2009

Setting targets for resource condition in Lake Towerrinning catchment

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December 2008

RESOURCE MANAGEMENT TECHNICAL REPORT 335

ISSN 1039-7205

Resource Management Technical Report 335

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ACKNOWLEDGMENTS

Andrew Huffer from Andrew Huffer and Associates facilitated and evaluated the workshops.

Katie Robinson, NRMO from Darkan helped to organise the workshops.

Dr Richard George from the Department of Agriculture and Food in Bunbury attended the first workshop and contributed valuable local insight into the groundwater processes and salinity risk of the catchment.

Arjen Ryder from the Department of Agriculture and Food in Albany undertook the technical review of the report.

The report was edited by Bill Russell from the Department of Agriculture and Food in Bunbury.

The project is an initiative of the South West Catchments Council, funded jointly by the Australian Government and the Government of Western Australia under the National Action Plan for Salinity and Water Quality.

SUMMARY

The Department of Agriculture and Food, Western Australia (DAFWA) was commissioned by the South West Catchments Council (SWCC) to set resource condition targets for land salinity and native vegetation in the portion of the South West Natural Resource Management Region with less than 600 mm mean annual rainfall. In the South West we believe that **realistic** and **achievable** targets can only be set by involving the landholders who will need to make the changes on their land to cope with and manage salinity.

The Department of Agriculture and Food (Keipert et al. in prep.) developed a process involving two half day workshops which combined the latest scientific information and simple models with local knowledge of salinity and its management to set long term targets for salinity and native vegetation.

The title for the first Lake Towerrinning catchment workshop was:

Linking science with local aspirations

At this workshop, an hydrologist from the department provided the latest information on current and future groundwater and salinity levels, as well as the likely impact of a range of recharge management scenarios. All the available management options were discussed and the group nominated three management options for further modelling to be presented at the second workshop.

The title for the second Lake Towerrinning catchment workshop was:

Setting targets for action

The results of the modelling were presented and the impacts of the different management options discussed. The group considered these options and then finalised the following resource condition targets for the Lake Towerrinning catchment.

The landholders in Lake Towerrinning agreed to the following resource condition targets:

- Salinity contained to 15 per cent of the catchment in 2028. (Landholders estimated that 12 per cent of the catchment is currently affected by salinity and the full-risk by 2028 was estimated as 20 to 25 per cent of the catchment.)
- Maintain water quality in Lake Towerrinning < 1200 mS/m during winter.
- Increase productive use from salt-affected land with no net loss in profitability.
- Capercup Nature Reserve stabilised and area affected by salinity to increase by no more than an additional 10 per cent (currently 30-40 per cent affected).

1. INTRODUCTION

The South West Catchments Council (SWCC) commissioned the Department of Agriculture and Food to set land salinity and native vegetation resource condition targets in seven catchments in the portion of the South-west region with mean annual rainfall of less than 600 mm. This follows the successful completion of a pilot project that involved five catchments in 2006. These targets were a requirement for investment under its regional natural resource management (NRM) strategy. The project is an initiative of the South West Catchments Council, funded jointly by the Australian Government and the Government of Western Australia under the National Action Plan for Salinity and Water Quality.

The project's Community and Stakeholder Reference Group initially identified 31 catchments to test a process for linking science with local aspirations and knowledge in setting realistic resource condition targets. The list of 31 catchments was re-evaluated and seven catchments in the low and medium rainfall areas of the Blackwood and Murray River basins were invited to collaborate with the Department of Agriculture and Food in setting measurable targets for dryland salinity.

The Lake Towerrinning catchment group was invited to take part in the target setting workshops because of the group's history of active involvement in Landcare. The process was assisted locally by Katie Robinson, Natural Resource Management Officer (NRMO) for the Shire of West Arthur.

1.1 Lake Towerrinning catchment

The Lake Towerrinning catchment covers approximately 15 700 ha and is situated about 15 km to the south of Darkan in the Shire of West Arthur (Figure 1). The townships of Duranillin, Moodiarup and Cordering all fall within the catchment. Lake Towerrinning sits at the bottom of the catchment above the flood-plain of the Arthur River to which it discharges.

The majority of the catchment sits within the Eastern Darling Range soil-landscape zone; some very small areas fall in the Western Darling Range Zone and the Southern Zone of Rejuvenated Drainage (Department of Agriculture and Food, 2008). The main valley floors in the catchment belong to the Darkan system and contain numerous small swamps in addition to Lake Towerrinning itself. Dunes and lunettes are present but rare on the valley floors in the lower portion of the catchment. The upper portion of the catchment is undulating with gravelly, lateritic slopes and ridges though breakaways are rare. Deep sandy duplex soils are also common.

Basic descriptions of the soil-landscape units mapped in the Lake Towerrinning catchment are presented in Appendix 4 and further information is presented in the in the Rapid Catchment Appraisal report for the Beaufort zone of the Blackwood Basin (Blackwood Catchment Appraisal Team, 2003).

Discussion of the impact of regional-scale geological faults on the hydrogeology and salinity risk in the Lake Towerrinning catchment can be found in Clarke et al. (1998 a and b), Clarke et al. (1999), Clarke et al. (2000) and George et al. (1994).

The long-term mean annual rainfall for the catchment is 525 to 625 mm. An analysis of rainfall trends for the study area by Raper et al. (in prep.) showed that the mean annual rainfall at Duranillin has fallen from 561 mm per annum for the period up to and including 1975 to 484 mm per annum for the period since 1975. This is a reduction of 14 per cent relative to the pre-1975 annual rainfall and is comparable to most centres in the study area where mean annual rainfall has decreased between 8 per cent and 15 per cent since 1975. Average May to October rainfall at Duranillin, however, has decreased from 446 to 367 mm since 1975, a fall of 18 per cent.

