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Salinity Investment Framework: Agricultural land and infrastructure

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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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Summary

Greater awareness of the potential impact of salinity has led to increased public and private expenditure. Because of the nature of the issue, costs of management, and amount of public funding available, the State Salinity Strategy called for a more strategic approach to planning which more clearly defines the requirements for the protection of assets (land, water resources, biodiversity, rural infrastructure). The Salinity Investment Framework was developed to insert rigour and accountability into decision-making processes and guide future investment.

The Department of Agriculture conducted the Salinity Investment Framework analysis for two asset 'classes'. This included an assessment of the impact of salinity on private and public land, and infrastructure (towns, roads, rail). The analyses were conducted at a State scale, using soil-landscape zones. Analysis of biodiversity and water-related assets was undertaken by CALM and Department of Environment and is reported elsewhere. The analysis used Land Monitor mapping, hydrologic data and models, judgment (impact and potential for adoption of options) and economic analyses.

Results showed that about 0.821 million hectares of 1.047 million hectares salt-affected land was owned privately. An area of between 2.9 and 4.4 million hectares was assessed to have a salinity hazard. Using current salinity management practices and adoption patterns, the areas that could be recovered, contained and actively managed in a saline condition (adaptation) were estimated to be 0.415, 0.445 and 0.750 million hectares respectively. The present value expressed as a gross economic benefit, of these areas, was computed to be $667 m. Investment in recovery (43%) and containment (42%) provided the major benefit.

An analysis of infrastructure indicates that roads managed by local government are at greatest risk and likely to carry the bulk of future costs of management. Rural Towns' risk and management were assessed and are the subject of detailed management planning in the Rural Towns – Liquid Assets project.

The following conclusions have been drawn from this analysis:

(i) Salinity either currently affects or threatens large areas of agricultural land and many sites containing high value infrastructure.

(ii) Most of the benefits (and losses avoided) for farmers stem from the recovery and containment of salinity.

(iii) There is a high degree of variability between the soil-landscape zones. Eastern zones had a lower return on investment than those to the west. The availability of economic solutions, time to the onset of full salinity and the scale of analysis explain some of this variability.

(iv) Improving either the technical feasibility or adoption rate greatly boosts the potential returns on investment in many zones. Determining the benefits of drainage is important.

(v) Further analysis of the options and their economics is required at regional scale. Such analysis needs to consider other benefits of investment in natural resource management.

Contents

1. Introduction

With limited public funds there is need for a strategic approach to expenditure on salinity which clearly defines the requirements for recovery, containment and adaptation and the protection of private and public assets (land, water resources, biodiversity, rural infrastructure). To address this, a Salinity Investment Framework was envisaged to insert rigour and accountability into decision-making processes and guide an overhaul of unsatisfactory, less strategic practices previously used for allocating investment in salinity action.

Development of the Salinity Investment Framework (SIF) was commissioned by the former State Salinity Council to guide public investment in salinity management initiatives at State, regional and catchment levels. The SIF Steering Committee oversaw the project. The lead natural resource management (NRM) agencies, the Departments of Agriculture; Conservation and Land Management; and Environment undertook the analysis.

This report describes the assessment of salinity impacts on agricultural land and rural infrastructure undertaken by the Department of Agriculture for the SIF project (Phase 1) and provides:

- spatial representation of areas of land and infrastructure affected or with a hazard to be used to underpin all of the analysis in the Salinity Investment Framework
- value of land and infrastructure at risk (where possible)
- technically feasible treatments
- probability of adoption of those options
- economic analysis.

Parallel analysis was undertaken by the Department of Environment (DoE) on ‘water resources and waterscapes’ and by the Department of Conservation and Land Management (CALM) on ‘biodiversity and natural assets’. A joint group also developed an approach for assessing the relationship between salinity and the ‘socio-economic’ assets of communities.

2. Methodology

The Department of Agriculture conducted the SIF analysis for the two main asset 'classes' of agricultural land and rural infrastructure. This included assessment of the impact of salinity on private and public lands and infrastructure (towns, roads, rail) and used spatial groupings of soil-landscape zones, agro-ecological zones, soil systems, hydrologic zones and local government areas). The area of current or potentially salt-affected native and planted vegetation was also assessed.

Land Monitor (a satellite-based assessment and mapping program of salinity, topography and vegetation extent and change; http://www.landmonitor.wa.gov.au) and National Land & Water Resources Audit (NLWRA http://www.nlwra.gov.au) datasets were used to assess the extent and hazard of salinity for each of the spatial groupings (see Table 1).

Related electronic tables, datasets and Geographic Information System-derived maps, prepared as part of this analysis, are available from the authors. All spatial data related to Land Monitor project are available on the website (http://www.landgate.com.au).

2.1 Agricultural land

The land analysis had two major steps:

1. **Technical analysis** used an expert panel to provide an assessment of the current extent and hazard of salinity for each soil-landscape zone (see map in Appendix 1), what could be done to manage it and the likelihood that these management actions would be undertaken.

2. **Economic analysis** used technical data to calculate the benefit of investment in these salinity management practices.

2.1.1 Step 1: Technical analysis

Using an expert panel approach (comprising regional hydrologists from the Department of Agriculture), each soil-landscape zone in the South West agricultural area was assessed for its area of current salinity and future salinity hazard, time to hydrological equilibrium, the technical feasibility of treatments and probability of adoption of applicable management options by land managers.

The principal analyses used in this report relate to areas of low productivity attributed to salinity by LANDSAT^{TM} analysis and areas of potential shallow watertables and salinity, previously defined by Land Monitor as AOCLP = area of consistently low productivity, and AHAVF = average height above valley floor. AHAVF is a topological output from analysis of the Land Monitor DEM, uses four elevation classes (0-0.5, -1, -1.5 and -2.0 m) and expert-derived decision rules (Dunne *et al.* 2001).

Areas of AOCLP (hereafter called 'current salinity') and AHAVF (now called 'valley hazard'[1]) were defined for each of 31 soil-landscape zones in the South West agricultural area. Soil-landscape zones were chosen as the basis of this analysis as they best reflect State-scaled regions with similar hydrogeological and farming system attributes (Figure 1).

[1] Hazard is defined as anything that can potentially cause harm to an asset. By contrast, risk is the likelihood that a hazard will eventuate. Risk requires definition of the timescale, consequence and probability of impact.

Primary analysis of the raw Land Monitor data used the 2.0 m valley hazard class (Dunne *et al.* 2001). However, the analyses also assessed the lower (0.5 m) valley hazard class. Valley hazard has therefore been reported as a range from analyses of both classes.

A water mask (process of extracting areas of current salinity associated with salt lakes from the raw Land Monitor data) was applied to the dataset in an attempt to remove areas of primary salinity[2] from the analysis. This process removed 100,000 hectares of land previously classified as 'current salinity'.

In areas where Land Monitor 'current salinity' mapping was unavailable or the hazard assessment methodology proved unreliable, regional hydrologists' estimates were used. Where estimates have been revised (see 'valley hazard' column in Table 2), they are reported to the nearest 1000 ha. For the Swan Coastal Plain (soil-landscape zones 211-213), regional scaled assessments from the Natural Resource Assessment database (N Schoknecht, pers. comm.) and ground electromagnetics (EM38) surveys, undertaken as part of the SW Irrigation Area mapping (Harvey Water; 20,000 ha) were used as alternatives.

