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Agricultural resource priorities and recommendations for the Avon River Basin Natural Resource Management Strategy

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AGRICULTURAL RESOURCE PRIORITIES AND RECOMMENDATIONS FOR THE AVON RIVER BASIN

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Summary

This report for the Avon Natural Resource Management Strategy provides an assessment of the current status of land resources throughout the Avon River Basin (ARB). It identifies the sub-regions and landscape components of the area and the land resource assets. Additional information about threats can be found in Resource Management Technical Report 288 (Galloway 2005), which provides analytical assessment of the key issues, risks and threats affecting land resources and suggests management response options.

The priorities for addressing threats to land resources within the region were identified through consultation with communities, organisations and agencies in the agricultural industry. The aspirational targets relate to the long-term visionary target (20 to 50 years) for the three most threatening processes. The resource condition targets are the medium-term goals to be achieved by 2025.

The greatest threats are salinity, soil acidification, subsurface compaction, waterlogging, water and wind erosion, and biosecurity. The targets to address the identified threats are outlined below.

The resource condition targets selected were:

- Topsoil and subsoil acidity levels at or above pH 5.5_{Ca} in soils with low capacity to buffer pH change by 2020*.
- A 50% reduction in the area affected by subsurface compaction and soil structure decline by 2020.
- A 50% reduction in the area impacted by erosion and waterlogging by 2015.
- Wind erosion reduced by 80% on soils at risk by 2020.
- Identification of all soils with fertility issues by 2010 and a 30% improvement in benchmarked fertility levels by 2020.
- Reduction in the average rate of groundwater rise on land in middle and upper catchment areas from 15-30 mm to 10-20 mm by 2025.
- Valley floor salinity extent reduced to less than 12% of the land used for agriculture by 2025^{+}.
- A 50% reduction in the economic and environmental impacts of all priority plant and animal pests across the region by 2014.

A systems-based approach has been adopted for management of threats to land resources. The land-based threats form part of the NRM strategic plan coordinated by the Avon Catchment Council.

* The extent and severity of subsoil pH levels need to be determined over the period noted. The documented long-term detrimental impacts of not managing subsoil acidity is the driver for this RCT.

$^{+}$ The extent and impact of rising groundwater tables in valley floors needs to be accurately quantified.

Contents

1. Introduction

There have been many assessments of the resources in the Avon Catchment. This report combines data from some, and extends information for use by the Avon Catchment Council in preparing a natural resource management regional strategy.

The regional strategy will be used to identify and guide investment in the management of natural resources, infrastructure and social heritage and cultural values within the Avon River Basin (ARB). This document identifies the current extent and potential for further impact of threats to land resources and provides a basis for investment in management actions to achieve Resource Condition Targets (RCTs). Land resources include many soil types, landforms and soil-water interactions.

Agriculture is the dominant land use in the ARB. Agricultural land (exclusive of remnant vegetation, townsites etc.) comprises nearly 7.2 million hectares (61%) of the total 11.8 million hectares. The region contains 25% of WA farms and accounts for 39% of all farmland in the agricultural area. Based on 1996-97 census data, the region contributes 34% of the State's gross value of agricultural production worth $1,467 million. Agriculture in the wheatbelt (of which the ARB is a significant proportion) generates 58% of the wealth and employs 41% of the workforce (WDC 1997).

Threats to land resources are described in Galloway (2005). They have been analysed according to the extent and severity of the likely impact to the region. This analysis identified the following significant issues:

- Salinity currently affects 388,000 ha (5.3% of agricultural land) and has the potential to affect 2,027,000 ha (27.4% of agricultural land).
- Soil acidity is the highest degradation risk to land and soil, with over half the ARB having a moderate to high risk of subsurface acidification. Thirty two per cent of soils have a high risk of subsurface acidification.
- Subsurface compaction could affect 42% of agricultural land. Soil structure decline affects up to 40% of the Carabbin and Southern Cross sub-regions and up to 30% of Mortlock, SE Lakes and Northern Sandplain.
- Waterlogging is significant and occurs frequently in areas of low relief where rainfall is greater than 400 mm (western areas). As a result, 24% of soils are prone to waterlogging in an average year.
- Water erosion is significant in shallow duplex and loamy soils in the eastern wheatbelt. Average soil losses through sheet erosion range from 6.6 to 9.8 t/ha/yr.
- Wind erosion occurs in small areas during most years although it can be widespread under exceptional conditions.

On the basis of this assessment, past and perhaps current land use practices in the Avon River Basin are not sustainable. It is however recognised, that developing sustainable agricultural systems and maintaining profitability is important for natural resource management. This document identifies opportunities for improving agricultural management towards sustainable practice in a way that also provides other social, economic and environmental benefits.

2. Asset description

2.1 Area

The Avon River Basin occupies 11.8 million hectares of the central and eastern wheatbelt and southern rangelands of WA (Figure 2.1).

Approximately 8.3 m ha is used for crop and pasture production in dryland agricultural systems. Natural vegetation has been cleared from most of this area, although approximately 1.1 million hectares (15%) retains original vegetation cover (including 648,000 hectares retained in reserves for conservation, recreation and other purposes). Remnant vegetation on private land occupies 491,000 ha (6.7%) of this area. Other land uses such as mining, currently occupy only small areas.

Land use across the region is closely linked to soil types and rainfall. The soils and landforms are described in full by Lantzke (1992), Fulton and Lantzke (1993) and Schoknecht (2002) and are documented in Galloway (2005).

To assist in resource threat identification and development of management actions, the region has been grouped into three zones based on land management, landscape features and land use planning criteria. (The land resource sub-regions in each zone are detailed in Appendix A2.)

The Avon Arc

The Avon Arc (0.9 m ha), is the western, high/medium rainfall zone, comprising the shires of Brookton, Beverley, York, Toodyay and Northam (town and shire). Landscapes are generally characterised by undulating hills and drainage is to the Avon and Mortlock Rivers. Between the Meckering fault line and the Darling Range is the Zone of Rejuvenated Drainage where the valleys are steeper and narrower and contain rivers and creeks that flow regularly. Water from these systems ultimately reaches the Indian Ocean via the Swan River. The hills of the western catchment have ironstone gravelly soils vegetated by jarrah and marri forest with a heath-type understorey. Sandy duplex soils in the west are vegetated by wandoo woodland. Due to the high level of small holdings and diverse land uses, the shires have comprehensive land use planning schemes in place.

Wheatbelt Zone

The Wheatbelt Zone (7.4 m ha) makes up most of the agricultural region and comprises the greater area of the Avon Valley, Yealering Lakes, Mortlock, Northern Sandplain, South-east Lakes, Carabbin and Southern Cross sub-regions (Figure 2.1). The central and eastern sections are in the Zone of Ancient Drainage, which Lantzke (1992) characterised as having broad flat valleys of low gradient with salt lake chains at their lowest point, gently sloping valley sides, some rock outcrops and large areas of yellow sandplain. Much of the surface water drains to salt lake chains in the valley floors. These may overflow to the Avon, Yilgarn and Mortlock Rivers during exceptionally wet years.

The broad valley floors contain mostly loamy duplexes, loamy earths and clay soils, all with calcareous subsoils. These were originally vegetated by eucalyptus woodlands; principally salmon gums and gimlets with various mallee-type eucalypts increasing further east. Slopes are dominated by sandy duplex soils originally vegetated by mallee-form eucalypts. Lateritic terrain comprising ironstone gravel and sandplain occupies crests and slopes with the original vegetation being a diverse flora dominated by Proteaceous heath.

Crown-Pastoral Zone

The 3.5 million hectares in the east of the Avon River Basin (Crown-Pastoral Zone) is mostly vacant Crown land, however six pastoral leases are located there.

The asset valuation and associated strategic NRM plan for the Crown-Pastoral Zone, will be addressed in the Rangelands Strategy (to be developed).

2.2 Land resource sub-regions

The ARB has three major river catchments (Yilgarn, Lockhart and Avon) in which nine sub-regions have been identified (shown in Table 2.1 and Figure 2.1). The sub-regions are described in Appendix A2 and Galloway (2004).

Table 2.1: Land resource sub-regions within the Avon River Basin

Zone	Catchment	Sub-region	Total area (ha)	Area used for agriculture (ha)	% of total used for agriculture
Wheatbelt	Yilgarn	Carabbin	2,032,700	1,794,000	21.5
		Southern Cross	248,800	189,000	2.2
	Lockhart	SE Lakes	2,010,900	1,604,000	19.2
		Yealering Lakes	679,300	661,000	7.9
	Avon & Yilgarn	Northern Sandplain	738,000	687,000	8.2
	Avon	Mortlock	1,370, 000	1,326,000	15.9
Avon Arc/ Wheatbelt	Avon	Avon Valley	833,100	813,000	9.7
		Dale/Upper Avon	169,300	163,000	1.9
Avon Arc	Avon	Darling Range	224,000	148,000	1.7
Unallocated *			6,100	2,000	<0.1
Total			**8,313,200**	**7,387,000**	**89**

* Refer to Galloway (2004)

Table A4.1 (Appendix A4) lists the main soils of the ARB, as classified by Schoknecht (2002) and documented in databases (Department of Agriculture 2005).