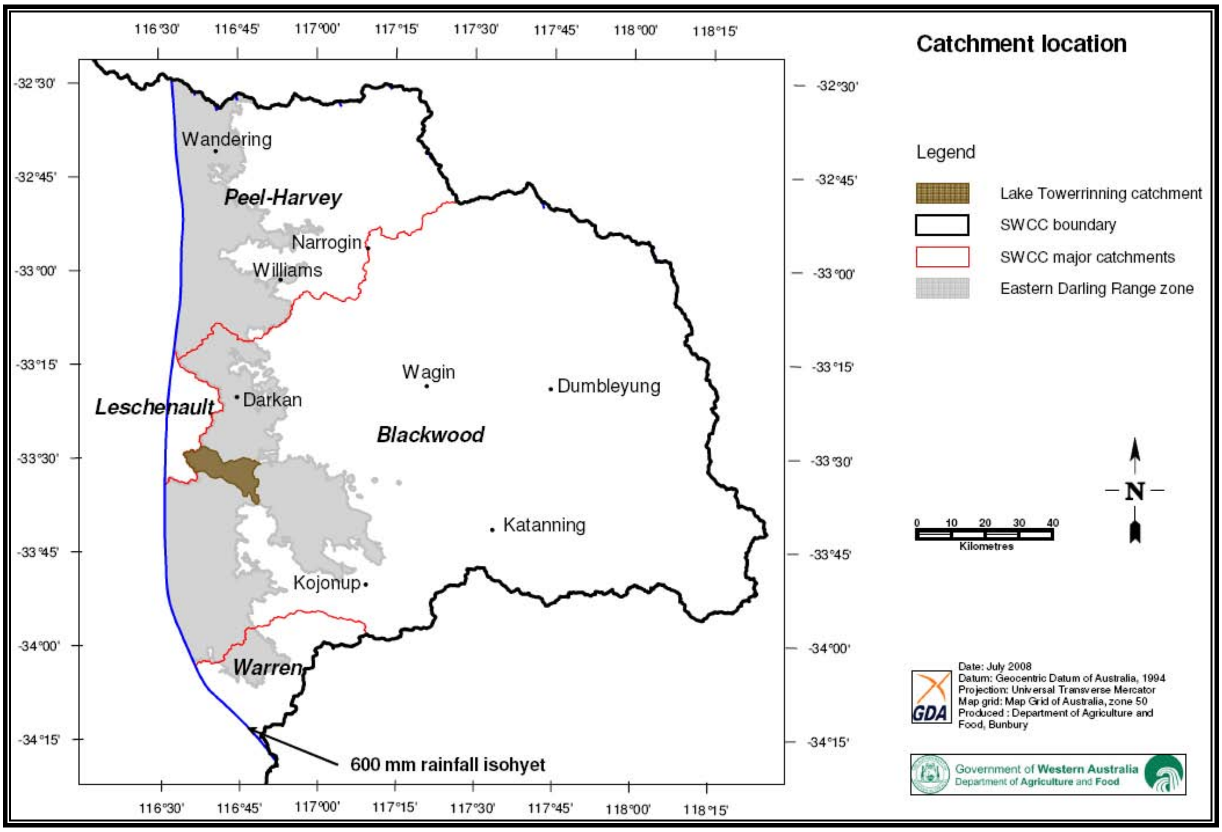

Figure 1 Location of the Lake Towerrinning catchment within the South West Natural Resource Management Region.

1.2 Workshop aims

The aims of the workshops were to:

- Determine landholders' perceptions of the salinity risk to the catchment **and their aspirations** for its management (that is, to incorporate landholder views on the likely future extent of salinity on their properties and in their catchment).
- Present catchment information on **current salinity impacts, trends for the future** and **an assessment of the likely impact of two levels of salinity management effort**.
- Identify **salinity management options** of interest to the landholders.
- Provide **an estimation of the likely impact of the salinity management options favoured by the landholders**.
- Agree to a **catchment resource condition target (20 year) for land salinity and native vegetation**.
- Identify and prioritise five-year management action targets.

1.3 Current salinity—local view

The landholders identified the salinity status of their properties. It was agreed that the works implemented have had some impact over the last 20 years. However concerns were still expressed regarding salinity expanding in the lower reaches of the catchment where the valley floors are flat and broad, as well as along some creeklines.

1.4 Local aspirations

At the first workshop, landholder aspirations for the extent of future salinity in their catchment were explored using a continuum (Figure 2). Landholders identified their aspirations based on the following criteria:

Full risk -allowing salinity to increase with no additional intervention (do nothing scenario).

Containment - keeping salinity within the catchment to current levels.

Full recovery - returning currently saline land back to previous level of agricultural production.

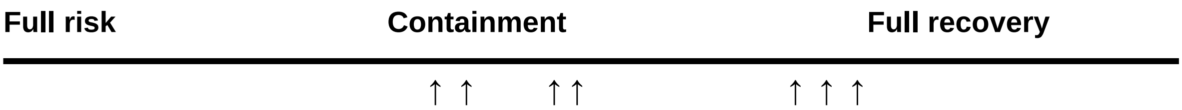

Figure 2 Continuum of landholder initial aspirations.

Degradation of Capercup Reserve due to rising groundwater.

2. CURRENT SALINITY IMPACTS AND FUTURE TRENDS

During the first workshop the landholders were presented with regional and catchment-scale information on groundwater trends, salinity status and future salinity risk. The limitations and scale issues associated with each information source were discussed and the landholders were then invited to provide feedback from their local knowledge.

2.1 Groundwater trends

The regional groundwater trends have been analysed for each of the main soil-landscape zones in the low and medium rainfall zones of the South West NRM region (Raper et al. in prep.). Groundwater trends for the Eastern Darling Range Zone, in which the Lake Towerrinning catchment is situated, are presented in Table 1. The regional analysis shows that roughly half of the observed bores in the lower slope and valley floor locations are at equilibrium and that half are rising at an average rate of 0.25 m/yr.

Table 1 **Regional groundwater trends (Raper et al. in prep.)**

Landscape position	Trend	Eastern Darling Range Z		
		Number of bores	Average rate of change (m/yr)	Mean depth to water (m)
Upland flat	*Rising*	10	0.40	-1.5
	Equilibrium	1		-0.7
Upper slope	*Rising*	13	0.30	-12.2
	Equilibrium	1		1.6
Mid slope	*Rising*	7	0.45	-7.4
Lower slope	*Rising*	5	0.25	-1.0
	Equilibrium	1		0.1
Valley floor	*Equilibrium*	3		-0.1

There are 134 bores at 51 sites within the Lake Towerrinning catchment for which the Department of Agriculture and Food has long-term groundwater observations; many are at revegetation trial sites. Groundwater trends for bores in the Lake Towerrinning catchment were therefore split into two groups; bores in cleared areas and bores in treed areas. The results are presented in Table 2. The vast majority of bores (23 of 27 bores) in revegetated areas are on valley floors and observed groundwater levels in most of these bores are static or falling (20 bores).

The majority of bores on revegetated sites have been monitored since the early 1990s and demonstrated a downward trend in summer minimum groundwater levels following tree planting. Winter maximum water levels at these sites are generally at similar levels to those observed prior to tree planting. Summer groundwater minima have now stabilised and there is no longer any significant trend in groundwater level at the majority of these sites.

Table 2 **Lake Towerrinning groundwater trends**

Landscape position	Average trend	Number of bores		Average rate of change (m/yr)		Mean depth to water (m)	
		Cleared	Treed	Cleared	Treed	Cleared	Treed
Upper slope	*Rising*	4		0.39		-7.2	
	Equilibrium	1				-4.5	
Mid slope	*Rising*	4	1	0.20	0.05	-7.9	-5.7
	Equilibrium	1				-7.5	
	Falling		2		-0.09		-2.6
Lower slope	*Rising*	1		0.03		1.5	
	Equilibrium	4	1			-0.7	-6.5
	Falling	1		-0.01		-0.2	
Valley floor	*Rising*	4	3	0.08	0.21	0.6	-0.8
	Equilibrium	4	19			0.3	-0.2
	Falling		1		-0.01		1.1

2.2 Current salinity impacts

The Land Monitor project used high resolution digital elevation data and remotely sensed vegetation health data to map salt affected land and to produce an estimate of the maximum possible future extent of salinity in the south-west agricultural region (McFarlane et al. 2004). Land Monitor (2001) estimated that 600 ha (4 per cent) of the Lake Towerrinning catchment was salt-affected in 1998 (Evans, 2001) with 3,400 ha (22 per cent) remnant vegetation in the catchment (Figure 3).

The Land Monitor estimate of current salinity has limitations that can affect the precision of information. The reported accuracy of the Land Monitor salinity mapping for the eastern zone of the Collie-Pemberton Landsat scene, within which Lake Towerrinning sits, was 99 per cent for bare saltland but only 70 per cent for marginally saline land (Evans, 2001). A field visit prior to the workshops indicated Land Monitor significantly underestimated the extent of salinity, highlighting only the most severely degraded areas, and did not include saline areas covered in samphire. At workshop 1, landholders agreed that the Land Monitor method underestimated the extent of current salinity, but also pointed out that some of the salinity only appeared since 1998 and could therefore not be detected during the Land Monitor project. The fact that Land Monitor used digital elevation as a basis to determine the low lying areas that might be affected meant that it was unable to identify the saline seeps and other small saline areas present in the upper slopes of the catchment. The average rate of expansion of salt-affected land, as mapped by the Land Monitor project, in the West Arthur Shire between 1990 and 1998 was 62 per cent or > 6 per cent per annum (Evans, 2001). These rates of expansion of salt affected land cannot be used as a direct indication of the likely rate of expansion in the Lake Towerrinning catchment because, unlike a catchment, a shire is an administrative area of land. The landholders estimated that salinity currently affected 12 per cent of the catchment area (1800 ha).