To assess the impact of management actions and allow an economic assessment of the benefit of interventions in each of the soil-landscape zones (using revised areas of current salinity and valley hazard), the following steps were taken (the datasets appear in the relevant columns in Table 2):

- Land Monitor data was assessed and current salinity and valley hazard areas analysed for each of the major classes described above.
- An Urgency Rating based on the timing of the salinity was calculated (see 2.1.1.1)
- The Technical Feasibility of each management action and its impact on the extent of salinity was assessed in terms of the three goal-based criteria defined in the State Salinity Strategy (2000); Recovery, Containment and Adaptation or RC&A (see 2.1.1.2)
- The resultant area of impact was then modified by an index that assessed the Probability of Adoption (see 2.1.1.3) and a final area of Treatment Impact calculated (see 2.1.1.4).
- An economic evaluation of these results was then undertaken to assess the benefits of the investment in each of the 31 soil-landscape zones (see 2.1.2). This provided a picture of how much of each zone was at threat of salinity, in what timeframe, and how much of the area was likely to have suitable salinity management applied.

2.1.1.1 Timing of salinity (urgency)

As part of the salinity risk assessment, an 'urgency' rating was developed for each soil-landscape zone to assess approximately how long it would take the groundwater system to come to equilibrium and the area of salinity to stabilise.

The average time required for a zone to reach hydrological equilibrium (when watertables in risk areas cease to rise as a result of land use change) was assessed on the basis of available data in the Department's *AgBores* database and analysis prepared as part of the National Land and Water Resources Audit (Short and McConnell 2000). Both analyses assessed average depth to groundwater and rate of rise for each soil-landscape zone. The

[2] Primary salinity refers to land that was saline prior to clearing and the development of agriculture. The water mask removed most saline lakes, considered to represent a source of error when assessing dryland salinity. Note that some of these lakes may not have been saline at the time of clearing.

assessment also used available numeric modelling to determine when the systems would come to effective equilibrium[3].

The rating scale developed by the expert panel for timing of salinity or Urgency Factor, was: Rating Scale – Urgency Factor

0 No significant problems from salinity

1 Most potential salinity after 2075

2 Most potential salinity after 2030 and before 2075

3 Most potential salinity after 2020 and before 2030

4 Most potential salinity after 2010 and before 2020

5 Most potential salinity at or before 2010.

2.1.1.2 Technical Feasibility

Technical Feasibility (TF) is a measure of the availability and capacity of salinity management options to recover, contain or allow management adaptations to saline soils and soil at risk of becoming saline. The factors used to assess technical feasibility are largely qualitative, and were based on available published data and supported by assessments of each of the regional hydrologists.

The options assessed include engineering and plant based practices, or systems of practices that already exist, that will deliver the maximum impact on the extent and severity of saline land. The matrix of generic options nominated for each of the soil-landscape zones is provided in Appendix 2.

In undertaking this analysis it was noted that with unlimited money and time, it is technically possible to reclaim nearly all areas of dryland salinity. In practice, the actual area of impact is constrained by an array of factors. The principal factors taken into consideration are represented below as key questions:

- Is the practice or series of practices possible according to the physical conditions of the soil-landscape zone?
- Is the practice appropriate across the majority of the zone?
- Will implementation of the practice lead to impact within a reasonable time-frame?
- Has the practice been modelled or demonstrated to be effective in that zone?
- Are there major off-site issues or downstream impacts that would prevent development?

The rating scale developed by the expert panel to use for rating Technical Feasibility was:

0 Not applicable

1 Very Low (0.1)

2 Low (0.175)

3 Moderate (0.375)

4 Good (0.625)

5 Excellent (>0.75)

The Technical Feasibility rating is a spatially averaged indication of the predicted effectiveness of treatments based on our current scientific knowledge of the impact of salinity management options. The factors used in this analysis are generic and must be

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[3] Effective equilibrium means that although groundwater levels may continue to rise in elevated areas, the *area* of discharge has come to equilibrium.

reviewed when applied to specific cases (e.g. catchment scale), and reviewed over time as knowledge of the processes, landscape response and management actions change.

2.1.1.3 Probability of adoption

In order to determine how likely it was that technically feasible salinity management options would be adopted by land managers, the 'probability of adoption' was assessed.

The probability of adoption was derived for each soil-landscape zone. It was partly based on results of the '…effectiveness and adoptability' surveys undertaken as part of the National Land and Water Resources Audit (McConnell 2001) and partly by the expert panel of hydrologists' assessment of the likelihood/probability of an option or suite of options being adopted.

As with technical feasibility, the adoption of practices or systems depends on a wide array of issues. The principal issues are represented below as key questions:

- Is the practice viable and affordable (cost effective)?
- Can the practice be easily adopted (advice, support, regulations etc)?
- Does the practice fit within the context of the current farming systems?
- Does the practice or system fit with the skills and aspirations of the farm owner?
- Are there major off-site issues or downstream impacts that would prevent adoption?

After assessment using these questions, each zone was rated according to the following rating scale developed by the expert panel:

0 No adoption
1 <10% adoption (x 0.1)
2 10-25% (x 0.175)
3 25-50% (x 0.375)
4 50-75% (x 0.625)
5 >75% (x 0.75)

2.1.1.4 Area of impact

The area of impact of a system of management options was assessed in terms of its capacity to recover, contain or adapt to saline land (as 'current salinity' and 'valley hazard') and applied at soil-landscape zone. The calculations (Equations 1-3) were applied from each assessment of a management systems technical feasibility (Technical Factors – TF1a, b) and the probability of adoption (Adoption Factor – AF).

Equations 1-3 were used to calculate the area of impact (based on currently available estimates of the impact of options for the goals of recovery, containment and adaptation).

$R = AF_R ((TF_R * CS) + TF_R (VH-CS))$ Equation 1

$C = AF_C * TF_C (VH-CS)$ Equation 2

$A = AF_A ((TF_A * CS) + TF_A (VH-CS))$ Equation 3

Where AF_R = Adoption Factor (Recovery, C = Containment or A = Adaptation)

TF_R = Technical Factor (Recovery, C = Containment or A = Adaptation)

CS = Current Salinity

VH = Valley Hazard

2.1.2 Step 2: Economic analysis

To assess the financial benefits of each of salinity management system, an analysis of the benefits was undertaken in terms of each goal (recovery, containment and adaptation), in each soil-landscape zone.

The estimation of the benefits to agricultural land of the salinity investments utilised the impact of the adoption of technically feasible practices provided by the expert panel of regional hydrologists. The benefits are the present value of a forecast stream of additional profits (and losses avoided) of farm businesses on each of the three land-based goals (RC&A) in each zone. Sensitivity analysis of these results was then undertaken.

The net profits from management of the land classes (e.g. recovery area) in the soil-landscape zones depends on the rate of change in the areas prior to equilibrium and the profit difference between land practices made possible by salinity investment compared with land practices when no salinity investment occurs. For example, on lands affected by salinity, now and in the future, farmers could generate additional profit due to improved management. Much greater profits would be possible on lands that would otherwise become saline were it not for public investment in salinity management. Also on salt-affected lands which are recovered due to public investment, larger gains in profitability will be experienced.

