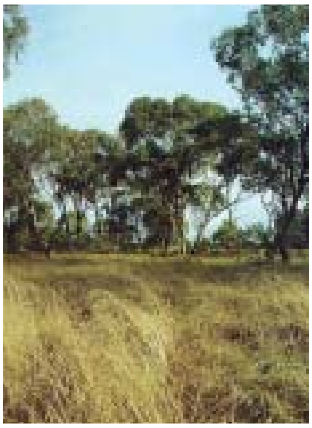
Healthy Catchment Guide

Vegetation for salinity management in the South West Slopes of the Murray Catchment (NSW)



Department of
Infrastructure, Planning and Natural Resources

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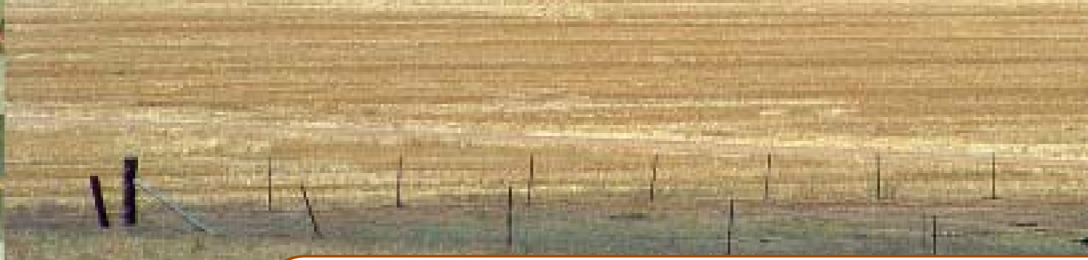
ISBN 0 7347 5419 1

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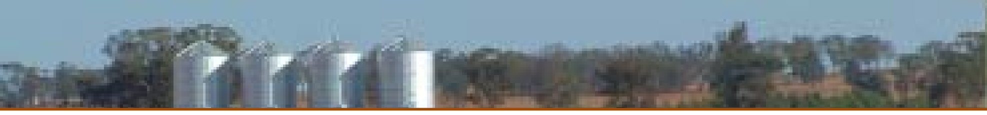
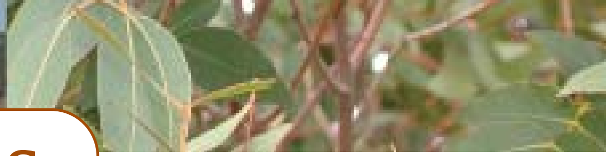



Acknowledgments

Several organisations and individuals are sincerely thanked for their contribution to this guide:

The Eastern Murray Dryland Salinity Project (EMDSP) contributed significantly: Elita Humphries (Project Officer) developed and sourced content in the early stages; Dale Stringer (Project Officer) assisted with coordination and editing; the Project committee provided valuable technical and editorial support. The EMDSP is a community and Landcare instigated project supported by Department of Infrastructure Planning and Natural Resources (DIPNR). Its charter is to better understand dryland salinity in the Eastern Murray and to promote the issue through community awareness and education.

Ground water flow systems of the NSW Murray Catchment are referred to frequently. These were identified and mapped using the National Dryland Salinity Project's *Catchment Characterisation* tool with the cooperation of National Dryland Salinity Project (NDSP), Murray Darling Basin Commission (MDBC), EMDSP and DIPNR. Several people contributed to this process including Elita Humphries (EMDSP), Phil Dyson (Phil Dyson and Associates), Ray Evans (Salient Solutions), Saji Joseph (Department of Infrastructure, Planning and Natural Resources) and workshop participants.

The following individuals provided valuable technical and editorial input: Hamish Cresswell (Heartlands Project); Bill Johnston, Geoff Beale, Gregory Summerell (Centre for Natural Resources); Anna Ridley (Department of Primary Industries (VIC)). Also Elizabeth Madden, Gareth Adcock, Mark Mitchell and Deb Slinger (Southern Salt Action Team); field officers including Kim Krebs, David Costello, Murray Brown, Andrew Lawson and others; Kaye Dalton, Tony Dawson, Bunty Driver, Saji Joseph, Nimal Kulatunga, Stuart Lucas and John Naimo (Department of Infrastructure Planning and Natural Resources).

Introduction

The NSW Murray Catchment contributes significantly to the salinity problems of the wider Murray Darling Basin – approximately 120,000 tonnes of salt was exported from this area in 2000 and a rising trend is predicted (Watson, 2002). To address salinity *The Murray Catchment Blueprint* (Murray Catchment Management Board, 2002) specifies an end of valley salt concentration target for 2012 and 2020, which is to be met by implementing on-ground actions in priority areas.

The South West Slopes (Figure 1) is identified in the *Blueprint* as the main salinity priority area - it has a high salinity risk[1] and is part of the Eastern Murray Catchment from where around eighty percent of the above-mentioned salt load originates. Most of the actions identified in the *Blueprint* to meet salinity targets consist of improvements to vegetation management in this area.

