula, Mt Lofty Ranges, South-East, Murraylands, Kangaroo Island, Eyre Peninsula, Rangelands.	Monthly.	Conducted since approx. 2002 on a monthly basis. Ongoing.	Information in these reports ensures that agency staff are informed and programs are relevant to regional needs. Information provided is somewhat sensitive and distribution is currently limited. Discussions to exclude sensitive information for wider distribution are underway.

3.1 LAND CONDITION MONITORING PROGRAM

The LCMP collates data from multiple sources that can quantify trends in land condition across South Australia's agricultural areas.

Data from the following sources is used by the LCMP:

- DWLBC's field survey program for wind and water erosion ('windscreen surveys')
- DWLBC's land manager surveys
- PIRSA's South Australian Soil and Plant Analysis Service soil test data
- Australian Bureau of Statistics agricultural census data.

(Further detail on these programs is contained in Tables 14–17)

Data from DWLBC's Land and Soil Information Framework have been used to determine the distribution of susceptible land for each monitoring target (e.g. acidity, salinity, etc). The monitoring programs could then be focused on those areas of the state that required monitoring. Not all land condition issues are relevant to all regions of the state.

The LCMP collates information for monitoring the following land condition issues:

- soil water and wind erosion
- soil acidity
- dryland salinity
- soil physical condition
- soil fertility and nutrition
- soil-water repellence (non-wetting soils)
- revegetation (not discussed in this report).

The LCMP was originally driven by a need to quantitatively assess land condition to justify investment into several land management programs. These programs were required to be

administered by DWLBC under the former Soil Conservation and Land Care Act 1989. The information also assisted with the development of state soil and land management targets.

Currently, one state-level LCM report has been generated in 2004. A separate draft report for the Eyre region has been developed upon request from the region. With new NRM boundaries in place and reporting requirements imposed on the regions, it may be more appropriate for regional reports to be produced regularly. The production of individual regional reports could enable important local and regional data, knowledge, and interpretation of conditions to be integrated with data produced by the LCMP.

Recommendation 1: If the LCMP undertakes to produce regional land condition reports within new NRM boundaries, part of the process of producing the report should be to enable local and regional data and knowledge to be incorporated to support regional interpretation.

The LCMP reporting frequency is very uncertain and currently no plans are in place for a second state report or further regional reports. Future reports could be created if enough interest was expressed, and the time and cost could be justified. Part of the problem generating interest for the reports is that a limited number of people or relevant groups are aware of their existence and/or potential use. Some time and assistance should be given to the LCMP to develop a communication strategy that would identify potential information products for stakeholders and determine the most appropriate ways to present and distribute the information. If a broader range of stakeholders could make productive use of the information, this might drive a more consistent reporting schedule.

Recommendation 2: DWLBC, in conjunction with the regional NRM Boards, considers development of a communication strategy for the LCMP reports and information, which includes consideration of the most suitable format for a variety of audiences.

The LCMP is presently considered to be ‘ongoing’, but it is a common difficulty to maintain funding and ‘attention’ for long-term monitoring. This program requires at least a 10–15 year period to demonstrate significant changes in land condition across the state. Shifting institutional arrangements also creates the potential to erode current funding regimes. A new focus on monitoring has been identified in the recent State NRM Plan that should ensure the sustainability of long-term programs. The development of the MER-OP will undoubtedly assist improved funding arrangements and plan long term for the various programs.

Recommendation 3: DWLBC and the regional NRM Boards incorporate the LCMP into a long-term strategic monitoring plan for South Australia, such as the MER-OP.

The LCMP Manager has predominantly been the sole person who collects, checks, corrects and collates the data from the four major data sources. This depth of experience is critical to the accuracy and continuance of the program. The program manager is intending to retire in the near future and little effort has been made to identify a replacement with relevant experience and skills to maintain the integrity of the program. There are also apparent data management issues that could be dealt with relatively easily and may minimise some of the data collection and checking processes the program manager currently has to accommodate. Some investment is required to update the database used for the field survey program. The current database also has some gaps and flaws that could be readily adjusted by an experienced database user. Much of the data collected by the program are sifted through manually before collation. With some assistance from experienced information technology technicians, the amount of time spent processing data could be significantly shortened.

Recommendation 4: DWLBC implement succession planning and mentoring activities to ensure experienced and trained staff continue to manage the LCMP.

Recommendation 5: DWLBC provides expert help to work with the LCMP Manager to update software and processes used to manage the LCM data.

3.1.1 FIELD SURVEY PROGRAM FOR WIND AND WATER EROSION

The 'windscreen survey' was developed for use in predominantly broadacre cropping districts of the state where land zones were considered to have an 'intrinsic potential for soil erosion' (McCord & Payne 2004a). This method is not considered suitable for use in more intensive, high rainfall agricultural areas including the Lower South-East, MLR and Kangaroo Island for several reasons:

- the paddock size is often too small to allocate it a representative grid size.
- too many changes in landform and condition can occur across even a smaller size grid.
- there are very few areas where copping and cultivation practices occur.
- many blocks through these regions are now owned and managed by non-farmers.
- the roads are not safe for vehicles to be continuously stopping on the side of the road to make assessments.
- roadside vegetation can make it near impossible to see enough sites.
- surveys in the MLR would have to go over waterways.
- MLR has more of a problem with mass erosion, such as gully erosion and landslips, rather than large-scale wind and water erosion.
- a survey of this kind would most likely only demonstrate that nearly all land in the region is almost always covered, therefore not providing any useful information.

Perhaps in light of these problems, an additional more specific monitoring regime could be developed for these intensively farmed, higher rainfall areas. Options might include the use of aerial photography or videography, or satellite imagery. Surrogate measures such as stream turbidity or land management activities could be utilised to determine an erosion index.

There are other gaps and inconsistencies within the 'windscreen survey' and they are further discussed in Table 14. Thomas (2001), in a report on the ability of remote sensing to support the LCMP, noted its limitations:

- '… survey sites being confined to roadside paddocks with difficult to reach areas not being surveyed at all; …
- … the large number of trained observers for extended periods results in high operating costs and logistical effort; and
- likely inconsistencies in sampling standards between different observers. Variability between data collectors — consistency in observations …'

The 'windscreen survey' transects have been developed to include enough sites to produce a statistically sufficient representation of the land that is being surveyed (see Fig. 5). The focus of the survey is on cropping lands and therefore some of the 'difficult to reach areas'

suggested by Thomas (2001) are not likely to be utilised for cropping and therefore are not likely to be relevant.

The LCMP Manager has spent significant time and effort preparing manuals and conducting training to ensure that the surveys are conducted consistently and accurately between the observers. Alternative approaches such as remote sensing may add value or help to confirm or calibrate the 'windscreen survey' index method and enable a spatial appreciation of the erosion index. Remote sensing could enable other regions such as the pastoral lands to be monitored. The use of remote sensing for these purposes has been trialled and documented by Thomas (2001). Discussions regarding future monitoring opportunities are discussed in Chapter 4. Presently, the 'windscreen survey' transects are being mapped using Global Positioning System (GPS) technology. This will enable observers to return to exactly the same survey sites and significantly decrease error margins when determining the soil type and slope at each site. This information will be confirmed once, and follow-on observations will not need to be done.

The issue of high operating costs raised by Thomas (2001) should be considered in context to other field observation monitoring programs.

Recommendation 6: DWLBC considers integrating remote sensing monitoring to expand current coverage of the LCMP and to provide a further level of confidence in the erosion indexes.

The expert panel for wind erosion, appointed by the National Committee on Soil and Terrain for NLWRA, has recommended the use of such roadside surveys for monitoring. The expert panel recommended a working group be established to define '… minimum standards and definitions for roadside surveys …' (McKenzie & Dixon 2006) because of variation between surveys conducted in several states. The expert panel also suggested that a '… rapid roadside survey technique of Wind Erosion Risk Assessment …' document be produced to make the methodology available for wider application.

3.1.2 LAND MANAGER SURVEY

This phone survey was designed to monitor change in land management practices, knowledge, and attitudes of land managers across time as an indicator of increasing or decreasing risk of degradation to land (see Table 15 for further information). The survey specifically targets broadacre, stock and dairy farmers as the largest group of landholders in South Australia. This targeted approach leaves out a huge number of other land managers who also contribute to land condition but for a far smaller portion of degradation-susceptible land. The LCMP has limited resources and has had to limit the scope of this survey in order to collect enough data to produce statistically sound results. However, similar surveys of a smaller audience could be developed for other land users and be of considerable value to many stakeholder groups.

Recommendation 7: State agencies and regional NRM Boards investigate the potential for additional Land Manager Surveys to expand the current understanding of land management trends.

Recommendation 8: DWLBC investigates potential stakeholder interest in additional Land Manager Surveys for possible resource assistance.

The NLWRA-appointed expert panel for water erosion has recommended monitoring land management practice changes as a surrogate for erosion trends.

3.1.3 SASPAS DATA

Soils analysis data is sourced from PIRSA's South Australia Soil and Plant Analysis Service (SASPAS) and collated into maps documenting trends in soil pH and fertility. A number of issues with these data are discussed further in Table 16. Two issues are discussed below.

Firstly, the data are provided to DWLBC in a particularly disorderly fashion. The data are stored on an archaic database system at SASPAS and can only be provided to DWLBC as an Excel™ spreadsheet.

There are often many errors and inconsistencies in the data such as no location details of samples analysed. Approximately half of the data received from SASPAS cannot be used.

The reason for the inadequacies is that PIRSA has no apparent use for these data and do not use it beyond providing information back to the client. Resource cuts have worsened these problems in recent years.

Secondly, the future of SASPAS itself is uncertain. The number of soil samples processed by SASPAS has dwindled from a maximum of 10 000 in 1996 to a mere 800 in 2004. The number of samples analysed can also be very indicative of the financial position of rural communities. It is estimated that SASPAS processes approximately 30% of all soil samples submitted for analysis across South Australia. The remaining 70% have been taken over by commercial fertiliser companies such as HiFert and Incitic Pivot. The fertiliser retailers sample soils from their client's properties and then sell their appropriate products based on the analysis results. The cost for soil analysis is minimal to the fertiliser companies compared to the value of product they are able to sell. A far larger number of soil analysis results were sourced from various fertiliser retailers for the National Land and Water Audit published in 2001 by Doug Reuter (formally CSIRO). Reuter had very good alliances with the fertiliser retailers that enabled him one-off access to these data. Most fertiliser retailers do not wish to release data for confidentiality reasons or to inadvertently give competitors useful marketing information. Ideally, DWLBC could negotiate an access agreement with the fertiliser companies to collect particular analysis results. DWLBC may be able to justify some contract of payment for data to be provided at an appropriate standard. Other organisations such as PIRSA or CSIRO may find the data useful and be able to contribute to the cost.

Recommendation 9: DWLBC investigates opportunities for creating an access agreement to soil analysis data from commercial fertiliser retailers.

Recommendation 10: DWLBC (and regional NRM Boards) investigates other potential users of soil analysis data and what kind of contribution they may make to the agreement.

3.1.4 AUSTRALIAN BUREAU OF STATISTICS AGRICULTURAL CENSUS

The LCMP utilises data from ABS to:

- generate a Water Use Efficiency (WUE) indicator
- map the application and distribution of gypsum
- map the application and distribution of phosphorus fertilisers (see Table 17).

ABS (2006a) has been conducting the agricultural census for several decades, and electronic versions of survey results have been available since 1982. In 1994, ABS introduced the short-form survey, which replaced the annual census for four out of every five years. Since the introduction of the short-form survey, the level of detail in data accessed on an annual basis has been significantly less. Annual data are only available at a statistical division scale, therefore broadening the monitoring framework from district to regional scales.

There is a significant delay in receiving census data from ABS at a Statistical Local Area level after it is first collected; data are received up to two years after originally collected. This has an impact on the timing of reports that can be generated for the state or regions. Perhaps an alternative source of commodity data could be used to generate the WUE index. For example, if an agreement was made to collect soil analysis data from fertiliser retailers (as per the previous section), perhaps additional data on the purchase of gypsum and phosphorus fertilisers could be negotiated.

ABS is currently considering reforming the boundaries of the statistical areas and divisions, which may have an impact on how the LCMP extracts data for regional areas and the new NRM Board areas. ABS has concerns about the scale of data that can be accessed, especially for remote areas where individuals could be identified. DWLBC is currently involved in the statistical areas discussion and can inform ABS of the possible impacts of future statistical areas.

3.2 LAND AND SOIL INFORMATION FRAMEWORK

The Land and Soil Information Framework (formerly SaLI) is a baseline dataset collected over a period of nearly 30 years of the soils and dominant landscapes of South Australia's agricultural areas. See Table 18 for further information.

The data have been collated and analysed to provide three general types of 'derived information':

- descriptions and maps of the soils and landscapes of South Australia's agricultural districts
- soil and land surface features (attributes) affecting land management and productivity
- the physical suitability of land for a range of agricultural uses (Crop Potential Models).

The derived data have been very useful for the development of other LCMPs, providing information on high priority landscapes for dryland salinity, soil acidity and erosion risk.

There are large data gaps in the chemical and physical characteristics of soils across the state. For a comprehensive state baseline of soils information, at least 1000 more sites should be chemically analysed and a significant subset of these analysed for physical characteristics. This is a significant amount of work and it is still only baseline data. Several regions could also benefit from additional survey sites. The data have been extrapolated significantly in some areas to create the large extent of coverage.

The derived data have been very useful for the development of other LCMPs, providing information on high priority landscapes for dryland salinity, soil acidity and erosion risk.

Table 13. Summary of information, data source and availability for each region derived from the Land Condition Monitoring Program (AW and Arid Lands not included in LCMP)

Information	Data source (see end of table)	Availability per NRM Region (not always complete match)					
		EP	*NYAD*	*SE*	*AMLR*	*SA MDB*	*KI*
Water erosion index	WS	✔	✔	✔		✔	
Proportion of cleared land (%) at risk from water erosion	WS	✔	✔	✔		✔	
Area of land at risk from water erosion	WS	✔	✔	✔		✔	
Wind erosion index	WS	✔	✔	✔		✔	
Proportion of cleared land (%) at risk from wind erosion	WS	✔	✔	✔		✔	
Area of land at risk from wind erosion	WS	✔	✔	✔		✔	
Proportion of cleared land (%) where wind erosion occurred	WSA	✔	✔	✔		✔	
Average proportion (%) of land managers considering water and wind erosion, soil structure decline and water repellence as land management issues in their district	LM	✔	✔	✔	✔	✔	✔
Average proportion (%) land managers using cultivated long fallows, direct drilling, no-till, feedlots for stock in autumn, burning residues, testing for soil fertility, off-farm advice and practices to overcome water repellence	LM	✔	✔	✔	✔	✔	✔
Average preferred month for cultivation for crop preparation	LM	Reported for high, medium and low rainfall zones					
Average proportion (%) of land managers considering stubble retention and tillage as important	LM	✔	✔	✔	✔	✔	✔
% of low pH soil samples	SASPAS	✔	✔	✔	✔	✔	✔
Estimates of lime required to raise low topsoil (includes area of land with topsoil with pH <5)	SASPAS	✔	✔	✔	✔	✔	✔
Estimate of lime required to neutralise acidification of cleared land (includes area of land with acid soils)	SLS	✔	✔	✔	✔	✔	✔
Lime applied	LM	✔	✔	✔	✔	✔	✔
Perceptions of acidification causes and amelioration practices	BASAS & LM	Reported for state as whole					

Key for data source:

WS — DWLBC-funded 'windscreen surveys' (part of LCMP) — 6 years of data 99–00, 00–01, 01–02, 02–03, 03–04 and 04–05

WSA — Additional information on visual evidence of erosion from DWLBC 'windscreen surveys'

LM — Land manager survey (part of LCMP) — 2000 (618 farmers), 2002 (1003 farmers) and 2005 (1003 farmers) (broadacre, stock and dairy farmers only)

SASPAS — soil testing data available from commercial soil testing (part of LCMP)

SLS — DWLBC survey of lime suppliers (part of LCMP) — 7 years 1998–99 to 2004–05

BASAS — PIRSA's Balancing Acidity in South Australia Soils project targeted 400 farmers in areas of the state with large areas of acid soils — 1999 and 2002.

Land and Soil Information Framework

There are large data gaps in the chemical and physical characteristics of soils across the state. For a comprehensive state baseline of soils information, at least 1000 more sites should be chemically analysed and a significant subset of these analysed for physical characteristics. This is a significant amount of work and it is still only baseline data. Several regions could also benefit from additional survey sites. The data have been extrapolated significantly in some areas to create the large extent of coverage.

A re-survey of sites already included in the database could potentially provide some indication of changes over time for a number of soil properties. There are potential logistical and resourcing issues with such a project; however, even a small subset of sites for trend analyses would be very informative.

All the point data collected during the surveys could be utilised by members of the public and other agencies if appropriately stored. Presently, much of the survey documentation remains paper based, and interpretation of this needs to be conducted by experienced staff and recorded in an appropriate system. Should this task be left much longer, a great deal of the knowledge to interpret this data could be lost due to staff retirements.

Recommendation 11: DWLBC considers the value of conducting additional soil surveys to enhance the SaLI database and mapping products.

Recommendation 12: DWLBC (and potential collaborative organisations) considers conducting repeat soil surveys for a select number of sites and parameters to trial the possibilities of repeat site sampling for monitoring.

Recommendation 13: DWLBC edits and adds to the database all the paper-based point soil survey data to ensure maximum information availability and that knowledge is not lost.

3.3 DRYLAND SALINITY PROGRAM

DWLBC has been engaged in dryland salinity monitoring (see Table 19) for many years, and priority regions and catchments have been selected across the state. Three major indicators have been identified (nationally and by the state) as key monitoring data to assess dryland salinity:

- depth to groundwater
- groundwater salinity
- location, size and intensity of salt-affected areas.

To ensure that groundwater trends can be accurately utilised for modelling and interpretation of groundwater flow systems, water level and groundwater salinity monitoring must be conducted regularly and without significant breaks in data. The apparent ad hoc reading of water levels and sampling regimes in some locations can render much data useless and does not make proper use of the funds invested in constructing piezometers. Funds and resources to conduct these monitoring programs should be given a higher priority status than they have in recent times.

Presently, only ‘high’ risk salinity areas have been allocated monitoring programs. There are potentially many more areas that have a moderate salinity risk that are not being monitored.

Recommendation 14: DWLBC (and potential collaborative organisations) review the current groundwater monitoring programs and considers whether areas currently at moderate risk of salinisation should be included in a monitoring program.

There are presently issues around the management of electromagnetic survey data within DWLBC. A concerted effort is required to manage and collate data into useful information for use and trend analysis.

A significant amount of monitoring and evaluation has been conducted around salinity issues. South Australia has had a Dryland Salinity Strategy in place since 2001 (PIRSA 2001). For this reason, this review does not repeat discussions that have already been concluded. Figure 7 shows the locations of catchments that have salinity management plans and are monitored. For further information regarding dryland salinity monitoring and reporting, see references provided in Table 19.

3.4 PASTORAL AREAS LAND MONITORING SYSTEM

This monitoring program is ongoing and is required under the *Pastoral Land Management and Conservation Act 1989*. Under the Act, leaseholders must pay rent that funds the majority of the program. The program collects information from photo-point survey sites, remote sensing imagery (presently in pilot form) and land condition indexes for lease properties (see Table 20). The program was designed to assess the condition of lands comprising pastoral leases and other tenures in the rangelands region at set intervals of time. It was not intended to provide complex trend data on land condition or biodiversity. For this reason, there are many opinions circulating about the methods used in the assessments and whether better options exist to meet the recent expansion of monitoring and evaluation drivers. Budget and time constraints have hampered the development of many of the possibilities. If the program had additional funding to expand slightly on the current methodology, not ignoring the need for pastoral assessment, far more useful monitoring and trend data could be collected to meet current monitoring and evaluation requirements.

A vast quantity of data has been collected over the years, even prior to the requirements of the Pastoral Act. Presently, the program is experiencing great difficulty in managing these data with the very slow development of the Arid Lands Information System (ALIS) and the shutting down of the former (very dated) Pastoral Management Information System (PMIS).

One of the major inconveniences in using the assessment data for monitoring is the time delay in collecting the information. An assessment cycle is once every 14 years. Most leases will be inspected at least once every eight years, but sometimes this is not the case. Even if a property is inspected more regularly, the level of data collected is often less than sufficient for ‘monitoring’ per se. The seasonal and annual climatic differences make it near impossible to logically compare assessments without some subjective criteria. The use of remotely sensed imagery models such as AussieGRASS and the Grazing Gradient have the benefit of being large scale and may capture a single time slot. The combination of ground-based and remotely sensed imagery would appear to be the most beneficial monitoring combination. A paper recently compiled by Bastin et al. (2006) found remote sensing data particularly useful to landholders in assessing vegetation cover. The potential exists for collaborative arrangements between landholders and monitoring agencies to make efficient use of remote sensing information.

Recommendation 15: The Pastoral Program, in cooperation with ACRIS and other rangeland monitoring bodies, continues to collaborate on data collecting methods to meet pastoral assessment and future monitoring requirements for land condition and biodiversity.

Recommendation 16: DWLBC hastens the development of ALIS to ensure the effective operation of the pastoral assessment and monitoring programs.

Recommendation 17: The Pastoral Program or DWLBC investigates means to fund and attract new staff to the program to assist with the current backlog of data processing.

Recommendation 18: Further investigation of the options for remote sensing monitoring in the rangelands in combination with the ground-based assessment and potential collaborative relationships with landholders.

3.5 LAND-USE MAPPING PROGRAM

Land-use maps are particularly important contextual information for monitoring land condition changes. Land-use change has a significant impact on the types of threats to land condition.

The Land Use Mapping Program (see Table 21) has been predominantly funded through external projects, particularly by the Bureau of Rural Sciences that endorsed a project to produce a digital dataset showing the distribution of land-use classes for the whole of South Australia. Given the large expense of collecting these data, the maps are considered to be a snapshot in time and are not generated regularly to monitor change. The datasets for each region were produced between 1998 and 2003 (see Fig. 9). As always, some difficulty is encountered on ground when surveyors are interpreting what they see, and what they cannot see. The Australian Land Use Management Classification has been devised to standardise the methodologies employed but some error is inevitable. Some regions of the state experience changes of land use more rapidly than others. DWLBC has monitored specific land-use changes as required, such as the expansion of farm dams and irrigated crops across the MLR.

Table 14. DWLBC's Field Survey Program for wind and water erosion

Name	DWLBC's Field Survey Program for Wind and Water Erosion (sometimes referred to as 'windscreen survey')	Comment (e.g. adequacy) and observations
Custodian	DWLBC, Knowledge & Information Division	
Contact details	Andy McCord, Senior Scientific Officer, DWLBC	Andy McCord is the sole person responsible for collating information and reporting on this project. Succession planning should be a key focus to maintain the value of the project.
Status	The LCMP is part of the work undertaken by the Information Management Group in Knowledge & Information Division of DWLBC. The LCMP is ongoing. Data for the Wind Erosion Index are collected each year. The report detailing the results has been produced once (in 2004) and it is not known when the next report will be commissioned.	The field survey work is part of the LCMP which is a DWLBC-funded project and therefore subject to the continued availability of funding. Institutional arrangements for the management of the LCMP require clarification. Actions have been taken to manage the information collected and ensure that the methodology is well documented.
General description	The Field Survey Program (FSP) is a part of the LCMP undertaken by DLWBC, which focuses on cleared agricultural land. The LCMP has collected six years worth of data using a variety of sources including field surveys four times a year. The purpose of the FSP is to collect data to assess trends in wind and water erosion predominantly across cropping land in South Australia. The information was first requested by the Land Management and Revegetation Program from DWLBC for the purpose of monitoring risk in relation to programs that encourage 'no till or direct drill' adoption. The information has been used previously for SoE reporting. Some of the information may be better reported at the regional level, especially with new regional NRM bodies and their reporting requirements.	The focus is on cropping land and does not cover rangelands, high rainfall and irrigated horticulture. The information currently appears to be very underutilised. PIRSA, industry groups, regional NRM Boards and other organisations such as LandCare and the SA No Till Farmers Association are likely to highly value this information if it could be communicated in methods appropriate to the variety of potential users. The regional NRM Boards have been made aware of the program but do not appear to have distributed the information to local groups and interested parties as perhaps envisaged.
Rationale	A risk assessment approach is used, which combines inherent susceptibility (soil and landscape type) and key management practices (disturbance and cover), with the underpinning rationale that an assessment of trend in exposure of land is a more viable approach to soil erosion monitoring than direct measures of soil loss. One of the key indicators used in the LCMP is an annual Wind Erosion Risk Index which 'is an estimate of the average period for which cropped land is exposed to ... erosion … risk during the year' (McCord & Payne 2004a, p.15). DWLBC (SaLI) wind and erosion risk mapping has been used to identify land at risk in agricultural areas. Land zone mapping has been used to identify zones considered to be at risk.	Other approaches may compliment the program but no alternative has yet been developed that can provide such detailed ground-based information. Remote sensing research may supplement the surveys and provide important calibration or contextual data. Presently, remote sensing data cannot be interpreted with enough confidence to be utilised without ground-based survey work. The University of Adelaide's MODIS work may be a possibility when further research work has been undertaken and a higher level of confidence reached.

Name	DWLBC's Field Survey Program for Wind and Water Erosion (sometimes referred to as 'windscreen survey')	Comment (e.g. adequacy) and observations
Survey methodology	The survey is designed to assess agricultural land cleared for cropping and grazing. Field surveys are undertaken four times a year to coincide with key cropping phases that have a bearing on soil erosion (October, March, May and peak sowing time, which is usually early to mid-June), along fixed transects, in 'at risk' zones. Data along transects are recorded manually in the field by Rural Solutions SA field staff (in some instances experienced casual staff are involved) and entered into an Excel spreadsheet. A transect has many 'sites', each of which are identified by a new fence line so that as many paddocks as possible are sampled along a transect with the aim of capturing a 'statistically sufficient' number of sites per zone. A pilot statistical study undertaken in the early stages of the LCMP development suggested that a minimum of 20/25 sites were required per zone and most zones have data from 75+ sites per zone. This means that, while the transects are repeated with each survey, not all sites are revisited on each survey, but that enough sites are recorded along the transects in each survey to produce an accurate representation of erosion risk for the zone and change from one surveys to the next. In 2006 it is intended that all sites will be GPS located so that more consistency can be achieved through site characterisation.	The survey methodology has been developed to collect data in agricultural cropping land and principally in areas considered 'at risk'. It is not a suitable methodology in other areas, for example the MLR where paddock size is small, variables are highly site specific and field (roadside) surveys are inherently more difficult. It is recognised that there will be variability between data collectors. Protocols and monitoring parameters have been determined and training sessions conducted to minimise the variability. The Program Manager has indicated that he will endeavour to be responsible for core data collection, which will reduce variability for the time being. Succession planning for the Program Manager's role in interpreting the data is a significant issue at present. There are some consistency issues with surveyors wrongly identifying the 'topographic rating for wind'. This involves determining if the soil is clayey or sandy and the general topography. In dry conditions a soil may appear to be sandy if it is un-worked and grains of soil are loose on the surface. If the soil is slightly moist or has been worked, it might appear to be clay. This interpretation issue can significantly change the results of the survey — extreme care needs to be taken to not mistake the soil type. The field survey program is gradually introducing GPS location of survey sites. This will significantly decrease error margins when observers determine the soil type and slope at each site. This information will be confirmed once, and subsequent observations will not need to make this assessment again. An additional benefit is the possibility of comparing specific sites.
Source data used in survey design	DWLBC's SaLI Land Description GIS dataset was used to create Soil and Land Information maps to then identify zones with an increased 'Erosion Potential'. Landscapes with increased risk of erosion include sandy soils, some calcareous soils, loamy soils on slopes, etc. Regional PIRSA officers were then informed of the zones that needed to be covered in their areas. The officers then determined the transect lines along appropriate roads using their local knowledge.	
Source data collected	45 land zones have been identified across SA using the DWLBC Land Description dataset. Field surveys are conducted along 14 transects across 38 of the zones considered to have significant potential for erosion (see Fig. 5). The zones include Northern and Yorke Agricultural Districts, Eyre Peninsula, Murraylands and Upper and Mid South-East. These areas represent 8.5 million hectares of the 10.2 million hectares of total cleared farming land. The remaining areas (Lower Yorke Peninsula, Kangaroo Island,	The surveyors sometimes make general observation comments on the record sheets. Some surveyors provide abundant detail and others do not provide any comments. Often the comments are particularly useful to analyse general conditions in the environment (e.g. presence of plagues or weather conditions) and provide information for the interpretation of the results. If general comments are particularly useful, perhaps they should be formally included in the data recording process.

Name	DWLBC's Field Survey Program for Wind and Water Erosion (sometimes referred to as 'windscreen survey')	Comment (e.g. adequacy) and observations
	Lower South-East and southern MLR) are considered to have a low potential erosion risk. Approximately 6000 sites are surveyed four times each year. Data collected at each site: Date, site number, transect number, zone number (a combination of land zone and rainfall), land type (may be more than one type), presence or absence of dunes, topographic rating for wind erosion (based on soil and land type), topographic rating for water erosion (based on slope), current rotation phase, detachment rating (based on stability as influenced by soil surface disturbance (cultivation or grazing)), cover rating, wind erosion severity (observance of evidence of wind erosion), sheet rill severity (evidence of sheet or rill water erosion), degree of residue burning if present, and general comments on observations that influence site cover (e.g. seasonal issues, pests, pasture treatments, etc.).	
Data format and location	Final data are stored in an Access 97 database.	The Access 97 database is not fully compatible with later versions of Microsoft Access. Additional database design work would be required to upgrade the database. This is not considered to be a difficult change to make, but would probably be time consuming.
Processing of source data	The data are recorded manually in the field, and then entered into an Excel spreadsheet. Data from each of the regions (data is grouped into regions and zones) are checked by the Project Manager and appended into an Access database. The menu-driven Access program calculates and compiles summary tables for proportions of land at risk. The final products including annual and indicator graphs are prepared by transferring data to specific Excel spreadsheets. The 'Rationale and Methodology' paper listed below describes the formulas to provide the following information: • Trends in proportion of land at risk (calculated and compiled by a menu-driven database at zone, regions and state levels). • Matrix of cover, detachment and topographic ratings. • Where sandhill and flat land occur together, both are characterised and then a single representative record for each site is selected based on highest Cover Rating or Erosion Hazard Index so that the facet of most risk is used. • Annual graphs are generated from the database.	A single individual currently has expertise in the data processing. Data goes through several stages of collation and analysis and it would be difficult for raw data to be processed by any other individuals. A thorough understanding of the methodology and site specific issues are required to consistently compute the data (e.g. some observation sites along transects have data recorded for two distinct land types). The breadth of knowledge of the individual currently undertaking the analysis enables data accuracy to be assessed. The index derived from the survey data often has to be time adjusted due to fluctuations in seasonal trends. Upon further investigation of this adjustment process, it became evident that the database itself has several limitations, which could potentially be overcome if some investment was made into redesigning and updating the program. This would also save the Program Manager a lot of time in adjusting data in and out of the database.

