

SALINITY MANAGEMENT

WITHIN THE

GOOLWA TO WELLINGTON

LAP AREA

A TECHNICAL REPORT PRODUCED FOR

THE GOOLWA TO WELLINGTON

LOCAL ACTION PLANNING BOARD

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PIRSA Rural Solutions

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October, 1999.

Chris Ainsworth,
Goolwa to Wellington LAP Board.

Dear Chris,

Here is the background technical report, produced under the terms of reference as provided by your committee.

As requested, we have included details of:

- hydrology of the LAP area
- types of salinity problems in the LAP area
- current extent/severity of dryland salinity in the LAP area
- an assessment of the “do nothing” scenario
- an assessment of the “do something” scenario
- a range of management options
- a range of specific strategies to target “hotspots”
- further investigation and monitoring that could be undertaken

Yours sincerely,

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Trevor Dooley and Chris Henschke are project Officers for the NHT project “Catchments back in balance”. They currently work with SA community groups helping the groups to develop salinity management plans. They also operate the CSAWS (seesaws) network, an alliance of stakeholders interested in managing rising watertables and salinity. This technical report was prepared separate to the NHT project, as a specific consultancy to the Goolwa to Wellington LAP Board. The LAP Board receives NHT funding.

EXECUTIVE SUMMARY.

The Goolwa to Wellington Local Action Planning (LAP) area covers approximately 265000ha. It can be divided geographically into two distinct components:

- the uplands (114000ha) - land systems of the central/eastern ranges and footslopes
- the lowlands (151000ha) – land systems of the lake plains and mallee country.

The hydrology of the LAP area is complex, with groundwater flowing through three main aquifer types – limestone, clay and fractured rock. Each have different characteristics which affect the extent and severity of salinity problems, and the likely impact that management strategies will have on such problems.

There are six major surface water catchments within the LAP, all draining into the lake system. Flooding occurs in wet years, particularly from the Angas and Bremer rivers.

There are two main salinity problems occurring within the LAP area.

land salinisation

- saltland associated with rising groundwater (includes irrigation areas)
- saltland not associated with rising groundwater (eg. gilgai soils)

water salinisation

- saline surface waters (streams, rivers, lakes, dams)
- saline groundwaters (aquifers)

Currently, 6000 ha of land (2% of the LAP area) are salinised to the extent that productivity is severely affected. Half of this saltland is associated with historical discharge sites (present in pre-European times). A 50% increase in salt-affected land (to 9000 ha) can be anticipated within 25 years.

Much of this increase in saltland will occur:

- As extensions of existing (historical) discharge sites in the lowlands
- In scattered valleys in the uplands
- In the (irrigation) area north and east of Milang adjacent to Lake Alexandrina

Export of salt and stream salinity levels are predicted to rise. Specific areas within the Bremer Barker catchment have been prioritised for action on the basis of salt output/input ratios, as part of previous work undertaken by the project officer for that catchment.

Under the “do nothing” scenario, land and water salinisation increase, with increased threat to agricultural productivity, infrastructure, ecosystems and water supplies. In the extreme case (a series of wet years), an extra 3000 ha of land (to 12000 ha total) could become temporarily saline.

Managing land and water salinisation problems is technically feasible through recharge reduction (increasing plant water use) and discharge enhancement (engineering solutions such as drainage and pumping). However, the former requires a large proportion of the catchment to be treated, the latter is expensive and requires a safe disposal point for saline water.

This report recommends specific recharge reduction targets which aim to control the spread of saltland, contribute to a reduction in water salinisation, and increase the buffering capacity of the system to cater for a series of wet years. Large-scale recharge reduction invariably requires change in the existing agricultural system to include a significant component based on perennial plants. Recharge reduction is likely to have a local impact on groundwater levels within ten years.

The process used to determine the amount and type of land use change necessary to achieve recharge reduction targets allows for considerable input from the LAP Board and individual landholders. Examples are included for recharge reduction to control salinisation at an upland and a lowland site.

The extensive area north and east of Milang (1000 ha) is at risk of salinisation from a combination of hydrological factors involving irrigation (water resources, practices, location of vineyards with respect to shallow watertables). Prior to irrigation, the area contained historical discharge sites – sites which may now be re-activated. This area is the subject of separate investigations undertaken at the behest of the Angas Bremer Water Resources Committee, and any action needs to be guided by the outcomes of this recently completed investigation. Engineering options such as pumping and drainage may be seriously considered here.

Saline resources have existed within the LAP area since pre-European times; clearing and agricultural development have accelerated the salinisation process. Increasing productivity from saline resources should be a high priority. Current technology exists for the successful establishment of salt-tolerant grasses, trees and shrubs. Feasibility studies into the establishment of industries based on aquaculture, salt harvesting and extraction of chemicals from algae are recommended. The scope for ecotourism ventures based on saline environments, given the proximity to the Lower Lakes Ramsar Wetlands, should also be investigated.

This report also identifies other areas for further work and investigation such as monitoring groundwater and biodiversity levels, quantifying local recharge from sand dunes, and quantifying the damage to infrastructure (roads, railways, pipes...) from salinity and rising watertables. An economic analysis of the various options for combatting land and water salinisation, and using saline resources, needs to be undertaken.

Recommendations to the LAP Board

It is recommended that the LAP Committee initiate and support programs which:

- strategically target hotspot saline areas with a 50% recharge reduction rate
- contribute to a general reduction in recharge of 33% across catchments within the LAP area
- promote the appropriate siting and management of irrigation ventures with respect to shallow watertables
- aim at increasing the use and productivity of saline resources
- raise general awareness and understanding of, and contribute to better identification and monitoring of, salinity problems within the LAP area.

The above recommendations are subject to the constraints of economic and social factors, and the relative priority given to the management of salinity compared to other land degradation problems within the Goolwa to Wellington LAP area. Generally speaking, there is a positive interaction between management for salinity control and management for other degradation problems.

Recharge reduction strategies will help reduce flooding and waterlogging problems. Saltland agronomy will help reduce soil erosion. Revegetation strategies for recharge reduction can help meet the demands for maintaining and increasing biodiversity. On the other hand, amelioration of acid soils and non-wetting sands will help increase water use and recharge reduction.

Planning for salinity management necessitates a whole catchment approach, and often provides a framework for management of associated problems. As the recommendations of this report intimate, the challenge for the LAP Board is to construct an integrated plan which includes elements of on-ground action, policy planning, industry development and education.

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APPENDIX 1 contains:

- Figures 1 to 12 (maps)
- HWU factsheets 1, 2, 3.

1) HYDROLOGY OF THE LAP AREA

Changes to the groundwater balance (recharge = water in, discharge = water out), are responsible for the spread of dryland salinity within the LAP area. Proposals to manage salinity must be based on an understanding of LAP area hydrology and the characteristics of groundwater flow systems (aquifers).

The Goolwa to Wellington LAP comprises two distinct physiographic units:

Uplands – land systems of the central and eastern ranges and footslopes

Lowlands – land systems of the lake plains and mallee country.

GROUNDWATER RESOURCES

The aquifer systems of the LAP are shown in Figure 1. They include:

- | | |
|----------|--|
| Uplands | - Fractured rock basement aquifer (F/R)
- Permian basement aquifer (P) |
| Lowlands | - Renmark Group confined aquifer
- Murray Group limestone aquifer (MGL)
- Quaternary clay aquifer (CLAY)
- Quaternary limestone aquifer (LST) |

a) Uplands

In the uplands, catchments are typically small and discrete, with local flow systems (fractured rock aquifers) operating. Recharge and discharge occurs at the local scale (within a distance of one to three kilometres).

Salinity outbreaks are mostly associated with discharge at drainage lines; because of the well-incised (steep sides) drainage, the potential for increase in saline areas is small.

Winter waterlogging exacerbates salinity and contributes to increased recharge.

The uplands export water to the lowlands via drainage lines, and via the western scarp (recharge to a regional limestone aquifer). Deep drainage from river flow (eg. Angas-Bremer) causes recharge to both the limestone aquifer and a clay aquifer under the lowlands (most goes to the limestone aquifer). This recharge has a local effect in reducing water salinity in these aquifers.

i) Fractured Rock Basement Aquifer (F/R)

Geology

The uplands are part of the Mt Lofty Ranges (MLR) which evolved from the folding of a great thickness of sediments (24,000m) deposited in a large geological sedimentary basin known as the Adelaide Geosyncline. The sediments formed sandstones, siltstones, and limestones.

The Kanmantoo trough was a subsequent sedimentary basin that evolved on the south eastern flanks of the Adelaide Geosyncline. Up to 15,000 metres of sediments accumulated to form the highly metamorphosed Kanmantoo Group which outcrop over the eastern Mt Lofty Ranges and consist of quartzites, slates, schists, gneisses and marbles. Pyritic shales (source of iron sulfates) are occasionally interbedded. Drilling has shown that the Kanmantoo Group also underlie much of the Murray Basin to the east (Barnett, 1996).

During a warm wet climatic phase, iron accumulated near the soil surface as “laterite”. Lateritic remnants occur throughout the uplands of the LAP especially in the Hope Forest and Meadows areas. Lateritic remnants have deeply weathered regolith profiles which store large quantities of soluble salts. Lateritic plateaux may also have a high recharge potential. Barrett-Lennard and Nulsen (1989) suggested that there may be considerable recharge through preferred pathways (often old root channels) in lateritic profiles in high rainfall areas.

Palaeochannels may be associated with some valley systems in the uplands of the MLR. The basement has been eroded by some tens of metres in the broader valleys and infilled with alluvial sediments such as clays and sandy or gravel lenses. Aquifers may develop in these materials. The hydraulic connection between the sedimentary valley aquifer and the fractured rock aquifer upslope requires further research.

Groundwater

Groundwater systems associated with basement rocks of the Adelaide Geosyncline and Kanmantoo Group contain fractured rock and weathered rock aquifers.

Local flow systems are likely due to the incised nature of the landscape, with groundwater flowing from elevated areas (recharge areas) to valley floors. Figure 2 is a groundwater flownet of the LAP. The uplands is an idealised flownet based on the HARSD principle (Salama *et al.*, 1996) whereby the flownet is a subdued (smoothed) reflection of the surface topography. It shows that all flow from the catchment boundary discharges into the nearest ephemeral/perennial drainage line. The major drainage lines are therefore groundwater accumulation zones for local flow systems in fractured rock aquifers. The lowlands flownet is derived from Barnett (1994). The extent of connection between uplands and lowlands groundwater systems is minimal and salt is transported to the lowlands mainly via the surface drainage system.

Groundwater flow in fractured rock (F/R) aquifers is greatly influenced by geology and rock structure. Systems may be compartmentalised by geological barriers (ie resistant bands of hard rock). George *et al.*, (1994) showed that groundwaters are contained within cells/compartments by basement structures (basic dykes, quartz dykes, faults, fractures and shear zones). Geological lineaments can act as barriers or conduits to groundwater flow (Lewis, 1991) and therefore affect the location of the discharge area. Groundwater flow may be preferentially controlled by the strike of the rock formations and therefore tend to flow along the strike of a fractured rock aquifer rather than down gradient (Kevin and Dyson, 1991). This has consequences for treatment of high recharge areas (see groundwater recharge section below).

F/R aquifers have variable yields and quality depending on rock type, degree of fracturing, topography and climate.

In the Kanmantoo Group, groundwater is generally more saline than in the Adelaidean sediments. Variations in groundwater salinity are related to rock type, rainfall and recharge conditions. In higher rainfall areas, groundwater salinity may be of the order of 200 to 1 500 mg/L TDS. It is more likely that salinity is in the range of 3 000 - 10 000 mg/L TDS. This may be due to the weathered rock aquifer of the Kanmantoo Group having a generally low hydraulic conductivity because of the clayey micaceous weathering products. The fractured rock aquifer extends a few tens of metres into the unweathered rock zone with micaceous clays reducing the permeability of fracture zones.

Groundwater recharge

Recharge areas are likely to occur along the rocky ridge lines that characterise the landscape of the eastern Mt Lofty Ranges. While groundwater recharge can occur across much of the landscape, it is highest under exposed rocky ridges where only thin skeletal soils develop. The concept of rocky ridges acting as high recharge areas in Victoria is well documented (Dyson and Jenkin, 1981). However, the waterbalance of a rocky ridge needs to be understood in terms of the amount of rain infiltrating the ridge and amount of surface water running off the ridge. Higher recharge may therefore occur at the base of the slope where ponding of water occurs.

Treatment of high recharge areas (eg planting trees on rocky ridges) is not always guaranteed of success. As mentioned previously, there may not be a direct groundwater connection between the fractured rock aquifer of the rocky ridge and the alluvial aquifer in the adjacent valley.