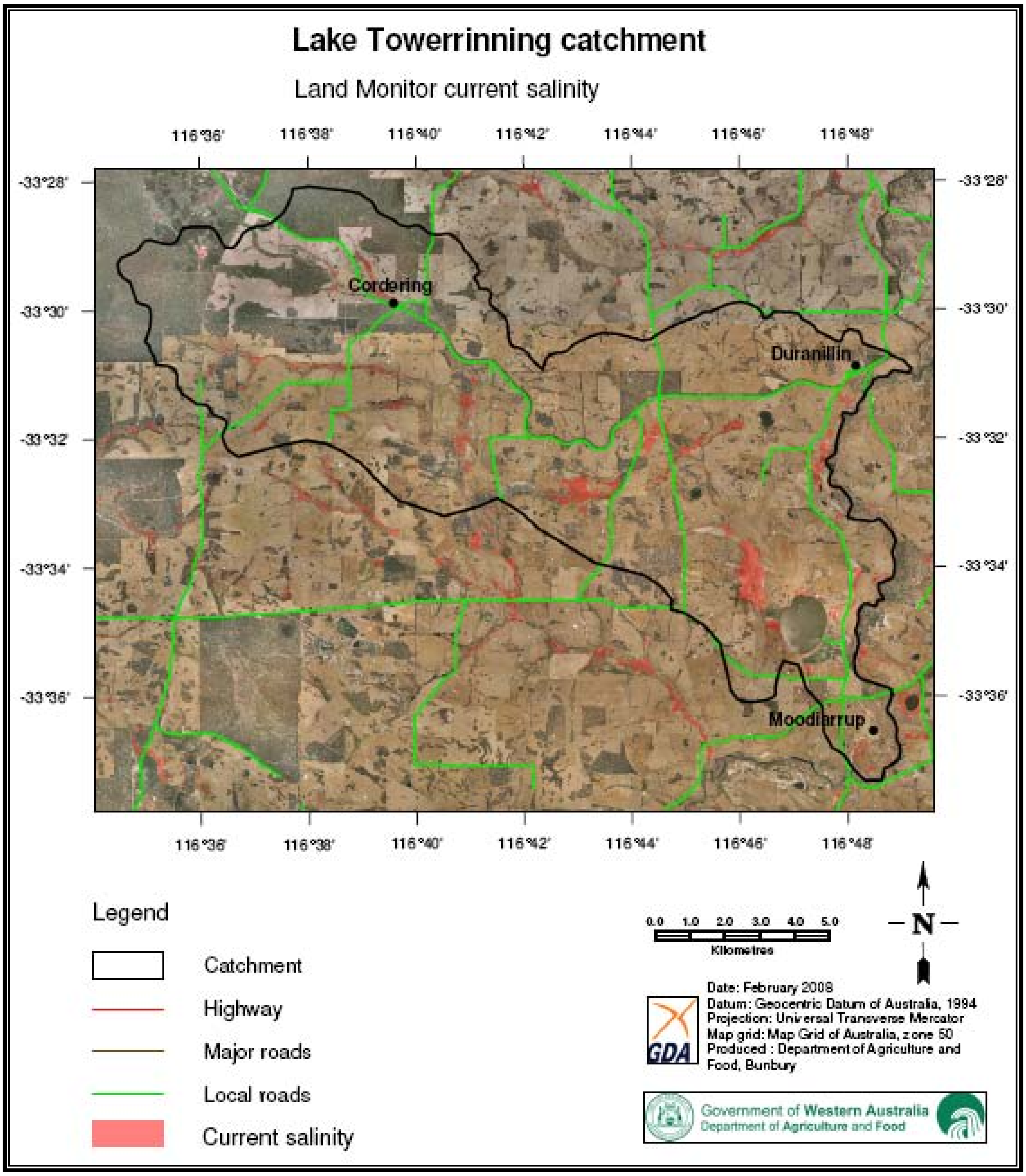

Figure 3 Current salinity in Lake Towerrinning *(Land Monitor 2001)*.

2.3 Valley floor hazards

Salinity hazard is best thought of as an area of land, usually on a valley floor, where the watertable may approach the ground surface at some future time and give rise to dryland salinity. Valley floor hazard, as shown in the Land Monitor (2001) information for low-lying areas, indicates areas which have the highest risk of waterlogging, flooding, shallow groundwater tables and salinity (Figure 4).

It is **important to note** that not all these areas will become saline. Variations in topography and soil type are critical factors in determining their susceptibility to salinity. Furthermore, the valley floor hazard mapping does not imply any particular time-frame for the realisation of salinity risk. It can only therefore be used to provide an estimate of salinity risk required to assist in the setting of a 20-year resource condition target.

The Land Monitor project uses digital elevation modelling to derive valley floor hazard. This is reported as the area of valley floor within a specified elevation of the main stream line. Table 2 presents this information as cumulative areas at four classes: 0-0.5 m; 0-1.0 m, 0-1.5 m and 0-2.0 m. The areas in the 0-2.0 m class are almost certainly an overestimate of the salinity hazard for the Lake Towerrinning catchment. The 0-0.5 m class offers a better estimation of the area at risk of becoming saline if land use remains largely unchanged (McFarlane et al. 2004).

Given the current extent of salt-affected land in the catchment, the reported rates of groundwater rise and their local knowledge, the landholders estimated that 20 to 25 per cent of the catchment is likely to be salt-affected in 2028, if no further action is taken.