Name	DWLBC's Field Survey Program for Wind and Water Erosion (sometimes referred to as 'windscreen survey')	Comment (e.g. adequacy) and observations
Derived information and format	Key indicators are: • Change profiles — annual wind and water erosion risk — graphs produced from Excel (Erosion risk can also be calculated purely on cover data). • Peak risk trends of wind and water erosion — graphs produced from Excel. • Estimated period of risk for zones, regions and state — graphs produced from Excel. Interpretative comments would also be required to explain why there are differences, what the index and graphs show, and contextual information on yearly conditions.	At present, a state land condition report and a regional report for Eyre Peninsula have been published. There are many products that could be developed from the information but its existence and level of data are not well known. Regional reports may become more relevant as regional NRM Boards develop their monitoring and evaluation policies. The Program Manager suggested these data may be very useful if combined with remote sensing projects in the future.
Area of coverage	The collection of erosion risk data through 'windscreen surveys' is conducted in the following regions: • Eyre Peninsula • Lower, Mid and Upper Northern and Yorke Agricultural Districts • Murraylands • Upper and Mid South-East To date, surveys have not been conducted in: • Lower Yorke Peninsula • Kangaroo Island • Lower South-East • Southern MLR These are considerably lower or non-risk erosion regions. Where erosion does occur, it tends to be on a far smaller scale than the regions surveyed.	The term 'region' refers to the major agro-ecological regions used by the LCMP — these do not in all cases match the boundaries of the new NRM Board regions. This might require further exploration to determine 'where' the transect data was attributed. The Project Manager does not consider this will produce major anomalies, but data could be adjusted over time. Any anomalies of this nature will have little influence on the Wind Erosion Risk Index but will have more impact on the associated products such as area at risk.
Useability scale	This information is useful for reporting at state level for agricultural cropping lands particularly, at regional level (subject to new NRM boundaries), and possibly at district (zone) level depending on where a particular transect is located.	If these data were to be used at subregional levels, care should be taken to ensure that the volume of data for the area is statistically robust. Further investigation of these details would be necessary.
Dates and/or recency	Index and associated products are available for 1999–00, 00–01, 01–02, 02–03, 03–04 and 04–05.	The executive summary of the LCMP's 2004 report notes that, as land condition changes occur over a long period of time, the information presented to date is only a baseline assessment. It is not known when the next report will be produced. This depends on need and funding availability. The data are still being collected regardless of reporting.
Availability	Information from the field surveys has been reported in McCord and Payne (2004). Whilst this includes information at regional level, the main focus of the report is the provision of the state-level land condition. There has been	Significant checking, collation, analysis and interpretation are required to produce the index and graphs from raw field data. It is advisable to access the final product itself or request DWLBC to process the data for the required use.

Name	DWLBC's Field Survey Program for Wind and Water Erosion (sometimes referred to as 'windscreen survey')	Comment (e.g. adequacy) and observations
	discussion of producing a LCMP report for each region but this requires additional resources, and an informal report for Eyre Peninsula is the only regional report produced. DWLBC will share the data and the intention is to make the summarised findings more publicly available. It was anticipated that the LCMP methodology, reports and information products will be available on the DWLBC web site. At this stage, only the paper listed below on 'Rationale & Methodology' and 'Monitoring Manual' are available.	DWLBC will then need to consider the resources required to meet the request. The development of the regional report for EP raised several issues that would be of relevance if further regional reports were to be produced: inclusion of rainfall on risk profiles would provide useful contextual information for interpreting profiles; it would be beneficial to include intended users in discussions of presentation of findings; and include diagrams of the 'ideal profiles' (how profiles should look if water and wind erosion were being well managed). The Project Manager also observed that any interpretation of results for the regional context should include discussion with local land management experts.
Additional relevant information	Estimated cost of the LCM erosion risk (both wind and water) assessment is ~$100–120 000 annually. Costs include data collection, checking and analysis. 140 person-days per year are required to electronically capture the data. A significant component of the total cost is data entry and data checking.	Reporting frequency is uncertain at this stage. A variety of information such as profiles can be produced after each data collection phase. Indices are calculated annually. Reporting on annual information such as indices is likely to be available by August though this time frame depends on the season. Reporting frequency is not an obligation or defined anywhere; the above describes what is desirable and possible. Significant logistical effort is being made to coordinate and train data collectors, which ultimately results in high operating costs.
Source of information	Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006. McCord, AK 2003, *State survey monitoring manual: cropping districts*, Department of Water, Land and Biodiversity Conservation, Adelaide (unpublished). McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, Department of Water, Land and Biodiversity Conservation, Adelaide. McCord, AK & Payne, RA 2004b, *Monitoring trends in wind and water erosion in South Australia: Rationale and methodology*, Department of Water, Land and Biodiversity Conservation, Adelaide (unpublished).	

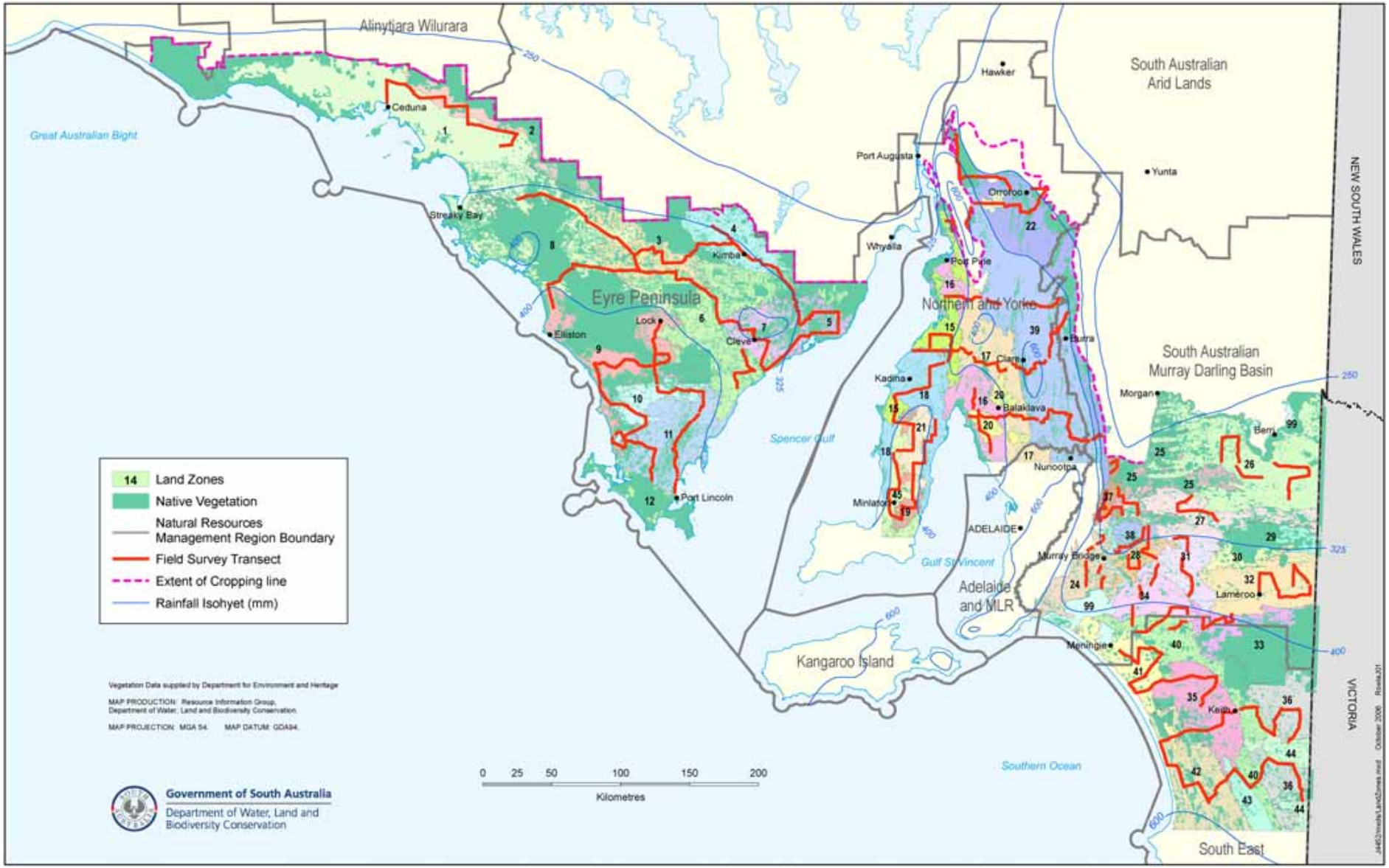

Figure 5. Land zones and 'windscreen' field survey transect locations in South Australia

Table 15. DWLBC's Land Manager Survey

Name	DWLBC's Land Manager Survey	Comment (e.g. adequacy) and observations
Custodian	DWLBC, Knowledge & Information Division	
Contact details	Andy McCord, Senior Scientific Officer, DWLBC Maggie Truscott, Survey Consultant, Truscott Research	
Status	The Land Manager Surveys are planned for every 2–3 years and are a component of the LCMP which is 'considered to be' ongoing.	The Land Manager Survey is part of the LCMP, which is a DWLBC-funded project and therefore subject to the continued availability of funding. Institutional arrangements for the management of LCMP require clarification.
General description	DWLBC's LCMP utilises information from phone surveys of South Australian broadacre, stock and dairy farmers. Surveys have been undertaken in 2000, 2002 and 2005 to monitor knowledge, attitudes and key management practices.	
Rationale	80% of South Australia's land resources are managed by private landholders. The survey monitors landholders' changing practices that either increase or decrease the risk of degradation of land. Data collected to date are regarded as providing useful baseline measures. It is considered that a longer monitoring period is required to evaluate trends.	
Survey methodology	Truscott Research conducted all three surveys to date on behalf of DWLBC. Land managers (specifically broadacre, stock and dairy farmers) were selected at random from a commercial database of South Australian farmers. Respondents were identified by postcode and subsequently assigned to regions and rainfall zones. 618 land managers were surveyed in 2000, and 1005 in 2002 and 2005. The surveys were conducted by phone between February and March. The issues to be surveyed were identified by DWLBC, and questions around these were formalised by Truscott Research.	The database used by Truscott Research is an amalgamation of people who have made agricultural type purchases. Apparently, the products they may have purchased are varied so the sample base should not be skewed. The respondents are then selected by: farming type (broadacre, stock and dairy farmers); landholding size (over 40 hectares); and post code. These criteria are double checked when the survey is commenced. Only 8% of the respondents from the 2002 survey were from low rainfall zones. This is because the number of landholders in these regions is far less but they manage a far greater proportion of land identified as being at risk. Statistical methods have been applied to the data to balance averages and proportion figures. Problematic survey questions have been modified over time. Respondents have occasionally been re-contacted to clarify their answers.
Source data used in survey design	The survey selects large-scale farming (broadacre, stock and dairy) since those farmers manage the majority of land identified to be at risk.	For more complete coverage, separate surveys may need to be developed for smaller scale landholders such as horticulture and intensive farming.

Name	DWLBC's Land Manager Survey	Comment (e.g. adequacy) and observations
Source data collected	Data are collected on the following topics: crop type and areas, wind and water erosion, cropping and cultivation practices, various land management issues, feed-lotting, acidification, salinity, soil structure, residue burning, soil fertility, soil testing, water repellence, revegetation, software and tools used to manage the property or business, and FarmBis training.	There is some scope for additional questions to be asked in the surveys. Some of the previous questions regarding revegetation and FarmBis may not be asked again and this space could be used for something else. Perhaps regional specific questions could be added. The surveys already take approximately 30 minutes to conduct so the surveys cannot become longer. It is also important to keep the same baseline questions so that trends can be determined. Should regions ask their extra questions themselves, it would seem sensible to have all questions asked at the same time and stored centrally.
Data format & location	Raw data are transferred from Excel spreadsheets to an Access 2000 database on the Program Manager's computer. The Program Manager also holds the processed data. These data are a component of the LCMP and have been published once, in 2004.	This information could be more widely distributed and is potentially very useful for many groups such as regional NRM Boards, LandCare and the SA No Till Farmers Association.
Processing of source data	Truscott Research conducts the surveys over the phone and enters the data into a database program which then collates much of the information into graphs and tables. A basic report with some of the graphed results and an Excel file with all the raw data is provided to the Program Manager, who then checks and amends any anomalies as required. The final data are then entered into a database. Given that the number of respondents in some low rainfall zones is very few, the data are weighted to more accurately interpret changes to land management activities. Statistical advice has been sought to ensure that this method is appropriate and not misleading.	The Project Manager has breadth of knowledge and is able to assess data accuracy and inconsistencies. Some documentation of how to check for various inconsistencies should be created to ensure the continued accuracy of data collected. The process of weighting data is only applied to overall state-scale information.
Derived information and format	Truscott Research provides a basic report with some of the results presented graphically, and an Excel spreadsheet containing all of the raw data.	It is important that raw data be collected and reviewed carefully after it is received by DWLBC.
Area of coverage	Number of land managers surveyed per region in 2002 was as follows: • Eyre Peninsula — 201 • MLR and Kangaroo Island — 201 • South-East — 202 • Murraylands — 199 • Northern and Yorke — 202	The questions focus predominantly on issues associated with cropping land and are not always relevant to many of the higher rainfall zones that the survey covers (parts of the South-East, MLR and Kangaroo Island). It must be made clear that the surveys cover the majority of agricultural land but not the majority of landholders. Additional surveys to cover other farming enterprises (in mostly higher rainfall zones) could be specifically developed if warranted.
Useability scale	This information can only be interpreted at regional level. The regions can be identified either by NRM region or rainfall region.	Local groups are more likely to be aware of the trends in land management in their own areas irrespective of the surveys. There should not be a need for the surveys to be made useable at a local scale.

Name	DWLBC's Land Manager Survey	Comment (e.g. adequacy) and observations
Dates and/or recency	Surveys have been conducted in 2000, 2002 and 2005.	
Availability	The 2000 and 2002 results have been included in the 'Report on the Condition of Agricultural Land in South Australia' (2004). A preliminary report of the 2005 survey results was completed in June 2005 by Truscott Research. This report has not been widely distributed. DWLBC will share the data, and the intention is to make the summarised findings more publicly available.	The executive summary of the LCMP's 2004 report notes that, as land condition changes occur over a long period of time, the current information presents only a baseline assessment. This information also has a potentially far wider audience if it was better publicised.
Additional relevant information	The cost of conducting the Land Manager Survey is currently ~$35 000. The majority of time spent collating and interpreting the information is accounted for in the LCMP. FarmBis (PIRSA) contributes some funding for the surveys.	
Source of information	Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006. Maggie Truscott, Survey Consultant, Truscott Research, pers. comm., March 2006. McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council, for the Department of Water, Land and Biodiversity Conservation, Adelaide. PIRSA 2002, *Survey of Land Managers Research Report: August 2002*, Primary Industries and Resources South Australia, Adelaide.	

Table 16. DWLBC's use of SASPAS data

Name	DWLBC's use of SASPAS data	Comment (e.g. adequacy) and observations
Custodian	South, Australian Soil and Plant Analysis Service (SASPAS), PIRSA, Loxton Centre	There is no official data access agreement between DWLBC and SASPAS, only the goodwill between the Project Manager and custodian.
Contact details	Andy McCord, Senior Scientific Officer, DWLBC Direct SASPAS contact is Tony Zimmerman, PIRSA	
Status	The LCMP is ongoing and SASPAS data is produced annually.	SASPAS may decide not to collate the analysis data at some stage if the work cannot be justified for its use.
General description	The South Australian Soil and Plant Analysis Service (SASPAS) deals in monitoring the physical and chemical health of soils, and diagnoses the nutrient status of plants and animals. The Project Manager for the LCMP accesses data from the SASPAS database, filters out the useful data, then generates maps to include in the LCMP report.	SASPAS is only one organisation analysing soil samples and collating sample data. Brian Hughes (PIRSA) has estimated SASPAS data comprises ~30% of all soil sampling data in SA; other dominant sources include HiFert and Incitec Pivot. He has attempted to access HiFert data but there are commercial and competition issues. Previously, HiFert soil testing was undertaken through SAPAS and consequently the volume of data available was greater. If other soil test data were accessible this would be useful but several issues would need to be discussed: whether different data sources can be combined together, and commercial and privacy issues. In the 2001 National Land and Water Audit, Doug Reuter (formerly CSIRO) was able to arrange a once-only data agreement to access data from several soil test companies.
Rationale	SASPAS provides a non-commercial location for landholders to have their soil and plant samples analysed.	The commercial fertiliser companies have taken on soil sampling for their clients as a means to sell their products. It would appear they are able to access laboratory analyses services at a far cheaper price, likely due to the bulk numbers of samples they can provide. Fertiliser companies can also cover the costs of sampling as part of their marketing, particularly when a single client can order tens of thousands of dollars worth of products in a single year.
Survey methodology	SASPAS distributes soil and plant analysis kits, which include a number of different analysis options (package deals) that are chosen by the client (mostly landholders). The client collects the samples, which are then forwarded to a private laboratory in Western Australia for the indicated analysis. The results are collated and presented in a suitable format for delivery to the client and/or nominated agronomist or agent.	The number of samples submitted to SASPAS for analysis has been declining each year since 1996. In 1996, 10 478 sample results were recorded, but there were less than 1000 in 2004. Roughly half of the sample results cannot be used because there is not enough information about their sample locations. The location only needs to be accurate to the name of the Hundred from which it was taken. The forms SASPAS provides to landholders allow for location details to be collected but landholders often do not write it in.

Name	DWLBC's use of SASPAS data	Comment (e.g. adequacy) and observations
Source data attributes	The database includes results from basic soil tests, research projects and other specialised tests. The column headings are not always 'obvious' in their meaning to the new observer. There is a column for the coordinates but this has not been consistently completed. Place names have been spelt in various ways. Only a limited number of samples from the database can be utilised (for varying issues including the lack of coordinates) and within these only a small number of parameters could be analysed further: soil P is regarded as the most reliable but pH is also analysed. SASPAS does not use the database, therefore data entry errors are not recognised and corrected.	The Project Manager has spent considerable time understanding the SAPAS database to 'untangle' the soil test results and determine the data that can be used. The database is one single file, which is just added to on an ongoing basis. It is possible to request data for specific periods but this creates more work for the custodian so it is easier to request the whole database and edit accordingly each time. The Project Manager has spent a lot of time examining the database and deciphering column headings. Given the database is not used by SASPAS itself, they have no need to upgrade and correct the data. Since this is often cited as a potential source for monitoring information, there may be benefit in the provision of support to the managers of the SASPAS database to improve data management. The Project Manager is confident he has extracted the most useful data. There is data on soil carbon but this has not been explored as there is debate on value of soil carbon as parameter to be measured.
Source data collected	The SASPAS database collates information on soil sampling for various purposes ranging from soil testing for a limited number of parameters to specific research work with a large number of samples.	Soil samples are mostly collected by individual property owners. Lack of consistency in soil sampling techniques is recognised as a weakness. The samples are also potentially biased, given that some are most likely collected because a problem has been recognised.
Data format and location	Data are recorded by the laboratory on sample analysis reports. Information from these reports and the landholder sample sheets are entered into an ancient database (dbase4) owned by SASPAS. Data can be easily exported to Excel spreadsheets.	The database is a valuable information resource, but if the custodian does not use it there is a possibility that at some stage PIRSA will consider it does not serve a business function and data entry will discontinue. The database itself is ancient and may at some stage require updating.
Processing of source data	The Project Manager has to analyse and correct data in the spreadsheets. Many location names are spelt incorrectly. Samples with no location details are deleted. The corrected data are then imported into a database that can collate and produce the required information.	A single individual (Project Manager) currently has expertise in data processing. Breadth of knowledge of the individual enables data accuracy to be assessed.
Derived information and format	Some of the data are mapped, e.g. areas affected by a low pH. Brian Hughes from PIRSA processes the sample data using various statistical calculations to identify what proportion of land is likely to be impacted by acidity. He collects additional data on lime sales from rural suppliers to then analyse whether enough lime is being applied to specific regions to limit the extent of acid soils.	There is limited scope in presenting this information in different ways given the ever decreasing sample size. Sooner or later there will not be enough information to keep doing the analyses currently being undertaken.
Area of coverage	The analysis results come from all agricultural regions of the state. Pastoral regions are not included.	Landholders in non-agricultural or pastoral regions have no need to analyse their soils.

Name	DWLBC's use of SASPAS data	Comment (e.g. adequacy) and observations
Useability scale	The data for each sample have been allocated to a Hundred and then collated into the Statistical Local Areas so information can be compared to the data generated by the ABS census. The data should not be utilised at any smaller scale.	The majority of samples come from the more highly populated and intensive areas of agriculture. Care must be taken to ensure that information is not presented with bias or extrapolated too far, particularly if sample numbers are decreasing.
Dates and/or recency	DWLBC has accessed data annually since 1976, with the most recent being 2004. The analysed data have most recently been presented in the 'Report on the condition of agricultural land in South Australia' (McCord and Payne 2004).	Data could be accessed more frequently but this will place extra demand on database managers, and presents time issues for the Project Manager who needs to tidy and analyse data. There has not been a need for the data to be presented more regularly.
Availability	Information from the analysis of SASPAS data has been reported in McCord and Payne (2004). There has been discussion of producing a LCMP report for each region which may require more regular reporting. The data are available from the Project Manager upon request. DWLBC will share the data and the intention is to make the summarised findings more publicly available.	If the data were more complete, other stakeholders such as PIRSA and rural groups might be more interested in its use. There are many potential users of this information who simply are not aware of its existence.
Additional relevant information	Discussions have already occurred regarding the closure of the services SASPAS provides in soil sample analyses. An alternative source of data needs to be considered to ensure the trends documented to date can be monitored into the future.	Ideally, a framework agreement could be made with the larger fertiliser companies to collect certain soil test data and provide it in a manner which does not provide advantageous information to competitive companies.
Source of information	Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006. PIRSA 2006b, *South Australian Soil and Plant Analysis Service*, Primary Industries and Resources South Australia, Adelaide, viewed January to June 2006 (last updated 12 July 2006), <http://www.pir.sa.gov.au/pages/agriculture/horticulture/diagnostic_services.htm:sectID=1699&tempID=11>.	

Table 17. ABS data used by the LCMP

Name	Australian Bureau of Statistics Agricultural Census	Comment (e.g. adequacy) and observations
Custodian	Australian Bureau of Statistics	
Contact details	Andy McCord, Senior Scientific Officer, DWLBC Monica Moss, Information Consultant, Australian Bureau of Statistics	
Status	A complete agricultural census across the state is conducted once every five years. A smaller survey is conducted in each of the intervening four years. The Agricultural census is considered to be ongoing.	It is expected that this information will continue to be collected into the future. Budget cuts appear to have had some impact on the level of detail provided in the information.
General description	The LCMP utilises some data provided by the ABS Agricultural census. The LCMP Project Manager utilises data from ABS to generate a WUE indicator. The LCMP also includes information on the distribution and application of gypsum and fertilisers from ABS census data. The smaller annual surveys often include supplementary questions regarding various topics such as salinity, irrigation, pest control and land management practices.	
Rationale	'Statistics from the annual Agricultural Census provide an updated picture of the performance and production levels of Australia's rural industries. Information obtained is used to formulate rural policies at the national, state and local levels. The data also provide the opportunity to evaluate the effectiveness of existing agricultural programs, and measure changes in production of various commodities.' (ABS 2006a)	
Survey methodology	'Questions in the Agricultural Census have been developed in consultation with primary producer and rural industry organisations, government agencies and research groups….' Surveys are mailed to the respondent. '…Farmers are asked to return their completed forms within two weeks, to give the ABS time to collate preliminary figures. These early figures are essential for Australian and state government planning, and are used extensively by industry organisations as input to policy discussions. ABS officers are available to assist farmers in completing the forms. As with all ABS surveys, no government or private organisation will have access to the individual information supplied by primary producers' (ABS 2006a). New questions will be asked in this year's census regarding the quantity of water used for irrigation, and the total number of sheep and lambs shorn and wool produced. Regular information from the census includes the assessment of land use, stock numbers and quantities produced for a large range of agricultural crops, fruits and vegetables.	Respondents are required under the *Census and Statistics Act 1905* to reply to the survey and answer the questions to the best of their ability. No doubt a number of surveys would never be returned and the skewness of results is unknown. It is expected that the process of data collection and interpretation from ABS is highly professional.
Source data attributes	The LCMP Program Manager requests the data from ABS and pays a fee. ABS sends the Program Manager Excel spreadsheets with the tallied data in	

Name	Australian Bureau of Statistics Agricultural Census	Comment (e.g. adequacy) and observations
	tables. BoM rainfall data are also required for the WUE calculations. This information can be downloaded from the BoM website in Excel spreadsheet format.	
Source data used in survey design	The ABS data utilised by the LCMP include: • wheat and barley crop yields at state, Statistical 'Division' and Statistical 'Local Areas' level • annual phosphorus fertiliser applications • area to which gypsum was applied to ameliorate soil structure decline.	
Data format & location	The raw and processed data from ABS are stored on the DWLBC network. Processed data are also published in the 'Report on the condition of agricultural land in South Australia' (McCord and Payne 2004).	It is suggested that the ABS data may be provided to the regions in some fashion if they are interested. As previously mentioned, in the future a regional land condition report may be more useful to the regions than a whole of state document.
Processing of source data	The LCMP Program Manager combines the ABS crop production data with BoM rainfall data to derive the WUE estimates. A mathematical model is used to correctly combine the appropriate data to produce the WUE estimate. The WUE estimates are used as an indicator of any limitations to crop production such as degrading soil fertility or structure. Other ABS data are simply referenced and plotted for regions in the LCMP reports.	The interpretation of yearly WUE indicators is very important and knowledge of the conditions encountered by farmers must be taken into account. Some of the information collected by surveyors during the 'windscreen surveys' can provide local condition details about weather, pests or other issues that impact on crop productivity.
Derived information & format	ABS provides data requested by the Program Manager to DWLBC in a tallied table format.	The data are already tallied into 'Divisions' or 'Local Areas' (depending on whether it is a census or survey year) and cannot be broken down into smaller areas or further manipulated. Perhaps there are questions DWLBC might be interested in collecting answers to via the ABS surveys in between the Land Manager Surveys. Cost may well inhibit this type of exercise. ABS did produce a CD, which had a user-friendly interface that could collate data as required by the user. Data are now available to some government agencies through a web interface. For regions with limited internet abilities, a CD might be a better way of accessing data.
Area of coverage	The five-yearly census and the smaller yearly surveys are state wide.	Coverage is very complete in a census year but far more limited in every other survey year.
Useability scale	The five-yearly census can be broken down into 'Statistical Local Areas', which is a fairly small scale and very useful to regions and local groups. The remaining yearly surveys in the off-four years are conducted on 'Statistical Division' scales that are large areas.	Some difficulty has been encountered when trying to compare data from the census, which are available in greater detail to that from the smaller surveys. The boundaries for the small surveys are very large and are even difficult to match to the regions used in the LCMP (i.e. the whole of Eyre is one 'Statistical Division' only). The ABS will not provide information on where its data are actually collected from within the 'Divisions' so extracting data at

Name	Australian Bureau of Statistics Agricultural Census	Comment (e.g. adequacy) and observations
		smaller scales is not possible. The census data are far easier to analyse but are only generated every five years, which is reasonably long term to compare with annually collected LCMP data. Census data were also previously available in Hundred levels, which was far more convenient to compare and allocate to rainfall isohyets. ABS can no longer provide data to this local scale because a respondent could be identified in low-density areas. ABS is currently reviewing the statistical areas it currently uses. A new area system called 'mesh-blocks' is being discussed. These units are smaller than the 'Statistical Local Areas', and may be able to better fit new NRM boundaries.
Dates and/or recency	The LCMP has most recently purchased data from the 2004 survey which is base on production during the 2003 season. The last census was conducted in 2001 regarding the 2000 production season.	Generally it takes two years from the time of the survey to obtain collated data from ABS. For example, production from the year 2000 was surveyed in 2001 and then collated and produced for publication by 2002. Depending on how it is to be used, this may be too slow for some monitoring and reporting needs.
Availability	Raw data already purchased by DWLBC are available from the Program Manager. Processed data are also available from the Program Manager or as published in the 'Report on the condition of agricultural land in South Australia' (McCord and Payne 2004).	
Additional relevant information	ABS often adds alternative questions to its surveys to add value to other agencies' needs. These in the past have included things such as: farm water use, irrigation water use, number of sheep and lamb shorn and wool produced, wine grape volumes, etc. The estimated cost of the ABS data is between $300 and $2000 depending on the amount of data requested. The majority of time spent collating and interpreting the information has been accounted for in the LCMP.	DWLBC has recently created an agreement (in the form of a licence) with ABS to access all data generated by ABS at any time. The information can be extracted from ABS@Gov, a website specifically for retrieving data. An additional service in this agreement is a process for requesting quotes for additional work projects.
Source of information	Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006. ABS 2006a, *1997 agricultural census underway (NT), Mar 1997*, Australian Bureau of Statistics, Belconnen, ACT, viewed January to June 2006 (last updated 20 June 2006), <http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbyReleaseDate/A97712631D61D5D0CA2568A90013621A?OpenDocument>. McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council, for the Department of Water, Land and Biodiversity Conservation**,** Adelaide. Monica Moss, Information Consultant, Australian Bureau of Statistics, pers. comm., March 2006. Russell Flavel, Manager Information Management, Information Resources, Knowledge and Information, DWLBC, pers. comm., January to July 2006.	