Groundwater discharge

Dryland salinity is a symptom of groundwater discharge and is generally confined to drainage lines although break-of-slope and hillside seeps occasionally occur. Many areas are only mildly salt affected; examples include Echunga and the Mt Barker area. These areas contain only small areas of salinity and are usually associated with poor drainage in valleys. In the Hope Forest area, dryland salinity occurs as wet seepage areas in gullies and valleys. Construction of numerous dams in these gullies is pressuring groundwater systems and resulting in seepage areas developing around some dams. Some hillside seeps also occur where geology controls groundwater flow patterns.

Mobilisation and accumulation of sulfur and iron causes the formation of Inland Saline Acid Sulfate Soils (ASS) in discharge areas (Fitzpatrick and Merry, 1998). They are associated with pyritic shales (Fitzpatrick *et al*, 1992), which are the source of sulfides. This has an impact on water quality with the release of sulfuric acid from these sites.

ii) Permian Basement Aquifer

Geology

Permian sediments outcrop over a considerable area of Fleurieu Peninsula where they are subject to rapid gully erosion if vegetative cover is removed (Ludbrook, 1980). The glacio-fluvial sediments consist of boulder and sandy till, gritty sandstone, and clay shale. The sediments were mostly deposited in fresh water and contain numerous erratics of granite and Kanmantoo Group rocks. Between Victor Harbour and Strathalbyn, fractured rocks of the Kanmantoo Group are sporadically overlain by Permian glacial sediments at varying depths.

Groundwater

Local groundwater systems with short flow paths occur in the dense low permeability tillite, with deep groundwater flow in the underlying fractured rock aquifer. Groundwater salinity ranges from 5 000 to 15 000 mg/L TDS in this aquifer type. Sandy glacial deposits around Mt Compass have been utilised for irrigation water.

Groundwater discharge

Dryland salinity is generally associated with poor drainage in valley floors. Many of the valley systems are incised with erosion gullies and dryland salinity may be expressed as saline baseflow into creeks. This has had an effect on water quality in the area and dams can no longer be sited in water courses. In some cases, salinity has extended up some tributary gullies. The main occurrences of dryland salinity in the Permian basement are in the Torrens Vale and Inman Valley areas. Saline baseflows occur in the Currency Creek catchment.

Some 5 ha of dryland salinity is associated with Permian sediments, 3 km west of Sandergrove. Increasing groundwater pressures have caused mound spring phenomena (relating to swelling clay soil types) at the lower end of a hillside saline seep.

Anecdotal information (Sandergrove Plains Landcare Group) indicates that the salinity at Sandergrove was caused by the 1954 earthquake. This is not unusual, as a number of occurrences of dryland salinity across Australia have been attributed to earthquakes (eg Meckering, WA). Geological controls on groundwater flow patterns have recently been documented (eg Please *et al.*, 1990, Lewis, 1991 and George *et al.*, 1994) and since earthquakes can re-activate fault lines, this may change groundwater flow patterns resulting in the development of new discharge areas. Although there is no direct data to support this theory, Figure 1 shows that the Encounter Fault passes through the Sandergrove area. Seismic activity may therefore have been responsible for changing groundwater flow along the basement / basin contact.

b) Lowlands

The Murray Plains portion of the LAP is underlain by Quaternary and Tertiary sediments of the Murray Basin. The Murray Basin is a saucer shaped geological depression filled with a sequence of sediments to a maximum thickness of 600m (Brown and Stephenson, 1991). The LAP lowlands is geologically part of the Murray Basin and is underlain by up to 300m thickness of Tertiary sands, clays and limestones (Barnett and Stadter, 1991).

There are two main regional aquifers under the lowlands: An upper unconfined or watertable clay aquifer and a deeper regional confined limestone aquifer. There is limited interaction between the two aquifers with some downwards leakage from the clay in local recharge areas, and upwards flux from the limestone in low-lying discharge areas adjacent to Lake Alexandrina.

While groundwater flow in the uplands is dominated by local flow systems, intermediate (sub-regional) systems occur on the lowlands. Waterhouse (1978) noted minimal contribution to the regional lowland systems from uplands fractured rock aquifers. While the local systems of the uplands discharge into streams, the streams act as recharge areas to groundwater on the lowlands.

i) Renmark Group confined aquifer

The Renmark Group is the deepest aquifer in the basin. It is a confined aquifer and is part of a regional groundwater flow system (long and deep flow paths) with flow from the basin margins toward the River Murray and Lake Alexandrina. Groundwater flows slowly (0.5-1.0 m/year) and discharges by upwards leakage into the overlying aquifer. The Renmark Group aquifer is not widely used as a water resource due to relatively high salinity. Salinities range from 2 000 to 23 000 mg/L TDS.

ii) Murray Group limestone (MGL) aquifer

Geology

The Murray Group consists of a number of units including the Mannum Formation. This is a Tertiary sequence dominated by fossiliferous limestones with some sandy and marly interbeds of variable thickness (Waterhouse *et al.*, 1978).

Groundwater

The Murray Group limestone (MGL) aquifer only occurs in the western half of the Murray Basin (see Figure 4) where it overlies and laterally abuts the Renmark Group aquifer (Telfer, 1990). The two deepest aquifers are separated by a marly aquitard (confining layer) which virtually envelops the Murray Group aquifer, therefore isolating it from direct hydraulic contact with the Renmark Group aquifer (Telfer, 1990).

The MGL aquifer occurs in sediments dominated by permeable limestones, which are cavernous in some areas. Aquifer testing showed high transmissivities ranging from 500 to 1500 m²/day (Waterhouse, *et al.*, 1978). The aquifer is 75 – 100m thick. Well yields are high and range from 10 to 40 L/s (Howles, 1999). Groundwater moves from the basin boundary in a general north-west to south-east direction toward Lake Alexandrina (see Figure 3).

The aquifer ranges from semi-confined to unconfined. It is confined where the clay system occurs above it. A weak confining layer generally caps the MGL between Goolwa to Wellington but disappears to the south nearer Lake Alexandrina. In the north east of the basin, the top of the limestone rises above the zone of saturation and the aquifer is unconfined (Waterhouse *et al.*, 1978). This is illustrated in the hydrogeological cross section in Figure 5.

The aquifer has been widely developed for stock, domestic, irrigation and town water supplies. Lenses of good quality water occur near the Angas and Bremer Rivers (1 500 to 3 000 mg/L TDS). The salinity of this aquifer rapidly increases with increasing distance from the recharge areas to reach a maximum of 20 000 to 35 000 mg/L TDS in discharge areas. At Murray Bridge the aquifer has a salinity of 12 000 mg/L.

The limestone aquifer was the main supplier of irrigation water in the Angas Bremer Irrigation Area (ABIA), when significant use of groundwater for irrigation commenced in the 1950's.

Overpumping subsequently caused a large cone of depression and increasing groundwater salinity during the 1970's. In recent years, the use of recharge wells and a very wet year in 1992 has led to a dramatic recovery in the water levels of this aquifer (Barnett, 1994). Hydraulic pressures in the confined aquifer are now equivalent to pre-irrigation pressures, although salinities will be slow to change.

The restored pressure in the confined aquifer means that there is now some potential for upwards leakage from the MGL aquifer in the south. This, combined with the application of irrigation water from Lake Alexandrina has increased the risk of rising watertable and salinisation in the low lying southern areas of the Basin. (Angas Bremer Water Resources Committee, 1996). It has been suggested that salinity problems are only expected to occur in some low lying areas in the south that were badly salinised prior to irrigation development.

Areas at risk have been defined by Howles (1995). Locations where groundwater is less than 3 metres and where large scale water allocations are applied are most at risk. It is noted that historically this area was subject to waterlogging and salinity and the re-emergence of such problems would only signify that the basin has returned to pre-irrigation conditions. In the pre-irrigation state groundwater was artesian with levels at 1.5m above ground level in low-lying areas near the lake.

Groundwater recharge

Recharge areas to the MGL aquifer are:

- Basin boundary – along the western escarpment where Tertiary sediments onlap the gently sloping basement (Barnett per comm).
- Faults - the western margin of the Murray Basin is strongly fault controlled with considerable vertical displacement (Barnett, 1994). Streams crossing these fault lines will therefore lose water more readily.
- Groundwater leakage from the basement into the MGL. - Lateral groundwater flow from F/R aquifers is unlikely to provide significant input due to the low permeability of F/R aquifers (Waterhouse *et al.*, 1978).
- Localised recharge where intermittent streams such as the Angas Bremer Rivers flow out of the MLR onto the plains especially in flood events. In the Angas-Bremer Irrigation Area (ABIA), although the MGL aquifer is semi-confined by overlying Quaternary clay, recharge still occurs by downwards leakage of winter stream flows (Barnett, 1994). More water drains down vertically to the MGL, than drains laterally into the Quaternary Clay aquifer (Barnett, pers comm).
- Outcrops of MGL occur where the clay is absent with potential point source recharge. Barnett (pers comm) noted sinkholes in the limestone upslope of Ferries McDonald Park in land systems in the north of the LAP area. Cleared land with deep sandy soils or sinkholes and few subsurface barriers will generate most infiltration from high rainfall “recharge” events (Day, 1997).

- Vertical downwards leakage from the overlying unconfined aquifer – this was stronger when there was a large cone of depression in the MGL aquifer.
- Artificial recharge bores in the ABIA.
- From land systems outside the LAP area.

Groundwater discharge

The limestone aquifer discharges by evapotranspiration from the floodplain or by direct inflows to the River Murray or to Lake Alexandrina (Barnett, 1994).

In pre-irrigation times, the MGL aquifer also discharged to low-lying land near Milang (adjacent to Lake Alexandrina) because the pressure head in the aquifer was above the ground surface in these areas. During the period of large groundwater abstraction for irrigation in the Angas-Bremer, these areas became inactive in terms of discharge.

However, with irrigation supplies now being sourced more from Lake Alexandrina, and less from the limestone aquifer, the increasing pressure in the MGL aquifer may cause positive heads to again develop in low-lying areas. Although the vertical gradient between the piezometric surface in the MGL aquifer and the watertable is upwards, it is not strongly so at the present time (Barnett, pers comm).

Howles (1999) has modelled the possible effects of irrigation regimes and wet years on positive heads redeveloping in the MGL aquifer. Such upward pressure has in the past and may in the future impact on the historical salinised areas near Milang. Historical discharge areas are part of the natural ecosystem and as such may be accorded a lower priority with respect to discharge control.

iii) Quaternary Clay aquifer

Geology

The Pleistocene sediments were deposited in a lake – ancestral rivers environment. A sequence of alluvial slope deposits and alluvial flat deposits resulted. This included outwash deposits of clays, silts and sands with occasional gravels. Much of this sequence is probably equivalent to the Blanchetown Clay.

Groundwater

The clay aquifer is more of a “regional” type of flow system, but contribution from the dunes adds a local component. The watertable aquifer lies within a Quaternary clay known as the Blanchetown Clay Equivalent. This clay overlies and semi-confines the MGL aquifer.

Water is stored in dominantly fine grained sediments such as clays and silts with some coarser layers such as sands and gravels. The aquifer is not always continuous, especially where the sequence is dominantly clay with minor sand and gravel lenses (Waterhouse *et al.*, 1978). Shoe-string sand aquifers are not as well developed as on the Riverine Plains of NSW and clay sediments dominate the aquifer system (Barnett pers comm).

The clay aquifer is unconfined and is 10 –35 m thick. The aquifer is up to 35 m thick near the basin margins where sands and gravels predominate, but becomes more clayey further downslope. Nearer the lake, the aquifer becomes thinner (10 metres), with less clay and coarser materials. This indicates a greater hydraulic connection with the underlying MGL aquifer (Waterhouse *et al.*, 1978).

The watertable aquifer has low well yields (0.6 L/s to 5.0 L/s). It is a very impermeable formation with hydraulic conductivities being an order of magnitude lower than the MGL aquifer (Waterhouse *et al.*, 1978).

Groundwater levels are rising at 10cm/yr north west of Wellington. Examples of hydrographs are provided in Barnett (1998). The water level rises in this area are not as strong as other areas of the Coastal Plain (eg in the Coorong and Districts LAP) due to the differences in aquifer characteristics between the two LAP areas.

The salinity of this watertable aquifer is generally high and suitable only for stock. Aquifer salinity ranges from 1 000 mg/L TDS near the rivers and increases with increasing distance from the rivers (Howles, 1995). This supports the concept that the rivers are recharging the aquifer. High salinities occur in shallow watertable areas near the lake due to concentration by evaporation (20 000 to 30 000 mg/L TDS).