The estimation of these benefits from salinity management depends on describing a flow of farm profits through time then expressing this flow in present value terms. The formula for deriving those benefits is not simple as it must allow for discounting, different profit flows depending on land class types, areas and rates of change in areas, zonal location, time to hydrological equilibrium or steady-state conditions, and perpetual benefits.

2.1.3 Value threat matrices

To help develop a consistent framework for investment in the four major asset classes (Land, Infrastructure, Water and Biodiversity) a matrix to assess values and threats was developed as part of the Salinity Investment Framework. The priority assets for investment – called Tier 1 assets - were determined to be those assets which had a high or imminent threat and high value. Tier 2 assets were those with a medium threat and value, while Tier 3 assets had a low threat and value.

For Land and Infrastructure, three matrices were used. The first compared the present value of gross benefit (total benefit), the second contrast the benefit per hectare of land, while the third reviewed to value of investment for roads. These values were related to the threat of salinity within three broad timescales; current or imminent (less than 20 years), 20-75 years, greater than 75 years (see Appendix 3).

2.2 Rural infrastructure

2.2.1 Towns

Data provided from 38 rural towns in the Rural Towns Program were analysed. Water levels and rates of groundwater rise were calculated from existing datasets and a median time to impact. The extent of current salinity and town areas at risk was derived from the existing groundwater models (see http://www.agric.wa.gov.au search on Rural Towns, Technical Reports and Land Monitor datasets).

The actual area of townsite salinity determined by Land Monitor was small, and inaccurate at the scale required. As a result, Land Monitor estimates were not used and a surrogate relationship derived.

The surrogate relationship was determined by relating the town's population (as a guide to infrastructure value and risk) by the rate of watertable rise and depth (as a guide to urgency). A value of 1.5 m depth to watertable was used at the critical point for initiation of impact (Department of Agriculture 2001).

The results of this simple analysis were compared to published ratings derived in 'Economic Impacts of Salinity on Townsite Infrastructure Study (Department of Agriculture 2001), which included a Benefit:Cost Analysis (BCA) on six representative towns.

2.2.3 Road and rail

Roads

The lengths of road assets at risk were classified according to classes used in the NLWRA and as provided by Department of Main Roads. Four classes were assessed: highways, main, local and unclassified roads. Of these, all but unclassified roads have a clear definition and could be easily mapped using existing datasets. Unclassified roads may include some unsealed shire roads, but also include roads within public land (e.g. forest tracks), and so-called 'unmade' roads on private land. As a result, care needs to be taken when interpreting results in soil-landscape zones with large areas of local and unclassified roads (public land, e.g. Zone 254, Warren-Denmark Southland).

Department of Main Roads' estimates of repair and maintenance costs (Jerome Goh, pers. comm.) were used to assess the costs of salinity on roads. The length of roads in each road class was assessed for areas of intersection between current salinity and valley hazard. Only raw[4] Land Monitor data were used to estimate road length affected or at risk.

The analysis assumes that all road pavements in areas determined to be currently saline or in areas of 'valley hazard' are affected, or potentially affected by excess salt and/or waterlogging. This will overestimate the actual area and length of asset at risk of salinity.

Railways

The length of railways in areas classified as currently saline or valley hazard was calculated (Table 1). Differing classes of assets were not provided nor assessed. Lengths of assets in areas of current salinity and valley hazard areas have been derived (Table 1). Raw Land Monitor data were used (see Table 2) but overestimate the assets at risk.

The costs of management were determined by methods documented in Rural Towns Program studies (Department of Agriculture 2001) which defined the two critical depth indicators (watertable as <1.5 m and <0.5 m). The costs in each class were assessed.

[4] Land Monitor data used in this analysis were provided to the Department of Agriculture in late 2002, and did not include the final Dumbleyung and Jackson scenes. It was considered that this would not significantly influence the results of this analysis.

3. Results

3.1 Land assets

The area of dryland salinity and length of the major road and rail assets affected (current salinity and valley hazard; 2.0 m class), are presented in Table 1. Results from revised Land Monitor data indicate over 1 million hectares of all land in the South West region is currently affected by salinity. Of this 0.821m ha is agricultural and 0.226m ha is public land.

Table 1: Land and infrastructure hazards based on analyses of revised Land Monitor data

Asset class	Extent	Current Salinity (AOCLP)	Valley Hazard (AHAVF <2.0 m class)
South West total	26,511,000 ha		
Agricultural land	18,790,000 ha		
Shires (% agricultural area)	(ha)	1,047,000 (5.6%)	5,428,000 (29%)
Agricultural land (%)	(ha)	821,000 (4.4%)	4,408,000 (23%)
Public land	(ha)	226,000*	1,020,000*
Towns	(ha)	4000	20,800
Roads	Highway (km)	1,100	520
	Local (km)	2,400	14,900
	Main (km)	140	670
	Unclassified (km)	1,450	8,100
Railways	Total (km)	210	1,050
Soil-landscape zones	(ha)	992,000	5,139,000
Soil systems	(ha)	992,000	4,794,000
Vegetation	CALM Estate (ha)	196,500	764,000
	Plantations (ha)	0	40
	Private (ha)	390	8,900

** Defined by subtraction of total shire area and area of valley hazard (includes towns).*

Estimates of 'valley hazard' ranged from 2,876,000 ha (<0.5 m class; not shown in Table 2) to 4,408,000 ha (<2.0 m class, Table 2). This range reflects the likely maximum 'hazard' for salinity and related waterlogged land if currently observed, long-term (1975-2000) trends in groundwater levels continue unabated. These estimates need regular evaluation on the basis of revised climate forecasts and continued groundwater level monitoring and modelling.

Results of analysis of the impact by salinity management options on areas of current salinity and valley hazard are presented in Table 2. The analysis shows that with current assumptions of technical feasibility and adoption, the total area of recoverable land in all zones is 415,000 ha. Areas that could be contained were estimated to be 445,000 ha and land for which systems of adaptation could be established was estimated to be 750,000 ha.

The impact of treatments is highly variable between zones and is affected by the assumptions (Technical Factors and Adoption Factors). An analysis of the impact of changing these inputs is provided in Table 5.