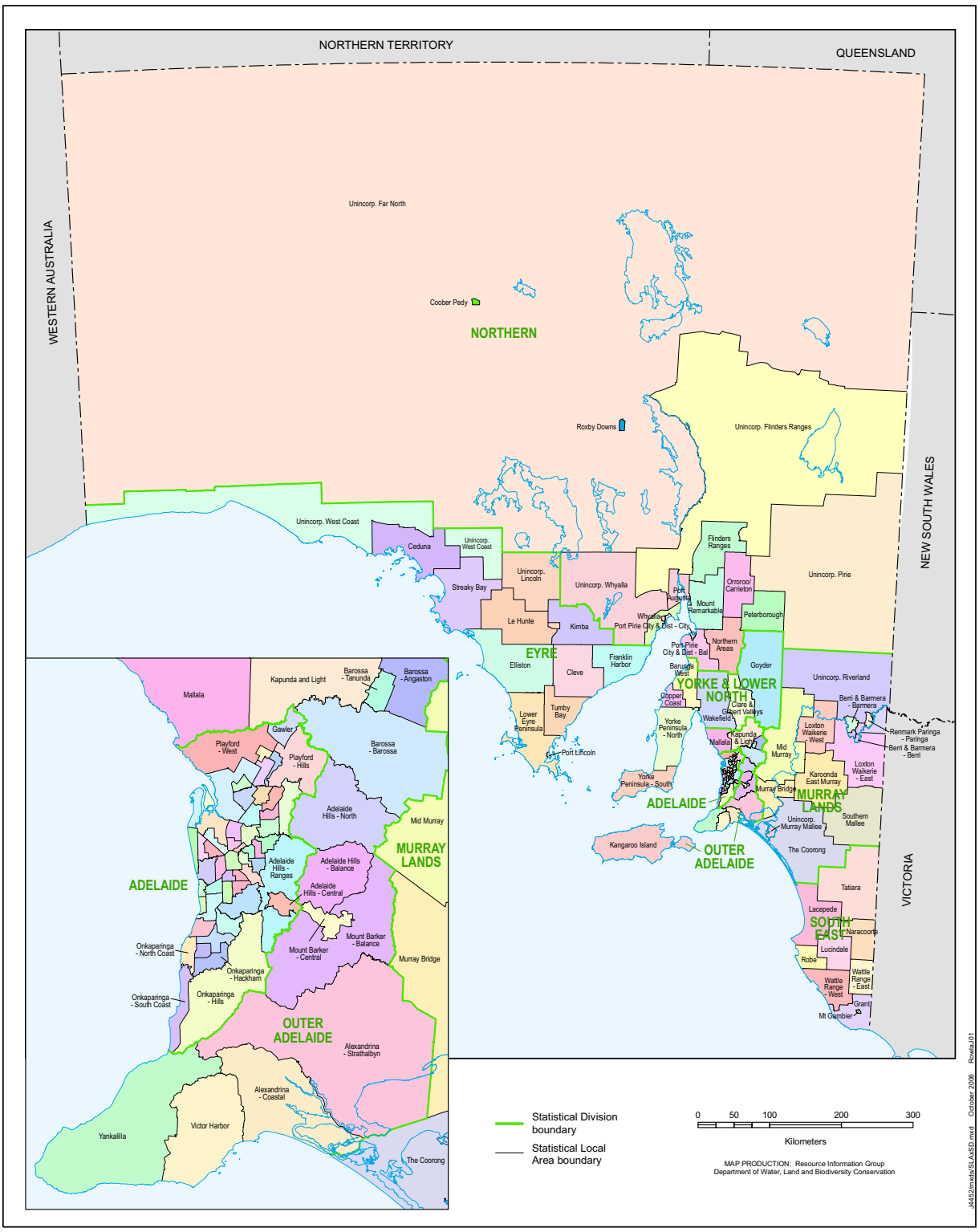

Figure 6. ABS Statistical Divisions and Statistical Local Areas of South Australia

Table 18. DWLBC's Land and Soil Information Framework

Name	Land and Soil Information Framework	Comment (e.g. adequacy) and observations
Custodian	DWLBC, Soil and Land Program (SaLP)	
Contact details	David Maschmedt, Soil Scientist, DWLBC Jan Rowland, GIS Officer, DWLBC	
Status	The Land and Soil Information Framework is a baseline dataset and updated opportunistically as new data are collected. ANZLIC unique identifier ANZSA1000001295	This framework is not a monitoring program but provides essential information for interpretation of monitoring data.
General description	This framework provides information about the dominant landscapes and soils of South Australia's agricultural districts. The soils information has been mapped at two levels — 'soil landscapes' which are then nested into 'land systems'. 'Land systems' are large areas of land (usually more than 50 km^2 in area) with a recognisable and repeating pattern of topography, geology, soils and vegetation. 'Soil landscapes' are smaller areas of land (typically 0.5–50 km^2) with recognisable topographic features and a limited range of soil types and underlying (substrate) materials. The data and information are used for determining the extent and distribution of a range of soil and land surface features, as input data to various landscape process, plant performance and related predictive models, land-use planning, development of land management guidelines and as a framework for monitoring of the condition of agricultural land. Maps and reports are available that describe: • the soils and landscapes of South Australia's agricultural districts • soil and land surface features affecting land management and productivity • the physical suitability of land for a range of agricultural uses.	
Rationale	People with an interest in using and managing land require some form of land assessment or classification system to help make informed decisions about developing and managing their land. The DWLBC data and information enable decision-making using standardised data and methodologies across the entire agricultural zone. The data and information are used for determining the extent and distribution of a range of soil and land surface features, as input data to various landscape process, plant performance and related predictive models, land-use planning, development of land management guidelines, and as a framework for monitoring the condition of agricultural land.	
Survey methodology	The data have been collated since 1976 (mostly between 1986 and 2000) through aerial photograph interpretation, soil profile and landscape descriptions, general field observations and limited soil sample analyses. Approximately 27 000 soil profile and landscape descriptions have been recorded. Of these, ~900 sites have had a chemical characterisation completed for each horizon up to a depth of	The chemical characterisation work has been conducted on the key agricultural soils in the state but not on all soils. At least another 1000 sites require detailed analyses to ensure a minimum level of coverage across the whole state. In addition, physical analyses are required on a significant sub-set of these sites to provide an adequate level of confidence

Name	Land and Soil Information Framework	Comment (e.g. adequacy) and observations
	1500 mm in the soil profile. The chemical analyses include pH, EC, carbonate, organic carbon, available P and K, extractable boron and sulfate, trace elements, cation exchange capacity and exchangeable cations.	when using the data in hydrological and plant performance models. There is currently no soil physical data.
Source data used in survey design	Existing soil, geological and topographic maps and aerial photographs.	
Data format & location	Digital data in ArcInfo and ArcView format including shape files and look-up tables of attribute data on CD available from DWLBC. PDF format maps and descriptions of land systems and soil landscape units, and soil characterisation sites available on CD from DWLBC.	
Processing of source data	Point data from the surveys is on a FoxPro database, but is unchecked and not suitable for public distribution.	The point data collected during a survey have been used for its intended purpose, which was to underpin the soil description part of the soil landscape mapping process. For the public to have access to this data, some edits need to be made such as updating codes and classifications, etc., and all data need to be transferred to an Access database. The task of doing this has to be carried out by experienced staff who collected the data. Attempts have been made to put all the data into an Access database, but at this stage ~5000 records are still on paper and need to be entered. Time and budgets have prevented this from happening.
Derived information & format	The data have been collated and analysed to provide three general types of 'derived information': • descriptions and maps of the soils and landscapes of South Australia's agricultural districts • soil and land surface features (attributes) affecting land management and productivity • the physical suitability of land for a range of agricultural uses (Crop Potential Models). The Crop Potential Models: • Preliminary models (or data interpretation rules) have been developed to derive crop potential maps for 27 field crops, horticultural and pasture species. • The framework has been developed using ArcGIS which contains all the map layers and look-up tables for any data that are required to be extracted. The same information can alternatively be sourced from PDF files which have been put on CD. Five 'Land Resource Information' CDs contain all the land descriptions and generalised soil profile descriptions for the following major agricultural regions: MLR and Kangaroo Island, Eyre Peninsula, Murraylands, Northern Agricultural Districts and the South-East. CDs are also available with the following data: • Soil Data Sheets — containing information from 900 soil sample reference sites.	The descriptions and maps of soils, landscapes, and soil and surface features are publicly available. The Crop Potential Information is in development phase, and has restricted availability.

Name	Land and Soil Information Framework	Comment (e.g. adequacy) and observations
	• Soils of South Australia's Agricultural Lands — includes photos, descriptions and distribution maps of 61 key soils across the state. • Attribute Atlas — includes the maps and statistics describing the 41 specific soil and landscape attributes across all the agricultural areas. See Appendix A for a short description of all the soil and landscape attributes. • Assessing Agricultural Land — contains the classification standards used to compile the attribute database. • Spatial Data — the mapping data in digital format as ArcInfo export files and ArcView shapefiles. All of the information can be provided in hardcopy format but is most useful to its users in electronic formats.	
Area of coverage	Point data are used to generate coverage for South Australia's agricultural regions. Soil landscapes data are available for Eyre Peninsula, Yorke Peninsula, Murray Mallee, Northern Agricultural Districts, South-East, Kangaroo Island and MLR.	Some of the regions included in the soil landscapes framework have limited surveyed points. There are no 'black holes' as such in the data coverage but there are some regions that could benefit from more survey sites. It is important that the information is not used inappropriately given the amount of extrapolation and interpretation involved in developing these land systems and soil landscapes.
Useability scale	Spatial database mapping scales: • 1:100 000 — Eyre Peninsula, Yorke Peninsula, Murray Mallee, Upper South-East and Northern Agricultural Districts • 1:50 000 — Lower South-East, Kangaroo Island, MLR and the foot of Yorke Peninsula.	
Dates and/or recency	Currency: Point data collection commenced 1976, and continues. This information is intended to be baseline data and is not monitored repeatedly.	Sites that have been surveyed for the baseline data could be re-surveyed to see if any change over time could be detected. There may be some difficulty locating sites since many properties are likely to have been significantly altered, ownership changed, property boundaries moved, etc.
Availability	The data are available on the DWLBC local GIS network and in hardcopy or on CD on request from the Soil and Land Program group.	
Source of information	David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006. DWLBC 2004, *Spatial data, soil landscapes of South Australian agricultural areas in GIS format (complete)*, data currency April 2004 to November 2004. Soil and Land Information Group, Department of Water, Land and Biodiversity Conservation, Adelaide. Jan Rowland, GIS Officer, DWLBC, pers. comm., January to July 2006. McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council, for the Department of Water, Land and Biodiversity Conservation, Adelaide.	

Table 19. Dryland Salinity Program

Name	Dryland Salinity Program	Comment (e.g. adequacy) and observations
Custodian	DWLBC	
Contact details	Glenn Gale, Senior Project Officer — Dryland Salinity, DWLBC	Many individuals and groups are involved in these programs; however, Glenn Gale is the key dryland salinity contact for DWLBC.
Status	Ongoing. State NRM Plan indicates that the South Australian Dryland Salinity Strategy should be adhered to.	Level of commitment is somewhat governed by available funds year to year.
General description	DWLBC has been engaged in dryland salinity M&E programs for many years. Focus M&E catchments were established in each major region of the state over 14 years ago, targeting local and regional groundwater flow systems. Depth to groundwater and groundwater salinity have been monitored in these catchments on an ongoing basis. Surveys of the location, size and intensity of salt-affected areas were undertaken in the focus catchments in 1991 and are intended to be repeated to determine any trends.	Dryland salinity is split into two categories: primary (pre-dating European settlement) and secondary (human-induced salinity (e.g. following vegetation clearance or irrigation)). For the purposes of this report, irrigation-induced salinity will not be discussed since this issue will be dealt with in detail in Land and Water Management Plans across the state.
Rationale	Monitoring the extent and severity of dryland salinity impacts is crucial to policy and planning. The rate of change of impacts such as land-use change is essential to forward planning and prioritising. Monitoring is used to assess and adjust modelled predictions of change, be it positive or negative. Monitoring also raises community awareness and can empower communities to make changes to limit the expansion of dryland salinity impacts.	A set of nationally agreed indicators and methodologies for monitoring salinity has been agreed upon. There may be some changes to what data and how data are interpreted for national level reporting.
Survey methodology	Three major indicators have been identified as key monitoring data to assess dryland salinity in South Australia: • depth to groundwater • groundwater salinity • location, size and intensity of salt-affected areas. The data for these three indicators are collected for multiples reasons and not solely for dryland salinity monitoring. <u>Depth to groundwater</u> Rising trends in the average level of watertables provide early indication of salinity risk, while falling levels may indicate the effectiveness of mitigation strategies (however other reasons may apply). Water levels in bores are measured by the depth in metres from ground surface to the watertable. Depending on the groundwater flow system (i.e. local, intermediate, regional), bores should be monitored 1–3 monthly up to annually. <u>Groundwater salinity</u> Salinity of groundwater is a useful indicator of salinity risk where watertables are	Monitoring has been confined to regions and catchments that have an apparent high risk of expansion of salinity extent and severity. Monitoring does not occur equally across regions since dryland salinity is more pronounced in some areas than others. Considerably more monitoring could take place in locations with a moderate risk but this expansion has been restricted by resource cuts in recent years. A discussion paper prepared in March 2006 by the National Coordinating Committee for Salinity suggests that baseflow salinity may be a fourth indicator. Baseflow salinity is measured by collecting water samples from streams that are known to be saline discharge zones for the local or intermediate groundwater flow system. The paper also suggests that given the slow response times of regional groundwater flow systems, baseflow salinity has limited value as an indicator of land salinity. Baseflow salinity also requires a large amount of interpretation and contextual information. For South Australia, baseflow salinity monitoring is simply not applicable for most catchments and regions since large parts of the state have no surface drainage. Baseflow salinity is only monitored in specific

Name	Dryland Salinity Program	Comment (e.g. adequacy) and observations
	close to the ground surface, particularly where the capillary fringe can impact on plant root zones or infrastructure foundations; or groundwater discharges directly to the land surface or into streams (as baseflow). Groundwater salinity is commonly measured in the laboratory as mg/L total dissolved solids (TDS) or as a measure of the electrical conductivity (EC) of water expressed as micro-siemens per centimetre (μS/cm) at 25°C. Preferably, the bores monitored for salinity will also be monitored for depth to groundwater. The frequency of salinity monitoring is less than that for depth to groundwater, but will also depend on the scale of the groundwater flow system. Location, size and intensity of salt-affected areas Monitoring the expansion or contraction of salt-affected land provides another tool to assess trends in salinity status. 'The severity and size of land salinisation is determined by the groundwater levels, groundwater salinity, climate, physical relief of the discharge zone, and the rates of discharge (Coram et al. 2001)'. The following combination of methods is used to measure the salt-affected areas: • field delineation of affected areas using a GPS • aerial photo interpretation • remote sensing imagery interpretation • electromagnetic surveys and correlation with soil salinity levels • soils tests. The intensity (or severity) of salinity can be assessed using a 'Salinity Category Classification' system. The system documented in the SaLI database looks at: the depth of the watertable; vegetation indicators such as presence of field crops, salt tolerant grass species, samphires or complete lack of vegetation; the EC of surface and subsoils; and a land class category. The methods used will depend on the scale of monitoring to be undertaken. Some methods are not practical or efficient to do on regional scale but are very representative for local and property scale. Salt-affected areas should be surveyed every 5–10 years.	catchments where it serves a specific need such as domestic and commercial water supplies (e.g. Murray–Darling Basin). Given the limitations of this indicator for South Australia, there is not a great deal of data available. However, if it becomes a nationally agreed indicator, the state does have some data that can be reported.
Data format and location	Depth to groundwater Water level data are stored on DWLBC's 'Obswell' website, which is linked to a complex internal database called SAGeodata containing all DWLBC's bore data. Groundwater salinity Groundwater salinity data are also stored on DWLBC's 'Obswell' website and in the SAGeodata database.	

Name	Dryland Salinity Program	Comment (e.g. adequacy) and observations
	Location, size and intensity of salt-affected areas The DWLBC Land and Soil Information Framework (SaLI, see Table 18) database contains the results from a state-wide program of soil sampling which includes several salinity parameters. Several remote sensing projects have been conducted or are underway and include: • various projects conducted by CRC's Spatial Analysis of Land and Water sub-program. • ground-based EM surveys as part of the Sustainable Grazing of Saline Land project. The information management and communication needs for these programs are yet to be dealt with.	The data and methodology documentation from the EM surveys as yet does not have a true 'home' and has not been compiled into a useful, accessible, logical location. Significant investment has gone into collecting the information and many more repeat surveys are planned for South Australia. It is critical that more importance be placed on the management, communication and distribution of this information. It is envisaged that a series of time series spatial datasets will be generated that can show the change in extent and severity.
Processing of source data	Depth to groundwater Hydrographs (time versus depth to watertable) should be generated from the data to show trends in water levels. Groundwater salinity Groundwater salinity data can also be graphed over long periods of time to show trends. Location, size and intensity of salt-affected areas The majority of data are translated into maps showing the extent of salinity at a given time. The total area of salinised land is the priority indicator trend to be followed. Secondly, the degree of severity will be zoned. The severity of salination is not being monitored particularly closely at present.	Various reports over time have collated this information for catchments or regions, even up to state level.
Derived information and format	Depth to groundwater and groundwater salinity data from the Obswell website can be printed from the internet or saved into Excel spreadsheets or Word documents. DWLBC staff can access further data from the SAGeodata database, and can extract complex data into Access databases for further analysis. EM survey data are currently only available upon request. Dryland salinity reports are being developed by DWLBC for each region of the state. Regions therefore have the information they need and can plan to adjust monitoring programs as needed or make decisions about other programs of work needed.	
Area of coverage	The following regions and their sub-catchments are monitored using one or more of the above methods: • Eyre Peninsula (Cummins Basin, Wanilla (Popes sub-catchments), Darke Peak, Tod River, Cowell (Driver and East Cleve Hills catchments)) • Murray–Darling Basin (Coastal Plain and Coorong, Northern Mallee, Sandergrove Plains, Herrmann's catchment, Keyneton regional network)	There are potentially plenty more sub-catchments surveyed and projects being conducted that are not captured. Many projects have been commissioned by private property owners and the results not accessed by DWLBC of other agencies. Rural Solutions SA conducts a significant amount of EM survey work for private clients. Access to some of this information could be useful in identifying future salinity issues. Most of these clients however, are likely to be from the horticulture industry

Name	Dryland Salinity Program	Comment (e.g. adequacy) and observations
	• South-East (Upper South-East Drainage Scheme catchments) • MLR (Northern Adelaide Plains, Keyneton (Mount Eagle) western drainage) • Northern and Yorke Agricultural Districts (Redhill, Wandearah, Jamestown, Minlaton, Upper Yorke Peninsula) • Kangaroo Island (MacGillivray Plains, Ellenore catchment, Narroonda)	where most salinity impacts would be irrigation induced.
Useability scale	The data collected are site specific and cannot be extrapolated beyond the physical boundaries of the groundwater flow systems. The extent and severity of dryland salinity maps etc. can be compiled to generate state-wide figures or even add to national figures.	
Dates and/or recency	Depth to groundwater and groundwater salinity measurements are updated continuously. The EM survey information is predominantly from 1991 and some areas have been repeated more recently in 2003 and 2004.	
Availability	All data stored on Obswell are publicly available at no charge. Any data stored on SAGeodata can be extracted upon request by the public at no charge. Interpretation of data and creation of reports may come at some charge if requested. Various reports are publicly available either electronically (in PDF formats) from the DWLBC website or email, or in hardcopy.	An information management system is being developed in DWLBC to better distribute these reports to the public and other agencies. At present, it would appear many of the reports are not well known or distributed.
Additional relevant information	A Salt Mapping and Management Support Project is underway in the Riverland region of the state. One of the key sub-projects is an airborne geophysics program which is determining the extent and depth of the Blanchetown Clay aquitard. The results of this information will be able to inform various policy decisions including irrigation zoning and appropriate locations for salt interception scheme production bores. This project is not considered to be monitoring per se, but may provide useful information for the future expansion of current monitoring networks.	A project commissioned by the National Land and Water Resources Audit has commenced in SA to trial run the collection of salinity data to meet nationally agreed protocols and data needs.
Source of information	Barnett, SR 2000, 'Extent and impacts of dryland salinity in South Australia', National Land and Water Resources Audit. *PIRSA Report Book,* 2000/45. Coram, J, Dyson, P and Evans, R 2001, *An evaluation framework for dryland salinity,* A Bureau of Rural Sciences Report prepared for the National Land and Water Resources Audit, September 2001, Canberra, ACT. David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006. Dooley, T & Liddicoat, C 2004, *Towards a South Australian Dryland Salinity Monitoring Action Plan,* Summary paper for the state (DWLBC Land Management): Including a pilot State Dryland Salinity Report, Rural Solutions, South Australia. Glenn Gale, DWLBC, pers. comm., January to July 2006. National Coordinating Committee for Salinity 2006. *Implementation of agreed national salinity indicators — Discussion paper* (Version 2; 27/2/2006), Australian Government, Canberra. PIRSA 2001, *South Australian Dryland Salinity Strategy*, prepared for the Soil Conservation Council of South Australia, Adelaide. Steve Barnett, Senior Hydrogeologist, DWLBC, pers. comm., January to July 2006.	

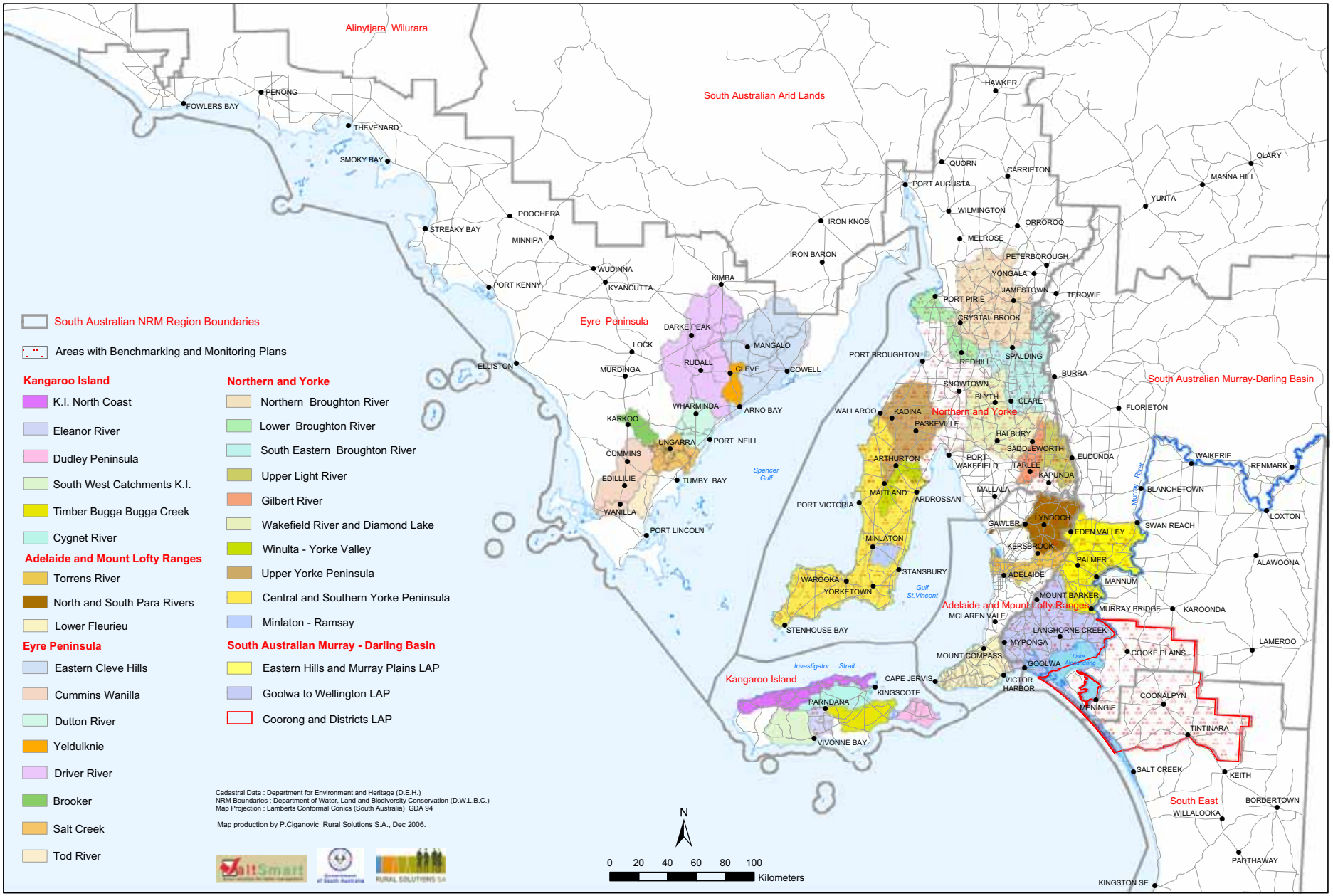

Figure 7. Salinity management planning/review catchments and salinity benchmarking and monitoring areas (Rural Solutions SA 2005)

Table 20. Pastoral Areas Land Monitoring System

Name	Pastoral Areas Land Monitoring System	Comment (e.g. adequacy) and observations
Custodian	DWLBC	
Contact details	Brendan Lay, Principal Scientific Officer, Pastoral Program, DWLBC Chris Turner, Senior Inspector, Pastoral Program, DWLBC Max (John) Maconochie, Senior Scientific Officer, Pastoral Program, DWLBC	Brendan Lay began work in the rangelands in the 1970s and is the most experienced pastoral lands inspector in DWLBC, but plans to retire in 2007. Chris Turner and Max Maconochie have been with the program since the early 1990s.
Status	Ongoing. Monitoring of the lease lands is required as part of pastoral lease arrangements under the *Pastoral Land Management and Conservation Act 1989*. The methods or process for monitoring may change over time as needed. The pastoral program running costs are jointly funded by state government and state-generated rent funds from the pastoral leases.	There have been recent structural changes in the operation of the monitoring team. Work that was once conducted within DWLBC is now outsourced to Rural Solutions SA. Some discussion is currently occurring to determine the appropriateness, practicality and costs associated with this arrangement. Regardless of how it is done, the work will continue and funds are available to pay for it. Given that Brendan Lay hopes to retire in 2007, it is important for DWLBC to consider the maintenance of permanent, experienced pastoral personnel to manage this program.
General description	The pastoral program conducts an 'assessment' on every pastoral lease every 14 years. An assessment is a full review of the pastoral lease including an assessment of every paddock, photo points including extensive quantitative data, and an LCI (for sheep grazing leases). The pastoral program also aims to conduct 'inspections' of pastoral leases at least every eight years. If following an assessment a property is identified to have degraded paddocks (termed 'priority paddocks'), or is at risk of degradation due to drought conditions, an inspection will be conducted every four years. An inspection may only be a revisit to priority paddocks (if time permits other paddocks may be inspected); it does not include an LCI and each priority paddock will have a photo-point site survey (usually an 'OB' level assessment, preferably a 'QS'; see definition below). There are three basic programs for monitoring the pastoral lands, currently ongoing: Photo-point site data — data stored in the Pastoral Management Information System Land Condition Index — assessment of average rangeland condition Grazing Gradient — capacity of land using remote sensing imagery.	The photo-point surveys are the mainstay of site-based monitoring. They are emphasised more on sheep lease lands due to the predominance of perennial vegetation. The Grazing Gradient is mostly used for cattle grazing land which has a more intermittent vegetation growth pattern due to rainfall in the region. Analysis of spatial data allows a large area of land to be monitored with far less person time investment. The Land Condition Index was developed to be able to compare the condition of pastoral leases, and to keep a subjective record of vegetation and soil condition as compared to the assumed original appearance of these resources on each lease. The index enables inspectors to highlight properties with particular problems and properties that may require further assessments earlier than required by the Act.

Name	Pastoral Areas Land Monitoring System	Comment (e.g. adequacy) and observations
Rationale	Cattle and sheep graziers lease large pastoral grazing regions of the state. The continuance of these lease arrangements is somewhat dependant on the graziers appropriately managing their properties. The most obvious impact from mis-management in these lands is over-grazing. The three programs in place essentially seek to monitor the overall condition of the lands.	The driver for these monitoring programs is to manage land for future grazing use and the assessments for lease arrangements. Indirectly, the data from these programs somewhat meets the needs of LCM. There is, however, some risk of bias in the assessments given the alternative drivers.
Survey methodology	<u>Photo points:</u> Approximately 6000 photo sites have been selected across the pastoral leases. There is at least one site for each stocked paddock for sheep grazing leases or each water point for unfenced cattle grazing leases. There are also a number of perpetual leases, national parks and other tenures within the rangelands region. There are four levels of assessment conducted at the photo point sites: 'Quantitative Site' (QS) = The most detailed assessment which includes a pegged site used for monitoring vegetation changes using the Jessup or step-point data methods. 'Observation Site' (OB) = Also a detailed assessment at a pegged site but does not generally include a Jessop transect. The site description includes a species list and change is detected by observation and photographic sequences. 'Reference Site' (RS) = These sites are remote from grazing influence (greater than 5 km from water in sheep country and 8 km in cattle country). All site sheet, soil and plant data are collected. Some sites may be completely enclosed. 'Type Site' (TS) = These sites were used to characterise mapped land systems during the baseline assessment phase and collect similar information to the OB sites. 'PC' = A photo comparison site only (no quantitative data). At each of the sites the following details may be recorded on site sheets: • location details (station, paddock, GPS coordinates, weigh point, water point and distance, mud map) • flora species composition, abundance, condition (grazed fruiting, etc.) • details of fire treatments • condition of site • rock outcrop percent • soil surface (gilgai, saline, gravel, stone) • rainfall (presently wet or date of last fall)	<u>Photo points</u> The photo points generate a massive volume of data to be stored and managed for appropriate use. A system called the Arid Lands Information System (ALIS) is currently being developed to manage all the information generated by the Pastoral Areas Land Monitoring System. Not all of the information on the site sheets is collected each time. More often than not, very little information is collected given the time constraints of the field surveyors and the landholders who travel with them. Sometimes no data are collected at the site, and perhaps only a photo. In recent times staff resource issues and time constraints have limited the number of 'QS' level assessments being conducted. The photo point sites collect additional monitoring information and are rarely utilised for the pastoral assessments. A report by Ireland (2004) provided comments for the second round of lease assessments. They included: Abandoning step-point measurements in perennial shrub land Using a Jessup transect or a step point but not both at one site. Use the Richards/Green Functionality and Trend Indices methods for rapid assessment of condition and trend. This method is very subjective and only offers a very coarse assessment of condition. Another report by White and Gould (2002) stated that the combination of the Jessup transect and step point data collected at the same site allowed an objective assessment of changes at each site over time. However, generating trends from this data requires many more points in time, and requires some contextual information for interpretation. There is currently much deliberation regarding the methods used in these types of surveys, and deciding which method is best should be conducted during a biodiversity monitoring review. The rangelands Australia wide are not well understood and the methods for monitoring condition are bound to change in the coming years. Hopefully new methods will be able to capture data from decades of pastoral assessments. Further information on these issues may be found in the references at the bottom of this table.