Over-irrigation causes deep percolation of water in this aquifer; this tends to increase the salinity of the unconfined aquifer and the vertical leakage to the confined aquifer.

Groundwater recharge

The clay aquifer receives recharge from upland drainage (eg. Angas Bremer), and from sections of the lowlands. The clay aquifer is fairly impermeable (“tight”) and flow is stronger vertically rather than laterally. Recharge would be expected to predominate especially in cleared sand dune areas.

The Angas and Bremer Rivers are important sources of recharge as indicated above. Lake Alexandrina is also a source of recharge as groundwater flows from the lake which is at a higher AHD towards the depressions at lower AHD. This occurs east of Milang (see flownet, Figure 2).

Groundwater discharge

The rising watertable in the clay aquifer has resulted in increased land salinisation. Figure 2 shows the flownet for the watertable aquifer within the clay. Flow terminates at the discharge areas which would appear to be “windows” to the watertable. The aquifer

discharges to low areas which intercept the groundwater flow. Discharge also occurs to Lake Alexandrina and the Murray River.

Figure 6 is a depth to watertable map for the Lowlands. It shows that the depth to groundwater varies from 20 to 40 metres near the basin boundary to 2 m around the perimeter of Lake Alexandrina. A tongue of shallow groundwater extends northwards from Lake Alexandrina between Langhorne Creek and Wellington. This is one of the high risk areas for any future development of dryland salinity (Barnett, 1998).

In low-lying areas around the Lake, there is highly saline groundwater (over 100,000 mg/L, TDS) due to strong evaporative discharge which has lowered the watertable below sea level (Barnett, 1994). These areas are the focus for regional groundwater discharge in preference to the Lake which is at a relatively higher level of 0.75m AHD.

Increasing dryland salinity has been reported at Sandergrove on the south eastern foothills of the Mt Lofty Ranges. On a broad valley floor north of Sandergrove, over 30 ha of land are affected by dryland salinity. This is associated with Quaternary alluvial slope deposits and scree along the foothills between Strathalbyn and Goolwa.

Examination of nearby wells and logs shows that the dryland salinity is caused by a perched watertable in Quaternary alluvial slope deposits which overlie Kanmantoo basement rocks. Incised creek beds (5m deep), about 500m distant are dry, indicating the localised nature of this occurrence (S Barnett, pers comm).

iv) Quaternary Limestone aquifer (Bridgewater Formation)

A previous marine transgression eroded much of the older sand and limestone to create a low-lying surface known as the Coastal Plain with Quaternary limestones being deposited at this time. This limestone known as the Bridgewater Formation is derived from ancient sand dune systems and beach ridges.

Figure 1 shows that this aquifer occurs near Goolwa, Hindmarsh Island and in the Point Sturt area. Dryland salinity occurs in all of these areas and the hydrogeology is similar to that occurring in the Coorong and Districts LAP (see Coorong and Districts LAP Steering Committee, 1997). The limestone aquifer is relatively transmissive in comparison to the Quaternary clays. The conceptual model for the Coastal Plain is for a local unconfined flow system in the superficial deposits and limestone overlying regional flow in the underlying MGL.

The Bridgewater Formation overlies and is in good hydraulic connection with the MGL and Renmark Group aquifers (see Figure 4). The Quaternary limestones are often difficult to distinguish from the older limestones. The combined thickness of these interconnected aquifers is 50 - 100m. Aquifer testing showed a high transmissivity of approximately 300 m²/day with a specific yield of 0.05 (Barnett, 1992).

SURFACE WATER RESOURCES

The rainfall map of the LAP area (see Figure 7) shows that rainfall in the uplands ranges from 500 to 800mm and in the lowlands ranges from 350-500mm.

The surface water catchments are shown in Figure 8. The major catchments of the LAP area which drain toward Lake Alexandrina are:

- Currency Creek
- Tookayerta Creek
- Finniss River
- Sandergrove Creek
- Angas River
- Bremer River.

Other subcatchments include Rodwell Creek and Mount Barker Creek. These catchments all drain into the Lake system via the eastern Strathalbyn Plains (Southern Hills Soil Board, 1995).

Flooding occurs in wet years (eg 1992) particularly from the Angas and Bremer Rivers.

Dams are a source of stock water, domestic water and may in some cases be used for irrigation. Salting of dams is an issue. For example, a reservoir on the Angas River that used to supply water to Strathalbyn has become too saline for direct use (Day, 1997).

Controlled flooding on the Angas - Bremer system is used as an irrigation supply (Southern Hills Soil Board, 1995). Pumping from this system and Lake Alexandrina is used for irrigation and artificial recharge to aquifers (MGL).

Issue of stream biodiversity

In the Angas River Catchment, increasing salinity is important from an ecological perspective. High salinity levels in waterways decreases the biodiversity of those waterways (ARCG, 1998). There is an opinion that the streams may already have been affected by salinity in the native state (Stokes, pers comm). Oh *et al* (-) report anecdotal evidence suggesting that spring discharge in the upper Rodwell Creek area was saline before there was any substantial clearing of native vegetation.

Salt loads in streams

The streams are a mechanism for transferring salt from uplands to the lowlands. Many of the streams flow only in times of high rainfall, though several flow the year round. Some of the streams carry high salt loads, due to both natural and catchment-induced processes (Clarke, 1996).

Each catchment has been ranked according to its salt load in tonnes as high medium or low. The Bremer River Catchment has a high salt load, while the Angas River Catchment and the Finnis River Catchment have medium salt loads. The Currency Creek Catchment has a low salt load. Tookayerta Creek is quite fresh, with stream salinities generally lower than 500 mg/L. (G. Butler, pers. comm.)

The tonnes of salt per annum to the plains provided by individual catchments is shown in Table 1 (Day, 1997). The total amount of salt exported to the lowlands from the highlands catchments exceeds 50 000 tonnes each year

Table 1. Salt loads of river catchments

Catchment	Tonnes of salt per annum	Kg/ha/yr
Bremer – Barker	32 000	680
Angas	6 000	350
Finniss	13 000	360
Currency Creek	2 500	490

Increasing salinity of in streams flowing out of the MLR could lead to an increase in the salinity in the aquifer they recharge under the plains (Day, 1997). One estimate is that 12% of the surface flow in the River Angas goes underground to recharge. The total contribution by the Angas Bremer system to natural recharge is estimated at 16% of the combined surface flow (Sinclair, 1976).

The issue for the LAP is the level or concentration of salt in the water (water quality) and the export of salt to the lake (salt loads). It is paradoxical that it is the high flows with relatively low concentrations that provide the highest salt loads. It is not known by how much the rivers draining the MLR have increased in salinity. It has been suggested that the Bremer River may have been saline in the native state (M. Stokes per comm).

Ecker (1998) carried out salt budgets for 18 subcatchments in the Bremer Barker catchment and found that the output/input (O/I) ratios were in the range of 5.5 to 8.5. These values were consistent with those calculated by Williamson (1990).

Baseflow is contributing to high O/I ratios in the Mt Barker catchment where there is only minor surface expression of dryland salinity but spring-fed creeks are producing the high O/I ratios and hence high salt loads. Ecker (1998) concluded that it was not always obvious which subcatchment to target for on-ground works since it was not apparent from surface evidence which catchment was contributing the highest salt loads.

2) SALINITY PROBLEMS IN THE LAP AREA

a) Land Salinisation

Cause and Effect

Land clearing and agricultural development has created change in the natural water balance such that more water enters the system, causing groundwater to rise and dissolve salts stored in the profile. When saline watertables rise to within one to two metres of ground level, evaporative forces can then deposit salt at the soil surface, creating saltland.

As Oh *et al* (-) note, groundwater discharges are common on flatlands and are obvious points of evaporative salt concentration.

Where irrigation is practised in the presence of shallow saline watertables, there is the potential to create groundwater mounds where the crop can be adversely affected by both salinity and waterlogging.

Land salinisation can also occur in the absence of a rising saline groundwater. An example is gilgai salinity which is basically a function of soil type - grey clay soils with a high natural store of salt and boron (Sandergrove Plains Landcare Group, -). Salts are mobilised and brought to the soil surface in an annual wetting and drying cycle. Local runoff and seasonal perched watertables contribute to waterlogging and the wetting process. When the surface soil becomes bare, it exacerbates the problem by increasing evaporation. As gilgai soils with this salinity problem are typically “landlocked”, there are few avenues for the export of salt from the system.

Land salinisation greatly reduces the traditional agricultural productive potential of the land, destroys native vegetation and wildlife habitat, and often occurs with allied problems such as erosion and waterlogging. Rising watertables also threaten infrastructure such as roads, railways, pylons, pipelines, and buildings. Structural foundations are weakened and the corrosive process accelerated by saline conditions.

Current Extent and Severity

The extent of land salinisation in the lowlands (Pt. Sturt to Wellington) has been estimated from interpretation of aerial photography at 2300 ha of saltland (G Gale, pers comm). Much of this is severe saltland associated with historic discharge areas (salt lakes and lagoons) in the Malcolm and Poltalloch/Pt. Sturt land systems (Figure 9). Examination of the GIS salinity potential map and aerial photography of other land systems in the lowlands (eg. Hindmarsh) brings the total estimate of land salinisation in the lowlands to 2550 ha.

In the uplands, an estimated area of 3350 ha is currently salt-affected. This estimate is based on 3000 ha within the Bremer Barker catchment (Ecker & Natt, 1998) and a derived estimate of 350 ha for the rest of the LAP area based on PIRSA survey results (Henschke, 1997). The Bremer Barker estimate of 3000 ha is based on interpretation of earlier GIS soil landscapes mapping (this method tends to overestimate the occurrence of saltland). Most saltland in the uplands occurs in depressions and drainage lines, with a few hillside occurrences.

In the Angas Bremer area, changes in irrigation supply (drawing water from Lake Alexandrina rather than from the limestone aquifer), and a wet year in 1992 has meant the recovery of pressure in the limestone aquifer, and additional recharge to and upward pressure on the clay aquifer (ABRWC, 1996). Combined with irrigation practices, the overall effect has been a rise in groundwater. In some vineyards east of Milang, groundwater is within reach of vine roots and is affecting productivity (D Loy, pers comm)

In the LAP, gilgai salinity occurs mainly in the Milang land system. Here, there are approximately 1000 ha of “clay soils”, of which an estimated 10% (100 ha) is badly salt-affected (Figure 10). It is thought that a 30 ha salinity outbreak close to Sandergrove, which is unrelated to rising groundwater but rather caused by perched watertables (Barnett, pers comm) also fits into this category.

The current status of damage to infrastructure from salinity is largely unknown but predicted to be significant. In the south-western region of NSW alone, road damage due to high watertables is costing about \$9 million annually (NDSP, 1998).

Trends

Barnett (1998) reports a trend for watertables to continue to rise in the lowlands over the next 25 years (at an average rate approximating 10 cm a year). Through topographic interpretation based on this rising trend, an estimated total of 3850 ha of land within the Malcolm (2900 ha) and Poltalloch/Pt. Sturt/Hindmarsh (950 ha) land systems will be salinised within 25 years. This represents an approximate 50% increase in land area that is currently severely affected. Much of the land at risk in the lowlands is either on the margins of historic discharge sites or in adjacent swale systems.

Barnett (1998) predicts 150 ha of land near Milang to re-salinise (being historic discharge areas) due to rising watertables. The Angas Bremer Water Resources Committee (1996) identified 1000 ha in the same locality (north and east of Milang) to be at possible risk in the future (land where watertables are within 2 metres of the soil surface). Howles (1999) undertook risk assessment modelling for irrigation development in the Angas-Bremer and concluded that the importation of water for irrigation from Lake Alexandrina would result in rising watertables, particularly in the area to the south of Langhorne Creek. He also suggested that the area adjacent to Lake Alexandrina may not be at as great a risk as has been believed, although even small rises in this area would be of significance.

Richardson *et al* (1994) predicted a 50cm rise in the watertable over 20 years for a higher rainfall catchment with fractured rock aquifers on EP. He noted that, because of the incised nature of the drainage lines, the watertable rise would not significantly increase the salt-affected area. Many of the drainage lines in the uplands of the LAP are well-incised, with most saltland occurring where the gradients flatten out. As discharge increases, and time since clearing elapses, many of these catchments will be tending

towards equilibrium. Given the above, it is estimated that the area of upland salinity will increase by 20% over the next 25 years, from 3350 ha to 4000 ha.

As watertables continue to rise and salinise land, the threat and extent of damage to infrastructure will rise accordingly. Similarly, remnant vegetation and associated wildlife will be under increased threat (Bremer Barker Catchment Group, 1996).