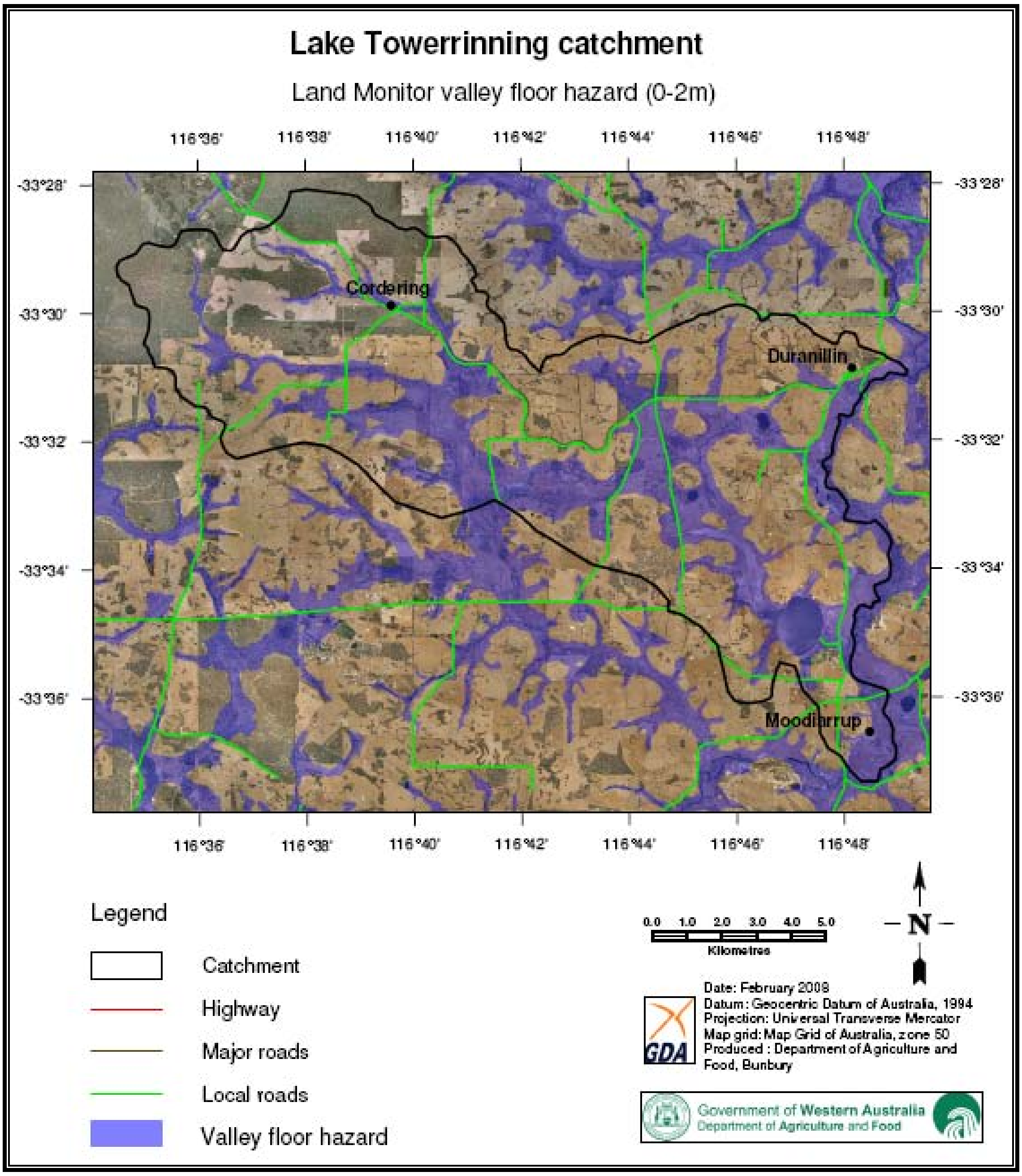

Figure 4 Valley floor hazard in Lake Towerrinning *(Land Monitor 2001)*.

Table 3 **Valley floor hazards in Lake Towerrinning** *(Source: Land Monitor 2001)*

Lake Towerrinning	Total area (ha)	% of catchment	Remnant vegetation (ha)	% of catchment	% of remnant vegetation
Catchment	15 705		3 434	22	-
Land Monitor valley floor hazard at different elevations above the main stream line					
0-0.5 m	4 445	28	735	4.7	21.4
0-1.0 m	4 777	30	789	5.0	22.9
0-1.5 m	4 837	31	800	5.1	23.3
0-2.0 m	4 838	31	801	5.1	23.3

2.4 Lake Towerrinning water quality

The landholders were presented with an update on the water quality in Lake Towerrinning which is considered a major regional asset by the catchment landholders and broader local community. A diversion structure was built in 1993 to direct saline surface flows which occur in early winter away from the lake, but allow fresher flows into the lake (George and Bennett, 1992). The Lake Towerrinning water quality data is presented in Figure 5, which shows that, since the diversion structure was commissioned in 1993, the electrical conductivity (EC) of the lake water has remained below 2500 mS/m on most observation dates. The figure also shows that the minimum EC reached each winter has not demonstrated any systematic change since 1993 and is probably dependant on the volume of fresh runoff received each winter.

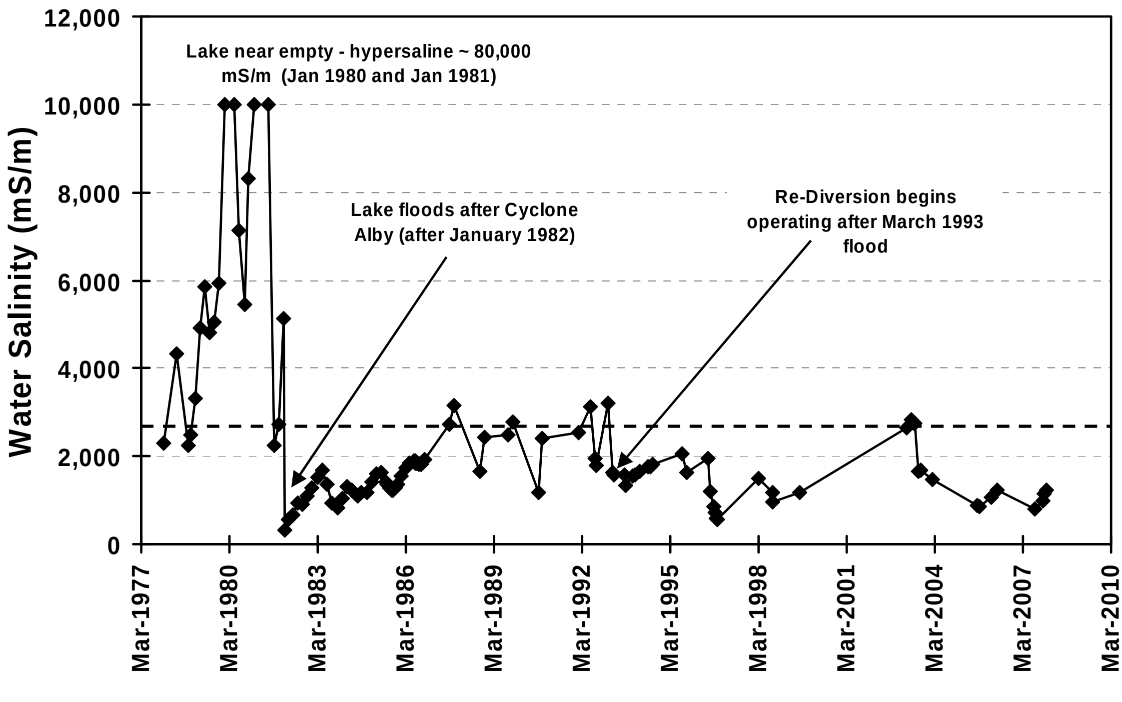

Figure 4 Lake Towerrinning water quality *(Source: Don Bennett, DAFWA, Bunbury and Katie Robinson, Shire of West Arthur.)*

2.5 Predicted impact of recharge reduction strategies

The Flowtube model (Argent 2005) was used to assess the likely impacts of three levels of recharge control on shallow watertables, and therefore salinity risk, for all catchments involved in the project. Flowtube is a simple two-dimensional model which simulates the position of the watertable over time along a groundwater flow line, either down a hillslope or down the main drainage line of the catchment. A limitation of this type of model is that the proportions of the catchment with shallow groundwater for different scenarios must be estimated from the length of the flow line saturated. However, because the model simulates the position of the watertable through time, an estimate at the end of the 20-year time frame required for this exercise is possible.

The model predicted that reducing recharge by 25 per cent, 50 per cent or 75 per cent across the catchment would have an impact on the area at risk from shallow watertables and thus the area at risk of becoming salt affected (see Table 4). The Land Monitor estimate of 28 per cent of the catchment potentially experiencing shallow groundwater was used as a base case, because the landholders' observations had not been included in the 20-year salinity risk estimate at this stage.

Table 4 **Predicted Lake Towerrinning salinity risk under three levels of perennial vegetation**

Scenario	Percentage of catchment with shallow watertable
Current practice	28
25% recharge reduction	23
50% recharge reduction	19
75% recharge reduction	18

3. SALINITY MANAGEMENT OPTIONS

The Lake Towerrinning landholders identified works that they had undertaken over the last 20 years to manage salinity. This is shown in the timeline in Figure 6. They also identified management actions that they were considering implementing to manage salinity in the future. These are captured in the mind-map in Figure 7. The mind-map shows the key areas for action (e.g. trees) and shows the linkages between some of the options identified.

