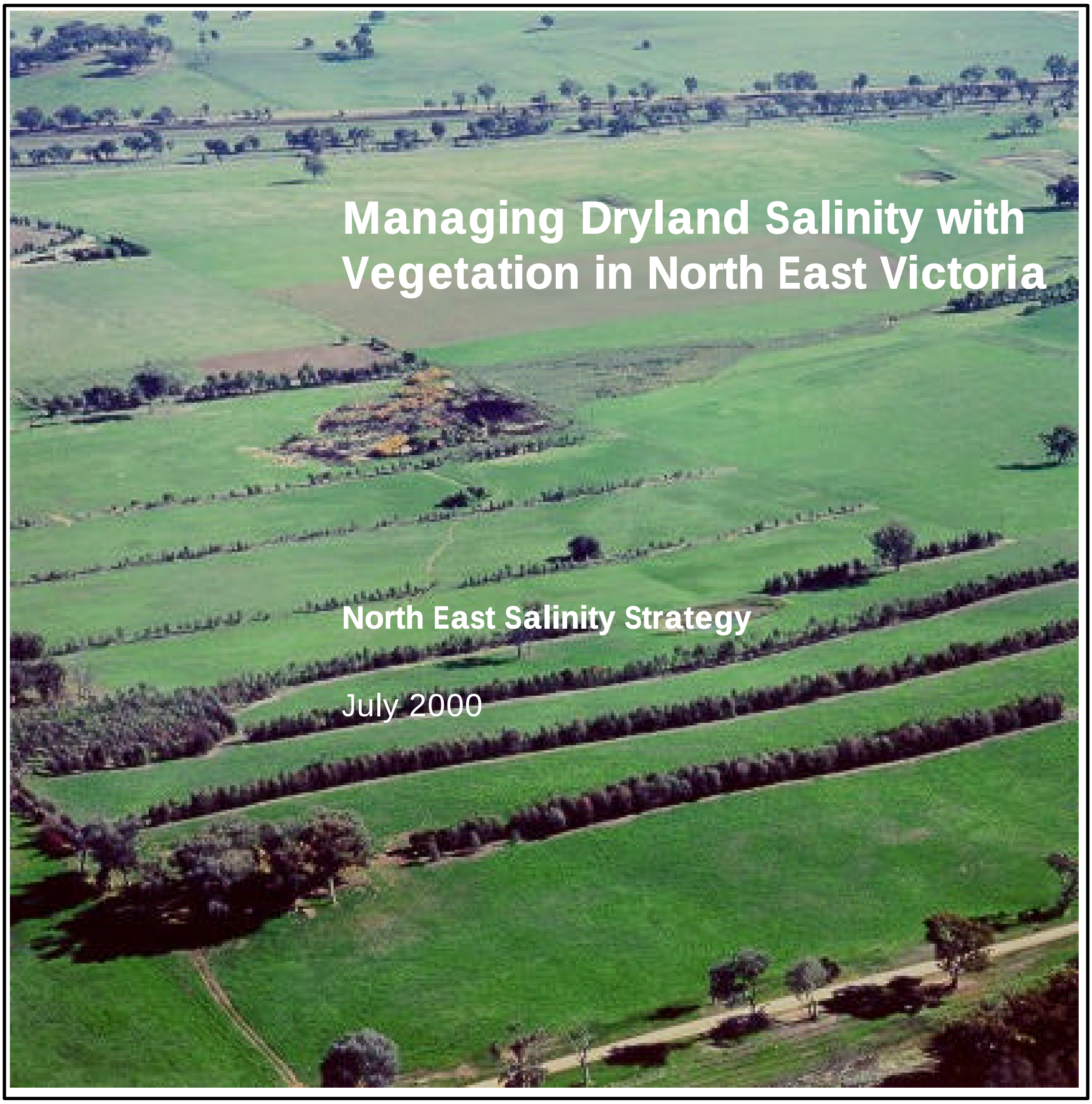

Managing Dryland Salinity with Vegetation in North East Victoria

North East Salinity Strategy

July 2000

Natural Resources and Environment
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North East Salinity Strategy

Managing Dryland Salinity with Vegetation in North East Victoria

by

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Contents

1. Introduction and outline

Dryland salinity currently affects over 2300 ha of land in the north-east region and may threaten up to 70 000 ha in the next 50 years.

Dryland salinity is emerging as an important natural resource management issue in the north-east region of Victoria. Over 2300 ha of land have been identified as being affected, with the predicted extent of shallow water tables and dryland salinity increasing to between 10 000 and 70 000 ha in fifty years time (Fanning 1996; Sinclair Knight Merz 1999).

Increasing community concern about dryland salinity lead to the formation of the North-East Salinity Working Group in 1994. The Working Group commissioned several studies to provide information on the extent of dryland salinity, trends in water table levels and the processes by which salinity had developed in the region. These studies provided the initial technical basis for the preparation of the (draft) North-East Salinity Strategy. The Draft Strategy document, which was published in 1997, describes the natural resources of the region, salinity processes, and most importantly, it outlines the means by which the regional community, in partnership with State and Commonwealth governments and the broader community, intend to tackle dryland salinity. The Strategy was approved by the Victorian government in December 1999.

By mid-1999, some eighteen months after the launch of the Strategy, there was a perception by members of the North-East Salinity Working Group that the community was becoming frustrated by a lack of specific technical information about how they should approach the management of dryland salinity on their properties. To address this concern, they commissioned Craig Clifton of Sinclair Knight Merz and Mark Reid of the Centre for Land Protection Research, Bendigo to run a series of field days across the North-East region to:

NE Salinity Working Group held field days to improve understanding of salinity processes in the community and to provide specific advice on management of dryland salinity in local catchments.

- provide an understanding of the processes contributing to dryland salinity and those associated with its successful management;
- provide specific guidance on how vegetation (perennial pastures and trees) might be used in the management of dryland salinity in local landscapes.

Four field days were held during September 1999, at Springhurst, Barnawartha, Everton and Greta. Over 120 members of the local community attended. Audiences comprised local landholders, landcare group coordinators, members of the Salinity Working Group, students, Department of Natural Resources and Environment primary industry and catchment management advisory staff and local politicians. The field days included a 2 hour information session in the local public hall, followed by lunch and inspections of two or three relevant sites in the field.

This booklet aims to help landholders to understand their land better and interpret the salinity processes operating.

This booklet is intended to provide similar information to that presented during the series of field days. It aims to provide sufficient detail about the processes of dryland salinity for readers to begin to understand or "read" their landscapes and interpret the ways in which salinity has developed. This is a key step in landholders developing and applying improved land management practices that will help to reduce the risk of dryland salinity. By learning to "read" their landscapes landholders will be able to combine information presented in this booklet with that derived from other sources to develop farm plans that address the unique physical circumstances of their property.

The booklet provides guidance on placement and management of vegetation for salinity management.

The booklet also aims to provide specific guidance on the placement and management of vegetation used to mitigate dryland salinity. The parts of the booklet dealing with these topics are based on the current understanding of salinity processes and the means by which they may be mitigated. These sections of the booklet are also framed around real examples from various parts of the North-East region. Landholders are encouraged to seek further information and advice; from their neighbours, landcare group coordinators and/or NRE extension staff, before embarking on a program of changing the management of their property. Key contact points for this information are given in Appendix A.

As our understanding of salinity processes develops in coming years, approaches to salinity management may change. Whilst information in this book is based on current knowledge and is provided in good faith, the suitability of any particular approach cannot be guaranteed.

2. The North-East Salinity Strategy

The North East Salinity Strategy has been accepted by the State Government

The North East Salinity Strategy was launched as a draft document in December 1997. The Strategy was accepted by the State Government as an approved Salinity Plan in Victoria in 1999.

As a component of the North East Regional Catchment Strategy (NERCS), the Salinity Strategy is part of the 'big picture' in addressing land degradation in the North East Region. The Regional Catchment Strategy identified salinity and rising watertables as a major threat within the North East region. The Salinity Strategy addresses the issue of dryland salinity as it is expected to develop over the next 30 years.

Most of the other land and water degradation issues identified in the Regional Catchment Strategy have links to varying degrees with the Salinity Strategy, particularly water quality, rural tree decline, water-logging, soil acidity, soil structure decline, erosion, habitat decline and biodiversity decline. The strategies put in place to address these key regional issues will also complement the objectives and programs of the Salinity Strategy.

Salinity has emerged as a serious issue in the North East Region. By 1998, over 2100 hectares of salt-affected land had been identified and mapped. Water table levels are also rising steeply in some Land Management Units (LMU), pointing to the prospect of continued increases in the area of salt-affected land. The area affected in 1999 was thought to be approximately 2300 ha.

The Salinity Strategy encourages on ground works - pasture improvement and tree growing. It is integrated with farm and sub-catchment plans

On ground works to address the salinity issue are being carried out by land managers because of increasing concern about salinity. Works have included pasture improvement, alley farming and tree growing. Some groups are also developing their own sub-catchment plans.

The Salinity Strategy focuses on implementing options that promote higher water use in all cleared areas of the region and the promotion of activities that protect and enhance remnant vegetation. It takes an integrated approach to salinity management by linking it to property management and sub-catchment planning. Although high water use vegetation options will continue to be promoted, specific recommendations about the use of trees, pastures and crops may change as new information arises.

3. The Water Balance

3.1 Introduction

Dryland salinity is caused by a change in the water balance of landscapes.

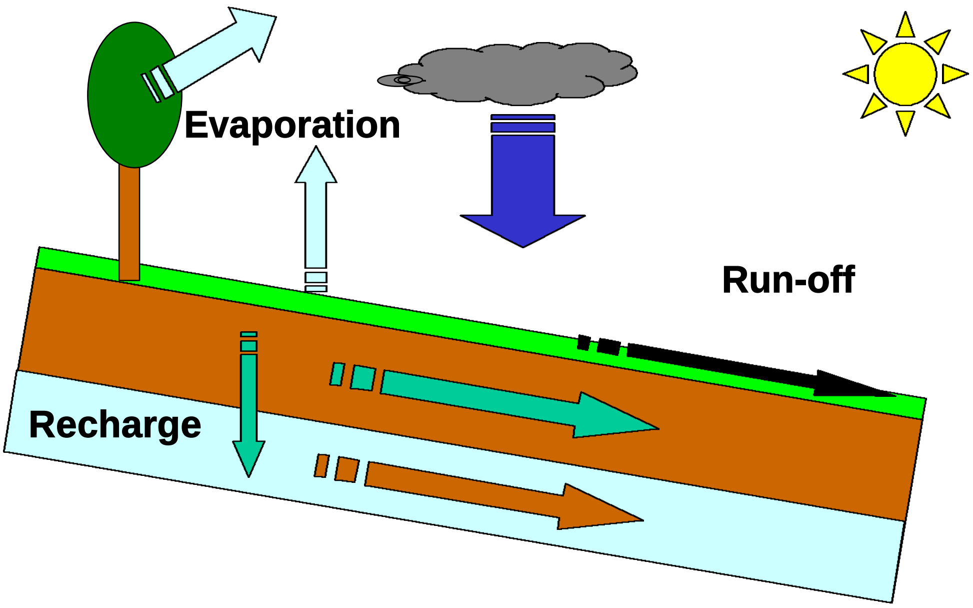
Dryland salinity and several other important land degradation issues (e.g. erosion, acidification) have at least in part been caused by a change in the *water balance* that has accompanied European settlement and the development of agricultural land use. The starting point for understanding dryland salinity and developing a sound approach to its management is to understand the water balance of landscapes.

The *water balance*, which is depicted in Figure 3.1, is simply a way of describing the fate of rain falling on an area of land. Some rain is *intercepted* by vegetation and evaporated directly from the leaf surfaces. In forests and plantations up to 10-20% of the rainfall is intercepted and evaporated before it has a chance to reach the ground and seep into the soil.

Rain that does reach the soil surface may either *infiltrate* into it or move laterally across the surface, as *run-off*. Run-off occurs when rain is falling at a greater rate than the water can infiltrate into the soil and/or is falling on to a soil profile that is "full" of water and cannot accept any more. *Interflow* is a form of run-off that takes place below the soil surface. It occurs when water that has already infiltrated into the soil reaches a less permeable layer (e.g. a clay subsoil). If there is sufficient slope, water that cannot infiltrate into the less permeable layer will move downslope through, rather than on top of the soil.

Rainfall is balanced by outputs of water as evaporation, run-off and recharge and by changes in soil profile water storage.

Figure 3.1: An illustration of water balance processes in a landscape



Some of the water that infiltrates into the soil profile is taken up by plant roots. This water, which contains the mineral nutrients plants require for growth and development, is then transported upwards through the plant to the leaves. Water is evaporated (called *transpiration* or *plant water use*) from the inner surfaces of the leaves through tiny pores, called stomata. When the soil is moist, some water is evaporated directly from the soil surface. Some 50-90% of the total rainfall is lost as evaporation. The rate at which evaporation proceeds is largely determined by the amount of energy available from sunlight.

Soil profiles leak once they fill with water – this is groundwater recharge.

At about the time of the autumn break, the soil profile would typically be “empty” of water to a depth of about 60 cm. Following the break, water from successive rainfall events infiltrates into the soil and progressively wets or “fills up” the soil profile. Once full, the soil profile begins to “leak” from the bottom. Once this leakage of water reaches the water table, it has recharged the groundwater system. Like interflow, groundwater may move downslope if the *aquifer* in which it lies is sufficiently permeable.

These processes of water movement are referred to as being part of the *water balance* because the inputs of water as rain must be in balance with losses through evaporation (by plant water use, soil evaporation or interception), run-off or recharge and the change in water storage in the soil profile.

3.2 Variation in landscape water balances

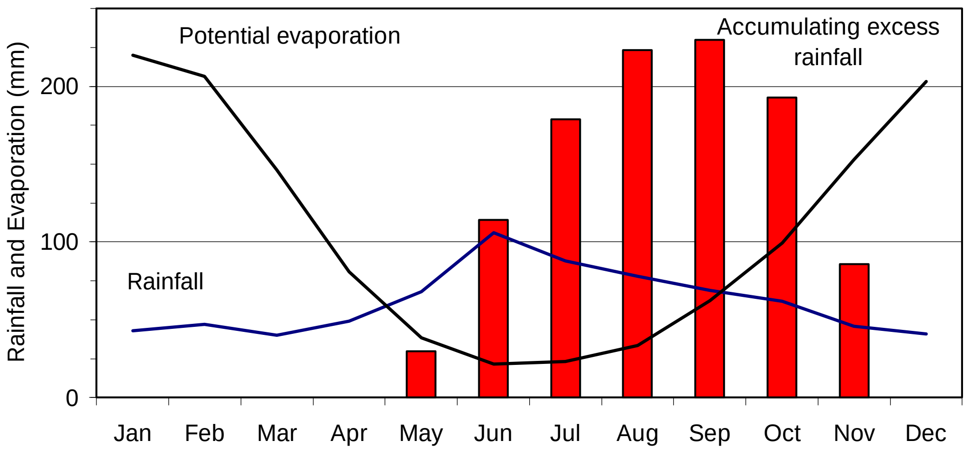
Water balance processes vary over time, with the balance between rainfall, evaporation and the filling and emptying of soil profiles.

Water balance processes operate over time. The balance between rainfall, evaporation, soil water storage and the other terms changes on a monthly and even daily basis. This time dimension to the water balance is a major factor explaining why some landscapes are more prone to developing dryland salinity than others. The importance of time is illustrated by Figure 3.2

More rain is typically received in winter than can be evaporated by any type of vegetation.

Figure 3.2 shows the balance between average monthly rainfall and *potential evaporation* (rate of evaporation from vegetation if water was freely available). Potential evaporation greatly exceeds rainfall during the relatively sunny, warm and dry weather typically encountered in north-east Victoria between late spring and early autumn. However, rainfall exceeds even potential evaporation during winter, with its lower temperature and reduced amount and intensity of sunlight. Regardless of the type of vegetation present (tree or pasture), more rain is received in each month between about May and September than can be evaporated. The red columns in Figure 3.2 show how this excess rainfall accumulates during winter and is ultimately balanced by excess evaporation during spring. The average excess cool season rainfall for Wangaratta is approximately 230 mm.

Figure 3.2: Indicative monthly water balance for Wangaratta



Water accumulates in the soil profile due to excess rainfall in winter - this is potentially available for run-off or recharge. If it can be stored in the soil until spring, it may be used by vegetation.

One consequence of this excess of rainfall during winter is that the soil profile, which was at least partly empty of water at the time of the autumn break, begins to fill. The red columns in Figure 3.2 also indicate how the soil profile might fill up following the autumn break. The storage capacity of soil profiles is not unlimited and will typically range between about 50 and 250 mm. Once storage capacity is exceeded, the soil will begin to leak and/or overflow, allowing groundwater recharge and/or run-off.

Excess rainfall increases in wet years - leading to an increased risk of leakage.

Figure 3.2 illustrates the average monthly rainfall, evaporation and excess cool season rainfall for Wangaratta. While the seasonal pattern of evaporation is relatively consistent between years, rainfall patterns are enormously variable. In any particular year the balance between potential evaporation and rainfall may differ greatly to that depicted in Figure 3.2. There may be little or no excess rainfall under drought conditions. In very wet years, excess rainfall may be double that for an average year. At locations where excess cool season rainfall under average conditions exceeds soil water storage capacity, almost all of the additional excess rainfall received in wet years will be lost as recharge and/or run-off.

The water balance varies with climate, soils, topography and vegetation.

The balance between rainfall, evaporation and water storage in the soil profile varies across catchments, particularly in north-east Victoria, where there is so much topographic relief. Variation occurs with several factors, including:

- *climate* – in addition to variation with seasonal and longer term weather patterns, the water balance will vary across catchments with climate. Rainfall typically increases with altitude, and in north-east Victoria rises sharply south of the Hume Highway. Potential evaporation also varies between the more exposed northerly and westerly aspects and the more sheltered southerly and easterly aspects;

- *soils* – shallow and/or light textured soils have lower water storage capacities than deeper or heavier soils. Lighter soils therefore tend to leak more than heavier soils. Soils that set hard or have a heavy clay sub-soil allow only slow infiltration of water and tend to shed water as run-off or interflow rather than as leakage or recharge;

- *slope* – increased slope encourages lateral movement of water at the expense of vertical seepage. Run-off and/or interception tend to increase and recharge decrease on more sloping sites;

- *vegetation* – the type and management of vegetation may exert a major influence on the *actual* (as opposed to *potential*) evaporation and on the balance between storage of water in the soil profile, run-off and leakage to the water table. Since the type and management of vegetation can be changed relatively easily (compared with slope, climate, soil type), it is one of the key tools in the management of catchment water balances, whether for dryland salinity management or other purposes.

3.3 Dryland salinity and the water balance

Dryland salinity has accompanied European settlement and the development of agricultural land use across many parts of Australia. It arises because landscapes supporting agricultural vegetation leak more water than did the same landscapes when they supported native vegetation. Greater rates of groundwater recharge across catchments have seen water tables rise (often from depths exceeding 20 or 30 m) to within 1-2 m of the surface. When they do so, water can evaporate directly from the water table, concentrating salt at the soil surface and in the root zone of any vegetation present. The soil becomes salinised and suited only to specialised salt tolerant plants.