It is more difficult to predict trends for gilgai salinity as it is unrelated to groundwater rise. However, farmers in the area have noted gradual increases in the extent of salt-affected land, with some extensive increases occurring following wet years. If current land management practices continue, it is not unreasonable to estimate that the area of salt-affected land could increase by 50% to 150 ha in 25 years time.

b) Water Salinisation

Cause and Effect

Rising watertables mobilise salts stored in the soil. Salt is exported when saline groundwater discharges as baseflow direct to water bodies, or when surface runoff carries salt into streams and out of the system. As Oh *et al* (-) note, discharge mostly follows watercourses in the valley floors, with groundwater being a major contributor to stream salt mass. Salt will continue to be exported and water salinity levels remain high until a new salt equilibrium is reached in several hundred years time (Williamson, 1990).

Stream salinity and groundwater discharge affect the usefulness of any water resources (for human consumption, industrial use, irrigation) that they recharge. The health of stream/riparian zone ecosystems can be adversely affected by high salinity (Angas River Catchment Group, 1998), as can the major sinks for such water (wetlands, lakes). There is anecdotal evidence from the upper Rodwell Ck. area that spring discharge was saline before there was any substantial clearing of native vegetation (Oh *et al.*, -).

Current Extent and Severity

In the LAP area, groundwater currently discharges direct to Lake Alexandrina and the Murray River, to streams, and to low-lying lagoons that intercept groundwater flow.

The Angas, Bremer and Finniss are all classified as carrying medium to high salt loads, while that of Currency Creek is low. Oh *et al* (-) record figures for mean stream total dissolved solids of 660 mg/L for the Finniss and 2130 mg/L for the Bremer. For Tookayerta Creek, stream salinity levels rarely exceed 500 mg/L (Butler, pers. comm.). Ecker (1998) carried out salt budgets for 18 subcatchments in the Bremer Barker catchment and found that the output/input ratios were in the range of 5.5 to 8.5 (compared to a ratio approaching 1.0 in the native state). Some reservoirs on the Angas R. have become too saline for use for human consumption (Day, 1997).

Recharge from flows in the the Angas Bremer to the clay and limestone aquifers in the lowlands has the effect of maintaining relatively low salinity aquifer water in close proximity to the rivers. Water salinity levels in the clay aquifer are high (away from the rivers) and generally only suitable for stock use. Near L. Alexandrina, levels reach 30000 mg/L due to concentration by evaporation. Similarly, salinity levels in the limestone aquifer increase dramatically with distance from the Angas Bremer recharge zone.

Changes in the Lake Alexandrina ecosystem occurred when barrages were constructed at the mouth of the River Murray - the water in L. Alexandrina changed from predominantly salty to fresh water, and the lake level was raised to 0.75 m AHD (Southern Hills Soil Board, 1995). Currently, water of 1500 mg/L salinity or less is being drawn from Lake Alexandrina for use in the Angas Bremer irrigation area. Under natural conditions, the salinity of the lake would have varied greatly through the year and between seasons (Day, 1997).

In the north-east portion of Lake Alexandrina, the watertable gradient is causing a slow outflow of fresher water from the lake to adjacent land. Shoreline plant communities have changed from those suited to semi-saline conditions to freshwater loving species (Day, 1997).

River Murray water salinity levels have increased significantly since clearing, as it acts as an effluent drain and provides the only natural outlet for the removal of salt from the entire Murray-Darling Basin. Flow of saline groundwater to the River Murray between the SA/VIC/NSW border and Morgan accounts for nearly all of the salinity increase in the River Murray in South Australia. (Clarke, 1995).

Trends

Because of low watertable gradients (and the influence of the whole Murray-Darling Basin), further watertable rise within the LAP will not significantly increase River Murray salinity levels (Barnett, 1998). However, influences outside the LAP area could see increases in River Murray salinity in the order of 30 mg/L (50 EC) within 25 years (Clarke, 1995). This rising trend in River Murray salinity has been estimated at between 1.5 and 5.0 EC units per year (Williamson *et al.*, 1997).

The effect of direct discharge from rising watertables on Lake Alexandrina salinity levels is less certain, but expected to be minimal as most increased discharge will occur to low-lying areas rather than to the lake. However, in limited areas where ground elevation adjacent to the lake is higher than 5m, direct discharge to the lake from the clay aquifer may occur. Most discharge to Lake Alexandrina will continue to occur from the limestone aquifer (Barnett, 1998).

Williamson (1990) noted that, over a 15 year recording time, the water salinity levels (annual flow-weighted concentrations) were quite uniform for some streams (Finniss R.) but highly variable in others (Mt. Barker Ck.). He concluded that, from this study, it was not possible to establish whether salt export was at an increasing rate or at equilibrium.

In WA, as a result of clearing, stream salinities are predicted to increase for a further 20 to 50 years, before declining over hundreds of years due to depletion of soil salt. The prognosis is worse (the time span longest) for lower rainfall catchments (WAWA, 1989).

In the LAP area, it is likely that stream salinity levels and salt export will increase over the next 25 years, bringing a corresponding decline in the quality of water bodies they recharge, and the ecosystems they support. This is supported by the modelling work of Oh *et al* (-), who predict extensive areas of saline discharge risk in the Angas and Bremer catchments.

For the Angas-Bremer Irrigation Area, Howles (1999) suggests it is likely that the slow deterioration of groundwater quality is inevitable.

The “do nothing” scenario.

As illustrated in Table 2, the “do nothing” scenario includes increasing levels of both land and water salinisation. The effect of this scenario on water salinity in the River Murray/Lake Alexandrina is not attributable to the influence of the LAP area alone, but rather also to changes in the SA portion of the Murray-Darling Basin.

Predicted trends for the “do nothing” scenario are based in large part on the assumption that rainfall will be “average” over the next 25 years. Several authors have commented on the significant effect on groundwater rise of a series of above-average or below-average rainfall years; an “extreme case” scenario has been included in Table 2 to illustrate the potential effect of a series of wet years. Even when a hydrologic system is at equilibrium, high rainfall periods can further exacerbate the extent of salinity for short periods of time.

Richardson *et al* (1993) noted that two or three years of high rainfall would be enough to negate the effects of remedial management strategies in the short term. Pavelic *et al* (1997) suggested that several dry years in succession can have a similar effect to a recharge reduction of 50% for the natural sequence of rainfall years. Similarly, Barnett (1998) noted that for periods of below-average rainfall (10% to 15% below average), groundwater levels within the LAP tended to be static. For the LAP, a (temporary) 33% increase in the area of salinised land is assumed under the “extreme case” scenario (Table 2).

Table 2. Salinity problems in the LAP area – trends.

SALINITY PROBLEM	EXTENT NOW	IN 25 YRS TIME “Do nothing”	EXTREME CASE high rainfall/flooding
<u>Land Salinisation</u>			
Uplands -	3350 ha	4000 ha	General Increase By 33 %
Lowlands – groundwater	2550 ha	3850 ha	
- gilgai - irrigation area	100 ha -	150 ha 1000 ha	
TOTAL	6000 HA	9000 HA	12000 HA *
% of LAP area (265 000ha)	2 %	3 %	4 %
ecosystems/infrastructure	unquantified	increased threat	increased threat
<u>Water salinisation</u>			
River Murray (at Morgan)	450 mg/L	30 mg/L increase	Flooding/high rainfall would be generally beneficial
Lake Alexandrina	600 mg/L	50 mg/L increase	
Stream salinity	~ 2000 mg/L	increasing	
Salt loads in streams	~ 30000 t/yr	increasing	
Wetlands/ecosystems/dams	unquantified	increasing threat	

* The increase to 12000 ha after a series of wet years would be temporary, and should be followed by a corresponding decrease again to 9000 ha, depending on rainfall patterns and the time taken for rehabilitation of the newly-salinised land.

3) MANAGEMENT OPTIONS FOR SALINITY.

The “do something” scenario

Determining whether there is an achievable and worthwhile influence that can be made on salinity problems within the LAP requires consideration of :

- The cause, current extent and likely future extent of the problem
- The options available, and their likely impact on the problem
- The economics (eg. benefit/cost) of “doing something”

The current extent and likely future extent of salinity problems have been summarised in Table 2. Their causes are summarised in Table 3.

The options available for the “do something” scenario include:

- a) Slow, halt, or reverse the salinisation process.**
- b) Increase productivity from saline resources.**

a) Slow, halt or reverse the salinisation process

The salinity processes operating within the LAP area can be discussed in terms of recharge and discharge, and the pathway that links the two (refer to Table 3). Most of the processes involve groundwater, with the exception of gilgai salinity. The pathway (eg. aquifer characteristics) can often determine the likelihood of, and time frame for, possible success in managing the salinisation process.

There are two basic methods of managing the salinisation process - by increasing discharge and/or by reducing recharge.

Discharge can be increased by drainage and engineering options (eg. pumping). Drainage and engineering options can be costly, and require a “safe” disposal site for the saline water.

Managing surface and subsurface water (perched watertables, waterlogging, runoff and flooding) will provide some control over the salinisation process, as these factors contribute to recharge as well as often having a direct effect on the severity of saltland.

Reducing recharge involves the use of more water (rainfall) where it falls so there is little deep drainage to the groundwater. High water use strategies can help reduce recharge and thus maintain watertables at current levels, or lower them (Nulsen, 1993).

Table 3. Main salinity problems and their causes

MAIN PROBLEMS		MAIN CAUSES		
Problem	Discharge areas	Pathway	Recharge areas	High recharge areas
Land salinisation (uplands)	Slopes Drainage lines Depressions	Fractured rock Aquifers	Local subcatchments	Rocky ridges
Land Salinisation (lowlands)	Low areas within the Malcolm land system	Clay aquifer	Malcolm and Brinkley land systems.	Sand plains, sand dunes and stony rises.
	Low areas within the Poltalloch land system	Clay aquifer	Poltalloch, Milang and Sandergrove land systems.	Sandy rises and stony rises. Sand hills and calcareous soils. Alluvial soils.
	Low areas within Pt. Sturt/ Hindmarsh land systems	Limestone aquifer (LST)	Pt Sturt Hindmarsh Land systems	Deep sands, sandy flats, calcareous rises
Gilgai salinity	Gilgai soil types in the Milang land system	Local runoff and perched watertables	Local slopes	Sandy rises
Irrigation	Irrigation areas in the Angas Plains and Langhorne Ck land systems	Clay aquifer	Local	Irrigation Point source
Water Salinisation (lowlands)	L. Alexandrina	Limestone (MGL) & clay aquifer	Most of the LAP area.	Uplands
	Murray River	Limestone (MGL) and clay aquifer	Eastern portion of LAP area. Outside the LAP	Lowlands M-D Basin
Water Salinisation (uplands)	Drainage lines	Fractured rock	Local subcatchments	Rocky ridges

A total catchment approach is necessary to effectively manage the salinisation process. Recharge reduction should be combined with discharge enhancement and increased productivity from the salt-affected environment. The scale of recharge reduction needs to be significant to influence land and water salinisation (refer to Table 4).

The boundaries of the catchment will differ according to the salinisation process at work, and the management strategies used will depend on the scale at which management is being implemented. Where intermediate or regional groundwater systems are operating, modelling studies have predicted that recharge reduction at the individual farm scale will have little impact on salinisation (Richardson *et al.*, 1994; Pavelic *et al.*, 1997).

Table 4. The scale of recharge reduction required to influence salinisation.

Percentage recharge reduction within the contributing catchment *	Likely impact within 10 to 25 years
< 30 %	Slow the spread of saltland Increase the buffering capacity of the system to help cope with episodic recharge events (eg. high rainfall years)
30 % to 50%	Stop the spread of saltland
> 50 %	Reverse the spread of saltland Stop groundwater baseflow to streams
Greater recharge reduction equates to a larger proportion of the cleared catchment requiring treatment.	

* The contributing catchment refers to the total groundwater catchment (recharge – pathway – discharge) that is contributing to the salinity problem.

Table compiled after Schofield and Scott, (1991), Richardson *et al.*, (1994), Pavelic *et al.*, (1997), Hatton *et al.*, (1996), George *et al.*, (1993), Bari (1998), WAWA (1989).

High water use strategies will reduce recharge and thus the discharge of saline groundwater. However, yield and salt discharge generally decrease in the same proportion, so that for smaller localised water supplies, there would be no nett change in the levels of water salinity resulting from implementation of high water use strategies. (WAWA, 1989). To optimally reduce stream salinity, it is necessary to completely stop saline groundwater contributions.