Table 2: Analysis of biophysical factors impacting on area of salinity on agricultural land

Region	Soil-landscape zone	Urgency	Technical feasibility			Probability of adoption			Area of treatment impact			Revised area		Raw Land Monitor	
			R	C	A	R	C	A	R	C	A	Valley Hazard	Current Salinity	AHAVF	AOCLP
SWAN	211 Perth Coastal	5	0.375	0.625	0.100	0.100	0.175	0.100	1,425	0	380	38,000	38,000		
	212 Bassendean	5	0.625	0.625	0.625	0.175	0.375	0.375	1,006	1,078	2,156	9,200	4,600		
	213 Pinjarra - Dryland	5	0.625	0.625	0.625	0.175	0.625	0.625	4,375	2,344	15,625	40,000	34,000	2	1
	(Pinjarra - Irrigated)	5	0.625	0.625	0.625	0.375	0.750	0.175	2,344	1,172	1,094	10,000	7,500		
	214 Donnybrook Sunkland	0												21	
	215 Scott Coastal	0													
	216 Leeuwin	0													
GREENOUGH	221 Geraldton Coastal	2	0.375	0.375	0.625	0.175	0.175	0.100	656	525	625	10,000	2,000	258	7
	222 Dandaragan Plateau	4	0.375	0.625	0.750	0.175	0.375	0.750	8,203	25,314	70,313	125,000	16,993	85	16,992
	223 Victoria Plateau	3	0.100	0.175	0.625	0.100	0.100	0.375	800	1,372	18,750	80,000	1,628	166,553	1,628
	224 Arrowsmith	2	0.625	0.625	0.750	0.375	0.375	0.625	18,750	18,281	37,500	80,000	2,000	71	
	225 Chapman	5	0.625	0.625	0.625	0.175	0.175	0.175	4,519	4,458	4,519	41,314	557	41,314	557
	226 Lockier	3	0.375	0.375	0.375	0.100	0.100	0.175	1,750	1,662	3,063	46,676	2,354	46,676	2,354
CARNARVON	231 Port Gregory Coastal	0										296	107	295	107
	232 Kalbarri Sandplain	3	0.625	0.625	0.750	0.175	0.175	0.375	1,669	1,655	4,290	15,255	121	15,254	121
STIRLING	241 Pallinup	3	0.625	0.750	0.375	0.375	0.375	0.375	19,522	20,659	11,713	83,295	9,841	83,294	9,841
	242 Albany Sandplain	2	0.175	0.625	0.375	0.375	0.625	0.175	788	2,344	788	12,000	6,000	151,108	4,380
	243 Jerramungup	4	0.625	0.750	0.375	0.375	0.375	0.375	14,063	9,563	8,438	60,000	26,000	53,961	15,525
	244 Ravensthorpe	2	0.375	0.375	0.375	0.375	0.175	0.375	1,723	294	1,723	12,249	589	12,249	589
	245 Esperance Sandplain	2	0.375	0.625	0.750	0.375	0.625	0.375	38,961	84,788	77,923	277,058	60,000	277,057	7,777
	246 Salmon Gums-Mallee	1	0.175	0.375	0.375	0.100	0.175	0.175	3,345	11,902	12,545	191,168	9,803	357,829	9,803
	248 Stirling Range	5	0.375	0.375	0.625	0.375	0.175	0.375	3,797	1,403	6,328	27,000	5,618	40,099	5,618

Continued next page

Region	Soil-landscape zone	Urgency	Technical feasibility			Probability of adoption			Area of treatment impact			Revised area		Raw Land Monitor	
			R	C	A	R	C	A	R	C	A	Valley Hazard	Current Salinity	AHAVF	AOCLP
AVON	250 SE Ancient Drainage	2	0.175	0.375	0.375	0.375	0.175	0.375	27,396	21,330	58,705	417,459	92,436	417,458	92,435
	253 Eastern Darling Range	3	0.625	0.625	0.750	0.375	0.375	0.375	35,204	31,647	42,245	150,204	15,177	150,203	15,176
	254 Warren-Denmark	5	0.625	0.750	0.750	0.375	0.625	0.625	19,463	29,550	38,925	83,040	20,000	83,040	5,238
	255 Western Darling Range	4	0.625	0.750	0.750	0.375	0.375	0.625	4,050	4,187	8,100	17,281	2,395	17,281	2,395
	256 Northern Rejuvenated Drainage	3	0.375	0.375	0.625	0.375	0.375	0.375	37,500	26,743	62,500	266,666	76,495	266,666	76,494
	257 Southern Rejuvenated Drainage	3	0.375	0.625	0.625	0.375	0.375	0.375	43,506	62,529	72,511	309,378	42,587	309,378	42,587
	258 Northern Ancient Drainage	2	0.175	0.375	0.375	0.375	0.100	0.175	95,595	45,258	95,595	1,456,679	249,796	1,456,679	248,796
	259 SW Ancient Drainage	2	0.175	0.375	0.625	0.375	0.375	0.375	15,985	25,741	57,091	243,587	60,537	243,587	60,536
KALGOORLIE	261 Southern Cross	1	0.100	0.375	0.375	0.100	0.100	0.100	574	2,117	2,154	57,450	1,006	57,449	1,006
MURCHISON	271 Irwin River	3	0.175	0.175	0.375	0.175	0.175	0.375	7,577	6,567	34,794	247,426	32,988	247,426	32,987
TOTAL									**414,546**	**444,953**	**750,392**	**4,407,682**	**821,129**	**4,495,305**	**653,958**

3.2 Economic

3.2.1 Agricultural land

With the current set of assumptions, the total benefit of salinity management across all zones is $667 million (Table 3). This figure represents the present value of additional profits (and losses avoided) by farm businesses that arise from alteration in land class areas and improved management on saline lands. In other words, the investment in salinity management is estimated to eventually generate a stream of additional profits (and losses avoided) for farmers that, in present value terms, equates to $667 million.

As shown in Table 3 most of the benefits (and losses avoided) for farmers stem from the containment of salinity and recovery of salt-affected areas. This is intuitively correct, as the profit differential between land uses on salt-affected land versus land either protected from salinisation or recovered from being salt-affected is likely to be large. By contrast the profit improvements on saline land that remains saline are likely to be much less, even with emerging technologies. There is likely to be a many-fold difference in losses avoided by maintaining agricultural land to be unaffected by salt compared to profit improvement on land that remains saline. In effect, the profits derived from use of several hectares of saline land will equate to profits derived from a single hectare of land unaffected by salinity.

However, the relative benefits of recovery, containment and adaptation need to be informed by knowledge of the true costs of set-up required to actually recover saline land. In many cases, the costs of recovery may be so high relative to its benefits that containment and adaptation will offer a higher return on investment.

Table 3 also shows the gross benefit per hectare of investment in salinity management across the zones. For example, recovery benefits on the high value coastal areas (e.g. Warren Denmark 254, West Darling Range 255) are far greater than those in the wheatbelt (e.g. Northern Ancient Drainage 258, SW Ancient Drainage Zone 259). The area impacted is also relevant with large area zones giving high aggregate benefits based on low benefits per hectare. Estimation of benefits on the Perth Basin zones are also problematic due to their small area, high value of land and uncertainty in application of the Land Monitor data.

The results indicate that priority areas for investment of public funds are in soil-landscape zones where salinity can be managed most effectively. These exist in areas where salinity management options are available (feasible and likely to be adopted) and where commodity returns are high. Although annual rainfall is a surrogate for successful management in most cases, the extent of impact is also important. As such, wheatbelt valleys that are at risk, but not yet affected, may become important target for subsequent evaluation.