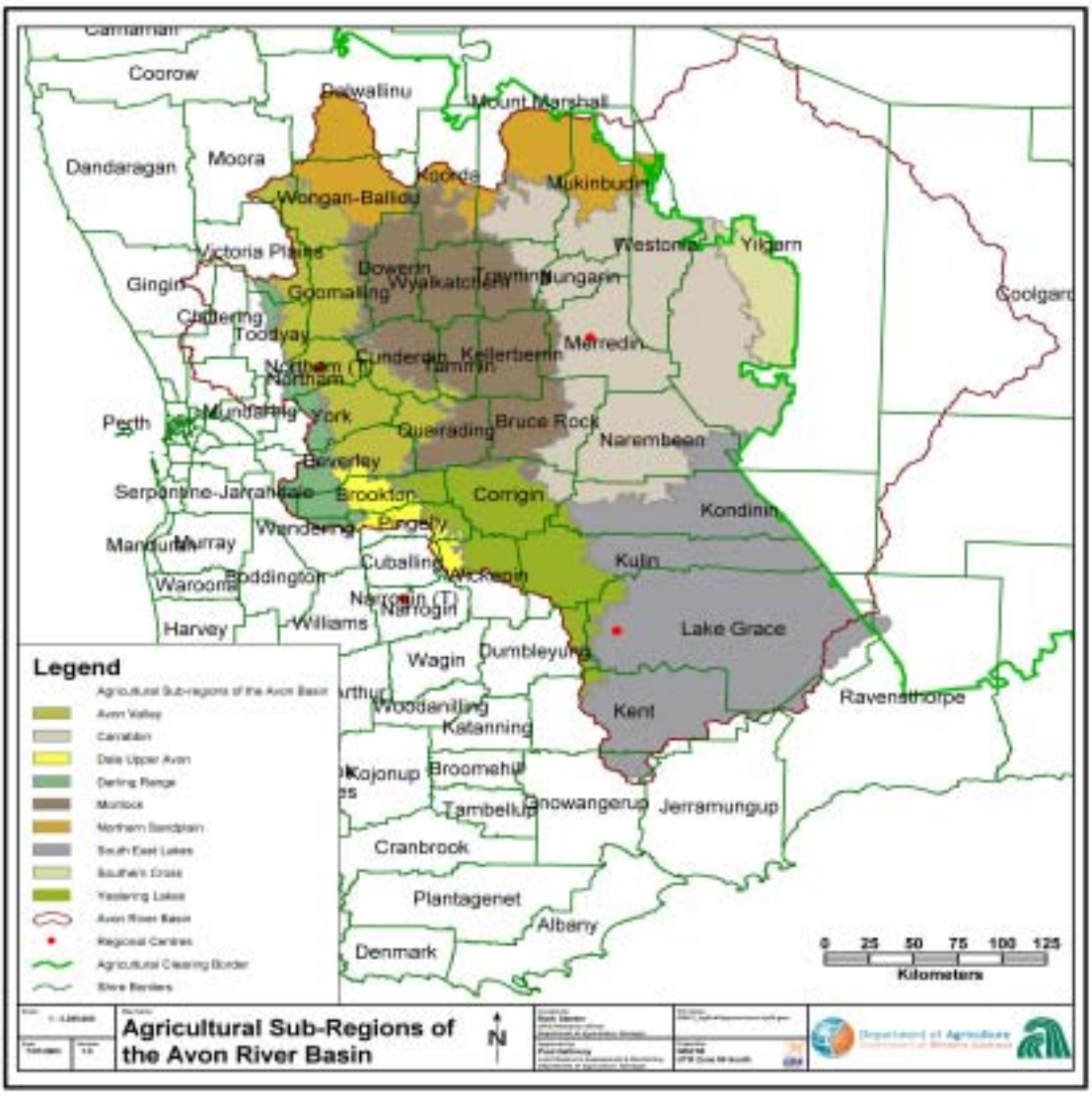


Figure 2.1. Land resource sub-regions of the Avon River Basin

3. Agricultural industries

3.1 Agricultural industries in the Avon River Basin

Agricultural production is based on annual broad-acre cropping and pasture systems. The main crops are wheat, barley, lupins and canola. Other cereals such as oats and alternative legumes such as field peas, are grown to a lesser extent. Wool, sheepmeat, and to a minor extent dairying, pork and beef production, comprise the animal component of farming enterprises.

Increasing diversification is occurring in the Avon Valley, Darling Range and Dale/Upper Avon sub-regions. Specialised plantations/orchards for such products as wine grapes, citrus, olives and pistachios have increased following subdivision of larger holdings. Some plantation timber is also grown in the higher rainfall areas in the Darling Range.

Agricultural activity in the ARB contributes 34% ($1,467M) of the State's gross value of agricultural production (GVAP). Over 60% is derived from wheat production (Department of Agriculture 2001). Table 3.1 provides an overview of the gross value of agricultural production for the major agricultural activities in the sub-region (based on 1996-97 census data).

3.2 Farm business capacity

The capacity of farm businesses to invest in land resource management actions has been limited since 1998-99 due to poor seasons.

The general investment patterns, as shown in the PlanFarm (2000) client data for natural resource management by farmers, differ across the region. In western areas there tends to be a long-term focus, where there is a willingness to draw down farm equity and small amounts may be invested frequently (despite adverse seasons/conditions). In eastern areas there is more typically a short-term focus, reliant upon a surplus to invest in NRM, rather than drawing down equity. As such large amounts are invested infrequently.

A range of difficulties is associated with investment in NRM, including:

- high initial capital outlay;
- return on investment is not always positive;
- long lead times before income is generated;
- limited infrastructure for processing in new industries; and
- capacity driven by high income-producing years that provide cash surpluses and improved equity.

Table 3.1. Gross value of agricultural production (GVAP) in the Central Agricultural Region*

Agricultural industry	Value of farm production ($'000)	Total area of production (ha)
Intensive animal products		
Apiculture	288	210
Intensive meat	25,077	460
Eggs	936	10
Total intensive animal products	26,302	680
Pasture animal products		
Wool	177,414	1,281,709
Milk	158	300
Grazing meat	90,254	1,601,282
Other	1,370	2,200
Total pasture animal production	269,196	2,885,491
Crops – broadscale		
Cereal crops for grain	1,021,803	2,860,594
Grain legumes and oilseeds	122,745	555,885
Hay/pastures	22,156	54,043
Total broadscale crops	1,166,704	3,470,522
Crops – horticulture		
Nurseries, turf and cut flowers	4,000	248
Vegetables	836	982
Fruit	5	334
Grapes	395	206
Total horticulture crops	5,237	1,770
Total Central Region Agriculture	1,467,439	6,358,463

* Source: Department of Agriculture 2001. Central Agricultural Region includes the 'Avon Arc' and 'Wheatbelt' Zones of ARB and areas of the adjacent Hotham River Catchment.

4. Land resource condition

4.1 Potential extent of major threats

It is important to identify and quantify the threats to the land resources to help determine the scope of the issue, management options and priorities. Table 4.1 summarises the current extent of salinity in the ARB and the area of land at risk. The estimates of the extent of soil, land and water management threat impacts, as listed in Table 4.2, are derived from land quality attributes and soil-landscape mapping (van Gool and Moore 1999, Galloway 2005).

Land resource threats include:

- Salinity, which currently affects 388,000 ha (5.3% of agricultural land) and has the potential to affect 2,027,000 ha (27.4%).
- Soil acidity, the second highest degradation risk to land and soil, with over half the ARB having a moderate to high risk of subsurface acidification. Thirty-two per cent of soils have a high risk of subsurface acidification.
- Subsurface compaction, affecting 42% of agricultural land. Soil structure decline affects up to 40% of the Carabbin and Southern Cross sub-regions and up to 30% of Mortlock, SE Lakes and Northern Sandplain.
- Waterlogging, which is significant and occurs frequently in areas of low relief and where rainfall is greater than 400 mm (western areas). As a result, 23% of soils are prone to waterlogging in an average year.
- Water erosion, which is significant in areas of shallow duplex and loamy soils in the eastern wheatbelt. Sheet and rill erosion are evident in western areas.
- Wind erosion, which occurs in small areas during most years, although can be widespread under exceptional conditions. Nearly 20% of soils have a high to extreme risk from wind erosion.

The potential resource impacts of threats, their extent and management options are described in Appendices 3 and 4.

4.2 Other threats to land resources

4.2.1 Plant and animal pests and diseases

Plant and animal pests and diseases threaten not only the environment but agricultural production and sometimes human health. Such threats are managed through use of biosecurity measures, including exclusion, eradication and control actions. In practice, biosecurity involves measures to protect the State, regions, the environment, agricultural industries and individual enterprises from the entry and impact of unwanted animals, pests, diseases and weeds.

The potential impacts of biosecurity threats include:

- Agricultural and environmental pests create significant problems for land managers. Introduced pests compete with native plants and/or agricultural crops and pasture species, and the cost to agricultural industries has been estimated at over $3.3 billion per annum nationwide (Cook 2003).

- Invasive environmental weeds can permanently alter the composition of natural species associations in reserves, forest, wetlands and vegetation remnants through competition with and displacement of native and endemic species.
- Weed invasion may alter nutrient cycling patterns. Specific impacts on agriculture include; plant competition for moisture, light and nutrients, toxic effects and injury to stock, interference with operations, contamination of crops and produce (market access risk), and the harbouring of animal and plant pests and diseases.
- Pest animals degrade the landscape and are significant causal agents leading to the extinction of native animals and plants, and control measures by landowners add to the cost of agricultural production.

The plant and animal pests and disease risks for land resource sub-regions are described in Table A1.3. These risks have been identified from interviews with biosecurity staff in the Department of Agriculture.

Table 4.1: Current extent of salinity and potential for further impact in sub-regions of the Avon River Basin

Sub-region	Area used for agriculture ('000 ha)	Current extent of salt-affected land		Low-lying areas	
		ha	%	'000 ha	%
Darling Range	148	2,700	1.8	24	16.1
Dale/Upper Avon	163	5,300	3.3	33	20.4
Avon Valley	813	47,000	5.8	195	23.9
Yealering Lakes	661	35,900	5.6	123[3]	19.1
Mortlock	1,326	111,800	8.4	431	32.5
Northern Sandplain	687	34,700	5.1	209	30.4
South-east Lakes	1,604	98,000	6.1	399[1]	24.9
Carabbin	1,794	49,500	2.8	553[2]	30.8
Southern Cross	189	3,200	1.7	60[4]	31.7
TOTAL	**7,385**	**388,300**	**5.3**	**2,027**	**27.4**

Information from Land Monitor

1 – upland valleys, soil mapping limitations
2 – low relief, incomplete Land Monitor coverage
3 – soil mapping limitations
4 – over-estimation, deep regolith and watertables.