Name	Pastoral Areas Land Monitoring System	Comment (e.g. adequacy) and observations
	• feral animals (sighted, dung present, tracks, etc.). Land Condition Index (LCI): This is an objective assessment of the average condition of the lease property. It is undertaken on all sheep grazing leases south of the Dog Fence. 100 sites are randomly sampled (initially, but are returned to each assessment) and allocated a theoretical condition value with a minimum value of 1.00 (meaning a poor value) and a maximum value of 3.00 (a good rating). The values are assessed on the following basic criteria: Class 1 — all palatable perennial species eliminated except old trees; unpalatable species heavily pruned, many weeds present or, in some cases, the integrity of plant cover totally destroyed. Class 2 — the original palatable perennial species being eliminated (if grasses or low shrub species) or lacking all juveniles (if large long-lived perennials) and with replacement by much less-palatable perennial species including weeds or by ephemerals. Class 3 — the original stock-palatable perennial species still present and reproducing. The LCI is based on descriptors and photo standards for approximately 20 pasture types and components found across the sheep grazing lease areas. The 100 sites are aggregated to generate an average value across the property. This index number then suggests that a 1.00 means the whole property is in 'degraded' condition, and a 3.00 means the whole property is in 'un-degraded' condition. The LCI is only utilised as a station-level indicator and not paddock level. Grazing Gradient: This method is based on remotely sensed images of reflectance that detect changes in vegetation cover over time and space. The images are used to detect long-term changes in the capacity of land areas near water to recover fully once a significant rainfall has been received. Satellite images of land surrounding water points, taken for the same area before and after a rain event, are analysed to determine the ability of pastures to regrow. The Grazing Gradient uses several GIS data layers including vegetation cover, distance from water and landscape types. This method does not require every site to be ground truthed, but some ground truthing is required to further determine the response by different flora species. Since there is no LCI for the cattle grazing lands, it was envisaged the Grazing Gradient could fill this monitoring gap.	LCI Property index values can only be compared if the properties have similar pasture types and components in similar proportions. The natural variability between properties has to be considered. There are also some issues with the condition scoring system which can falsely state the site being in good condition. Occasionally, heavy grazing of certain species of plants may give rise to another species which is still highly palatable. The pastoralist would receive a high score but the original vegetation has not been protected. The repeated monitoring sites may somewhat prevent this mistake being made. The LCI was not intended to monitor trends; it was designed to help fulfil the assessment requirements of the Pastoral Act only. Given this, it has been suggested that the LCI could give a snap shot in time of general land condition on a bioregion scale (Australia's rangelands have been divided into 53 bioregions to separate the different environments within the rangelands). GG This program was somewhat experimental and pilot surveys were conducted in 2000–01 for the NLWRA. Further pilot work will be necessary but has not been conducted due to budget restrictions. Imagery from the dry period of 1988 to 1989 was used to compare to wet periods to monitor vegetation recovery. Some results were impaired by changes in geology. The imagery only reflects general vegetation and does not indicate diversity or the type of vegetation structure. There were difficulties interpreting the images in heterogenous landscapes and soil types. Interpretation could be improved with finer pixel images; however, the low-lying, flatter landscapes are the dominant areas for grazing where impacts would preferably be monitored. Floods also affect these areas and pasture response is different between flood and rainfall events. This is difficult to capture. CSIRO considers the grazing gradient '… methods compare favourably with conventional ground-based monitoring in terms of cost and labour requirements. The remote sensing-based method is capable of providing comprehensive, objective and repeatable analysis of grazed country after future significant rainfalls. It also offers the significant additional advantage of immediate information about landscape condition through the analysis of archived remotely-sensed data'.

Name	Pastoral Areas Land Monitoring System	Comment (e.g. adequacy) and observations
Source data attributes	Each time a survey or assessment is conducted, the assessor uses old maps to navigate to the appropriate sites. The introduction of GPS and GIS technology is making return assessments on exactly the same land far easier.	There is a backlog of site location and paddock plan changes that have not been amended on the Pastoral Management Information System (PMIS). This is a problem for surveyors trying to relocate sites and assess changes to paddocks over time when no new maps are being generated. DWLBC is in the process of updating these maps, and GPS coordinates will slowly be incorporated to improve accuracy.
Data format and location	95% of the photos are presently paper based and are simply filed away. The remaining 5% (which is now increasing) has been digitally stored in various haphazard file locations. A system for referencing and filing photos is urgently required. The site sheets for the first round of surveys have been entered and stored on PMIS. PMIS is housed on a DEH server and access to enter data is via an online Citrix application. Citrix enables assessment officers to enter data they collected at different office locations across the state. 80% of the site data collected since 1991 has been entered on PMIS. The remaining exists on paper only. Since 2000, only 30–40% of inspections have been entered. The remaining assessments are still paper based.	PMIS was a database developed for the management of pastoral land assessment data and was able to generate reporting documents to enable a hasty inspection report to be completed for the Pastoral Board. The system is reasonably old and was taken offline in 2005 for upgrading and data cleanup. For 12 months, no data could be entered onto the system and hence the backlog of data entry required. Many issues were identified with the database. Work is currently underway to facilitate easier use of the database by constructing new forms, cleansing data, upgrading security and administrative access processes, and preparing data for exporting to ALIS. PMIS is going to be replaced by ALIS which will store all the pastoral land assessment information including all photos. The ALIS project is currently under development but may take some years before it is complete and operable. PMIS will be maintained in the meantime.
Derived information and format	All data collected from each pastoral lease are to be entered into a database and can be manipulated to retrieve information. Information regarding fence and water point locations (etc.) is stored and updated on GIS. Only recently has the second round of assessment commenced, enabling site comparisons to be measured.	ALIS will enable far more sophisticated methods for storing, processing and retrieving data.
Area of coverage	The monitoring programs cover mainly pastoral lease areas, which are predominantly within the SA Arid Lands NRM region. The pastoral lease lands collectively occupy 410 000km^2. There are some pastoral leases in the SA Murray–Darling Basin, Alinytjara Wilurara Lands, Eyre Peninsula, and Northern and Yorke NRM districts. See Figure 8.	The programs do not cover any significant part of a region other than the SA Arid Lands.
Useability scale	The scale of these programs was originally property level. However, these properties are much larger than the usual more intensively farmed lands. The data collected may be manipulated to give an indication of the status of the region over time.	The main point of these programs was originally to monitor and assess the condition of the pastoral lease properties. As a secondary benefit, this monitoring can be utilised to assess land condition across a region with particularly unique management issues. There are, however, issues with comparing data from one property to another. The time of year or the seasons prior to the assessment will have a significant impact on the condition of the land at a single point in time. The topography can be very different from one property to another which impacts on the areas of quality grazing land. Rainfall can also vary considerably from one landform to another within somewhat small distances.

Name	Pastoral Areas Land Monitoring System	Comment (e.g. adequacy) and observations
		The accuracy of data at individual sites over time is questionable and should not be used to generate site trends.
Dates and/or recency	Under the Pastoral Act, the pastoral lands must be assessed every 14 years and inspected within the following eight years. Properties identified with paddocks in a degraded condition must be inspected once every four years. The first round of pastoral land assessments (as required under the Act) were conducted between 1990 and 2000. Resource condition assessment reports were created for each of the leases. The inspection and monitoring program is driven by properties identified with 'priority paddocks' (degraded paddocks) and those properties at risk of degradation due to drought conditions. The photo-point data dates back as far as 1942. One of the earliest Pastoral Board members collected and documented photos for lease inspection reports dating back to 1942. Many of these sites have been relocated in recent years. Brendan Lay initialised a state-wide, numbered, photo-point system in 1970. By the time the Act was in place and the lease assessment process endorsed, ~1500 photo-point sites were established. There is now a series of ~6000 photo point sites used for assessments and monitoring.	The period of time between assessments seems very long but, given the pastoral lands cover 41 million hectares, it is a considerable task. Changes to these regions are moderately slow compared to higher rainfall regions.
Availability	Raw data are currently only available to those directly monitoring or inspecting on behalf of the Pastoral Board. PMIS data are available upon request. An email can be sent to pastoralsupportdwlbc@saugov.sa.gov.au. A member of staff will then collate and forward the data requested. In future, data will be accessible directly from ALIS.	Once ALIS is up and running, information will be much more freely available and accessible. Presently there is very little distribution of information, quite possibly since there has been very little collation of relevant data.
Additional relevant information	GG = There may be some initial set-up costs to run this program. Estimates of the on-going costs were provided in the report by Brook et al. (2001) and suggest a yearly cost of ~$240 000. This costing was generated in 2001, and since then satellite images have decreased in cost significantly. The cost included the purchase of three images that could cover an area of ~180 000 km^2 and a team of three staff to manage the project. Once the project is up and running, one person could manage the workload alone.	The pastoral monitoring programs are facing several challenges. These include: the lack of suitably experienced staff willing to do this type of work; the remoteness of the rangelands; the lack of understanding of these diverse ecosystems; escalating costs involved to conduct the monitoring and assessments and continual cuts to funding; the declining number of rangeland programs that support knowledge sharing and development; data storage and management.
Source of information	Bastin, G, James, C, Brook, A & Chewings, V 2006, Woolgrowers with remote control new tools for whole of property management. CSIRO and DWLBC, Adelaide (unpublished). Bastin, GN, Pickup, G, Chewings, VH & Pearce, G 1993, 'Land degradation assessment in Central Australia using a Grazing Gradient method', *The Rangeland Journal,* 15(2):190-216. Brendan Lay, Principal Scientific Officer, Pastoral Program, DWLBC, pers. comm., January to July 2006. Brook, A, Tynan, R & Fleming, M 2001, *Indices of change in ecosystem function (cover) for northern South Australia using Landsat TM*, National Land and Water Resources Audit, Canberra, ACT.	

Name	Pastoral Areas Land Monitoring System	Comment (e.g. adequacy) and observations

Chris Turner, Senior Inspector, Pastoral Program, DWLBC, pers. comm., January to July 2006.

CSIRO Sustainable Ecosystems 2002, *Monitoring and assessment of grazing*. CSIRO Centre for Arid Zone Research, Alice Springs, Fact Sheet, viewed January to June 2006, <http://www.cazr.csiro.au/documents/monitoring_ass.pdf>.

Gould, P 2003, *Kingoonya assessment 2*. Department of Water, Land and Biodiversity Conservation, Pastoral Program, Sustainable Resources, Adelaide (unpublished).

Ireland, C 2004, *Recommended methods for the second round of pastoral lease assessments — South Australian Arid Lands — final report*. Ireland Resource Management Pty Ltd, Adelaide.

Lange, RT, Lay, BG & Tynan, RW 1994, *Evaluation of extensive arid rangelands: the land condition index (LCI)*. *Royal Society of South Australia. Transactions,* 118(2):125-131.

Laszlo Katona, GIS Analyst and Web Developer, Knowledge and Information, Information Resources, DWLBC, pers. comm., January to July 2006.

Lay, B, Maconochie, J & McCord, A 2003, *Land condition in the Rangelands Region of South Australia* prepared for the Soil Conservation Council of SA, Report No 1, Department of Water, Land and Biodiversity Conservation, Adelaide.

Lay, B, Tynan, R & White, J 2005, *Pastoral lease assessment technical manual —Revised technical manual for the second round of assessments of pastoral leases in South Australia*. Department of Water Land and Biodiversity Conservation, Adelaide.

Max (John) Maconochie, Senior Scientific Officer, Pastoral Program, DWLBC, pers. comm., January to July 2006.

Mike Fleming, Technical Officer, Knowledge and Information, Information Resources, DWLBC, pers. comm., January to July 2006.

White, J & Gould, P 2002, *Notes regarding the Richards/Green Functionality Index*. Department of Water, Land and Biodiversity Conservation, Pastoral Program, Sustainable Resources, Adelaide (unpublished).

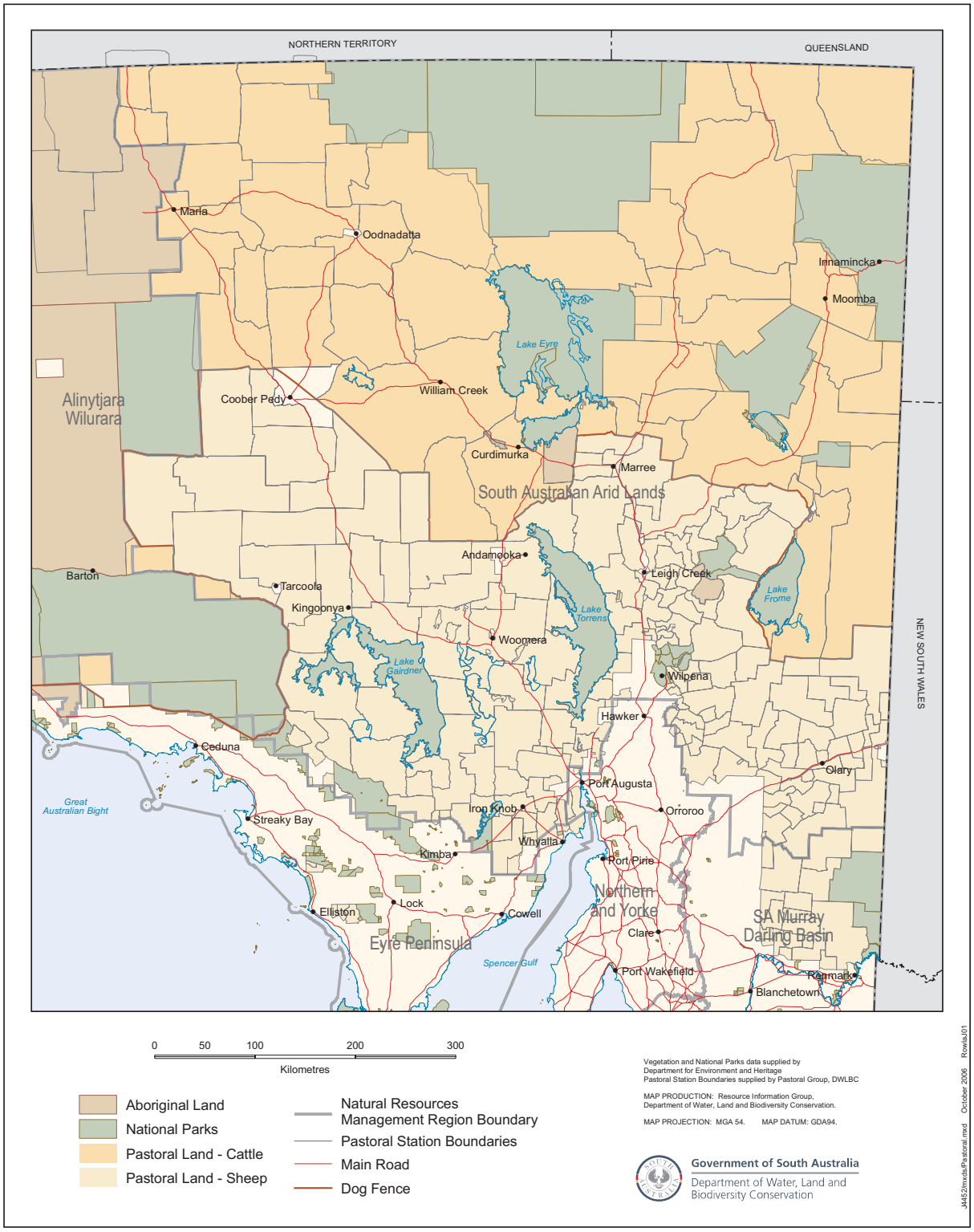

Figure 8. Pastoral lands of South Australia

Table 21. DWLBC's Land-Use Spatial Datasets

Name	Land-Use Mapping Program	Comment (e.g. adequacy) and observations
Custodian	DWLBC, Soil and Land Information and Bureau of Rural Sciences	
Contact details	Sandra Keane, GIS Officer, Soil and Land Information, DWLBC	
Status	This dataset is a baseline only. No further land-use mapping is intended at this stage. If funding becomes available through external projects, only then will DWLBC update the data already created.	DWLBC has conducted additional land-use mapping projects for specific land uses such as the expansion of farm dams and irrigated crops.
General description	The Bureau of Rural Sciences funded DWLBC to produce a digital dataset showing the distribution of land-use classes (Australian Land Use Management classification) for the whole of South Australia. The state was divided into major regions to facilitate the mapping process.	
Rationale	Land-use information can be a vital tool in improving the management of land, vegetation and water resources.	
Survey methodology	Initially, a 'draft' land-use map was generated by combining information from satellite imagery, aerial photographs, and ancillary datasets (such as heritage listed areas, vegetation cover, protected areas, land cover (lakes, swamps)). These data were combined with the DCDB information on property boundaries and roads, etc. These draft maps were taken into the field with various GPS tracking devices and surveyed by driving along the roadsides. Inaccessible areas were mapped by satellite imagery and aerial photography only. Land uses were classified under the Australian Land Use Management classification system. A second surveyor duplicated a sample of sites in each area and then compared the difference between the two, and completed an assessment of accuracy.	There are many issues that can impact on the quality of the data collected for the maps. Most of the errors are human induced, made when surveying in the field, including: • Since most of the surveys are conducted by road, some land uses can be completely missed if a change in land use occurs in the middle of a large property. • Wetland areas can be mistaken for livestock grazing depending on what time of the year the survey was conducted. • Grazing and cropping land can be difficult to interpret depending on the time of year the survey was conducted. During drought periods, what is predominantly cropping land was being grazed instead. Crops can be very difficult to identify if surveys are conducted in winter when crops are just germinating. • Irrigation equipment can also be difficult to see depending on the crop and time of year. • Classifications of land uses are through an individual's interpretation and may differ from person to person. • Some difficulties were encountered when data regarding irrigated horticulture were provided by growers to LAP officers. There was concern that this information would become public knowledge and be used for financial gain.

Name	Land-Use Mapping Program	Comment (e.g. adequacy) and observations
Source data used in survey design	The data were collected and processed as per the methodology described in the Australian Land Use Management classification version 5. Several other datasets were used to produce the 'draft' land-use maps to provide information to the surveyors. As an example, the datasets used in the Murray–Darling Basin Land Use Mapping included: • Collaborative Australian Protected Areas Database • SA Heritage Agreement Areas • SA Landcover • SA Agricultural Area Land Cover Change grids • 1999 MLR Land Use.	
Data format and location	The data have been captured using ArcGIS software. Many of the maps and reports have been converted to PDF files. Maps may be extracted from ArcGIS in various image formats as requested from GIS Officers within DWLBC.	
Processing of source data	Maps have been generated for each map area at 1:100 000 scale. Each map has a colour-coded display of land uses and a legend describing the land uses.	There are many land-use classifications available and there is a system for selecting a land use that may in fact have multiple levels of use.
Derived information and format	The information is stored on the DWLBC local network in ArcGIS formats. GIS staff in DWLBC are able to access the land use data using ArcGIS software. Other staff who do not use ArcGIS can access CDs of maps with the associated reports. CDs are available for each region. Some regions have more than one set of land-use data if they have been surveyed more than once. A state-wide CD is also available but only has the most recent land-use data for each region. Reports are available for each of the regions surveyed and contain copies of the maps generated.	
Area of coverage	The whole of South Australia has been mapped at least once under the Bureau of Rural Sciences Land Use Mapping Program. Figure 9 shows the extent of regions mapped and the year in which the mapping was completed.	
Useability scale	The maps generated by the Land Use Mapping Program are at 1:100 000 scale and are recommended not to be used at a greater scale. The maps were intended to be used at a regional level and are not suitable for use at a local or property level assessment.	
Dates and/or recency	The mapping conducted under this project commenced in 1998 and was completed in 2003. No further land-use mapping is planned at this stage.	DWLBC does not fund land-use mapping projects and some datasets are now becoming outdated. Development has been more pronounced in some regions than others and updating these data may become more important as time goes by.

Name	Land-Use Mapping Program	Comment (e.g. adequacy) and observations
Availability	The Bureau of Rural Sciences has the national land use datasets available. DWLBC has the data store on the local network, and has also produced regional CDs with the mapping data and reports. The CDs are available free to staff at DWLBC and other government agencies, but are sold to external clients at a cost of $90 plus GST. A state-wide CD has been collated with the most recent data for each region and costs $180 plus GST.	
Additional relevant information	The Bureau of Rural Sciences paid for the cost of the initial data, but has no need for further mapping. DWLBC does not fund any of the mapping process. Previous Catchment Water Management Board funded projects at catchment level have cost up to $15 000, while a whole region may cost between $60 000 and $80 000.	
Source of information	Bureau of Rural Sciences 2002, *Land use mapping at catchment scale: Principles, procedure and definitions,* Edition 2, Bureau of Rural Sciences, Canberra.	
	Keane, S 2003, *Land use and management mapping of South Australia, Part 4: Murray–Darling Basin.* A project for Bureau of Rural Sciences Land Use Mapping Program, Department of Water, Land and Biodiversity Conservation, Adelaide.	
	Sandra Keane, GIS Officer, Knowledge and Information, Information Resources, DWLBC, pers. comm., January to July 2006.	

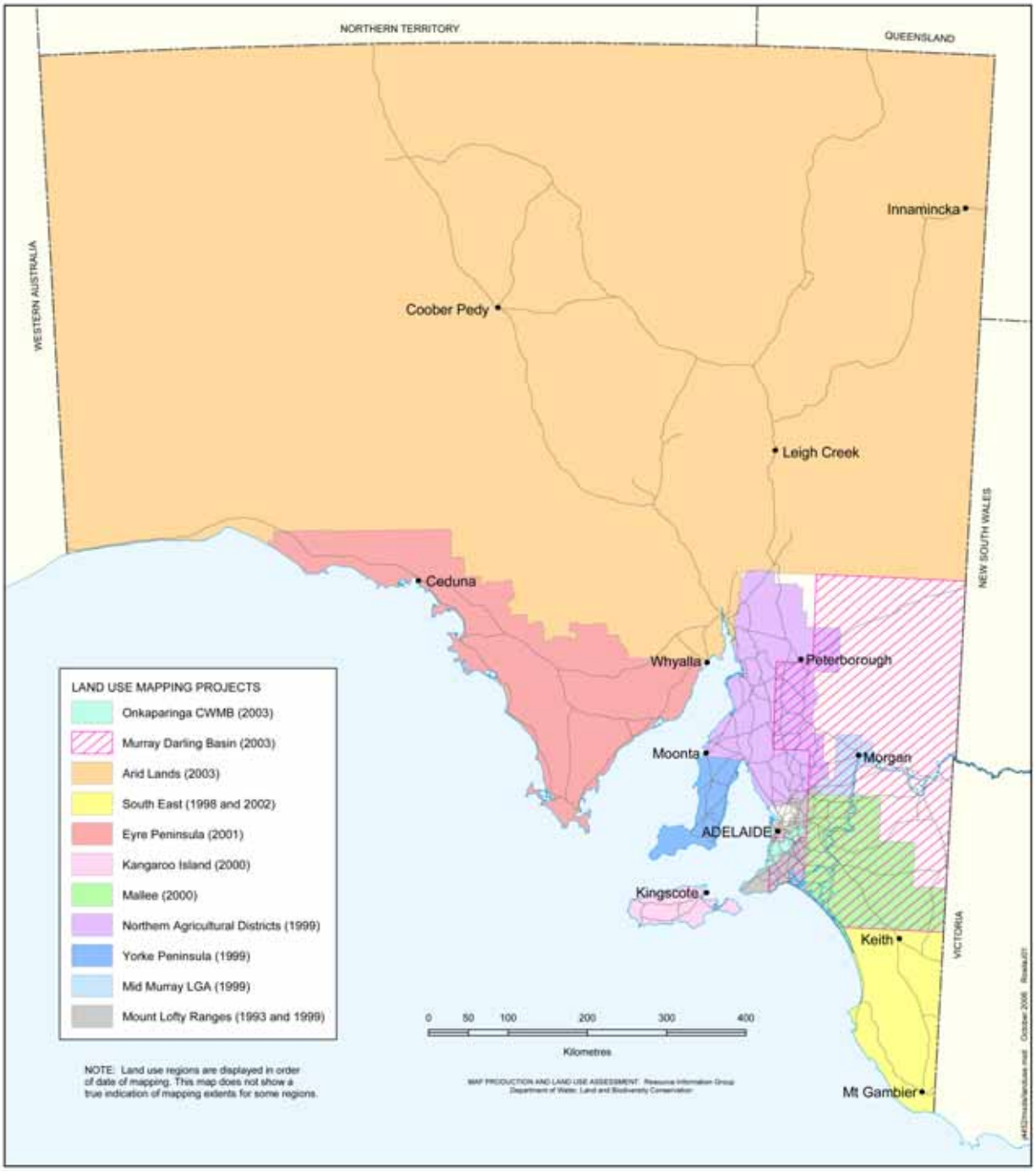

Figure 9. Land use mapping projects in South Australia

4. 'IDEAL' STATE LCM MODEL

The purpose of developing the 'ideal' monitoring model is to assist the development of the State MER-OP and ensure that monitoring meets the needs of stakeholders at national, state and regional level. This proposed model will also assist the regional NRM Boards to plan future monitoring programs and in target-setting exercises.

4.1 METHODOLOGY

4.1.1 THEMES

The LCM model proposed here is driven primarily by targets identified by the South Australia Soil Conservation Council in its Directions for the Agricultural Lands of South Australia paper (Morgan et al. 2005) and, secondly, the National Monitoring and Evaluation Framework recommended indicators. There are eight key land condition themes, five of which are nationally driven targets:

- soil acidity
- soil wind erosion
- soil water erosion
- soil carbon content
- dryland salinity.

The remaining three themes are not nationally recommended but have significance in the South Australian landscape:

- soil physical condition
- soil fertility and nutrition
- soil water repellence.

In the following sections, each land condition theme has been dealt with individually, identifying the programs that will collect appropriate data and indicator trends. Given the landscape variation across the state, each land condition theme may have more than one monitoring program identified in order to provide logical information in consideration of extreme regional variation. Several of the monitoring methods are simply not useable across such variable landscapes and land uses. Some monitoring programs identified are required for contextual information or provide surrogate indicator trends.

4.1.2 MONITORING PROGRAMS

The 'ideal' LCM programs have been identified through:

- a detailed assessment of data and information needs (Chapter 2)
- an assessment of the current roles and responsibilities at the national, state, and regional level (Chapter 2)
- extensive discussions with experts in the field of land condition and soils research

- assessment of the existing monitoring programs and their ability to meet LCM needs (Chapter 3)
- reviews of current research
- discussions with regional NRM staff regarding their RCTs and information needs
- reports from national expert panels on recommended protocols for monitoring provided by the National Land and Water Resources Audit.

Some programs already exist and references will be made to the 'Existing monitoring programs, data and information' sections. Each newly proposed monitoring program (as noted in the 'Monitoring Program' column in the following tables) is discussed broadly. More detailed discussions are required to confirm the methodology and arrangements for undertaking these new programs. The outline of such programs is conceptually discussed in this report.

For each of the monitoring programs, potential indicators have been listed so that it is clear what information the program can produce to meet stakeholder's needs.

4.1.3 DATA COLLECTION AND REPORTING TIME FRAMES

The timing intervals assigned for data collection and reporting are based on the apparent most practical intervals that could be determined at this point in time. For existing programs, data collection will mostly remain the same as it was previously, and reference should be made to further information in those appropriate sections or tables. Data collection timing for new programs is based on recommendations made by technical experts or dictated by when the data are generated.

4.1.4 ROLES AND RESPONSIBILITIES

In order to establish this proposed monitoring model, some level of responsibility needed to be assigned to the organisations conducting the monitoring programs and those requiring the information produced. To facilitate ordering the proposed roles and responsibilities in a broad fashion, the method used in the 'Integrated Water Monitoring Review of the Northern Adelaide and Barossa Catchment Area' (SKM 2002) report was used. All stakeholders involved are divided into three levels of involvement:

- Lead agencies — responsible for monitoring effort, plans and protocols; supervising data quality and assurance; supporting monitoring undertaken by other parties; data are critical for business requirements.
- Potential collaborative agencies — require access to data to deliver business services; will require access to information generated; contribute to monitoring through joint funding or advising.
- Interested agencies — in the best interests of the business that monitoring is undertaken (not directly responsible for monitoring but may require access to information generated).

4.1.5 NRM REGION INFORMATION NEEDS

The following tables detailing each region's information requirements have been adapted from data interpreted in Appendix E (see Section 2.3.2 for explanation). The tables include whether the information required is RCT critical, context critical (CC) or context useful (CU):

- RCT critical — critical for the assessment of the RCT
- CC — information critical to interpreting the RCT critical data
- CU — information that is useful to interpret the RCT critical data.

Some interpretation was required to match the data needs and monitoring programs, e.g. Eyre Peninsula requires information on pH forecasting, therefore it is critical information to know current pH levels and lime sales trends. Often the same information may be required for one or more RCTs. In this case only the most critical priority is listed.

4.1.6 INFORMATION AND REPORTING REQUIREMENTS

Specific sources have been used to facilitate matching the proposed monitoring programs with information and reporting requirements.

- The national SoE reporting requirements are based on the core indicators only, as listed in the 2001 report (see App. A).
- The state-level SoE reporting needs are based on information contained in the most recent 2003 report (see App. C).
- The Greenprint information requirements have been adapted from the 2003, 2004 and 2005 reported indicators and targets (see Table 8).
- The ACRIS requirements or interests are presumed to be almost all data generated in the rangelands.
- The National Carbon Accounting System is presumed to be interested in information generated regarding soil carbon monitoring in any way, shape or form.

4.1.7 NLWRA RECOMMENDED MONITORING METHOD

It was considered important to identify whether the expert panels, in the recent report prepared for NLWRA (McKenzie & Dixon 2006), recommended the proposed monitoring programs. Each monitoring program in the following tables is assigned a 'Yes' or 'No' as to whether it is recommended by the expert panels. As a guide, Appendix H contains a list of national indicators and proposed monitoring protocols available on the Australian Government's NRM monitoring website (Australian Government 2006b,c,d,i,j). The website is likely to be updated with the expert panel's recent report, but the programs are not significantly different.