Southern Australia is prone to salinity because of the mismatch between rainfall and evaporation in winter.

The increased leakiness of agricultural landscapes across southern Australia is easily explained in terms of the water balance. The landscapes themselves are prone to leakage because of the inherent mismatch between rainfall and potential evaporation in the cooler months. Under natural conditions in north-east Victoria, there was a considerable excess of cool season rainfall. It is likely that, in many areas, a certain amount of recharge was a natural feature of the environment.

Landscapes have become more leaky with the introduction of agricultural land use.

The potential for leakage in the landscapes of southern Australia has been enhanced by agricultural development. This has typically resulted in native vegetation being replaced by introduced crop, pasture and weed species. This has generally been accompanied by a reduction in evaporation and the extent to which soil profiles are emptied of water during the warm season, as explained below:

- most commonly used agricultural plants have a growing season that is confined to months of relatively low potential evaporation (compare Figure 3.2). For much of this period their water use is limited by lack of evaporative demand. In contrast, native vegetation in the north-east was generally dominated by evergreen trees, shrubs and perennial grasses that are able to use water throughout the year, including times when evaporative demand is high;

- agricultural plants have relatively shallow root systems which limits both the amount of water they have access to and their capacity to empty the full soil profile of water. Native vegetation is generally dominated by trees, which generally have deep root systems that are able to fully exploit the water storage capacity of the soil profile and in some cases the weathered rock below.

The impact on the water balance is further compounded in grazed pastures by stock (and pest animals such as rabbits) eating the leaves, which are necessary for plant water use (see Section 5). In some areas, particularly in hill country, overgrazing by stock and/or rabbits and weed infestation has lead to erosion and loss of soil with a consequent reduction in the water storage capacity of the soil profile.

Since a balance of inputs and outputs of water must be maintained, these reductions in the evaporation and soil water storage capacity are matched by greater recharge and/or run-off. In catchments or landscapes, this has resulted in dryland salinity, soil erosion, increased flooding, water-logging and contributed to soil acidification.

Unused rainfall (leakage) represents a lost productive opportunity.

In addition to its contribution to a wide range of land degradation issues, unused excess rainfall can represent a lost productive opportunity. In many areas, lack of water is a major impediment to agricultural production. By changing from traditional agricultural systems that effectively "waste" unused excess rainfall, to systems that make the fullest possible use of it, it should be possible to increase the productivity of an enterprise.

4. The Development of Dryland Salinity

4.1 Recharge and discharge areas

Salinity management needs to address the source and symptoms of the problem - recharge and discharge areas.

Dryland salinity has become a common feature of landscapes across north-eastern Victoria. Although the area of land affected by salinity is generally relatively small, such areas are indicative of changed water balances across much larger areas. Management of dryland salinity will need to address both the source (areas where recharge has increased) and symptoms (areas of enhanced groundwater discharge) of these changes.

Salinity discharge areas may become recharge areas at certain times of year.

Recharge areas are simply the "leaky" parts of the landscape - the areas where some of the excess winter rainfall leaks through the soil profile, past the root zone of vegetation and on to the water table. In many of the higher rainfall areas of north-east Victoria, recharge would have been a natural feature of the environment. Salinity has developed in catchments because changes in vegetation and land use have resulted in an increase in the rate of recharge. This increased leakiness is a feature of almost all agricultural land, although its rate and timing vary widely. Even areas where groundwater discharge and soil salinisation are evident may be recharge areas for part of the year.

Strategic recharge areas.

While agricultural landscapes as a whole tend to be leaky, some parts of the landscape leak more than other parts. Examples of the types of land that tend to have elevated rates of recharge are:

- areas with shallow soil – which have reduced capacity to store excess rainfall;
- areas of light textured and permeable soil – which are unable to prevent excess winter rain from draining before it could be used by vegetation during the period of excess evaporation during spring or summer;
- sparse vegetation coverage (due to salinity, infertile soil, overgrazing, weed infestation etc.) – where there is insufficient leaf area, particularly during the warm season, to allow plants to empty the soil profile of water to the extent required to store excess rainfall;
- breaks of slope – water moving over the surface as run-off or through the soil as interflow slows and accumulates at the break of slope between steeper hills and middle or lower slopes. It then has more opportunity to infiltrate vertically through the soil profile to the water table;
- land that is prone to flooding – which may receive water well in excess of rainfall, thus greatly increasing the risk of leakage to the water table.

These areas may be on the ridges and slopes, flood plains and perhaps even in areas that for part of the year are areas of groundwater discharge.

Discharge areas are those parts of a landscape where water tables are close enough to the surface for groundwater to evaporate directly from the soil surface. This process results in a concentration of salt at the soil surface or in the root zone of plants that take up groundwater. The soil can become salinised through this process, even when the groundwater is relatively fresh. In some cases, the discharge of groundwater may be subtle, resulting only in slow accumulation of salt. Other areas have higher rates of discharge and salinisation.

4.2 Development of dryland salinity in the catchments of North-East Victoria

This section provides an overview of several landscape settings in which the processes of groundwater recharge and discharge are believed to operate in north-east Victoria. While based on the best available information and interpretation, further hydrogeological investigation is required in many cases to provide greater confidence in these interpretations.

4.2.1 Ovens and King riverine plain

Changes in groundwater and surface water hydrology in Ovens catchment since settlement.

The Ovens catchment landscape and hydrology have undergone fundamental changes since European settlement. Native vegetation has been replaced across large areas of the catchment with shallow rooted pastures and crops. These use less of the rainfall and allow more water to leak to the groundwater system. Another result of this vegetation and land use change may have been an increase in overland flow, or run-off, leading to higher stream flows and a greater incidence of flooding.

The Ovens and King Riverine Plain runs north from Whorourly, Moyhu and Everton and is the main floodplain area of the two river systems. Its alluvial sediments (stream deposits) occupy a broad trough-like geological structure known as the Ovens Graben. The fault lines that mark the eastern and western boundaries of the Graben also define the edges of the Riverine Plain. The Riverine Plain landscape has two components, an older plain (the upper terrace), and the present floodplain (the lower terrace). The lower terrace is quite deeply incised, being up to about 8-10 m below the level of the upper terrace.

The upper terrace forms most of the riverine plain. However, the lower terrace can be up to 8 km wide in places. The entire lower terrace of the King and Ovens Rivers has been flooded repeatedly over the last 30 years. While flood events have occurred in wet years (e.g. 1973-75, 1983 and 1988-93), increased run-off from cleared areas may also be a factor in both the frequency and extent of flooding.

The Ovens lower terrace cuts a broad swathe across the riverine plain and comprises many stream channels and billabongs. The lower terrace of the King River is less prominent, but may be up to 3 km wide in places. The sedimentary sequence in the lower terrace and adjacent areas generally contains more sand and gravel than upper terrace areas which are distant from the rivers. In the outer parts of the Riverine Plain, clay and silt dominate the sequence.

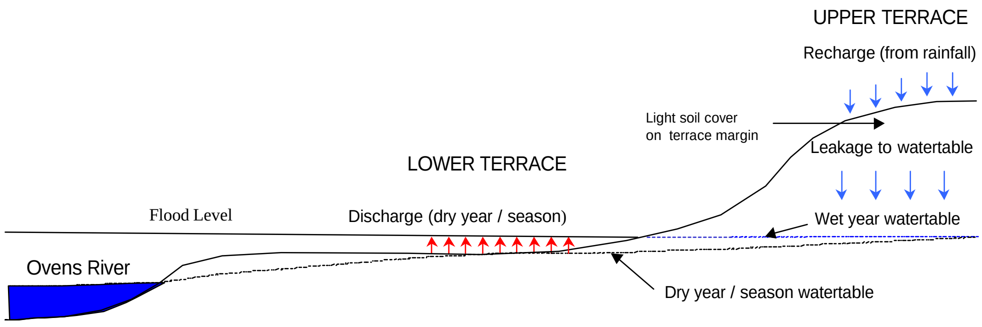
Geological observations and the limited available groundwater data suggest that substantial recharge to the alluvial sediments occurs during high stream flows or floods. Water table responses in the lower terrace and immediately adjacent areas are highly fluctuating, whilst those further from the lower terrace are subdued.

Groundwater recharge associated with high flow events in Ovens River and is accentuated by leakage through lighter soils on upper terraces.

It is believed that mounds or ridges in the watertable develop in the vicinity of the lower terrace during times of high flow or flood (Figure 4.1). This may be accentuated by infiltration of rainfall through the generally lighter soils along the edges of the upper terraces. Return flows from these groundwater "ridges" contributes to seepages along the edges of the lower terrace when the river subsides. It is thought that the ridging also causes increased groundwater flows to the upper terrace areas.

The impact could be greatest on the eastern side of the Riverine Plain, as recharge along the Ovens lower terrace is believed to have generated an increased amount of northerly groundwater flow. This is causing rising groundwater levels in the eastern upper terrace areas, including the Tarrawingee, Carraragarmungee (including Reedy Creek), Boorhaman and Norong areas. The generally higher groundwater levels existing across the riverine plain have probably led to increased amounts of seepage occurring along the lower terrace edges (including Reedy Creek) and possibly other drainage lines and depressions.

Figure 4.1: Conceptual model for the development of dryland salinity on the Ovens and King riverine plain



Note: Vertical scale exaggerated

Figure 4.1 is a simplified representation of the watertable in the lower terrace and adjacent upper terrace during wet and dry cycles. During periods of wet climate and/or high river level, a watertable mound, or ridge, develops causing recharge to the Riverine Plain groundwater system. When the river level declines, watertables near the margins of the upper terrace remain relatively elevated. This results in some return flow of groundwater towards the river.

Shallow groundwater levels on the lower terrace are a result of extensive flooding in recent decades.

With the extensive flooding in recent decades along the lower terraces and resultant rising groundwater levels in the upper terrace areas, there has been an increase in the incidence and magnitude of this return groundwater flow to the lower terrace. The accumulated impact of these events has resulted in saline groundwater discharging at the surface along the edges of the lower terrace and causing salting in many of these areas. Numerous large discharge areas are now active and steadily worsening along the Ovens and King Rivers and the Reedy Creek.

4.2.2 Bobinawarrah and Greta areas

A significant number of saline discharge sites occur along the boundary of the Ovens/King Riverine Plain and the highlands. Geological structure and rock type are believed to play prominent roles in the cause of these sites. Two notable areas in which these sites occur are Bobinawarrah and Greta, adjacent to the southern margin of the Riverine Plain.

Most saline discharge located at the foot of hills fringing the upslope side of the Ovens Graben fault lines.

The margins of the Riverine Plain are defined by major geological faults associated with the formation of the Ovens Graben, a trough-like structure in which alluvial sediments of the ancestral and present day streams of the King and Ovens Rivers are deposited. The occurrences of discharge at Greta West and Bobinawarrah appear to be mainly situated at the foot of the fringing hills on the *upslope* side of the Ovens Graben fault lines (Figure 4.2). They are thought to be partly overlying a high point in the bedrock that is providing a preferred pathway for leakage of (pressurised) groundwater to the surface.

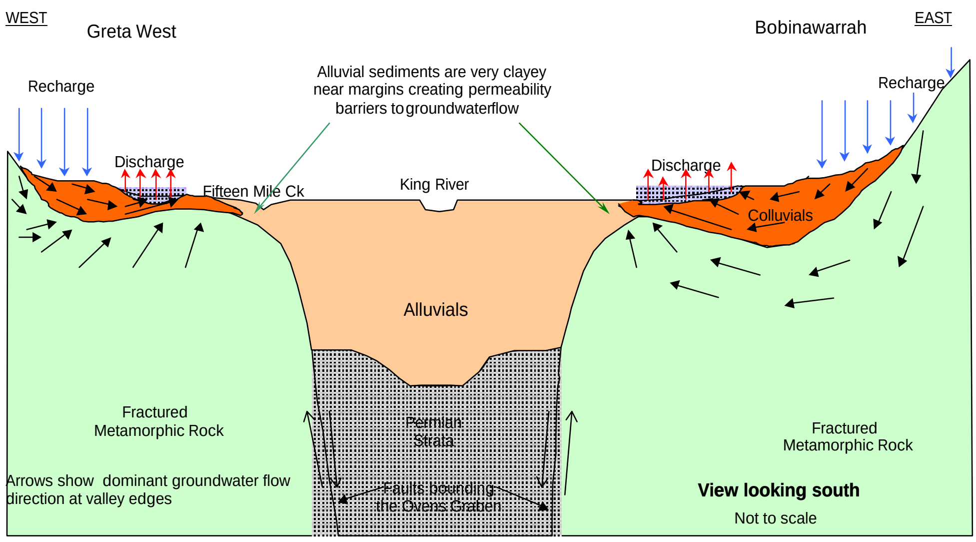
Poor drainage through the clayey sediments on the margins of the Riverine Plain also helps water to accumulate and contributes to saline discharge.

The sediments in the Riverine Plain margins are predominantly clayey and have low permeability. This has potential to restrict the lateral movement of groundwater from the hills and force it to accumulate and discharge along the base of the hills.

Figure 4.2 is a simplified hydrogeological cross-section from Greta West to Bobinawarrah, as viewed from the south. It portrays the current understanding of salinity processes (which are based on very limited information). Series of arrows define recharge and discharge areas within the hillslope environments, as well as groundwater movement. Replacement of native vegetation with shallow-rooted pastures has resulted in increased groundwater recharge on the crests and mid-upper slopes of the hills. This has led to significant rises in groundwater levels within both the fractured metamorphic bedrock and the colluvial (hillwash) deposits covering the bedrock.

The raised pressures in the fractured bedrock are believed to be causing upward leakage of groundwater at the base of the hills. It is possible that the clayey sediments at the Riverine Plain margins could be assisting this upward leakage by limiting horizontal groundwater flow into the Plain. In addition, the excessive amounts of water entering the shallow colluvial system are not draining effectively into the underlying fractured rock due possibly to high bedrock pressures and the duplex nature of the colluvial soils. This results in severe seasonal waterlogging in mid-lower slope areas and further deterioration of the saline discharge sites. The salinity is tending to concentrate around the heavier colluvial soils developed at the base of the hills and appears to stop short of the alluvial sediments of the Plain. Early evidence from new observation bores suggests that watertables drop away at the edge of the Plain.

Figure 4.2: Conceptual model for the development of dryland salinity in the Bobinawarrah and Greta areas



Salinity processes at Hansonville may be associated with poor drainage of groundwater out of the catchment.

Some other occurrences of salinity in the Greta area are located around fringing foothills in the south (e.g. Hansonville). These are associated with different rock types and there is very limited information on groundwater processes at this stage. On the first brief examination, soils on the ridges and upper slopes of the surrounding low hills in this area appear to be lighter in texture and thin and stony. They may allow relatively high rates of recharge to the groundwater system. It is possible that the almost closed shape of the sub-catchment at Hansonville and the suspected higher clay content of the alluvial sediments at the downstream end combine to trap excess groundwater within this area.

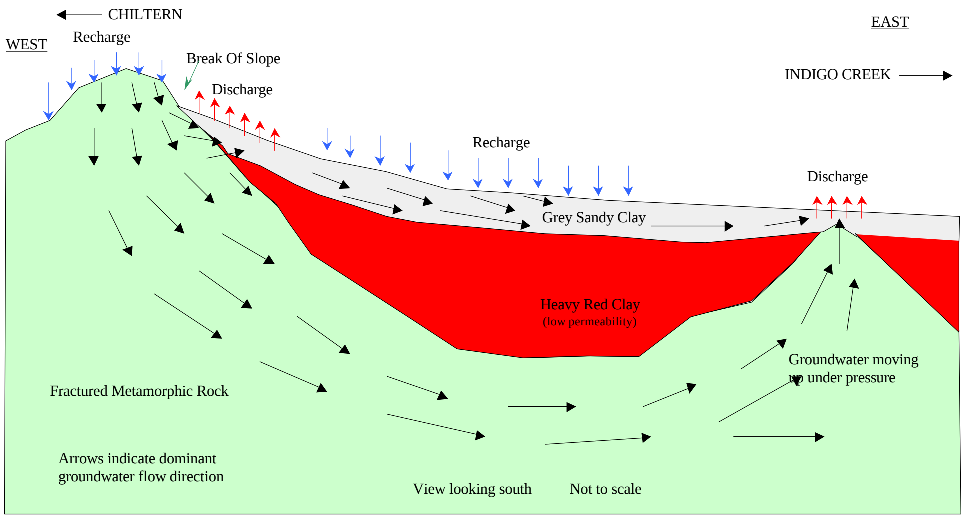
4.2.3 Development of dryland salinity on the western side of Indigo Valley, Barnawartha South

The western margin of the Indigo Valley is defined by a fairly steep range of hills composed mainly of hard, fractured metamorphic rocks. These include slates, quartzites and hornfels. The crests and upper slopes of these hills are mostly cleared and are either rocky or covered by a thin, stony soil. Accordingly, rates of recharge into the fractured rock system are expected to be relatively high along the tops of these hills.

A long slope extends from the break of slope of the metamorphic hills down to the edge of the Indigo Creek alluvial plain. It is composed of varying thicknesses of colluvium (hillwash) and alluvium (stream) deposits overlying the metamorphic bedrock. Anecdotal information and brief examinations to date indicate that this sedimentary cover is mostly made up of grey sandy clay at the surface overlying heavy red clay.

Figure 4.3 is a simplified hydrogeological cross-section of the western side of Indigo Valley near Barnawartha South, as viewed from the south. It portrays the current understanding (based on very limited information) of salinity processes in this area. Series of arrows define recharge and discharge areas within the hillslope environment and groundwater movement.

Figure 4.3: Conceptual model for the development of dryland salinity on the western side of the Indigo Valley, Barnawartha South



Main aquifers are in the fractured metamorphic bedrock and overlying colluvium.

Replacement of native vegetation with shallow-rooted pastures has resulted in increased groundwater recharge on the crests and slopes of the hills. This is likely to have led to significant rises in groundwater levels within both the fractured metamorphic bedrock and the overlying deposits. The metamorphic bedrock and the sandy clay layer shown in Figure 4.3 appear to be the two main aquifer systems and both are thought to be influencing salinity occurrence on the western slopes of Indigo Valley.

Observations to date reveal two distinct locations of discharge on the valley slope, one just below the major break of slope of the metamorphic hills, and the other on the lower parts of the slope (Figure 4.3). Three major groundwater flow cells are suggested to explain these occurrences.

The uppermost occurrence is most likely caused by a small groundwater flow cell generated by recharge on the metamorphic hills. Groundwater then moves via preferred pathways through bedrock fractures and finally discharge through a thin cover of sandy clay below the break of slope. The lower discharge is thought to be caused by a combination of two groundwater flow cells, a deep one within the fractured metamorphic rock aquifer and a shallow one within the grey sandy clay layer. A low permeability, heavy red clay layer limits groundwater flow between the two systems, especially where it is thick (see Figure 4.3).

