PRINCIPLES OF SUSTAINABLE AGRICULTURE

DRYLAND SALINITY

– EARLY INDICATORS & CONTROL MEASURES –

Department of Food and Agriculture

Conservation & Environment

National Soil Conservation Program

The year 1990 was the Year of Landcare and the beginning of the Decade of Landcare, with its focus on soil degradation.

As part of this initiative, the Federal government, through the National Soil Conservation Program (NSCP), is supporting this booklet, the fourth in a series outlining the principles of rational and sustainable agriculture.

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4. DRYLAND SALINITY

- EARLY INDICATORS

AND

- CONTROL MEASURES

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DRYLAND SALINITY

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AND
- CONTROL MEASURES

Contents

Foreword

By the Hon. Ian Baker, Victorian Minister for Agriculture

Salinity is one of the most pressing environmental problems facing Victoria, but one which is increasingly being controlled through the efforts of landholders and community groups assisted by government agencies.

This booklet presents a clear overview of what dryland salinity is, why is has become a problem and how it can be overcome. Written in a clear and easily understood way, it outlines some of the processes controlling water balance in different parts of Victoria and shows how these can effect the optimum management strategy for each region. It will assist land managers and their advisers in developing sustainable farming systems and will also be useful for the general community to gain a better insight into the dryland salinity issue.

INTRODUCTION

Salinity is the term which describes the accumulation of salt in soil and water. Often described as the states' greatest environmental threat, salinity is costing Victoria over $60 million a year in lost agricultural production. More than 300,000 ha (about 2% of agricultural land in Victoria) is salt affected. The rate at which salinity is spreading is not exactly known, although a rate of 2% a year is often quoted.

Salinity is spreading in many parts of Victoria.

DRYLAND SALTING

Widespread clearing of deep rooted native vegetation and its replacement with shallow rooted species under European style management practices, have allowed more water to enter the subsoil. As the water moves through the soil and material beneath, it dissolves stored salt which is carried to the underlying groundwater. This process increases the salt content of groundwater and the extra volume of water raises the groundwater level (watertable) closer to the surface. Land areas where water moves through the subsoil and adds to groundwater are called recharge areas.

Recharge area – water enters groundwater up slope
Discharge area – groundwater discharged at soil surface downslope.

As saline groundwater moves up towards the plant root zone, salt retards plant growth. Water moves upward from the watertable through fine air spaces in the soil leaving salt crystals in the topsoil as water evaporates from the surface. Groundwater levels fluctuate seasonally and yearly, depending on the amount of water entering the soil. After wet years, the watertable may rise 1.0 - 1.5 m and cause salt patches to spread or create new areas of salt affected land. Eventually, groundwater reaches the surface in low lying areas and saline water may emerge as a permanent seep or flow. These areas are called discharge zones.

Land in which groundwater is discharged at the soil surface is called a discharge area.

Saline groundwater discharge in Victorian dryland areas affects about 150,000 ha and degrades the water quality of hundreds of streams.

Man's activities have altered the natural water balance of many catchments. In stable catchments, water inputs (i.e. rainfall) equals water outputs (i.e. surface/subsurface runoff, evaporation and plant water use). Clearing native vegetation has reduced plant water use resulting in inputs to the groundwater system being greater than outputs. In response, groundwater discharge (causing salinity) is increasing and will continue to increase until a new equilibrium is achieved (i.e. when outputs equal the new level of inputs). Therefore the focus of controlling dryland salinity is to devise new farming systems which are profitable and which reduce recharge to groundwater by using more water.

EFFECTS

Salinity causes large production losses. When saline groundwater comes into contact with plant roots it affects plant growth in a number of ways:

i. Robbing the Plants of Water

Salt attracts water and thus competes with plant roots for vital soil moisture. So although an area may look quite wet the salt out competes plants and they suffer from lack of water.

One of the ways in which plants have adapted to salty conditions (such as saltbush) is the ability to extract more water out of salty soils.

ii. Toxicity of Particular Elements

Too much of a certain element (e.g. Chloride, Sodium or Boron) inhibits plant growth and fruit production.

iii. Soil Structure Breakdown

Salting can also break down the structure of the soil resulting in less moisture and oxygen availability and reduced root development causing poor plant growth.

A sodic, or dispersal soil (soil containing sufficient sodium attached to clay particles to adversely affect soil stability and plant growth) turns into a sticky slurry when wet and "cakes" or sets hard when dry. When dry the soil surface can easily be broken up into a loose powder by stock or machinery, making it prone to wind erosion.

"Caking" and "crusting" may also cause the soil surface to seal making seed germination very difficult.

IDENTIFYING SALINITY

The best indicator of soil salinity is the presence of salt tolerant plant species. Salinity can also be identified by soil (electronic conductivity) measurements and the observation of plant and soil behaviour, however these indicators vary seasonally. Plant indicator species have been used to successfully identify and map salinity throughout many regions of Victoria.

Salty land is categorised into one of three classes ranging from 1 (mild salinity) to 3 (severe). The following "type" descriptions of mild, moderate and severe salinity are adapted from Matters, J. and Bonzon, J. (1989) "Spotting Soil Salinity - A Victorian Guide to salt indicator plants."

Class 1 salting on pasture.

Class 1.
Mild salting (soil salinity 600-900 micro Siemens/cm^{-1})

Low level salting can be very hard to identity. Early recognition of soil salting is crucial. The earlier a salt problem is recognised, the quicker action can be taken to rectify the problem.

Signs of mild salting include:-

- Isolated or scattered areas of patchy growth, particularly in pasture areas and seeps along a break of a slope.
- Reduced vigour or stunting in improved pasture or crop species.
- Productive annual or perennial species, including clovers begin to die out and are replaced by plants with a higher salt tolerance such as, Sea Barley Grass, Swamp Couch and Wimmera Rye Grass.

Swamp Couch grass

Class 1 salting is often an early warning of a potentially larger problem.

Class 2 salting – identified by scattered bare patches.

Class 2.
Moderate salting (soil salinity 900-1700 micro Siemens/cm^{-1})

Signs include:-

- Class 1 plant species disappear and are replaced by others with higher salt tolerance. e.g. Australian Salt Grass, Ruby Saltbush, Water Buttons, Ice Plant and Spiny Rush.
- Salt stains are visible when soil surface is dry.
- Affected areas may occur as "scalds" when exposed by heavy grazing on flats, or as seeps at breaks of slopes.
- Affected areas may worsen after high seasonal rainfall.
- Some species show marked changes in leaf colour and shape due to salt stress.

Spiny Rush

Water buttons

Class 3 – only highly salt tolerant plants present.

Class 3.
Severe salting (>1700 micro Siemens/cm^{-1})

Signs include:-

- Only highly salt tolerant plants such as Beaded Glasswort, Samphire and Rounded Noon Flower are present.
- Large areas of exposed ground.
- Trees will be dead or dying.
- Often only two or three plant species will dominate such an area.

Samphire

Rounded Noon Flower

MEASURING SALINITY

Salts in Water

The salt content of solutions is determined by the amount of dissolved salts usually expressed as parts per million (ppm) or milligrams per litre (mgL^{-1}) or milligrams per kilogram ($mgkg^{-1}$). The most accurate method of measurement is to take a sample of the solution, dry it and weight the salts that remain. This procedure however, is slow and cumbersome and it is simpler and quicker to measure the ability of the solution to conduct electricity, a characteristic which has been shown to be related to the amount of salt in solution. The electrical conductivity, (EC) is measured by means of a conductivity meter and units are expressed in deciSiemens per meter ($dS\ m^{-1}$) although micro Siemens per centimetre ($uS\ cm^{-1}$) is often used.

$$1\ dS\ m^{-1} = 1000\ uS\ cm^{-1}$$

The relationship between soluble salts (TSS) in solution and EC varies with the concentration and proportion of individual ions, however a general approximation is that:

$$\text{Total Soluble Salts (ppm or } mgL^{-1} \text{ or } mgkg^{-1})$$
$$= \text{EC } (dS\ m^{-1} \text{ at } 25^{o}C) \text{ times } 600$$
$$\text{thus } 100 \text{ ppm} = 1.56 \text{ ds } m^{-1}$$

The relationship between Total Soluble Salts (ppm) and EC varies according to the concentration and proportion of individual ions, however the general approximation is the:

$$\text{EC } (dS\ m^{-1}) = \text{ppm} \times 600\ (1.56\ dS\ m^{-1} = 1000 \text{ ppm})$$

or $$\text{EC } (uS\ cm^{-1} = \text{ppm} \times 0.6\ (1560\ uS\ cm^{-1} = 1000 \text{ ppm})$$

Salts in Soil

Sampling the Soil

Soil salinity is extremely variable and many samples should be taken to ensure that a representative measurement is obtained. These should be collected from both salinised and unaffected areas for comparison. If a number of soil types occur in the sampling area, each should be sampled and measured separately and adequately. There are two main laboratory methods used to determine the EC of soils, the saturation extract and 1:5 soil water extract.