Table 4.2: Potential extent of threats to land resources within the Avon River Basin based on soil type risk assessment

Area	**'000 hectares and (percentage of total)**							
Land quality *Value*	**Phosphorus export**	**Soil structure decline**	**Subsurface acidification**	**Subsurface compaction**	**Water erosion**	**Waterlogging/ inundation**	**Water repellence**	**Wind erosion**
Extreme	76 (1%)				64 (<1%)			<0.5 (<1%)
Very high	670 (9%)				92 (1%)	213 (3%)		251 (4%)
High	74 (1%)	10 (<1%)	2,171 (30%)	3,000 (42%)	178 (2%)	132 (2%)	978 (14%)	1,204 (17%)
Moderate	2,267 (32%)	716 (10%)	1,906 (27%)	2,883 (40%)	1,147 (16%)	1,346 (19%)	2,517 (35%)	2,225 (31%)
Low	3,998 (56%)	6,362 (89%)	2,766 (39%)	1,200 (17%)	2,652 (37%)	898 (13%)	317 (4%)	3,440 (48%)
Very low					2,945 (41%)	1,263 (18%)		
Presently acid			145 (2%)					
Nil						3,225 (45%)	3,177 (44%)	
Not applicable	79 (1%)	76 (1%)	177 (2%)	82 (1%)	87 (1%)	87 (1%)	175 (2%)	45 (<1%)
TOTAL *	7,165 (100%)	7,165(100%)	7,165 (100%)	7,165(100%)	7,165 (100%)	7,165 (100%)	7,165 (100%)	7,165 (100%)

Source: van Gool and Moore 1999, and Department of Agriculture 2005

Does not include analysis of miscellaneous/undescribed soils.

4.3 Issues not addressed in the strategy

4.3.1 Climate change

Due to the uncertainty about how much effect human action will have on climate change and how much these changes will affect agriculture, this issue has not been addressed in the context of land resources.

It should be noted that the short-term impact of climate change on agriculture may not be significant, however, predicted changes (2070 compared to 1990) for the south-west of Western Australia (CSIRO 2001) include:

- higher temperatures (1-5^{o}C warmer),
- changing rainfall trends (lower, by up to 60%, or higher by up to 10%)
- higher evaporation rates
- more frequent extreme weather events.

CSIRO's website (accessed in 2004) estimates that greenhouse gas emissions from agricultural production represented 20% of Australia's national emissions in 1999 (excluding land clearing). Methane gas emission by ruminants contributes 60.3 Mt of the total greenhouse gases produced in Australia. There are significant opportunities to reduce gas emissions or provide carbon trading offsets for areas with excess gas emissions through tree plantation industry development with the Avon River Basin (Shea 1997, Barlow 2001). This may be undertaken as a part of the agricultural industry or through independent industry development.

4.3.2 Remnant vegetation decline

The value of remnant natural vegetation is considered in detail in the Biodiversity Conservation Supporting Document, prepared by the Department of Conservation and Land Management for the Avon Catchment Council (2004).

4.3.3 Biotechnology

The recent moratorium on commercial production of genetically modified crops in Western Australia reduces immediate decisions and their impacts in the ARB. In the longer term these may have an influence and strategies will be developed then.

4.3.4 Herbicide resistance

Herbicide resistance, while a threat to farming systems, may be managed by individual farmers. The impacts of this issue on native vegetation has not been determined.

5. Assessment of threats to land resources

5.1 Methodology

An assessment of threats has been undertaken through processes that consider the potential risk and the potential impact for land resources. Risk was considered in terms of timing, i.e. was the risk likely to be imminent (0-20 years), medium-term (20-75 years) or long-term (>75 years). Then the potential scope and severity of the risk was broadly assessed. The assessment process was based on the set of guidelines shown in Table 5.1. Information used in the assessment process also included the condition of the asset impacted and the potential benefits of available management options and the ease with which these options could be implemented.

Table 5.1. Categories for assessment of land resource threats

Threat category*	**Definition#**
High	Current/imminent risk of high impact
Moderate	Current/imminent risk of moderate impact OR Medium-term risk of high impact
Low	Current/imminent risk of low impact OR Medium-term risk of low-moderate impact OR Long-term risk of high impact

*** Impact scale**	**# Time scale**
High impact (majority of asset at risk)	Current/imminent (within 0-20 years)
Moderate impact (some of asset at risk)	Medium-term (within 20-75 years)
Low impact (minority of asset at risk)	Long-term (greater than 75 years)

The threats were assessed through consultation with representatives of agricultural industries to establish priorities. The factors considered in setting priorities were:

- impact of natural resource trends on agricultural industry activities;
- impact of industry activities on resource condition;
- distribution of threats within land resource sub-regions;
- review of the priority of threats; and
- industry targets relevant to resource management.

Key stakeholders involved in the consultation processes were:

- District Consultative Groups (for agriculture industry development);
- Department of Agriculture (Agricultural Resource Management, Animal Production and Grains Programs);

- Department of Fisheries;
- Greening Australia (WA);
- attendees at the Newdegate and Dowerin Agricultural Field Days; and
- local communities throughout the ARB.

5.2 Sub-regional threat rating

Using the methodology described in Section 5.1, threats were assessed on a sub-regional scale on the basis of 'community concern' and then assessed according to 'feasibility of options to address the threat' and investment value in threat abatement. The results of community assessment are shown in Table 5.2.

Table 5.2: Priority of threats for each land resource sub-region

Land resource threat	DARLING RANGE	DALE/UPPER AVON	AVON VALLEY	YEALERING LAKES	MORTLOCK	NORTHERN SANDPLAIN	SOUTH-EAST LAKES	CARABBIN	SOUTHERN CROSS
Soil acidity	Mod	High	High	Mod	High	High	High	High	Low
Dryland salinity[1]	Mod	High	High	High	High	High	Mod	High	Mod
Subsurface compaction	Mod	Mod	Mod	High	Mod	Mod	High	High	Low
Waterlogging	High	High	Mod	Mod	Mod	Low	Mod	Mod	Mod
Water erosion	High	Mod	Mod	Mod	Mod	Low	Low	Low	Low
Soil structure decline	Low	Mod	High	Low	Mod	Low	Mod	Mod	Low
Flooding	Low	Low	High	Low	Mod	Low	Low	Low	Low
Water repellence	Low	Low	Low	Mod	Mod	Mod	Mod	Low	Low
Surface water supply shortages	Low	Low	Low	Low	Low	Mod	Mod	Mod	Mod
Wind erosion	Low	Low	Low	Mod	Mod	Mod	Low	Low	Low
Nutrient loss/ eutrophication	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Land use pressure	Low	Mod	Low	Low	Low	Low	Low	Low	Mod
Acid sulfate soils	Low	Low	Mod	Low	Low	Low	Low	Low	Low
Soil fertility decline	Low	Low	Low	Low	Low	Low	Low	Low	Low
Groundwater acidity				Low		Low	Low	Low	
Biosecurity[2]	High	High	High	Mod	Mod	Mod	Mod	Mod	Mod
Remnant vegetation decline[3]	Low	High	High	High	High	High	Mod	High	Low

[1] Salinity discussions identified that a potential extended period between current and predicted full extent of salinity. This could be perceived to lower the priority of activities. However, the rate of management response is also slow, and it was deemed important that management activities occur as a priority in order to prevent or minimise future impact.

[2] Biosecurity was ranked as a key threat across sub-regions. This is a management issue rather than a physical resource issue. It was identified as a key industry issue and has been addressed as such.

[3] Remnant vegetation is impacted by resource threats and is not a resource threat in its own right. Consequently the management of resource threats should contribute positively to remnant vegetation e.g. protection of remnant vegetation to assist in salinity management. Remnant vegetation was considered highly important from a biodiversity perspective.

6. Goals, targets and actions

6.1 Setting strategic direction

The approach to managing the threats to land resources within the Avon River Basin outlined in Section 5 is based on identifying:

- Resource indicators (threats);
- Resource condition targets;
- Management action targets; and
- Outputs/actions.

This process follows NRM planning logic as outlined by the Australian Government (see Figure 6.1).

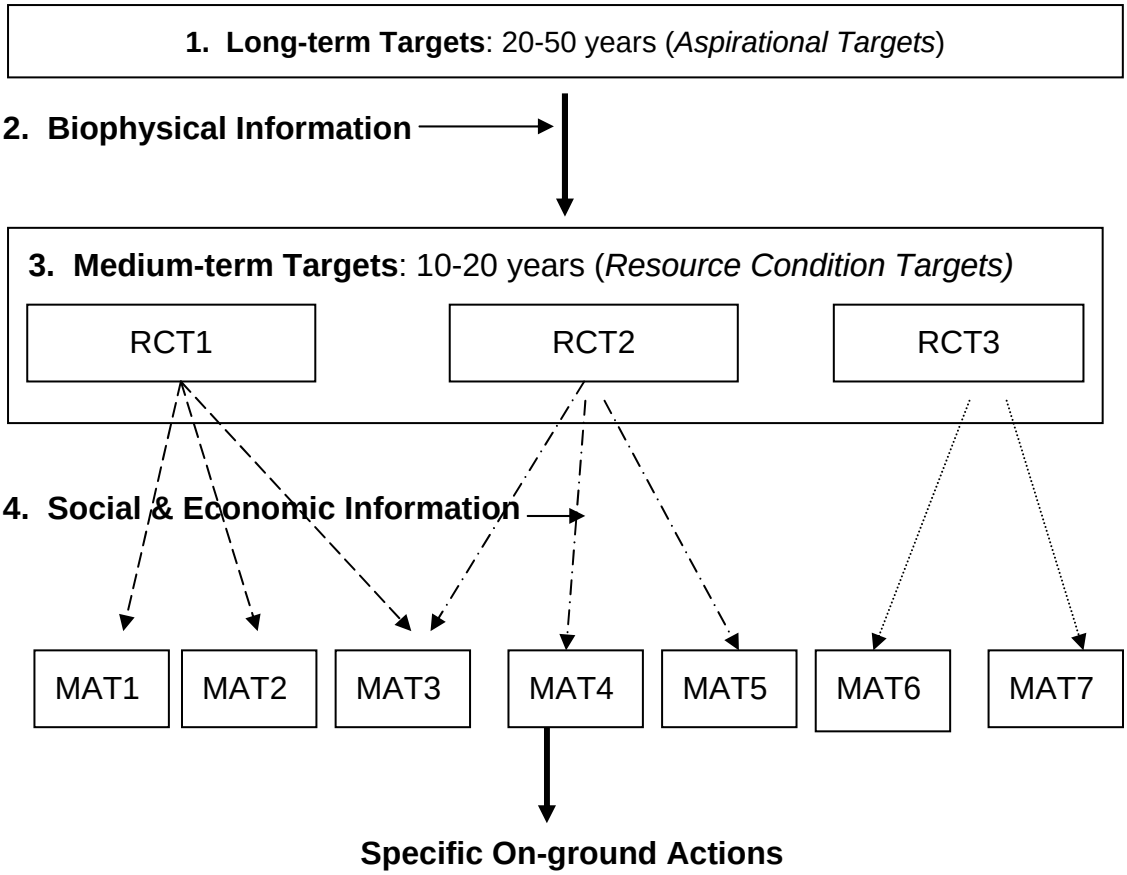


Figure 6.1. Natural resource management planning logic

The threats have been assessed for each sub-region through workshop processes with informed people in the agricultural industry. Resource condition targets were developed during these processes in a format consistent with recommendations of the NRM Council Monitoring and Evaluation Working Group (August 2003).