Outcropping bedrock hills (e.g. Ironbark Hill) indicate that the metamorphic bedrock may be close to the surface at several locations lower down the valley slope (Figure 4.3). At these points, the heavy red clay layer would be thin or absent, and provide an opportunity for groundwater to leak upward under pressure from the bedrock, causing discharge in the lower slope locations.

This situation could be made worse by too much groundwater in the shallow sandy clay system. The underlying red clay would limit deep drainage to the bedrock and would cause groundwater to accumulate in the sandy clay layer. Groundwater also discharges in lower slope areas due probably to changes in topographic slope and increased clay content. There could also be some discharge of groundwater from the red clay where it thins out.

4.2.4 Development of dryland salinity in the Everton Upper area

Everton Upper is located in the eastern foothills of the Ovens Valley. Its geology is variable and salinity in the area is mostly associated with metamorphic and granitic rock landscapes. Both types of landscape are present at the Everton Upper school site (discussed below) and both are believed to have some influence on the salinity discharge at the site.

Figure 4.4 is a simplified hydrogeological cross-section of the saline discharge site near the old Everton Upper school, as viewed from the east. It broadly portrays the conceptual salinity processes, but is based on only limited information. Series of arrows define recharge and discharge areas, as well as groundwater movement.

Replacement of native vegetation with shallow-rooted pastures has resulted in increased groundwater recharge on the crests and mid-upper slopes of the hills. Over time, this has resulted in groundwater levels rising within both the fractured metamorphic bedrock and the colluvial (hillwash) deposits covering the metamorphic and granitic bedrocks.

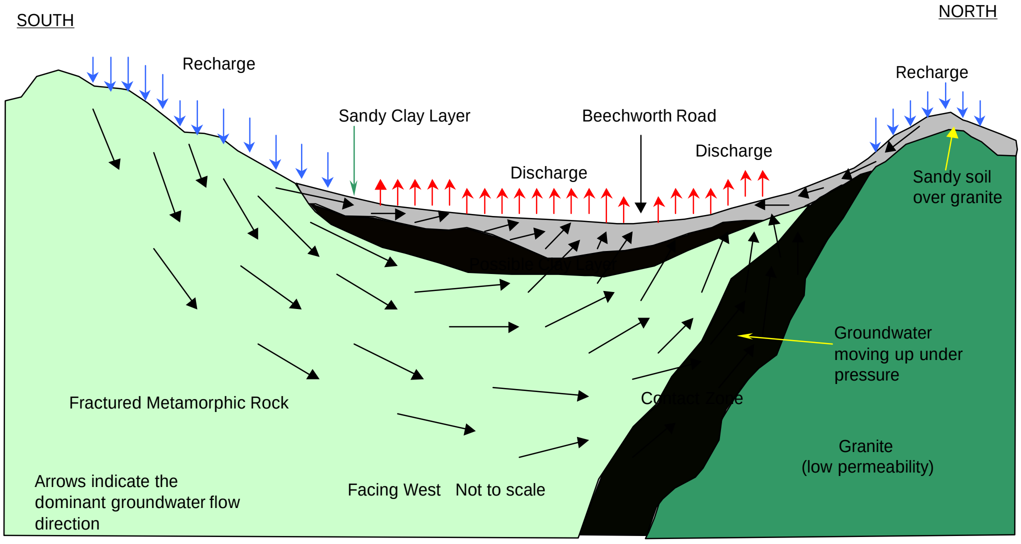
Recharge to the fractured rock system is the main driver of salinity processes.

The larger, predominantly cleared hills to the south are composed of fractured metamorphic rocks including slates, quartzites and hornfels. Most of the recharge and groundwater flow is believed to be occurring in this fractured rock system (Figure 4.4). This system is therefore regarded as the main “driver” of the salinity process. However, other hydrogeological factors are also believed to have a significant influence on the location and severity of the discharge.

Granite restricts flow out of the area and contributes to groundwater discharge.

The fresh granite bedrock in the north (i.e. right hand side of Figure 4.4) plays a significant role in restricting groundwater flow out of the sub-catchment. With its sparse fracturing and very low permeability it forms a substantial barrier to groundwater flow. Groundwater in the metamorphic rock is forced upwards under pressure so that it slowly leaks through the overlying weathered material to the surface.

Figure 4.4: Conceptual model for the development of dryland salinity at Everton Upper



Some recharge is also interpreted to occur in the upper reaches of the sandy clay layer shown on the lower slopes of the metamorphic hills in Figure 4.4. This would contribute additional groundwater flows towards the discharge area. The lower slopes seem to be subject to considerable waterlogging which is possibly made worse by high groundwater pressures in the underlying metamorphic rock and poor surface drainage.

Weathering has formed thin sandy soils over the granite. These soils are likely to rapidly fill with water in wetter years and are believed to be contributing

Geology and topography contribute to poor drainage from the area – this has resulted in the catchment filling with water.

additional flows towards the discharge area. The topography of the area around the Everton Upper school also increases the salinity risk. The broad, flat nature of the discharge area and lack of a well-defined drainage line and contribute to poor surface drainage may all exacerbate the salinity risk.

Increased recharge in the crests and mid-upper slope areas surrounding the Everton Upper School site has contributed significantly to the raised groundwater levels. However, the geology and topography appear to combine to help trap groundwater at this particular site, thus accentuating the overall groundwater rise. The site could be regarded as a small, closed catchment, somewhat like a "bath tub" that has filled with water that cannot drain away. This would help to explain why the discharge site has expanded so dramatically in the last twenty years as well as the site's continued expansion in the recent dry years.

4.2.5 Development of dryland salinity in the Rutherglen area

Tertiary sands overlying bedrock appear to be main aquifer.

The Rutherglen area is characterised by low, rounded hills that form the northern limit of the Ovens Valley foothills. The Ovens Riverine Plain lies to the south and the Murray Riverine Plain to the north and west. The hills are predominantly mapped as Ordovician age sedimentary rock, comprised of sandstone, siltstone and mudstone. While this probably forms the bedrock underlying all these hills, a recent field inspection suggests that most could be covered by at least a thin layer of Tertiary age sand, gravel and clay deposits (of which there are only minor indications on the Wangaratta Geology map sheet). A further, more detailed survey of this area and interpretation of borehole data will be required to verify this observation.

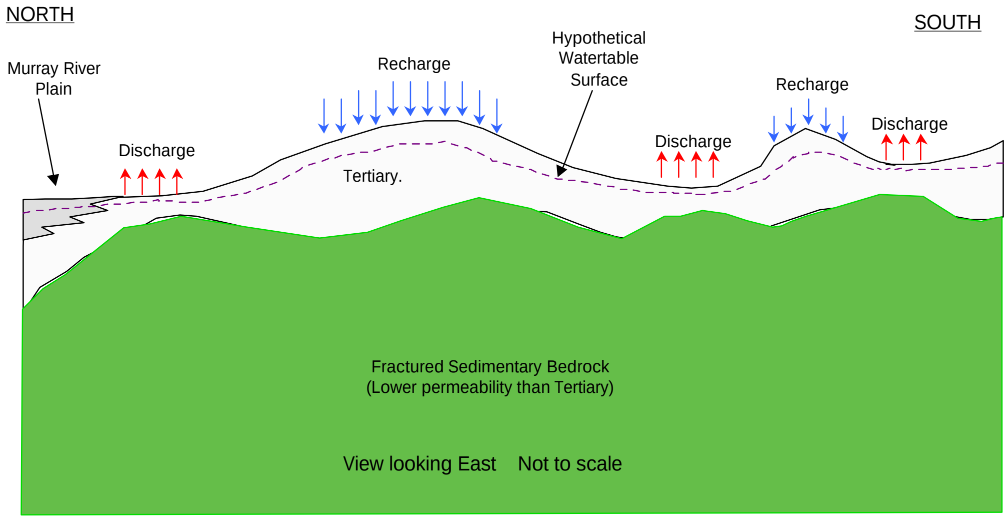
Most recorded salinity in the Rutherglen area occurs on the outer edges of the hills at their junction with the Riverine Plains, with some additional outbreaks along breaks of slope and depressions within the hills.

The recently identified Tertiary deposits are thought to form the primary aquifer implicated with saline discharge at Rutherglen. The soil cover on the hills appears to be mostly of light texture and is likely to permit high rates of recharge into the Tertiary layer.

The underlying sedimentary bedrock is regarded as being of lower permeability than the Tertiary layer and thus would limit the deep drainage. Groundwater would therefore tend to build up more quickly in the Tertiary layer than in the underlying rock. The bedrock could be a controlling factor in the occurrence of discharge but its nature and significance are unknown.

Figure 4.5 presents a hypothetical picture of the salinity process in the Rutherglen hills, but is based on limited information. It is a very simplified hydrogeological cross-section of the hills as viewed from the west. Series of arrows define recharge and discharge areas, and a hypothetical watertable surface is shown. Replacement of native vegetation with shallow-rooted crops and pastures is believed to have resulted in increased groundwater recharge on the crests and slopes of the hills, leading ultimately to elevated groundwater levels within the Tertiary sediments and, perhaps to a lesser extent, the underlying sedimentary bedrock. The raised levels of groundwater have resulted in saline discharge at breaks of slope and depressions, particularly at the junction of the hills and the Murray Riverine Plain.

Figure 4.5: Conceptual model for the development of dryland salinity in the Rutherglen area



5. Vegetation and the Water Balance

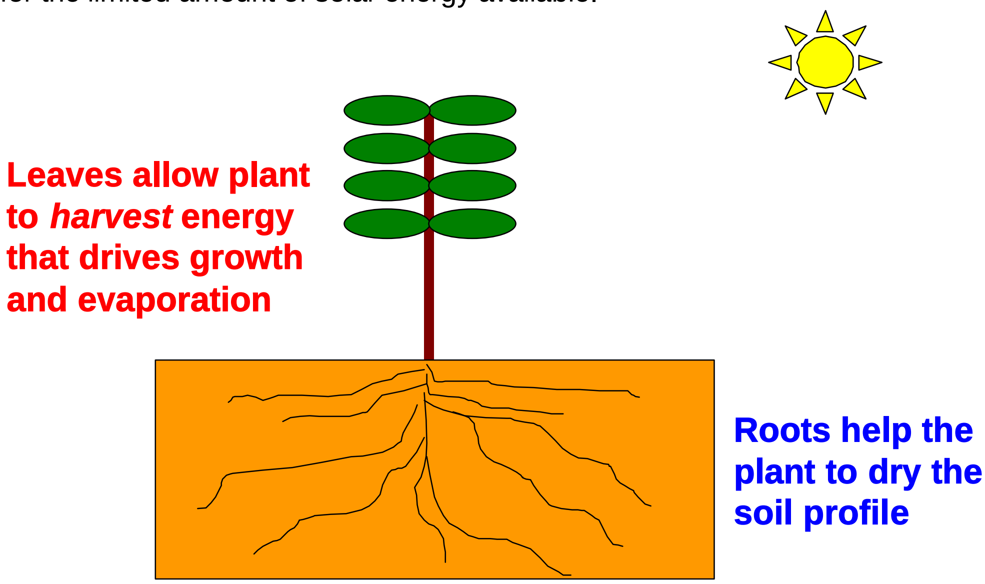
Use of water by vegetation has a major influence on the water balance of landscapes.

Evaporation is generally the largest component of the water balance after rainfall. Plant water use, in turn, would be expected to account for most evaporation from the agricultural landscapes of north-east Victoria. Vegetation therefore has a major influence on the water balance of landscapes.

While there are many factors that determine the rate at which plants *transpire* or use water, the availability of energy and water are the most important.

To use water plants need leaves to harvest energy for evaporation and roots to capture water from the soil profile.

Evaporation is a physical process that is largely driven by the amount of *solar energy* (sunlight) intercepted by the leaves of plants. For a given level of solar energy, the rate of plant water use will increase as the amount of foliage a plant supports (the *leaf area*) or the amount of leaf cover in a paddock, forest or plantation increases (called the *leaf area index – LAI*, the area of leaf per unit ground area). The rate at which plant water use increases with additional leaf area slows as further leaf is added, as the leaves increasingly compete for the limited amount of solar energy available.



Growth and water use increase with leaf area.

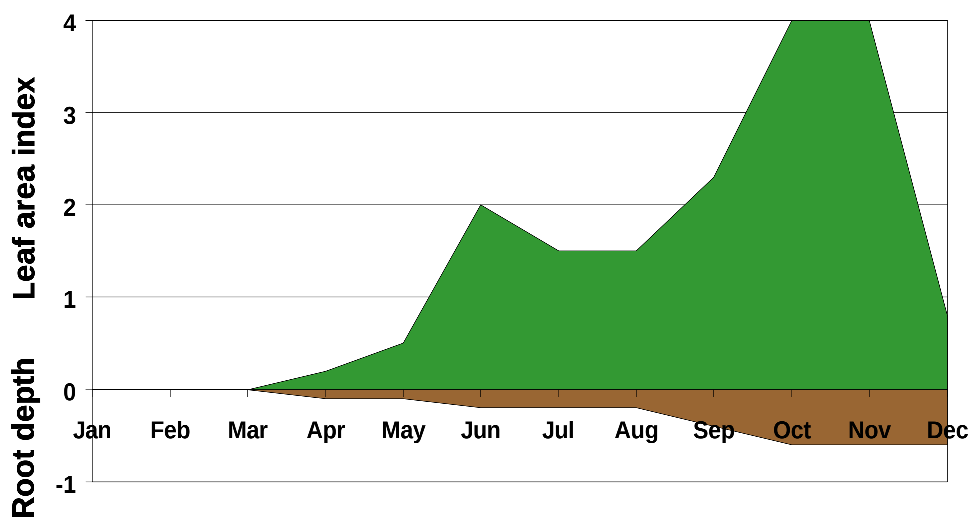
The growth rate of plants follows a similar pattern, since it too is driven by energy from the sun. Both growth and water use increase with leaf area to the point at which most of the solar energy is intercepted by plants. Leaf area may accumulate beyond this level, however it adds little to either production or water use. Most pasture plants periodically require light to reach their crown in order that tiller development be stimulated and longer term growth (and water use) be maximised.

If there is energy available to drive the plant water use process and leaves present to harvest that energy, the major factor that will then limit the rate of evaporation will be the availability of water. Availability of water is influenced by climate and weather and the nature of the soils, as discussed previously (section 3.2). However availability of water to the plant is also influenced by its root system. The depth and extent of the plant root system will determine its capacity to exploit the available soil water. Soils permitting, plants with deeper root systems will have access to more soil water and be able to sustain greater rates of evaporation during the drier months of the year. By emptying the soil profile of water to a greater depth at this time of year, deep-rooted vegetation will reduce the risk of excess winter rainfall leaking to the water table.

Timing of growing season important - maximum water use depends on plants taking advantage of summer rainfall and greater potential for evaporation during summer.

As with most elements of the water balance there is a time dimension that must be considered. The timing and length of the *growing season* of agricultural plants (particularly) may strongly influence their potential for water use. Annual pastures and crops may accumulate relatively high levels of leaf area, but this is typically concentrated in late winter and spring, when evaporative potential is relatively low (see Figure 5.1). The plants die and support no green leaf cover during summer and early autumn, when potential evaporation is greatest. Although they can empty the upper part of the soil profile of water during the latter part of their growing season, they are unable to stop summer and early autumn rains from refilling it.

Figure 5.1: Representation of seasonal growth pattern of annual pastures



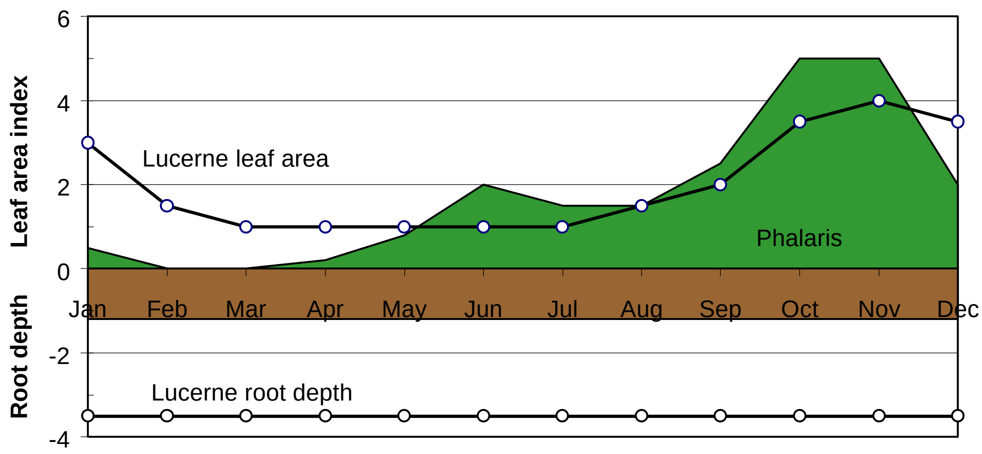
Typical monthly average values of leaf area index (shaded green) and root depth (in metres, shaded brown) for annual pasture. The growth pattern of an annual winter crop would be similar, although there would be less leaf in autumn, possibly more leaf and greater root depth in spring.

Growing more vigorous pastures and crops can increase leaf area, but only during winter and spring, when potential evaporation is generally low. This may increase annual water use, but only by a relatively small amount.

Crops may develop deeper root systems than annual pastures, however there is little evidence that they use more water than annual pastures

The longer growing season of perennial pastures (e.g. lucerne, phalaris) is one reason why they have greater capacity for water use than annual pastures. Lucerne, in particular, is active through summer and can support relatively high levels of leaf area during the time of year when evaporative potential is greatest (Figure 5.2). Their very deep root systems (on suitable soils) help to supply lucerne pastures with water for evaporation over the summer months and may result in the soil profile being emptied of water to a depth of several metres. This provides an important buffer against excess winter rainfall in the following season.

Figure 5.2: Representation of seasonal growth patterns of lucerne and phalaris pastures



Typical monthly average values of leaf area index and root depth (m) for phalaris and lucerne pastures. Values for phalaris are shown by the green and brown shadings on the graph. Those for lucerne are indicated by the line graph. Being summer active, lucerne generally supports less leaf than phalaris pastures during winter, but more during the warmer summer months. The winter active phalaris pastures support more leaf during winter and spring, but are largely dormant during summer. If the soils allow, the roots of lucerne plants may extend to several metres depth, unlike those of phalaris, which extend only to 1-2 m.

Phalaris pastures generally have a longer growing season than annual pastures. However, being summer dormant means that they support little green leaf during summer and autumn. They are relatively effective at emptying the soil profile of water over their root zone, however dormancy may not allow them to re-empty the soil after heavy summer rains. Their shallower root systems (on some soils) also mean that they may not empty the soil profile of water to the same depth, nor provide the same level of protection from leakage during winter as lucerne pastures.

Long-term effect of vegetation on the water balance depends on persistence of perennial species.