Table 3: Present value of gross benefits to agriculture of forecast salinity management outcomes

		Present value of gross benefit				
Soil-landscape zone	**No.**	**Recovery area ($'000)** R	**Containment area ($'000)** C	**Adaptation area ($'000)** A	**Total ($'000)** R+C+A	**($/ha)**
Perth Coastal	211	18,721	0	998	19,720	168
Bassendean	212	8,813	9,443	3,777	22,033	149
Pinjarra - Dryland	213	22,991	12,317	16,422	51,729	212
Geraldton Coastal	221	310	248	59	616	5
Dandaragan Plateau	222	5,586	17,238	9,576	32,401	66
Victoria Plateau	223	383	657	1,797	2,837	4
Arrowsmith	224	5,689	5,547	2,275	13,511	31
Chapman	225	3,562	3,514	712	7,788	28
Lockier	226	664	631	232	1,527	10
Kalbarri Coastal	232	4,997	4,957	2,570	12,524	138
Pallinup	241	7,795	8,249	935	16,980	46
Albany Sandplain	242	170	506	34	710	1
Jerramungup Plain	243	12,968	8,818	1,556	23,342	67
Ravensthorpe	244	848	377	170	1394	19
Esperance Sandplain	245	15,761	34,300	6,304	56,365	68
Salmon Gums-Mallee	246	1,164	4,141	873	6,178	7
Stirling Range	248	2,993	1,106	998	5097	54
SE Ancient Drainage	250	6,465	5,033	2,771	14,269	8
Eastern Darling Range	253	21,086	18,955	5,061	45,102	53
Warren-Denmark Southland	254	28,978	43,998	11,591	84,567	180
Western Darling Range	255	10,056	10,394	4,022	24,472	110
Nrthn Rejuvenated Drainage	256	20,215	14,416	6,738	41,370	37
Sthn Rejuvenated Drainage	257	24,756	35580	8252	68588	52
Nrthn Ancient Drainage	258	22,558	10,680	4,512	37,750	8
SW Ancient Drainage	259	5,604	9,025	4,003	18,632	16
Southern Cross	261	65	241	49	355	2
Irwin River	271	2,874	2,491	2,640	8,005	10
Total		**286,864**	**278,257**	**101,803**	**666,923**	**36**
Share of Total		43%	42%	15%	100%	

3.3.2 Towns

The potential risk of salinity on rural towns shows that those with higher population and relatively short time to realisation of the risk have the highest ranked index. The analysis supports the results and general priorities for investment of studies by the Rural Towns Program (Department of Agriculture 2001) and is the basis for ongoing analysis (Mark Pridham, pers. comm.).

3.3.3 Roads

The length of highways and main roads currently affected by salinity is about 252 km. The length of local and unclassified roads is assessed to be 3850 km. The annual cost of repairs and maintenance due to salinity (Main Roads WA) is assessed to be $19,840/km for highways and main roads and $6,614/km for local and unclassified roads. The total combined current annual cost is around $21 million. However, the length of highways and main roads with a high hazard (likely to be an over-estimate) is 1,194 km and the length of local and unclassified roads affected is assessed to be 22,960 km.

Assuming no change in the cost per kilometre repaired, and assuming all roads in need of repair are fixed, then the annual cost of repairs and maintenance due to salinity will increase to $23.7 million for highways and main roads and $151.9 million for local and unclassified roads. The combined annual cost will be $175.5 million. Allowing for the gradual increase in repair and maintenance of roads as salinity spreads, and assuming all affected roads are repaired then, the present value of forecast road repair costs is $1938 million, of which $271 million is needed for highway and main road repairs. If only highways, main roads and local roads are repaired (i.e. unclassified roads are not repaired) then the present value of future repair and maintenance costs is forecast to be $1,355 million.

Around 80% of this cost is attributed to local roads rather than highways and main roads. Hence, an issue for many rural shire councils will be whether or not it is financially wise to maintain the current network of local and/or unclassified roads. Even halving repairs and maintenance expenditure will still mean that the impact cost of salinity on these roads will be higher than the farm-level benefits generated by the adoption of the intervention strategies forecast in Table 2.

3.3.4 Railways

The length of railways in areas currently affected by salinity and within areas with a high hazard is estimated to be 210 and 1,050 km respectively. The potential costs associated with this risk are defined by the depth to watertable (Department of Agriculture 2001). The likely cost range for the *currently* affected rail area is $458,800 to $1,427,000 and for *potentially* affected rail $2,242,000 to $6,977,000. The present value of ‘in perpetuity annual costs’ of rail repair and maintenance is $176 million.

Table 4: Ratings to establish priority towns for evaluation in Salinity Investment Framework

Town	Population	Years to impact (watertable <1.5 m)	Index (Population/Years to impact)	Ranking
Katanning	4,163	1	4,160	1
Wagin	1,450	1	1,450	2
Narrogin	4,700	4	1,175	3
Darkan	500	1	500	4
Bakers Hill	455	1	455	5
Merredin	3,630	9	403	6
Pingelly	800	2	400	7
Wongan Hills	800	3	267	8
Lake Grace	1,035	4	259	9
Narembeen	950	5	190	10
Mullewa	700	5	140	11
Moora	1,800	14	129	12
Morawa	600	5	120	13
Brookton	700	6	117	14
Boddington	1,420	17	84	15
Tambellup	300	4	75	16
Dowerin	400	6	67	17
York	2,000	31	65	18
Woodanilling	130	2	65	19
Kellerberrin	855	15	57	20
Cranbrook	320	6	53	21
Perenjori	250	6	42	22
Nyabing	120	4	30	23
Quairading	680	24	28	24
Corrigin	750	27	28	25
Bruce Rock	700	31	23	26
Goomalling	600	31	19	27
Dumbleyung	230	12	19	28
Mukinbudin	400	26	15	29
Koorda	315	22	14	30
Bencubbin	170	15	11	31
Piawaning	10	1	10	32
Wandering	80	10	8	33
Beacon	120	16	8	34
Bullaring	10	2	5	35
Trayning	120	30	4	36
Pingrup	80	24	3	37
Carnamah	410	217	2	38

4. Discussion

4.1 Threat and value matrices

To assess the relative benefit (present value of gross benefit) of future public investments, a value versus threat matrix was constructed (Appendix 3) for both agricultural land (soil-landscape zones) and road assets. A matrix could not be developed for town infrastructure as sufficient data were only available for six rural towns (Department of Agriculture 2001). The ranking column in Table 4 is presented as a surrogate, until further data are collected as part of the Rural Towns Program.

For agricultural land, the benefits are greatest where land values and probability of salinity management are highest. This area includes many of the higher rainfall zones where the effectiveness of salinity management options is greater and probability of adoption is higher. However, this result also depends on the time before onset of salinity. Lower returns in eastern zones may be due to the long lead times for salinity development (urgency factor) and management, reducing returns on money invested today. Conversely, if reported as the product of the area and benefit, then those areas that are larger may become those where the total value is highest (eg wheatbelt valley floor soils). However, in terms of investing public funds, the value per hectare is preferred for comparative assessments of the priority for investment of public funds.

Highest value roads occur in the areas where the threat is imminent (<20 years, 20-75 years) and the length of roads affected is greatest. In this analysis the Warren-Denmark Southland Zone is the only one with a high-high rating. This result reflects some difficulties of the methods used in this analysis. In this area Land Monitor under-estimates the area of current salinity. Combined factors such as the relatively small area cleared, large areas reforested, extent of local and unclassified roads, and relative impact of treatments, suggests the high-high rating may over-estimate its actual priority.

We suggest that areas of greater threat, where there are likely to be significant benefits from investment of public funds, are those soil-landscape zones classified as high threat, medium value and medium threat, high value (see Appendix 2).