Saturation Extract

This method involves adding distilled water to the soil while stirring until a characteristic sticky point is reached. A suction filter is then used to extract a sufficient amount of water to perform a conductivity measurement. The advantage of this method for measuring salinity is that it is related to the water holding capacity of the soil and thus is representative of what a plant root would actually experience. Hence EC determined in a saturated extract is a good measure of a soils' salinity and its likely effect on plant growth.

The method unfortunately is tedious and time consuming to carry out.

Soil Suspension

A more rapid and commonly used measure of soil salinity is the conductivity of a 1:5 soil-water extract. This technique consists of mixing one part (by weight) of the dried soil sample, with five parts (by volume) of distilled water and shaking for 1 hour. The soil is settled out and the resulting solution measured.

While this is a quick and simple technique it does not take into account the effects of soil texture. It is therefore inappropriate to compare the readings from two different soil types.

In addition the effect of soil grinding and the addition of large amounts of water during sample preparation can bring more salt into the solution which would otherwise remain undissolved. For example, over-estimation of the effect on crops is very likely in soils where significant gypsum is present. This method is therefore subject to greater errors than the saturation technique.

It is however possible to approximately relate the conductivity of a 1:5 soil-water extract to that of the saturation extract and predict likely effects on plant growth (Table 1), and the ease of this method means that it is the most common way of assessing soil salinity.

Other Methods

Soil salinity may also be measured indirectly in the field by methods such as electromagnetic induction (EM) or time domain reflectometry

(TDR). These methods involve the use of magnetic fields and radar respectively and have the advantage that they are non destructive and allow rapid measurements to be made. However, the amount of water in the soil and the conductive capacity of clay can effect EM readings and actual measurements of soil salinity must be made to calibrate the equipment. TDR is relatively new technology used to measure volumetric soil water content. While it is virtually unaffected by soil properties such as bulk density in the measurement of soil water, it can also measure EC, but requires specific soil type calibration.

Table 1. Conductivities of 1:5 and saturated soil extracts at which 10% yield reductions occur for plants of varying salt tolerance.

Plant Salt Tolerance	Soil Salinity Rating	Saturated Extract EC_{sat} (dS m^{-1})	1:5 Soil/Water Extract EC (dS m^{-1}) Soil Texture			
			Sand	Sandy Loam	Silt Loam	Clay
Sensitive						
eg. Field Peas	Very low	<0.95	0.008	0.03	0.08	0.19
Moderately Sensitive						
eg. Lucerne Faba beans Sunflower	Low	0.95- 1.9	.008-.02	.03-.06	.08-.15	.19-.38
Moderately tolerant						
eg. Wheat Oats Safflower	Medium	1.9- 4.5	.02-.04	.06-.14	.15-.36	.38-.90
Tolerant						
eg. Triticale Wheat (semi-dwarf) Barley	High	4.5- 7.7	.04-.06	.14-.25	.36-.62	.90-1.54
Very tolerant						
eg Barley grass	Very high	7.7-12.2	.06-.10	.25-.39	.62-.98	1.54-2.44
Extremely tolerant						
eg. Salt bush Glassworts	Extreme	>12.2	>0.10	>0.39	>0.98	>2.44

Note: Actual plant response is influenced by the soil, rainfall, management and the distribution and composition of soluble salts in the soil profile.

Salts in Water

The salinity of water also varies and should be sampled carefully. Water samples are tested directly with a conductivity meter. The Electrical Conductivity of water determines how it is used (see table 2).

Table 2. Water Quality Standards

Conductivity d S/m	Use
0 - 0.8	• Good drinking water for humans (provided there is no organic pollution and not too much suspended clay material). • Generally good for irrigation, although above .3 dS/m some care must be taken, particularly with overhead sprinklers which may cause leaf scorch on some salt sensitive plants. • Suitable for all livestock.
0.8 - 2.5	• Can be consumed by humans, although people would prefer water in the lower half of this range. • When used for irrigation, requires special management including suitable soils, good drainage and consideration of salt tolerance of plants. • Suitable for all livestock.
2.5 - 10	• Not recommended for human consumption, although water up to 3.0 d S/m could be drunk if nothing else was available. • Not normally suitable for irrigation, although water up to 6.0 dS/m can be used on very salt tolerant crops with special management techniques. Over 6.0 d S/m, occasional emergency irrigation may be possible with care or, if sufficient low salinity water is available, this could be mixed with the high salinity water to obtain an acceptable supply. • When used for drinking water by poultry and pigs, the salinity should be limited to about 6.0 d S/m. Most other livestock can use water up to 10 d S/m.
over 10	• Not suitable for human consumption or irrigation. • Not suitable for poultry, pigs or any lactating animals, but beef cattle can use water to 17 d S/m and adult sheep on dry feed can tolerate 23 d S/m. However, it is possible that waters at or below those levels could contain unacceptable concentrations of toxic compounds. Detailed chemical analysis should therefore be considered before using high salinity water for stock. • Water up to 50 d S/m (the salinity of the sea) can be used to flush toilets provided corrosion in the cistern can be controlled, and for making concrete provided the reinforcement is well covered.

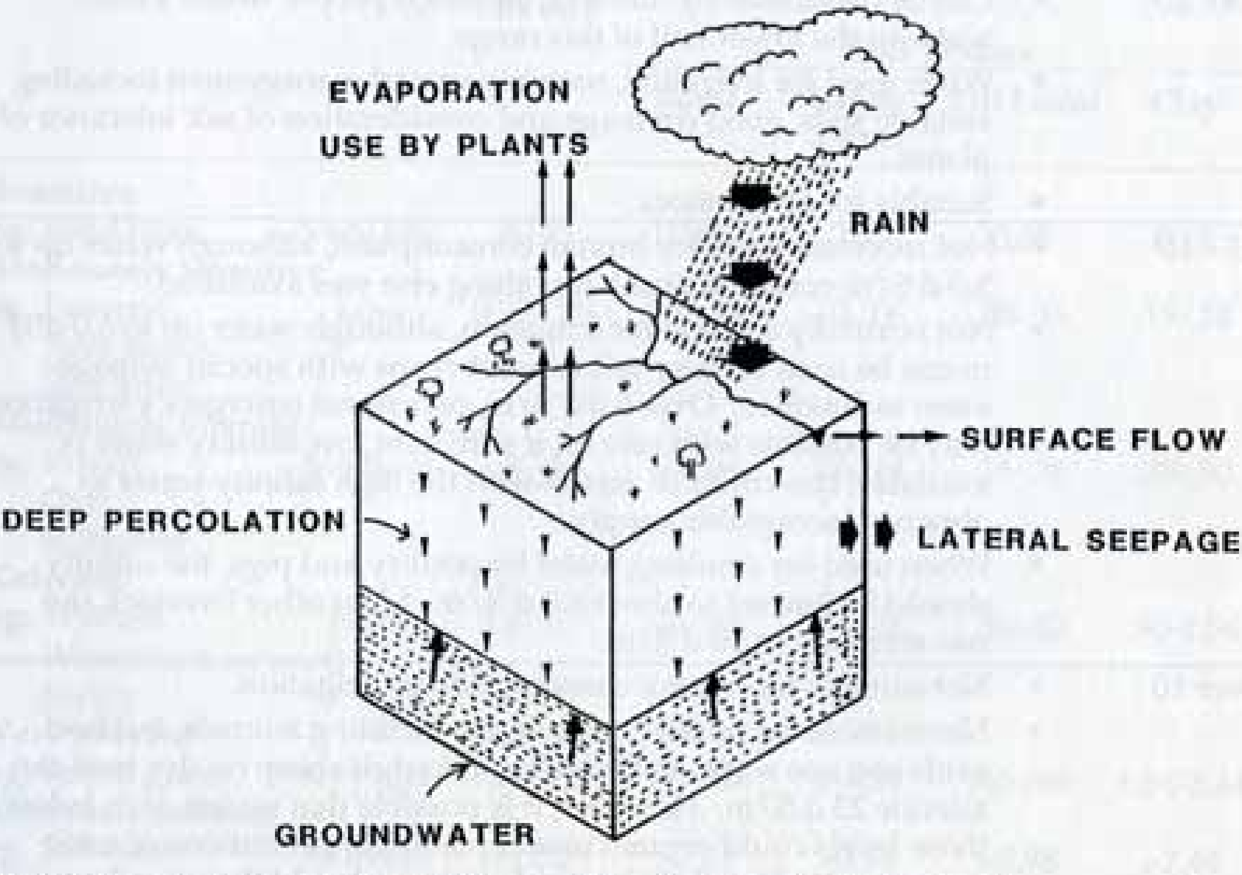
CONTROLLING SALINITY

There is a range of measures which can control salinity, but it is important to understand the peculiarities of each situation (eg. topography, climate, geology) so that the most effective methods are used. In this section, the principles which underlie salinity are explained and illustrated with selected examples:

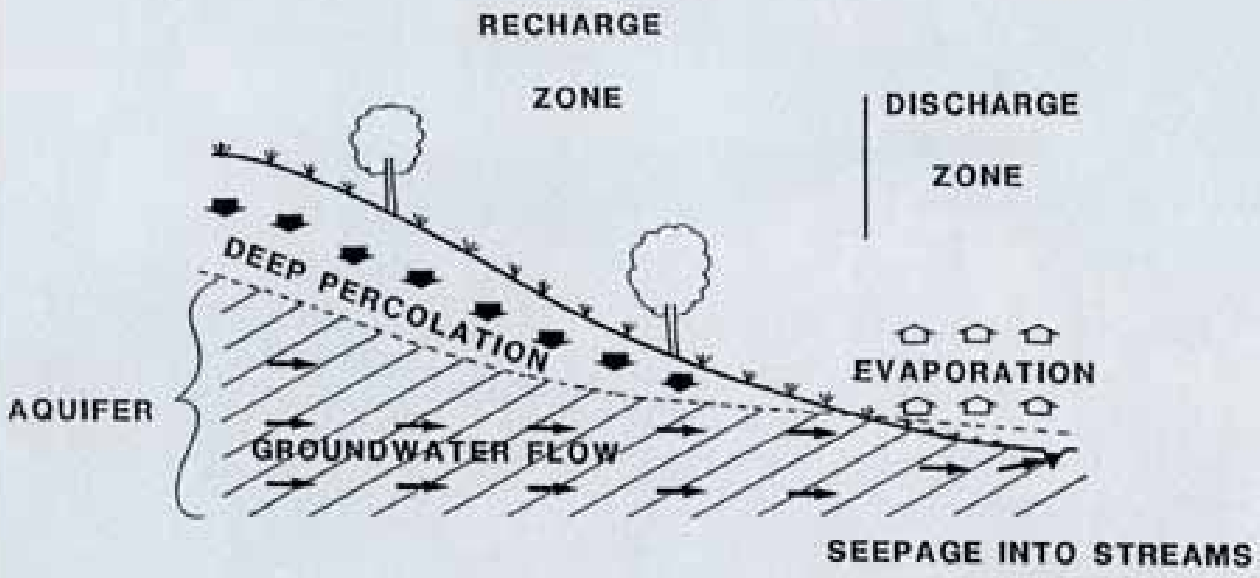
Water Balance - The Key to Controlling Salinity

For any given piece of land, there is a water balance made up of:

- Inputs - usually as rainfall, but sometimes as seepage from channels, irrigation etc.
- Water use - water evaporates from the soil and is used by plants.
- Sideways movement of water either on the surface or in the soil.
- Deep percolation to underlying groundwater.



If a groundwater system is in equilibrium and stable, the inputs to the groundwater are balanced by evaporation in discharge zones and seepage of the groundwater into streams.



Note: Water only flows downhill, so a slope or pressure gradient develops in the groundwater. How steep this is depends on the ease with which water can flow through the soil, and on the amount of water moving. Soil which allows water to move within it is called an aquifer, and the ease with which water flows through it is called the permeability of the aquifer.

In Victoria, the level of inputs to groundwaters has increased as forests and scrub (which use large amounts of water) were replaced with grasses and crops (which use less water). Accordingly, groundwater levels throughout the state are rising and the discharge areas are increasing in size. Eventually, a new equilibrium will be established in which evaporation and seepage in the discharge zones balances groundwater inputs and, it is this growth in the area of discharge zones and increased saline seepage into streams which makes up the salinity problem.

The challenge is to devise new farming systems which are profitable, and which reduce recharge to groundwaters. Failing this, management of discharge zones must take place to minimise land degradation, loss of productivity and salinisation of streams.

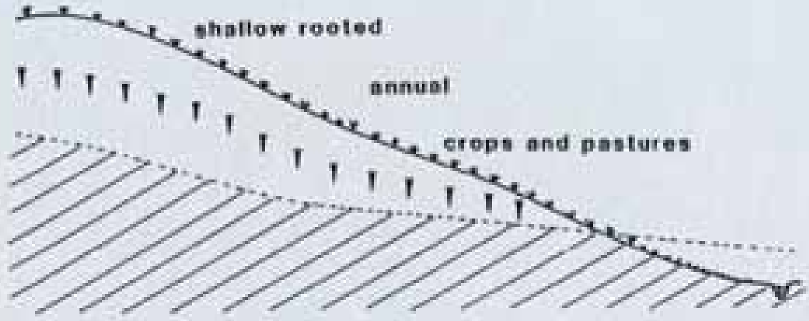
Saline groundwater seeping into a stream near Coleraine, South West Victoria.

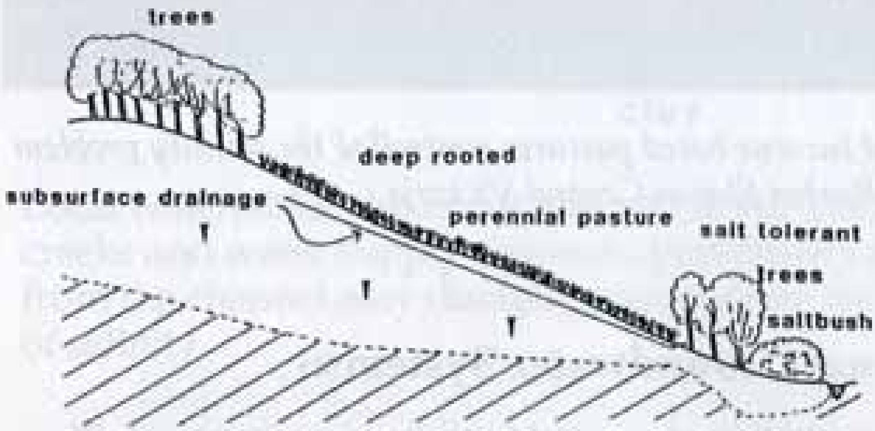
In order to tackle salinity, it is important to understand the extent of the underlying groundwater system. A few simple pointers will help determine whether the groundwater system is local or regional.

Local Groundwater Systems:-

- Are contained within the immediate catchment of the salt affected site.
- Groundwater levels follow surface topography.
- Surface discharge occurs at the break of slope and in low lying areas.
- Do not allow large volumes of water to move very far.
- Commonly occur in deeply weathered, fractured bedrock around the fringes of major highlands.
- Are found in only 20% of dryland of Victoria.
- Groundwater recharge occurs in relatively small, identifiable areas.
- Perched watertables.
- Salinity associated with man made structures (e.g. channels, lakes, dams, etc.)

Restoration of the water balance is relatively easy in these systems because the groundwater is only recharged within the immediate catchment and because the aquifer permeability is low. This latter property means it is possible to lower the watertable (for example under a group of trees) without having to deal with a large inflow from surrounding areas.





One example of this is the Burkes Flat Salinity Control Project which comprises a small catchment (872 ha) that has been totally treated by the landholders (i.e. trees on rocky ridges, perennial pasture on midslopes and salt tolerant pasture species on salt affected land - see control options). In less than 10 years, the watertable under the treated catchment has fallen between two and five metres while the watertable nearby in an untreated area has continued to rise.

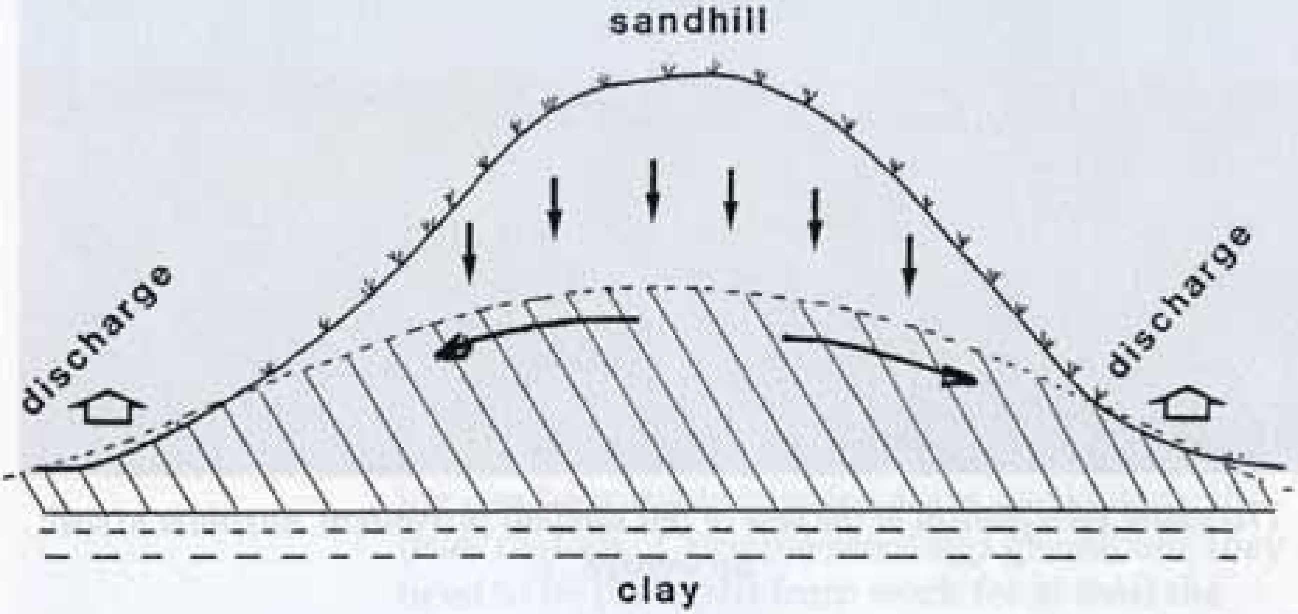
Burkes Flat – Salinity control undertaken by local landholders.