The long term effect of vegetation on the water balance is also influenced by the longevity or persistence of the perennial component. This is true for perennial pastures as well as trees. Factors that influence persistence include:

- *soil conditions* – soil acidity and aluminium concentration, for example, are known to strongly influence persistence of perennial pastures such as phalaris and lucerne. Soil acidity is increasingly being recognised as a constraint on pasture production and/or persistence throughout north-east Victoria;

- *climate and weather condition* – extremes of temperature (particularly frost) and lack of water under drought conditions are major factors influencing the suitability of a site to particular types of vegetation. Species need to be matched with both averages and extremes of temperature and rainfall. Trees (for example) that are not well suited to their environment are more prone to disease or insect attack;

- *management and grazing* – grazing can impose stress on pastures. Its management can influence the survival of perennial species, especially when they are under stress from other factors, such as soil acidity or water-logging. Perennials such as phalaris and lucerne appear to favour rotational or strategic grazing, in which the pasture is periodically rested from grazing, to continuous grazing or set stocking.

  Management can be an important factor in ensuring the long-term survival and effectiveness of trees and native vegetation in reducing groundwater recharge. Inclusion of appropriate native shrubs, which provide habitat for insectivorous birds, may help to reduce insect damage and mistletoe in planted trees. While grazing may be compatible with some forms of farm forestry and revegetation, it must be carefully managed to ensure that stock do not ringbark the trees or trample their shallow roots.

6. Managing Dryland Salinity

6.1 Approaches to salinity management

Much of the early activity under the Victorian Salinity Program was directed at the *control* of dryland salinity. Experience from North America and some promising demonstration sites in north-central Victoria gave rise to considerable optimism that the control of salinity and ultimate rehabilitation of saline land was generally feasible. As the Program developed, it was increasingly apparent that while *control* of salinity was possible in specific locations, this was not generally the case in higher rainfall areas if most of the land was to be maintained under agricultural use. Strategies such as the North-East Salinity Strategy now seek to *manage* dryland salinity. They recognise that with continuing agricultural land use and the finite resources available for salinity management programs, some level of land and water salinisation is likely to continue.

Figure 6.1: Potential outcomes of no intervention, control and management approaches to dryland salinity

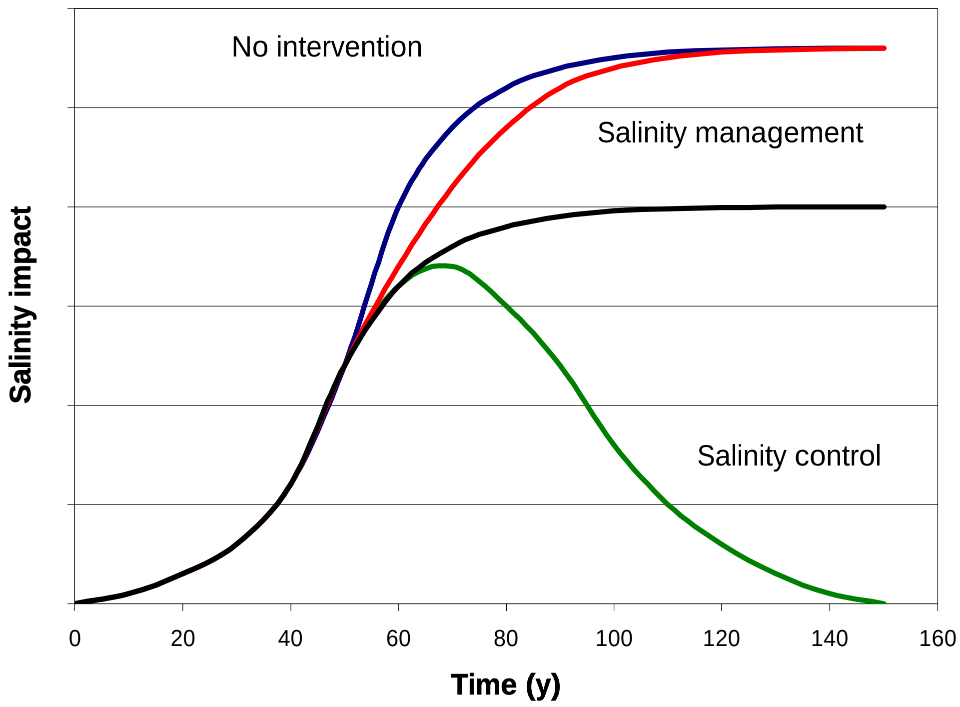


Figure 6.1 illustrates the hypothetical outcomes of management and control approaches to the management of dryland salinity. The blue line illustrates the progression of salinity impact over time if no attempt was made to either control or manage it. It shows that at some future point a new hydrologic equilibrium would be established such that there was no further increase in salinity impact.

The green line indicates the outcome of an effective salinity control process that was implemented after about 50 years. Salinity might worsen initially, but ultimately the trend of worsening salinity impact would be reversed. The rate of improvement in salinity impact might be expected to slow as increasingly large resources were required to address the more intractable salinity problems.

The red and black lines illustrate the impact of salinity management. Depending on the nature of the salinity processes and level of resources allocated to the issue, salinity management may either delay the realisation of the full impact or achieve a new hydrologic equilibrium with lower impact than would be the case without intervention. There is concern expressed in Western Australia that implementation of their Salinity Action Plan may only delay the time before the no intervention level of salinity impact is realised.

Broad approaches to salinity management.

Four broad approaches to the management of dryland salinity are outlined below:

- *Recharge reduction* - in common with other strategies, the North-East Salinity Strategy is largely based on attempting to reduce the leakiness of landscapes. Landholders are encouraged to establish trees, shrubs or perennial pastures to increase water use and empty soil profiles of water so that groundwater recharge is reduced. Implementation programs are often concentrated on what are thought to be the leakiest parts of the landscape.

  In Western Australia, farmers are increasingly turning to engineering measures to reduce recharge across their properties. Surface and sub-surface drains are constructed to channel water into streams and drainage lines, effectively increasing the run-off component of the water balance. If the drainage system is well designed and constructed they may achieve the double benefit of eliminating water-logging and reducing its impact on crop yields and groundwater recharge.

- *Enhancing groundwater discharge* – groundwater pumps are one means by which groundwater can be artificially discharged to the surface and the water table lowered. These measures may have application in parts of north-east Victoria and the Salinity Strategy recommends that they be investigated. A major issue with groundwater pumping is the disposal of groundwater. Where fresh, it should be used to irrigate pasture, trees or even horticultural crops. More saline groundwater could be used to operate a saline aquaculture enterprise. Off-site disposal of saline groundwater is unlikely to be authorised.

  Groundwater pumping and any off-site disposal of effluent to streams would need to be authorised by Goulburn-Murray Water. The Environment Protection Authority might also need to be consulted.

In some settings in the landscape, it may be possible to use trees to enhance the discharge of groundwater. Plantations may be established in areas where the water table is relatively shallow (within 2-5 m of the surface) and *fresh*. As the tree root systems develop they may take up (*discharge*) the groundwater and lower water tables. This was the principle behind the development of break of slope forestry in the Warrenbayne area, south of Benalla.

- *Saline agriculture* – this approach recognises that salt-affected land will remain (at least for some time) a feature of some environments. It attempts to return that land to a productive use. Establishment of salt tolerant pastures in groundwater discharge areas has been successful in many areas. Species such as tall wheatgrass and *Puccinellia*, possibly in combination with more salt-tolerant clovers (e.g. balansa, strawberry) may be successfully used. Trials in south-west Victoria have shown an increase in stocking rate on salt-affected land from less than 1 dse/ha to as much as 8-10 dse/ha with a tall wheatgrass – balansa clover pasture. A dense pasture cover also reduces the risk of erosion and may help to prevent the accumulation of salt at the soil surface.

Doing nothing about salinity may result in a 20-30 fold increase in the area of land affected over the next 50 years.

- *Do nothing* – doing nothing is one possible response to dryland salinity. It may be a reasonable response where the cost of controlling or managing salinity is high and the benefits modest. However, as a general rule it is a risky strategy. Doing nothing is likely to result in an on-going expansion in the area of salt-affected land and a decline in water quality and aquatic habitats. It also means that water that might otherwise be used productively by trees or perennial pastures is being wasted.

6.2 Managing salinity across catchments

Salinity management in priority areas needs to address the whole landscape, including land with high, moderate and low recharge potential.

It is important to understand the scale at which dryland salinity processes operate and at which land management must change if the impacts of salinity are to be minimised. Dividing the land into units of high, moderate and low potential recharge is a useful step in setting priorities for on-ground works. However, in doing so there is a risk that some might mistakenly think that the contribution of land with moderate and low potential recharge to dryland salinity process can effectively be ignored.

Table 6.1 provides hypothetical examples which demonstrate that land of relatively low potential recharge rate can be very important in the management of salinity within some catchments. Relative contributions to overall recharge of several catchments with various arrangements of low, moderate and high recharge rates have been calculated.

As the proportion of “high recharge” land falls from an unrealistic 50% (catchment 1) to 5% (catchment 4), the area of “low” recharge land rises accordingly. At the same time, the relative contribution of the moderate and low recharge land also increases from 9% for catchment 1 to 56% in catchment 4 (75% low recharge). Ignoring the need to reduce the leakiness of the low recharge zone would mean that 56% of catchment recharge (in catchment 4) would remain, even if land management had changed and been effective in preventing recharge from the entire high and moderate recharge zone.

Table 6.1: Managing salinity in catchments: an illustration of the potential importance of land with low recharge rates.

	Average recharge rate	High (100 mm/y)	Moderate (50 mm/y)	Low (25 mm/y)	Catchment Recharge
1	% catchment area	50%	25%	25%	69 mm/y
	% catchment recharge in each land unit	73%	18%	9%	
2	% catchment area	25%	25%	50%	50 mm/y
	% catchment recharge in each land unit	50%	25%	25%	
3	% catchment area	10%	30%	60%	40 mm/y
	% catchment recharge in each land unit	25%	38%	38%	
4	% catchment area	5%	20%	75%	34 mm/y
	% catchment recharge in each land unit	15%	30%	56%	

The table illustrates the potential importance of managing recharge across entire catchments and not just focusing on "high" recharge areas. Four hypothetical catchments are described, with increasing proportions of "low" recharge land. In catchment 4, where 75% of the catchment is classified "low" recharge and just 5% "high" recharge, 56% of total catchment recharge would be derived from low recharge land. Unless this land *and areas of high and moderate recharge* are managed effectively to reduce leakage to the water table, rising groundwater and dryland salinity will remain a problem.

The diversity of landscapes in north-east Victoria means that there is no "magic bullet" for salinity management - a range of salinity management options will be required.

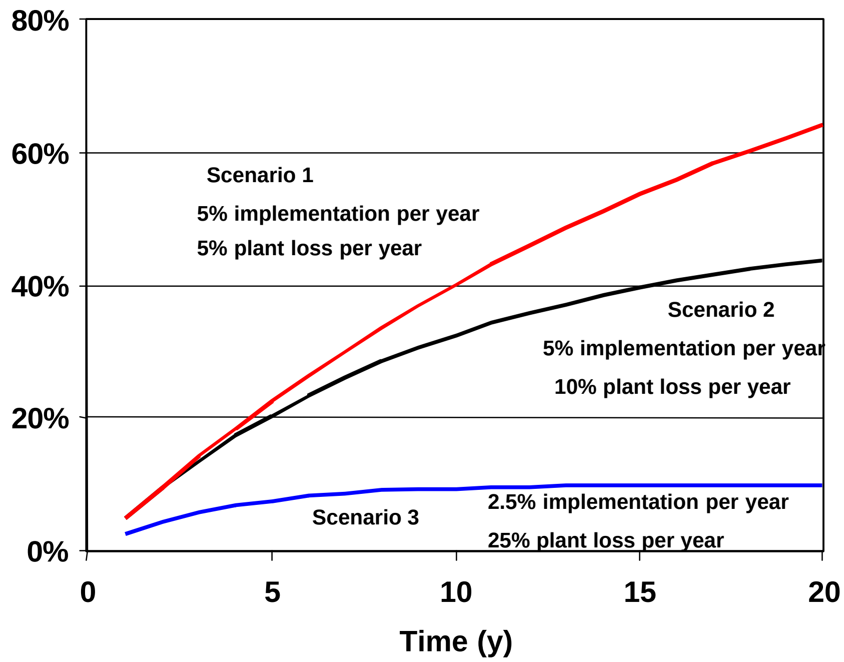
If the management of whole or large parts of catchments must be changed to reduce the risk of dryland salinity, then it will be necessary to identify vegetation systems that suit the range of catchment conditions likely to be encountered. These systems will need to be capable of persisting under the range of soil and climate conditions encountered, be at least partly compatible with existing farming systems and be effective in containing leakage from the particular parts of the landscape where they are established. It is most unlikely that there will be a single "magic bullet" or panacea that may be applied equally effectively across the landscape. Salinity management in the catchments of north-east Victoria require a range of treatments, integrating various species of trees and perennial pastures, according to the nature of the land, the farming enterprise and the dryland salinity processes.

Effective management of salinity in catchments requires persistent perennial vegetation and broad landholder participation.

Figure 6.2 provides a further illustration of the importance of managing salinity processes across catchments with vegetation systems that will be readily adopted by landholders, be effective in reducing recharge and will persist in the long-term. The changing level of catchment impact ("% catchment effectively treated") is plotted for three implementation scenarios:

- *Scenario 1* - program of implementation of best management for salinity that will see the whole catchment treated in 20 years (i.e. 5% implementation per year) and with a 5% p.a. decline in perennial plant numbers each year;
- *Scenario 2* - 5% p.a. implementation program with 10% decline of plant numbers per year;
- *Scenario 3* - program of implementation in which only 50% of landholders participate (2.5% implementation per year),with 25% p.a. decline in plant numbers.

Figure 6.2: Managing salinity in catchments: an illustration of the impact of low adoption and poor persistence of perennial vegetation on effectiveness of "treatment"



This graph assumes that treatments are fully effective in the year in which they are implemented and that effectiveness declines in proportion to plant loss. In reality treatments (particularly involving trees) may take several years to be fully effective, but may be able to absorb the impact of some level of plant loss.

Full participation by landholders and persistent perennials are required for effective salinity management across catchments.

Figure 6.2 highlights that even with full participation by landholders across a catchment in implementing best management for dryland salinity, only about 65% of the catchment would be effectively treated if 5% of the perennial plants were lost per year (scenario 1). The comparable figure for scenario 2, where the rate of perennial plant loss was 10%, would be for less than 50% of the catchment to be effectively treated. If only half of the landholders participated in implementation of salinity management and in which the loss rates were 25% (scenario 3), only 10% of the catchment would be effectively treated at the end of the 20 years.

Effective management of salinity across catchments requires close to full participation by landholders of vegetation systems that will persist for the long-term. Decline in the populations and effectiveness of perennial plants at even low rates over the implementation period threatens the overall effectiveness of catchment management programs.

6.3 Pastures for recharge area management

Most agricultural land use across north-east Victoria is based on grazed pastures. This is likely to continue for the foreseeable future, even with the likely expansion of plantation forestry and horticulture in the region. Effective management of dryland salinity across the region's catchments is likely to continue to depend, in large measure, on the nature and management of its pastures. Broad-scale establishment and effective management of perennial pastures is required across the region, although by itself this measure is unlikely to be sufficient to fully contain dryland salinity.

The effectiveness of pastures in salinity management varies with environmental conditions, the species used and their management.

The effectiveness of pastures in the management of dryland salinity is influenced by the environment in which they grow (climate, soil conditions, aspect and slope), as was discussed in section 3.2. It also varies between species and with management. Together, these factors determine the availability (or excess) of water, the amount of leaf present for water use and how this changes over the growing season, the relative abundance of perennials and annuals in the pasture, rooting depth and long-term persistence of the perennial species. The influence of these factors is discussed briefly below.

Effectiveness of perennial pastures in preventing water from leaking to the water table declines with increasing rainfall once average rainfall exceeds about 600 mm/y.

- *Climate and weather* – the effectiveness of any vegetation system in dryland salinity management will vary with climate. As discussed in section 3.2, the risk of any soil profile filling and leaking to the water table increases with rainfall. The point at which leakage commences varies according to the capacity of the pasture to empty the soil profile and the rate at which it is filled by excess rainfall during winter. A range of studies have suggested that the capacity of perennial pastures to contain leakage or water table recharge progressively diminishes once average annual rainfall exceeds approximately 600 mm. However, there is no single *point* at which pastures become ineffective in salinity management. Rather, there is a progressive decline in effectiveness as rainfall increases.

Soil type influences water availability to plants, recharge risk and plant root development.

- *Soils* – soil type influences both the availability of water to plants and the tendency for it to leak to the water table. Factors such as structure, texture, depth and rockiness determine the capacity of the soil profile to store water. The availability of water to the plant (the *effective soil water storage capacity*) depends on these factors as well as those, such as soil acidity or sodicity, which have potential to impede root growth and development. The risk of recharge will be greater where effective storage capacity is low. Low effective storage capacity places plants at greater risk from drought and can, in the long-term, be implicated in poor persistence with perennial pastures.

- *Species* - perennial pasture species vary considerably in their suitability for the landscapes of north-east Victoria and in their likely effectiveness in salinity management. Key requirements for an effective pasture species are:

Effective pastures require deep root systems, summer activity, acid soil and grazing tolerance

  - capacity to develop a deep root system – to maximise the depth to which the soil profile can be emptied of water and to aid in survival of summer droughts;
  - growing season that extends into summer – to ensure plant water use takes place during the time of year when potential evaporation is high and that summer and early autumn rains are used productively rather than allowing the soil profile to refill before the autumn break;
  - tolerance of the highly acid soils that are common across north-east Victoria;
  - persistence and productivity under grazing - to ensure that the pastures are a viable and long-term option for land managers.

  Unfortunately there is not a wide range of suitable species, with few satisfying each of the above criteria. The strengths and weaknesses of the main pasture species that have potential to play a role in recharge area management are listed in Table 6.2.

Pasture management influences the composition, persistence, growing season leaf area and rooting depth of pastures ... all impact on the water balance.

- *Management* – pasture and grazing management have potential to influence perennial pasture composition, persistence, growing season length, leaf area and root depth – all of which may, in turn, influence the water balance. Implications of each of these factors is discussed briefly below.

  - composition – studies with phalaris have shown that continuous grazing favours annual grasses in a mixed pasture at the expense of the perennial, whereas rotational (or strategic or tactical grazing) tends to favour the perennials and result in a greater drying of soil profiles during spring and summer;

Evaluation of pasture species for salinity management.