For larger water supply catchments, targeting those subcatchments which are contributing most of the salt (usually in lower rainfall areas) while retaining the capacity of those subcatchments which yield more water (usually in the higher rainfall areas) can reduce water salinity levels at the outlet of the whole catchment (Williamson, 1990).

b) Increase productivity from saline resources

Whether nothing is done, or major management changes are put in place to ameliorate the effects of salinity, it is most likely that there will always be some salt-affected land and water salinity problems within the LAP area. Increasing productivity (looking at salt-affected environments as an opportunity rather than as a threat) from such areas is a viable option.

Current technology is available for establishing saltland agronomy options including salt-tolerant grasses such as puccinellia and tall wheat grass, and shrubs such as saltbush. Growing salt-tolerant trees for wood and other products is also an option (Dooley, 1995).

Grey clay gilgai soils are often difficult to manage for cropping, those areas worst affected by salinity and waterlogging may best be placed under permanent perennial saltland vegetation (Sandergrove Plains Landcare Group, -).

Using saline water for aquaculture (finfish, shrimp), for algal production of chemical extracts (betacarotene), and for the commercial production of salt and brine is currently under investigation in Australia at several sites eg. the Bedford site at Cooke Plains (G. Gates, pers comm) and Victoria (Wettenhall, 1996; Anon, 1995).

The opportunities for educational, recreational and ecotourism ventures that utilise visits and inspections of saline environments should also be considered (DENR, 1997).

Increasing water use

Recharge can be reduced by increasing water use over a catchment. The attached HWU factsheets (Appendix 1) outline the relative water use of various agricultural systems, and the increase in water use to be expected by changing land management or land use.

Nulsen (1993) outlines the opportunities and limitations for using agronomic techniques to control dryland salinity. He suggests that while agronomic manipulation can increase water use by 10% (and so reduce recharge), it will not have a significant impact on land salinisation unless trees are also included in the catchment management plan.

The necessity for inclusion of perennial deep-rooted vegetation in plans to increase water use and reduce recharge has been highlighted by several authors as well as Nulsen. Clifton *et al* (1995) discuss the relative success of lucerne, phalaris and cocksfoot pastures in reducing recharge and lowering watertables at Burkes Flat in Victoria. Whitfield (1995) discusses the ability of dryland lucerne to create soil water deficits by exploiting deeper stored soil water and capturing any additional water that percolates to the dry soil zone. George *et al* (1993) discusses the effectiveness of revegetation strategies for salinity control, and relates many examples in WA of recharge reduction and lowering of watertables being achieved by treeplanting.

From field trials, Schofield (1990) developed a relationship between rate of change in watertable level and the proportion of cleared area of a catchment reforested. He further refined the relationship by regressing rate of watertable change against the product of the proportion of cleared land reforested x percentage crown cover. His results reinforced the fact that the amount of recharge reduction required to influence salinisation processes is large (eg. reforesting 32% of a cleared catchment with trees at 50% crown cover would lower watertables at a rate of 200 mm per year).

Best-bet management options for the LAP

High water use strategies to reduce recharge can be targetted according to the source of recharge to those areas at risk of further land salinisation. Furthermore, high recharge areas within contributing land systems can be identified for preferred treatment (refer to Table 3). By combining this information with the use of HWU factsheet No 3 (Appendix 1) and appropriate recharge reduction targets (Table 4), it is possible to determine the location and extent of technical best-bet management options for reducing recharge and managing salinity. The benefit/cost ratios of such options then need to be determined.

As an example, reducing recharge to the clay aquifer by adopting high water use options is possible. To counter the risk of further land salinisation, recharge would need to be reduced by 30% or more, which roughly equates to reforestation or conversion to lucerne of 30% of the recharge areas that feed this aquifer.

The clay system is however very “tight”, and any changes induced in groundwater levels at one particular point (by recharge reduction) will only slowly be transmitted elsewhere (to the saline discharge areas). For this reason, response at the discharge sites (lowering of watertables) to the implementation of high water use strategies will be quickest when the strategies can be implemented as close to the discharge sites as possible. Because the clay aquifer is regional in nature, treatment of significant areas some distance away will still be required so an effective “30% of the catchment” is treated.

On Hindmarsh Is. and portions of the Pt. Sturt land system, watertable rise is occurring in the underlying limestone aquifer, as the clay system is absent. Limestone aquifers are more transmissive, with the result that recharge reduction further afield would affect saline discharge areas. Reducing recharge by 30% by targetting identified high recharge areas (see Table 3) on Hindmarsh Island should prevent the spread of further land salinisation there.

For control of land salinisation in the uplands, 30% of each discrete catchment would need to be treated to manage the spread of salinity within that catchment. Ecker (1998a) has calculated output/input ratios for many subcatchments within the Bremer Barker, and detailed a strategy to manage salinisation within this catchment. She estimates that the reduction in salinity required will be achieved by revegetating approximately 20% to 30% of the catchment in the identified priority areas.

Control of water salinisation is more difficult and requires a greater reduction in recharge (see Table 4). Given that future trends indicate no likely significant impact on river and lake salinity levels from rising watertables within the LAP lowlands area, management options may well be better targeted at other problem areas. The reliance on water from the limestone aquifer for irrigation in the Angas Bremer has also diminished as most supplies are now sourced from Lake Alexandrina.

On Hindmarsh Island, landlocked saline areas have been successfully drained to the sea (Landcare Australia, 1997). The potential influence that large-scale pumping can have on aquifer characteristics and salinity has been dramatically illustrated in the Angas Bremer irrigation area (ABWRC, 1996). Drainage and pumping may well feature in management strategies directed at the salinity threat north and east of Milang. A groundwater modelling study of the area has been completed (Howles, 1999).

As the Sandergrove Plains Landcare Group (-) reports, establishment of salt-tolerant pastures and trees is well worthwhile on saltland (including gilgai soils). Most of the published catchment plans and district plans recommend appropriate revegetation of saltland with productive salt-tolerant grasses, trees and shrubs. Innovative use of saline resources (aquaculture, chemical production), though still in its infancy, needs to be considered. As Barnett (1998) notes, historical discharge sites such as in the Mulgundawa area (between Milang and Wellington) have previously been utilised for the commercial harvesting of salt.

Hotspots in the LAP/Priorities for Action

Hotspots are those areas within the LAP where the priority for implementing salinity management strategies is high.

Priorities will differ according to which specific and associated outcomes are pursued:

- Stopping the spread of saltland
- Reducing water salinity levels
- Maintaining and improving biodiversity
- Reducing the effects of waterlogging and flooding

For individual landholders, any saltland area that is spreading is a hotspot to them, and deserving of action according to their priorities. Major zones where saltland is spreading are shown in Figure 10 and can be grouped as -

- Swales and flats in the Malcolm land system
- Swales and flats in the Potalloch/Pt. Sturt/Hindmarsh Is. area
- Scattered valleys in the uplands
- An (irrigation) area north-east of Milang, adjacent to Lake Alexandrina.

(Land Systems are shown in Figure 9).

Table 5 summarises these main discharge zones, with the corresponding recharge zones (land systems) that require treatment to control the spread of saltland. Particular soil types (high recharge) within these land systems should be targeted first in any recharge reduction strategy. These soil types have low or very low water holding capacity.

The order of priority for treatment of discharge zones, on the basis of area affected by saltland spread (--ha) , would be -

- irrigation area near Milang (1000 ha)
- Malcolm land system (1000 ha)
- Uplands valleys (650 ha)
- Potalloch/Pt. Sturt/Hindmarsh land systems (300 ha)
- gilgai salinity in the Milang land system (50 ha)

Each of these discharge zones can be subdivided further on the basis of where the saltland spread will have the most impact initially - hotspot areas (Table 5 and Figure 10). While it is valid to target any areas of spreading saltland within these zones, hotspot areas may be afforded a higher priority. Implementation of recharge reduction strategies for management of discharge zones can be staged such that the first remedial effects will be directed towards hotspot areas.

Table 5. Hotspots (Spread of saltland)

DISCHARGE ZONES	CORRESPONDING RECHARGE Zones requiring treatment **	HOTSPOTS for discharge (see Figure 10)
In the Malcolm land system (1000 ha spread)	Land systems: Malcolm and Brinkley Particular soils: sand plains/dunes, stony rises	Malcolm system north "tongue" (see Figure 9)
In the Poltalloch land system (200 ha spread)	Land systems: Poltalloch, Milang, Sandergrove Particular soils: sand hills and sandy rises, stony rises, calcareous soils and alluvial soils. Local recharge: Sandergrove "blind" creeks.	Northern and western swales
In the Pt. Sturt and Hindmarsh land systems (100 ha spread)	Land systems: Pt Sturt and Hindmarsh Particular soils: deep sands, sandy flats and calcareous rises	Western section of Hindmarsh Land system
In the Langhorne Creek, Angas Plains and Malcolm land systems north-east of Milang (1000 ha spread)	Land systems: Angas Plains, Milang, Langhorne Ck. Particular soils: deep sands, calcareous sands and loams. Local recharge: from irrigation drainage and from the uplands (Angas-Bremer system)	Langhorne Creek land system section
Scattered valleys in the uplands (650 ha spread)	Land systems: local catchments Particular soils: rocky ridges and stony soils, loamy sands.	Possible priority order: <ul style="list-style-type: none"> • Bremer Barker • Sandergrove • Strathalbyn • Hope Forest

** Examples of recharge reduction strategies:

- for lowlands (Malcolm, Poltalloch, Pt. Sturt, Hindmarsh) - see Table 6
- for uplands (scattered valleys) - see Table 7

Table 6. An example of a recharge reduction strategy for land salinisation control in the lowlands

Saltland in the Malcolm land system (Figure 9) is predicted to increase. The recharge areas for this salinisation process have been identified (see Table 5).

Goal: Stop the spread of salinised land in the Malcolm land system.

Method: Reduce recharge by implementing high water use strategies *

Outcomes: Halt rising watertables.
Increase the capacity of the system to cater for wet years.

Target: Reduce recharge by 33% over the whole “catchment”

(catchment = Malcolm and Brinkley land systems)
(eg. return 30% to 40% of the catchment to its original water use rate)

Using Factsheet HWU No. 3 (Appendix 1) and information from the Murray Plains Soil Conservation Board District Plan (1995) –

MALCOLM land system	BRINKLEY land system
Saline flats 40% x 0.6 = 24%	Swales 45% x 0.7 = 32%
Sand plains 28% x 0.6 = 17%	Stony rises 35% x 0.6 = 21%
Sand flats 20% x 0.6 = 12%	Dunes 20% x 0.6 = 12%
Sand dunes 12% x 0.5 = 6%	
Current water use = 59% of rainfall	Current water use = 65%
Potential recharge = 41%	Potential recharge = 35%
Target potential recharge = 27% (33% reduction) ie. 73% water use	Target potential recharge = 22% (33% reduction) ie. 78% water use
Changing land use on sand plains and dunes (40% of catchment) from annual to perennial can achieve this target.	Changing land use from annual to perennial on stony rises (35% of catchment) can achieve this target.
Eg. establish dryland lucerne	Eg. establish revegetation/woodlots

* Because a salinity hotspot tongue of land has been identified in the Malcolm system (Table 5), land use changes should be initiated first in a northern arc around this tongue. A 50% reduction in recharge should be the target for this hotspot area.

Table 7. An example of a recharge reduction strategy for salinisation control in the uplands

The Kanmantoo subcatchment (570 ha) is 4 km northeast of Kanmantoo, and has been identified by Ecker (1998a) as having a high salt input/output ratio. It currently has 10 ha of saline land which is actively spreading.

Arable land constitutes 67% of the subcatchment. Of the 33% non-arable land, 90 ha (15% of the subcatchment) is remnant scrub. 85% of the subcatchment is under annual crops or pastures.

Goal: Reverse land salinisation in the subcatchment.
Contribute to the control of water salinisation.

Method: Reduce recharge by implementing high water use strategies.

Outcomes: Lowering of watertables in the subcatchment.
Increased capacity of the subcatchment to cater for wet years.
Possible halt of baseflow to the subcatchment drainage line

Target: Reduce recharge by 50% over the subcatchment.

Using the HWU factsheet No. 3 (Appendix 1)

Current water use = 62% of rainfall.

Potential recharge = 38 % of rainfall

Target potential recharge = 19% of rainfall (a 50% reduction)

(ie. a water use equalling 81% of rainfall)

This 50% recharge reduction can be achieved by:

- Revegetating all non-arable land that is currently grazed (18% of subcatchment).
- Protecting and enhancing the vigour of remnant scrub (15% of subcatchment).
- Revegetating along the riparian zone/creek (7% of subcatchment).
- Maximise crop/pasture production from the remaining 60% of the subcatchment.