Strategic tree planting and lucerne based pastures controlled the salinity problem at Burkes Flat in Central Victoria.

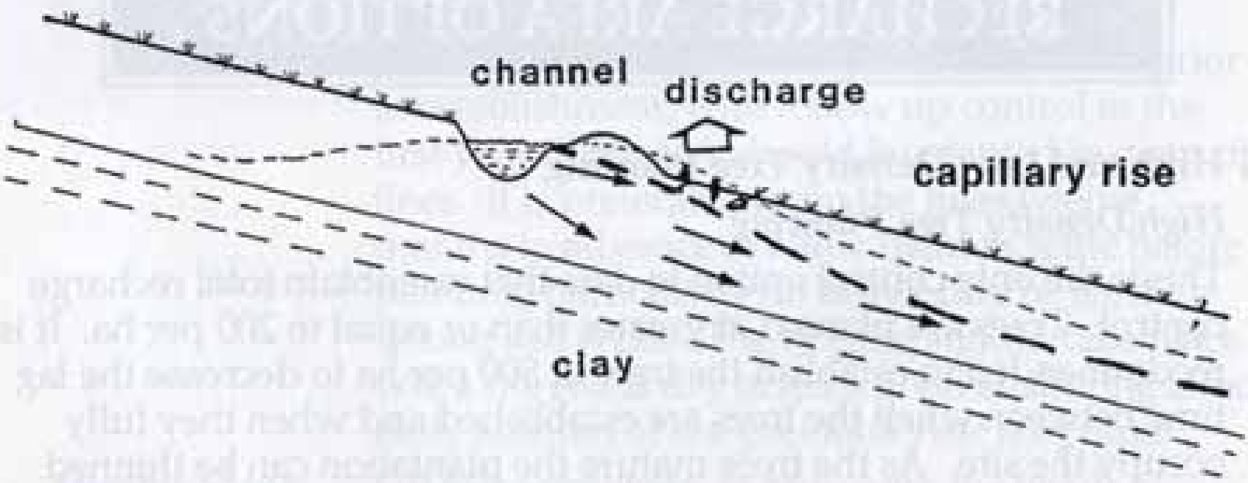
Regional Groundwater Systems:-

- May underlie several catchments and the discharge (salinity) may be many kilometres away from recharge areas in different surface water catchments, i.e. catchment divides do not necessarily correspond with groundwater divides.
- Surface discharge is located in low lying areas where gently sloping regional groundwater intersects the land surface.
- Are continuous over large areas.
- Large volumes of water are transported over great distances.
- Are commonly associated with large unconsolidated sedimentary basins e.g. Murray-Darling Basin.
- Groundwater recharge is often evenly distributed over a large area.

Isolated local watertables are often "perched" above regional groundwater systems. These occur where infiltrating water encounters less permeable layers. Water flows along the top of the layer and usually discharges near the base of the slope. Perched watertables result in salinity in many regions, particularly the Mallee dunefields, lunettes (crescent shaped clay dunes) and the Wimmera Plains. Fresh water seeps in large sand dunes are also due to perching.



Local watertables also occur adjacent to surface water sources such as creeks and water supply channels, particularly in sandy soils. Water from the channel may discharge downslope and result in linear patches of salinity.



Trees have been planted at the base of this sandhill in Western Australia to soak up seepage.

Regional groundwater systems however, threaten much larger areas of land and therefore planning which includes alteration of land management practices to use more water on a regional scale, needs to be undertaken now to minimise future loss.

RECHARGE AREA OPTIONS

i. High and Low Density Tree Planting

High Density Tree Planting

This is the only control option to date that can obtain total recharge control. Trees are planted at greater than or equal to 200 per ha. It is recommended to establish the trees at 500 per ha to decrease the lag time between when the trees are established and when they fully occupy the site. As the trees mature the plantation can be thinned.

Species generally recommended are those that were originally found in the area.

Establishment:	There are three methods, direct seeding, planting out tubed stock and natural regeneration.
Direct Seeding:	Direct seeding requires specific recommendations for any one site.
Preparation:	Good weed control is essential, whether it be mechanical or chemical. Weed control should start in the spring prior to the year of establishment. Germination rates can be increased by some form of seedbed preparation, however successful establishment is possible without soil disturbance. Deep ripping in high recharge rocky areas is not recommended as it provides a poor seedbed.
Time of sowing:	Time of sowing is site dependent, however spring sowing in August or September appears to be more successful due to higher soil temperatures coupled with available moisture. Autumn sowing can be suitable in some areas particularly the drier regions. Once the seedlings germinate, they need to be protected from stock for at least the first two or three years.
Maintenance:	Some follow up weed control may be necessary, as it is preferable to keep the immediate area around the seedlings weed free in the first year.

Planting out Tubed Stock

Preparation:	Good pre-planting weed control is essential, preferably starting in the spring of the year prior to establishment, with follow up control in the first year. The trees should be planted in deep rip lines. It is preferable to rip the lines twelve months in advance to allow them to settle before planting, particularly on heavy clay or hard setting soil types. The ripping should take place when the soil is dry to get a good shattering affect, early autumn of the previous year is optimal.
Time of sowing:	On recharge areas, in May with the break.
Maintenance:	Trees need to be adequately guarded from rabbits

and hares for the first year or two. They need to be protected from stock for the first two to five years depending on the rate of growth. Sheep can graze amongst the trees once they have reached 1.5 - 2 metres and cattle when the trees are 2.5 - 3 metres or more.

Natural Regeneration

This is a quick and cost effective method of tree establishment that makes use of existing remnant vegetation.

Preparation: The remnant tree or trees need to be fenced out with a greater area being left on the opposite side to the prevailing winds. Spray the fenced out area in the early spring. Seedlings will then appear naturally. Leave them to establish for one or two years before thinning out to a particular density, if required.

Low Density Tree Planting

Approximately 20 trees per ha (regularly spaced). The recommended process for tree establishment is as above, i.e. hand planting tube stock, open root stock with individual tree guards.

Trees are used to lower watertables.

This method is recommended for use in conjunction with perennial pasture establishment or modifications in cropping practices. The advantage of this method is that the trees can be strategically placed where pasture or crop establishment is poor, but where recharge is still high, e.g. where there is a large percentage of rock on the surface. They also compliment a grazing system by cutting down the energy requirement of stock by providing shade and shelter. Low density tree planting may also be an effective long term recharge control treatment with unimproved pastures in areas which are not suited to perennial pastures.

ii. Introduction of Perennial Pastures

Lucerne and Phalaris are recognised as the most successful species for recharge control.

Preparation:	Good weed control is essential. This must be planned and undertaken in the year prior to sowing. The following methods may be considered:– spray topping in the spring before sowing, cropping the area before pasture establishment and establishing the pasture under crop.
Time of Sowing:	Phalaris and lucerne can be successfully established from both spring and autumn sowing. The time of sowing is area and season specific, the decision being entirely dependent upon seasonal rainfall, the water holding potential of the soil type and the likelihood of follow up rains. In general, areas with soil types that have a low water holding potential and lower seasonal rainfall e.g. Northern Wimmera and Mallee light soils, autumn sowing with the break is recommended; and those areas with a higher seasonal rainfall and with soil types with a higher water holding potential, e.g. the grey self mulching clays, or areas that trend to be prone to some winter waterlogging, spring sowing may be the better option.