Table 6.2: Strengths and weaknesses of main pasture species with potential for use in salinity management in north-east Victoria

Pasture species/type	Strengths	Weaknesses
Lucerne	▪ deep root system ▪ summer growing season – response to summer rainfall ▪ highly productive on good sites, palatable fodder ▪ high water use	▪ susceptible to acid soils, particularly those with greater acidity and aluminium in the sub-soil ▪ susceptible to water-logging ▪ long-term persistence depends on pastures being rotationally grazed
Phalaris	▪ moderately deep root system ▪ growing season may extend into summer under appropriate management ▪ highly productive on good sites, palatable fodder ▪ moderate to high water use, reduces run-off ▪ tolerant of broader range of grazing management than lucerne	▪ susceptible to acid soils, particularly those with greater acidity and aluminium in the sub-soil ▪ summer dormant and largely unresponsive to summer rainfall – reduces summer water use ▪ susceptible to drought, particularly on acid soils
Cocksfoot	▪ acid soil tolerant ▪ moderate water use ▪ moderately productive pasture ▪ responsive to summer rainfall, remains green through summer if water available	▪ more susceptible to drought than phalaris ▪ intolerant of heavy summer grazing
Native grasses	▪ already present in many hill country pastures and have shown to be persistent under grazing ▪ many species respond positively to grazing and modest levels of fertiliser (e.g. Weeping Grass, Wallaby Grass) ▪ drought and acid soil tolerant ▪ moderate water use ▪ moderately deep rooted ▪ many species summer active and/or utilise summer rainfall (e.g. Weeping Grass, Red Grass, Kangaroo Grass)	▪ some species relatively unproductive or not persistent under grazing ▪ limited information on establishment for many species ▪ little seed available at realistic prices for broad acre establishment
Consol lovegrass	▪ highly drought and acid soil tolerant ▪ summer active – when water availability permits, produces relatively large amounts of green feed during summer ▪ relatively deep rooted ▪ moderate to high water use ▪ flexible grazing management	▪ not permitted for use in Victoria due to wild form (African lovegrass) being a declared weed

- persistence –lucerne will generally only persist if rotationally grazed. Although phalaris is more tolerant of continuous grazing, its persistence can be jeopardised by regular close grazing. Soil acidity is a major challenge to the persistence of many pasture species, particularly lucerne and phalaris;
- growing season length – continuous heavy grazing of phalaris pastures can effectively cut its growing season length to that of an annual pasture. Once annuals die off in a mixed pasture, stock selectively

Grazing management for persistence, production and water use by perennial pastures are based on the same principles ... effective pasture utilisation and periodic resting from grazing.

graze the green shoots produced by the phalaris plants. Since they are continuously exposed to grazing pressure, these shoots are unable to develop and accumulate an effective level of leaf area;

- leaf area – grazing results in the removal of leaves, the main plant organ responsible for water use. Heavier grazing can result in lower levels of leaf area accumulating and reduced water use. In the short term, spelled pastures have greater rates of water use than heavily grazed pastures, as they support more leaf. In the long-term ungrazed pastures become rank and unproductive and may not support any more green leaf than grazed pastures. In most species tiller development is stimulated by grazing that exposes the crown of the pasture plant to light. Rotational grazing, in which there are cycles of spelling to accumulate leaf area and cycles of grazing to encourage tiller development (and allow productive use of the pasture), appear to provide a satisfactory compromise between long-term water use and production;
- root depth – continuously and heavily grazed pastures tend to accumulate little leaf and have similarly restricted root systems. This will reduce opportunities for the plant to empty deeper parts of the soil profile of water.

Most landscapes in north-east Victoria are likely to remain somewhat leaky, even with good quality perennial pastures.

There has been considerable research into the use of perennial pastures in the management of dryland salinity. There are several examples in Victoria of water tables falling following the establishment of lucerne pastures (see Figure 6.7), but fewer examples of similar responses to the establishment of phalaris pastures. Most reports of water tables falling in response to perennial pasture establishment are from areas receiving less than about 550 mm average annual rainfall. Landscapes in higher rainfall areas are likely to remain leaky, even with good quality perennial pastures.

Perennial pastures will play a role in the management of dryland salinity in the higher rainfall areas of north-east Victoria (i.e. land generally south and east of the Hume Freeway). Plant water use (evaporation) should be greater and recharge reduced, relative to annual pastures. It is expected that lucerne might be quite effective in containing water table recharge along the margins of the floodplain of the Ovens and King Rivers and the hills and flats of the Rutherglen area. Phalaris pastures (and most other perennial grasses) are unlikely to be as effective, either in these locations or in more hilly country. Integration of this type of pasture with trees will be required to provide an agricultural system that is more effective in reducing the risk of groundwater recharge and salinity.

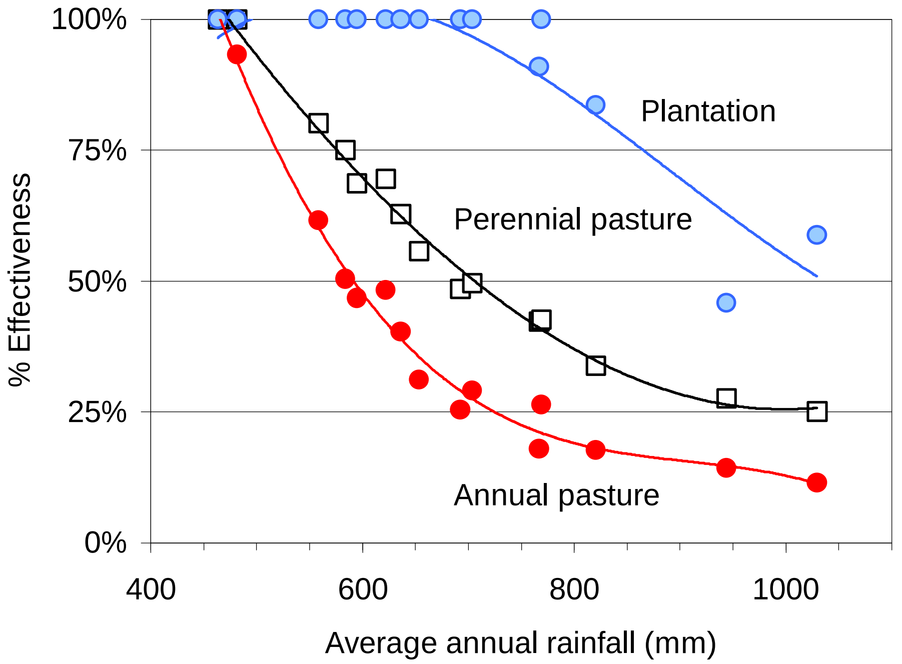
6.4 Trees and dryland salinity management

Retaining remnant native vegetation will assist in the management of dryland salinity.

There has always been a strong interest in the use of trees and revegetation in the management of dryland salinity. This is based on a belief that changing land use from pasture back to native vegetation in at least part of the catchment will reverse the changes in water balance that gave rise to dryland salinity. The North-East Salinity Strategy recognised the potential benefits of trees and native vegetation in the management of dryland salinity by recommending that existing remnant vegetation cover be retained and that landholders consider strategic revegetation (of high recharge areas and at breaks of slope in some landscapes) and farm forestry.

The effectiveness of trees in the management of dryland salinity is influenced by soils and climate in similar ways to pasture (see section 6.3). The capacity of trees to empty soil profiles of water and prevent leakage also declines as rainfall increases and soils become shallower and more freely drained. However, the decline in effectiveness with increasing rainfall occurs less rapidly and commences at higher average rainfall than for pasture (Figure 6.3).

Figure 6.3: Relative effectiveness of plantations and perennial and annual pastures in drying soil profiles with change in average annual rainfall.



Effectiveness of annual and perennial pasture and eucalypt plantations at emptying the soil profile of water declines with increasing annual rainfall. 100% effectiveness is achieved if vegetation was able to empty the soil profile sufficiently (on average) to store at least the average annual rainfall. High effectiveness of tree plantations was achieved up to 750 – 800 mm rainfall. Effectiveness of pastures declined rapidly with rainfall above about 500 mm. Data derived from water balance modelling for 15 locations throughout Victoria (Clifton and McGregor 2000).

Tree and plantation water use varies with species, age and density.

The water use by trees in forests and plantations might be expected to vary with the species of tree and the age and density of the stand. The influence of each factor is discussed briefly below.

- *Tree species* – there are several ways in which species can influence the water balance of forests and (particularly) plantations. For young plantations and those that are relatively widely spaced, water use by faster growing species that accumulate leaf more rapidly should be greater than for slower growing species. Species differences would be expected to decline as stands mature and begin to fully exploit the water available to them. Provided they are not out-competed, water uptake by slower growing species might be expected to eventually match that of faster growing species.

  The extent to which particular species are suited to the soils and climate conditions (e.g. frost, drought, soil type) of the site will influence their long-term survival and water balance. Planting fast growing species such as Blue Gum on marginal sites may be effective in quickly emptying soil profiles. However if the trees exhaust their water supply and die from drought stress after several years, their long-term effectiveness in salinity management will be low.

  Different kinds of trees (e.g. eucalypts – pines – deciduous oaks) might be expected to have a somewhat different water balance from each other. Pine plantations have been shown to dry out catchments relative to some native forests, however they are unlikely to be more effective in doing this than Blue Gum plantations, for example. There is little information on the water balance of deciduous trees. It is likely that the soil profile below deciduous trees would wet up rapidly during winter, since there would be no plant water use. Evaporation from the very dense canopy of some deciduous trees during summer may be greater than from eucalypts. The extent to which summer water use compensates for the lack of water uptake in winter will depend on the capacity of the soil profile to store the additional excess rainfall.

- *Age* – as with species, the main impact of age on the water balance of trees and plantations is expressed via the size of the tree. As trees age and grow they accumulate leaf and use more water. This pattern continues to the point where competition between trees for light, water, nutrients and/or space prevents further accumulation of leaf area. Older (native) forests may use less water than younger forests, because they have a lower density and lesser leaf area. However the individual trees in the older forest are likely to use much more water than the smaller trees in the younger forest.

- *Density* – the water use of both individual trees and a plantation or forest may vary with density. In a plantation or forest that is effectively water-limited, the water use by individual trees would be less with greater density, although over a broad range of densities the water use (and water balance) of the plantation as a whole would remain unchanged. Water use per tree by dense stands or plantations would be less than it would for less dense stands (see Figure 6.4).

Figure 6.4: Illustration of variation in water use per tree with stand density

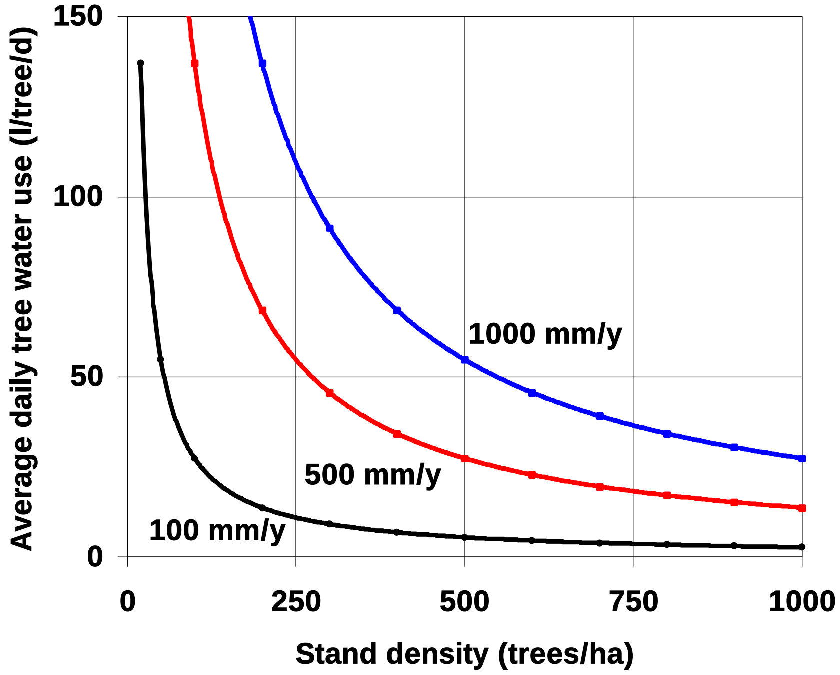


Figure 6.4 illustrates how the capacity of plantations or forests to achieve a given level of water use varies with stand density. If average water use per tree was 50 l/d, a stand of about 550 stems/ha could evaporate 1000 mm/y, whereas a stand of about 250 stems/ha could evaporate a little less than 500 mm/y. At very low stand densities (<50 trees/ha) individual tree water use would have to be quite high to achieve even 100 mm/y of evaporation. (55 l/d at 50 stems/ha; 137 l/d at 20 stems/ha). At 1000 stems/ha (a typical early plantation density), if average water use of individual trees was 27 l/d, overall plantation water use would be 1000 mm/y. A plantation of very small trees, which might evaporate about 3 l/d, would use about 100 mm/y of water, equivalent to a widely-spaced stand of large trees, each averaging 137 l/d of water use.

In plantations where water availability is not limiting, increasing stand density should be accompanied by increased overall water use. This condition occurs in young plantations before their canopies and/or root systems fully occupy their site. Water use by individual trees in this case is not limited by water availability, but by the size of the tree (the amount of leaf). Increasing the tree density would increase the overall water use of the plantation and reduce the time taken for it to fully exploit the site.

In the long-term, water use of plantations, like that of pastures, also depends on persistence. Maintaining tree and plantation health are essential for long-term impact on salinity processes. Species selection, management of adjoining paddocks, grazing of plantations and the presence and composition of any understorey all have potential to impact on the persistence of trees in farmland.

Table 6.3 provides a summary of some tree water use measurements undertaken in Victoria. It provides an indication of the range in water use that might be achieved by eucalypt trees in similar plantations in the North-East region in areas with 600-900 mm average annual rainfall. It also provides a reference to assess the feasibility of a plantation of given density and achieving a specific water use target.

Table 6.3: A summary of tree water use measurements in Victoria.

	Average (range) tree water use	Stand water use
Low density plantings and remnant vegetation:		
20 trees/ha – 7 year old		
20 trees/ha – 20 year old		
20 trees/ha - >100 years old	140 (10-450) l/tree/d	105 mm/y
Medium density salinity plantings:		
200 trees/ha – 6 year old	18 (2-100) l/tree/d	135 mm/y
Alley farming system - 20 year old	70 (10-200) l/tree/d	-
High density forest plantings		
1100 trees/ha – 3-5 years old	17 (2-80) l/tree/d	660 mm/y
950 trees/ha – 10 years old	32 (0-120) l/tree/d	1114 mm/y

Sources: Clifton *et al*. 1993; Clifton *et al.* 1997; Clifton and Miles 1998
NB – Stand water use not readily calculated for alley farming system.

Effectiveness of trees in the management of salinity also varies with the design and placement of plantations.

The effectiveness of tree plantations in the management of salinity may also be determined by the *design* of the plantation and its *placement* in the landscape. Tree growing for salinity management has traditionally concentrated on the most leaky parts of the landscape (areas of high potential recharge). This was based on the understanding that by planting these strategic, but relatively restricted areas out to trees, a relatively large impact on total landscape recharge could be achieved (see Table 6.1).

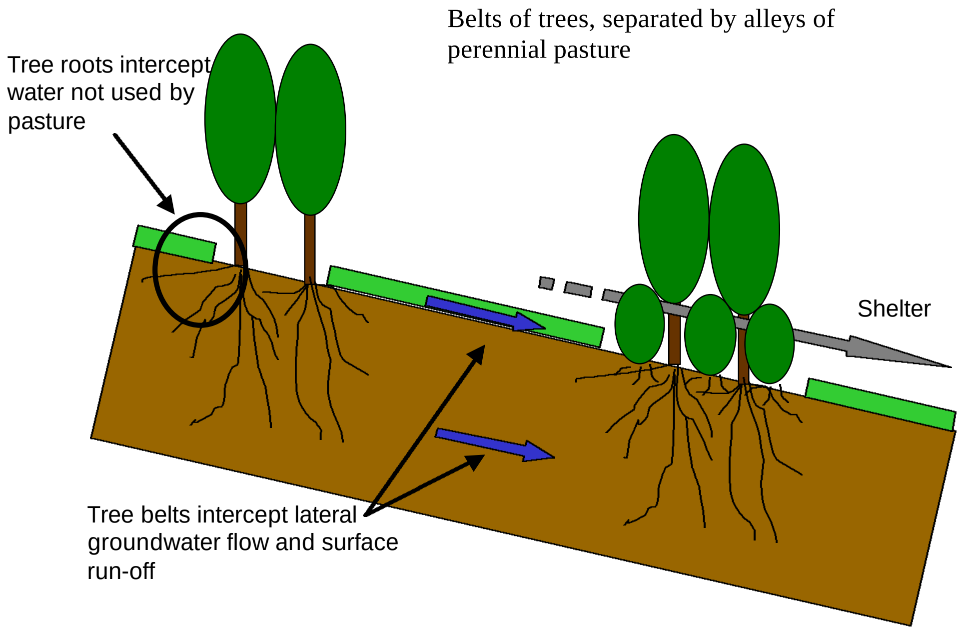
There are a range of tree growing options that have been used in the management of dryland salinity. These have been briefly described and assessed in Table 6.4. The most suitable options for the north-east region are alley farming, interception plantings (which are similar to alley farming) and traditional recharge area plantings. The concepts of alley farming and interception plantings are also illustrated in Figure 6.5 and Figure 6.6.

Table 6.4: Strengths and weaknesses of major tree growing designs used in salinity management

	Strengths	Weaknesses
Alley farming system – *narrow (2-5 row) belts of trees established either across the slope or in a north-south direction. Trees closely spaced within belts and may include shelter and timber trees. Belts of trees separated by alleys up to 50 m wide.*	▪ Design maximises opportunity for trees to intercept water that is not used by pastures in alleys. ▪ Use of water from adjacent pasture alleys can supplement that available from rainfall and increase growth rate. ▪ With good fencing layout, provides opportunity to closely control grazing to maximise productivity of improved pastures. ▪ Provides additional shelter and environmental benefits, if belts incorporate low growing shrubs as well as trees.	▪ Expensive to fence by conventional means. ▪ Maximises competition between trees and adjacent pasture and may result in reduced yields due to both shading and lack of water. ▪ Narrow belts may require more intensive management for production of high quality timber. ▪ Little local experience with alley farming. ▪ Trees occupy land suited to pasture.
Interception plantings – *belts of trees established along breaks of slope between steep hills and mid slopes and potentially at other locations where there is a noticeable change in slope. Belts may be 5-10 or more rows wide and are likely to be planted at densities of 1000 trees/ha or more.*	▪ Break of slope is an area of the landscape where water accumulates. Trees planted here can dispose of this water before it contributes to salinity or other forms of land degradation further downslope. Tree belts can reduce recharge and may directly extract groundwater. ▪ Can provide additional shelter benefits for stock. ▪ Water from further upslope effectively increases rainfall and may boost tree growth. ▪ Location will generally be consistent with land class fencing. Subdivisions may help to gain improved control over grazing.	▪ Multiple tree belts may be difficult and expensive to fence by conventional means. ▪ Competition for water and/or light adjacent to tree belts. ▪ Trees occupy land suited to pasture.
High recharge area plantings – *blocks or belts of trees established at moderate densities 200-500 trees/ha) on land of high potential recharge*	▪ Tree growing concentrated on leakiest parts of landscape and so proportional reduction in catchment recharge may be greater than area planted. ▪ Once well established, plantation should reduce recharge to low levels. ▪ Planting trees in blocks can allow economical fencing designs and fit with land class fencing. ▪ Often takes place on land of low productive capacity	▪ Steep and/or rocky terrain can make tree establishment difficult and may hamper subsequent commercial use of timber produced. ▪ Tree growth may be slow and substantial water balance impact only slowly achieved (5-15 years).
Low density tree growing or wide-spaced agroforestry – *individual trees planted at wide spacings (to give 20-50 trees/ha) into existing pastures. Trees may be managed for timber production.*	▪ Should allow continuation of existing land use patterns in grazing areas. ▪ May be able to use horticultural trees (e.g. olives, some nut trees) as a commercial alternative to natives.	▪ Individual trees very expensive to establish and must be individually guarded. ▪ Wide-spaced trees generally have poorest establishment and survival rates and have poor form and branching unless carefully managed. ▪ At very wide spacings (<50 trees/ha), time taken for trees to have major water balance impact may be 20-50 years or more. ▪ Not suited to cropping or hay cutting
Farm forestry plantings – *extensive blocks of eucalypt or pine plantation across suitable land. Plantation density >800 trees/ha*	▪ High establishment density and rapid early growth allow water balance impact within 2-3 years of establishment.. ▪ Recharge should be reduced to very low levels over life of plantation. ▪ Economical fencing designs possible. ▪ Financial returns may be equivalent to or better than for wool growing or beef.	▪ Impact on recharge generally confined to area planted.