This will result in an overall water use of 81%. The changes include revegetation of 25% of the cleared subcatchment, protecting and re-invigorating the remnant scrub (15% of the subcatchment), and increasing water use by 10% over the remaining 60% of the subcatchment.

Air photo interpretation has identified a number of swales/flats (each about 2ha to 10 ha in size) in the hotspot north "tongue" section of the Malcolm land system (Figure 9). In total, about 70 ha of land that is low-lying but currently non-saline is at-risk to land salinisation. Other areas at-risk to salinisation are adjacent to or on the margins of currently salt-affected land. This pattern is basically repeated in the Poltalloch/Pt. Sturt/Hindmarsh Island land systems, with the northern and western swales of Poltalloch and the western section of the Hindmarsh system being probable hotspots.

On a LAP scale, the 1000 ha area north and east of Milang adjacent to Lake Alexandrina and within the general Angas Bremer irrigation area is a concern, with watertables currently at three metres or less below the soil surface. The Langhorne Creek land system section of this discharge zone is a hotspot, with watertables at two metres depth or less. The Angas Bremer Water Resources Committee is currently considering management strategies, based on a groundwater modelling risk assessment report. (Howles, 1999).

The scattered valleys of the uplands have been given a priority order based on both land and water salinisation potential, starting with the Bremer Barker zone as higher priority (Table 5). Within the Bremer Barker catchment, Ecker (1998a) has identified specific subcatchments and recharge areas for attention (Figure 5-2), with an on-ground works program targeting these areas already in place.

In the LAP uplands area, stream salinity levels and salt export are likely to increase, leading to a further decline in water quality and ecosystems. Recharge reduction strategies that target land salinisation (spread of saltland) can also contribute to the control of water salinisation by reducing saline baseflow to streams (eg. the strategy outlined in Table 7). To optimally reduce stream salinity, it is necessary to completely stop saline groundwater contributions from the whole catchment by reducing recharge at a rate greater than 50%.

On a LAP scale, given Lake Alexandrina as the ultimate sink for continuous surface water flow, the priorities for improving the lake's water quality would include:

- reducing salt export from higher salt/lower water yield catchments (eg. Bremer, Angas)
- maintaining/protecting "fresher" water yield from lower salt/higher water yield catchments (eg. Tookayerta, Currency, Finniss).

As Ecker (1998a) has shown, this principle can be used at the subcatchment scale, according to the "sink" under consideration (eg. by targetting tributaries to reduce salt export to aquifer water supplies in the Angas-Bremer Irrigation Area).

Based on consideration of both land and water salinisation trends, Table 8 summarises the relative priorities for action to combat salinity. Priorities are on a LAP scale, based on physical factors (eg. expected spread of saltland, relative ease of control, associated benefits), and are meant as a guide only. Priorities may change once benefit:cost analysis is undertaken by the LAP Board.

Table 8. Summary of priority actions for managing LAP salinity

PRIORITY	LAND SALINISATION	WATER SALINISATION
HIGHER	<p>Reduce recharge (by 50% for hotspots and 33% overall) for saltland zones:</p> <ul style="list-style-type: none"> • Malcolm land system • Upland valleys <p>Reduce recharge/pursue engineering options to target the Milang saltland zone</p> <p>Increase productivity from saltland and productive use of saline resources</p>	<p>Maintain/protect the lower salt/higher water yields from:</p> <ul style="list-style-type: none"> • Tookayerta Ck., • Currency Ck. • Finnis R. <p>Maintain/protect the water quality of the Angas-Bremer irrigation aquifer (Water Resources C'tee)</p> <p>Increase productive use of saline resources</p>
LOWER	<p>Reduce recharge (by 50% for hotspots and 33% overall) for saltland zones:</p> <ul style="list-style-type: none"> • Potalloch • Pt. Sturt/Hindmarsh <p>Reduce gilgai salinity in the Milang land system</p>	<p>Reduce salt loads in the Angas-Bremer system</p> <p>Reduce salt loads to the Murray River and Lake Alexandrina</p>

Figure 11 highlights those recharge hotspot zones within which a 50 % recharge reduction is required. These areas target both land and water salinisation, and should be given a high priority for on-ground action. When combined with a recharge reduction of 30% over most of the remainder of the catchment, salinisation spread within the LAP area will be controlled.

4) RECOMMENDATIONS

The recommendations of this technical report are based on two major factors:

- The likely future extent and severity of salinity problems in the LAP area
- The likely impact of management options on these problems

There has been no attempt to quantify the economics of proposed actions.

Recommendations include -

- a) **that the LAP committee support programs that strategically target hotspot areas with a 50% recharge reduction rate**

A 50% recharge reduction rate can halt and reverse the land salinisation process, as well as contributing significantly to stopping baseflow to drainage lines. In hotspot areas where the salinity “front” is spreading to previously unaffected sites, a larger recharge reduction will safeguard these areas from predicted salinisation and also help create a buffer to cater for high rainfall/episodic recharge events.

This approach would complement those strategies suggested by Ecker (1998a) to target subcatchments producing high salt loads in streamflow, where land salinisation is also apparent in the subcatchment. Table 7 illustrates an example of 50% recharge reduction for such a subcatchment.

- b) **that the LAP Committee support programs which contribute to a general reduction in recharge of 33 % across all contributing catchments within the LAP**

It has been shown that recharge reduction in the order of 30% is capable of slowing and halting the land salinisation process. Recharge reduction has the potential to “save” 3000 ha of land under threat of salinisation within 25 years, and limit the adverse effects of wet years.

Recharge reduction strategies should be integrated with other catchment programs designed to reduce land degradation and increase productivity (revegetation and biodiversity programs, protection of remnant vegetation, clay spreading, ameliorating acid soils,...). Recharge reduction will directly benefit control of allied problems such as flooding and waterlogging.

While recharge reduction can be achieved through a number of high water use strategies, it will often necessitate a major land use change (from production based on annuals to production based on perennials) over a large part of the catchment. Table 6 illustrates a possible recharge reduction strategy for control of land salinisation within the Malcolm land system.

c) that the LAP Committee support programs committed to efficient and appropriate irrigation management and appropriate siting of irrigation ventures

Approximately 1000 ha of land near Milang is at risk from salinisation. Historical discharge sites will be re-activated due to changes in irrigation management (less pumping for irrigation from the limestone aquifer which has now re-pressurised, more drawing of water supply from Lake Alexandrina). Current irrigation scheduling practices result in groundwater mounding beneath vineyards where a shallow watertable exists. Local recharge occurring under irrigated vineyards is contributing to rising watertables in the clay aquifer.

Future recommendations for change from modelling studies (Howles, 1999) and monitoring activities undertaken by the Angas-Bremer Water Resources Committee should be supported. These may include engineering options (pumping and drainage), high water use strategies appropriate to irrigation areas (windbreaks, cover cropping), and planning policies (siting of vineyards in relation to watertable depth).

d) that the LAP Committee support programs aimed at increasing the use and productivity of saline resources

As thousands of hectares of saltland and large quantities of saline groundwater will remain within the LAP area, it is appropriate to consider maximising the potential returns from such a resource.

Examples of successful plantings of salt-tolerant grasses, trees and shrubs already exist within the LAP area, along with trial plots of newer plants such as Salado lucerne. An extension program to promote saltland agronomy should build on these initiatives.

Where salt was once harvested, it is possible to harvest again. Along with the fledgling aquaculture and betacarotene industry, productive use of saline resources should be the focus of feasibility studies carried out in conjunction with the regional economic development boards.

Given the proximity of salt-affected areas to the coast and the existence of the Coorong and Lower Lakes Ramsar Management Plan, the potential for ecotourism based on saltland, and efforts to manage the problem, should also be investigated.

- e) **that the LAP Committee support programs which raise general awareness and understanding of salinity problems, and which contribute to better identification and monitoring of such problems**

A continuing education program for all sections of the community is important, as salinity affects a wide cross-section of people and resources within the LAP. The existence of large tracts of historical discharge areas close to Lake Alexandrina, the interplay between irrigation and salinity, the inherent salinity of gilgai soils, the notion of recharge reduction as a management strategy, the existence of different aquifers, are all facets of a complicated salinity story which need to be told.

While most land and water salinisation problems have been identified to some degree, there remain other components such as infrastructure damage which require further work and greater effort to properly identify and quantify. As on-ground works are implemented, it is important to monitor the effect they have on the salinity problem. Further work required (monitoring/studies/investigation) is outlined in the following section.

5) FURTHER WORK

Monitoring Requirements

Review of existing groundwater networks

Existing networks were installed by the Point Sturt Landcare Group and the Sandergrove Plains Landcare Group. These sites were monitored in the early 90s but the data and enthusiasm to continue monitoring has generally been lost. Further monitoring of the Point Sturt site is recommended by Barnett (1998). It is further recommended that all existing sites be reviewed in terms of existing data and future monitoring.

New groundwater networks

A complete piezometer network is necessary to monitor future groundwater trends, including those areas where management strategies are to be implemented. It is recommended that when introducing land use changes at an appropriate scale (eg 1000 ha of trees), that a monitoring system be installed.

The groundwater monitoring network in the LAP is currently inadequate and needs to be improved by drilling new piezometers and including additional existing observation well sites (Barnett, 1998).

Barnett (1998) recommends that the observation network be expanded with 5 additional regional watertable piezometers (10m deep) and two piezometers in the dunes (25m deep).

Irrigation area

Barnett (1998) recommends close monitoring of the impact of irrigation on low-lying areas of the ABIA close to the lake. An observation well / piezometer network is currently being installed in the salinity risk zones, where groundwater is within 3m of the soil surface as identified in ABWRC (1996). Regular monitoring of this network will be required.

Stream salinity

Water quality is a significant indicator of catchment health. It is recommended that water monitoring points be set up in catchments to document stream salinity levels (similar to those already established for the Bremer Barker and Tookayerta catchments).

Biodiversity

Increasing stream salinity is also important from an ecological perspective as salt degrades stream ecology. High salinity levels in streams decreases the biodiversity by affecting the aquatic fauna and flora of those waterways (ARCG,1998). Monitoring of biodiversity and ecosystems under threat should be carried out.

Further Studies / Investigations

Irrigation Area Groundwater modelling

This has been undertaken for the Angas Bremer Irrigation Area by the PIRSA groundwater program (Howles, 1999). The model determined the interaction between the clay and limestone aquifers and quantified more accurately the threat of land salinisation northeast of Milang under different irrigation management scenarios. The findings of this modelling study need to be considered, and recommendations concerning remedial action formulated.

Local recharge from sand dunes

In the area north of Lake Alexandrina, the relative contributions from dune recharge to regional recharge is unknown and needs to be investigated (Barnett, 1998). The local recharge contribution from sand dunes must be assessed before the impacts of land management change can be estimated (Barnett, 1998). This work needs to be done since the clay aquifer is unique to this LAP and results cannot be extrapolated from other areas on the Coastal Plain.

It is recommended that three wells be drilled to 6m depth across a dune-swale system to obtain a hydrogeological section and conceptual understanding of the flow system including a waterbalance.

Riparian zone biodiversity

The impact of salinity on riparian zone biodiversity and aquatic ecosystems needs further work. Environmental flow requirements affect biodiversity and need to be assessed. Work is currently being undertaken by DEHAA on this topic in other parts of the state (A Chambers, pers comm).

The impact of the salt load being exported from the uplands via streams needs to be assessed including the impact on ecosystems and on biodiversity of the riparian zone.

Infrastructure

Surveys are required to determine infrastructure damage / costs from salinity. On a statewide basis, this will be undertaken as part of the National Land and Water Audit (Barnett, pers comm). Local co-operation for this audit will be sought.

Saline resources

Feasibility studies into industries based on saline resources (aquaculture, ecotourism, salt harvesting, irrigating with saline water) are desirable.

Economic Analysis

An economic analysis of the various options for combatting land and water salinisation, and using saline resources, needs to be undertaken. Benefit cost ratios will also help determine cost-sharing arrangements for the funding of on-ground works.

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**SALINITY MANAGEMENT
WITHIN THE
GOOLWA TO WELLINGTON
LAP AREA**

APPENDIX 1

Trevor Dooley and Chris Henschke

PIRSA Rural Solutions

October 1999

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Colour originals are available for viewing. See the LAP Officer for details.