Lucerne

Requirements:	Well drained neutral to alkaline soils, (pH 6 to 8),weed free in the first year.
Preparation:	If the soil type is moderately acidic, (pH 5.5 - 6.5), lime is required. This should be incorporated three to six months prior to sowing, the rate will vary depending on the situation. If red legged earth mite are present they must be controlled, pre and post sowing. Weed control is essential, they must be controlled and prevented from setting seed in the spring before sowing. A firm moist seed bed is preferable, rolling may be

required after sowing. The seed must be inoculated and lime coated.

Seeding Rate: One to two kg per hectare is the general recommendation, this rate may be increased in high rainfall areas, greater than 550 mm.

Fertiliser: The rate required is site specific, the general recommendation is 150 to 200 kg/ha of superphosphate with trace elements. The seed must not be sown with straight super but there are various options, e.g. Incorporate the super with the last working and sow the seed with lime, sow the seed with 1:1 lime/super, sow the seed with 1:1 mix at 200 kg/ha and topdress after sowing with 200 kg of superphosphate and trace elements.

Method: It is preferable to direct drill the seed into a firm moist, well prepared seedbed at a depth of between 10 and 20 mm depending on soil type, e.g. clay soils, 10 mm.

Lucerne planted adjacent to discharge area.

Maintenance: Annual top dressing should be applied at rates which will be site specific, anything up to 250 kg/ha. Grass weeds need to be controlled, one method is to use the product "Sprayseed"® and spray top in the spring. Another is to lightly graze the lucerne during the autumn period leaving large, strong plants to outcompete the germinating weeds. The lucerne should be checked for the following insect pests, particularly in the first year: spotted alfalfa aphid, Red legged earth mite, Sitona weevil, Cut worms, Lucerne flea, Blue green aphid, Pea aphid and White fringed weevil.

Management: The general recommendation is to refrain from grazing the lucerne during the first twelve months of establishment and allow it to flower. However carefully managed rotational grazing in the first year has been successful in some areas, whilst still allowing the plants to flower in the spring. Once the lucerne has established it requires rotational grazing. Six weeks on six weeks off is a standard rotation.

Phalaris

Phalaris grows on a wide range of soil types, in areas of both low (350 mm) to high (750 mm) rainfall and will tolerate a broad range of soil pH. They are most productive on areas which have rainfall greater than 400 mm with heavier soil types and cooler summer temperatures, however these are by no means prerequisites.

Phallaris established on hillside discharge area.

Preparation: Phalaris requires very good weed control prior to sowing. This can be achieved by spraying or spray topping in the previous spring or by cultivation. Red legged earth mite if present must be controlled before and after sowing.

Seeding Rate: One to three kg/ha. Phalaris does not tolerate competition from other grass species. It can be sown with a clover mix and cocksfoot mix but never with Rye grass.

Fertiliser: As phalaris grows over a wide variety of areas its fertiliser requirements vary accordingly. Rates of approximately 150 kg/ha are generally required and trace elements must be applied if needed for clovers.

Method: There are several methods of phalaris establishment all of which are site specific. Pre-sowing weed control, adequate application of fertiliser and the allowance of a suitable period of establishment is the key to success in all cases.

i. Areas that are too steep for conventional sowing equipment.

These areas can be sown by bulldozer. A trickle box drops seed into rip lines made by the bulldozer. Fertiliser and weed control is carried out by plane. Weed control should take place in the spring before sowing. Sowing should take place in the months of July/August.

Aerial Sowing: It is generally more successful on higher rainfall areas, greater than 500 mm. Soil moisture content is critical as failures will occur if the topsoil dries out whilst the seed is germinating. High levels of soil fertility are required, it is preferable to have built the level up by annual topdressings in the years prior to sowing, ten years is optimal. July is generally the recommended month for sowing, as good soil moisture and follow up rains are essential. With the good fertility weeds proliferate, these weeds are then knocked down by spraying and provide a mulch for the germinating phalaris.

ii. Areas that are too steep to crop but can still be accessed by tractor.

These areas are suitable for direct drilling by a specialised direct drill pasture seeders. The area must be weed free. The seed is direct drilled with no prior cultivation. The months of July and August are generally recommended.

iii. Areas that are physically suitable for cropping.

Phalaris can be established independently or under a cover crop. A successful strike is more likely if sown independently with good weed control. However stands can be successful established under crop if the following is adhered to. The normal seeding rate of the crop must be approximately halved. Crops with less flag achieve more successful pasture strikes and establishment as more light can reach the developing pasture plants. Barley is the most commonly recommended. Preparation is as for normal cropping practices and good weed control prior to sowing is essential. It is important that the stubble is not grazed to allow the pasture to establish. The first grazing should take place in the autumn of the following year.

Further detailed information on pasture establishment methods and management use are in the booklet "Pasture Improvement in Victoria". Contact Bob Chaffey, VIDA, Private Bag 260, Horsham, or your local Department of Food and Agriculture office.

iii. Cropping

Healthy, well managed, high yielding crops use more water than poor crops, and so it follows that recharge is less. Well managed crops are also more profitable. Particular attention should be given to controlling root diseases as this ensures a healthy root system which will penetrate deep into the soil. In most cases, this is achieved by sound rotation practices which alternate grass and non-grass crops. Adequate soil fertility is essential for vigorous crop growth and a dense canopy which in turn ensures better water use and crop production. Earlier sowing of crops will cause only slightly increased water use during autumn and winter, but results in higher yields in most districts, the main exceptions being cereal and field pea crops in the Wimmera.

Long fallows (begun in the winter prior to the crop) are common in the Wimmera and Mallee districts. This practice results in increased recharge in the Mallee soils as water passes beyond the root zone of subsequent crops. It is preferable (and more profitable) to substitute a grain legume for the fallow in this area. Wimmera soils by contrast are of heavier texture and can store larger amounts of water within reach of crop roots. In this case, fallowing only results in a small increase in recharge, and has a role in stabilising farmers' incomes against drought. Highest profits (plus risk) still occurs with continuous cropping in the Wimmera.

Later maturing crops (e.g. safflower, linseed) and cultivars will use more water if it is available. In many situations however, the crops are limited by water supply and the use of later maturing varieties will result in lower yields.

iv. Tile Drainage

Large parts of south-west Victoria, Gippsland and north-east Victoria regularly suffer from waterlogging resulting in lower production, less profits and land degradation. Drainage prevents waterlogging and allows new enterprises and management systems to be implemented. Tile drainage is a proven and widely accepted technology in most parts of the world, and is now becoming part of farming in Victoria. Research by the Department of Food and Agriculture at the Pastoral Research Institute, Hamilton has shown that drainage increased wheat and triticale yields some three tonnes per hectare, and that lucerne could be grown successfully. More then 70,000 metres of underground drains have been installed commercially over the last five years with good results being achieved.

Table 3. Effect of Drainage at Hamilton, 1986 - 90

Yield (t/ha)	Triticale 1986/87	Lucerne 1986/87	1987/88	Wheat 1988/89	Wheat 1989/90	Lucerne 7/7 - 29/7
Drained	4.6	5.6	Fallow	4.0	4.5	6.8
Undrained	1.7	2.4	Fallow	1.4	1.0	2.1
LSD (P<5%)	1.6	-	Fallow	2.0	0.4	-

Foreground – improved production through underground drainage.

Underground drains typically consist of flexible, perforated plastic pipe placed about one metre deep in the soil with 10 to 50 cm of permeable fill (usually gravel) placed around and above the pipe. While some soils can be drained by a grid of drains, others require additional treatments such as moling or subsoiling to facilitate the flow of water to the pipes. Pipe sizes and spacings are calculated using drainage theory developed overseas and adapted to Australian conditions.

Recharge to saline groundwaters is also reduced by drainage. At Coleraine, Victoria, research has shown that drains were removing 50 percent of excess water and watertables have now fallen one to two metres due to the combined effects of drainage and improved management (the areas has been sown to lucerne). The quality of discharge water is very good where recharge areas are drained. Where salt affected ground has been drained water quality is lower but experiments to date suggest there is no increased salt exported from drained areas.

Tile drainage is an additional weapon in the armoury against salinity. It should not be viewed in isolation, but included along with tree planting, perennial pastures and so on in an integrated approach to the problem.

The cost of drainage can be recouped quite quickly by several cash crops and the long life time of properly installed systems means that returns on this type of investment is high. Drained land can be put to a variety of uses giving farmers more options to deal with fluctuations in the prices of particular commodities. All this suggests drainage is going to become more widely accepted and practiced throughout Victoria in the future.

DISCHARGE AREA OPTIONS

Salt Tolerant Trees

Trees are sometimes recommended for planting around saline discharge areas because of their high water using potential and the ability of some species to tolerate high levels of salinity. If planted around the edge of a salt affected site its rate of spread can be halted or restricted as the tree belt can cause a localised drop in the watertable. Note, though, that the trees used, should be salt tolerant and should only be planted **around** the edge of a saline seep and never actually on it, or substantial tree deaths will occur.