Actions that did not work **Actions that worked**

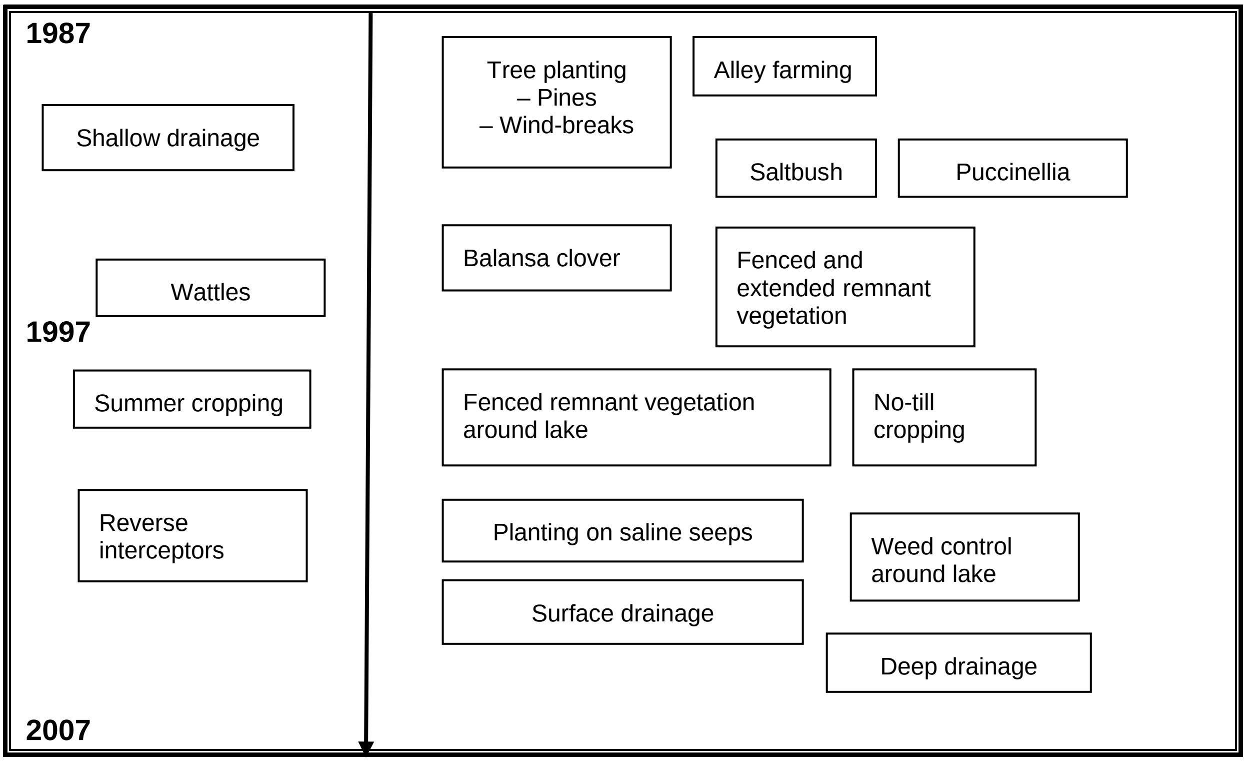

Figure 6 Works undertaken in Lake Towerrinning catchment.

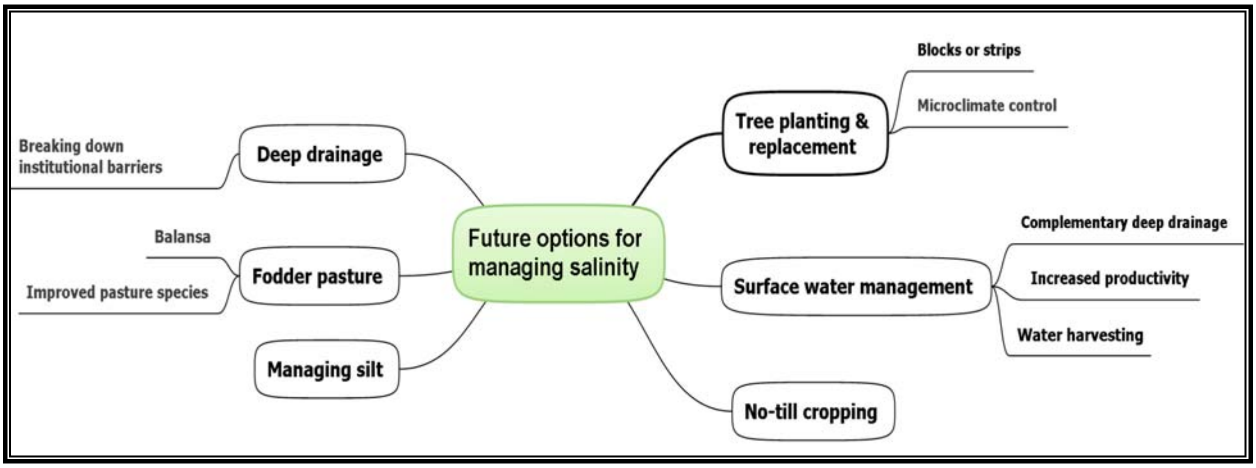

Figure 7 Potential options for managing salinity in the Lake Towerrinning catchment.

4. MODELLING

The landholders chose three scenarios from the salinity management options identified in Figure 7 for modelling to estimate their impact on salinity risk. The most appropriate modelling tool available for the simulation of each scenario was chosen, the choice being dependant on the nature of the management option to be simulated and the availability of data to support the modelling. Case studies from other catchments were used where no data were available for the Lake Towerrinning catchment. The following management options were nominated:

- Deep drainage
- Commercial trees
- Pumping.

4.1 Scenario 1—Deep drainage

The impact of deep drainage was estimated using Geographical Information System (GIS) tools. A network of arterial drains through the currently salt-affected and adjacent areas at risk was digitised on the valley floor, roughly parallel to the natural drainage (Figure 8). The areas hypothetically drained included the majority of the currently salt-affected area in the catchment. A hypothetical drain running parallel to the Arthur River was also included and its impact assessed separately to the other hypothetical drainage shown in the figure.

Areas impacted by the hypothetical drains were calculated from drain length and assumed lateral impacts only, not from an explicit simulation of drainage impacts on the groundwater system. Therefore the results are only indicative of the area of impact and the reduction in shallow watertables in the catchment and do not represent an expected outcome from deep drainage. Soil-landscape units expected to contain significant areas of soils likely to respond poorly to deep drainage, because of either low permeability or instability, were identified and are also shown in Figure 8.

4.1.1 Assumptions

- Safe disposal of drainage effluent is available.
- 49 km of feeder and arterial drains.
- 18 km of river drainage.
- Lateral impact ranges from 100 to 200 m either side of drain.
- Drain efficiency is between 75 per cent and 100 per cent.
- 200 m lateral impact required to make drain cost effective at 75 per cent efficiency.
- Sodic sub-soils likely to restrict lateral impact of drains.

4.1.2 Impact

The estimated impact of deep drains is based on a main drain with feeder drains to a total drain length of 49 km, as well as 18 km of river drainage as shown in Figure 8. Table 5 presents the possible effect of the drains with a 100 m and 200 m lateral impact. This was calculated to give an indicative area of impact and the reduction in shallow watertables in the catchment. The most likely impact is a reduced area of shallow watertables of between 980 ha and 1340 ha, assuming a lateral impact of 100 m and 75 to 100 per cent drain efficiency. It is not likely that the lateral impact will be more than 100 m because of the presence of unstable or low permeability sub-soils on the valley floors. These areas cover approximately 2500 ha but not all of this area is on valley floors where the primary salinity risk exists.