4.2 SOIL ACIDITY

Soil acidity is a degradation process mostly caused by the inappropriate use of nitrogen fertilisers, organic matter breakdown, and increased rates of product removal. Land that becomes too acidic impacts on plant growth (reduced plant growth causes a rise in salinity,

reduced soil cover and hence erosion) and soil fertility. In more severe cases, acidity can cause leaching of nutrients from the soil into groundwater and streams. Approximately 1.9 million ha of cleared land in South Australia is moderately to highly susceptible to soil acidification. Some soils are naturally acidic, particularly those in high rainfall regions, and require lime treatment to raise the pH to productive levels (McCord et al. 2004a).

Soil acidity is a commonly understood land management issue and relatively easy to monitor. Sulfidic soils, however, are a far more site-specific land management problem and are not well understood by the majority of the farming community. Sulfidic soils have a very low pH (<3–4) and occur in predominantly coastal environments but also inland. These sites are not detrimental if left undisturbed. If these sites are excavated or drained, the sulfides within the soil react with oxygen in the air and produce sulfuric acid (acid sulfate soils). The sulfuric acid can react with other elements in the soil and cause leaching of toxic materials into the environment. Acid sulfate soils can be split into two categories — ‘actual’ acid sulfate soils (AASS) and ‘potential’ acid sulfate soils (PASS). It is important for land managers to identify PASS to determine where development is best avoided and the most appropriate land management treatments if needed.

Sulfidic soils are a potential and increasing risk to environments in some regions of South Australia. It is considered important to establish a monitoring program. Various research projects are currently in progress to tackle acid sulfate problems across the state. Only sulfidic soils in inlands regions are documented in this report, and coastal land condition issues are not discussed.

Additional to the two broad programs detailed below, regions may consider collecting data from landholders who have identified sulfidic soils on their properties and measures taken to ameliorate potential impacts.

Table 22. Ideal soil acidity monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Land and Soil Information Framework	A state-wide baseline mapping framework of land systems and soil landscapes. Provides crucial baseline information for development and prioritising of LCM and management programs. This is not a monitoring program so no repeat data are collected. Some data may be added to the framework over time to improve datasets but will not be reported as such. See Table 18 for further details. Indicators: • distribution of soils susceptible to acidity (and other degradation issues, e.g. erosion, salinity).	DWLBC	(useful resource for multiple purposes)	NA	NA
Repeat pH sampling sites *(Proposed new program)*	Approximately 150 sample sites to be selected (some already existing from soil surveys conducted by Richard Merry) across South Australia's acid soil susceptible regions. Many pre-existing sites may be difficult to find since location details were not GPS located and landmark objects for site identification have most likely altered significantly. However, the repeat survey of these sites would provide unique long-term data on pH trends. A small sample of repeat pH surveys (from original 'Richard Merry' sites) has been conducted successfully on Kangaroo Island (Dohle 2005). The establishment of permanent monitoring sites was recommended by the Expert Panel for soil acidity in their July draft report (McKenzie & Dixon 2006). Indicators: • long-term soil pH trends.	DWLBC	Regional NRM Boards, PIRSA	Every five years	Every five years
Commercial laboratory soil analysis data *(Proposed new program)*	Collect and review all commercial soil testing laboratory data. pH is a standard analysis and is inexpensive. The location details are often not precise but can usually be grouped into districts or Hundreds. This level of accuracy is appropriate for monitoring trends over time. This has also been successfully implemented on Kangaroo Island. Indicators: • soil pH trends.	DWLBC	Regional NRM Boards, PIRSA	Annually	As required
Lime sales	Rural Solutions SA annually surveys commercial lime suppliers throughout South Australia to estimate the amount of lime applied each year. The figures reported are not entirely accurate, with some volumes of lime being sourced from interstate suppliers or private pits. For further information see Table 12 (summary table). Indicators: • lime volume sale trends.	DWLBC	Regional NRM Boards, PIRSA	Annually	As required

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Inland acid sulfate soils mapping (National Atlas of Acid Sulfate Soils) *(Proposed new program)*	This is a national project already underway. The project outputs include: • improve field methods for identifying ASS environments • develop more accurate soil-landscape process models of inland ASS • provide new information on the distribution and properties of inland ASS • produce an atlas on inland ASS for all of Australia • provide a scientific basis upon which ASS risk assessment and management strategies can be developed. Indicators: • distribution of inland ASS sites and level of risk of land degradation.	CSIRO Land and Water, CRC for Landscape Environments and Mineral Exploration	Adelaide University, PIRSA, Australian National University, DWLBC	10 yearly	10 yearly
Inland acid sulfate environments water quality monitoring *(Proposed new program)*	Following the above mapping project, a selection of sites should be identified for long-term monitoring. Monitoring sites will have shallow groundwater or surface water (as appropriate) wells with redox potential probes installed to provide field redox data via a wireless link. The redox data will provide information on any changes occurring in the waters which may signal degradation processes. This information will assist predictive modelling and risk assessment methods. There may be opportunities for sharing these monitoring sites with other water quality monitoring sites. This potential collaborative arrangement will need to be investigated. Two sites in each of the following regions (currently known to have acid sulfate soils) should be identified: • Kangaroo Island • Eyre Peninsula • South-East (adjacent drainage scheme most likely) • Riverland (Murray–Darling Basin) • MLR.	CSIRO Land and Water	DWLBC, regional NRM Boards	Continuous	Annually

Table 23. Organisations and NRM regions requiring soil acidity monitoring data

Monitoring program	NLWRA recommended monitoring method	Information or reporting requirements				NRM regions requiring information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Land and Soil Information Framework	Y	N	N	N	N	CU	RCT	RCT	RCT	RCT	RCT	N	N
Repeat pH sampling sites	Y	N	Y	N	N	CU	RCT	RCT	RCT	RCT	RCT	N	N
Commercial laboratory soil analysis data	N	N	Y	Y	N	CU	RCT	RCT	RCT	RCT	RCT	N	N
Lime sales	Y	Y	N	Y	Y	CU	CC	RCT	RCT	RCT	RCT	N	N
Inland acid sulfate soils mapping (National Atlas of Acid Sulfate Soils)	N	N	Y	N	N	CU	CU	CU	CU	CU	CU	CU	CU
Inland acid sulfate environments water quality monitoring	N	N	N	N	N	CU	CU	CU	CU	CU	CU	N	N

Note: pH trends for the South-East region will not only be used for assessing soils acidity but also for monitoring trends in irrigation induced alkalinity.

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

Australian Government 2006c, *NRM Resource Condition Indicators: Soil condition: Soil properties — Soil acidity (Indicator status: for advice),* Australian Government, Canberra, ACT, viewed January to June 2006 (last updated Friday, 19 May 2006), <http://www.nrm.gov.au/monitoring/indicators/soil/acidity.html>.

Brian Hughes, Land Management Consultant, PIRSA, pers. comm., January to July 2006.

David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006.

Fitzpatrick, RW 2003, **'**Overview of acid sulfate soil properties, environmental hazards, risk mapping and policy development in South Australia', in Roach, IC (Ed.), *Advances in regolith*, CRC for Landscape Environments and Mineral Exploration, CD, Adelaide, pp.122-125.

Fitzpatrick, RW 2006a, *Research Program 3: Environmental applications of regolith geoscience; Inland acid sulfate soils: distribution and regolith processes*, CRC for Landscape Environments and Mineral Exploration, viewed January to June 2006, <http://www.crcleme.org.au/Research/p3projects/Inland%20ASS%2006-07.html>.

Fitzpatrick, RW 2006b, *Towards a national atlas of acid sulfate so*ils, Draft fact sheet, CSIRO Land and Water, Adelaide.

Fitzpatrick, RW, Cox, JW, Munday, B & Bourne, JF 2003, **'**Development of soil-landscape and vegetation indicators for managing waterlogged and saline catchments**'**, *Australian Journal of Experimental Agriculture,* 43:245-252.

Fitzpatrick, RW & Skwarnecki, MS 2003, 'Mount Torrens, Eastern Mount Lofty Ranges, South Australia', in Anand, RR and de Broekert, P (Eds), *Regolith-landscape evolution across Australia: a compilation of regolith-landscape case histories and landscape evolution models,* CRC for Landscape Environments and Mineral Exploration, Adelaide, <http://crcleme.org.au/RegLandEvol/>.

Fitzpatrick, RW, Thomas, M & Kookana, R 2006, *A decision support toolkit for water quality in acid sulfate environm*ents, Theme 2 WRON proposal PowerPoint presentation, CSIRO Land & Water, Adelaide (unpublished).

James Hall, Senior Soils Officer, Soil and Land Information, Knowledge and Information, DWLBC, pers. comm., January to July 2006.

Rob Fitzpatrick, Chief Research Scientist, Pedology and Soil Mineralogy, CSIRO Land and Water, pers. comm., January to July 2006.

South Australian Coast Protection Board 2003, ‘Coastline: A strategy for implementing CPB policies on coastal acid sulfate soils in South Australia’, *South Australia, Department for Environment and Heritage, Coast and Marine Branch, Information Booklet,* 33.

4.3 SOIL WIND EROSION

Wind erosion predominantly occurs when a soil is left loose, dry, and bare of vegetation and is subjected to strong winds. Most of South Australia's 2.4 million hectares of wind erosion susceptible land is a sandy soil type. These sandy soils are mostly found in Eyre Peninsula, Murraylands, and the South-East. The pastoral lands are also susceptible if they become degraded due to overgrazing and drought conditions. Soil wind erosion events are highly variable spatially and temporally and are therefore very difficult to measure directly. (McCord & Payne 2004a) The following monitoring programs are seen as the best fit of information across all regions of the State and are well accepted at a National level.

4.3.1 DUSTWATCH

DustWatch is a volunteer observer program developed between the BoM and Griffith University in Queensland to collect data on dust storms across Australia. The volunteers (either individuals or schools who wish to be involved) make simple observations about the timing and characteristic of dust storms. The volunteers document dust events on an observation sheet which comes with clear guidelines of what to document. No equipment is necessary. Observation data are combined with satellite imagery, meteorological records and field measurements of dust concentrations to help better understand wind erosion.

Griffith University has continuous records of dust activity in Australia dating as far back as the 1940s. An indicator called the Dust Storm Index (DSI) was developed to provide a measure of the intensity and frequency of dust activity. The DSI combines local, moderate and severe dust storms using weightings based on estimated dust concentrations. The DSI is an ANZECC approved measure of wind erosion and is widely used for environmental audit and SoE reports at state and national level. The DSI has also been recommended by the Expert Panel for Wind Erosion monitoring under the NLWRA.

South Australia could relatively easily join the DustWatch program and encourage volunteers to collect data. It is envisaged that DustWatch would be most useful in the pastoral regions and parts of other dry regions of the state. BoM may need to upgrade or install additional equipment to facilitate the calibration of the data collected by volunteers. Further investigation is required to assess the possibility of establishing this program.

In the pastoral regions, the DSI, combined with remote sensing programs including AussieGrass and the Grazing Gradient and the ground-based Pastoral Areas Land Monitoring System, could provide a very useful indicators of land condition.

Source of information:

Griffith University 2006, *School DustWatch*, Fact Sheet, viewed January to June 2006, <http://www.griffith.edu.au/centre/riverlandscapes/dustwatch>.

McTainsh, GH 1998, 'Dust Storm Index', in Sustainable agriculture: Assessing Australia's recent performance, A report for the National Collaborative Project on Indicators for Sustainable Agriculture, *SCARM Technical Report,* 70:56-62.

Table 24. Ideal soil wind erosion monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Field survey program for wind and water erosion (LCMP 'windscreen' survey)	A field survey program conducted along set transects across the agricultural districts to collect information on land identified as being at risk of erosion. The survey is conducted four times each year to derive a wind erosion risk index. For further information see Table 14. Indicators: • wind erosion risk index (Wind ERI) • peak risk trends of wind erosion • trends in proportion and area of land at risk.	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Four times each year	Annually (for regions, longer periods for state-level reporting)
Land manager survey (LCMP)	See Table 15 for further information. The phone survey asks land management practice questions to broadacre, stock and dairy farmers from a wide area of regions. Indicators: • Trends in: ○ proportion of land managers considering wind erosion as a land management issue ○ changes in cropping, tillage and grazing practices (e.g. long fallows and direct drilling, feed-lotting) ○ changes preferred month for initial crop preparation cultivation	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	Three yearly (or as required for regions)
Grazing Gradient	Remotely sensed images of reflectance used to calculate the capacity of land to recover following significant rainfall events. This method can be used as a surrogate indicator for wind erosion (and other variables) in the rangeland regions. Also provides data for cattle lease properties where the Land Condition Index method is not used. Pastoral lease inspections and assessments may be used as site-specific ground-truthing data for calibrating the model. For further information see Table 20. Indicators: • change in vegetation cover in response to rainfall.	DWLBC	Pastoral Board, PIRSA, regional NRM Boards,	Three images each year	Annually
DustWatch *(Proposed new program)*	Proposed new program for SA. See section 4.3.1 for more information. Indicators: • Dust Storm Index (intensity and frequency of dust activity).	DWLBC	Griffith University, BoM, CRC for Desert Knowledge, regional NRM Boards	Continuously	Annually

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
AussieGrass	A spatial simulation model developed to predict and monitor historical grass production and land cover in all Australian regions. The model can simulate pasture growth, feed shortages, total standing dry matter and fire risk on a 5 km^2 grid at the state and national level (Carter et al. 2000; Hall et al. 1999). By inputting stocking rates, the model can assess grazing pressure and therefore indicate degradation risk and identify opportunities for improving land management. Pastoral lease inspections and assessments may be used as site-specific ground-truthing data for calibrating the model. See Table 12 for additional information. Indicators: • maps showing recent past periods and next three month expected rainfall, pasture biomass production and pasture growth relative to long-term averages • current land cover and likely future trends • land degradation alert identifying where land may be at risk (from low rainfall, low pasture availability, high stocking rates) • seasonal condition assessment for drought analysis • climate change analysis; predict climate change impact on pasture production and livestock carrying capacity.	DWLBC	QLD Department of Natural Resources, Mines and Water, regional NRM Boards, PIRSA	Continuously	Annually
Land cover *(Proposed new program)*	'CSIRO Atmospheric Research (specifically the Earth Observation Centre) and CSIRO Land and Water are embarking on a program to make the 20-year Australia-wide record of NOAA–AVHRR (National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer) data available via the Internet. This series, combined with new data from the satellite, provides an excellent opportunity to monitor soil cover. It also provides the opportunity to assess the management of soil cover across Australia during the last two decades ... AVHRR data have been acquired for the entire Australian continent since 1981, and indicators can be derived from these data at the regional, State and National level.' (Australian Government 2006d) Additional research in this area is still required to establish techniques for identifying bleached dry annuals and dry vegetation. The use of this dataset has also been recommended by the Expert Panel for wind erosion monitoring under NLWRA. The Expert Panel also recognises the need for research to identify other forms of cover as protection from erosion. Indicators: • changes in land cover • management of soil cover.	CSIRO	DWLBC, PIRSA, regional NRM Boards	Continuously	As required

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Vegetation cover monitoring in the Perpetual Lease Rangelands	See Table 12 for further information. This ground-based monitoring program covers an area of land not monitored under any other program and is currently a gap. This program is relatively inexpensive to conduct and could be combined with satellite imagery programs (such as AussieGrass, or the Land Cover datasets) to generate long-term trends.	DWLBC	PIRSA, regional NRM Boards	Annually	As required (annually to five yearly)

Table 25. Organisations and NRM regions requiring soil wind erosion monitoring data

Monitoring program	NLWRA recommended monitoring method	Information or reporting requirements					NRM regions requiring information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*ACRIS*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Field survey program for wind and water erosion	Y	Y	Y	Y	Y	N	RCT	RCT	RCT	N	N	RCT	N	N
Land manager survey (LCMP)	N	N	N	N	N	N	CC	CC	CC	CU	CU	CC	N	N
Grazing Gradient	Y	N	Y	Y	N	Y	N	N	N	N	N	N	CU	RCT
DustWatch	Y	N	Y	Y	N	Y	CU	CU	N	N	N	CU	CU	CU
AussieGrass	Y	N	Y	Y	N	Y	N	Y	N	N	N	CU	CC	RCT
Land cover	Y	N	Y	Y	N	Y	CC	CU	CC	CU	RCT	CU	CC	RCT
Vegetation cover monitoring in the Perpetual Lease Rangelands	Y	N	Y	Y	N	Y	N	N	N	N	N	N	CC	N

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

Bastin, G, James, C, Brook, A & Chewings, V 2006, *Woolgrowers with remote control new tools for whole of property management*. CSIRO and DWLBC, Adelaide (unpublished).

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CSIRO Sustainable Ecosystems 2002, *Monitoring and assessment of grazing*. CSIRO Centre for Arid Zone Research, Alice Springs, Fact Sheet, viewed January to June 2006, <http://www.cazr.csiro.au/documents/monitoring_ass.pdf>.

David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006.

Hall, WB, Bean, J, Beeston, G, Dyer, R, Flavel, R, Richards, R, Tynan, R & Watson, I 1999, AussieGrass: Australian Grassland and Rangeland Assessment by Spatial Simulation, in *Proceedings of the 6th International Rangelands Congress,* July 1999, Townsville, pp.854-855.

Ireland, C 2004, *Recommended methods for the second round of pastoral lease assessments — South Australian Arid Lands — final report*, Ireland Resource Management Pty Ltd, Adelaide.

James Hall, Senior Soils Officer, Soil and Land Information, Knowledge and Information, DWLBC, pers. comm., January to July 2006.

Land & Water Australia 2004, *Australian Grassland and Rangeland Assessment by Spatial Simulation (AussieGRASS) summary June 2004*, Land and Water Australia, viewed January to June 2006, <http://www.lwa.gov.au/library/scripts/objectifyMedia.aspx?file=pdf/29/66.pdf>.

McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council, for the Department of Water, Land and Biodiversity Conservation, Adelaide.

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Mike Fleming, Technical Officer, Knowledge and Information, Information Resources, DWLBC, pers. comm., January to July 2006.

Park, JN, Cobon, DH & Crabb, DM 2006, *Integrating climate forecasts and geospatial systems to enhance grazing management in Northern Australia*, Conference paper, The Regional Institute, Queensland Department of Primary Industries, Queensland Centre for Climate Applications, Longreach, Queensland, viewed January to June 2006, <http://www.regional.org.au/au/gia/03/056park.htm>.

4.4 SOIL WATER EROSION

The majority of land in South Australia susceptible to water erosion is in the Northern and Yorke Agricultural Districts, Lower and Eastern Eyre Peninsula, and MLR. Inherent susceptibility of land to water erosion is governed by soil type, slope of the land, and intervals between rainfall events and their intensity.

Land is also susceptible to water erosion if left bare due to inappropriate cropping and grazing practices. Water erosion rates are very difficult to directly measure especially given the different forms and processes of erosion, e.g. sheet, rill, gully, and mass erosion.

Table 26. Ideal soil water erosion monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Field survey program for wind and water erosion (LCMP 'windscreen' survey)	A field survey program conducted along set transects across the agricultural districts to collect information on land identified as being at risk of water erosion. The survey is conducted four times each year to derive a water erosion risk index. For further information see Table 14. Indicators: • annual water erosion risk index • peak risk trends of water erosion • average water erosion risk index (days) • trends in proportion and area of land at risk.	DWLBC	Regional NRM Boards, PIRSA	Four times each year	Annually
Gully, mass and riparian zone erosion surveys in water erosion risk regions *(Proposed new program)*	Conduct a survey of gully and mass erosion locations using aerial photography and/or videography to assess location and extent of erosion sites and stability of riparian zones. Riparian zones will include riverbanks, lake edges and cliffs. Fixed photo points may also be used to monitor erosion. Indicators: • gully erosion density (kilometre of gully length per square kilometre of land (km/km^2)) • mass erosion location and extent • riparian zone erosion location and extent.	DWLBC	Regional NRM Boards	10 yearly	10 yearly
Gully, mass and riparian zone erosion monitoring *(Proposed new program)*	Monitor the rate of expansion of gully networks in priority regions and selected catchments (selected on the basis of known risk) using standard geomorphic erosion measurement techniques. For mass or riparian zone erosion use photo points to assess the stability or extent of erosion sites identified in the survey. This monitoring should incorporate any management practices or on-ground works adopted to control the erosion. Indicators: • expansion or recovery of eroded sites.	DWLBC	Regional NRM Boards	1–5 yearly	Five yearly
Land manager survey (LCMP)	See Table 15 for further information. The phone survey asks land management practice questions to broadacre, stock and dairy farmers from a wide area of regions. Indicators: • Trends in: o land manager knowledge, awareness and involvement in land management issues o land manager knowledge and awareness of soil health issues o changes in cropping and tillage practices.	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	Three yearly (or as required for regions)

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
AussieGrass	As per Table 24. Indicators: • maps showing recent past periods and next three month expected rainfall, pasture biomass production and pasture growth relative to long-term averages • current land cover and likely future trends • land degradation alert identifying where land may be at risk (from low rainfall, low pasture availability, high stocking rates) • seasonal condition assessment for drought analysis • climate change analysis; predict climate change impact on pasture production and livestock carrying capacity.	DWLBC	QLD Department of Natural Resources, Mines and Water, regional NRM Boards, PIRSA	Continuously	Annually
Grazing Gradient	As per Table 24. Indicators: • change in vegetation cover in response to rainfall.	DWLBC	Pastoral Board, PIRSA, regional NRM Boards	Three images each year	Annually
Land cover *(Proposed new program)*	As per Table 24. Indicators: • changes in land cover • management of soil cover.	CSIRO	DWLBC, PIRSA, regional NRM Boards	Continuously	As required
Stream turbidity monitoring *(Proposed new program)*	'Turbidity is the measure of the light scattering properties of water and depends on the amount, size and composition of the suspended matter such as clay, silt, colloidal particles, plankton and other microscopic organisms.' (Australian Government 2006e) For those regions that have surface water flow, a small number of sites need to be selected, preferably in collaboration with water monitoring programs and downstream of identified priority catchments and erosion sites. Monitoring sites additional to those identified by the water monitoring programs may need to be negotiated. Waterwatch is a community water quality monitoring program with networks all over Australia. Most of South Australia's Waterwatch networks are monitored by school groups. Networks already exist in the following areas: Broughton Wakefield, South-East, Northern Adelaide and Barossa, Onkaparinga, River Murray (Lower and Riverland), Patawalonga and Torrens. The Waterwatch program could possibly be expanded or adjusted to monitor additional sites for water erosion monitoring. If possible, flow volume would add value to the turbidity data to provide contextual information. Indicators: • stream turbidity.	EPA	DWLBC, SA Water, regional NRM Boards, Waterwatch	Continuously	As required

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Assessment of erosion hazard *(Proposed new program)*	This assessment will clearly identify those areas of the state that are most susceptible to water erosion. The assessments involve the collation of many data sources to define the locations that are an erosion hazard; they should include: • soil or land cover data • rainfall erosivity (a function of total rainfall amount and intensity) • digital elevation models (slope angle and length) • soils attribute data (Australian Soil Resource Information System) • land use • Water Erosion Risk Index • land-use practice (reduced tillage, stubble retention, etc.). Indicators: • change in erosion hazard over time.	DWLBC	PIRSA, (useful resource for multiple purposes)	Continuous	10 yearly
Vegetation cover monitoring in the Perpetual Lease Rangelands	See Table 12 for further information. Indicators: • perennial vegetation cover and population changes.	DWLBC	PIRSA, regional NRM Boards	Annually	As required (annually to five yearly)

Table 27. Organisations and NRM regions requiring soil water erosion monitoring data

Monitoring program	NLWRA recommended monitoring method	Information or reporting requirements					NRM regions requiring information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*ACRIS*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Field survey program for wind and water erosion	Y	Y	Y	Y	Y	N	RCT	RCT	CU	N	N	RCT	N	N
Gully and mass erosion surveys in water erosion risk regions	Y	N	N	Y	N	N	RCT	RCT	N	CC	RCT	RCT	CU	N
Gully and mass erosion monitoring	Y	N	N	N	N	N	RCT	RCT	N	CC	RCT	RCT	CU	N
Land manager survey (LCMP)	Y	N	N	Y	N	N	CC	CU	RCT	CU	RCT	CU	N	N
Grazing Gradient	Y	N	Y	Y	N	Y	N	N	N	N	N	N	CU	RCT
AussieGrass	Y	N	Y	Y	N	Y	N	Y	N	N	N	CU	CC	RCT
Land cover	Y	N	Y	Y	N	Y	CC	CU	CC	CU	RCT	CU	CC	RCT
Stream turbidity monitoring	Y	N	N	N	N	N	CC	CC	CU	CU	CC	CU	CU	CU
Assessment of erosion hazard	Y	N	Y	Y	N	Y	CC	CC	CC	CU	CC	CC	CC	CU
Vegetation cover monitoring in the Perpetual Lease Rangelands	Y	N	Y	Y	N	Y	N	N	N	N	N	N	CC	N

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

Australian Government 2006d, *NRM Resource Condition Indicators: Soil condition: Soil properties — Soil erosion by water (Indicator status: for advice)*, Australian Government, Canberra ACT, viewed January to June 2006 (last updated Friday, 19 May 2006), <http://www.nrm.gov.au/monitoring/indicators/soil/water.html>.

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4.5 SOIL CARBON CONTENT

Soil carbon levels are a good indicator of soil health and help to measure the impact of land management and land-use change. Land management practices that result in degradation tend to reduce soil carbon levels. Monitoring soil carbon also contributes to the National Carbon Accounting System to meet international reporting requirements. Soil carbon monitoring does present some problems — 'Some of the difficulties associated with monitoring changes in soil carbon are: short-range spatial variability, slow temporal change, areas may be large and measurement is expensive' (Skjemstad et al. 2002). There is a good deal of research currently being undertaken that may lead to an increased understanding of the impacts of soil carbon on South Australian agricultural soils. To date, there is no clear guide as to how much soil carbon should we be aiming to achieve, and how much carbon is the minimum for productive yet sustainable land practices. The subject of soil carbon is clearly still under development, and the cost of current monitoring methods presently suggested far outweighs the benefits the data may provide.

Soil carbon analysis is commonly conducted by laboratories that commercially analyse soil samples, predominantly for fertiliser companies and their landholder clients. This information is not appropriate for the following reasons:

- Commercial laboratories use methods that are not always consistent with the relevant standards.
- Commercial laboratories use different methods and the results would not be consistent between them.
- Soil carbon amounts have huge spatial variance in small paddock areas; '… over relatively small areas of a few hectares or less, coefficients of variation for organic carbon content may exceed 35% and >25 samples would be required to give a 95% confidence interval for the mean with an accuracy of ±10% …' (Wilding & Drees 1983).
- The sampling methodology used by landholders and fertiliser companies is not suitable. Several samples collected from appropriate depths are required to create a bulk sample to minimise the effect of variance.
- % carbon is not an appropriate measure. Tonnes per hectare of carbon is the right measure, but to get this, a measure of bulk density is required which is also difficult to do and expensive to analyse.

The CSIRO has been calibrating and verifying a model called 'RothC' to Australian sets of measured carbon pools. The calibration and verification of the model has included locations in South Australia (Tarlee, Freeling, Victor Harbor) where archival soil samples and background data could be accessed.

Presently, there does not appear to be enough evidence of the benefits, or a clear mandate requiring South Australia to monitor soil carbon to the extent required to establish an appropriate baseline and trend data. For this reason, the monitoring program suggested in Table 28 may be considered a stepping stone to a more complete program in the future as research and drivers for monitoring evolve.

Table 28. Ideal soil carbon content monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Land manager survey (LCMP)	See Table 15 for further information. Impacts of cropping and tillage practices have well-known impacts on carbon levels in soils. These impacts can be modelled across the majority of dryland cropping landscapes where RothC has already been calibrated and verified. These data can also be utilised in the CRCGA calculator as per below. Indicators: • trends in cropping and tillage practices.	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	Three yearly (or as required for regions)
ABS data for crop production	Soil scientists have been able to establish reasonably well-expected rates of increasing or decreasing soil carbon amounts based on cropping land management practices and the crop yield. There is a clear relationship between increasing crop yields and increasing soil carbon. This is due to the fact that the more a plant produces above the ground (biomass), the more carbon that will be put back into the soil. Barley and wheat grain yield data collected by the ABS could be modelled to predict soil carbon trends. To incorporate this data into the RothC model, an initial baseline carbon survey would need to be conducted. Without baseline data, a number of alternative scenarios could be used to report against. This does lead to a lot of assumptions having to be made. The above land management practice trends could also be incorporated.	ABS	DWLBC, CSIRO	Annually	As required
Soil carbon analysis and modelling (RothC) *(Proposed new program)*	In addition to the above two programs, a limited sampling regime could continue at the sites that were used to calibrate and verify the RothC model in SA. These sites (Tarlee, Freeling and Victor Harbor) already have background data and analysis results for soil carbon and could be designated permanent monitoring sites. The results from continued analysis could be incorporated into the model to continue to fine tune and calibrate the model's trend predictions. The Expert Panel for soil organic carbon monitoring has recommended that long-term monitoring and research sites be the priority of soil carbon monitoring if a choice has to be made for resourcing purposes.	CSIRO	DWLBC	Five yearly	Five yearly
CRCGA calculator modelling *(Proposed new program)*	CSIRO has developed a simple spreadsheet model used to calculate '… likely maximum organic carbon contents across a wide range of soil types, climates and system of land use' (McKenzie & Dixon 2006). This calculator may prove to be very useful for regional groups to set targets and monitor carbon input trends. The practical application of this model is still under development but may prove very useful for regions to estimate the status of carbon in their soils. The Expert Panel for soil organic carbon monitoring recommended this calculator as a very useful tool for regional groups to set targets.	CSIRO	DWLBC. regional NRM Boards	Annually	Five yearly (or as required)

Table 29. Organisations and NRM regions requiring soil carbon content monitoring data

Monitoring program	NLWRA recommended monitoring method	Information or reporting requirements						NRM regions requiring information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*ACRIS*	*National carbon accounting system*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Land manager survey (LCMP)	Y	N	N	Y	N	N	Y	CC	RCT	RCT	CU	RCT	CU	N	N
ABS data for crop production	Y	N	N	N	N	N	Y	RCT	RCT	RCT	RCT	RCT	CU	N	N
Soil carbon analysis and modelling (RothC)	Y	N	N	N	N	N	Y	N	CU	N	N	CU	N	N	N
CRCGA calculator modelling	Y	N	N	N	N	N	Y	RCT	RCT	RCT	RCT	RCT	CU	N	N

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

Australian Government 2006b, *NRM Resource Condition Indicators: Soil Condition: Soil Properties — Soil organic carbon (Indicator status: for advice)*, Australian Government, Canberra, ACT, viewed January to June 2006 (last updated Friday, 19 May 2006), <http://www.nrm.gov.au/monitoring/indicators/soil/carbon.html>.