Tree belts planted on the upslope side of channel seepage or small localised discharge sites may rectify the problem entirely.

Methods of Establishment: As for recharge areas. Tubed stock plantings are generally favoured as the tree belt can be accurately placed. Five metre spacings with at least two rows five metres apart are recommended.

Preparation: As for recharge areas. If the site is susceptible to water-logging or periodic inundation, spring planting is recommended. Mounding or hilling the soil for seedlings may be useful.

Recommended Species: The preferred species is the Albacutya Red Gum, because of its ease of establishment, growth rate, high water using ability and salt tolerance. However, a range of species may be considered as tree belts planted primarily for salinity control may be used for additional purposes eg. firewood production, stock and shelter, wildlife habitat and post cutting, the species should be selected accordingly.

The following is a range of recommended species and the degree of salinity they will tolerate. However, as salinity levels increase tree growth rates and survival rate will decrease.

Class 1 areas - eg. Good cover of Sea Barley Grass.

Albacutya River Red Gum, Black Box, Salt River Gum, Swamp Yate, Swamp Mallet, Kangaroo Paperbark, Moonah (Dogwood), Cross Leaf Honey Myrtle (Totem Poles), Scented Paperbark, Swamp Paperbark, River Sheoke, Grey Buloke, Buloke (Allocasuarina leuhmannii), Scarlet Bottlebrush.

Sea Barley Grass

Class 2 areas - eg. Patchy Sea Barley Grass and bare ground.

Albacutya River Red Gum, Swamp Yate, Swamp Mallet, Kangaroo Paperbark, Moonah, Grey Buloke, Swamp Paperbark, River Sheoke.

Class 3 areas - eg. Areas of predominantly bare ground with some patchy cover.

Kangaroo Paperbark.

SALT TOLERANT PERENNIAL PASTURES

Tall Wheat Grass

Suitable for Class 1, Class 2 and some lower level Class 3 areas.

Preparation: If annual species are present, the area will need to be spray topped in the spring prior to sowing. A shallow cultivation is required prior to sowing. If the area is bare of vegetation, then one cultivation is all that is required.

Sowing Time: Mid to late April with the break is optimal.

Tall wheat grass growing on salt affected land.

Sowing Depth: Shallow, approximately one centimetre.

Fertiliser: Sow with 100 kg of Pivot 15, or equivalent, and give an annual top-dressing of 50 kg. Once legumes re-appear switch the top-dressings to 90 kg of superphosphate.

Management: The area should not be grazed for eighteen months. Establishment can be quite slow in the first year, and it often appears as though germination has failed. In the second year, however, the stands thicken up.

Grazing needs to be monitored for the first couple of years to ensure stock do not graze out the plants' crowns. The stand should be kept down to a height of twelve centimetres. This will keep the stand fresh and palatable to stock and will ensure maximum water usage.

Puccinellia

Suitable for Class 1, Class 2 and some Class 3 areas.

Puccinellia's main role is to improve ground cover thereby reducing erosion and evaporation. It should be noted that its potential productivity is quite low when compared to other perennial pasture species.

Requirements:	Rainfall greater than 375 mm.
Preparation:	Weed control, if necessary. Sea Barley Grass must be removed if present. Spray topping in the spring prior to sowing is recommended. One shallow cultivation immediately prior to sowing is all that is required.
Sowing Time:	Mid to late April with the break.
Sowing Rate:	2 - 4 kg/ha.
Sowing Depth:	Very shallow, approximately 1-4 mm. Broadcasting the seed is suitable.
Fertiliser:	100 kg/ha Pivot 15 at sowing with 50 kg/ha annual top-dressings. Puccinellia shows little response to top-dressing with straight superphosphate.
Management:	Puccinellia requires an eighteen month establishment period, during which it must not be grazed. The stands may be set stocked or opportunity grazed. It is advantageous to remove stock at the end of August and allow the plants to set seed to thicken up the stand.

SALT TOLERANT ANNUAL PASTURES

The main benefit of salt tolerant annual pastures is in lifting production and maintaining vegetative cover on Class one discharge areas.

Balansa Clover

Suitable for Class one areas, e.g. areas with a good cover of Sea Barley Grass.

Requirements:	Rainfall greater than 450 mm. Ph 5.5 - 8.
Preparation:	Good weed control is essential and spray topping in the spring prior to sowing is recommended. A shallow cultivation prior to sowing is required. Harrowing may be necessary if the seed bed is rough.
Time of Sowing:	Early autumn with the first rain. Early sowings result in rapid growth as Balansa benefits from the higher soil temperature.
Sowing Rate:	5 kg per ha on salt affected areas. The

	seed requires inoculating particularly if no legumes are present.
Sowing Depth:	Shallow, approximately one centimetre.
Fertiliser:	100 kg per ha of superphosphate at sowing with annual top dressing of 50-100 kg per ha.
Management:	Red legged earthmite control is critical, prior to, during and after germination. Earthmite will destroy germinating Balansa seedlings.

Balansa can be grazed in the first year. To ensure maximum seed production and hence stand persistence, stock removal at flowering time in the first year is advisable. Once the seed heads have formed the site can be restocked. Records shows that stands persist better when continuously grazed rather than rotationally grazed.

Strawberry Clover

Suitable for Class one areas, e.g. areas with a good cover of Sea Barley Grass.

Requirements:	Rainfall of 500 mm or more. The seed may need inoculating if no legumes are present on the site.
Preparation:	As for Balansa clover.
Time of Sowing:	Autumn with the break is generally preferred on saline areas. Spring sowing may be suitable for some areas, such as those that have a large weed burden.
Sowing Rate:	3 kg per ha on salt affected areas.
Sowing Depth:	Direct drilled to 20 mm is optimal. Broadcasting may be considered and can be successful.
Fertiliser:	As for Balansa
Management:	Earthmite must be controlled, particularly at establishment. Close grazing helps control grass weeds. Strawberry clover responds well to set stocking.

SALTBUSH AND BLUEBUSH

Saltbush and Bluebush are halophytes or salt loving plants, which will establish under both saline or non saline conditions. Under saline conditions the choice of species is regulated by the purpose of the stand and site conditions such as the pH, level of salinity and incidence of waterlogging.

Saltbush – established on Class 1 discharge area.

A number of introduced and native Australian species (listed below) are being assessed for their survival and growth in Victorian conditions.

Common Name:	Scientific Name:
Bladder Saltbush	*(Atriplex vesicaria)*
Creeping Saltbush	*(A.semibaccata)*
Desert Saltbush	*(A.polycarpa)*
Fourwing Saltbush	*(A.canescens)*
North African Saltbush	*(A.halimus)*
Oldman Saltbush	*(A.nummularia cv'dekock')*
Oldman Saltbush	*(A.nummularia)*
Quail Brush	*(A.lentiformis)*
River Saltbush	*(A.amnicola)*
Wavyleaf Saltbush	*(A.undulata)*
Cotton Bluebush	*(Maireana aphylla)*
Gascoyne Bluebush	*(M.polypterygia)*
Small-leafed Bluebush	*(M.brevifolia)*

Salt tolerant plants like this may help reclaim badly affected areas.

Benefits

There are a number of benefits associated with the introduction of Saltbush and Bluebush to saline land, including:

- Increased total farm productivity by making better use of discharge.
- Reduction in supplementary feed costs and time and labour savings associated with feeding. Initial studies indicate that grazing would be of most benefit during the autumn and early winter when stubbles have deteriorated and annual pastures are at their lowest in quantity and quality. Utilisation of stands at this time will also allow the deferred grazing of pastures after the autumn break.
- Stands may be used for shelter for sheep off-shears or during lambing.
- Seed may be collected from single species stands for sale.
- Stands may be used as a drought fodder reserve.
- Improved year-round ground cover reduces erosion and watertable levels (although the extent is unknown).

The following notes provide a broad guideline of the establishment and management of Saltbush and Bluebush.

Establishment

- Acidic sites with pH levels less than 5.5 throughout the soil profile should be avoided.
- Care should be taken when selecting sites susceptible to waterlogging. Careful species selection will be required and mounding may be necessary.
- Shrubs will grow on most soil types although establishment appears to be much slower on heavy clay soils.
- Stands may be established by direct seeding or by transplanting seedlings grown from seed or cuttings.

  i. *Seed:*

  - Direct seeding is the cheapest establishment technique but complete failures often occur. Failures have been attributed to a range of factors including insect damage, weed competition, inadequate rainfall or flooding, seed quality, soil type and soil temperature at the time of sowing.