4.2 Sensitivity analysis of investment in management of agricultural land

Table 5 shows the variability or sensitivity of investment returns to an increase in the level of technical feasibility or adoption by a one unit change (increase or decrease) for each zone. Changes to these factors change the present value of gross benefit by the nominated per cent (Table 3). For example, in Table 5 the 20% change in gross benefits for Dandaragan Plateau (Zone 222) when the Technical Factor changes by one unit means there is a change in gross benefits of $6,480,000 (20% of $32,401,000). By comparison a one unit change in the Adoption Factor for the Southern Rejuvenated Drainage Zone (259) means there is a change in gross benefits for that zone of $45,954,000 (67% of $68,588,000).

Investment in industry development that enables the improvement of technical feasibility factors (e.g. new practices) or supports the increased level of adoption (e.g. by provision of farm scaled datasets to underpin decision making, improved services) should be assessed in detail as part of the Salinity Investment Framework Phase 2.

Table 5: Impacts on investment returns of changes in technical feasibility and adoption likelihood of salinity management options[1]

Soil-landscape zone	Code	Change in benefit due to 1 unit change in	
		Technical feasibility (%)	*Adoption likelihood (%)*
Bassendean	212	20	86
Pinjarra - Dryland	213	20	62
Geraldton Coastal	221	62	111
Dandaragan Plateau	222	26	59
Victoria Plateau	223	49	70
Arrowsmith	224	19	59
Chapman	225	20	114
Lockier	226	67	81
Pallinup	241	19	67
Albany Sandplain	242	45	36
Jerramungup Plain	243	21	67
Ravensthorpe	244	67	80
Esperance Sandplain	245	32	38
Salmon Gums-Mallee	246	76	107
Stirling Range	248	58	77
SE Ancient Drainage	250	88	83
Eastern Darling Range	253	19	67
Warren-Denmark Southland	254	16	36
Western Darling Range	255	16	59
Northern Rejuvenated Drainage	256	59	67
Southern Rejuvenated Drainage	257	37	67
Northern Ancient Drainage	258	95	75
SW Ancient Drainage	259	71	67
Southern Cross	261	68	75
Irwin River	271	99	99

[1] This calculation of benefits is a partial measure of benefits as it only includes farmers' returns. Excluded are on-site and off-site public benefits and off-site private benefits.

4.3 Scale of analysis

Our analysis was applied at a regional scale (soil-landscape zones) and hence is not reliable at a local or catchment scale. As a result, it is likely that the assessment of an area of land within a zone may differ from that of the zone as a whole.

For example in Zone 257 (Southern Zone of Rejuvenated Drainage) the Technical Factor for recovery was moderate (0.375). Targeted pumping and more general application of deep drainage and water management were seen as a means to achieve recovery. However in terms of pumping, optimal sites (e.g. those that contain palaeochannels) are confined to specific areas within the catchment (maybe only 5%). While it may be possible to lower watertables in a specific area in this zone, e.g. Toolibin Lake, and attain recovery (i.e. Technical Factor >0.75), it was considered that there is currently insufficient knowledge to extend this result to a soil-landscape zone scale.

Technical Factors are thus a spatially averaged indication of effectiveness and exist within the context of our current scientific knowledge of the impact of salinity management options. They are also more appropriate when considering the impact of extensive treatments (recharge-based options) than they are for more targeted treatments (e.g. engineering). The latter require site-specific information.

The Technical Factors developed for this analysis need to be reviewed at a local scale when assessing specific assets, and need to be updated as knowledge increases with time.

4.4 Certainty in underpinning science

These forecasts are based on our knowledge of the ability of treatments to influence trends in soil salinity or groundwater levels. Assessments of the impact of biological systems have been undertaken for two decades or more on many of the soil-landscape zones. There is therefore a relatively high confidence in these results, relative to those where treatments systems have been less rigorously assessed (e.g. Perth Basin).

The impacts attributed to engineering are based on recent, limited analyses of the impact of drains, the development of raised bed systems and the opportunity for the productive management of saline land. The relative effectiveness of practices (e.g. deep drains) and farming systems needs to be continually assessed. In particular, the role of engineering systems requires the highest level of input and is the least well represented category of practices represented in this analysis.

Groundwater trends over the period 1975-2000 have been used in this analysis. This period has been dry compared with the rest of the twentieth century, but is consistent with forecasts of drier climates. Implicit in our estimates of risk is that groundwater trends in the next 25 years will reflect those in the last 25 years. Continued monitoring and modelling is essential to ensure forecasts are regularly updated.

4.5 Adoption of treatments

The adoption patterns used in this report were based in part on an earlier assessment by McConnell (2000) and in part on the knowledge of regional hydrologists. McConnell's review of available salinity management options and workshops with senior extension staff revealed the limited capacity of the current systems to reduce recharge.

In this analysis we used questions (see Methodology) and a review of the level of adoption over the past decade to define Adoption Factors for each zone. We concluded that the factors that lead to the adoption of salinity management practices or systems are extremely variable. They not only depend on the technical feasibility, but also on the knowledge, skills, attitudes and aspirations of the property owner. As shown in Table 5, altering the degree of adoption has a significant effect on the effectiveness of the options.

In addition, the effectiveness of the technical options varies according to the scale at which they are adopted. For example, the adoption of tree-based systems needs to be undertaken on very large areas in broadacre catchments to have a measurable impact on salinity, or contain it (George *et al.* 2001). Similarly in eastern zones with low topographic and groundwater gradients, the effectiveness of valley floor-based engineering systems may be compromised unless there is full participation by landholders in the catchment.

5. Conclusions

The following conclusions can be drawn from this analysis:

(i) Salinity either currently affects or threatens large areas of agricultural land and many sites containing high value infrastructure.

(ii) Most of the benefits (and losses avoided) for farmers from the adoption of factors assessed in this review stem from the containment of salinity. Benefits from recovery of salt-affected areas are imputed to be higher than those for the improved management of saline areas, although this is dependent on actual costs of recovery.

(iii) There is a high degree of variability between the zones where benefits were incurred (or losses avoided), with many eastern zones having a lower return on investment than those to the west. Net return per hectare needs to be considered along with return per zone.

(iv) Improving either the technical feasibility or adoption rate greatly boosts the potential returns on investment in many zones, and should be assessed as part of Phase 2 of the Salinity Investment Framework.

(v) Further analysis of the economics is warranted as this analysis was only undertaken at regional scale and was related to agriculture and infrastructure alone. An analytical tool is required that allows further sensitivity analysis to be undertaken, and takes better account of regional variations.