Management Action Targets and Management Actions were also developed for each threat to land resources in the Avon River Basin and priorities established for these.

6.2 Resource condition targets for land resources

Resource Condition Targets (RCTs) are identified based on management of threats to the resources. RCTs address the key threats to land resources described in Section 5 and identify sub-regional priorities. Land resource threats have been grouped into Soil condition, Land salinity and Biosecurity.

Information used in the development of the targets is shown in the supporting report (Galloway 2005).

6.2.1 Soil condition

Soil condition combines soil acidity, compaction, structure decline, erosion and waterlogging threats. Soil is the largest natural resource and often considered only in the context of its use by agricultural industries. Most is on privately-owned land. Healthy soils are important for many reasons, not only sustaining plant and animal productivity, but also maintaining or enhancing water and air health, and supporting human health and habitation.

Microbial diversity within soils is directly related to indicators such as pH. In theory, soil is a renewable resource, however processes such as acidification, erosion, compaction and waterlogging all contribute to its decline. The off-site impacts of soil condition decline are often difficult to identify, however, if the example of acidification is examined, the impacts of reduced plant growth and water usage may be seen in increased water run-off, waterlogging downslope, increased turbidity of streams and nitrate leaching. As most threats to this resource are derived from agricultural management, the response to managing soils should primarily be taken in an agricultural industry context.

The aspirational target for soils is:

"Soil health and productivity is significantly improved through the management of top and subsoil acidity, soil compaction, soil structure decline, waterlogging, water erosion and wind erosion."

The resource condition targets are:

1. Soil acidity levels (top and subsurface) at or above pH 5.5_{Ca} by 2020, in all soils with low capacity to buffer pH change*. Priority areas for immediate action include Carabbin, Avon Valley, Mortlock and Yealering Lakes (total of 55,000 ha).

2. A 50% reduction in the area affected by soil structure decline and subsurface compaction by 2020. Priority areas for immediate action are 182,000 ha of coarse-textured soils in Carabbin, Northern Sandplain and Mortlock and 587,000 ha of medium to heavy-textured soils in Carabbin, SE Lakes and Southern Cross.

3. A 50% reduction in the area most affected by soil erosion and waterlogging by 2015. Priority should be given to land with slope classes from 3-10%, which have very high to extreme water erosion problems. In areas with slopes less than 3% the combined impact of waterlogging (perched watertables at 50 cm for three to six months in an average year) and water erosion should be the focus.

4. Annual average wind erosion extent is determined for at-risk sandy duplex soils (197,000 ha) in the South-east Lakes and Yealering Lakes, on deep sand and sandy and loamy duplex soils in the Northern Sandplain and on heavy-textured soils in the Avon Valley by 2010. Wind erosion is reduced by 80% over the determined benchmark by 2020.

5. All soils with recognised fertility issues (elements, organic matter and microbial activity) are identified within five years and a 30% improvement over benchmarked fertility levels is achieved by 2020.

* The extent and severity of subsoil pH levels need to be determined over the time period noted. The documented long-term detrimental impacts of not managing subsoil acidity is the driver for this RCT.

6.2.2. Land salinity

Nearly one-third of the landscape is at risk from dryland salinity and the lower rainfall wheatbelt zone currently has the highest levels of salinisation in and around valley floors. Such risk is not confined to valleys and drainage lines but includes many lower to middle landscape positions. While at present most of the area affected by salt is on agricultural land, the impacts for a range of regional resources such as water, biodiversity and infrastructure will be significant, including:

- As salinity encroaches on wetlands and remnant vegetation, species loss will occur and is likely to include species extinction.
- Available domestic and stock water supplies will also be impacted and the combination of waterlogging and salinity in some areas will not only limit plant growth, but will also contribute to erosion and off-site impacts.
- Rural population decline will increase, due to the impact of salinity on income and livelihoods.
- Loss of infrastructure will occur; roads in particular will be significantly affected, as will towns in susceptible areas.

The scale and type of management responses to deal with salinity need to be targeted at the range of landscapes that are and may be affected, and consider both engineering and biological responses to salinity management.

The aspirational target for land salinity is:

“The extent of impact of surface and groundwater salinity on productive land is contained and where possible, reduced. Land that is salt-affected is used productively or to enhance conservation values.”

The resource condition targets are:

6. Reduction in the average rate of groundwater rise on land in middle and upper catchment areas from 15-30 mm to 10-20 mm by 2025.

7. The extent of valley floor salinity to be less than 12% of land used for agriculture by 2025. (Note: the area currently affected is 5.4%. This is expected to eventually increase to over 27%.)

6.2.3 Biosecurity

Agricultural and environmental pests and diseases create significant problems for land managers. Introduced pests compete with native plants and/or agricultural crops and pasture species, and the cost to agricultural industries has been estimated at over $3.3 billion per annum nationwide. Pest animals can cause severe degradation of agricultural land and the costs associated with their management adds to the total cost of agricultural production. The environmental costs of not managing such problems include the disruption of the natural ecosystems and the extinction or decline of native species.

Awareness of biosecurity risk issues and threats to agriculture and environmental systems within the region needs to be enhanced and all landholders (private and public) need to take

responsibility for managing biosecurity issues. Planning for biosecurity needs to be carried out at all industry levels, including State and local government. Such management should consider the value of biosecurity in an industry and NRM context.

The aspirational target for plant and animal pests and diseases is:

"Cooperative action undertaken by local communities across landscapes is effectively controlling or has eradicated plant and animal pests as well as diseases across the region. Additional biosecurity threats are contained or avoided."

The resource condition target is:

8. A 50% reduction in the economic and environmental impacts of all priority animal and plant pests across the region by 2014. (Note: this target is to be considered in relation to both regional and State responsibilities for threat reduction, including the statutory requirements currently administered by government. There are opportunities within the region for coordinated management of nearly all pests, especially environmental weeds, foxes, wild dogs and rabbits.)

6.3 Management action through farming systems

The RCTs are expected to be supported by management actions that are integrated into farming systems. A systems-based approach provides the following benefits:

- multiple benefit outcomes by managing more that one threat to natural resources;
- land management practices based on improved production for which the likelihood of successful adoption is high; and
- a range of landscape-scale resource management approaches is adopted.

Components of farming systems that are required to be implemented to achieve land resource condition targets by 2025 are:

- land use is matched to land capability;
- soil acidity is managed to Best Management Practice (BMP) standards and subsoil acidity is the focus of ongoing research and management;
- new and improved options for managing saline land are developed, including incorporation of phase farming approaches (commercial and non-commercial annuals and perennials), native pastures, engineering options (including drainage), remnant vegetation protection/enhancement and application of new commercial salt-tolerant plant species;
- there is ongoing implementation of BMP for soil compaction and soil structure decline, and tramline and precision farming skills are applied where appropriate;
- waterlogging is managed with a focus on waterlogging-tolerant pastures and better surface water control;
- surface water management is considered in a whole of farm context and is put in place to prevent water erosion and for water harvesting benefits; and
- stubble retention, windbreak establishment and livestock management have increased importance for prevention of soil loss through wind, and to some degree, water erosion.

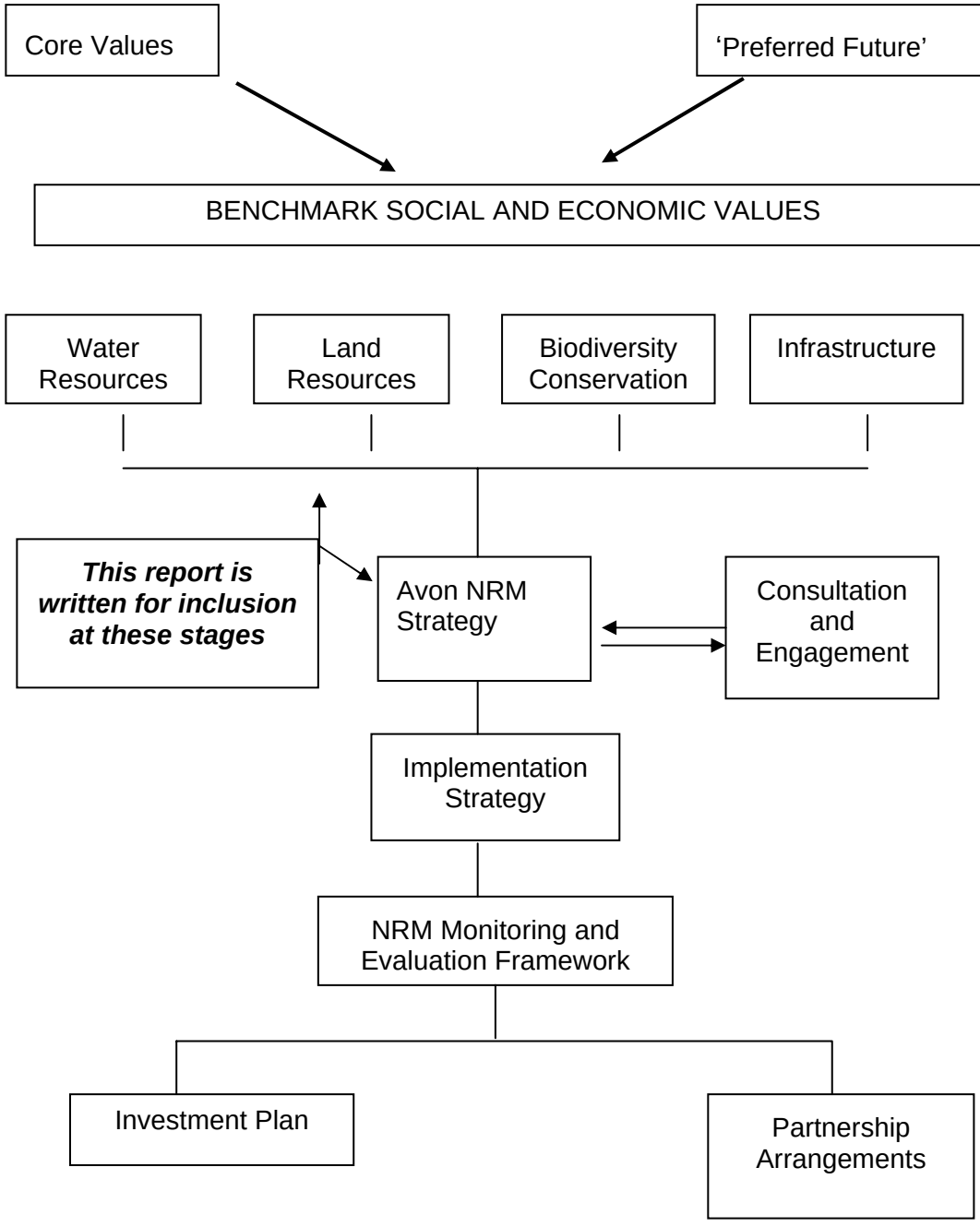
The information required to implement some components of farming systems is not currently available or has not been demonstrated sufficiently to encourage adoption. Practical skills required in the adoption of farming systems application may also be a limiting factor in some communities. Landholders' capacity to change may be limited by sufficient funds, knowledge