- Seed quality is highly variable ranging from 0 to 80 percent germination.
- Seeding is completed in autumn or spring using a specialised seeder (Kimseed Niche Seeder) which mounds the soil before dropping a seed/vermiculite mix at a set spacing. Mounding leaches the salts from the surface soil, providing a better environment for germination and seedling establishment.
- Seeding costs approximately $130 per ha (includes weed control, seed and vermiculite).

ii. Seedlings:

- Transplanting should be completed in spring into ground prepared the previous autumn with riplines.
- The site should be sprayed for weed control before planting and fenced to exclude stock during the 18 month establishment period, and thereafter to control grazing.
- Transplanting costs approximately $575 per ha (includes weed control and seedlings ($555 per ha).
- Red legged earth mite will damage both germinating and transplanted seedlings, and should be sprayed for control at the first signs.

Management

- An adequate fresh water supply is essential for stock grazing these shrubs due to the higher salt content of the plants.
- Once established the shrubs may be grazed at any time of the year. A three to four month grazing period is generally recommended with an eight month recovery period. Set stocking is not recommended.
- Stock need to learn to eat Saltbush, this may take three to four days.
- Sheep and cattle will both eat Saltbush and Bluebush although the degree to which they utilise the plants varies with its palatability. Palatability variations occur between species and may occur between mature plants of the same species. The reason for the variation in palatability is not known.
- Nutritional evaluations to date suggest Saltbush and Bluebush would only be suitable as a maintenance feed.

- Production levels vary considerably according to the species and the site conditions. Production levels under Victorian conditions are unknown, with only limited information available on selected species from interstate.

  Range of reported stocking rates for a four month period:

River Saltbush	12-16	dse/ha
Wavyleaf Saltbush	8-14	dse/ha
Marsh Saltbush	11-12	dse/ha
Small-leafed Bluebush	9-13	dse/ha
Oldman Saltbush	12-18	dse/ha

- The recovery of the shrubs after grazing varies according to the species and the degree of devegetation. Some species will withstand severe grazing but production may be reduced from successive hard grazings. Other species have a low survival rate if severe grazing occurs.
- Some species have a high oxalate content. This has been identified as a potential problem and is being studied; however no problems with grazing have been reported to date.

SELECTED SALINITY REGIONS

Salinity manifests itself in many different landscapes in Victoria. Varying geology, landform, soils, relief, climate and groundwater systems between salt affected catchments mean that successful control options differ from region to region.

The Basalt Plains of South West Victoria

Approximately four to five million years ago, the landscape of south western Victoria was much different to that seen today, and consisted of an undulating landscape with streams generally flowing southwards. Massive volcanic activity then produced very extensive lava flows which today comprise the Basalt Plains of the Western District. The lava flows average about 50 metres in thickness and can reach up to 150 metres thick, particularly over older, pre-volcanic stream valleys.

Isolated areas such as those near Willaura and Glenthompson were high enough to escape being buried by the lava flows.

The main period of volcanic activity ended approximately two million years ago. The basalt lavas during this period are known as first phase basalts and due to their relative old age are highly weathered. A second period of volcanic activity began approximately 20,000-30,000 years ago and ended around 5,000 years ago. These basalts and associated scoria cones are known as the second phase basalts, and make up landmarks such as Mt Rouse, Mt Napier, Mt Elephant, Mt Fyans and associated Stony Rise country.

A waterfall at the edge of a lava flow west of Hamilton.

The first phase basalts generally contain brackish to saline groundwater, and form a regional-scale aquifer. The second phase basalts (stony rises) typically contain fresh, good quality groundwater and due to their less extensive area, form a local to intermediate-scale aquifer. The underlying sediments contain groundwaters of fresh to saline quality, depending largely on whether or not they are overlain by first or second phase basalt. These sediments form regional-scale aquifers.

The flow directions in these aquifers are generally to the south, particularly in the sand aquifers underneath the basalts. The groundwater flows in the basalts, however, are complicated by radial flows generated by groundwater "mounds" formed under the original volcanic cones.

Recharge to the basalts occur at varying rates across the Basalt Plains, depending largely on the type of basalt. In the highly weathered first phase basalts, the regional recharge is relatively low, except in certain preferential recharge areas corresponding to old volcanic cones. The relatively unweathered second phase basalts, on the other hand, are rapidly recharged by rainfall over their whole area. Both the first and second phase basalts discharge to swamps, lakes and streams.

A saline lake in the Western District overflowing due to groundwater discharging into it.

Lake Corangamite is a typical example of a groundwater discharge lake. The lack of surface outflow means that evaporation concentrates salts in the lake water to levels in excess of 50,000 mg/L Total Dissolved Solids (TDS). Other lakes, such as Lake Purrumbete, a crater lake, are relatively fresh (<1000 mg/L TDS).

Streams in the Basalt Plains are also relatively saline. The Hopkins River has been recognised as Victoria's most consistently saline stream.

Control

i. Recharge Areas

The regional scale of the first phase basalts means that any groundwater and salinity control option must also be of a large scale. Recent studies have shown that preferential recharge areas exist, decreasing the area where control options (e.g. tree planting, groundwater pumping) may be applied to achieve the most efficient use of resources.

The second phase basalts, because of their high permeabilities, are well suited to groundwater pumping as a control option. The good quality water and relatively high volumes could possibly be used to promote a profitable agronomic industry while simultaneously controlling groundwater levels.

There is considerable debate as to whether a moderate degree of tree cover and perennial pastures can restore the water balance, or even whether the water balance is actually out of equilibrium given the relative lack of trees in the pre-European landscape. This particularly applies to the first phase basalts whose thick clay soils were mainly vegetated by grasslands.

The second phase basalts, however, appear to have been heavily forested before European settlement, judging from the existing forest in the Mt Napier State Park. Clearing of these forests may have also increased discharge from these areas to streams and lakes. There is no firm evidence at this stage to support the perceived rise in groundwater levels. Further monitoring is required before any trends can be determined.

Subsurface drainage is an option, as the technique reduces recharge by diverting fresh water to streams before it can infiltrate to the groundwater system.

ii. Discharge Zones

Revegetation along discharge zones, which usually correspond to stream lines and lakes, is a further option. This option is limited in effectiveness, however, if tree planting is at too low a density. Tree planting would probably be more effective along streams cut into the first phase basalts, since groundwater movements are relatively slow. Tree planting on the stony rises, on the other hand, would have to be very dense indeed to have any effect on the large and relatively fast moving groundwater contained within this aquifer.

The area of land affected could be reduced by various engineering options (e.g. tile drainage or a saline lake overflow) although the issue of disposal is as yet unresolved. Various investigations are underway to develop productive and profitable uses for these areas, but considerable work remains to be done. Planting of salt tolerant tree species around the discharge area will assist in controlling the spread of that area, and bring some productivity back to the land.

This discharge area has been fenced out and trees planted around its perimeter.

Loddon, Campaspe and Goulburn River Plains

Regional groundwater flows rise out of the highland valleys of the Campaspe, Loddon and Goulburn catchments and extend northward beneath the Riverina Plain. Two major regional groundwater systems occur in this Riverina Plain region. These are the shallow Shepparton Formation overlying the deeper Calivil/Renmark or Deep Leads aquifer.

Calivil/Renmark Aquifer (Deep Leads)

The Deep Leads originates well upstream of the Plain in the highland valleys of the catchment, where it is often overlain by basalts. The lead was formed many millions of years ago when ancient rivers cut deep valleys into the bedrock and dumped loads of gravel and sand in their path. Today they are buried deep beneath the land surface and act as preferred pathways (aquifers) for groundwater flow. Gold deposits were mined from these leads during the late 19th and early 20th centuries. Since this material is often buried by thick basalt flows, the Calivil Formation has become known as the "deep lead". A number of tributary or minor leads which rise in the headwater areas merge downstream to become the Loddon, Campaspe and Goulburn deep leads. Groundwater salinities in the deep lead beneath the Plain range from less than 800 EC increasing to more than 7000 EC in some areas.

The Shepparton Formation

This is the shallow aquifer consisting of clays, some of which overlies the deep lead on the Riverine Plain. In some parts of the plain there are good connections between the shallow groundwater system and the deep lead. Groundwater salinities in this shallow aquifer range from 1600 EC to in excess of 10,000 EC in some parts of the dryland plain.

Interaction of the Shallow and Deep Aquifers

Groundwater is often under pressure, depending on the presence or absence of a confining layer which can prevent the upward movement of water. Seams of dense clay often act as confining layers. When a bore is constructed into the lead the water level within the pipe rises under pressure, to a level well above the top of the gravelly material. This is called the static level and throughout a significant area of the Riverina Plain this level is very close to the surface.

Recharge to these deep leads takes place on the Plain itself with an average of 20-30 mm recharge occurring in an average year. During wet periods and accompanying regional floods, higher rates of recharge are experienced. Large increases in groundwater pressure have been measured following the 1973-75 wet period. Steady increases in groundwater pressures (10-20 cm per year) have been measured in many parts of the Plains since this time.