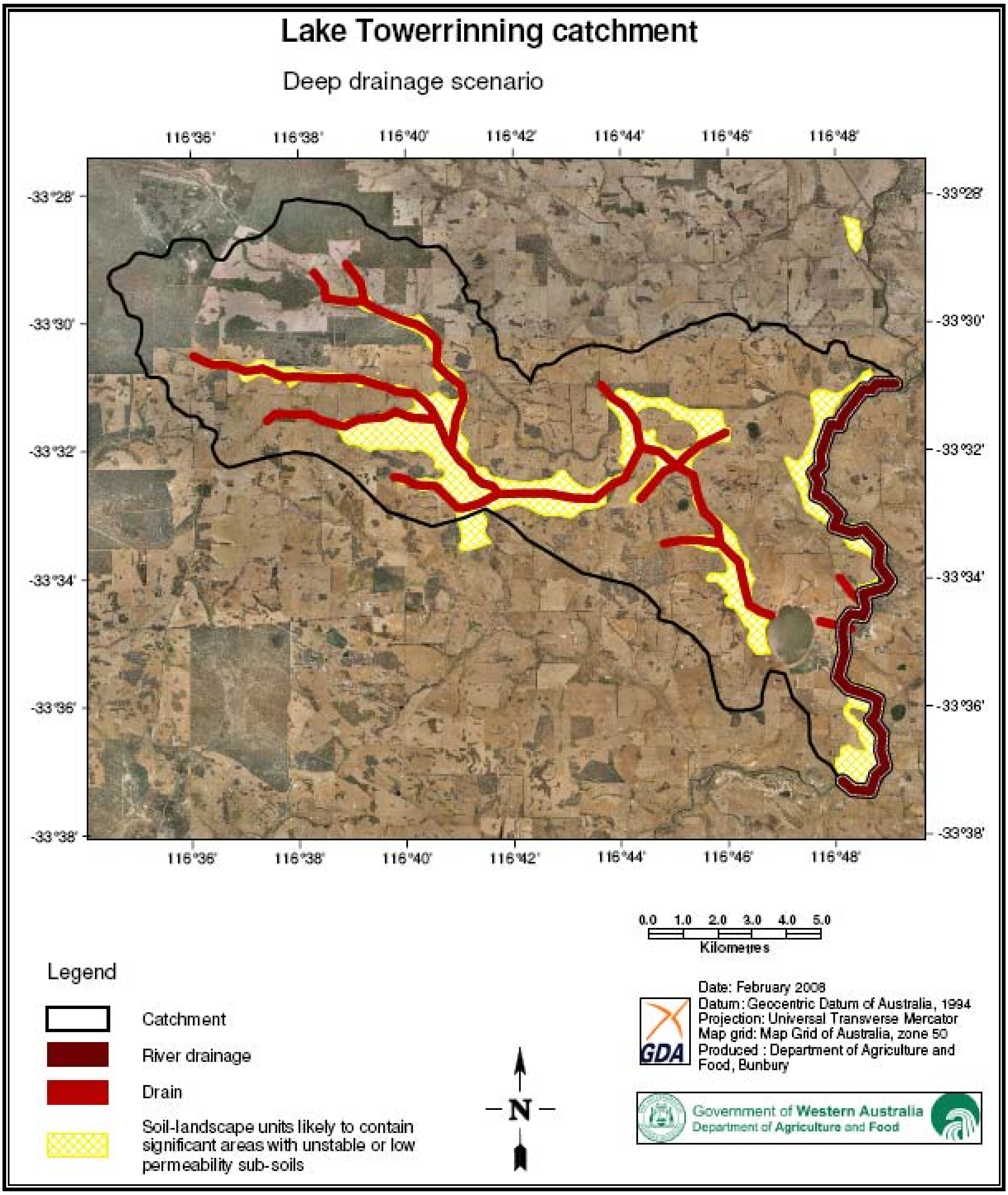

Figure 8 Deep drainage scenario (only indicative placement to calculate total drain length).

Table 5 **Impact of deep drains on shallow groundwater in Lake Towerrinning catchment**

Management	Area (ha)	Percentage of catchment with shallow watertable
Catchment	15 705	
Land Monitor valley floor hazard (0-0.5 m)	4 445	28
Deep drains – 100 m influence	979	22
Deep drains – 200 m influence	1 964	16
Deep drains plus river damage – 100 m influence	1 339	20
Deep drains plus river damage – 200 m influence	2 685	11

4.2 Scenario 2—Perennial pasture and surface water control

4.2.1 Assumptions

- Perennial pastures are healthy and are effective in reducing recharge.
- Surface water control at 100 m intervals reduces recharge by 30 per cent.

4.2.2 Impact

Different scenarios for perennial pasture were modelled and the results are summarised in Table 6. As discussed above, the Flowtube model predicts the proportion of a groundwater flow line that experiences a shallow watertable and this figure is converted to an area by reference to the Land Monitor valley floor hazard maps. The model does not explicitly simulate the impact of the shallow watertable on the surface condition because this is heavily dependant on factors such as soil type and management. The surface condition and productivity of areas with a shallow watertable cannot therefore be predicted and this was discussed with the landholders.

Table 6 **Impact of perennial pasture and surface water control on shallow watertable**

Management	Percentage of catchment with shallow watertable
Base case	20
Perennials 20:80	19
Perennials 30:70	19
Perennials 50:50	16
Surface water control every 100 m	18

5. ASSETS AND TARGETS

5.1 Assets at risk to salinity

The Lake Towerrinning landholders nominated, that in addition to agricultural land, the following assets are at risk or are already affected by salinity:

- Capercup Reserve
- Lake Towerrinning
- Local roads
- Water quality and dams
- Paleochannel
- River system.

5.2 Lake Towerrinning catchment targets

The landholders in Lake Towerrinning agreed to the following resource condition targets:

- Salinity contained to 15 per cent of the catchment in 2028. (Landholders estimated that 12 per cent of the catchment is currently affected by salinity and the full-risk by 2028 was estimated as 20-25 per cent of the catchment.)
- Maintain water quality in Lake Towerrinning < 1200 mS during winter.
- Increase productive use from salt-affected land with no net loss in profitability.
- Capercup Reserve stabilised and area affected by salinity to increase by no more than an additional 10 per cent (currently 30-40 per cent affected).

6. FUTURE OPTIONS TO MANAGE SALINITY AND NATIVE VEGETATION

The landholders identified salinity management options that they considered appropriate for them to implement in the short to medium term and these are summarised in Appendix 3. Further Management Action Targets (MATs) were discussed during workshop 2 and then prioritised according to the group's and/or individual's ability to implement the action and the potential impact on the likelihood of achieving their agreed land salinity resource condition target (Figure 8).