Factsheet

- HWU No. 1 High Water Use Strategies For SA - An Overview
- HWU No. 2 Water Use Potential
- HWU No. 3 Farm Water Use, Productivity and Dryland Salinity

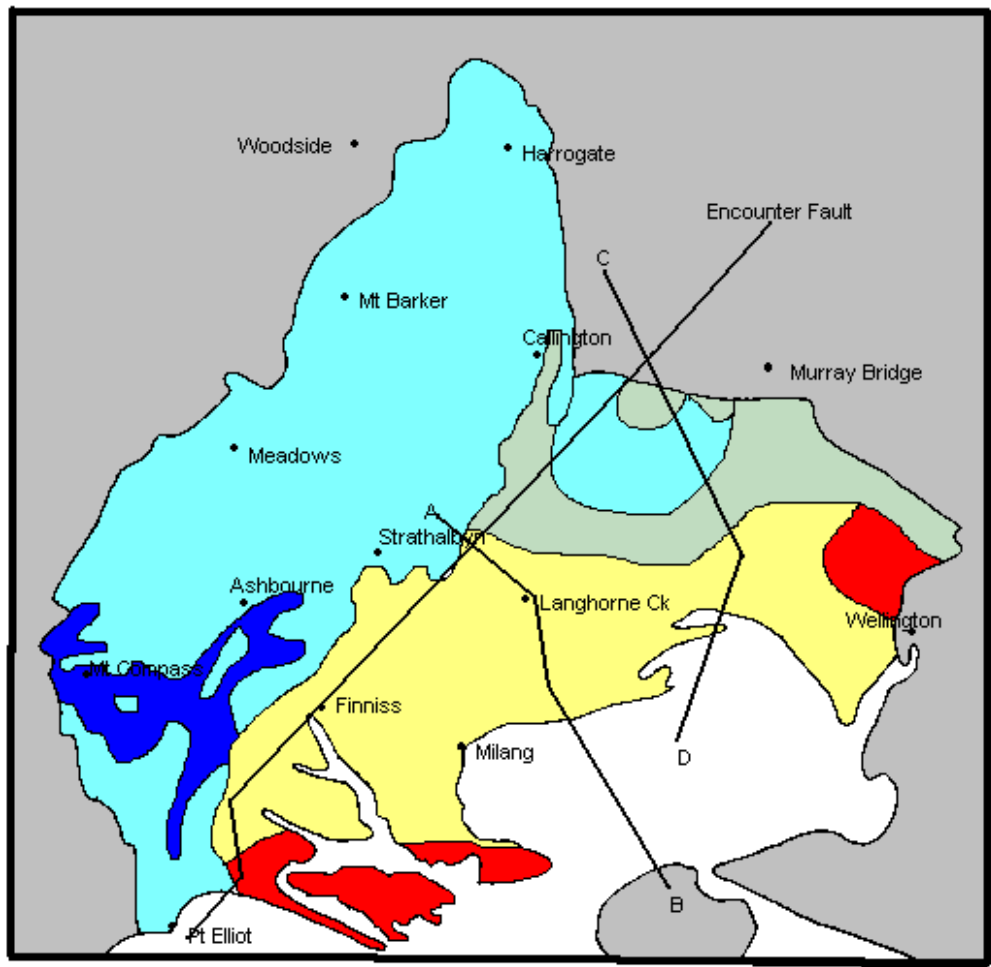


Figure 1. Aquifer Systems of the Goolwa to Wellington LAP (after Barnett, 1994)

- Quaternary Clay Aquifer
 - Murray Group Limestone Aquifer
 - Fractured Rock Basement Aquifer
 - Quaternary Limestone Aquifer
 - Permian Basement Aquifer
- A ——— B Hydrogeological Cross-Section

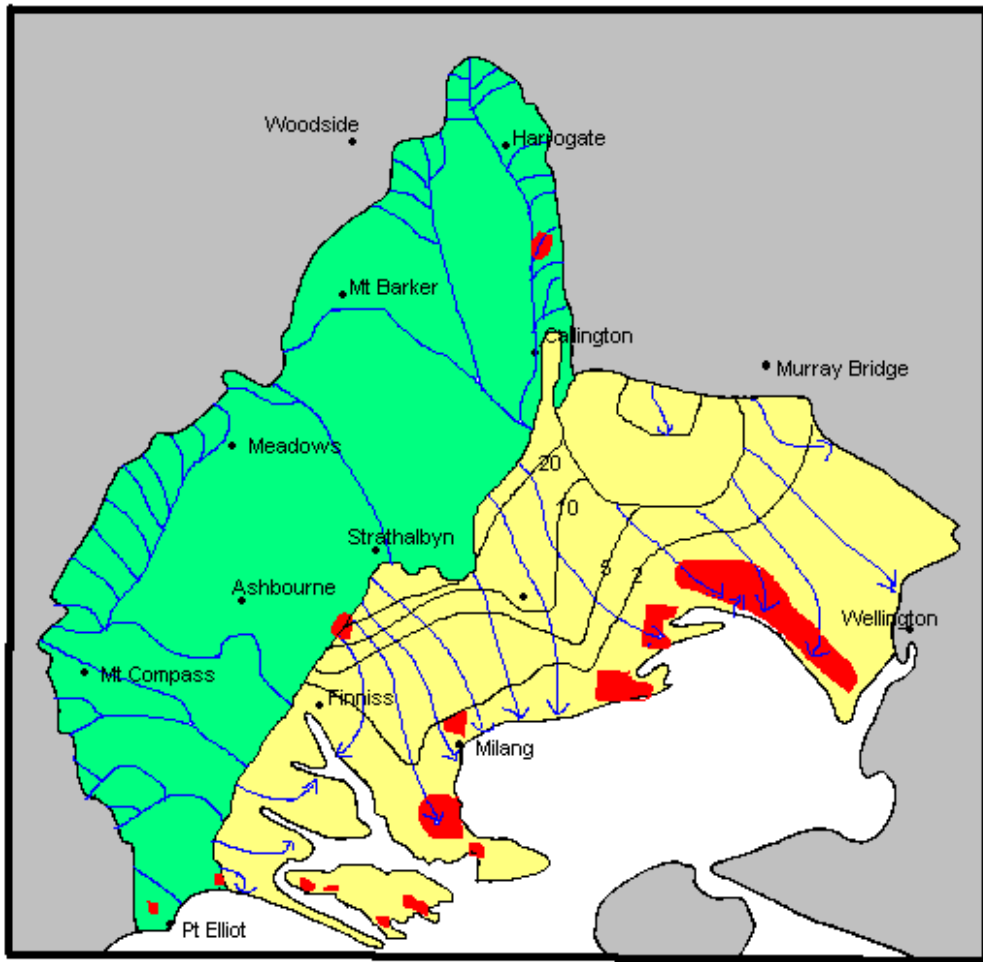
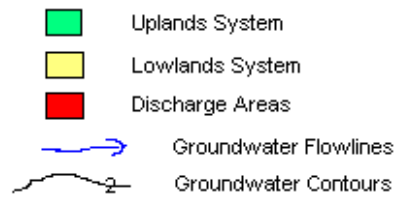


Figure 2. Groundwater Flownet for the shallow watertable aquifer.
 Uplands - inferred
 Lowlands - after Barnett (1994)



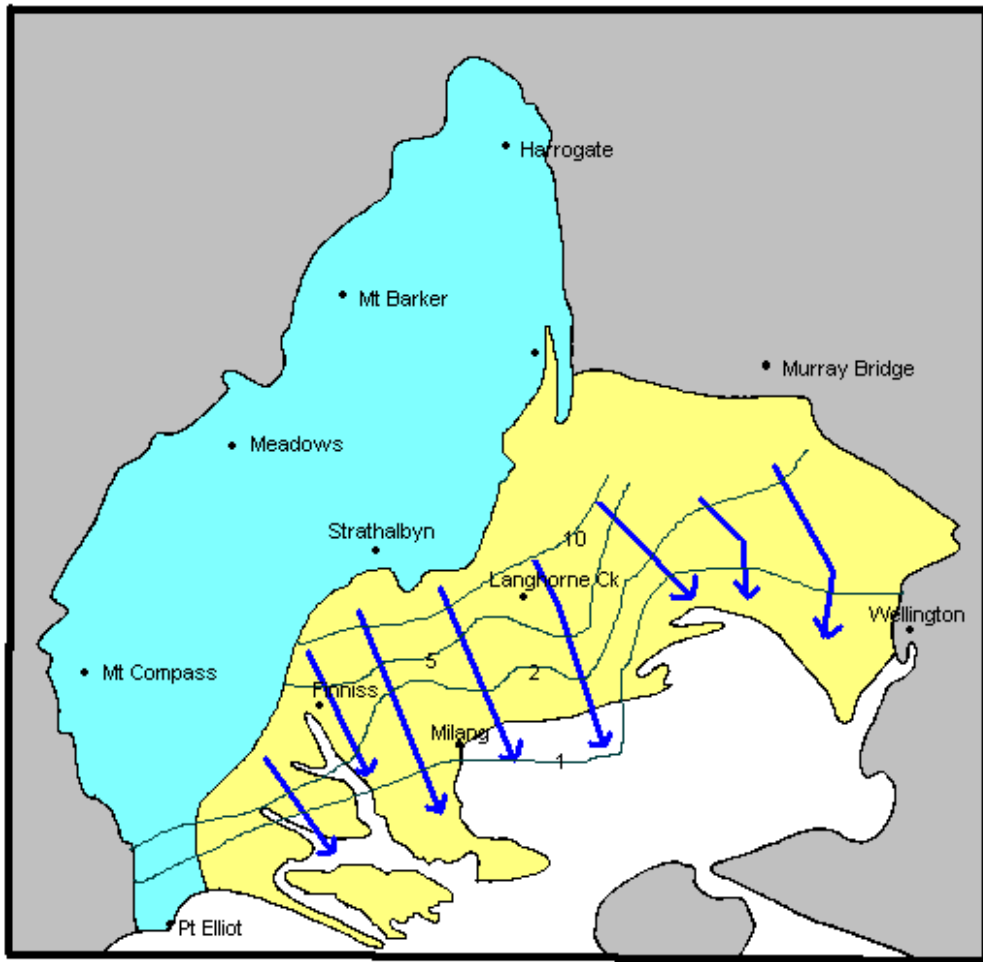


Figure 3. Murray Group Limestone Aquifer System Groundwater Flow Map. Goolwa to Wellington L.A.P.

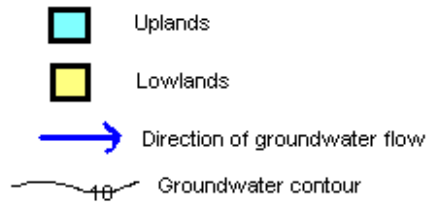
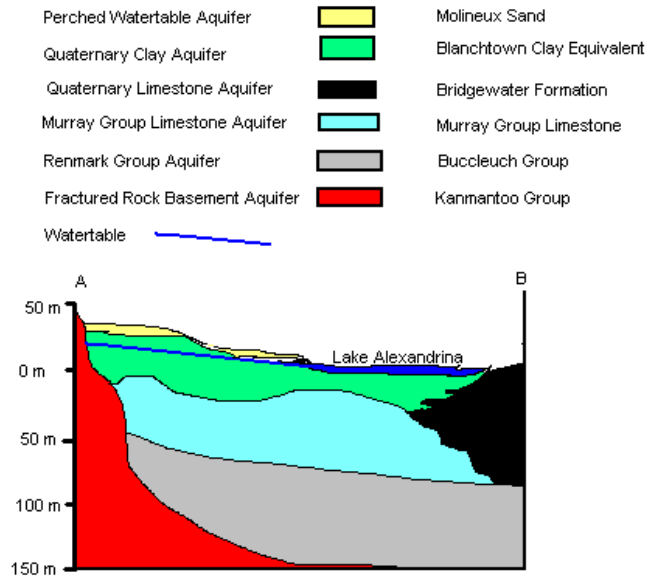
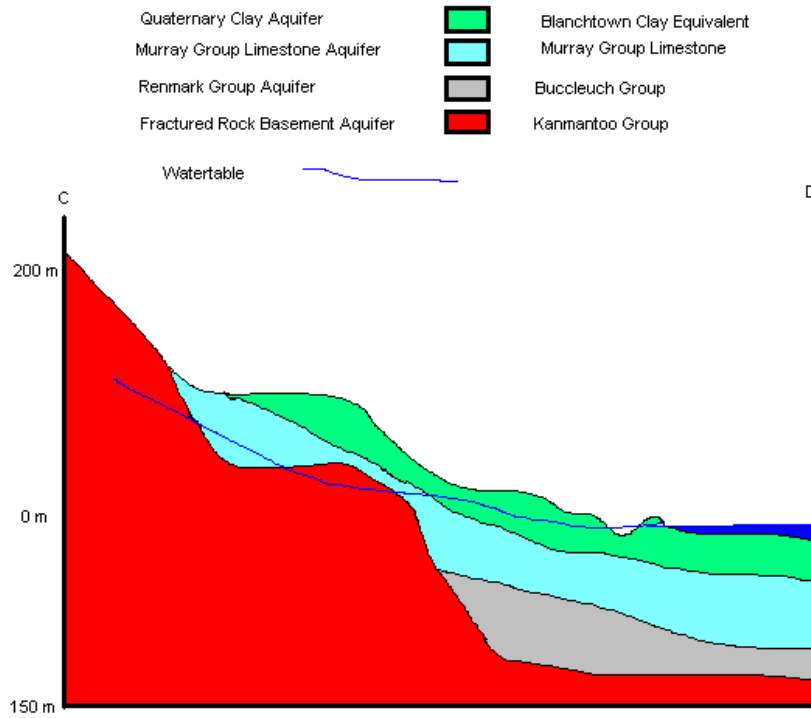


Figure 4. Hydrogeological Cross-Section.
Goolwa to Wellington L.A.P.