or technical skills but these can all be addressed if the need to change is clear. To achieve farming system outcomes, the following actions are proposed:

- undertake a comprehensive assessment of land resources to determine the spatial extent of threatening processes;
- develop new management actions appropriate to RCTs;
- build capacity to encourage adoption and adaptation of BMPs;
- demonstrate management actions for farming systems and the benefits of threat reduction;
- address specific issues that may inhibit adoption rates of recommended practices; and
- identify 'benchmarks' for actions and outcomes to enable ongoing development of BMPs and to monitor change (positive or negative) as a result of actions.

7. Conclusion

This document was prepared for use in developing the land resources component of the Avon River Basin NRM Strategy coordinated by the Avon Catchment Council in 2004. The other major components in the strategy are water resources, biodiversity conservation and infrastructure. Figure 7.1 outlines the process used to develop the strategy and where this report contributed in the process.



Adapted from ACC NRM Strategy presentation 2004

Figure 7.1. Flow diagram for the development of the Avon NRM Strategy

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9. Appendices

Appendix 1: Targets

When reading the information below it is important to note that:

- Some resource monitoring should be undertaken at cross-regional level to fulfill State requirements and provide consistency across regions (indicated as cross-regional in the tables). The responsibility for such actions has not been allocated but in many cases a continuation of State agency activities may be appropriate.
- Surrogate measures of the outputs of Management Action Targets (MATs) may be applicable, where specific indicators are absent, difficult to quantify, or have not been adequately identified e.g. number and type of surface water management structures could measure the impact of controlling water erosion.
- The term Best Management Practice (BMP) is applied in nearly all targets and outputs. The choice of best practice/s will depend on the physical conditions of the area, location within a landscape and scale of the problem. The primary practices that would constitute a BMP have been identified in the accompanying report (Galloway 2005). All BMPs include consideration of general biosecurity risks and management.
- There is a benchmarking component against most outputs in managing soil condition and salinity. This will involve reviewing available methods of measuring practice impact; developing (existing or modified) mechanisms for relating a practice to resource condition; determinating other resource benefits that occur from the practice (e.g. perennials for recharge control also provide ground cover reducing erosion) and providing practical mechanisms for farm-scale application. It will also include providing feedback to ongoing review and development of BMPs. Key outcomes will include indicating the amount of practice change (adoption) and impact of management choices on resource condition.

Soil condition

Acidity

The resource condition target is to achieve soil acidity levels (top and subsurface) at or above pH 5.5_{Ca} by 2020, in all soils with low capacity to buffer pH change*. This target has very high priority.

This RCT and its associated management action targets and outputs (Table A1.1) applies for all soils with low capacity to buffer pH change[1], in upland, slope and valley landscapes across the Avon River Basin. It does not apply to heavy-textured and/or alkaline soils. The area suggested for immediate action covers 55,000 hectares of the Carabbin, Avon Valley, Mortlock and Yealering Lakes sub-regions.

[1] pH buffering capacity refers to the ability of soil to resist changes in pH after the addition of an acid or base. Organic carbon levels, exchangeable aluminium levels and clay percentage are important criteria for determining pH buffering capacity of soil.

Table A1.1: Management action targets and outputs for soil acidity

Management Action Target	Output (Action)
1. By 2008, establish a database to record point measurements of topsoil and subsoil pH.	Established methodology for monitoring the pH of topsoil and subsoil. Land use practices that affect soil pH are monitored. A pH status map at sub-regional scale is produced from point data.
2. By 2008, complete research on viable alternative options to manage topsoil acidity and viable alternative options for agricultural production to reduce the cause of acidity.	A report documenting the outcomes of research about alternative options including: - Application of ash produced from biomass energy production - fertiliser type and application rates - Lateral translocation of bases from alkaline to acid areas.
3. By 2008, map the spatial extent of management actions that ameliorate low pH.	Monitoring of land use practices that affect soil pH and their trends. The management actions map is linked to a pH status map, contributing to State-level monitoring and evaluation. A benchmark of management actions is established via targeted biennial land manager surveys.
4 (a). By 2006, hold workshops that educate and train land managers about appropriate soil management, at 20 locations throughout the region **4 (b).** By 2008, 80% of land managers have knowledge of best management practices for ameliorating soil acidity (including economic benefits).	Arrange soil management workshops. Network arrangements with farm consultants and other information or service providers to ensure 'best practice' advice is provided for soil management. Extend and review BMP for managing acidity in relation to practice adoption, linking acidity management to overall soil health and cumulative impact on resource condition. Specific BMP for management of acid subsoils developed by 2007. Recommence soil acidity awareness extension campaign focusing on both topsoil and subsoil acidity.
5. By 2005, establish a regional monitoring and evaluation plan with links to State monitoring and evaluation structures.	Actions and outputs to be determined after regional monitoring and evaluation strategy is developed.

Soil structure decline and subsurface compaction

The resource condition target is a 50% reduction in the area of soils most affected by structural decline and subsurface compaction by 2020.

This RCT and its associated management action targets and outputs (Table A1.2) applies to all uplands, slopes and valleys with a medium priority.

Priority areas for immediate action are 182,000 ha of coarse-textured soils in Carabbin, Northern Sandplain and Mortlock and 587,000 ha of medium to heavy-textured soils in Carabbin, SE Lakes and Southern Cross.

Suggested compaction indicators would include penetrometer readings at representative monitoring sites, infiltration rates and area of surface sealing. Possible surrogate indicators

could include controlled traffic usage and ripping rates (both farmer-sourced), rates of gypsum application (from ABS), minimum tillage application, green/brown manuring rates, stubble incorporation rates.

Table A1.2: Management action targets and outputs for soil compaction and structural decline

Management Action Target	Output (Action)
6. A reliable method of assessing the extent of compaction and structural decline is available by 2006.	Method to determine the extent of soil compaction and structural decline in soils used for agriculture (cross-regional).
7. A 50% increase in the adoption of viable soil management techniques by 2009.	**(a).** Extend BMP for soil compaction/structural decline including tramline and precision farming techniques. **(b).** Benchmark - changes in uptake of practice - resulting contribution to resource condition change (threat focus).

Soil erosion and waterlogging

The resource condition target is a 50% reduction in the area of land affected by soil erosion and waterlogging by 2015.

This target and its associated management action targets and outputs (Table A1.3) applies to all soils in uplands, slopes and valleys.

Priority is very high, particularly for land with slope classes from 3 to 10% which have very high to extreme water erosion problems. The Avon Valley, Darling Range, Dale/Upper Avon and Mortlock West sub-regions have sheet and rill erosion potentially affecting 87,000 ha.

In areas with slopes less than 3% the combined impact of waterlogging (perched watertables at 50 cm for three to six months in an average year) and water erosion should be the focus. The South-east Lakes, Darling Range, Avon Valley, Mortlock and Yealering Lakes have about 219,000 ha of this country.

Management of water erosion on slopes is difficult and long-term revegetation may be the only feasible technique. In the longer term, techniques established now may allow this to be expanded. It is important to note that flooding in the Avon Valley is dealt with in the management action targets for this resource condition, as management of 10-20 year flood events may be feasible using management described. Capacity to deal with 50-100 year flood events is beyond the scope of most planned activities in a land use context.

Waterlogging often depends on environmental conditions (soil type and climate). This target is focused on areas with the highest risk and where waterlogging is having the highest impact (combined with erosion). A 50% reduction is considered feasible in an average year, using current management. Longer term, with the compounding effects of perennial species, it is estimated that management will result in a wider area recovered. Waterlogging is still important as the combined effects of waterlogging, subsurface compaction and salinity can have major on- and off-site impacts.

All areas are affected, particularly uplands and slopes with immediate priority in Avon Valley, Darling Range, Dale/Upper Avon and Mortlock (West).

Suggested indicators could include caesium measurements, satellite image of ground cover at end of summer, run-off to dams, sediment levels in streams and rivers, extent of gullies etc. Other possible indicators include satellite images of extent, linked to yield reductions (crop and pasture), accessibility for vehicles and associated water erosion. Surrogates might include length, type and landscape position of earthworks, extent of creeklines protected and excluded.