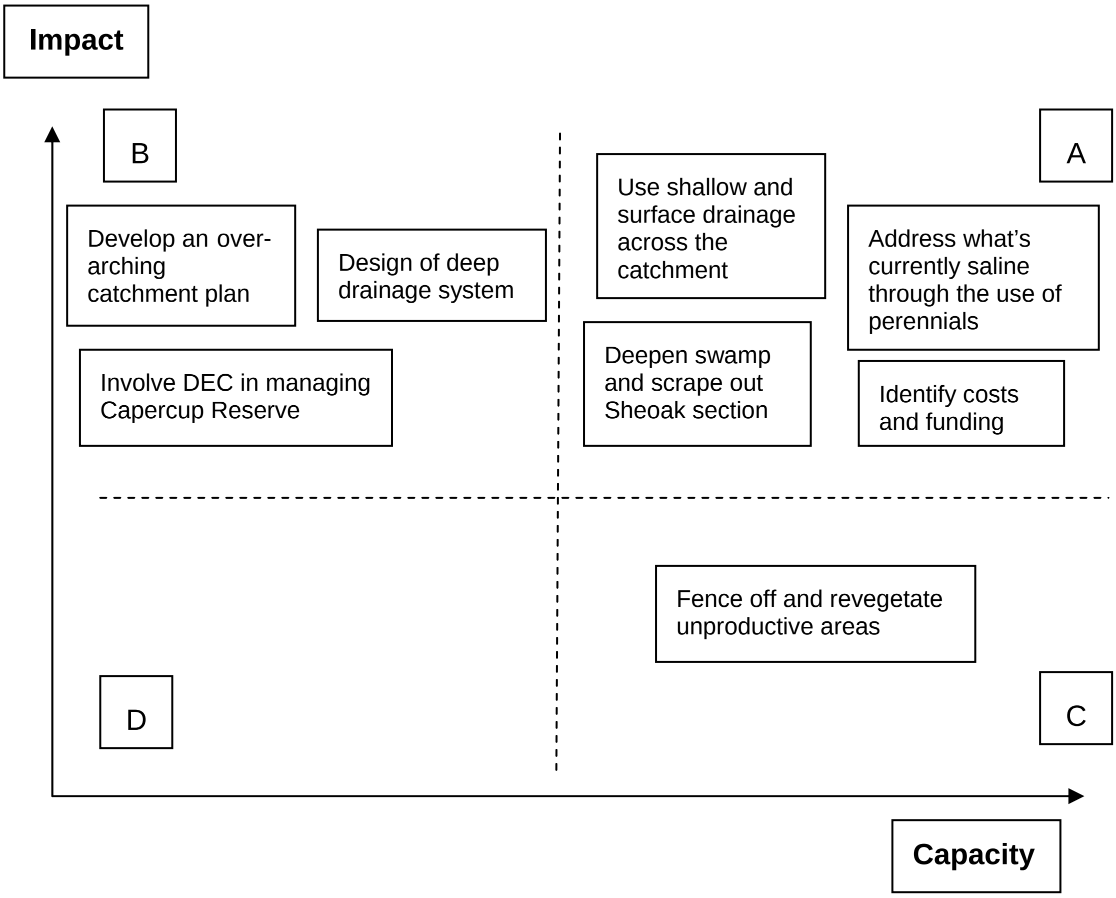

Figure 9 Prioritised management actions based on impact of action and capacity to implement.

Each of the nominated management actions was discussed to determine if it will have a low or high impact on achieving the agreed land salinity resource condition target. The group then decided if members had a low or high capacity to implement the action. This determined the quadrant in which the management action was placed (A, B, C or D). The quadrant in which an action is placed indicates its priority and timeline for implementation.

A = Immediate (0-3 years) action (high impact and high capacity).

B = Longer or medium-term action (needs more resources—high impact and low capacity).

C = Short-term action (a small win can help build confidence—low impact and high capacity).

D = Needs to be reviewed in future to see if priority or circumstances have changed (low impact and low capacity).

7. CONCLUSION AND RECOMMENDATIONS

The Lake Towerrinning landholders were presented with information on the extent of salt-affected land in the catchment derived from remotely sensed data under the Land Monitor project. The data suggested that over 600 ha (4 per cent) of the catchment was salt-affected in 1998. The landholders mapped currently salt-affected land and determined that 1800 ha (12 per cent) of the catchment is currently affected, the difference between the Land Monitor estimate and that made by the landholders is made up of saline areas not identified by the Land Monitor process and an expansion of the salt-affected area in the intervening decade. Analysis of the Land Monitor data indicates that the area mapped as salt-affected within the Shire of West Arthur increased at > 6% per annum in the period between 1990 and 1998.

The Land Monitor valley floor hazard mapping suggests that the maximum area at risk from salinity within the Lake Towerrinning catchment is 28 per cent, but this estimate is not time-bound and the landholders estimated that between 20 and 25 per cent of the catchment is likely to be salt-affected within 20 years if no further action is undertaken.

The Lake Towerrinning landholders nominated three scenarios for modelling to assist them in setting time-bound, achievable resource condition targets for land salinity. These were:

- Deep drainage
- Commercial trees
- Pumping.

The Lake Towerrinning catchment landholders set a 20-year, land salinity resource condition target to contain the extent of salt-affected land to 15 per cent of the catchment area and to limit the further degradation of the Capercup Reserve to an additional 10 per cent by 2028.

The modelling of potential salinity management actions suggested by the catchment group (section 4) shows that the resource condition target agreed to by the landholders is optimistic but achievable. The modelling suggests that large-scale drainage works and/or large-scale revegetation may deliver the agreed target. In the case of the proposed drainage works, significant issues concerning the safe and legal disposal of the drainage effluent would require resolution before any detailed planning could be started. Furthermore, a significant portion of the valley floors in the Lake Towerrinning catchment are likely to contain soils that will not respond well to deep drainage, due to either low sub-soil permeability or instability. Extensive site investigations would be required to ascertain sub-soil properties and to determine the best route for a drainage network. An economic analysis of the benefit to cost ratio for a drainage scheme is also recommended.

The Lake Towerrinning landholders prioritised the following salinity management actions in support of their agreed land salinity resource condition target:

- Use shallow and surface drainage across the catchment.
- Address what’s currently saline with the use of perennial pasture.
- Deepen swamp and scrape out sheoak section.
- Identify cost and funding options.
- Design deep drainage system.
- Develop an overarching catchment plan.

8. REFERENCES

Argent RM (2005) Flowtube Groundwater Calculator, Department of Agriculture, WA, Perth, Western Australia, Technical and User Manual 29 pages.

Blackwood Catchment Appraisal Team (2003) Blackwood Catchment: Beaufort Zone (Zone 4) Catchment Appraisal. Department of Agriculture, WA, Resource Management Technical Report 243, Perth, WA.

Clarke CJ, George RJ, Bell RW (1998, a) Major faults in the development of dryland salinity in the western wheatbelt of Western Australia, Hydrology and Earth Systems Sciences; 2(1): 77-91.

Clarke CJ, Hobbs RJ, Bell RW, George RJ (1999) Incorporating geological effects in the modelling of revegetation strategies for salt affected landscapes, Environmental Management 24: 99-109.

Clarke CJ, Mauger GW, George RJ, Bell RW, Hobbs RJ (1998, b) Computer modelling of the effect of revegetation strategies on dryland salinity in the western wheatbelt of Western Australia. I The impact of the revegetation strategies. Australian Journal of Soils Research 36: 109-129.

Clarke CJ, George RJ, Bennett DL, Bell RW (2000) Geologically related variations in saturated hydraulic conductivity in the regolith of the western wheatbelt of Western Australia and its implications for the development of dryland salinity. Australian Journal of Soil Research 38: 555-568.

Department of Agriculture and Food (2008) Map Unit Database (Database of the soil, soil-landscape and land system mapping of Western Australia). Accessed on 18/03/2008.

Evans F (2001) Collie and Pemberton Landsat TM Scenes: Salinity Mapping. CSIRO Mathematical and Information Science, CMIS Task Report 3/01, Perth, Western Australia.

George RJ, Bennett DL (1992) ‘The Rediversion’. A submission to the NPNCA.

George RJ, Cochrane DL, Bennett DL (1994) ‘Groundwater systems responsible for dryland salinity in the Lake Towerrinning catchment, Western Australia’. In: Proc. Water Down Under, IAH and IEA Conference, Adelaide, pp 355-360.

Keipert N, Percy HM, Raper GP (in press) Setting targets for resource condition in Queerfellows Catchment. Department of Agriculture and Food, WA, Summary for Workshop Participants Bunbury, WA.

Keipert N, Percy HM, Read V (in prep.) Setting Target for Resource Condition: Community Consultation and Involvement. Department of Agriculture and Food, WA, Resource Management Technical Report Perth, WA.

Land Monitor (2001) www.landmonitor.wa.gov.au

McDonald MG, Harbaugh AW (1988) A modular three-dimensional finite-difference ground-water flow model. US Geological Survey, US Dept. Interior, Techniques of Water Resources Investigations Washington.