6. References

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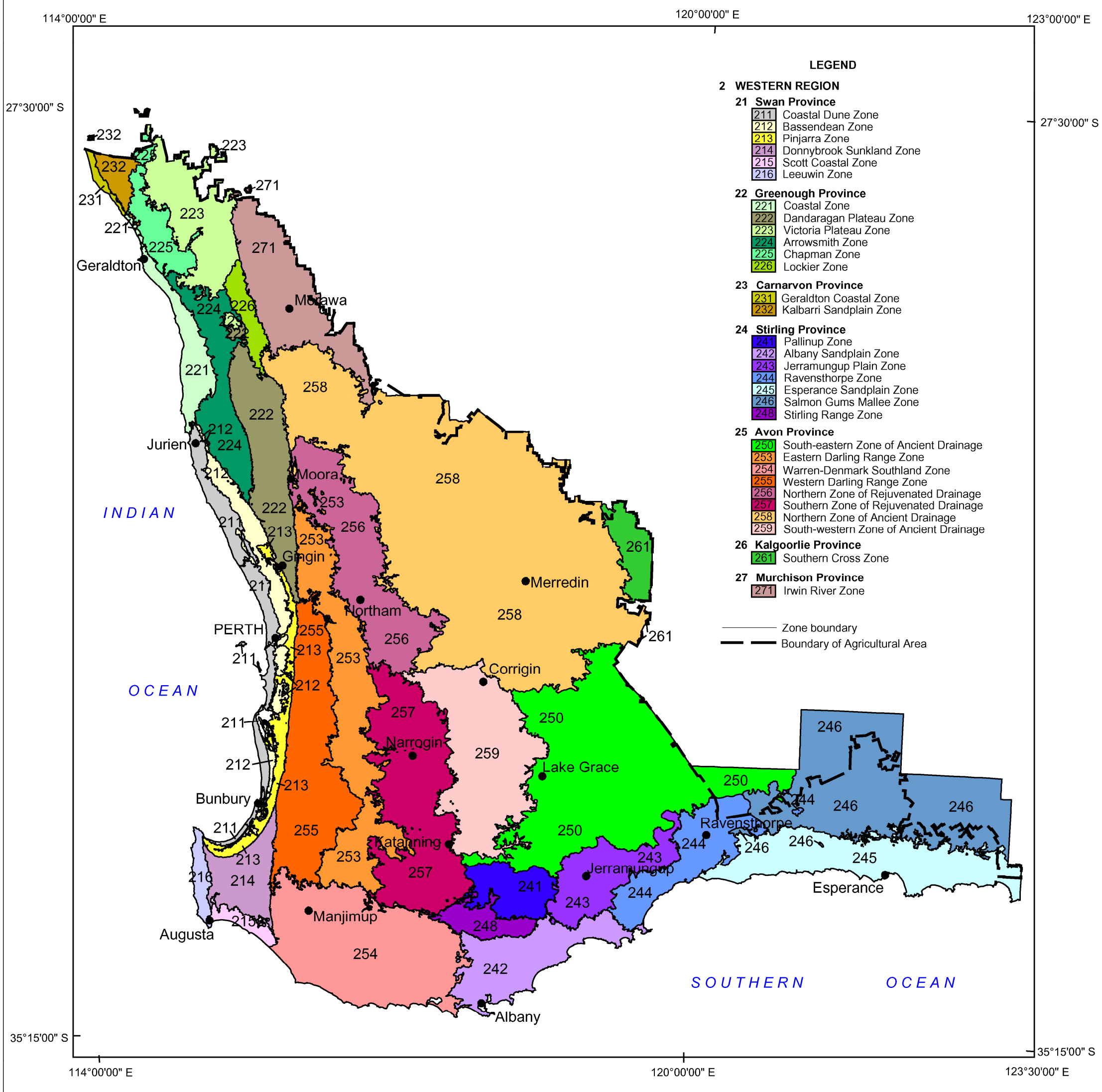
Ross Kingwell undertook the economic analysis while Bob Nulsen and Janette Hill-Tonkin managed the project.

8. Appendices

Appendix 1: Soil-landscape zones for south-western Australia

**SOIL-LANDSCAPE ZONES
OF SOUTH WESTERN AUSTRALIA**

Based on Soil-landscape systems map version 3 - October 2001



Reference

Projection: Universal Transverse Mercator Zone 50
Datum: GDA94
Source data: Soil-landscape systems mapping at various scales (1:50,000 - 1:250,000)
Date: December 2002

50 0 50 100 150 200 250 kilometres

8.2 Management options for agricultural land

Management practices (generic descriptions only) used for zone-scaled definition and assessment of the Technical Feasibility and Probability of Adoption of salinity management options.

ZONE	OBJECTIVE	MANAGEMENT OPTIONS
211 **Perth Coastal (mainly north of Perth)**	**Recovery**	Drainage
	Containment	Tillage and changed irrigation practice
	Adaptation	Changed crop to increase salt tolerance
212 **Bassendean**	**Recovery**	Drainage (north and south)
	Containment	Deep ripping (south of Perth), pines and other commercial trees (north of Perth)
	Adaptation	Saltland grazing systems based on legumes/grasses, and saltbush (north of Perth).
213 **Pinjarra (irrigated)**	**Recovery**	Drainage (related to ~30,000 ha commandable area)
	Containment	Not usually appropriate in high value areas, but may include surface water management, deep ripping,
	Adaptation	Selection and tolerance of pastures/crops
213 **Pinjarra (dryland)**	**Recovery**	Drainage (25% readily drainable (as above), remainder requires improved drainage/tillage/soil management systems
	Containment	Surface water management, deep ripping.
	Adaptation	Saltland grazing systems based on grasses/legumes
214 to 216		No significant area of salinity
221 **Geraldton Coastal**	**Recovery**	Drainage from sediments
	Containment	Perennials (where not at equilibrium)
	Adaptation	Saltbush and grass-based systems
222 **Dandaragan Plateau**	**Recovery**	Drainage from sediments, commercial trees and tagasaste if in large areas
	Containment	Lucerne, tagasaste, pines and surface water management
	Adaptation	Saltland perennials
223 **Victoria Plateau**	**Recovery**	Internal swales – no drainage possible without management of enhanced internal drainage and gradient
	Containment	Oil mallee alleys and high water use farming system and surface water management
	Adaptation	Perennial pasture and saltbush system (alleys)

ZONE	OBJECTIVE	MANAGEMENT OPTIONS
224 Arrowsmith	**Recovery**	Drainage for water supplies, northern areas less suitable for
	Containment	Lucerne + fodder shrubs and surface water management
	Adaptation	Saltland perennials, saltbush in the south
225 Chapman	**Recovery**	Drainage for water supplies (siphons, pumps)
	Containment	Perennials where appropriate, saline land at equilibrium
	Adaptation	Saltland perennials and surface water management
226 Lockier	**Recovery**	Possibility of tube or open drains?
	Containment	Oil mallees alleys and surface water management
	Adaptation	Saltbush and related perennial systems
231		No significant area of salinity
232 Kalbarri Sandplain	**Recovery**	Drainage and perennials
	Containment	Perennials where appropriate, saline land at equilibrium
	Adaptation	Adapt and benefit from excess water (aquaculture)
241 Pallinup	**Recovery**	Phase farming – lucerne, drainage
	Containment	Drains & perennials (lucerne phase) and surface water management
	Adaptation	Saltbush, tall wheat grass
242 Albany Sandplain	**Recovery**	Commercial trees, phase farming, some pumping & drainage
	Containment	Phase farming and surface water management
	Adaptation	Saltbush, tall wheat grass and related PURSL (Productive Use and Recovery of Saline Land) activities
243 Jerramungup	**Recovery**	Phase farming – lucerne
	Containment	Drains & perennials (lucerne phase) and surface water management
	Adaptation	Saltbush, tall wheat grass and surface water management
244 Ravensthorpe	**Recovery**	Perennials, drainage (open, siphon) and surface water management (including raised beds)
	Containment	Perennials (lucerne) and drains
	Adaptation	Surface water management and PURSL