Control

Farming systems which use more water are the key to controlling groundwater recharge across the Plains, during an average year. Profitable alternatives to the present land management on this type of country include incorporating deep rooted perennial pastures into the system, in particular lucerne which can be intercropped with cereals, and increasing levels of crop management which will convert more rainfall into grain production. Both options will lead to greater profitability to land managers on the Plains.

Water in some parts of the deep lead is of high quality and of vast quantity. Groundwater pumping may be an appropriate strategy in some parts of the Plains. Farm management changes however, are considered to be the only major long term and sustainable means of salinity control on the Plain.

Wimmera-Mallee System

The Wimmera-Mallee is part of the Murray Sedimentary Basin. The sediments that fill this basin are up to 600 metres thick under parts of the Mallee. The sequence of sediments consists of gravels and sands at the bottom, which are overlain by marine clays and limestones, marine sands (Parilla Sand) and finally superficial clays and sands. The marine sequence was deposited when the basin was covered by a sea approximately five million years ago. The watertable beneath the Wimmera-Mallee is within the Parilla Sand. Unfortunately, the groundwater within the Parilla is very saline. The only aquifers in which the groundwater quality is good is in the limestone which occurs west of the Wimmera River and in the western Mallee and also near the mountain ranges to the south.

Looking across the Wimmera Plains towards the Grampians.

Where the watertable intersects the ground surface, salinity occurs. These discharge areas occur throughout the Wimmera-Mallee, examples of which are the salt lake valley in the southern Wimmera, Raak Plains and the Pink Lakes in the Mallee and even the Wimmera and Murray Rivers. Trying to control salinity is a major problem. Water enters the ground water system by percolating through the surface soils until it reaches the watertable. Some areas let more water recharge than others. For example the areas around the highlands with sandy soils and high rainfall allow more water per hectare to enter the groundwater than, say, the clay plains of the Wimmera. However, because the plains occupy such a large area, although the rate of which water recharges the groundwater is slower, it is still significant.

A lake west of Horsham formed where the regional watertable intersects the soil surface. A crescent shaped bank of wind-blown soil (called a lunette) is usually present on the side away from the prevailing winds.

Control Options

i. Recharge Zones

At present several studies are underway by the Department of Food and Agriculture, Rural Water Corporation and CSIRO looking at exactly how much water enters the groundwater under both natural conditions and under various agricultural practices. Early indications suggest that good agricultural practices and management are the best way to minimise recharge over these plains areas.

The limiting factor to crop production in north west Victoria is moisture (provided fertility levels are adequate). Because of this, there are few if any changes in crop management which will increase total water use during the growing season. Most changes result in a different pattern of water use but little effect on the total used. If fertility is low however, water use by cereals may be reduced. The most economic option to increase water use (and returns) is therefore to improve overall levels of fertility either by use of nitrogen fertiliser (risky) or use of better managed and longer pasture leys, particularly if these include lucerne.

Fallowing is an exception in that it is specifically aimed at increasing moisture in the soil. On the heavier soils of the Wimmera, this moisture is held within reach of subsequent crops and little additional recharge occurs as a result of fallowing. In the Mallee however, less moisture can be stored due to the lighter texture of the soil and shallow penetration by the roots of crops. Fallowing therefore is likely to increase recharge in the Mallee and on the lighter soils of the Wimmera and it has been demonstrated that it can profitably be replaced with a crop provided root diseases are controlled.

ii. Discharge Zones

The Wimmera-Mallee region has extensive discharge zones. Available options attempt to stabilise the spread of such areas by planting salt tolerant vegetation species. If the water using capacity of these plants is sufficient, they can also reclaim land by locally lowering the watertable.

iii. Groundwater Pumping

Another option suggested has been to extract groundwater around the highland margins where recharge is higher and the quality is good. Preliminary assessment of this proposal suggests that the limiting factor would be the ability of the aquifers to supply high yields. Also along the highland margin of the Wimmera, tree and pasture programs are being developed to minimise recharge.

WHOLE FARM PLANNING

Most of our decisions on farms are made with reference to one or two enterprises and in relation to one particular year or a period of years. Farm planning is a process that considers the whole farm, its potential and the requirements for maintaining the quality of its resources.

Whole Farm Planning, Property Planning, Land Use Planning - are all synonymous terms for the process of planning the "appropriate" use of land and other natural resources (e.g. soil, water, vegetation, habitat, fauna, scenery) on the farm.

The farm planning process is based firstly on a study of the natural features of the land and its capability for different uses. This assessment also considers the extent of damage to the land and the risks of further decline through salinity, wind and water erosion, soil structural loss and other degradation processes.

The aims of farm planning are to:

- optimise the production of saleable products (i.e. efficient productivity in terms of output/input of labour, feed, etc.);
- to maintain (or improve) the condition/quality of farm resources;
- to maintain (or improve) the quality of the farm as a living environment;
- to increase the capital value of the land and farm;
- to integrate the farm plan with the needs of the whole catchment and the community.

While the aims and process in farm planning are similar across a wide range of land types, the emphasis can be very different for particular farming systems.

- In the *irrigation areas*:- Whole Farm Planning places primary importance on detailed mapping of the contours (and soil type), and the computer analysis of the most efficient irrigation and drainage layout to be achieved through laser levelling. There may also be some tree planting activities and water re-use dams to counter the risks of salinity;
- In the *Western District*:- Whole Farm Planning consists of a more rapid land assessment and emphasis on new paddock layout, fencing, laneways, and trees for shelter and salinity control, and pasture improvement;

- In *dryland cropping areas*:- Whole Farm Planning depends on a thorough examination of soils (and hence more detailed land classification), consideration of management practices best suited to each land type, and the planning of changes to both management practices (e.g. tillage), and farm layout. These plans can also incorporate trees for wind breaks and salinity control;
- In areas where salinity is a major issue Whole Farm Planning should start by assessing the current level of salinity and also the risks of salinity all over the farm, and then seek ways of (a) reducing salinity levels in affected areas, and (b) preventing further build up of salt levels in soil and water. The farm plan shows a map of the various salinity concerns, recharge and discharge areas (if applicable) and then a list of solutions and priorities for action on the farm.

The Farm Plan Itself

A farm plan usually consists of the following items:

1. Aerial photographic enlargement of the farm;
2. Map of permanent features;
3. Map of proposed farm layout;
4. A Farm Plan document, comprising;
   - table of areas of each main land class,
   - descriptions of each main land class,
   - a summary of main land degradation risks,
   - strategies for overcoming/avoiding land damage,
   - list of priorities for farm development.
5. Maps of specialist enterprises;

   e.g. irrigation and drainage layout,
   pasture improvement plan,
   stock water distribution plan.

Farm Planning Courses and Benefits

Whole farm plans can be conducted by consultants, by individual farmers, or by farmers participating in group farm planning courses. The main advantage of working in a group to produce farm plans is that one can share problems and ideas on solutions with others from the same area.

The farm plan can also identify the need for monitoring of water tables, vegetation, soil structural properties, and other aspects of resource condition that are vital to the long term future of farmers in the area.

** Short courses in Whole Farm Planning are conducted in rural areas by the Victorian College of Agriculture and Horticulture.

INTEGRATED CATCHMENT MANAGEMENT

The most effective approach for long term salinity management is through Integrated Catchment Management (ICM). Salinity in a catchment may be a result of rises in the watertables in local or regional groundwater systems. It if is a regional groundwater system, the recharge area may be many kilometres from where the actual salinity problems are apparent. If water quality in rivers and streams is a major priority, even a local groundwater system can have significant effects far removed from the point of discharge.

Integrated Catchment Management is the management of land, water and vegetation on a whole catchment scale. The benefits from Integrated Catchment Management come from considering all these resources as a total system rather than in isolation from one another. There is a real danger that a recommended control or management option for one particular problem may create further problems in the management of other resources.

So while it is important that management of salinity be planned in detail, it is also important that other natural resources also be considered in planning.

In the Wimmera this is exactly what is happening. A detailed Salinity Management Plan is being prepared which integrates all aspects of land, water and vegetation management as they relate to salinity. However, this Plan is a component of a broader Integrated Catchment Management Strategy which ensures that salinity is considered with issues such as soil erosion, pest plant and animal control, flora and fauna management, recreation and tourism and cultural heritage.

So Integrated Catchment Management is like a "giant whole farm plan" and just as an individual farmer preparing a plan needs to consider all elements of farm management, so a catchment management plan or strategy considers all aspects of natural resource management.

To be successful Integrated Catchment Management must involve a genuine co-ordinated and co-operative approach from government and the community. The problems to be addressed should be agreed upon and the solutions should be determined co-operatively.

The many hours being spent by the various community salinity working groups bear testimony to the fact that Integrated Catchment Management is not a simple process and does require a great deal of careful planning.

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