David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006.

James Hall, Senior Soils Officer, Soil and Land Information, Knowledge and Information, DWLBC, pers. comm., January to July 2006.

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4.6 DRYLAND SALINITY

Dryland salinity impacts a large area of South Australia's agricultural soils and has been well researched and monitored. The methods for monitoring salinity have been documented and agreed upon in the *South Australian Dryland Salinity Strategy* (PIRSA 2001) and the summary paper titled *'Towards a South Australian Dryland Salinity Monitoring Action Plan'* (Dooley & Liddicoat 2004). The Dryland Salinity Strategy is also endorsed by the State NRM Plan. The methods and indicators are consistent with the national protocols as they are currently, and as far as is relevant for our landscapes.

Table 30. Ideal dryland salinity monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Land manager survey (LCMP)	The survey asks landholders about the area of saline soils and land on their properties, whether they consider salinity as a land management problem in their area, and if they have saline land what practices do they use to control the impacts. See Table 15 for further information. Indicators: • area of saline land • landholder knowledge and awareness of salinity issues • landholder management of saline land • landholder perception of change in salinity trends.	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	three yearly (or as required for regions)
Depth to groundwater monitoring	DWLBC has a considerable network of monitoring wells installed across the state. Some areas have been highlighted (using the SaLI framework) as having a high risk of salinity expansion and additional sites will need to be established. A rationalisation of water level monitoring timing is also required. All observation bore monitoring data are available on the Obswell Internet-based database. See Table 19 for further information.	DWLBC	Various	Continuous	As required
Groundwater salinity monitoring	Many of the wells monitored for groundwater level are also monitored for salinity. There is a large network of monitoring wells all over the state used for salinity monitoring, and are managed by a variety of agencies, community groups and individuals. The majority of monitoring data are captured on the Obswell database and used in reporting as required.	DWLBC	Various	Continuous	As required
Ground-based EM surveys	A selection of sites across the state has been surveyed with EM equipment to determine the extent and severity of saltland. A program of re-surveying these sites has commenced. This method offers a repeatable, accurate and quantifiable assessment of saltland extent and severity. See Table 19 for further information.	DWLBC	Regional NRM Boards	Five yearly	Five yearly
Extent and severity surveys	Additional to the above electro-magnetic surveys, extent and severity of saltland can be mapped and monitored using remotely sensed images, aerial photography and airborne geophysics (where appropriate). Areas that are expected to change can be ground-truthed by recording GPS locations and surveying the severity salinity impacts using the salinity category classification from the SaLI framework. See Table 19 for further detail.	DWLBC	Regional NRM Boards	5–10 yearly	5–10 yearly

Table 31. Organisations and NRM regions requiring dryland salinity monitoring data

Monitoring Program	NLWRA recommended monitoring method	Information or Reporting Requirements				NRM regions requiring information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Land manager survey (LCMP)	Y	N	N	Y	N	RCT	RCT	RCT	RCT	CC	CU	N	N
Depth to groundwater monitoring	Y	N	Y	Y	N	RCT	RCT	RCT	RCT	RCT	CU	CU	CU
Groundwater salinity monitoring	Y	N	Y	N	N	CC	RCT	CU	RCT	RCT	CU	CU	CU
Ground-based EM surveys	Y	N	N	N	N	RCT	CC	RCT	RCT	RCT	CU	N	N
Extent and severity surveys	Y	Y	Y	Y	Y	RCT	CC	RCT	RCT	RCT	CU	CU	CU

Source of information:

Barnett, SR 2000, 'Extent and impacts of dryland salinity in South Australia', National Land and Water Resources Audit, *PIRSA Report Book,* 2000/45.

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Dooley, T & Liddicoat, C 2004, *Towards a South Australian Dryland Salinity Monitoring Action Plan*, Summary paper for the state (DWLBC Land Management): Including a pilot State Dryland Salinity Report, Rural Solutions South Australia, Adelaide.

Glenn Gale, DWLBC, pers. comm., January to July 2006.

National Coordinating Committee for Salinity 2006, *Implementation of agreed national salinity indicators* — Discussion paper (Version 2; 27/2/2006), Australian Government, Canberra.

PIRSA 2001, *South Australian Dryland Salinity Strategy*, prepared for the Soil Conservation Council of South Australia, Adelaide.

Steve Barnett, Senior Hydrogeologist, DWLBC, pers. comm., January to July 2006.

4.7 SOIL PHYSICAL CONDITION

Soil physical condition is important for two main reasons; firstly, the relationship a soils physical condition has with hydrological processes including infiltration, run-off, drainage and erosion; and secondly, the ability of soil to provide fundamental plant requirements including water, nutrients and oxygen.

Key indicators for general soil physical health are:

- water intake rate
- slaking and dispersion
- sodicity versus salinity
- soil drainage status
- air-filled porosity at field capacity
- total plant-available water
- soil strength
- water repellency test (if relevant)
- surface cracking pattern (if relevant; Walker & Reuter 1996).

Soil physical condition is not a 'matter for target' at the national level but is an issue identified by the former South Australia Soil Conservation Council. The Council's 'Directions' document (which is endorsed by the State NRM Plan) targets water-use efficiency as an indicator of soil physical and nutritional condition (see Table 7). The Northern and Yorke region has estimated over 1 million hectares of land at risk of soil structure break down. State wide, almost 20% of cleared agricultural land is susceptible to surface soil structure break down, which may result in surface crusting, sodic surface soils, compaction of soil layers, and development of hardpans (Morgan et al. 2005).

Directly measuring soil physical condition on a state-wide scale is not economically possible at this stage. There are too many components of soil physical condition that would need to be assessed and the methods for structure analysis are very expensive if conducted accurately and scientifically. Soil compaction is a very serious and real issue for agricultural land across many regions in South Australia. This is also a very difficult problem to measure directly and requires significant further research.

There are many simple farm-level methods that could be used by landholders to conduct monitoring on their own properties, but this information would not be suitable for collating and up-scaling for reporting. The alternative to direct measurements is 'surrogate' indicators, shown in Tables 32 and 33.

Table 32. Ideal soil physical condition monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Land manager survey (LCMP)	See Table 15 for further information. Changes in land management practices have well-known impacts on soil physical condition. Using trends in land management practices may be used as a surrogate measure for trends in soil physical condition. Indicators: • trends in cropping and tillage practices (e.g. direct drill, number of cultivations, spraying) • trends in land management practices (e.g. contour banking, perennial revegetation, gypsum–lime–fertiliser application).	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	Three yearly (or as required for regions)
Water use efficiency (WUE)	The LCMP produces WUE indicators annually from rainfall and crop production data as collected by ABS. The WUE is a measure of the amount of grain produced per unit of water available. This indicator is used in the dryland cropping districts. There are no reliable data for pasture production, and irrigated crop WUE is a separate, complicated formula. WUE can be used as an indicator of any limitations on crop production. Other contextual data must be used to interpret the WUE indicator but broadly, if all other factors appear consistent, a high WUE suggests the soil is productive and must be in good physical condition. A declining trend in WUE may suggest a decline in the physical condition of the soil as a result of degradation.	DWLBC	Regional NRM Boards	Annually	Three yearly
Vegetation cover *(Proposed new program)*	Vegetation cover monitoring has not been explored or developed in this report. It is expected that vegetation indicators will be documented in a biodiversity monitoring review. However, it must be acknowledged that vegetation cover plays a key role in maintaining and improving soil physical condition. Monitoring trends and changes in vegetation can provide useful surrogate indications of change and is crucial contextual information.	DEH	DWLBC	Unknown	Unknown

Table 33. Organisations and NRM regions requiring soil physical condition monitoring data

Monitoring Program	Nationally recommended monitoring method	Information or reporting requirements					NRM regions requiring information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*ACRIS*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Land manager survey (LCMP)	N	N	N	Y	N	N	CC	RCT	RCT	CU	RCT	CU	N	N
Water use efficiency (WUE)	N	Y	N	N	N	N	RCT	RCT	RCT	CU	CU	CU	N	N
Vegetation cover	N	N	N	N	N	Y	CC	CU	CU	CU	CU	CC	CC	RCT

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006.

James Hall, Senior Soils Officer, Soil and Land Information, Knowledge and Information, DWLBC, pers. comm., January to July 2006.

McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council, for the Department of Water, Land and Biodiversity Conservation, Adelaide.

Morgan, SJ, Nichols, CW & Payne, RA 2005, *Soil conservation and land management: Directions for the agricultural lands of South Australia*, South Australian Soil Conservation Council, for the Department of Water, Land and Biodiversity Conservation, Adelaide.

Walker, J & Reuter, DJ 1996, *Indicators of catchment health: A technical perspective*, CSIRO Publishing, Australia.

4.8 SOIL FERTILITY AND NUTRITION

The majority of Australian soils are naturally low in fertility. For cropping and grazing production, fertilisers must be used to increase the soil fertility to a productive level and be maintained at higher than natural levels. Soil nutrients are predominantly contained in clay minerals or organic matter. Lowest fertility soils are deep siliceous sands having little ability to hold nutrients in the soil profile. The largest areas of low fertility soils are in the Eyre Peninsula, Murraylands and South-East regions. Details of inherent soil fertility characteristics across South Australia have been mapped and are recorded in the Soil and Land Information Framework (see Table 18 for further information).

Table 34. Ideal soil fertility and nutrition monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Land manager survey (LCMP)	See Table 15 for further information. The survey asks landholders questions about: • using soil testing to determine fertiliser application regimes • the use of agricultural service providers, agronomists, consultants and fertiliser agents for advice. These trends in land management practices may be used as a surrogate measure for trends in soil fertility and nutrition.	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	Three yearly (or as required for regions)
SASPAS data (LCMP)	See Table 16 for further information. The LCMP uses information from the SASPAS database to track changes in phosphorus levels in soil samples analysed. As suggested in Table 16, future access to this data is questionable and access to commercial soil analysis data is a preferred alternative (as per below).	DWLBC	PIRSA (SASPAS)	Annually	Three yearly
Commercial soil testing data *(Proposed new program)*	As discussed in Section 3.1.3, access to this data will require negotiation and collaboration with the major fertiliser agencies to gain access to this data. Presently only phosphorus level data has been analysed for soil fertility monitoring. Preferably, an extended list of analysis data would be accessed for interpretation. These might include: • phosphorus • nitrate nitrogen • exchangeable potassium (or CEC) • DTPA trace elements (copper, iron, zinc, manganese).	DWLBC, PIRSA	Various fertiliser agencies	Annually	Three yearly
ABS fertiliser application data (LCMP)	ABS collects data on fertiliser application rates in their agricultural censuses and annual surveys. The LCMP utilises these data to follow trends in fertiliser application rates. See Table 17 for further information.	ABS	DWLBC	Annually for SLA data, five yearly for census data	Three yearly
Repeat pH and soil nutrient sampling sites *(Proposed new program)*	As discussed in Table 22, a number of permanent monitoring sites (some of which already exist) could be sampled for pH and a range of soil nutrients. The samples should be analysed for the following minimum nutrients: • phosphorus • nitrate nitrogen • exchangeable potassium (or CEC) • DTPA trace elements (copper, iron, zinc, manganese).	DWLBC	Regional NRM Boards, PIRSA	Five yearly	Five yearly

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
	Preferably some minimum level of land use and management history information could be collated for each site selected. Indicators: • long-term soil fertility trends.				
Water use efficiency (WUE)	As per Table 32. WUE is also used as a target indicator of soil nutrition status in the Soil Conservation Council's Directions Paper.	DWLBC	Regional NRM Boards	Annually	Three yearly

Table 35. Organisations and NRM regions requiring soil fertility and nutrition monitoring data

Monitoring program	NLWRA recommended monitoring method	Information or Reporting requirements						NRM regions requiring information						
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*ACRIS*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Land manager survey (LCMP)	N	N	N	Y	N	N	CU	CU	CU	CU	CU	CU	N	N
SASPAS data (LCMP)	N	N	N	N	N	N	CU	RCT	RCT	RCT	RCT	CU	N	N
Commercial soil testing data	N	N	N	N	N	N	CU	RCT	RCT	RCT	RCT	CU	N	N
ABS fertiliser application data (LCMP)	N	N	N	N	N	N	CU	CU	RCT	RCT	RCT	CU	N	N
Repeat pH and soil nutrient sampling sites	N	N	N	N	N	N	CU	RCT	RCT	RCT	RCT	CU	N	N
Water use efficiency (WUE)	N	Y	N	N	N	N	RCT	RCT	RCT	CU	CU	CU	N	N

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006.

James Hall, Senior Soils Officer, Soil and Land Information, Knowledge and Information, DWLBC, pers. comm., January to July 2006.

McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council**,** for the Department of Water, Land and Biodiversity Conservation, Adelaide.

Morgan, SJ, Nichols, CW & Payne, RA 2005, *Soil conservation and land management: Directions for the Agricultural Lands of South Australia*, South Australian Soil Conservation Council**,** for the Department of Water, Land and Biodiversity Conservation, Adelaide.

Walker, J & Reuter, DJ 1996, *Indicators of catchment health: A technical perspective*, CSIRO Publishing, Australia.

4.9 SOIL WATER REPELLENCE

Soil water repellence is a naturally occurring problem where waxy organic materials coat the soil particles. Siliceous sands are more likely to have this problem than clayey soils. Water repellence causes uneven wetting of soils and results in poor vegetation establishment and patchy crop production. These impacts can contribute to further soil degradation including increasing the risk of erosion and an increase in groundwater recharge, which then increases dryland salinity issues. The distribution of known water repellent prone soils is documented in the Soil and Land Information Framework (see Table 18 for further information). There are limited monitoring alternatives for water repellence, but this is currently a lower priority land condition issue and does not have a target set by the former SCC.

Table 36. Ideal soil water repellence monitoring programs

Monitoring program	Program details	Lead agency	Collaborative agency	Timing	
				Data collection	*Reporting*
Land manager survey (LCMP)	See Table 15 (LCMP Land manager survey) for further information. Landholders are asked whether they have water repellence issues on their properties and what, if any, methods have they used to manage the problem. The survey also provides trends in landholder knowledge and awareness of water repellence in their district. Indicators: • water repellence knowledge and awareness • use of alternative tillage practices • use of clay spreading • use of clay delving • use of soil wetting agents.	DWLBC	Regional NRM Boards, PIRSA, potentially several soil, cropping and grazing management groups	Three yearly	Three yearly (or as required for regions)
Clay spreading contractors *(Proposed new program)*	Regional M&E staff will be able to provide contact details for their local clay spreading contractors. Once a year the regional officers should contact these contractors to determine how many tonnes of clay they have spread in the past 12 months. This information will be approximate only but can provide useful regional information that can also be calibrated with trends identified in the previous two programs.	DWLBC	Regional NRM Boards	Annually	Three yearly
Water use efficiency (WUE)	As per Table 32 WUE is also used as a target indicator of soil water repellence in the Soil Conservation Council's Directions Paper.	DWLBC	Regional NRM Boards	Annually	Three yearly

Table 37. Organisations and NRM regions requiring soil water repellence monitoring data

Monitoring program	Nationally recommended monitoring method	Information or Reporting Requirements					NRM Regions Requiring Information							
		State NRM Plan (Directions Paper targets)	*National SoE*	*State SoE*	*Greenprint*	*ACRIS*	*SAMDB*	*NYAD*	*SE*	*KI*	*AMLR*	*EP*	*AL*	*AW*
Land manager survey (LCMP)	N	N	N	Y	N	N	CC	CU	RCT	CU	CU	CU	N	N
Clay spreading contractors	N	N	N	N	N	N	CC	CU	RCT	CC	N	CU	N	N
Water use efficiency (WUE)	N	Y	N	N	N	N	RCT	RCT	RCT	CU	CU	CU	N	N

Source of information:

Andy McCord, Senior Scientific Officer, DWLBC, pers. comm., January to July 2006.

David Maschmedt, Soil Scientist, DWLBC, pers. comm., January to July 2006.

James Hall, Senior Soils Officer, Soil and Land Information, Knowledge and Information, DWLBC, pers. comm., January to July 2006.

McCord, AK & Payne, RA 2004a, *Report on the condition of agricultural land in South Australia, Report No 1*, South Australian Soil Conservation Council**,** for the Department of Water, Land and Biodiversity Conservation, Adelaide.

Morgan, SJ, Nichols, CW & Payne, RA 2005, *Soil conservation and land management: Directions for the agricultural lands of South Australia*, South Australian Soil Conservation Council**,** for the Department of Water, Land and Biodiversity Conservation, Adelaide.

Walker, J & Reuter, DJ 1996, *Indicators of catchment health: A technical perspective*, CSIRO Publishing, Australia.

4.10 CONCLUDING DISCUSSION

The 'ideal' monitoring model proposed here provides a realistic and complete approach to monitoring land condition across South Australia. Expert opinions have been consulted to ensure that this approach is consistent with national protocols yet is practical and achievable for South Australia. The M&E representatives from the regional NRM Boards have provided a great deal of assistance to identify and prioritise data needs and reach agreement on the proposed programs. This exercise will provide a great source of information for those regions in future planning processes.

Please note that the regional data needs explored are based on currently endorsed RCTs. Several regions are in the process of reviewing their RCTs and this may significantly alter their future monitoring data needs. Many of the current RCTs are difficult to assess and do not always clearly represent the real needs and priorities of the region (e.g. Eyre Peninsula NRM region clearly has a need for dryland salinity monitoring and assessment but does not have a clear RCT representing this need so the table is marked with a 'Context Useful' level priority). For these reasons it was considered important to have an overriding framework to plan monitoring programs and potential data sources, hence the use of the National 'Matters for Target' and the information and targets identified in the 'Directions for agricultural lands in South Australia' paper (Morgan et al. 2005).

The proposed timing for reporting the data collection is somewhat subjective and in most cases will need to be negotiated further with appropriate stakeholders. The reporting timing documented is a current best fit of reporting needs and data collection processes.

Clearly the field of monitoring and data collection is diverse and ever evolving, and consideration must be given to this fact. This is in part why details of the actual methods utilised to capture data have not been discussed in detail.

Table 38 provides a summary of the proposed 'ideal' monitoring programs for each land condition theme. Some monitoring programs are able to provide information for several themes. The Land Manager Surveys are very useful for a number of indicators, however the surveys are not a direct measure of the natural resources and are considered a surrogate measure of the condition of land. The Land Manager Surveys are best utilised in conjunction with monitoring programs that directly assess land condition.

In conclusion, it is expected that this proposed 'ideal' monitoring model for land condition would be analysed further in conjunction with the other natural resource monitoring programs that will be discussed during the development of the State MER-OP. The LCMP methodologies may need to be adjusted to add other data collecting processes (e.g. the pastoral areas land monitoring program may be adjusted slightly to include more biodiversity measures). Significant further discussion and endorsement of this 'ideal' model should occur during development of the MER-OP.

Table 38. Land condition themes and proposed 'ideal' monitoring programs

Monitoring programs	Land condition theme							
	Soil acidity	*Soil wind erosion*	*Soil water erosion*	*Soil carbon content*	*Dryland salinity*	*Soil physical condition*	*Soil fertility and nutrition*	*Soil water repellence*
Land and Soil Information Framework	✓							
Repeat pH and soil nutrient sampling sites	✓						✓	
Commercial laboratory soil analysis data	✓						✓	
Lime sales	✓							
Inland acid sulfate soils mapping	✓							
Inland acid sulfate environments water quality monitoring	✓							
Field Survey Program for Wind and Water Erosion		✓	✓					
Land Manager Survey		✓	✓	✓	✓	✓		✓
Grazing Gradient		✓	✓					
DustWatch		✓						
AussieGrass		✓	✓					
Land cover		✓	✓					
Vegetation cover monitoring in the Perpetual Lease Rangelands		✓	✓					
Gully, mass and riparian zone erosion surveys in water erosion risk regions			✓					
Gully, mass and riparian zone erosion monitoring			✓					
Stream turbidity monitoring			✓					
Assessment of erosion hazard			✓					
ABS data for crop production (also used in WUE calculation)				✓				
Soil carbon analysis and modelling (RothC)				✓				
CRCGA calculator modelling				✓				

Monitoring programs	Land condition theme							
	Soil acidity	*Soil wind erosion*	*Soil water erosion*	*Soil carbon content*	*Dryland salinity*	*Soil physical condition*	*Soil fertility and nutrition*	*Soil water repellence*
Depth to groundwater monitoring					✓			
Groundwater salinity monitoring					✓			
Ground-based EM surveys					✓			
Salinity Extent and Severity Surveys					✓			
Water use efficiency (WUE)						✓	✓	✓
Vegetation cover						✓		
SASPAS data (LCMP)							✓	
ABS fertiliser application data (LCMP)							✓	
Clay spreading contractors								✓

5. CAPABILITY ANALYSIS

The capability analysis contained in Table 39 summarises the monitoring data needs at national, state and regional level; describes existing monitoring programs; and compares those to the 'ideal' monitoring programs in order to identify gaps, overlaps or program deficiencies.

In most cases there are data gaps, not overlaps. Many programs have small to significant deficiencies, the details of which are contained in previous sections of this report.

There are obvious limitations to implementing the 'ideal' monitoring programs, predominantly the cost of resources including staff, equipment and external services. This report has taken into consideration the relative cost of various monitoring techniques and has tried to identify programs that meet as many national, state and regional needs as possible without being excessively expensive. It was felt by technical staff that a practical, realistic and affordable approach was far more useful to develop than an 'ideal' that will never be achievable.

The indicators identified in Table 39 are derived from targets or indicators documented through the findings of this report (details in Chapter 2). Not all indicators identified by the regional NRM Boards have been acknowledged in this capability analysis (the full list of indicators is presented in App. H). In many cases there are too many possible indicators identified, and these need to be rationalised in light of state and national monitoring protocols and directions. A review of RCTs may be necessary for several regions, rather than trying to create monitoring data to fit an inappropriate and amendable RCT.

Some process of prioritisation may be required to justify the development of the proposed 'ideal' monitoring programs. Table 40 is a collation of monitoring programs meeting national, state and regional targets or indicators extracted from the capability analysis in Table 39. All of these high priority programs meet more than one LCM need. Many of these monitoring programs, particularly the vegetation survey programs, will also be able to provide valuable data for biodiversity monitoring.

This capability analysis has highlighted that there are several areas of monitoring requiring development (new programs or improvements to be made) and no overlaps at this stage. Several monitoring programs have multiple information uses. There are potentially many more uses for this land condition information when combined in the State MER-OP with water, biodiversity, coast and marine monitoring. An analysis of the overlap between monitoring programs and information needs for the various natural resource themes should be conducted during the development of the MER-OP to identify efficiencies and priority programs.

Table 39. LCMP capability analyses

Land condition theme	Indicator	Indicator use and/or reporting need			Existing monitoring programs	'Ideal' monitoring programs	Comments
		National	*State*	*Region*			
Soil acidity	Area of land at risk of acidity		✓	✓	• Land and Soil Information Framework (formerly SaLI)	• Land and Soil Information Framework	Comment: This resource is not a monitoring program but provides a once only assessment of land at risk. It will continue to improve with additional data and system improvements. See Table 18.
	Area affected by acidity	✓	✓	✓	• SASPAS soil testing data.	• Commercial laboratory soil analysis data. • Repeat pH sampling sites.	GAP: SASPAS data are unlikely to meet data needs for much longer. As discussed in Section 3.1.3, commercial lab soil testing data are the best alternative. Commercial lab data are also required for other soil parameters. Repeat pH sampling is a great opportunity for obtaining leading edge trend data.
	Lime use (lime required to balance acidity)		✓	✓	• Survey of commercial lime suppliers.	• Survey of commercial lime suppliers.	Comment: Very useful data but would be better if accuracy could be improved.
	Land management practices		✓	✓	• Land Manager Surveys (LCMP). • ABS Agriculture Census data on lime application.	• Land Manager Surveys (LCMP). • ABS Agriculture Census data on lime application.	Comment: Several potential collaborative relationships possible for Land Manager Surveys. Improvements for existing programs documented in Tables 15 and 17.
	Distribution of inland ASS sites and risk of land degradation	✓			• Project mapping ASS sites and level of risk of land degradation.	• Project mapping ASS sites and level of risk of land degradation. • ASS monitoring sites (groundwater and/or surface water redox potential monitoring).	GAP: Regions known to have ASS sites include KI, EP, SE, MDB and MLR. Extent of monitoring will depend on risk identified in mapping project.
Soil wind erosion	Erosion risk indices	✓	✓	✓	• 'Windscreen' field surveys (LCMP).	• 'Windscreen' Field Surveys (LCMP).	

Land condition theme	Indicator	Indicator use and/or reporting need			Existing monitoring programs	'Ideal' monitoring programs	Comments
		National	*State*	*Region*			
	Erosion potential (distribution of land susceptible to erosion due to soil type, soil cover, rainfall erosivity and digital elevation data)	✓	✓	✓	• Land Manager Surveys (LCMP). • Land and Soil Information Framework (formerly SaLI). • Grazing Gradient (incorporating data from the Pastoral Areas Lands Monitoring System).	• Land Manager Surveys (LCMP). • Land and Soil Information Framework. • Grazing Gradient (incorporating data from the Pastoral Areas Lands Monitoring System). • AussieGrass (see Table 24). • Access to land cover data where suited (see Table 24). • Vegetation cover monitoring in the Perpetual Lease Rangelands (see Table 12 and 24).	GAP: Monitoring in the arid areas of the state is not particularly thorough or consistent, and requires a combination of remote sensing and ground-based monitoring programs to identify real trends.
	Frequency of dust storms	✓		✓		• DustWatch (see Table 24).	GAP: DustWatch is a nationally recognised and supported program, and could contribute significantly to SA's understanding of wind erosion issues in the arid regions of the state.
Soil Water Erosion	Erosion risk indices	✓	✓	✓	• 'Windscreen' field surveys (LCMP).	• 'Windscreen' field surveys (LCMP).	
	Erosion potential (distribution of land susceptible to erosion due to soil type, soil cover, rainfall erosivity and digital elevation data)	✓	✓	✓	• Land and Soil Information Framework (formerly SaLI). • Grazing Gradient (incorporating data from the Pastoral Areas Lands Monitoring System).	• Land and Soil Information Framework. • Grazing Gradient (incorporating data from the Pastoral Areas Lands Monitoring System). • Use of land cover datasets where useful. • Vegetation cover monitoring in the Perpetual Lease Rangelands (see Table 12 and 24).	GAP: Additional coverage sought for arid regions still susceptible to water erosion. Comment: Assessment of erosion hazard is a combination of many data sources to conduct a thorough assessment.

Land condition theme	Indicator	Indicator use and/or reporting need			Existing monitoring programs	'Ideal' monitoring programs	Comments
		National	*State*	*Region*			
						• AussieGrass (see Table 24). • Assessment of erosion hazard (see Table 26).	
	Area and length of erosion (river, sand, dune, lake edge) Locations of unstable sites			✓		• Gully, mass and riparian zone erosion surveys in water erosion risk regions. • Gully, mass and riparian zone erosion monitoring.	
	Stream turbidity	✓		✓		• Stream turbidity monitoring (possibly utilising existing Waterwatch networks).	GAP: Turbidity monitoring could provide very useful water erosion trend data for many regions.
	Location of remedial works	✓		✓			GAP: This information is recommended as useful by NLWRA and requested by regions. The regions may need to develop their use of NRM Tracker or similar reporting options to record the location of remedial works projects.
	Land management practices	✓		✓	• Land Manager Surveys (LCMP)	• Land Manager Surveys (LCMP).	Comment: Possible improvements to this program documented in Tables 15 and 17.
Soil carbon content	Changes in carbon stocks	✓				• Soil carbon analysis and modelling (RothC). • CRCGA calculator modelling. • Land Manager Surveys (LCMP). • ABS data for crop production.	Comment: The CRCGA modelling program will utilise data from ABS and the Land Manager Surveys to calibrate inputs and outputs for carbon trend calculations.
	Soil organic carbon content			✓			GAP: As per explanation in Section 4.4, soil carbon analysis to generate trends is unlikely to be of real benefit and is not recommended in this report.

Land condition theme	Indicator	Indicator use and/or reporting need			Existing monitoring programs	'Ideal' monitoring programs	Comments
		National	*State*	*Region*			
Dryland Salinity	Depth to groundwater or area of rising water tables	✓	✓	✓	• Depth to groundwater monitoring (various regions, locations, networks).	• Depth to groundwater monitoring (various regions, locations, networks) (see Table 19).	Comment: Some additional networks should be established, and a rationalisation of water level monitoring timing.
	Area affected by salinity (area of salinised land)	✓		✓	• Assessment of area affected conducted state-wide in 2000 (using aerial photography interpretation). • Regions and selected sub-catchments are being assessed using airborne geophysics or ground based electro-magnetic surveys.	• Assessment of area affected conducted state-wide in 2000 (using aerial photography interpretation). • Regions and selected sub-catchments are being assessed using airborne geophysics or ground based electro-magnetic surveys.	Comment: Current methodology meets the monitoring needs but needs to be conducted at appropriate intervals to meet stakeholder needs.
	Areas predicted to be affected by dryland salinity		✓		• State-wide assessment conducted in 2000, water level monitoring continues.	• State-wide assessment conducted in 2000, water level monitoring continues.	Comment: Additional water level monitoring networks required to capture at-risk areas.
	Salinity severity	✓		✓	• Mostly monitored by groundwater salinity (various regions, locations, networks). • Salinity severity surveys conducted in selected sub-catchments using EM surveys and the 'Salinity Category Classification' system.	• Mostly monitored by groundwater salinity (various regions, locations, networks). • Salinity severity surveys conducted in selected sub-catchments using EM surveys and the 'Salinity Category Classification' system.	GAP: Salinity severity not closely monitored at this point in time. Requires further survey work and investment.
	Land management practice change		✓	✓	• Land Manager Surveys (LCMP). • ABS data for crop production.	• Land Manager Surveys (LCMP). • ABS Data for Crop Production.	Comment: Possible improvements to Land Manager Survey program documented in Tables 15 and 17.
	Land manager perception change		✓	✓	• Land Manager Surveys (LCMP).	• Land Manager Surveys (LCMP).	Comment: Possible improvements to Land Manager Survey program documented in Tables 15 and 17.
	Productivity (or vegetation cover) in salt affected areas			✓	• Land Manager Surveys (LCMP).	• Land Manager Surveys (LCMP).	GAP: This indicator seems more a management practice surrogate and could be monitored by regions recording the location of works projects.