ZONE	OBJECTIVE	MANAGEMENT OPTIONS
245 **Esperance Sandplain**	**Recovery**	Commercial trees, some perennials, drainage and surface water management
	Containment	Perennials, drainage and surface water management
	Adaptation	Surface water management and PURSL
246 **Salmon Gums-Mallee**	**Recovery**	Drainage where permeability and soils allow, and surface water management
	Containment	Oil mallees, lucerne where practical, surface water management
	Adaptation	Surface water management and PURSL
248 **Stirling Range**	**Recovery**	Phase farming (lucerne) and drainage (e.g. deep open drains, siphons) where gradient is adequate (including raised beds)
	Containment	Phase farming (lucerne)
	Adaptation	Saltbush, tall wheat grass, alleys with annuals
250 **SE Ancient Drainage**	**Recovery**	Drainage systems (except where limited by sodicity), limited siphons and pumping
	Containment	Some lucerne, oil mallee, surface water management (including raised beds in SW areas)
	Adaptation	Saltbush systems (PURSL)
253 **Eastern Darling Range**	**Recovery**	Drainage (siphons, deep drains), commercial trees,
	Containment	Block planting of commercial trees, alleys, lucerne (including raised beds)
	Adaptation	PURSL, salt-tolerant grasses and shrubs
254 **Warren-Denmark Southland**	**Recovery**	Commercial trees, drainage (siphons, deep drains), large engineering systems in Recovery Catchments
	Containment	Alleys including perennials, and surface water management (including raised beds)
	Adaptation	Salt-tolerant pastures, surface water management
255 **Western Darling Range**	**Recovery**	Commercial trees, deep drainage (siphons) and some pumping, large engineering in Recovery Catchments (e.g. pipelines, void disposal, desalinisation)
	Containment	Commercial trees (wood lots, blue gums etc), lucerne on selected soils and surface water management (including raised beds)
	Adaptation	Alleys including perennials, and surface water management

ZONE	OBJECTIVE	MANAGEMENT OPTIONS
256 **Northern Rejuvenated Drainage**	**Recovery**	Drainage systems, surface water management
	Containment	Oil mallee alleys, lucerne and long season annuals, surface water management (including raised beds)
	Adaptation	PURSL, surface water management
257 **Southern Rejuvenated Drainage**	**Recovery**	Drainage and pumping (siphons in dissected area)
	Containment	Oil mallee alleys, lucerne and long season annuals, surface water management (including raised beds)
	Adaptation	PURSL, surface water management
258 **Northern Ancient Drainage**	**Recovery**	Drainage systems, (deep open drains most effective in permeable valley sediments)
	Containment	Oil mallee alleys, targeted perennials, surface water management (including raised beds in western areas)
	Adaptation	Saltbush, bluebush, samphire (PURSL) systems, surface water management
259 **SW Ancient Drainage**	**Recovery**	Drainage systems, targeted perennials in valley areas
	Containment	Oil mallees, lucerne (including raised beds)
	Adaptation	Saltbush systems (PURSL)
261 **Southern Cross**	**Recovery**	Drainage systems (limited by sodic and low permeability soils) most effective in permeable valley sediments
	Containment	Oil mallee alleys, where rainfall is sufficient
	Adaptation	Saltbush, bluebush, samphire system
271 **Irwin River**	**Recovery**	Engineering options limited by permeability and gradient
	Containment	Oil mallee options limited by soils and growth rates
	Adaptation	Saltbush only

8.3 Value threat matrices for land and roads

Value of land (Present Value of Gross Benefit)

Value versus Threat		**Value of land (Present value of Gross Benefit)**		
		High (>$20m)	Medium ($10-20m)	Low (<$10m)
Threat to land (years)	Current or Imminent <20 years (high threat)	Warren-Denmark Southland (85) Dandaragan Plateau (32) Western Darling Range (24) *Pinjarra Dryland (52)* *Bassendean (22)*	Jerramungup (23) *Perth Coastal (19)*	Chapman (8) Stirling Range (5)
	0-75 years (medium threat)	Southern Rejuvenated Drainage (68) Esperance Sandplain (56) Eastern Darling Range (45) Northern Rejuvenated Drainage (41) Northern Ancient Drainage (38) SW Ancient Drainage (19)	Pallinup (17) SE Ancient Drainage (14) Arrowsmith (14) *Kalbarri Coastal (13)*	Irwin River (8) Victoria Plateau (3) Lockier (2) Ravensthorpe (1) Geraldton Coastal (1) Albany Sandplain (1)
	>75 years or asset insignificantly impacted (low threat)	Nil	Nil	Salmon Gums-Mallee (6) Southern Cross (0)

Zone names in *italics* are Perth Basin where Valley Hazard and Current Salinity are least well defined.

Value of land ($/ha)

Value versus Threat		Value of land ($/ha)		
		High (>$100/ha)	Medium ($50-100/ha)	Low (<50 ha)
Threat to Land (years)	Current or Imminent <20 years (high threat)	Warren-Denmark Southland (180) Western Darling Range (110) *Pinjarra Dryland (212),* *Perth Coastal (168),* *Bassendean (149)*	Jerramungup Plain (67) Dandaragan Plateau (66) Stirling Range (54)	Chapman (28)
	20-75 years (medium threat)	*Kalbarri (138)*	Esperance Sandplain (68) Eastern Darling Range (53) Southern Rejuvenated Drainage (52)	Pallinup (46) Northern Rejuvenated Drainage (37) Arrowsmith (31) Ravensthorpe (19) SW Ancient Drainage (16) Lockier (10) Irwin River (10) Northern Ancient Drainage (8) SE Ancient Drainage (8) Geraldton Coastal (5) Victoria Plateau (4) Albany Sandplain (1)
	>75 years or asset insignificantly impacted (low threat)	Nil	Nil	Salmon Gums-Mallee (7) Southern Cross (2)

Zone names in *italics* are Perth Basin where Valley Hazard and Current Salinity are least well defined.

Value of roads

Value versus Threat		Value of roads: High (>$10m)	Value of roads: Medium ($5-10m)	Value of roads: Low (<$5m)
Threat to roads (years)	Current or Imminent <20 years (high threat)	Warren-Denmark[5]	Western Darling Range	Chapman Stirling Range Jerramungup Dandaragan Plateau *Pinjarra* *Perth Coastal*
	20-75 years (medium threat)	Northern Ancient Drainage Southern Rejuvenated Drainage Northern Rejuvenated Drainage SE Ancient Drainage Irwin River SW Ancient Drainage Eastern Darling Range	Albany Sandplain Esperance Sandplain Victoria Plateau	Pallinup Lockier Ravensthorpe *Kalbarri Sandplain* *Geraldton Coastal* *Arrowsmith*
	>75 years or asset insignificantly impacted (low threat)		Salmon Gums-Mallee	Southern Cross

Zone names in *italics* are Perth Basin where Valley Hazard and Current Salinity are least well defined.

[5] This zone is dominated by local and unclassified roads and benefits need to be assessed at regional scale prior to investment.