Table A1.3: Management action targets and outputs for soil erosion and waterlogging

Management Action Target	Output (Action)
8. 50% of the landscape managed using BMP for water erosion by 2009 (improved surface water management aligned with farm water supply to minimise erosion and optimise water balance across landscapes).	**(a).** Review, revise and extend BMP for water erosion to land managers including: - Whole of catchment (farm as subset) surface water management planning - Broad-based banks and feedlots - Tillage methodology (including no-till) - Management for 10-20 year flood events in susceptible catchments (Avon Valley focus) - Guidelines for stubble retention - Capacity building for catchment planners and technical service providers. **(b).** Extend BMP for stream and waterway management and promotion of catchment planning to regenerate riparian vegetation. **(c)** Benchmark - changes in uptake of practice - resulting contribution to resource condition change (threat focus).
9. Reduction of area of waterlogged soils on agricultural land, including: - 25% increase in length of reverse interceptor banks in >450 mm rainfall area by 2009. - 50% increase in area of waterlogged soils planted to tolerant species, including perennials in >400 mm rainfall area by 2009.	**(a).** Develop catchment-scale surface water management plans. **(b).** Waterlogging BMP extended to land managers, including benefits of waterlogging-tolerant pastures (e.g. balansa, tall wheat grass). **(c).** Benchmark - changes in uptake of practice - resulting contribution to resource condition change (threat focus).

Wind erosion

The resource condition target is for wind erosion to be reduced by 80% on the sandy duplex soils (197,000 ha), at risk in the South-east Lakes and Yealering Lakes, on deep sand and sandy and loamy duplex soils in the Northern Sandplain and on heavy-textured soils in the Avon Valley by 2014.

This RCT and its associated management action targets and outputs (Table A1.4) applies to uplands, slopes and valleys with high priority.

Wind erosion can be managed and there is sufficient information to allow land managers to significantly reduce the incidence of this problem (hence the 80% target). Low investment is generally required, aimed at capacity building activities.

Suggested indicators could include caesium measurements, satellite image of ground cover at end of summer, and air quality testing. Surrogates might include extent and type of windbreaks, stock numbers.

Table A1.4: Management action targets and outputs for wind erosion

Management Action Target	Output (Action)
8. 80% of soils with 50% of anchored ground cover at the end of summer by 2008.	**(a).** Review, revise and extend BMP for wind erosion, emphasis including: - Raised awareness of on-farm risk areas and management possibilities - Stubble retention and broad scale livestock management - Windbreak establishment - BMP to be closely linked to oil mallee establishment in the Northern Sandplain. **(b).** Benchmark changes in uptake of practice, and resulting contribution to resource condition change (threat focus).
9. The extent of wind erosion and environmental and economic loss due to this process estimated across all asset classes by 2009.	Develop a GIS-based system to map the extent of wind erosion and equate loss in a range of climate conditions, to benchmark: - Physical extent (from ground cover remaining at the end of summer) - Estimated economic loss based on extent and severity mapping.

Soil fertility

Resource condition target is that recognised fertility issues (elements, organic matter and microbial activity) are identified within five years and a 30% improvement over benchmarked fertility levels is achieved by 2020.

This is very high priority affecting all areas with very high priority. Management action targets and outputs are shown in Table A1.5.

Table A1.5: Management action targets and outputs for soil fertility

Management Action Target	Output (Action)
10. A reliable method of assessing soil fertility levels for all regional soil groups is available by 2009.	Develop a method using existing database to determine the extent of soil fertility rates in soils used for agriculture (cross-regional).
11. 80% of land managers have knowledge of BMP for maintaining soil fertility by 2008.	Using existing data, develop and extend BMP for sustainable soils by 2008. BMP to include: - Benefits of increasing organic matter - Options for increasing major and minor soil elements in deficient soils - Role, benefits and management of soil microbes and soil macro-fauna.

Land salinity - *Groundwater and salinity*

Resource condition targets are reduction in average rate of groundwater rise on land in middle and upper catchment areas from 15-30 mm to 10-20 mm, and the extent of valley floor salinity less than 12% of land used for agriculture by 2025. In valley floors, the area currently affected is 5.4% but expected to increase eventually to more than 27%.

The target covers all asset classes with very high priority. Management action targets and outputs are shown in Table A1.6. It involves very significant reductions in groundwater rise, but is considered essential to allow recovery and containment and ongoing use of the land resource.

These activities require the greatest level of investment, generally over the longest period. However the benefits to all resources and specific assets (water, biodiversity and infrastructure) from management are very high.

In valley floors, the aim is to contain salinity and use saline land. Drainage will be examined for its ability to impact on groundwater and off-site impacts such as acid groundwater movement. This is considered an interim target. Current data suggest that recovery in this landscape position is unlikely without massive intervention (e.g. >70% of landscape). This is unlikely in the mid-term given economic and agricultural trends. Further action is required to determine condition of this asset.

Groundwater levels, quality and rate of change (levels and quality), extent of salt-affected land (satellite images and Land Monitor) are likely indicators.

The target for valley floors recognises that saline land has a value in its own right and the intent is to contain salinity in these areas and use saline land as a resource. There should also be recognition that time from clearing will impact on salinisation rates in different areas.

Table A1.6: Management action targets and outputs for groundwater and salinity

Management Action Target	Output (Action)
12. High risk groundwater recharge landscape zones identified for all shires, linked to priority assets by 2009.	**(a).** Identify areas of greatest risk (including local flow systems) as part of preparing local area plans. **(b).** Develop targeted options to manage such sites.
13. Review of dryland salinity best practice options by 2006.	Determine the impacts of minimum tillage on recharge and run-off and investigate alternative tillage methods. Research and improve salinity options BMP. Specific focus includes: - Phase farming systems which use commercial woody perennials - Native pastures for saline lands - Saltland pastures and saltbush alleys - Arterial and local drainage feasibility and impact assessment - On-farm pumping and evaporation basins - Aquaculture and mineral extraction using pumped groundwater.
14. Integrated catchment plans are prepared for 50 catchment as part of local area plans in high salinity risk areas by 2009.	**(a). Identify catchment priorities for integrated planning processes.** **(b). Arrange preparation of five integrated catchment plans each year.**
15a. Conduct 50 workshops for best management practice as part of integrated catchment planning processes by 2009. **15b.** 80% of land managers understand the benefits of the application of alternative groundwater management techniques and a systems-based approach by 2009.	Extension of BMP for salinity management, including: - surface water management - phase farming processes that incorporate commercial perennial, annual crop and pasture options targeted to environmental conditions and linked to positive farm productivity outcomes **-** valuing remnant vegetation for resource management protection and farm production - salt-tolerant species (including plant breeding outcomes), saltland pastures, saltbush alleys and PURSL options - farm drainage and pumping guidelines (technical/legal) - financial management skills to budget for NRM expenditure. Extension of BMP for seepage management, including: - Alley farming and block plantings using salt-tolerant commercial and non-commercial species - Options for desalinisation, siphoning and water usage.
16a. At least 50% of the landscape identified within local area plans using best management practice options by 2009 (with a focus on managing local flow systems and points of high recharge e.g. bases of granite outcrops). **16b.** More than 100,000 ha of saltland revegetated for production of conservation benefit by 2009.	Catchment demonstration of best practice for salinity management. Benchmark - changes in uptake of practice - resulting contribution to resource condition change (threat focus).

Management Action Target	Output (Action)
16c. More than 50,000 ha of deep-rooted perennial pastures established for groundwater management by 2009. **16d.** More than 10,000 ha of commercial tree crops are established in areas to gain groundwater control benefits by 2009,	
17. Benchmark groundwater levels and quality consistent with National Land and Water Resources Audit standards by 2008.	Groundwater level and quality monitored and assessed (cross-regional) Area of salinity monitored, including improved mapping (cross-regional).

Biosecurity threats

The resource condition target is for a 50% reduction in the economic and environmental impacts of all priority animal and plant pests by 2014.

Table A1.7 lists the main biosecurity threats in the Avon River Basin sub-regions and Table A1.8 summarised the targets and planned actions.

This target involves both regional and State responsibilities, including the statutory requirements currently administered by government. There are opportunities within the region for coordinated management of nearly all pests, especially environmental weeds, foxes, wild dogs and rabbits.

Indicators could include numbers and extent of animal pests; the extent and density of weeds (priority areas) and extent of plant and animal pest programs coordinated though community groups. Surrogate measures could include uptake of control measures such as specific herbicide usage rates (e.g. targeted at woody plant species), 1080 usage, attendance at field days etc, target group surveys.

Table A1.7. Plant, animal and disease threats managed by biosecurity for Avon River Basin sub-regions

Biosecurity threat	Impact	DARLING RANGE	DALE/ UPPER AVON	AVON VALLEY	YEALERING LAKES	MORTLOCK	NORTHERN SANDPLAIN	SOUTH-EAST LAKES	CARABBIN	SOUTHERN CROSS
Animal pests										
Dogs	Predatory	Y						Y	Y	Y
Foxes	Predatory/ Environmental corridors	Y	Y	Y	Y	Y	Y	Y	Y	Y
Emus								Y		Y
Pigs	Environmental		Y		Y				Y	
Deer	Environmental/production	Y	Y	Y	Y					
Rabbits		Y	Y	Y	Y	Y	Y	Y	Y	Y
Exotic birds	Environmental	Incident reports only								
Native parrots	Environmental/production	Y	Y	Y						
Hydatids	Stock	Y	Y	Y						
Plant pests										
Bridal creeper	Environmental impact	Y	Y	Y	Y					
Boneseed (biteou)	Production		Y							
Golden dodder	Production		Y							
Heliotrope	Production				Y			Y		
Skeleton weed	Production	Y	Y	Y	Y	Y	Y	Y	Y	Y
Saffron thistle	Production/Env. impact							Y	Y	Y
Bathurst burr	Production/Env. impact							Y	Y	Y
Cape tulip	Environmental impact		Y							
Tagasaste	Environmental impact	Y	Y	Y						
Distichlis	Weed potential									
Salt grass	Weed potential									
Introduced grasses		Y	Y	Y						
Diseases										
Soil-borne	Stock and potentially native fauna	Stock movement - intra and inter-region								
Plant e.g. rust	Production	Machinery and people movement - intra and inter-region								
Intensive feedlots, piggeries	Stock and environment	Site-specific								

Table A1.8. Biosecurity targets and actions

Management Action Target	Output (Action)
18. State and national strategic planning for plant and animal pests and diseases is understood by all LGAs, LCDCs and catchment groups and the ACC is providing local implementation groups with such threat assessments via formal communication methods (e.g. regular pest and disease updates) by 2005.	Review, discussion and distribution of State and national strategies for animal and plant pest and disease management with regional stakeholder groups.
19. By 2007 the ACC will be a key information source and provide a link between policy planning and local issues to ensure coordinated regional responses to State and national pest and disease strategies.	Support for distribution of threat assessment information from State and National governments to local groups.
20(a). By 2008, 80% of land managers have knowledge of the impacts and management of priority plant pest species. **20(b).** By 2009, extent of rabbit, cat, dog and fox pests, their economic and environmental impacts and management options will be understood by 80% of land managers.	Use of modelling of distribution patterns of target animal and pest species, linked to development of appropriately scaled management responses and BMP. Facilitation of coordinated management plans between all land users at local level for implementation of BMP. Awareness campaign for land managers targeting the environmental and economic impacts of animal pests. Awareness campaign for land managers targeting identification of priority plant pest species (environmental and economic).