McFarlane DJ, George RJ, Caccetta PA (2004) The extent and potential area of salt-affected land in Western Australia estimated using remote sensing and digital terrain models, Proceedings of the First National Salinity Engineering Conference, 9–12 November 2004, Perth, Western Australia.

Raper GP, Kowald JM, Percy HM, Smith MS, Hu S (in prep.) Groundwater Trends and Salinity Risk in the Medium to Low Rainfall Zones of the South-West Natural Resource Management Region. Department of Agriculture and Food, WA, Resource Management Technical Report Perth, WA.

South West NRM Region Appraisal Team (2006) Hillman and Narrogin zones (Blackwood Zones 8 and 9) rapid catchment appraisal. Department of Agriculture and Food, WA, Resource Management Technical Report 309, Perth, WA.

9. APPENDICES

Appendix 1. Workshop dates and attendees

Workshop 1: ***Linking science with local aspirations***

Tuesday, 4 March 2008. Moodiarup Sports Pavillion, Moodiarup.

Attendees

Landholders: Greg Ricetti, Tom Quill, Gary Abbott, Des O'Connell, Ian Pierce, Tereasa Pierce

Support team: Paul Raper, Leon van Wyk, Katie Robinson, Richard George, and Andrew Huffer

Workshop 2: ***Setting targets for action***

Wednesday, 19 March 2008. Moodiarup Sports Pavillion, Moodiarup.

Attendees

Landholders: Greg Ricetti, Tom Quill, Gary Abbott, Des O'Connell, Ian Pierce, Tereasa Pierce, Ray Harrington

Support team: Paul Raper, Leon van Wyk, Katie Robinson and Andrew Huffer

Appendix 2. Workshop feedback

What was worthwhile?	What should be changed?
• Achievable targets identified. • Community input. • Change in mindset by DAFWA (to consider drainage). • Data provided. • Know what we have to do to achieve targets. • Looking at the big picture. • Modelling provided valuable data.	• Combined impacts of all scenarios identified. • Greater involvement of all land managers in catchment.

Appendix 3. Future methods of managing salinity in the Doradine catchment

	Management options	Name	Please specify (type, approx when)
1.	**Deep-rooted perennial species to increase water use**		
•	Woody shrubs and trees	Des O'Connell	Windbreaks for crop and livestock
•	Commercial tree crops (e.g. pines, oil mallees)		
•	Land conservation (add to existing remnant veg)	Greg Ricetti	Around discharge areas
•	Forage crops (e.g. tagasaste)	Ian and Tereasa Pierce	Planned
2.	**Plant crops and pastures to increase water use**		
•	Increase productivity of saline lands (e.g. balansa, tall wheat grass, or saltbush)	Ian and Tereasa Pierce Tom Quill Greg Ricetti Gary Abbott	More Pucchinella Balansa on river flat Balansa on-going
•	Perennial pastures (e.g. Lucerne)	Ian and Tereasa Pierce Tom Quill Gary Abbott	Planned for future Combined with tree ally
•	Summer crops		
•	Improved agronomy of annual pastures and crops	Greg Ricetti Gary Abbott	No till
3.	**Collect, reuse and dispose of surface water**		
•	Surface earthworks (e.g. grade backs, inceptor banks, w drains)	Ian and Tereasa Pierce Des O'Connell Tom Quill Greg Ricetti Gary Abbott	Planned for 2008 To complement and control deep drainage Shallow drainage In conjunction with deep drains
•	Other strategies (e.g. woody perennials).		
4.	**Drain or pump, reuse and disposal of groundwater**		
•	Deep drains	Ian and Tereasa Pierce Des O'Connell Greg Ricetti	Planned for 2009 Essential as starting point to attack salinity Priority
•	Pumps		
•	Aquaculture		
•	Siphons and relief wells		
5.	**Protect and manage remnant native vegetation**		
•	Protective fencing	Gary Abbott	
•	Rehabilitation	Gary Abbott	
•	On-going management (e.g. weed control)	Gary Abbott	

Appendix 4. Soil-landscape units of the Lake Towerrinning catchment (DAFWA, 2008)

Mapping unit	Area (ha)	Proportion of catchment (%)	Landform	Soils
253Bo_1	570	3	Hillcrests, summit surfaces, middle to upper slopes (rarely extending to lower slopes)	Deep sandy gravels, duplex sandy gravels and shallow gravels
253Bo_3	< 10	-	Mid to upper slopes	Grey deep sandy duplex soils with rock outcrop, gritty brown deep sands and red shallow loamy duplex soils
253Bo_4	< 10	-	Valley flats and alluvial plains (150-2500 m wide), swamps and lunettes	Grey deep and shallow sandy duplex and saline wet soils
253Dk_1	2190	13	Crests, mid to upper slopes	Deep sandy and loamy gravels, duplex sandy gravels and shallow gravels
253Dk_1p	40	0	Mid to upper slopes, crests and breakaways	Duplex sandy gravel, shallow gravel with minor loamy gravel and grey sandy duplexes
253Dk_2	790	5	Lower to upper slopes and crests	
253Dk_2i	1890	11	Lower to upper slopes and crests	Deep and duplex sandy gravels, shallow gravels and minor grey deep sandy duplex
253Dk_3	1770	10	Lower to upper slopes and crests	Friable red/brown loamy earth, red loamy duplexes, brown deep loamy duplex and minor rock outcrops
253Dk_4	230	1	Footslopes and lower slopes	Grey sandy duplex, duplex sandy gravel and loamy gravel
253Dk_5	2580	15	Valley flats and narrow alluvial plains (300-900 m wide)	Grey deep sandy duplex with minor grey shallow duplexes and saline wet soils
253Dk_5w	340	2	Swamps and lakes	Salt lake soil and saline wet soil with minor yellowish brown deep sand
253Dk_6f	2110	13	Footslopes, lower slopes and occasional elevated flats	Deep and duplex sandy gravels, shallow gravel, loamy gravel and gravely pale deep sands
253Dk_6i	1300	8	Lower to upper slopes and crests	Deep sandy gravel, pale shallow and deep sands and gravely pale deep sand
253Dk_7	410	2	Dunes and large lunettes	Alluvial yellowish brown deep sands
253EuDM	200	1	Lateritic ridges	Duplex sandy gravels, Loamy gravels, Yellow/brown deep sandy duplexes and Brown deep loamy duplexes
253EuDMi	640	4	Lateritic ridges	Duplex sandy gravels and Loamy gravels
253EuLK	490	3	Shallow minor valleys with swampy floors incised into lateritic terrain	Duplex sandy gravels, Loamy gravels, Grey deep sandy duplexes, and Saline and Semi-wet soils

Mapping unit	Area (ha)	Proportion of catchment (%)	Landform	Soils
253EuLKd	400	2	Minor valleys (20-40 m deep)	Loamy gravels, Duplex sandy gravels, Brown deep loamy duplexes and Brown loamy earths
253EuLKu	300	2	Swampy floored minor valleys (5-20 m deep)	Duplex sandy gravels, Loamy gravels, Grey deep sandy duplexes and Wet, Saline wet and Semi-wet soils
255DpDW	200	1	Broad, undulating lateritic divides, lower to upper slopes and hillcrests	Duplex sandy gravels and Loamy gravels with pockets of deep sands, often gravely, and minor Shallow gravels
255DpMH	160	1	Low lateritic hills rising above the plateau surface	Loamy gravels and Duplex sandy gravels
257Be_1	180	1	Broad valley flats and alluvial plains (1.5-6 km wide)	Grey deep and shallow sandy duplex soils with sodic subsoils
257Be_3	50	-	Dunes	Yellowish brown deep sands and minor grey duplex soils