Barnett, S.R. (1994)

Figure 5. Hydrogeological Cross-Section.
Goolwa to Wellington LAP.



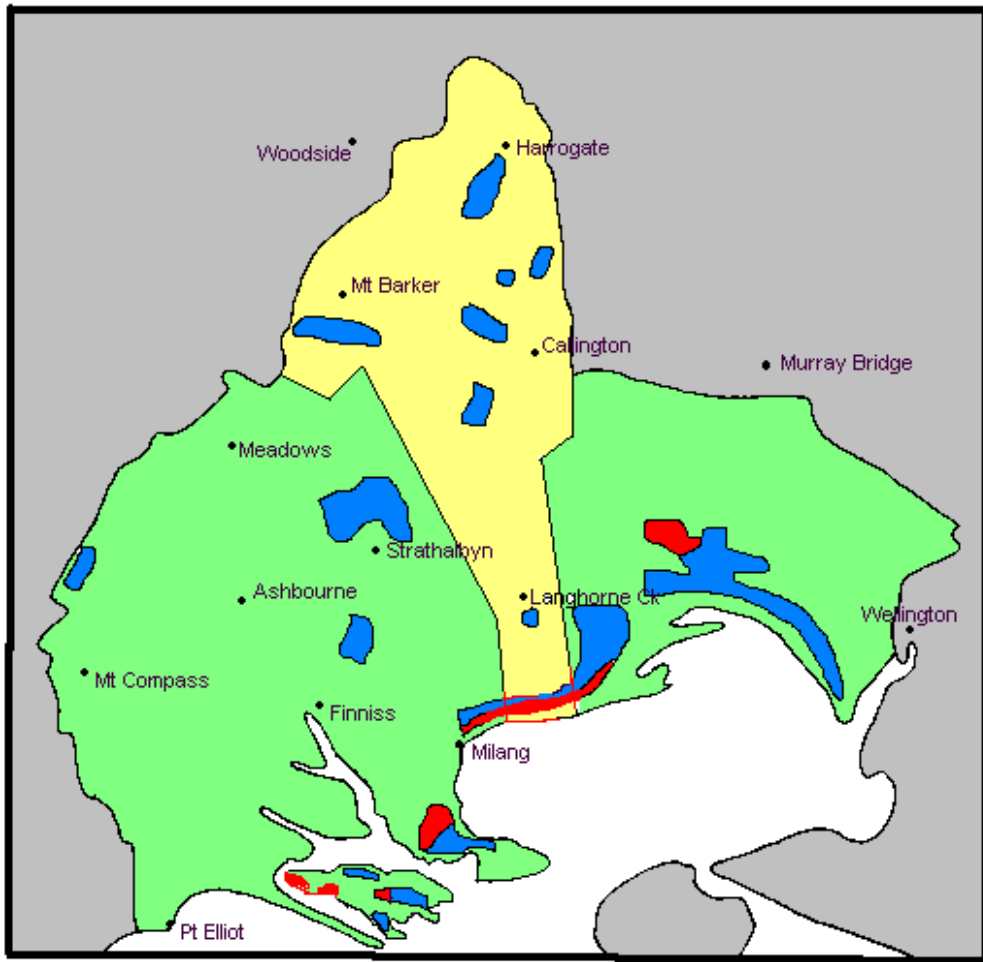


Figure 10. Main Saltland Discharge Zones within the Goolwa to Wellington L.A.P.

Note: Boundaries are approximate.

- Main Saltland Discharge Zones
- Discharge Hotspot Areas
- Bremer Barker Catchment

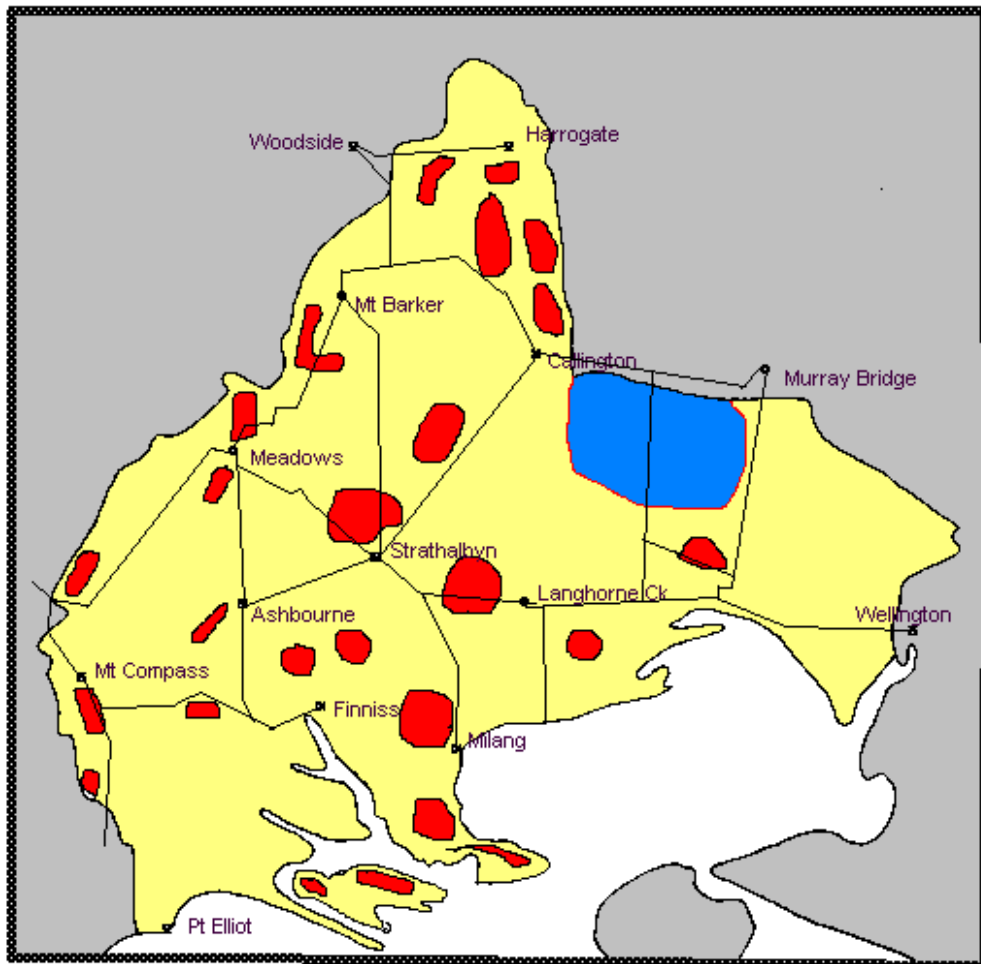


Figure 11. Recharge hotspots in the Goolwa to Wellington LAP.

- 50% recharge reduction required
- 30% recharge reduction required
- low priority for recharge reduction

Note: Boundaries are approximate. Detailed maps are available.



HIGH WATER USE STRATEGIES FOR S.A. – AN OVERVIEW

The application of high water use strategies is an accepted component of a total catchment approach to dryland salinity control.

The basic aim of high water use strategies is to increase water use over a catchment and thus **reduce recharge to the groundwater**.

Over time, the end result of successful application of high water use strategies may be:

- salinity increases, but at a slower rate
- salinity stabilises at a certain level
- salinity is slowly reversed.

The major factor affecting the end result will be **the proportion of the catchment** over which high water use strategies are applied. To have a major effect on the water balance (ie. to reverse salinity), water use may need to be increased **over 80% of the cleared area of a catchment**.

This will depend on the type of high water use strategy adopted, the hydrogeology of the catchment and the allied remedial measures (eg. drainage) put in place.

High water use strategies encompass improved water use from utilising:

- annual winter crops and pastures
- opportunistic summer cropping
- perennial pastures such as dryland lucerne, phalaris, native grasses
- trees and shrubs (farm forestry, alley farming, woodlots...).

For high water use strategies to be successfully applied in catchments and regions of South Australia, there must be:

- a **clear end result being targetted** (do we want to slow, stop or reverse salinity?)
- a clear **understanding of the hydrological processes** acting within the catchment
- a clear understanding and acceptance of high water use strategies
- a clear understanding and acceptance of the **relative costs and benefits** that apply
- a **support system** for successful implementation of high water use strategies.

Catchment clearance and development have created an imbalance in our water systems. Successful high water use strategies can accelerate us towards a new equilibrium.

WATER USE POTENTIAL

High water use strategies to counterbalance salinity include the establishment and management of vegetation to use proportionally more water than is currently being used.

Plants have a certain water use potential, depending largely on physiological factors such as leaf area index – the ratio of total leaf area to unit area of soil surface.

Higher water use potential	Lower water use potential
Perennials	Annuals
Deep-rooted	Shallow-rooted
Higher leaf area index	Lower leaf area index
Suited to climate and site conditions	Not suited to climate and site conditions

Water use of plants can be expressed as a percentage of rainfall. Research has yielded various estimates (order of magnitude only) of potential water use for vegetation types.

Vegetation Type	Potential water use (% of rainfall)	Potential Recharge (% of rainfall)
Native forest vegetation	100%	<div style="display: flex; flex-direction: column; align-items: center;"> <div style="margin-bottom: 10px;">Low (0%)</div> <div style="margin-bottom: 10px;">↓</div> <div style="margin-top: 10px;">High (20%)</div> </div>
Dryland lucerne/phalaris	100%	
Other perennial pasture	90%	
Continuous cropping	80%	
Cereal/pasture	70%	
Annual pasture	60%	
Cereal/fallow	50%	

Potential water use should be viewed as a long-term factor, and one that does not necessarily correlate directly with recharge, as rainfall, landscape and soil characteristics have a significant influence on the mechanics of recharge.

Higher water use vegetation has a greater capacity to reduce recharge.

Selection, location and management of such vegetation will largely determine whether their potential for higher water use is realised and recharge is consequently reduced.

FARM WATER USE , PRODUCTIVITY AND DRYLAND SALINITY

Work out how much rainfall you are using on your property.
 Your water use for each component equals the water use factor x the % area of your farm.

For rainfall areas less than 550 mm

EXAMPLE

Water use component	Water use factor		% farm area	Water use	% farm	Water use	
	Higher	Lower				Higher	Lower
Interception trees	1.2	1.0					
Native vegetation	1.0	0.9			5	5	4.5
Lucerne	1.0	0.9			5	5	4.5
Phase farming	1.0	0.9					
Other perennial	0.9	0.8					
Continuous cropping	0.8	0.7			60	48	42
Crop/pasture	0.7	0.6			25	17.5	15
Annual pasture	0.6	0.5			5	3	2.5
Cereal/fallow	0.5	0.4					
Bare	0.4	0.3					
TOTALS			100% area% rainfall	100 % area	78.5% rainfall	68.5% rainfall

THE EXAMPLE. On average over 10 years, 90% of the farm is under annual crops and pastures, and 10% under perennials.

By maximising annual crop and pasture productivity (higher water use), an extra 10% or more of annual rainfall can be used each year (78.5% vs 68.5%).

This equates to an average 1t/ha increase in grain yield, and a 2t/ha increase in pasture dry matter production over 90% of the farm.

YOUR FARM. Rainfall that you are using =% of rainfall.
 Rainfall that you are not using =% of rainfall

Unused rainfall ends up as runoff, evaporation, soil storage or deep drainage (recharge).

Unused rainfall is potential production going down the drain, contributing to dryland salinity and waterlogging problems on your farm and in your catchment.

Use the table to run through a few different scenarios eg. more perennials, more cropping, less bare soil. By how much can you increase your farm water use without making major changes to your enterprise?% Will this help stop dryland salinity?.....