Alley farming

Figure 6.5: Concept diagram for alley farming system in dryland salinity management



Alley farming is a system which incorporates relatively narrow belts of trees, established at regular intervals, across crop or pasture paddocks. For maximum impact the alleys between the belts of trees should support productive perennial pastures, based on phalaris and/or cocksfoot. Trees on the edge of the belt would extend their root systems into the pasture alley and help to empty the soil profile of water. Over time tree roots might extend10-20 m into the pasture belt.

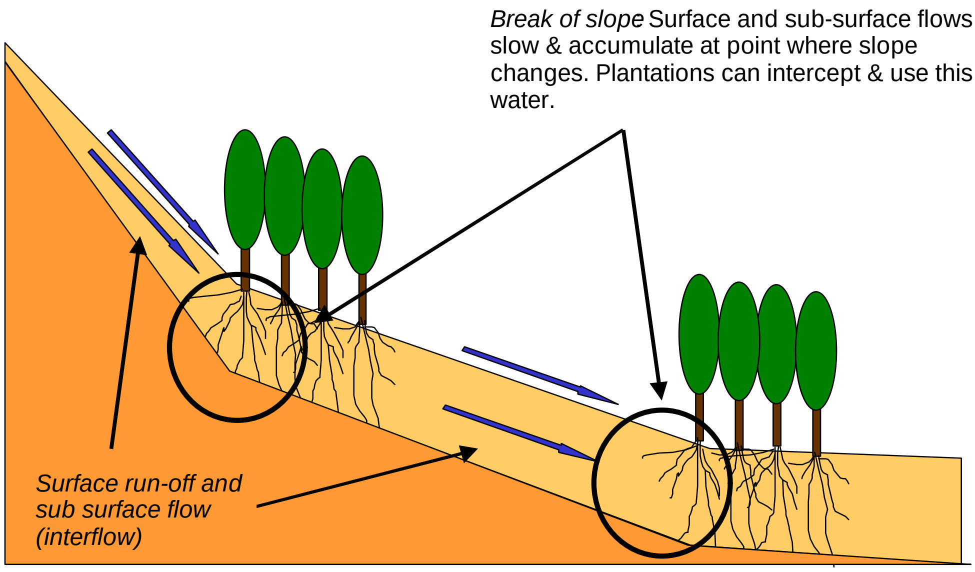
Regularly spaced belts of trees oriented across the slope will help to intercept any lateral flow of surface water across (run-off) or through (interflow) the soil.

Low growing shrubs may be established with the trees to improve the shelter properties of the belt. The shrubs may also encourage better stem form and branching as the trees develop and reduce the need for intervention if the trees are eventually to be harvested for timber. Belts will need to be fenced to maintain shelter benefits. The cost using conventional fencing would be prohibitive. Electric or other forms of light fencing are recommended.

The effectiveness of alley farming in recharge reduction will increase with the proportion of the hill slope over which the edge trees in the belts have extended their roots. Thin belts (2-4 rows), separated by relatively narrow alleys will be more effective in achieving this than wider belts (5-10 rows) separated by much wider alleys.

Interception or break of slope plantations.

Figure 6.6: Concept diagram for use of interception plantings in dryland salinity management



Interception plantings differ from alley farming, in that the belts of trees are located strategically, along breaks of slope, rather than at regular intervals. The change in slope in this part of the landscape results in water slowing and accumulating as it moves down hill. This can include both surface run-off and interflow. In some geological settings it may also include groundwater.

Belts of trees can intercept and evaporate this water, drying out what would otherwise be a water-logged and potentially salt-affected area of land. The width of the belt would be greater than for alley farming to ensure that all of the available water was intercepted. The additional water available in this part of the landscape may allow improved tree growth above what might be expected on the basis of rainfall alone.

Tree belts in interception plantings should be at least 10 rows wide and may be up to 50-100 m wide (as are some break of slope plantations at Warrenbayne, south of Benalla in north-east Victoria). With wider belts, trees on the lower edge of the plantation may not have access to any of the water moving laterally through the landscape.

Multiple belts of trees may be used if there are several breaks of slope. A single interception belt could be used where there is one break of slope and an alley farming system established over the remainder of the slope.

Perennial pastures are recommended for land between interception plantings.

Some of the early salinity management works focused tree growing on saline discharge areas. Trees were established with the expectation that they could reduce local recharge, discharge groundwater and achieve a sustained reduction in the water table level. However, even when salt tolerant trees were established, such plantations were often unsuccessful. Water-logging and salinity often slowed the growth of trees and reduced long-term survival. Water uptake was relatively low and so there was little impact on the water table. Tree growing in saline groundwater discharge areas is now not normally recommended.

Recent studies have suggested that if large areas of agricultural land in north east Victoria were to be converted to tree plantations there would be a reduction in run-off and stream flow from the region. While groundwater recharge and the risk of salinity would be reduced by such action, the expected decline in streamflow would have important consequences for the quantity and quality of water in the entire Murray River system.

6.5 Cropping and dryland salinity management

Water use efficient crops are effective in converting "rain into grain", but may not use much more water overall than less efficient crops.

Crop production is an important land use in several of the priority areas identified by the North-East Salinity Strategy. Options for improving the water balance of annual cropping are limited. Considerable effort has been invested in increasing the *water use efficiency* of crop production. Crops are managed more intensively, with timely and effective use of herbicides, fertiliser etc. to maximise the conversion of growing season rainfall into grain. “Water use efficient” crops may use more water than lower yielding crops, but not in all cases. The extent to which increased water use is possible is limited, as with all annual plant systems, by the restricted growing season.

Improving the water balance of cropland depends on the introduction of perennial vegetation.

Substantial improvements in the water balance of cropping systems can only be achieved by incorporating perennial vegetation. Three main options exist, as described in Table 6.5. The table also outlines some of the strengths and weaknesses of each option.

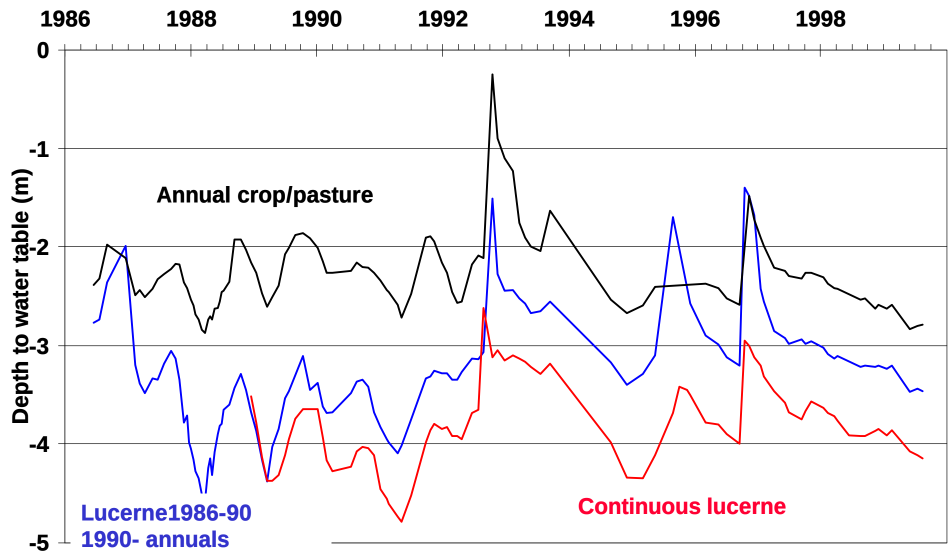
The most promising system for incorporating perennial vegetation into cropping rotations appears to be phase farming with lucerne. Three years of lucerne appears to be sufficient in the cropping areas of the Rutherglen district of north-east Victoria to largely empty the soil profile of water to a depth of 3-3.5 m. This may provide protection from recharge for up to three years into the cropping phase, depending on rainfall.

Table 6.5: Relative strengths and weaknesses of options for incorporating perennial vegetation into cropping systems

	Strengths	Weaknesses
Phase farming – perennial pastures (particularly lucerne) form the ley pasture phase of the cropping rotation. The pasture empties the soil profile of water over several years, allowing several years of cropping before being refilled.	▪ Lucerne phase farming systems have been demonstrated in the Rutherglen area and can offer protection against recharge for up to three years following the lucerne phase. ▪ Summer fodder produced by lucerne can support prime lamb enterprise. ▪ Nitrogen fixed by lucerne provides a boost to crop growth in at least the first year of the cropping phase.	▪ In higher rainfall cropping zones of north-east Victoria, soil profile may refill in the year following the lucerne phase if rainfall is well above average. ▪ Length of cropping phase (based on risk of soil profile refilling with water) may be too short to be economically viable. ▪ Yield loss under dry conditions will be exacerbated for crops sown on former lucerne pastures ▪ Acidic soils of much of NE Victoria mean that lime is required for successful lucerne establishment – hence increasing costs. Acidity may also reduce production during the lucerne phase
Intercropping – *crops are sown into existing lucerne stands. Lucerne plants are sprayed to suppress growth during crop establishment, but begin to grow during the latter part of the crop growing season.*	▪ Technology for establishment and management of intercropping systems exist. ▪ Land managers can take advantage of cropping opportunities, without serious detriment to long-term pastures ▪ Intercropping can help to maintain drier soil profiles that annual cropping alone. This may reduce recharge and can help to reduce water-logging in higher rainfall cropping areas.	▪ Reduced yield in some crops because of lack of water. ▪ Lucerne burrs can cause vegetable degrade in grain sample (if not used for stock feed). ▪ Lucerne may not persist in the more acid cropping soils.
Alley cropping - *crops are sown in alleys between belts of trees or perennial shrubs.*	▪ Alleys may provide shelter for crops and/or stock. ▪ Edge trees may take up unused water from below crops ▪ Cropping phase of rotation can be longer and incorporate greater choice of species than with phase farming or intercropping	▪ Difficult to fit system in with farm machinery. Alleys need to be multiples of machine widths. ▪ Competition between crops and trees or shrubs. ▪ At alley spacing likely to be adopted by crop producers, alley farming unlikely to reduce water table recharge.

Figure 6.7 illustrates the potential of lucerne phase farming to reduce salinity. Lucerne (at Marnoo in the Avon-Richardson catchment in north-central Victoria) was able to lower water tables by up to 2 m within three years of establishment. The effect of the lucerne persisted for 3-5 years into the cropping/annual pasture cycle. A continuous lucerne pasture maintained the water table at about 4 m depth, well beyond the depth at which the soil is likely to become salinised.

Figure 6.7: Changes in groundwater levels in response to cropping and lucerne pasture establishment, Marnoo.



Source: Centre for Land Protection Research

6.6 Discharge area management

Salt-affected land represents a resource that must be actively managed.

If inappropriately managed, the productivity of saline discharge areas declines and they become covered with unpalatable weeds (e.g. spiny rush), unproductive salt tolerant pastures (e.g. sea barleygrass) or become bare, salt scalded and exposed to the risk of erosion. While focussing attention and on-ground activity on the cause of salinity (excessive groundwater recharge) rather than the symptoms (discharge areas) is an attractive philosophy, in the medium term it is likely to result in the condition of saline land worsening. In most cases, it would take 5-10 years *at least* for complete and fully effective recharge area management to be expressed as declining water tables and improving soil conditions in the current discharge areas.

Active management of groundwater discharge areas is increasingly being recognised as an important component of salinity management. Several management systems are available that can return salt-affected land to productive use and reduce the risk of further land degradation.

Salt tolerant pastures

Pastures based on salt-tolerant species such as tall wheatgrass and *Puccinellia* appear to be the most applicable to north-east Victoria. When sown in combination with moderately salt-tolerant clovers (balansa, strawberry) and managed appropriately, they should form stable and productive systems. This type of pasture has been able to support 8-10 dse/ha in south-west Victoria. Management of the pasture focuses on maximising long-term production from the clover (through spelling during flowering and seed set and heavy grazing prior to the autumn break) and preventing the site becoming pugged by grazing when the soils are wet. Salt tolerance of a range of fodder plants is indicated in

Table 6.6: Salt tolerance of common pasture species

Category	Species
Sensitive Plants	Many clovers including, White Clover, Red Clover, Subterranean Clover
Moderately Sensitive Plants	Strawberry Clover, Balansa Clover, Persian Clover, Lucerne
Moderately Tolerant Plants	Tall Fescue, Phalaris, Perennial Ryegrass, Wimmera Ryegrass
Tolerant Plants	Tall Wheat Grass, Puccinellia, Salt Bush

Source: Ian Gamble NRE Wangaratta

Saltbush

Salt bush has been widely used in Western Australia to improve the productivity of salt affected land. Its use has been less successful in most places in Victoria, with the species appearing to perform poorly on the relatively acid soils.

Tree growing in discharge areas unsuccessful

Tree growing was once recommended for discharge areas. However they were not generally successful, with the trees growing slowly due to water-logging and salinity and having minimal impact on water tables. Trees that did establish successfully may slowly decline in health as salt gradually accumulated in their root zone. In some cases, trees planted immediately upslope of discharge areas may be able to help contain their spread. The trees are more likely to establish successfully, as the water table will be deeper than in the discharge area itself.

If water tables are not too shallow, groundwater discharge areas may become recharge areas at certain times of year. Having a dense coverage of perennial vegetation on these areas may reduce the rate at which this occurs. Deep-rooted salt tolerant pastures (e.g. tall wheatgrass) may take up and effectively *discharge* groundwater during the warmer months. This may help to lower water tables in these areas, at least temporarily. In some landscapes pastures in discharge areas may be able to achieve a sustained lowering of the water table and contribute to the rehabilitation of salt-affected land.

6.7 Horticulture

Horticulture is an increasingly important land use in the North-East region. Like other key wine producing regions of Victoria, the area of land under vineyard is expanding rapidly. Most development is taking place on river flats and the lower slopes of hills. Vineyards are generally irrigated. The Salinity Strategy encouraged the use of high water use horticultural crops and recommended that the groundwater impacts of large scale horticultural developments be monitored.

Little is known in Victoria about the impact of recent horticultural developments on water tables and salinity processes in what were previously dryland agricultural areas. Historically, much of the horticultural development has been in irrigation areas and has probably contributed to elevated water tables and soil salinisation in those areas. There is some recent evidence from the Wimmera catchment of water tables falling below vineyards. Seepage from on-farm dams used to irrigate horticultural crops has been implicated in local saline discharge in some regions.

The impact of horticultural development will vary between enterprises, with the type of crop (deciduous or evergreen, shallow or deep rooting etc.), its management and the extent to which the crop water requirement is supplied by irrigation. Crops with deep root systems, relatively large, leafy crowns and an irrigation deficit should have a beneficial impact on the water balance relative to annual pastures. Horticultural crops that are over-irrigated (i.e. irrigation supply exceeds plant requirements) may serve to increase the risk of salinity.

7. Using Vegetation to Manage Dryland Salinity in North-East Victoria

7.1 Getting started

Changing land management across entire landscapes is essential if the rate of leakage and the risk of dryland salinity are to be reduced. Achieving this change will be a long-term process, both for financial and practical reasons. Four key steps are considered necessary in embarking on this process of long-term change in land management:

Effective whole farm planning is the first step in successfully managing dryland salinity.

- *Planning* – landholders need to understand their own land and the way in which water moves through it. They need to seek information on the options available to them, identifying their strengths and limitations in relation to use on their own property. Implementation of new management needs to be carried out according to a plan, to ensure that activities are well targeted, scheduled appropriately and carried out in priority order. The elements of planning should be brought together in the formulation of a whole farm plan.

Good site preparation is essential for tree and pasture establishment.

- *Preparation* – good preparation will generally provide the necessary foundation for successfully establishing trees or pasture. The preparation required will vary from property to property and with the management option to be used. In most cases, particularly in hill country, land class fencing is an important first step in gaining greater control over and improving the quality of land management. Similarly, in areas with rabbit problems, controlling these pests will be essential for successful tree and pasture establishment programs.

Retaining and managing native perennial vegetation is less expensive than reestablishing it.

- *Encourage existing perennial vegetation* – parts of many properties already support perennial vegetation, in the form of native vegetation remnants, scattered trees in paddocks and native grass pastures. Retaining these and encouraging regeneration can be a relatively inexpensive means of improving perennial vegetation coverage across properties.

- *Experiment* – the only thing more demoralising than failure is a large scale failure. New practices, for example new pasture species or grazing management practices, should be experimented with at a relatively small scale so that land managers gain confidence and skills.

Seek and evaluate information about the environmental and financial impacts of farm management decisions.

- *Get advice and information* – there are many avenues of advice available to landholders unsure about changing the management of their properties. Landholders are encouraged to seek the information they need to make a balanced and well informed decision before changing land management. They need to consider the short and long term *environmental* and *financial* implications of management and investment decisions.

7.2 Managing salinity using vegetation

This section outlines approaches by which vegetation may be used to manage dryland salinity processes throughout north-east Victoria. The approaches are based on the best current interpretation of salinity processes and of the way in which vegetation may be used to influence them. They often represent a compromise between what might be needed to fully control salinity processes and maintaining an appropriate level of agricultural land use. In some instances, the nature of the landscape and climate may mean that these land management options will not entirely control salinity, although they should lessen the impact.

Landholders should carefully consider their own financial position prior to adopting the practices recommended here. They are also encouraged to seek specific advice for their own property.

7.2.1 Ovens and King riverine plains

Recharge processes are driven by flooding and leakage from pastures on the upper terrace. Saline groundwater discharge occurs mainly on the lower terrace.

Salinity and groundwater processes on the Ovens and King riverine plains were discussed in section 4.2.1. Groundwater recharge in the area appears to be driven by two processes, flooding of the lower terrace and leakage from below the pastures being grown on the upper terrace (especially those close the lower terrace boundary). Saline seeps are developing on the lower terrace and, in some locations, at the break of slope immediately above the lower terrace.