Land condition theme	Indicator	Indicator use and/or reporting need			Existing monitoring programs	'Ideal' monitoring programs	Comments
		National	*State*	*Region*			
	Soil salinity			✓	• Land and Soil Information Framework (formerly SaLI).		GAP: This is not an ongoing program but salinity measures were taken as part of identifying soil characteristics. This indicator can be replaced with EM surveys or groundwater salinity monitoring.
	Groundwater salinity		✓	✓	• Groundwater salinity monitoring (various regions, locations, networks).	• Groundwater salinity monitoring (various regions, locations, networks).	Comment: Some additional networks should be established.
	Location of remedial works	✓		✓			GAP: This information is recommended as useful by NLWRA and requested by regions. The regions may need to develop their use of NRM Tracker or similar reporting options to record the location of remedial works projects.
Soil physical condition	Water use efficiency		✓	✓	• Land Manager Surveys (LCMP). • LCMP WUE indicator (ABS crop production and rainfall data). • Vegetation cover.	• Land Manager Surveys (LCMP). • LCMP WUE indicator (ABS crop production and rainfall data). • Vegetation cover.	Comment: Not economically possible to monitor all soil physical parameters. WUE indicator accepted by former Soil Conservation Council and utilised by regions. Vegetation cover requires more investigation, not comprehensively discussed in this report.
Soil fertility and nutrition	Water use efficiency		✓	✓	• Land Manager Surveys (LCMP). • LCMP WUE indicator (ABS crop production and rainfall data). • Vegetation cover.	• Land Manager Surveys (LCMP). • LCMP WUE indicator (ABS crop production and rainfall data). • Vegetation cover.	Comment: Not economically possible to monitor all soil physical parameters. WUE indicator accepted by former Soil Conservation Council and utilised by regions. Vegetation cover requires more investigation, not comprehensively discussed in this report.

Land condition theme	Indicator	Indicator use and/or reporting need			Existing monitoring programs	'Ideal' monitoring programs	Comments
		National	*State*	*Region*			
	Proportion of farmers using soil and plant tissue testing (or technical advice)	✓	✓		• Land Manager Surveys (LCMP).	• Land Manager Surveys (LCMP).	Comment: Possible improvements to Land Manager Survey program documented in Tables 15 and 17.
	Phosphorus fertiliser application (fertiliser sales)		✓	✓	• ABS fertiliser application data (LCMP).	• ABS fertiliser application data (LCMP).	
	Phosphorus content in soil samples analysed (and other nutrients)	✓	✓	✓	• SASPAS soil testing data (LCMP) (see Table 16)	• Commercial soil testing data. • Repeat pH and soil nutrient sampling sites (see Table 34).	GAP: SASPAS data is unlikely to meet data needs for much longer. As discussed in Section 3.1.3, commercial lab soil testing data are the best alternative. GAP: Repeat soil sampling sites established could be monitored for a select range of soil nutrients.
Soil water repellence	Water use efficiency		✓	✓	• LCMP WUE indicator (ABS crop production and rainfall data).	• LCMP WUE indicator (ABS crop production and rainfall data).	
	Remedial works		✓	✓	• Land Manager Surveys (LCMP) (see Table 36).	• Land Manager Surveys (LCMP). • Clay spreading contractors (see Table 36).	GAP: Clay spreading data could be collected by regions. Can provide valuable information on land management works that can have a positive impact on many soil properties.

Table 40. High priority LCMPs meeting national, state and regional monitoring needs

Land condition theme	Monitoring program	New or improved program	No. of indicators program contributes to
Soil acidity and soil fertility and nutrition	Commercial laboratory soil analysis data	New	2
	Repeat pH and soil nutrient sampling sites	New (based on existing sites)	2
Soil wind and water erosion	'Windscreen' field surveys (LCMP)	Improved (as per Table 14)	2
	Land Manager Surveys (LCMP)	Improved (as per Table 15)	11
	Land and Soil Information Framework (formerly SaLI)	Improved (as per Table 18)	2
	Grazing Gradient (incorporating data from the Pastoral Areas Lands Monitoring System)	Improved (as per Table 20)	2
	AussieGrass (see Table 24)	New	2
	Access to land (or vegetation) cover data	New (requires development at state and national level)	4
	Vegetation cover monitoring in the Perpetual Lease Rangelands	New (existing methodology, last conducted 2004)	2
Dryland salinity	Depth to groundwater monitoring (various regions, locations, networks)	Improved (as per Table 19)	2

6. ADDITIONAL CONSIDERATIONS

There are several issues that may impact or alter the content and discussion provided in this report in a potentially short space of time. There are also considerations that should be acknowledged to clearly understand the intent and direction of this report.

Limitations

Land degradation issues associated with, and restricted to, irrigation industries have not been addressed in detail in this report. Irrigation induced salinity, for example, may be monitored in the same way that dryland salinity might be, but has not specifically been noted and developed throughout this report. The Soil Conservation Council's Directions Paper (Morgan et al. 2005) includes two irrigation management targets (see Table 7), one regarding sustainable management of irrigation drainage and the second regarding land lost to irrigation induced salinity. Irrigation drainage issues and specifically irrigation induced salinity issues should be monitored and addressed appropriately in land and water management plans associated with the relevant Water Allocation Plan.

Chemical contamination of land and food supplies is not regarded as a land condition issue for the purposes of this report and no comment is made for the monitoring of these issues.

The Soil Conservation Council's Directions Paper (Morgan et al. 2005) also includes a target for the re-establishment of habitat and revegetation. Revegetation and establishment of perennial vegetation has been noted on occasion in this report, specifically the use of vegetation establishment trend data as a useful surrogate indicator for improved land condition for a number of land degradation issues. Further investigation of vegetation establishment data is envisaged to occur in a biodiversity monitoring review.

Contextual data

Contextual data needs have to some extent been captured by the regional Monitoring and Evaluation Officers (in Appendix H) and in some of the existing monitoring programs detailed in Chapter 3. The Land and Soil Information Framework and the Land Use Mapping Program are examples of contextual data sources. These particular data sources provide crucial contextual information to enable logical interpretation of monitoring data. The Land Use Mapping Program also has the potential to provide land-use change trends if the survey is repeated. This report does not include an assessment of contextual data collection programs but the importance of quality contextual data should not be overlooked. The Beaten Track Group produced a report for the NLWRA (Beaten Track Group Pty Ltd 2004) that detailed contextual data requirements for the National indicators as they were at the time. A copy of the land condition related indicators and data needs is included in Appendix G and may provide some indication of contextual data South Australia will require to compliment its LCMPs.

State NRM Plan

Implementation of the recently introduced State NRM Plan brings with it many questions about the roles and responsibilities of the agencies, regional boards, and groups. Over time,

the intentions of the plan will be unravelled and changes made to the current expectations and former arrangements (or lack thereof). Some discussion and interpretation of the roles and responsibilities under the plan and NRM Act have been provided in this report and will require further discussion and endorsement during development of the MER-OP.

State Monitoring, Evaluation and Reporting Operational Plan

The State Monitoring and Evaluation Framework (which resides within the State NRM Plan) requires that an operational plan be developed between the relevant bodies to provide direction on implementing the framework at state and regional levels. DWLBC has commenced undertaking this task and has formed the Monitoring, Evaluation and Reporting Policy Group (MER PG) as a tool to link appropriate agencies and groups at a policy level to coordinate and contribute to the MER-OP. The objectives and scope of the MER-OP include:

- Gaining agreement between NRM agencies on the natural resources to be monitored and resource condition indicators to be measured and reported.
- Developing a clear understanding of roles and responsibilities of NRM agencies.
- Identifying gaps and overlaps in the natural resources to be monitored.
- Developing an agreement on the distribution of physical monitoring infrastructure.
- Establishing baseline measures of the agreed resource condition indicators.

In undertaking the MER-OP, many discussions and decisions will need to take place to develop an agreed approach on all levels concerned. These decisions may result in changes to existing monitoring programs and the focus of future monitoring programs discussed in this report. This report, however, will contribute to the discussions held by the MER PG and provide important information to assist the development of the MER-OP.

Regional NRM Plan Development

All regional NRM Boards across the state are required under the state NRM Act to develop a regional NRM Plan. There are several components of the regional plan (discussed further in Section 2.2.1) and includes monitoring the state, condition and related trends of natural resources, and evaluating the effectiveness of the board's programs. As part of establishing the monitoring component of the regional plan, a clear method of setting targets to monitor is a key component of the work ahead. A target setting project conducted by the Joint Commonwealth and State Steering Committee for NAP and NHT (JSC) is discussed below.

The development of the State MER-OP will provide further direction the boards need, but the time frame for the intended completion may not be ideal.

Joint Steering Committee 'Evaluation of Regional Target Setting in South Australia' project

The JSC commissioned the 'Evaluation of Regional Target Setting in South Australia' project. It was recognised by the JSC that there were many complications for regions developing their RCTs and MATs, which has resulted in immeasurable and inconsistent target setting. The Regional Target Setting project aims to:

- review and evaluate current processes used to set regional RCTs and MATs and their use in determining management actions and activities
- identify impediments to setting effective and appropriate targets across regions

- provide guidance on how to best determine causal relationships between investments, outputs, MATs and RCTs as integral to an effective approach to target setting
- provide advice on what improvements could be made to current target setting approaches including best-practice examples.

This project is due to be completed by the end of September 2006. The impacts of the project may, or are likely to, include:

- regions completely overhauling their RCTs, which will impact on current data requirements (including those documented in this report)
- regions may need to prioritise certain NRM issues to focus investments and outcomes, which may result in changes to data needs and monitoring program collaboration
- a new target setting approach may facilitate the alignment of regional, state and Australian Government monitoring requirements.

The JSC quite clearly recognises the difficulty encountered by the regions with target setting, and this project will hopefully provide some clearer direction to their development. But each NRM Board is somewhat independent, and their plans will be influenced by local priorities.

Development of national resource condition indicators and monitoring protocols

The Natural Resource Management Ministerial Council continues to develop the national set of indicators and monitoring guidelines through the consultation of expert panel working groups. The indicators for 'land salinity' have all been agreed to, but the remaining 'soil condition' indicators are still currently 'for advice' only. A National Committee on Soil and Terrain is responsible for developing the monitoring protocols. The committee formed four expert panels to identify and recommend monitoring methods for soil erosion by water, soil erosion by wind, soil acidification, and soil organic carbon. A draft report titled 'Monitoring Soil Condition Across Australia: Recommendations from the Expert Panels' (McKenzie & Dixon 2006) was released in July 2006. The report proposes several indicators with corresponding monitoring protocols but also suggests that some of these methods need to be tested in the field or require further research, developing, checking, or documenting before they can be implemented. A number of NRM regions have been nominated for trials of many of the methods proposed. The trials hope to test and document the technical feasibility, practicality, outputs, utility of information produced, data management issues, and adequacy of resources to conduct the monitoring. The report recognises the current needs for many regions to have guidance on monitoring protocols, and recommends that the protocols in the report be published and the expert panels be available to guide and provide technical advice to the regions through this process.

The expert panel report has provided a number of monitoring protocols as options. This report details a proposed model for monitoring land condition in South Australia that best fits our existing programs and past and present needs. Additional programs recommended by the expert panels could be implemented but as with all new programs will be subject to funding and resourcing issues.

The regions and states will need to be kept informed by the expert panel's work and trial results. Some changes may occur over time to the expert panel's monitoring protocol recommendations. South Australia will be required to consult with NLWRA and expert panels

to develop the MER-OP, which would be far easier if the national core indicators were complete.

Monitoring research and developments

There is significant research being conducted utilising satellite imagery to monitor various aspects of land surfaces across South Australia. Much of the research is focused on the arid regions of the state and is envisaged to be a useful tool to accurately monitor trends, especially when used in conjunction with appropriate ground-based monitoring programs. It is expected that continual investment into research of spatial imagery technologies will be required to develop solid, scientifically robust monitoring trend data and information. Any changes in methodology used over time should compliment ground-based programs and not be considered appropriate as a stand-alone monitoring tool.

Technical assistance for regions

Whilst compiling this report, it has become apparent that access to technical expertise and information has become paramount to the successful implementation of the State NRM Plan. The responsibility for preparing technical information and reporting has shifted to the regions under the new NRM Plan and the boards need support from state agencies and others for this transition to occur successfully. The state agencies have acknowledged this issue and DWLBC is undertaking a project to facilitate strategic investment into technical and scientific expertise to support the implementation of the NRM Plan. In addition agencies are becoming more heavily involved in NRM Board planning processes.

7. MONITORING STRATEGY RECOMMENDATIONS

This review aims to provide direction for LCM in South Australia and aid development of the State Monitoring, Evaluation and Reporting Operational Plan as required by the State NRM Plan. This report has reviewed the existing monitoring programs conducted at regional, state and national level (not local level); stakeholder roles, responsibilities, business and information needs; and has consulted broadly to develop an 'ideal' monitoring model.

The 'ideal' monitoring model is the result of discussions with technical experts and stakeholders throughout development of this report. The monitoring model is intended as a guide and should not limit the potential of new monitoring programs nor dictate the maintenance of existing programs. The model is the current best fit of data needs and programs that can meet those needs in the most practical, efficient and effective manner. The model is comprised of a range of new and existing programs. Most of the existing programs could be improved in some way as discussed in Chapter 3. The key recommendations identified for improving the existing programs are collated in Table 41. It must be noted that the existing monitoring programs provide an excellent basis for the development of a comprehensive state-wide monitoring program.

Many new programs are proposed in the 'ideal' monitoring model in Chapter 4, including:

- repeat pH and soil nutrient sampling sites
- commercial laboratory soil analysis results
- inland acid sulfate soils mapping (already underway and funded externally)
- inland acid sulfate environments water quality monitoring
- DustWatch
- land cover and/or vegetation cover
- gully, mass and riparian zone erosion surveys in water erosion risk zones
- gully, mass and riparian zone erosion monitoring
- soil carbon analysis and modeling (RothC)
- CRCGA calculator modeling
- clay spreading contractors.

AussieGrass and vegetation monitoring in the Perpetual Lease Rangelands projects are existing programs that have not been funded or resourced since 2004, so may need to be considered as new programs.

The new programs proposed are designed to fill the coverage gaps of existing programs and provide information on important issues that have not been prioritised in the past.

This report has not intended to make judgement of the science or technical components of the monitoring programs presented. Technical expertise was consulted to establish agreement with the broad types of monitoring programs recommended. Further work will be required to develop data collection, storage and interpretation protocols for new programs.

Table 41. Existing monitoring program recommendations

Recommendations
Land Condition Monitoring Program
Recommendation 1: If the LCMP undertakes to produce regional land condition reports within new NRM boundaries, part of the process of producing the report should be to enable local and regional data and knowledge to be incorporated into the report to support regional interpretation.
Recommendation 2: DWLBC, in conjunction with the regional NRM Boards, considers development of a communication strategy for the LCMP reports and information, which includes consideration of the most suitable format for a variety of audiences.
Recommendation 3: DWLBC and the regional NRM Boards incorporate the LCMP into a long-term strategic monitoring plan for South Australia, such as the MER-OP.
Recommendation 4: DWLBC implement succession planning and mentoring activities to ensure experienced and trained staff continue to manage the LCMP.
Recommendation 5: DWLBC provides expert help to work with the LCMP Manager to update software and processes used to manage the LCM data.
Field Survey Program for Wind and Water Erosion
Recommendation 6: DWLBC considers integrating remote sensing monitoring to expand current coverage of the LCMP and to provide a further level of confidence in the erosion indexes.
Land Manager Surveys
Recommendation 7: State agencies and regional NRM Boards investigate the potential for additional Land Manager Surveys to expand the current understanding of land management trends.
Recommendation 8: DWLBC investigates potential stakeholder interest in additional Land Manager Surveys for possible resource assistance.
SASPAS data
Recommendation 9: DWLBC investigates opportunities for creating an access agreement to soil analysis data from commercial fertiliser retailers.
Recommendation 10: DWLBC (and regional NRM Boards) investigates other potential users of soil analysis data and what kind of contribution they may make to the agreement.
Land and Soil Information Framework
Recommendation 11: DWLBC considers the value of conducting additional soil surveys to enhance the SaLI database and mapping products.
Recommendation 12: DWLBC (and potential collaborative organisations) considers conducting repeat surveys for a select number of sites and parameters to trial the possibilities of repeat site sampling for monitoring.
Recommendation 13: DWLBC edits and adds to the database all the paper-based point soil survey data to ensure maximum information availability and that knowledge is not lost.
Dryland Salinity Program
Recommendation 14: DWLBC (and potential collaborative organisations) review the current groundwater monitoring programs and considers whether areas currently at moderate risk of salinisation should be included in a monitoring program.
Pastoral Areas Land Monitoring System
Recommendation 15: The Pastoral Program, in cooperation with ACRIS and other rangeland monitoring bodies, continues to collaborate on data collecting methods to meet pastoral assessment and future monitoring requirements for land condition and biodiversity.
Recommendation 16: DWLBC hastens the development of ALIS to ensure the effective operation of the pastoral assessment and monitoring programs.
Recommendation 17: The Pastoral Program or DWLBC investigates means to fund and attract new staff to the program as a matter of priority to assist with the current backlog of data processing.
Recommendation 18: Further investigation of the options for remote sensing monitoring in the rangelands in combination with the ground-based assessment and potential collaborative relationships with landholders.

Additional work will be required to establish collaborative monitoring arrangements and agreements. Consideration must be give to the timing of the findings in this report due to the current broadly unknown realms of monitoring and evaluation across Australia. Business needs and responsibilities are likely to change between all stakeholders involved. However, the essence of the information required to adequately monitor land condition would remain the same.

APPENDICES

A. LAND THEME INDICATORS REPORTED IN THE 2001 NATIONAL STATE OF ENVIRONMENT REPORT

Actual reported land theme indicators in 2001 National SoE Report
Change in total exposed soil surface contributing to erosion, as a percentage of land area per landcover region, stratified by major land use
Total grazing pressure relative to net primary productivity (biomass) by landcover regions and AERs
Domestic vertebrate grazing pressure per landcover region and AER
Non-domestic vertebrate herbivores per landcover region and AER
Surface soil loss index
Gullying index per major catchment
Change in dust storm index relative to number of high wind events by AERs and landcover regions
Implementation of new drought policies
Percent of land managers using agreed best practice by land use and/or catchment
Area of forested lands in which the legal framework encourages best practice codes of forest management, and the conservation of special environmental values
Index of human accessibility related to landcover regions
Change in land use by catchments, AERs and landcover regions
Landcover change: proportion of each region covered by forest, wood, shrubs and grasses compared with 1990 baseline, by landcover and tenure
Fire control measure compared with natural fires, related to landcover regions
Number of reports of all, and of new, weeds, pests and diseases per AER and IBRA region
Number of passenger and cargo entries per port or entry location by IBRA region
Impact of agriculture on conservation land by AER and state or territory
Effectiveness of reduction in damage caused by weeds, pests and diseases that are harmful at ecosystem scale by IBRA regions
Ratio of area of catchment under perennial annual vegetation, as proportion of total catchment (report also by state)
Percent area of land affected by dryland salinity, and acidity, by catchment and AER
Variation in plant water utilisation with landcover change
Index of measures to increase perennial vegetation cover, by area of catchment and AER affected
Total nutrient export nitrogen, phosphorus and potassium from each AER and drainage basin
Rates and distribution of nitrogen, phosphorus and potassium accessions into each AER and drainage basin
Sources of phosphorus derived from land activities reaching rivers by catchment
Terrestrial carbon (organic matter) loss rate by IBRA region
Rate of land carbon (organic matter) sequestration by AER and IBRA region
Proportion of each forestry and farming system with stable nutrient balance by major catchment, AER
Estimated success of programs to reduce land carbon loss and increase sequestration by landcover regions
Proportion of farmers using soil and plant tissue testing regularly by industry and AER
Total immobile contaminant load on land area by catchment
Condition of environments surrounding high-radiation sites
Quality of mining operations relative to total mine sites, and regulation requirements by drainage basin
Estimated area of pesticide application by catchment
Rate of violations in residue levels (metals and organics) in harvested rural produce and foodstuffs
Implementation of integrated pest management (IPM) and agrichemical risk reduction by rural industry

Hamblin A 1998, *Environmental indicators for national state of the environment reporting: The land,* Australia: State of the environment (Environmental indicators reports), Department of the Environment, Canberra.

B. NATIONAL MONITORING & EVALUATION FRAMEWORK 'MATTERS FOR TARGET', INDICATORS AND STATUS

Matter for target	Indicator heading	Recommended indicators	Status
Biophysical			
1. Land salinity	Area of land threatened by shallow or rising water tables	Depth to groundwater.	Agreed
		Groundwater salinity.	Agreed
		Location and size of salt affected areas.	Agreed
2. Soil condition	Soil condition	Soil acidification.	For advice
		Soil erosion — water.	For advice
		Soil erosion — wind.	For advice
		Soil carbon content.	For advice
3. Native vegetation communities' integrity	Native vegetation extent and distribution	The extent of each priority native vegetation type by IBRA subregion measured in hectares.	For advice
		The extent of each present native vegetation type by IBRA subregion measured in hectares.	
		The proportion remaining of each native vegetation type by IBRA subregion measured as a percentage of the pre-European extent.	
	Native vegetation condition	The proportion of each native vegetation type in each IBRA subregion that is estimated to be in specified condition classes based on a selected set of attributes.	For advice
4. Inland aquatic ecosystems integrity (rivers and other wetlands)	River condition	Benthic macro-invertebrate community assemblages.	All for advice
		Fish community assemblages.	
		Benthic diatom community assemblages.	
		Riparian vegetation community assemblages.	
		Riverine physical structure and in-stream habitat.	
		Water quality.	
		Hydrology.	
	Wetland ecosystem extent and distribution	Extent of regionally significant wetlands.	Unclear
	Wetland ecosystem condition	Colour.	All for advice
		Dissolved oxygen and temperature.	
		Extent of inundation.	
		Macro-invertebrate diversity and community composition.	
		Macro-invertebrate index.	
		Macro-invertebrate indicator species.	
		Nutrients (phosphorus and nitrogen).	
		Transparency.	
		Vegetation.	
		Phytoplankton.	

Matter for target	Indicator heading	Recommended indicators	Status
5. Estuarine, coastal and marine habitat integrity	Estuarine, coastal and marine habitat extent and distribution	Previously - Area of each estuarine, coastal and marine habitat type measured in hectares. Currently: Thirty one (31) possible indicators developed by CRC — under revision by ICAG.	All for advice
	Estuarine, coastal and marine habitat condition	Condition of habitat at significant sites of selected estuarine, coastal and marine habitats.	Unclear
6. Nutrients in aquatic environments	Nitrogen in aquatic environments	Total Nitrogen + flow leaving sub-catchment or whole catchment.	Agreed
	Phosphorus in aquatic environments	Total Phosphorus + flow leaving sub-catchment or whole catchment.	Agreed
7. Turbidity or suspended particulate matter in aquatic environments	Turbidity or suspended solids	Turbidity OR Total Suspended Solids (TSS) + Flow.	Agreed
8. Surface water salinity in freshwater aquatic environments	In-stream salinity	Total dissolved solids (TDS) + Flow OR Electrical conductivity (EC) + Flow.	Agreed
9. Significant native species and ecological communities	Selected significant native species and ecological communities extent and conservation status	An interim approach to monitoring significant native species and ecological communities.	For advice
10. Ecologically significant invasive species	Selected ecologically significant vertebrate invasive species extent and impact	Reduction in impact of regionally significant invasive vertebrate pests (excluding fish).	For advice
	Selected ecologically significant invasive vegetation species extent and impact	The area and density of weeds under active management.	For advice
		New incursions of significant weeds.	For advice
Social and Economic Indicators (not a 'Matter for Target')			
Land manager's capacity to change & adopt sustainable management practices	Aspirations	Under development by SENCC.	Interim
	Capacity of rural decision makers		
	Attributes of management practices		
	Rural livelihood context		
	Outcomes of improved NRM		
Regional group's capacity to make decisions on NRM	Management capacity	Under development by SENCC.	
	Management outcomes		
	Program capacity		
	Environmental controls		
Community	Under development	Under development by SENCC.	Interim
Contextual Information (not a 'Matter for Target')			
Land Use	Land Use	Change in land use.	Not MfT

(Natural Resource Management Ministerial Council 2006)

C. STATE OF ENVIRONMENT LAND RESOURCES REPORTING (SA STATE LEVEL)

Theme	Indicators	Pressure, condition or response	Description	Data/Info reported in SoE 2003	Source
Dryland salinity	Area of land affected by dryland salinity	Condition	Reports on the area currently affected by dryland salinity.	Regional estimates of current areas affected by dryland salinity for 2000	Barnett 2000 (DWLBC)
	Area threatened by dryland salinity	Pressure	Identifies the area at risk from dryland salinity.	Regional estimates of current and predicted areas affected by dryland salinity for 2000, 2020 and 2050	Barnett 2000 (DWLBC)
				Map of estimated area affected by dryland salinity in SA — 2000	DWLBC
				Estimate of areas at risk from rising groundwater for SA regions for 2000, 2020 and 2050	NLWRA 2001
				Summary of threats to biodiversity in agricultural regions of SA	Barnett 2000 (DWLBC)
				Significant habitat affected by dryland salinity	Barnett 2000 (DWLBC)
				Interim costs of dryland salinity	Barnett 2000, 2002 (DWLBC)
Land use	Current land use in SA	Condition	This provides an indication of current land uses and a baseline against which to assess change over time.	Land-use mapping (including 1993 and 1999 for MLR)	DWLBC
				% population living in city (Adelaide)	ABS 2003
	Land-use change	Pressure	Land- use change is a direct measure of potential pressure on the environment.	Vineyard area, SA pre 2000 and 2002	Phylloxera and Grape Industry Board of SA 2002
	Site contamination	Pressure	Site contamination provides an indication of potential pressure on water, soil, biodiversity and human health.	Discussed broadly: EPA's groundwater monitoring, EPA's follow-up monitoring of locust spraying, PIRSA's Property Residue Management	Environment Protection Authority (SA) 2001
				Food analysis survey, National Residue Survey during 2000–01	Australian Academy of Technological Sciences and Engineering 2002

Theme	Indicators	Pressure, condition or response	Description	Data/Info reported in SoE 2003	Source
Soil erosion and acidity	Area of agricultural land at risk of wind and water erosion	Pressure	This indicates the areas at risk from erosion. Increased rates of erosion can have a negative effect on water quality in streams and rivers. These areas require special management measures to avoid unacceptable soil loss.	Cites figures of areas at risk or susceptible to erosion; maps of distribution of land susceptible to wind or water erosion, estimated cost of lost nutrients	DWLBC LCMP
	The area of land at risk from soil acidity	Pressure	This indicates the areas at risk from significant soil acidification.	Cites figures of area at risk from soil acidity; map of distribution of arable land susceptible to induced soil acidification, rates of lime use	DWLBC soil survey data, LCMP
	Land and crop management practices	Response	The adoption of conservation-based land management practices is an indirect measure of the sustainability of farming systems.	Graph of estimates of lime required to balance annual acidification rates, use of direct drilling techniques	DWLBC LCMP

(Government of South Australia 2005a)

Note: 2003 Supplementary report includes additional data and information.

D. LIST OF CURRENT REGIONAL RCTs RELATING TO LAND CONDITION

Region	Resource condition targets
SA Murray Darling Basin	By 2020, a 30% reduction in priority areas of floodplain currently affected by salinity from groundwater discharge.
	Maintain and improve the stability of river banks, lake edges, sand dunes and cliffs by 2020.
	By 2020 to have constrained the area of salt affected land within the region to 120 000 ha.
	By 2020, reduce the area of agricultural land at risk of wind erosion during June each year by 40%.
	Reduce recharge by improving dryland water use efficiency to 70% across the region by 2020.
	To have an increasing trend in soil carbon levels in cropping soils leading to improved soil health by 2020 [likely to be reviewed].
	By 2020 groundwater resources will not have salinity impacts on land condition and will meet the needs of dependent ecosystems.
Eyre Peninsula (RCTs under review)	20% reduction in loss of soil from erosion prone (804 000 ha) or affected sites by 2009.
	Soil health in areas affected or prone to salinity, acidity or sodicity maintained or restored to optimal level to maximise production and minimise impact on biodiversity and water quality, with clear targets defined by 2005.
South-East	Area of saline land to be reduced [change in class] by 30% within the drained area of the Upper South-East by 2110.
	Predicted rate of increase in salinity across all other salinity affected areas in the Upper South-East reduced by 50% by 2020.
	No net increase in soil fertility decline in soil fertility in the South-East by 2015 and beyond.
	Reduce recharge from areas of repellent sands by 50% over 200 000 ha by 2024.
	Maintain or improve the extent of waterlogging affecting agricultural productivity in the SE by 2020 and beyond.
	To have 80% of agricultural soils with pH ($CaCl_2$) > or equal to 5.0 by 2015.
	To have the period of wind erosion risk on agricultural lands not exceeding 25 days by 2015.
	Irrigation induced alkalinity reduced by 50% by 2020.
	The impact of existing soil borne diseases is managed by 2020.
	No new soil borne diseases are introduced into the region by 202 and beyond.
	No increase of soils contaminants in agricultural land by 2020 and beyond.
Adelaide and Mount Lofty Ranges (RCTs under review)	Reverse the trend in rising water tables in at least three priority sub-catchments by 2022.
	Increase the productivity of existing salt-affected land by 30% (not in 2nd IS).
	No net increase in areas affected by acidification by 2022.
	A progressive reduction in area of land affected by soil erosion by water by 2017.
	Rehabilitation of soils erosion sites of high biodiversity potential by 2025.
	No further decline in sand resources and associated marine and dune ecosystems by 2010 (not in 05/08 IS).