Appendix 2. Description of land resource sub-regions

The Avon River Basin has been divided into nine land resource sub-regions (Table A2.1), each with distinct bio-physical characteristics. They form the spatial basis for reporting on the condition of natural resources used and affected by agriculture.

These sub-regions were defined by the extent and characteristics of 17 hydrological zones (HDZs) that lie within the ARB. Smaller units have been amalgamated with larger ones where appropriate, to form meaningful regional-scale areas.

Note that apparent (small) errors in the areas documented throughout this report may result from:

- methods used to generate the National Land and Water Resources Audit (NLWRA) datasets, where all remnant vegetation of less than 50 ha on private land was classed as 'agricultural land';
- 'smoothing' (vector weeding) the NLWRA land-use spatial data to simplify the dataset;
- using some datasets that do not provide a blanket cover of the ARB or its sub-regions, even though they are the most accurate available; and
- presenting rounded numbers that have been compiled from more precise figures in the original datasets.

Table A2.1: Land resource sub-regions within the ARB

Agricultural sub-region	Total area (ha)	Agricultural area (ha)	Agricultural area (%)
Darling Range	224,000	148,000	2.0
Dale/Upper Avon	169,300	163,000	2.2
Avon Valley	833,100	813,000	11.3
Yealering Lakes	679,300	659,000	9.2
Mortlock	1,370,000	1,326,000	18.5
Northern Sandplain	738,000	687,000	9.5
South-east Lakes	2,010,900	1,397,000	19.5
Southern Cross	248,800	189,000	2.6
Carabbin	2,032,700	1,777,000	24.8
Land unallocated	6,100	2000	<0.1
Total ILZ part of Basin	**8,313,200**	7,161,000	100.0

Note: Area limited to 'Avon Arc' and 'Wheatbelt' zones of the ARB.

For a full description of the land resource sub-regions, refer to Galloway (2005).

1. Darling Range

The Darling Range sub-region occupies the woolbelt in the far west and includes the towns of Westdale, Clackline and Bakers Hill. Annual average rainfall is 700–450 mm and evaporation 1800–2200 mm/yr. Rolling hills have been variably dissected by the eastward-flowing tributaries of the Dale and Avon Rivers. The dominant soils are ironstone gravels originally vegetated by jarrah forest.

2. Dale/Upper Avon

The Dale/Upper Avon sub-region lies on granites in the western wheatbelt and woolbelt and includes the towns of Brookton and Pingelly. Annual average rainfall is 450-380 mm and evaporation 1800-2000 mm/yr. The Dale River and south branch of the Avon River have incised the landscape, forming undulating hills, and granite rock outcrops are common. Soils are sandy and loamy duplexes, originally vegetated by York gum, wandoo and jam woodlands with jarrah/marri woodlands in the west and flooded gums on the river flats. Rivers and streams flow to the Swan River regularly.

3. Avon Valley

The Avon Valley lies on the metamorphosed volcanics of the Jimperding metamorphic belt in the western wheatbelt and northern woolbelt. This sub-region encompasses the towns of Beverley, Bolgart, Goomalling, Meckering, Northam, Toodyay, Wongan Hills and York. Annual average rainfall is 450–350 mm and evaporation 1900–2400 mm/yr. The landscape has been incised by the Avon River and the Toodyay Brook, forming undulating hills with rocky outcrops. Dominant soil types are red loamy soils originally vegetated by York gum and jam woodlands, with flooded gums along river flats. Rivers and streams flow to the Swan River regularly.

4. Yealering Lakes

Yealering Lakes lies on granites and gneisses in the central wheatbelt and Great Southern, encompassing the towns of Corrigin, Kulin, Wickepin and Yealering. Annual average rainfall is 400-340 mm and evaporation 1900-2100 mm/yr. The area is characterised by low relief. Grey lateritic gravelly sandplain occurs on uplands originally vegetated by diverse heath, and sandy duplex soils are found in flat valleys (2-3 km wide), originally vegetated by salmon gum and wandoo woodland. The sub-region encompasses the upper reaches of the main branch of the Avon River. Salinity has become apparent since the 1940s and most lakes were fresh prior to clearing.

5. Mortlock

Mortlock lies on granites and gneisses in the central wheatbelt and incorporates the towns of Bruce Rock, Cunderdin, Dowerin, Kellerberrin, Koorda, Quairading, Tammin, Trayning, and Wyalkatchem. Annual average rainfall is 350–300 mm and evaporation ranges from 2000-2500mm/yr. The sub-region is characterised by gently undulating and low relief landscapes with slow drainage through salt lake systems in broad valley floors (5–8 km wide). Drainage improves towards the western margin. Crests and upper slopes are typically yellow sands and sandy earths originally vegetated by diverse heath. Lower slopes are sandy duplex soils and valley floors are loamy earths and loamy duplexes. Lower slopes and valleys were originally vegetated by eucalyptus woodlands dominated by York and salmon gum.

6. Northern Sandplain

The Northern Sandplain lies on granites and gneisses in the north-eastern wheatbelt and encompasses the towns of Ballidu, Beacon, Bonnie Rock, Cadoux, Dalwallinu, Gabbin and Pithara. Annual average rainfall is 350–300 mm and evaporation ranges from 2400–2800 mm/yr. The landscape is characterised by very low relief with slow-moving drainage through salt lake systems in broad valley floors (5–8 km wide). Crests and upper slopes are dominated by yellow sands and sandy earths, originally vegetated with diverse heath. Lower slopes and valley floors are typically loamy earths and loamy duplexes, both with calcareous subsoils, originally vegetated by salmon gum and gimlet woodland.

7. South-east Lakes

The sub-region lies on granites and gneisses in the south-eastern wheatbelt and incorporates the towns of Kondinin, Holt Rock, Hyden, Lake Grace, Lake King, Newdegate, Pingrup and Varley. Annual average rainfall is 400-350 mm and evaporation ranges from 1800-2200 mm/yr. The area is characterised by gently undulating and low relief landscapes with sluggish drainage through salt lake systems in broad valley floors (5–8 km wide). Crests and slopes are typically duplex soils with some gravels, originally vegetated by mallee-form eucalypts, interspersed with scattered heath. Lower slopes and valley floors are typically sandy and loamy duplexes, usually with sodic and calcareous subsoils. These soils were originally vegetated by salmon gum, melaleuca, moort and yate woodland.

8. Carabbin

Carabbin lies on granites and gneisses in the eastern wheatbelt and includes the towns of Bencubbin, Merredin, Mukinbudin, Muntagin, Narembeen, Nungarin and Westonia. Annual average rainfall is 320-300 mm and evaporation from 2200-2800 mm/yr. The sub-region is characterised by very low relief with poor drainage through salt lake systems in broad valley floors (5–8 km wide). Crests and upper slopes are typically yellow sands and sandy earths and gravels. Original vegetation was diverse heath. Lower slopes and valley floors have loamy earths and loamy duplexes, both with calcareous subsoils, originally vegetated by salmon gum and gimlet woodland.

9. Southern Cross

Southern Cross sub-region lies on greenstone terrain with some granitic inclusions, and encompasses the towns of Marvel Loch and Southern Cross. Annual average rainfall is approximately 300 mm and evaporation rates range from 2500-2700 mm/yr. The sub-region is characterised by very low relief landscapes with poor drainage and isolated salt lakes in broad valley floors (5–8 km wide). The characteristic greenstone terrain has crests, slopes and broad valley floors of red loamy earth and clays, originally vegetated by eucalyptus woodland of morrel, salmon gum and gimlet. Within the smaller areas of granitic terrain, broad crests and upper slopes are typically yellow sands, sandy earths and gravels originally vegetated by ‘wodjil', a tall grevillea and acacia shrubland. Lower slopes and valleys in granitic terrain have duplex soils originally vegetated by mallee-form eucalypts.