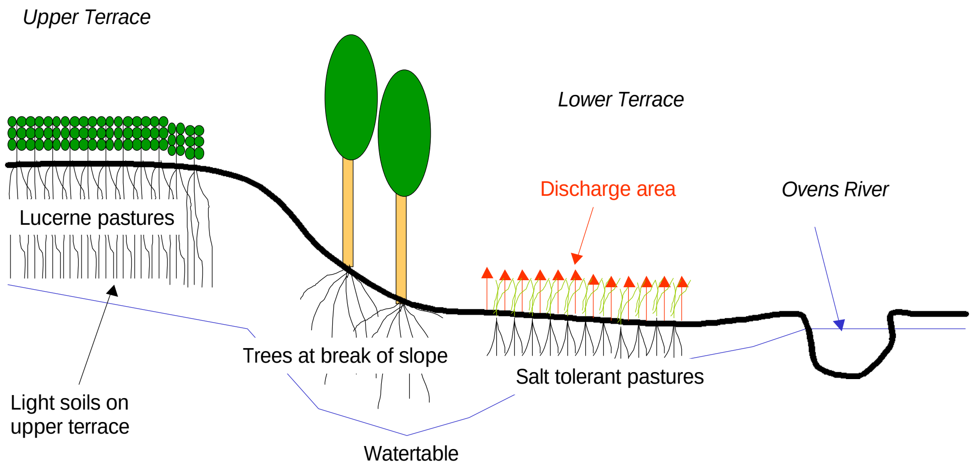
Flooding is a natural event in the Ovens and King River systems and there is little that riverine plain landholders can do to prevent it. However, they should be able to manage other components of the salinity process. Three changes in land management are recommended, as described below. These changes are depicted in Figure 7.1.

Lucerne to reduce recharge on the upper terrace.

- *Lucerne pastures on the upper terrace* – soils on the upper terrace are deep and well drained and are particularly leaky if supporting only annual pastures. Some local farmers have demonstrated that lucerne can be successfully established and maintained here. Careful management of grazing and possibly lime application will be required to ensure the lucerne persists and maintains good levels of production. The deep root systems and summer growth of lucerne pastures should enable them to greatly reduce leakage from the upper terrace, relative to annual pastures.

  Lucerne pastures could be supplemented by belts of trees.

Figure 7.1: A model for using vegetation to manage dryland salinity on the Ovens and King riverine plains



Note: Drawing not to scale

- *Trees above the break of slope of the lower terrace* – shallow water tables and saline seep development are often found along the lower break of slope and further out onto the lower terrace. A narrow and densely planted belt of trees (3-5 rows, approx. 3 m spacing) immediately above the break of slope should reduce leakage and intercept groundwater moving laterally from the upper to the lower terrace. These plantations would be expected to lower the water table in the immediate vicinity of the break of slope, where discharge is currently occurring.

- *Salt-tolerant pastures on groundwater discharge areas on the lower terrace* – the water table in these areas is currently very shallow. Water-logging and soil salinity reduces production of the pasture. Establishment of salt tolerant pastures, combining perennial grasses (e.g. tall wheatgrass, *Puccinellia*) and salt tolerant clovers (e.g. strawberry clover) should improve the productivity of this land. Pastures should not be grazed over winter, while the soil is water-logged. Otherwise, they should be managed to favour the salt tolerant clovers, by spelling while the clover is flowering and grazing heavily prior to the autumn break.

  Unless the water table is lowered across the lower terrace by reducing water table recharge, there is a significant long-term (over 20-30 years) risk that salt will accumulate in the root zone of these pastures and diminish their effectiveness.

The key recharge zones are the ridges and upper slopes of the metamorphic hills. Salinity is found on the lower margins of the hills and at the edge of the riverine plain.

7.2.2 Metamorphic hills of the Bobinawarrah and Greta areas

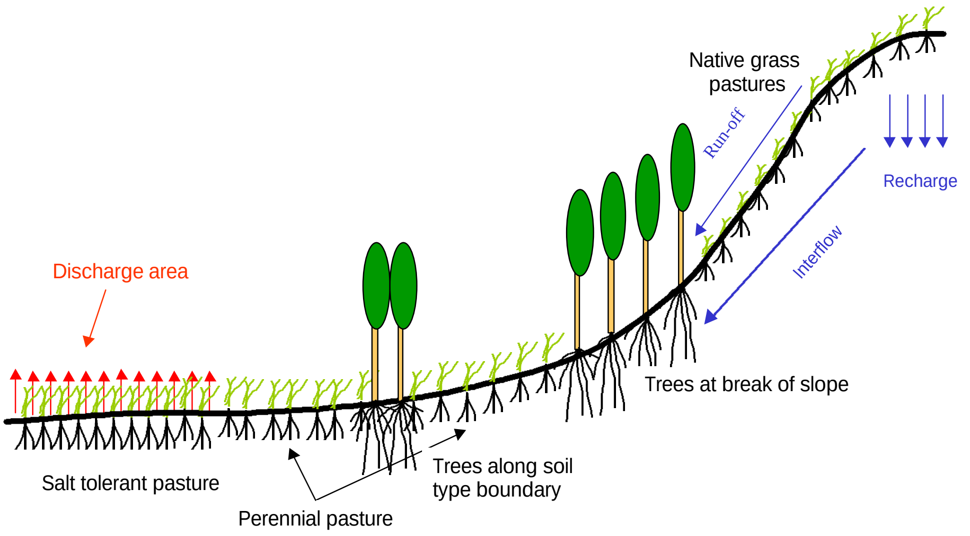
Salinity and groundwater processes in the Bobinawarrah and Greta areas were discussed in section 4.2.2. The major recharge areas comprise the ridges and upper slopes of the metamorphic hills and colluvial deposits on the mid and lower slopes. Groundwater discharge and the development of dryland salinity is associated with changes in the permeability of soils along the lower margins of the hills and on the edge of the riverine plain and possibly with highpoints in the bedrock on the edge of the Ovens Graben.

A model for managing recharge and discharge processes in the Bobinawarrah and Greta areas is given in Figure 7.2. Elements of that model are described below.

Retain and manage native grass pastures on ridges and upper slopes to reduce run-off and groundwater recharge.

- *Management of native grass pastures on the ridges and upper slopes* – ridge and upper slope areas often support native perennial grass pastures (commonly Red Grass). Soils in these areas are generally too acidic to support improved species, such as phalaris. Rather than attempt to replace native perennial pastures, they should be actively managed to increase in plant density and assist in the management of recharge and run-off.

Figure 7.2: A model for using vegetation to manage dryland salinity in the Bobinawarrah and Greta areas



Note: Drawing not to scale

The first step in this process is land class fencing. This will allow ridges and upper slopes to be managed separately from mid and lower slope areas, which have different limitations and will support different pasture types. If combined with (for example) mob stocking, land class fencing may be used to reduce selective grazing of the more palatable native species. It may also help manage stock camping behaviour, which results in nutrients being transported to the tops of hills and these areas being dominated by winter weeds and baring-off in summer.

Grazing should be timed to avoid flowering in the native to help regeneration. Tactical rotational grazing, based on maintaining minimum levels of feed on offer should help to encourage the native perennials, provide improved utilisation and reduce run-off and soil loss, particularly during summer storms.

Given the relatively high rainfall in the Bobinawarrah and Greta areas and the steep slopes and shallow soils of the ridges and upper slopes, it would not be expected that native grass pastures would be fully effective in controlling recharge. Run-off from these areas may also contribute to recharge in colluvium at the break of slope between the upper and mid slope areas. Effective management of the native grass pastures should, however, reduce the level of run-off.

Trees would perform a useful function in ridge and upper slope areas. All native vegetation should be retained and natural regeneration encouraged wherever possible. The cost and difficulty of establishing trees and limited opportunity for farm forestry in these relatively inaccessible areas mean that encouraging native grass pastures is considered a more appropriate management option.

Forestry plantations at the break of slope to intercept and use run-off and shallow groundwater.

- *Trees at the break of slope* – the first major break of slope between the steeper upper slopes and the mid-slopes is a zone of strategic importance in many parts of the Greta – Bobinawarrah areas. It is the part of the landscape where run-off from the steep upper slopes infiltrates and contributes recharge to the colluvial aquifer causing some of the saline discharge in the lower slopes. It may also be a place where that aquifer is relatively thin and can be relatively easily dewatered (or dried out) to reduce the risk of salinity in the lower slopes.

  Establishing a belt of trees at this break of slope can have several advantages, as listed below:

  - trees can use the water that runs on to the plantation from upslope and so prevent it from recharging the colluvial aquifer;
  - trees can extend their roots throughout the colluvial aquifer and “mine” the water that has accumulated under the current land use;
  - tree growth can be supplemented by the extra water received as run-off from upslope and the risk of drought damage reduced.

  It is recommended that the plantations would need to be about 50 m wide, although the width required would vary with length of slope above the plantation and its steepness (greater length and steepness of slope would require a wider plantation). Break of slope plantations would not be recommended in areas where the water table is very shallow (<2 m) or of poor quality (>3000 EC units).

Similar 50-100 m wide *Eucalyptus globulus* (Blue Gum) plantations have been effective in lowering water tables in colluvial aquifers of the Warrenbayne-Boho areas, south of Benalla. In some areas, this effectiveness in removing water from the landscape, combined with a prolonged dry period resulted in the death of a large number of trees. The risk of drought damage may be reduced by early thinning of the plantation or the use of slower growing but more drought tolerant species.

- *Perennial pasture across the mid and lower slope* – perennial pastures based on phalaris and cocksfoot (and clovers) should be established across the lower and mid slope areas. Tactical or rotational grazing should be used to maximise the persistence, growth and water use of the perennials (particularly where the soils are acidic). Such pastures should reduce run-off and make more effective use of the rain that falls than annual pastures. They are unlikely to use all of the water that is received as rain.

- *Tree plantation along change in soil texture* – groundwater discharge is often associated with a change in soil type along the lower slopes of the hills. The permeability of the soil (an indication of its capacity to allow water movement) is reduced as texture becomes heavier. Water "slows" as it encounters the soil type boundary and begins to accumulate. Water-logging from this source and discharge from the colluvial and bedrock aquifers lead to salinity in the land immediately downslope of this boundary.

  The boundary could be determined using a ground-based EM survey (also used to map salinity). The more clayey soils in the lower slope will be more conductive than the lighter texture soils further upslope.

  A relatively narrow belt of trees (2-5 rows) should be planted immediately upslope of the soil texture boundary to remove some of the interflow from further upslope. Trees should not be planted within the discharge area, as water-logging may threaten establishment and early growth and the accumulation of salt may threaten the long-term viability of the trees.

Salt tolerant pastures to return water-logged and salt-affected land to productivity.

- *Salt-tolerant pastures on groundwater discharge areas on the lower slope* – the water table in these areas is currently very shallow. Water-logging and soil salinity reduces production of the existing pasture. Establishment of salt tolerant pastures, combining perennial grasses (e.g. tall wheatgrass, *Puccinellia*) and salt tolerant clovers (e.g. strawberry clover) should enhance the productivity of this land. Pastures should not be grazed over winter, while the soil is water-logged. Otherwise, they should be managed to favour the salt tolerant clovers, by spelling while the clover is flowering and grazing heavily prior to the autumn break.

However, unless there is a long-term fall in the water table across the lower slope, there is a significant long-term risk that salt will accumulate in the root zone of these pastures and diminish their effectiveness.

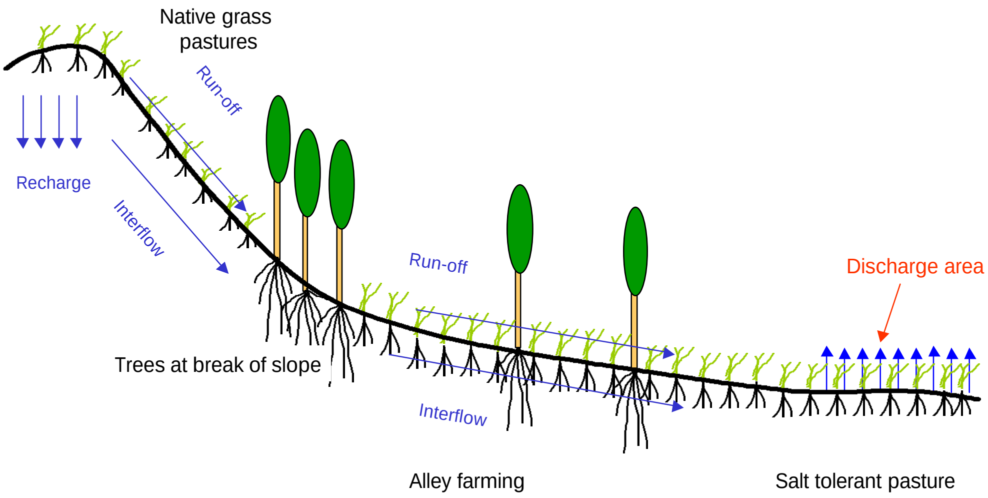
The major recharge areas are the metamorphic ridges and grey sandy clay soils of the mid-lower slopes. Saline discharge occurs at the upper break of slope and in the lower parts of valleys associated with shallow bedrock.

7.2.3 Metamorphic hills of the Indigo Valley and Barnawartha areas

Salinity and groundwater processes in the Indigo Valley-Barnawartha areas were discussed in section 4.2.3. The major recharge areas comprise the ridges and upper slopes of the metamorphic hills and grey sandy clay soils of the colluvial deposits on the mid and lower slopes. Groundwater discharge and the development of dryland salinity is associated with the break of slope between the steep upper slopes and the less steep mid-slope and with outcropping or shallow bedrock in the lower parts of the valley (see Figure 4.3).

A model for managing recharge and discharge processes in the Indigo Valley-Barnawartha areas is given in Figure 7.3. Elements of that model are described below.

Figure 7.3: A model for the use of vegetation in the management of dryland salinity in the Indigo Valley - Barnawartha areas



Retain and manage native grasses.

- *Management of native grass pastures on the ridges and upper slopes* – ridge and upper slope areas often support native perennial grass pastures (commonly Red Grass). Soils in these areas are generally too acidic to support improved species, such as phalaris. Rather than attempt to replace native perennial pastures, they should be actively managed to help improve plant density and assist in the management of recharge and run-off.

The first step in this process is land class fencing. This will allow ridges and upper slopes to be managed separately from mid and lower slope areas, which have different limitations and will support different pasture types. If combined with (for example) mob stocking, land class fencing may be used to reduce selective grazing of the more palatable native species. It may also help manage stock camping behaviour, which results in nutrients being transported to the tops of hills and these areas being dominated by winter weeds and baring-off in summer.

Grazing should be timed to avoid flowering in the native to help regeneration. Tactical rotational grazing, based on maintaining minimum levels of feed on offer should help to encourage the native perennials, provide improved utilisation and reduce run-off and soil loss, particularly during summer storms.

Given the relatively high rainfall in the Indigo Valley and the steep slopes and shallow soils of the ridges and upper slopes, it would not be expected native grass pastures would be fully effective in controlling recharge to the fractured metamorphic rock aquifer. Run-off from these areas may also contribute to recharge at the break of slope between the upper and mid slope areas. Effective management of the native grass pastures should, however, reduce the level of run-off.

Trees would perform a useful function in ridge and upper slope areas. All native vegetation should be retained and natural regeneration encouraged wherever possible. The cost and difficulty of establishing trees and limited opportunity for farm forestry in these relatively inaccessible areas mean that encouraging native grass pastures is considered a more appropriate management option.

- *Trees at the break of slope* – the first major break of slope between the steeper upper slopes and the mid-slopes is a zone of strategic importance in many parts of the Indigo Valley. It is the part of the landscape where some of the bedrock-derived saline groundwater discharge occurs. It is also where run-off from the steep upper slopes infiltrates and contributes recharge to the colluvial aquifer causing some of the saline discharge in the lower slopes.

  Establishing a belt of trees at this break of slope should allow the trees to use the water that runs on to the plantation from upslope and so prevent it from recharging the colluvial aquifer or contributing to local water-logging. Trees may also be able to dewater this upper part of the sandy clay colluvial aquifer. Run-on from upslope may also provide sufficient water to enhance tree growth (see section 7.2.2).

  It is recommended that the plantations would need to be about 50 m wide, although the width required would vary with length and steepness of slope above the plantation (greater length and steepness of slope would require a wider plantation). As discussed in section 7.2.2, similar plantations have been effective in lowering water tables in the Benalla area. These plantations would have little impact on water already in the fractured rock aquifer.

Alley farming with trees and perennial pastures to reduce recharge and intercept run-off and interflow.

- *Alley farming with trees and perennial pasture across the mid and lower slope* – land across the mid and lower slopes should support a combination of trees and perennial pastures to help reduce recharge and intercept any run-off and interflow from the sandy clay soils.

  Pastures would be based on phalaris, cocksfoot and clovers. Tactical or rotational grazing should be used to maximise the persistence, growth and water use of the perennials (particularly where the soils are acidic). Such pastures should reduce run-off and make more effective use of the rain that falls than annual pastures.

  Relatively narrow belts of trees (2-5 rows) would be established parallel to the slope, ideally at intervals of up to 50 m. Narrow belts should achieve the maximum impact from the trees for the smallest area planted. At spacings wider than about 50 m, the impact of the belts is likely to be relatively small. Electric fencing will be essential to reduce establishment costs.

  The trees should be able to intercept any water moving laterally through the landscape. Most such water would be leakage from below the perennial pastures. It cannot infiltrate deeply because of the low permeability of the underlying red heavy clay.

- *Salt-tolerant pastures on groundwater discharge areas on the lower slope* – may improve the productivity of salt-affected land. Again, establishment of salt tolerant pastures, combining perennial grasses (e.g. tall wheatgrass, *Puccinellia*) and salt tolerant clovers (e.g. strawberry clover) is recommended. Pastures should not be grazed over winter, while the soil is water-logged. Otherwise, they should be managed to favour the salt tolerant clovers, by spelling while the clover is flowering and grazing heavily prior to the autumn break.

  Unless there is a long-term fall in the water table in these areas, salt may accumulate in the root zone of these pastures and diminish their effectiveness. The risk of this may be greater than in other locations as recharge and discharge processes in the fractured rock aquifer will be difficult to manage, without completely revegetating the ridges and upper slopes.