Region	Resource condition targets
	Natural resources associated with primary production land sustained in accordance with land capability and in a manner that does not impact negatively on natural resources, targeting particular industries or priority areas by 2010 with clear targets established by 2007.
Kangaroo Island	A reduction in the area (ha in 2002) of bare scalded salt land by the year 2010.
	Ongoing improvement in soil pH across agricultural sites.
	50% of acid soils managed to an optimum pH range suitable for agricultural production by 2020.
	50% of soils managed to maintain optimal soil nutrient levels suitable for agricultural production by 2020.
	50% of water-logged soil returned to a condition that allows for agricultural production and/or biodiversity outcomes by 2020.
Alinytjara Wilurara	80% reduction in the area of eroding soils by 2015.
	Overall land condition across the region will be maintained or improved by 2015.
	All culturally important sites showing stable or improving trends in condition by 2015.
SA Aridlands	Land condition across the region will be maintained or improved by 2020.
Northern and Yorke	Halt the rise in saline groundwater levels in local and intermediate groundwater systems and the increase in salinity levels in surface water bodies by 2020.
	Achieve improved economic productivity in 50% of primary production lands affected by salinity by 2010.
	Demonstrate progressive improvement in condition of significant biodiversity areas affected by salinity by 2030.
	Soils supporting primary production reflecting their optimal capacity by 2015.
	Soils managed to support diverse soil biodiversity and natural ecosystems by 2015.
	Reduce incidence of sheet, rill and gully erosion events by 30% by 2015.

E. REGIONAL NRM GROUP DATA NEEDS TO REPORT TO RCTS

Well covered — enough to assess RCT	Some info but not really enough	Not enough information to assess RCT (or does not yet exist)

Data Need: RCT Critical	NRM Board Regions requiring data							
	SAMDB	*KI*	*AW*	*AL*	*EP*	*NYAD*	*AMLR*	*SE*
Soil Acidity								
Soil pH (fixed point surveys?)								
Lime sales								
Irrigation applications to area of land								
Irrigation water pH								
Sulfidic material pH<4; sulfidic material redox potential (0–1.5 m) 300 mv								
Soil Wind and Water Erosion								
Length and area of erosion (river, sand, dune and lake edge)	(lake-shore erosion)					(Dunes)		
Stability condition (river, sand, dune and lake edge) (location of unstable and stabilised sites)						(Dunes)		
Soil erosion rates (satellite) (erosion severity)								
Area of eroding soils								
Dust traps								
Fenceline observations								
Area of land affected by water erosion								
Area of erosion sites rehabilitated								
Erosion risk indices								
Soil loss per unit area of hillslope erosion (RUSLE)								
Soil Carbon								
Soil organic carbon content								
Dryland Salinity								
Depth to groundwater	(on floodplain)							
Salinity affected floodplain surveys								
Extent and severity of salt affected land								
Salinity severity in surface water bodies								
Measure productivity (or vegetation cover) in salt affected lands								
Measure of soil salinity								
Groundwater salinity								

Data Need: RCT Critical	NRM Board Regions requiring data							
	SAMDB	*KI*	*AW*	*AL*	*EP*	*NYAD*	*AMLR*	*SE*
Soil physical condition, fertility and nutrition and water repellence								
% of soil tests outside optimal range for production							→	
Extractable phosphorus and potassium		→						→
Changing land practices and planning (best practice adoption)							→	→
Vegetation cover, area and changes			→	→		→		
Area of perennial vegetation planted								→
Climate (rainfall)								→
Condition of significant biodiversity areas						→		
Biodiversity impact measure					→			
Measure of water quality impact					→			
Soil physical condition measure						→		
Identify indicators for 'production'					→			
Water use efficiency	→							
Soil chemical residue levels								→
Soil pathogen incidence								→
Soil microbial activity								
Area of waterlogged land returned to agricultural production or biodiversity		→						

Data Need: Context Critical	NRM Board Regions requiring data							
	SAMDB	*KI*	*AW*	*AL*	*EP*	*NYAD*	*AMLR*	*SE*
Soil Acidity								
Lime sales		→						
Lime quality (neutralising value, fineness, Ca, Mg)		→						
Location of acidic soils		→			→			
Irrigation application volumes							→	
Soil pH buffering capacity		→					→	
Soil pH		→						
No. of development plans relevant to sulfate soil risk areas							→	
Areas affected or prone to sodicity mapped					→			
Soil Wind and Water Erosion								
Location of remedial works — bank erosion	→							
Location of remedial works — wind erosion	→							
Location of remedial works — feral animals destroyed			→	→				
Location of remedial works — alternative watering points installed			→					

Data Need: Context Critical	NRM Board Regions requiring data							
	SAMDB	*KI*	*AW*	*AL*	*EP*	*NYAD*	*AMLR*	*SE*
Location of remedial works — perennial vegetation on high erosion risk areas						➡	➡	
Stream turbidity	➡						➡	
Soil type	➡	➡	➡	➡	➡	➡	➡	➡
Soil erosion sites with high biodiversity value							➡	
Erosion prone sites mapped or determined						➡	➡	
Soil Carbon								
Dryland Salinity								
Location of remedial works — groundwater	➡							
Groundwater flow systems	➡					➡	➡	➡
Depth to groundwater		➡					➡	➡
Groundwater salinity		➡					➡	
Location of remedial works — salt affected land	➡						➡	
Area affected or prone to salinity mapped					➡	➡		
Location of primary production on salt affected land						➡		
Extent of salt affected floodplains	➡							
Soil physical condition, fertility and nutrition and water repellence								
Soil microbial activity	➡	➡						
Soil meso and macro fauna density	➡	➡						
Location of remedial works — soil health	➡	➡						
Climate (rainfall)	➡	➡	➡	➡	➡	➡	➡	➡
Change of land management practices e.g. feed-lotting					➡			
Gypsum applied							➡	
Area and time soils are waterlogged		➡						
Soil nutrient levels							➡	
Various								
Area and extent of significant biodiversity						➡		
Land capability analysis						➡		
Land use	➡	➡	➡	➡			➡	
Vegetation cover	➡		➡				➡	➡
Stocking rates			➡					
Fire scars			➡					
Location of culturally important sites			➡					

Data Need: Context Useful	NRM Board Regions requiring data							
	SAMDB	*KI*	*AW*	*AL*	*EP*	*NYAD*	*AMLR*	*SE*
Soil Acidity								
Groundwater pH	→							
Lime quality (neutralising value, fineness, Ca, Mg)		→						→
pH forecasting					→			
Soil Wind and Water Erosion								
Frequency and size of dust storms			→		→			
Dryland Salinity								
Depth to groundwater		→	→	→	→		→	
Groundwater salinity			→	→	→			
Salt stores		→						→
Adoption of salinity risk assessment processes					→	→		
Involvement in NAP Salt Teams						→		
Landholder salinity awareness							→	
Remedial works sites		→			→		→	
Soil physical condition, fertility and nutrition and water repellence								
Water use efficiency — irrigated and dryland						→		→
Various								
Stocking rates	→						→	
Land function analysis			→					
Land capability assessments		→						
Climate (rainfall)	→	→						→
Geology		→				→		→
Soil types	→	→						→
Changing land practices (best practice adoption)					→	→ →	→	→
					(no till practices & contour banks)			
Vegetation cover						→		
Land cover	→	→				→	→	
Land use	→	→	→		→	→	→	→
Area of perennial vegetation established		→			→		→	
Data from soil tests conducted in region						→		
Fertiliser sales						→		
Proportion of land managers using technical experts to advise on fertiliser strategies							→	

NRM Board regions are defined in the list of abbreviations

F. SOIL LANDSCAPES — ANALYSIS DATA

Attribute Descriptions

Attribute category	Attribute	Description
Erosion	Gully erosion	Provides an estimate of proportion of land affected (in the past and currently) in a landscape mapping unit.
	Mass movement (landslip)	Assessed according to land with potential for movement (based on various geological or soil associations that are prone to damage and slope) and land currently affected.
	Scalding	Assessment of scalding is an estimation of the proportion of affected land in a soil landscape unit. Scalding is not associated with saline groundwater or magnesia patches.
	Water erosion potential	Includes rill and sheet erosion, and assessment is based on slope and soil erodibility (determined from soil landscape units). Does not include land use or vegetation cover to assess potential.
	Wind erosion potential	Indicates where wind erosion could be a problem, and assessed according to soil characteristics (mainly surface texture and thickness of erodible soil material) and topographic features and adjusted for rainfall. Does not include land use or vegetation cover to assess potential.
Irrigation	Deep drainage	Classed based on depth to impeding soil layers which prevent deep drainage.
	Potential rootzone depth: citrus, avocado	Some crops are more sensitive to soil parameters (including soil physical condition ('structure'), hard rock or hardpan, soluble salts, boron concentrations, alkalinity, acidity and sodicity) than others, so five indicative crops have been identified. For each soil type and crop an average root-zone depth has been calculated.
	Potential rootzone depth: stone fruit, almonds	
	Potential rootzone depth: grape, olive	
	Potential rootzone depth: root crops	
	Potential rootzone depth: above ground annual crops	
Land surface	Exposure	Exposure is classified by judging whether or not the land is unprotected by nearby high ground.
	Surface rockiness	Classified according to the overall amount of surface stone and outcropping rock or an estimate based on the proportion of rock and soil.
	Susceptibility to flooding	Land is assessed for susceptibility to flooding through observation and inference as to whether flooding is likely or unlikely. Classes are based on an interpretation of soil landscape map units.
Salinity	Dry saline land	Classified on the basis of soil test results and extrapolation to similar soils and subsoil materials.
	Salinity (induced by watertable)	Assessments are based on a combination of soil test results and observations of vegetation type. Classification accounts for the degree of salinity of the landscape as a whole, and for the proportion of land affected by discrete highly saline seepages. Classes do not distinguish between primary (natural) and secondary (European induced) salinity.
Soil chemistry attributes	Acid sulfate potential	Assessment based on observable morphological properties particularly land with a shallow watertable and a source of sulfate (e.g. gypsum or pyrite minerals). Soil landscape units are classified according to whether the major part is at risk, risk is confined to localised areas, or there is no risk.

Attribute category	Attribute	Description
	Alkalinity	Soils are classified according to their pH profiles (in the surface and subsoil), and by extrapolation between similar soil materials.
	Aluminium toxicity	Estimated from limited laboratory analyses and extensive extrapolation according to similarity of soil type. Classes used in this assessment are based on critical levels for aluminium sensitive plants such as lucerne.
	Boron toxicity	Assessments are made from soil test results and extrapolation between similar soil materials and environments. Classified according to the estimated depth to toxic boron concentration.
	Inherent fertility	Soils are ranked by their capacity to retain nutrients and release them to plant roots. Soil properties such as soil texture, exchangeable cation characteristics, leaching capacity, acidification potential, and carbonate and ironstone content are used in the ranking.
	Sodium toxicity	Estimates of 'exchangeable sodium percentages' are based on extrapolation of laboratory analyses between similar soil materials and soil types. Soils classified according to the estimated depth to toxic sodium concentration.
	Surface carbonate	The nature, depth to and concentration of carbonates are routinely assessed during field mapping work. Presence of carbonates is determined by the application of 1N HCl. Surface carbonate is classified by the strength of any effervescence.
	Subsoil carbonate	Classified by depth to very highly calcareous material (strong reaction to 1N HCl).
	Susceptibility to acidity	The assessment combines three elements of soil acidity: • Three levels of severity are used: non-acidic, acidic and strongly acidic. • Profile trend is included from topsoil to subsoil in the assessment. • Soils with low clay or low organic matter have a low buffering capacity (i.e. low capacity to resist acidification). All land susceptible to acidity is classified accordingly, regardless of land use or management.
Soil type	Soil groups	Fifteen broad 'Soil Groups' are identified.
	Soils	The 'Soil Groups' are broken down into 61 sub-groups, simply called 'Soils'. Each soil landscape unit includes at least one soil.
	Surface texture	Estimate of the most commonly occurring surface texture in a soil landscape unit with a range of qualifiers but basically estimating the clay content of the surface soil.
Soil moisture	Available water holding capacity	Available water holding capacity rankings are estimated from soil texture, structure and stone content within the potential rootzone of a wheat plant. Water holding capacities for soils are estimated from morphological properties, not laboratory analyses.
	Depth to watertable	Watertable depth is assessed on the maximum level maintained for at least two weeks per year. No distinction is made between saline and non-saline watertables. This assessment does not deal with perched watertables.
	Recharge potential	The assessment is based on the assumption that recharge is a function of soil profile water holding capacity, substrate porosity and rainfall. The nature of substrates is commonly estimated from local knowledge and/or an understanding of regional stratigraphy.

Attribute category	Attribute	Description
	Susceptibility to waterlogging	Ranked according to the period of time that all or part of the soil profile is waterlogged. Estimated based on observable soil and landscape features, and on opportunistic recordings of soil wetness under different weather conditions.
Soil physical condition	Depth to hard rock	Hard rock is basement or country rock. Routinely measured during field surveys where it occurs within a metre or so of the surface. Typical depths are defined for the range of soils. The class represents the average depth value within a soil landscape unit.
	Depth to hardpan	Hardpans are generally young materials. In southern South Australia they include calcrete, ferricrete and silcrete. Routinely measured during field surveys where it occurs within a metre or so of the surface. Typical depths are defined for the range of soils. The class represents the average depth value within a soil landscape unit.
	Surface soil condition	Hard setting soils usually have high proportions of fine sand and silt, and insufficient swelling clay to allow for internal volume changes. The clay particles may be dispersive, and organic matter levels may be low.
	Susceptibility to water repellence	Estimates made according to tests on soil samples and on extrapolation between similar soils. Regional assessments are not intended to show where water repellence is a problem, but where conditions are such that it could be a problem.

Source: DWLBC 2005 — this CD provides more detailed descriptions and the classification criteria.

G. DATA NEEDS FOR NATIONAL INDICATORS

Data need	Type
Indicator 1: Land Salinity — Depth to groundwater	
Depth to groundwater	Protocol
Climate (rainfall)	Context critical
Hydrogeology or groundwater flow systems	Context critical
Geology	Context useful
Land cover	Context useful
Land use	Context useful
Salt stores	Context useful
Indicator 2: Land Salinity — Groundwater salinity	
Baseflow volume	Protocol
Groundwater pH	Protocol
Groundwater salinity concentration	Protocol
Major ions	Protocol
Groundwater flow systems	Context critical
Climate (rainfall)	Context useful
Geology	Context useful
Land cover	Context useful
Land use	Context useful
Indicator 3: Land Salinity — Location and size of salt affected areas	
Intensity	Protocol
Location	Protocol
Size	Protocol
Climate (rainfall)	Context critical
Watertable fluctuations	Context critical
Geology	Context useful
Groundwater flow systems	Context useful
Land cover	Context useful
Land use	Context useful
Soils	Context useful
Indicator 4: Soil Condition — Soil acidification	
pH	Protocol
Lime sales	Protocol
Lime quality (neutralising value; fineness; Ca; Mg)	Context critical
Soil buffering capacity	Context critical
Soils	Context critical
Area of legumes or improved pastures	Context useful
Climate	Context useful
Land cover	Context useful
Land use	Context useful
NDVI	Context useful
Indicator 5: Soil Condition – Soil erosion - water	
Land cover	Protocol
Rainfall intensity	Protocol

Data need	Type
Rate of expansion of gully networks (density) per catchment	Protocol
Soil conservation structures	Protocol
Soil erodibility	Protocol
Soil loss per unit area of hillslope erosion (RUSLE)	Protocol
Stream turbidity and flow	Protocol
Suspended sediment ratio to hillslope erosion ratio	Protocol
Topography	Protocol
Agriculture on steep slopes -- alternative indicator to RUSLE	Context critical
Land use	Context useful
Indicator 6: Soil Condition — Soil erosion — wind	
Dust traps	Protocol
Fenceline observations	Protocol
Visibility	Protocol
Climate	Context critical
Soils	Context critical
DEM	Context useful
Land use	Context useful
Vegetation and land cover	Context useful
Indicator 7: Soil Condition – Soil carbon content	
Soil organic matter content (%)	Protocol
Climate	Context useful
Land cover	Context useful
Land use	Context useful
Soil type	Context useful

Protocol data type — data that were required directly for the indicator (these were derived from the national indicator protocols).
Context data needs — data that were required for interpretation of the protocol data needs.
(Beaten Track Group Pty Ltd 2004)

H. NATIONAL RCTs AND RECOMMENDED MONITORING METHODS

Matter for target	Indicator heading	Recommended indicators	Indicator (and protocol) status	Monitoring methods
Land salinity	Area of land threatened by shallow or rising watertables	Depth to groundwater	Agreed	The selection of bores, or locations for bores to be constructed for monitoring should be based on priority of the catchment areas for salinity control in a state or region; type of groundwater flow system; geology; climate; landscape position; length and continuity of record; how well the location represents the catchment as a whole; groundwater pressure or level trends (if known); quality of data; and land use (e.g. cropping, pastures, improved or unimproved).
		Groundwater salinity	Agreed	Bores or similar structures are needed for sampling groundwater. Since the chemistry of groundwater can be quite variable over short distances in some local flow systems, an understanding of the hydrogeology and flow dynamics of the system is important in the design stage of regional monitoring program.
		Location, size and severity of salt affected areas	Agreed	Where possible, the boundaries of the salinity outbreak should be measured by GPS and recorded on the same database as depth to groundwater, groundwater salinity, baseflow and baseflow salinity. Where outbreaks are small, recording the coordinates of the centre of the outbreak may be more practical. Elevation of the salinity outbreak should be measured by differential GPS or surveyed against a benchmark. Where neither of these methods is attainable, elevation may be estimated from the DEM. The area of the salt-affected land should be measured in hectares and estimated by using electromagnetic surveys, aerial or satellite photography, or soil surveys. Intensity should be assessed using criteria provided for 'Incipient', 'Moderate' and 'Severe'.
Soil condition	Soil condition	Soil acidification	For advice	Annual monitoring of lime sales at a regional level supported by appropriate analysis (e.g. allowance for buffering capacity of different soils and their lime requirements plus the impact of other factors such as seasonal or economic conditions). Monitoring of long-term resource condition using a site-based approach in high priority regions.
		Soil erosion — water	For advice	Hillslope erosion: • Soil cover across Australia is monitored using available NOAA-AVHRR data in conjunction with a scheme for field calibration. • Predict the potential for hillslope erosion using the new soil cover data with improved data sets for modelling (i.e. enhanced Australian Soil Resource Information System, rainfall erosivity, digital elevation data). Gully erosion: • The rate of expansion of gully networks in high priority catchments using standard geomorphic erosion measurement techniques. • Radionuclide-based studies in a set of representative catchments be undertaken to determine (i) the quantity and (ii) respective

Matter for target	Indicator heading	Recommended indicators	Indicator (and protocol) status	Monitoring methods
				sources of sediment. And other important or useful information: • number of properties undertaking soil conservation works and the kilometres of cut-off drains and contour banks installed; • areas of land use with hazard and risk of erosion; • area and method of fallow, tillage and stubble management; • stocking rate and livestock type; and trends in stream sediment load at appropriate monitoring stations.
		Soil erosion — wind	For advice	Direct measurements: • a wind tunnel to measure soil erosion and dust emission; • dust traps (both deposition and saltation); and • air quality monitors of dust concentration (generally by filtering air or measuring dust concentration by light scattering). Observational measurements: • visibility assessments (as done by the BoM and DustWatch participants); • roadside survey where erosion levels in paddocks beside the road are classified into four classes as the observer drives down the road; and • in-paddock assessments based on photostandards. Models used to date include: • the wind erosion assessment model; and • wind erosion risk model. Current monitoring methodologies work at: • The national scale using dust storm records recorded by the BoM and processed-based modelling; • regional or catchment scales using road side surveys, DustWatch and processed-based modelling; and • district or farm scales using dust traps, on-farm erosion assessments based on soil cover and aggregation levels.
		Soil carbon content	For advice	Set of expected values of soil carbon for combinations of climate, land use (based on district or regional practices), soil type and drainage which can be developed from local land management practices. One of the soil carbon models available to predict soil carbon levels (e.g. AGO or CSIRO Land and Water could be used to do this). Set of specific monitoring sites that are stratified according to climate, soils, drainage and district land management practices — local knowledge of local soils and climate and major land management practices essential. Access to the results of soil test results from farms in the area may also be useful in understanding the impacts of land management practices on organic carbon levels.

(Australian Government 2006b,c,d,i,j)

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	μg	10^{-6} g	mass
microlitre	μL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	356 or 366 days	time interval

LIST OF ABBREVIATIONS

ABS	Australian Bureau of Statistics
AASS	Actual acid sulfate soils
ACRIS	Australian Collaborative Rangeland Information System
AER	Agro-ecological region
AL	Arid Lands
ALIS	Arid Lands Information System
AMLR	Adelaide and Mount Lofty Ranges
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZLIC	Australian and New Zealand Land Information Council
ASS	Acid Sulfate Soils
AW	Alinytjara Wilurara
BoM	Bureau of Meteorology
CC	Context Critical
CD	Compact Disk
CEC	Cation Exchange Capacity
CRC	Cooperative Research Centre
CRCGA	Cooperative Research Centre for Greenhouse Accounting
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CU	Context Useful
DCDB	Digital Cadastral Database
DEH	Department for Environment and Heritage
DEM	Digital Elevation Model
DSI	Dust Storm Index
DWLBC	Department of Water, Land and Biodiversity Conservation
DWR	Department for Water Resources
EP	Eyre Peninsula
EP Act	*Environment Protection Act 1993*
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FSP	Field Survey Program
GG	Grazing Gradient
GIS	Geographic Information Systems
GPS	Global Positioning System
GRDC	Grains Research and Development Corporation
IBRA	Interim Biogeographic Regionalisation for Australia
INRM	Integrated Natural Resource Management
JSC	Joint Steering Committee
KI	Kangaroo Island
LAP	Local Action Planning
LCI	Land Condition Index
LCM	Land Condition Monitoring
LCMP	Land Condition Monitoring Program
LCMR	Land Condition Monitoring Review

MAT	Management Action Targets
MDB	Murray–Darling Basin
M&E	Monitoring and Evaluation
MERF	Monitoring, evaluation and reporting frameworks
MER-OP	Monitoring, Evaluation and Reporting Operational Plan
MER-PG	Monitoring, Evaluation and Reporting Policy Group
MLR	Mount Lofty Ranges
MODIS	Moderate Resolution Imaging Spectroradiometer
MSF	Mallee Sustainable Farming Inc.
NAP	National Action Plan for Salinity and Water Quality
NCAS	National Carbon Accounting System
NDVI	Normalised Difference Vegetation Index
NFNRMST	National Framework for Natural Resource Management Standards and Targets
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NMEF	National (Natural Resource) Monitoring and Evaluation Framework
NRM	Natural Resource Management
NRM Act	*Natural Resources Management Act 2004*
NRM Plan	State Natural Resources Management Plan
NSESD	National Strategy for Ecologically Sustainable Development
NSW	New South Wales
N&Y	Northern and Yorke District
NYAD	Northern and Yorke Agricultural Districts
OECD	Organisation for Economic Co-operation and Development
PASS	Potential acid sulfate soils
PM	Project Manager
PMIS	Pastoral Management Information System
PIRSA	Primary Industries and Resources of South Australia
PSR	'pressure-state-response'
QLD	Queensland
RCT	Resource Condition Target
SA	South Australia
SADSC	South Australian Dryland Salinity Committee
SADSS	South Australian Dryland Salinity Strategy
SAFF	South Australian Farmers Federation
SaLI	Land and Soil Information Framework (formerly known as SaLI)
SAMDB	South Australian (portion of) Murray Darling Basin
SAMEF	South Australia's Monitoring and Evaluation Framework
SASPAS	South Australian Soil and Plant Analysis Service
SAWIA	South Australian Wine Industry Association
SCC	Soil Conservation Council
SE	South-East
SENCC	Social and Economic National Coordination Committee
SKM	Sinclair Knight Mertz
SoE	State of Environment
TBL	Triple Bottom Line
TDS	Total Dissolved Solids
WUE	Water Use Efficiency

GLOSSARY

Ambient. The background level of an environmental parameter (e.g. a background water quality like salinity).

Aquifer. An underground layer of rock or sediment which holds water and allows water to percolate through.

Arid lands. In South Australia arid lands are usually considered to be areas with an average rainfall of less than 250 mm and support pastoral activities instead of broad acre cropping.

Baseflow. The water in a stream that results from groundwater discharge to the stream. (This discharge often maintains flows during seasonal dry periods and has important ecological functions.)

Basin. The area drained by a major river and its tributaries.

Benchmark condition. Points of reference from which change can be measured.

Biological diversity (biodiversity). The variety of life forms: the different life forms including plants, animals and micro-organisms, the genes they contain and the *ecosystems (see below)* they form. It is usually considered at three levels — genetic diversity, species diversity and ecosystem diversity.

Biota. All of the organisms at a particular locality.

Bore. *See well.*

Catchment. A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Catchment water management board. A statutory body established under Part 6, Division 3, s. 53 of the Act whose prime function under Division 2, s. 61 is to implement a catchment water management plan for its area.

Catchment water management plan. The plan prepared by a CWMB and adopted by the Minister in accordance with Part 7, Division 2 of the Water Resources Act 1997.

Council of Australian Governments (COAG). A council of the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association which exists to set national policy directions for Australia.

CWMB. Catchment Water Management Board.

Diffuse source pollution. Pollution from sources such as an eroding paddock, urban or suburban lands and forests; spread out, and often not easily identified or managed.

District Plan. (District Soil Conservation Plan) An approved soil conservation plan under the repealed *Soil Conservation Act 1989*. These plans are taken to form part of the relevant regional NRM plans under the transitional provisions of the *Natural Resources Management Act 2004* (Schedule 4 – subclause 53[4] until regional NRM plans are prepared under Chapter 4, Part 2 of the Act.

DWLBC. Department of Water, Land and Biodiversity Conservation. Government of South Australia.

EC. Abbreviation for electrical conductivity. 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25 degrees Celsius. Commonly used to indicate the salinity of water.

Ecologically sustainable development (ESD). Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.

Ecology. The study of the relationships between living organisms and their environment.

Ecosystem. Any system in which there is an interdependence upon and interaction between living organisms and their immediate physical, chemical and biological environment.

EMLR. Eastern Mount Lofty Ranges.

Environmental values. The uses of the environment that are recognised as of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

Environmental water provisions. Those parts of environmental water requirements that can be met, at any given time. This is what can be provided at that time with consideration of existing users' rights, social and economic impacts.

Environmental water requirements. The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.

EP. Eyre Peninsula.

EPA. Environment Protection Agency.

Erosion. Natural breakdown and movement of soil and rock by water, wind or ice. The process may be accelerated by human activities.

ESD. Ecologically sustainable development *(see above for definition)*.

Evapotranspiration. The total loss of water as a result of transpiration from plants and evaporation from land, and surface waterbodies.

GIS (geographic information system). Computer software allows for the linking of geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

Greenhouse effect. The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

Geological features. Include geological monuments, landscape amenity and the substrate of land systems and ecosystems.

Groundwater. *See underground water.*

Habitat. The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

Hydrogeology. The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See hydrology.)*

Hydrography. The discipline related to the measurement and recording of parameters associated with the hydrological cycle, both historic and real time.

Hydrology. The study of the characteristics, occurrence, movement and utilisation of water on and below the earth's surface and within its atmosphere. *(See hydrogeology.)*

Indigenous species. A species that occurs naturally in a region.

Infrastructure. Artificial lakes; or dams or reservoirs; or embankments, walls, channels or other works; or buildings or structures; or pipes, machinery or other equipment.

Integrated catchment management. Natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints.

Intensive farming. A method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or by mechanical means.

Irrigation. Watering land by any means for the purpose of growing plants.

Lake. A natural lake, pond, lagoon, wetland or spring (whether modified or not) and includes: part of a lake; and a body of water declared by regulation to be a lake; a reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

Land. Whether under water or not and includes an interest in land and any building or structure fixed to the land.

Land capability. The ability of the land to accept a type and intensity of use without sustaining long-term damage.

Leaching. Removal of material in solution such as minerals, nutrients and salts through soil.

Macro-invertebrates. Animals without backbones that are typically of a size that is visible to the naked eye. They are a major component of aquatic ecosystem biodiversity and fundamental in food webs.

MDBC. Murray-Darling Basin Commission.

MLR. Mount Lofty Ranges.

Model. A conceptual or mathematical means of understanding elements of the real world which allows for predictions of outcomes given certain conditions. Examples include estimating storm runoff, assessing the impacts of dams or predicting ecological response to environmental change.

Natural recharge. The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) *(See recharge area, artificial recharge.)*

NHT. Natural Heritage Trust.

Natural Resources. Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

Natural Resources Management (NRM). All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

Pasture. Grassland used for the production of grazing animals such as sheep and cattle.

Permeability. A measure of the ease with which water flows through an aquifer or aquitard.

PIRSA. (Department of) Primary Industries and Resources South Australia.

Pollution, diffuse source. Pollution from sources that are spread out and not easily identified or managed (e.g. an eroding paddock, urban or suburban lands and forests).

Pollution, point source. A localised source of pollution.

Potable water. Water suitable for human consumption.

Potentiometric head. The potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer.

Prescribed area, surface water. Part of the State declared to be a surface water prescribed area under the Water Resources Act 1997.

Prescribed lake. A lake declared to be a prescribed lake under the Water Resources Act 1997.

Prescribed water resource. A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Prescribed watercourse. A watercourse declared to be a prescribed watercourse under the Water Resources Act 1997.

Prescribed well. A well declared to be a prescribed well under the Water Resources Act 1997.

PWA. Prescribed Wells Area.

PWCA. Prescribed Watercourse Area.

PWRA. Prescribed Water Resources Area.

Ramsar Convention. This is an international treaty on wetlands titled The Convention on Wetlands of International Importance Especially as Waterfowl Habitat. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The Convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

Riparian zone. That part of the landscape adjacent to a water body, that influences and is influenced by watercourse processes. This can include landform, hydrological or vegetation definitions. It is commonly used to include the in-stream habitats, bed, banks and sometimes floodplains of watercourses.

State water plan. The plan prepared by the Minister under Part 7, Division 1, s. 90 of the Act.

Surface water. (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Taxa. General term for a group identified by taxonomy — which is the science of describing, naming and classifying organisms.

Underground water (groundwater). Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Water plans. The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act.

Watercourse. A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; and a lake through which water flows; and a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse.

Water-dependent ecosystems. Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

Well. (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

Wetlands. Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic/intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres.

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