Appendix 3. Assessment of threats within land resource sub-regions

Table A3.1: Assessment of threats in Darling Range

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water logging	Water repellence	Wind erosion
Extreme	6 (4%)				5 (3%)			<1 (<1%)
Very high	12 (8%)				3 (2%)	5 (3%)		<1 (<1%)
High	4 (3%)	<1 (<1%)	52 (35%)	78 (53%)	4 (3%)	1 (<1%)	29 (19%)	35 (24%)
Moderate	20 (14%)	2 (1%)	35 (24%)	49 (33%)	22 (15%)	8 (5%)	50 (34%)	61 (41%)
Low	103 (70%)	144 (98%)	53 (36%)	19 (13%)	61 (42%)	10 (7%)	<1 (<1%)	50 (34%)
Very low					51 (35%)	15 (10%)		
Presently acid			2 (1%)					
Nil						107 (72%)	62 (42%)	
Not applicable	2 (1%)	2 (1%)	7 (5%)	2 (1%)	2 (1%)	2 (1%)	7 (5%)	2 (1%)
TOTAL	148	148	148	148	148	148	148	148

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2005

Table A3.2: Assessment of threats within Dale/Upper Avon

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	5 (3%)				3 (2%)			<1 (<1%)
Very high	22 (13%)				5 (3%)	4 (2%)		3 (2%)
High	2 (1%)	<1 (<1%)	92 (56%)	80 (49%)	3 (2%)	1 (<1%)	37 (23%)	50 (30%)
Moderate	24 (15%)	<1 (<1%)	35 (22%)	65 (40%)	25 (16%)	23 (14%)	39 (24%)	47 (29%)
Low	110 (68%)	162 (100%)	30 (18%)	18 (11%)	64 (39%)	19 (12%)	<1 (<1%)	63 (39%)
Very low					62 (38%)	6 (4%)		
Presently acid			1 (<1%)					
Nil						109 (51%)	82 (51%)	
Not applicable	1 (<1%)	1 (<1%)	5 (3%)	1 (<1%)	1 (<1%)	1 (<1%)	5 (3%)	1 (<1%)
TOTAL	163	163	163	163	163	163	163	163

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2003

TableA3.3: Assessment of threats within Avon Valley

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	20 (2%)				14 (2%)			<1 (<1%)
Very high	131 (16%)				19 (2%)	20 (2%)		15 (2%)
High	4 (<1%)	1 (<1%)	369 (45%)	327 (40%)	29 (4%)	20 (2%)	207 (25%)	212 (26%)
Moderate	202 (25%)	47 (6%)	295 (36%)	335 (41%)	191 (23%)	138 (17%)	245 (30%)	271 (33%)
Low	451 (55%)	760 (93%)	119 (15%)	147 (18%)	202 (25%)	89 (11%)	10 (1%)	311 (38%)
Very low					353 (43%)	254 (31%)		
Presently acid			3 (<1%)					
Nil						287 (35%)	326 (40%)	
Not applicable	4 (<1%)	4 (<1%)	26 (3%)	4 (<1%)	4 (<1%)	4 (<1%)	24 (3%)	3 (<1%)
TOTAL	813	813	813	813	813	813	813	813

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2005

Table A3.4: Assessment of threats in Yealering Lakes

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Waterlogging	Water repellence	Wind erosion
Extreme	2 (<1%)				2 (<1%)			<1 (<1%)
Very high	26 (4%)				6 (<1%)	10 (2%)		24 (4%)
High	10 (2%)	<1 (<1%)	242 (37%)	289 (44%)	15 (2%)	18 (3%)	141 (21%)	188 (28%)
Moderate	151 (23%)	16 (2%)	227 (34%)	297 (45%)	36 (5%)	67 (10%)	230 (35%)	178 (27%)
Low	468 (71%)	642 (97%)	185 (28%)	73 (11%)	259 (39%)	81 (12%)	17 (3%)	267 (41%)
Very low					339 (51%)	163 (25%)		
Presently acid			1 (<1%)					
Nil						318 (48%)	268 (41%)	
Not applicable	2 (<1%)	1 (<1%)	4 (<1%)	1 (<1%)	2 (<1%)	2 (<1%)	4 (<1%)	2 (<1%)
TOTAL	659	659	659	659	659	659	659	659

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2005

Table A3.5: Assessment of threats within Mortlock sub-region

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	23 (2%)				21 (2%)			<1 (<1%)
Very high	232 (18%)				17 (1%)	50 (4%)		28 (2%)
High	33 (2%)	2 (<1%)	451 (34%)	693 (52%)	39 (3%)	15 (1%)	210 (16%)	263 (20%)
Moderate	194 (15%)	77 (6%)	295 (22%)	525 (40%)	218 (16%)	284 (21%)	427 (32%)	327 (25%)
Low	832 (63%)	1240 (94%)	531 (40%)	102 (8%)	202 (15%)	69 (5%)	5 (<1%)	699 (53%)
Very low					816 (62%)	178 (13%)		
Presently acid			21 (2%)					
Nil						716 (54%)	655 (49%)	
Not applicable	11 (<1%)	6 (<1%)	29 (2%)	6 (<1%)	12 (<1%)	12 (<1%)	29 (2%)	9 (<1%)
TOTAL	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2003

Table A3.6: Assessment of threats within Northern Sandplain

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	1 (<1%)				1 (<1%)			<1 (<1%)
Very high	38 (6%)				9 (1%)	4 (<1%)		33 (5%)
High	<1 (<1%)	<1 (<1%)	291 (42%)	400 (58%)	16 (2%)	4 (<1%)	9 (1%)	68 (10%)
Moderate	145 (21%)	22 (3%)	95 (14%)	237 (34%)	39 (6%)	74 (11%)	377 (55%)	209 (30%)
Low	496 (72%)	658 (96%)	217 (32%)	44 (6%)	171 (25%)	140 (20%)	4 (<1%)	376 (55%)
Very low					443 (65%)	121 (18%)		
Presently acid			64 (9%)					
Nil						338 (49%)	277 (40%)	
Not applicable	7 (<1%)	6 (<1%)	19 (3%)	6 (<1%)	7 (<1%)	7 (<1%)	19 (3%)	1 (<1%)
TOTAL	687	687	687	687	687	687	687	687

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2003

Table A3.7: Assessment of threats within the South-east Lakes

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	2 (<1%)				2 (<1%)			<1 (<1%)
Very high	73 (5%)				1 (<1%)	79 (6%)		125 (9%)
High	2 (<1%)	<1 (<1%)	249 (18%)	378 (27%)	35 (2%)	59 (4%)	227 (16%)	130 (9%)
Moderate	654 (47%)	257 (18%)	459 (33%)	533 (38%)	227 (16%)	330 (24%)	355 (25%)	508 (36%)
Low	634 (45%)	1102 (79%)	645 (46%)	447 (32%)	836 (60%)	202 (14%)	221 (16%)	611 (44%)
Very low					258 (18%)	140 (10%)		
Presently acid			1 (<1%)					
Nil						549 (39%)	551 (39%)	
Not applicable	32 (2%)	38 (3%)	43 (3%)	39 (3%)	38 (3%)	38 (3%)	43 (3%)	22 (2%)
TOTAL	1397	1397	1397	1397	1397)	1397	1397	1397)

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2003

Table A3.8: Assessment of threats within Carabbin sub-region

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	16 (2%)				16 (2%)			<1 (<1%)
Very high	134 (18%)				31 (1%)	36 (4%)		21 (2%)
High	14 (2%)	6 (<1%)	407 (34%)	727 (52%)	35 (3%)	13 (1%)	93 (16%)	214 (20%)
Moderate	792 (15%)	233 (6%)	416 (22%)	744 (40%)	378 (16%)	374 (21%)	733 (32%)	563 (25%)
Low	800 (63%)	1520 (94%)	861 (40%)	287 (8%)	674 (15%)	259 (5%)	47 (<1%)	972 (53%)
Very low					622 (62%)	299 (13%)		
Presently acid			49 (2%)					
Nil						776 (54%)	861 (49%)	
Not applicable	20 (<1%)	18 (<1%)	44 (2%)	19 (<1%)	21 (<1%)	21 (<1%)	43 (2%)	6 (<1%)
TOTAL*	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2003

Table A3.9: Assessment of threats in Southern Cross

Threat assessment	Phosphorus export	Structural decline	Subsurface acidity	Subsurface compaction	Water erosion	Water-logging	Water repellence	Wind erosion
Extreme	<1 (<1%)				<1 (<1%)			<1 (<1%)
Very high	<1 (<1%)				<1 (<1%)	5 (3%)		<1 (<1%)
High	5 (3%)	<1 (<1%)	17 (9%)	27 (14%)	1 (<1%)	1 (<1%)	25 (13%)	43 (23%)
Moderate	81 (43%)	60 (32%)	49 (26%)	95 (50%)	10 (5%)	46 (24%)	60 (32%)	60 (32%)
Low	103 (54%)	128 (68%)	120 (64%)	63 (33%)	177 (94%)	27 (14%)	11 (6%)	86 (46%)
Very low					<1 (<1%)	87 (46%)		
Presently acid			2 (1%)					
Nil						23 (12%)	93 (49%)	
Not applicable	1 (<1%)	1 (<1%)	1 (<1%)	5 (3%)	1 (<1%)	1 (<1%)	1 (<1%)	<1 (<1%)
TOTAL	189	189	189	189	189	189	189	189

'000 hectares and percentage (in parentheses)

Source: van Gool and Moore 1999, and Department of Agriculture 2003

Appendix 4. Regional soil types

Broad soil type	Brief description	Area	
		('000 ha)	(%)
Deep sandy duplexes	Soils with a sandy surface and a texture or permeability contrast at 30-80 cm	977	13.2
Shallow loamy duplexes	Soils with a loamy surface and a texture contrast at 3-30 cm	964	13.1
Sandy earths	Soils with a sandy surface and grading to loam by 80 cm. May be clayey at depth.	937	12.7
Loamy earths	Soils with a loamy surface and either loamy throughout or grading to clay loam or clay by 80 cm	924	12.5
Shallow sandy duplexes	Soils with a sandy surface and a texture or permeability contrast at 3 to 30 cm	870	11.8
Ironstone gravelly soils	Soils that have ironstone gravels or duricrust dominant within the top 15 cm	792	10.7
Deep sands	Sands greater than 80 cm deep	546	7.4
Wet or waterlogged soils	Soils seasonally wet within 80 cm of the surface for a major part of the year	390	5.3
Shallow sands	Sands less than 80 cm deep over rock, hardpan or other cemented layer	236	3.2
Rocky or stony soils	Rock outcrop and shallow soils with more than 50% gravels and stones (>20 mm) throughout the profile.	168	2.3
Non-cracking clays	Soils that have a clay surface at least 30 cm thick that does not crack strongly when dry	163	2.2
Cracking clays	Soils that have a clay surface at least 30 cm thick that cracks strongly when dry	119	1.6
Shallow loams	Loam 80 cm deep, over rock, hardpan or other cemented layer	117	1.6
Deep loamy duplexes	Soils with a loamy surface and a texture contrast at 30-80 cm	116	1.6
Miscellaneous soils	Other minor soils	68	0.8
TOTAL		7,387	100

Source: van Gool and Moore 1999, and Department of Agriculture 2003