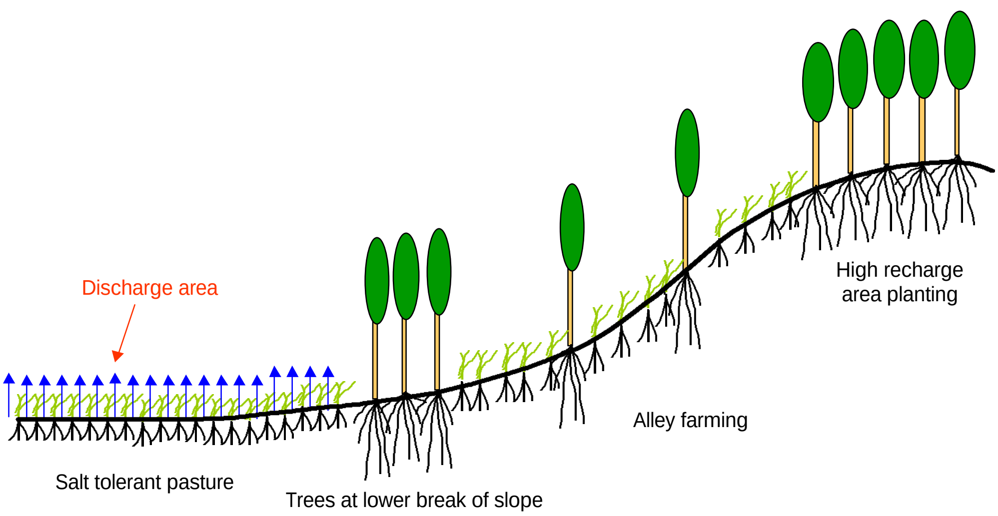
Recharge is concentrated on the ridges and upper slopes of metamorphic and granite hills. Discharge is widespread across the lower landscape and may be associated with poor

7.2.4 The Everton Upper area

Salinity and groundwater processes in the Everton Upper area were discussed in section 4.2.4. The major recharge areas comprise the ridges and mid to upper slopes of both the metamorphic and granite hills. Groundwater discharge and dryland salinity is widespread across the lower slopes and depressions. Salinity is influenced by poor surface and sub-surface drainage and upward groundwater pressures in the fractured metamorphic rock aquifer.

A model for managing recharge and discharge processes in the Everton Upper area is given in Figure 7.4. Elements of that model are described below. The suspected poor sub-surface drainage at Everton Upper (see section 4.2.4) is likely to limit the responsiveness of the catchment to changes in land use and vegetation coverage. The model described in Figure 7.4 should limit intake to the aquifers, but may not produce a rapid response.

Figure 7.4: A model for the use of vegetation in the management of dryland salinity at Everton Upper



Note: Drawing not to scale

Indigenous or other native trees in moderate density planting on high potential recharge areas.

- *High recharge area tree planting* – the upper part of the relatively gently sloping metamorphic ridge would be planted to trees to reduce leakage to the fractured rock aquifer which is considered to be one of the main drivers of the salinity processes. Soils are mostly shallow across the upper slopes of the metamorphic ridge. This means that water availability would not be sufficient for fast growing, water demanding species such as *E.globulus*. More slowly growing, but drought tolerant indigenous or other native trees with some forest product potential would be suitable. Trees should be established at densities of approximately 400-600 stems/ha to ensure that they are able to reduce leakage to the water table relatively soon after establishment.

If planted at the recommended density and successfully established, the plantations should be able to contain recharge on this part of the landscape within 5-10 years of establishment.

- *Alley farming with trees and perennial pasture across mid slope areas* – land across the mid slopes should support a combination of trees and perennial pastures to help reduce recharge and intercept lateral flow in either the sandy clay soils or the fractured rock aquifer. This system would reduce recharge relative to perennial pastures alone and would allow agricultural production to continue.

  Pastures would be based on phalaris, cocksfoot and clovers. Tactical or rotational grazing should be used to maximise the persistence, growth and water use of the perennials (particularly where the soils are acidic).

  Relatively narrow belts of trees (2-5 rows) would be established parallel to the slope, ideally at intervals of up to 50 m. Narrow belts should achieve the maximum impact from the trees for the smallest area planted. At spacings wider than about 50 m, the impact of the belts is likely to be relatively small. The trees should be able to intercept any water moving laterally through the sandy clay colluvial layer. Electric fencing will be essential to reduce establishment costs.

Trees at the lower break of slope to intercept lateral groundwater flow.

Trees at the lower break of slope – the break of slope immediately above the valley floor is considered to be a strategic location for a tree plantation. Planting trees immediately above the break of slope should allow them to avoid water-logging associated with the valley floor, but enable them to intercept any additional water moving laterally through the sandy clay layer. Since there is a relatively small area of land upslope of this position (to contribute later groundwater or soil water flow), the treebelt at the lower break of slope need not be any wider than 30-50 m.

- *Salt-tolerant pastures on groundwater discharge areas on the lower slope* – may help to return salt-affected land in the valley floors to productivity. Again, establishment of salt tolerant pastures, combining perennial grasses (e.g. tall wheatgrass, *Puccinellia*) and salt tolerant clovers (e.g. strawberry clover) is recommended. Pastures should not be grazed over winter, while the soil is water-logged. Otherwise, they should be managed to favour the salt tolerant clovers, by spelling while the clover is flowering and grazing heavily prior to the autumn break.

  Salt tolerant perennials may not be suited to any areas within the discharge area where the soil is already quite saline and the water tables remains less than about 1 m from the surface. Salt tolerant annual pastures (e.g. salt tolerant clovers) may be better suited, as they are less likely to accumulate salt in their root zone.

7.2.5 Rounded hills of the Rutherglen area

Recharge is widespread across the landscape, with higher rates on ridges and upper slopes. Saline discharge occurs in valleys and at edge of riverine plain.

Salinity and groundwater processes in the Rutherglen area were discussed in section 4.2.5. The major recharge areas comprise the ridges and upper slopes of the hills, although the entire landscape would contribute some recharge. Groundwater discharge and dryland salinity is widespread around the outer edges of the hills at the boundary between the Tertiary sand, gravel and clay layer and the Murray riverine plain (see The recently identified Tertiary deposits are thought to form the primary aquifer implicated with saline discharge at Rutherglen. The soil cover on the hills appears to be mostly of light texture and is likely to permit high rates of recharge into the Tertiary layer.

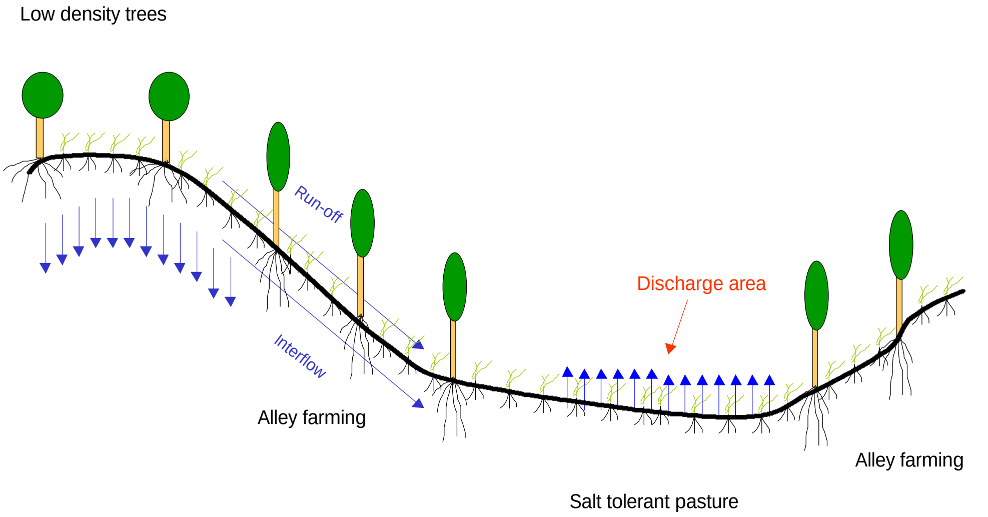
The underlying sedimentary bedrock is regarded as being of lower permeability than the Tertiary layer and thus would limit the deep drainage. Groundwater would therefore tend to build up more quickly in the Tertiary layer than in the underlying rock. The bedrock could be a controlling factor in the occurrence of discharge but its nature and significance are unknown.

Figure 4.5 presents a hypothetical picture of the salinity process in the Rutherglen hills, but is based on limited information. It is a very simplified hydrogeological cross-section of the hills as viewed from the west. Series of arrows define recharge and discharge areas, and a hypothetical watertable surface is shown. Replacement of native vegetation with shallow-rooted crops and pastures is believed to have resulted in increased groundwater recharge on the crests and slopes of the hills, leading ultimately to elevated groundwater levels within the Tertiary sediments and, perhaps to a lesser extent, the underlying sedimentary bedrock. The raised levels of groundwater have resulted in saline discharge at breaks of slope and depressions, particularly at the junction of the hills and the Murray Riverine Plain.

Figure 4.5). There are also some outbreaks along breaks of slope and valley depressions within the hills

A model for managing recharge and discharge processes in the Rutherglen area is given in Figure 7.5. Elements of that model are described below. Cropping without a perennial pasture phase in this landscape is not advisable as it is as leaky a land management practice as annual pastures.

Figure 7.5: A model for the use of vegetation in the management of dryland salinity in the Rutherglen area



Note: Drawing not to scale

Low density tree growing over perennial pasture to reduce recharge.

- *Low density tree growing and perennial pastures on ridges* – retention of native vegetation and establishment of widely spaced trees and perennial pasture is an option to help to contain groundwater recharge and allow on-going agricultural production. Trees should be planted at densities of at least 50 stems/ha, using indigenous or other native species. Any benefit from these trees will be long-term, as at this density it will take decades for the trees to grow large enough to impact on the water balance of the site. Establishment of trees in this way is generally more expensive than for establishment of blocks or belts.

  Pastures would generally be based on phalaris, cocksfoot and clovers. Subject to confirmation from soil testing, it may be possible to grow lucerne in these areas. Tactical or rotational grazing should be used to maximise the persistence, growth and water use of the perennials (particularly where the soils are acidic). Pastures alone (with the possible exception of lucerne) are unlikely to be effective in eliminating recharge on their own.

- *Alley farming with trees and perennial pasture across mid slope areas* – land across the mid slopes should support a combination of trees and perennial pastures to help reduce recharge and intercept lateral flow through the Tertiary deposits that are considered to form the main aquifer. This system would reduce recharge relative to perennial pastures alone and would allow agricultural production to continue.

Pastures would be based on phalaris, cocksfoot and pastures. Tactical or rotational grazing should be used to maximise the persistence, growth and water use of the perennials (particularly where the soils are acidic). It may be possible to continue to crop this area provided lucerne is used for at least three years during the pasture phase of the rotation.

Relatively narrow belts of trees (2-5 rows) would be established parallel to the slope, ideally at intervals of up to 50 m. Narrow belts should achieve the maximum impact from the trees for the smallest area planted. At spacings wider than about 50 m, the impact of the belts is likely to be relatively small. The trees should be able to intercept any water moving laterally through the sandy clay colluvial layer. Electric fencing will be essential during the establishment phase to reduce establishment costs.

Alley farming could be practiced to the ridge top. It may be more practical to do so that use low density tree planting.

- *Salt-tolerant pastures on groundwater discharge areas on the lower slope* – may allow productivity to be improved from salt-affected land in the valley floors. Again, establishment of salt tolerant pastures, combining perennial grasses (e.g. tall wheatgrass, *Puccinellia*) and salt tolerant clovers (e.g. strawberry clover) is recommended. Pastures should not be grazed over winter, while the soil is water-logged. Otherwise, they should be managed to favour the salt tolerant clovers, by spelling while the clover is flowering and grazing heavily prior to the autumn break

  Unless there is a long-term fall in the water table in these areas, salt may accumulate in the root zone of these pastures and diminish their effectiveness. The risk of this may be greater than in other locations as recharge and discharge processes in the fractured rock aquifer will be difficult to manage, without completely revegetating the ridges and upper slopes.

8. Further Reading

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Appendix A - Key Contacts for Further Information

North East Salinity Strategy Implementation Team:

Department of Natural Resources and Environment

- Tara Court, Ford St, Wangaratta – ph 03 5720 1750
- 1 McKoy St, Wodonga – ph 02 6055 6110

Ovens Landcare Network

Contact through Department of Natural Resources and Environment, Wangaratta

North East Catchment Management Authority:

1 McKoy St, Wodonga – ph 02 6055 6133

Sinclair Knight Merz:

36 Wattle St, Bendigo – ph 03 5444 1861

Centre for Land Protection Research:

Midland Hwy, Epsom – ph 03 5430 4444

Appendix B - Glossary

Alley farming	-	a farming system in which pasture or crops are grown in strips or alleys between belts of trees or perennial shrubs. Tree belt is typically between 1 and 5-10 trees wide. Belt of perennial vegetation may consist of trees or fodder shrubs and is included in the farming system to diversify production to include forest products, provide fodder, shelter or protection from wind erosion and to reduce landscape recharge.
Alluvium	-	a general term for river or stream deposits found in valley floors or floodplains
Annual vegetation	-	vegetation such as grain crops, subterranean clover, annual ryegrass whose life cycle is completed in a single growing season. Continued presence of the species on a site depends on regeneration from seed each growing season.
Aquifer	-	layer or body of rock or sediment which stores and transmits water.
Autumn Soil Water Deficit (ASWD)	-	the actual water storage capacity of the soil profile prior to the autumn break. As ASWD increases, so does the capacity of the landscape to retain excess winter (or cool season) rainfall and so prevent deep drainage.
Break of slope	-	any place in the landscape where there is a change in the topographic slope (e.g. between steep upper slopes and gentler mid slope areas or at the base of slopes that connect lower and upper terraces on Ovens riverine plain). They are important in dryland salinity processes as they often represent places where water accumulates.
Colluvium	-	unconsolidated deposits usually found in the lower parts of cliffs or hillslopes and generally moved by gravity. The hillslope deposits in the focus areas of this report are mostly a combination of alluvium and colluvium.
Cool season vegetation	-	vegetation (e.g. annual crops & pastures, phalaris, cocksfoot, wallaby grass) that is most active during the cooler months between the autumn break and late spring or early summer. The vegetation typically retains little green foliage nor grows rapidly during summer.
Deep-drainage	-	water that infiltrates or drains through the soil beyond plant root zones and so is unable to be utilised.

Discharge areas	-	parts of the landscape where groundwater is discharged to the surface. Discharge may occur as liquid water or the groundwater may be evaporated directly from the soil surface.
Discharge enhancement	-	a system of managing dryland salinity in which water is discharged directly from the water table by evaporative (vegetative) or mechanical means (e.g. pump). In the correct hydrological setting and when the rate of discharge is adequate, this system can result in a lowering of water tables.
Evaporation	-	the physical process by which liquid water is converted to its gaseous phase (water vapour). Across landscapes, evaporation may occur as transpiration, soil evaporation or interception (see this glossary.
	-	*potential* evaporation is the amount of water that could be evaporated from a vegetated surface if the water supply was not limiting. *Actual* evaporation is the amount of water evaporated under the conditions of water availability that exist.
Fault	-	a major fracture occurring in rocks, along which opposite sides have been displaced relative to each other.
Growing season	-	seasons in which plants (particularly crops and pastures) are active and growing. The growing season is normally winter and spring for annual crops and cool season pastures (e.g. clover, phalaris) and spring-autumn for warm season pastures, such as lucerne
Growing season rainfall	-	rainfall received during the growing season of a particular crop or pasture species. The term typically applies to annual crops or pastures or summer dormant cool season perennial pastures.
Interception	-	evaporation of water that is retained on the surfaces of leaves during and directly after rainfall events.
Interception plantings	-	belts of trees established along breaks of slope between steep hills and mid slopes or at other locations where there is a noticeable change in slope. Belts located strategically to intercept water moving downslope before it has the chance to recharge shallow water tables in lower slope areas.

Intercropping	-	a farming system in which crops are periodically sown into “permanent” lucerne pastures. Lucerne stands are lightly sprayed with herbicide to suppress growth during crop establishment. Lucerne regrows during following spring and summer period.
Interflow	-	lateral movement of water through the soil. Interflow often takes place above a less permeable layer in the soil (e.g. a clayey sub-soil lying below a relatively light textured top-soil).
Metamorphic rock	-	describes rocks that are partly or completely altered by geological processes involving high temperature and/or pressure.
Perennial vegetation	-	vegetation (trees, shrubs, pasture plants) whose life cycle extends over periods greater than a single growing season. Some perennial pasture plants become dormant at certain times of year (e.g. phalaris in summer, lucerne in winter), however they regrow from dormant buds in the “crown” rather than from seed as do annual plants.
Persistence	-	the tendency of a perennial plant to survive at a particular location. Persistence normally refers to the long-term survival of the original plant. However plants that are short-lived, but are able to naturally regenerate (recruit) on site, may also be considered to be persistent.
Phase farming	-	a cropping rotation in which perennial pastures (particularly lucerne) form the ley pasture phase of the rotation. The role of the perennial pasture is to empty the soil profile of water over several years to allow several crops to be grown before the soil profile refills.
Phenology	-	the seasonal growth habit of a plant.
Recharge	-	the process by which water infiltrates beyond plant root zones to the water table.
Recharge areas	-	parts of the landscape where not all of the rain is taken up by vegetation and some leaks to the water table. Recharge areas are normally considered to be the leakiest parts of the landscape, where rates of recharge are highest (e.g. hills with shallow, lightly textured soils, sandy soils on river terraces). However most parts of cleared landscapes are recharge areas at some stage.

Recharge reduction	-	a salinity management strategy by which attempts are made to reduce the amount of water infiltrating past plant root zones and/or reaching the water table. The objective may be achieved by drainage to effectively increase run-off or by increasing evaporation by changing the type or management of vegetation.
Recruitment	-	natural regeneration of plants by seed or various vegetative means (e.g. suckers, rhyzomes)
Run-off	-	lateral movement of water through the landscape. May occur over the surface (surface run-off or overland flow) or above a less permeable layer in the soil (interflow). The term also refers to surface water flow in streams.
Saline agriculture	-	a salinity management strategy that encourages productive use of land that has been affected by saline discharge.
Soil water storage capacity	-	the capacity of soil to hold and retain water for use by vegetation rather than allow it to leak to the water table. Storage capacity is greatest in deeper and heavier (more clayey) soils and least in shallow and lightly textured (more sandy) soils.
Solar energy	-	energy provided by light from the sun. This is the main source of energy driving evaporation and plant growth.
Stand density	-	the density of trees in plantation or woodland.
Timberbelt	-	a plantation established for timber production whose width is greatly exceeded by its length. Width may vary from a few rows of trees (e.g. alley farming) to 50-100 m (e.g. break of slope forestry).
Transpiration	-	evaporation of water from plant foliage. Water passes from inside the leaves to the atmosphere via pores (stomata) on the leaf surfaces. Often termed plant water use.
Warm season vegetation	-	vegetation whose period of most active growth extends over the warmer months of the year, typically from mid-late spring to autumn. Growth of some warm season plants may be curtailed by lack of soil water in some years.
Water balance	-	a term describing the movement of water through landscapes. It refers to the fact that inputs of water to a landscape as rain (or snow) must be balanced by either losses (as evaporation, run-off and deep drainage or recharge) or a change in storage (soil profile filling with or emptying of water).

Water table	-	the uppermost surface of complete water saturation. Below the water table surface, all pores, cracks or openings are filled with groundwater. The depth of the water table is a function of geology, topography, climate, plant cover and land use.