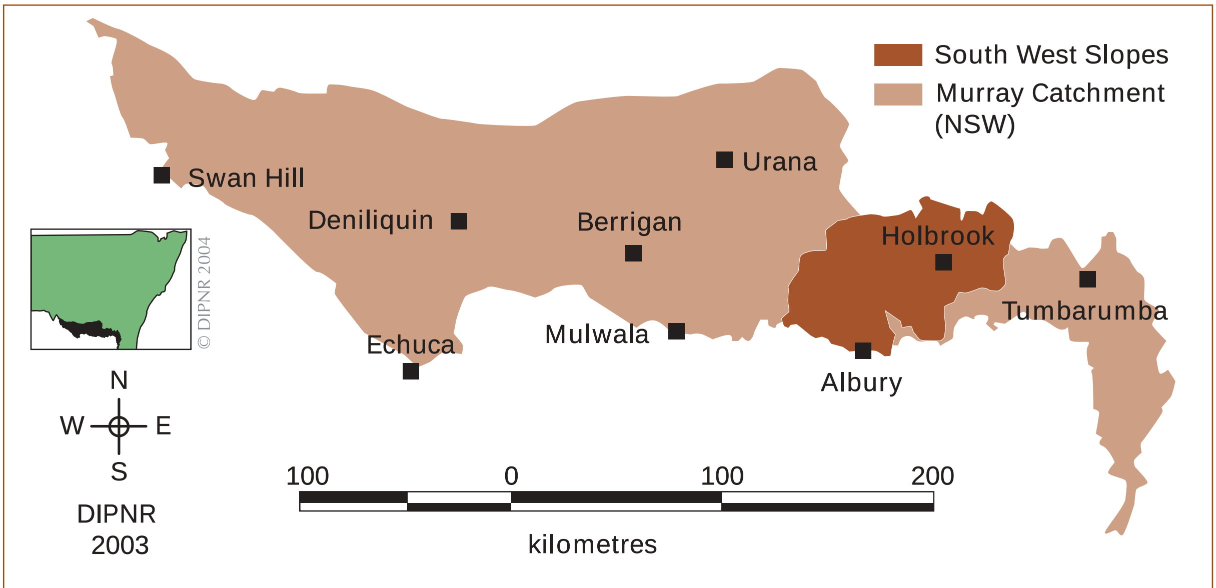


Figure 1: The South West Slopes and NSW Murray Catchment.

Specifically this guide provides:

- A rationale for selecting the South West Slopes as a salinity priority area.
- A discussion of dryland salinity processes and the related interactions of vegetation, geology, topography, soil and climate.
- A guide to prescribing vegetation to treat salinity, on farms and in subcatchments, based on interpreting the landscape: ground water flow systems, topography and other physical information.
- An introduction to the effectiveness of vegetation types in treating salinity.

The main landuse in the South West Slopes is dryland agriculture, which traditionally consists of vegetation that, due to its shallow-roots and short growing season, uses less water over a year than native and other perennial deep-rooted vegetation. Dryland agriculture consequently implies a greater tendency for soil saturation and leakage (also termed recharge or deep drainage), which contributes to groundwater rise, salt mobilisation, land salinisation and reduced water quality.

The vegetation practices that are promoted in the South West Slopes to address salinity are aimed at correcting the long-term imbalance in the water cycle. Leakage is to be reduced to prevent ground water rise; clean runoff is to be preserved in sufficient quantity to help dilute saline intrusions to streams. These objectives occasionally compete, though in general a 'healthy catchment' approach is required that will achieve a range of environmental, social and economic benefits.

1. The South West Slopes is reported by Watson (2002) to have a high salinity risk: a relatively high chance of land salinisation and concentrated salt export due to factors of soils, geology, climate, and land use.

Most leakage in the South West Slopes occurs in winter. Perennial vegetation that uses water in late spring and summer (prior to winter) tends to reduce leakage by drying the soil profile and creating a buffer. In many cases increasing perennial vegetation throughout the landscape for salinity outcomes is compatible with other environmental, social and economic objectives. For example strategically grazed perennial pastures are often encouraged for increased productivity; targeted tree planting to reduce leakage or lateral ground water flow may also suit biodiversity or forestry objectives.

Modelling of the relationships between landuse and in-stream salt concentration in the NSW Murray Catchment is in its early stages. Our confidence in recommending vegetation to address salinity will continue to improve as more information about the Catchment comes to hand. This guide provides a means to prescribe appropriate landuse options to treat salinity based on interpreting the landscape.

Background and Discussion

Why the South West Slopes is a 'salinity priority area'

The *Murray Catchment Blueprint* (Murray Catchment Management Board, 2002) identifies the South West Slopes as a salinity priority area. The opportunity exists in this area to apply vegetation management improvements for a significant outcome in terms of the catchment's 'end of valley' salinity target. The factors that make the South West Slopes a priority: salt loads, salinity risk, ground water flow systems and climate, are discussed below.

Salt loads

The former Department of Land and Water Conservation (DLWC) undertook a study in 2002 to estimate and compare the amount of salt exported from eight 'evaluation areas' that make up the NSW Murray Catchment (Figure 2), for the years 2000, 2010 and 2020.

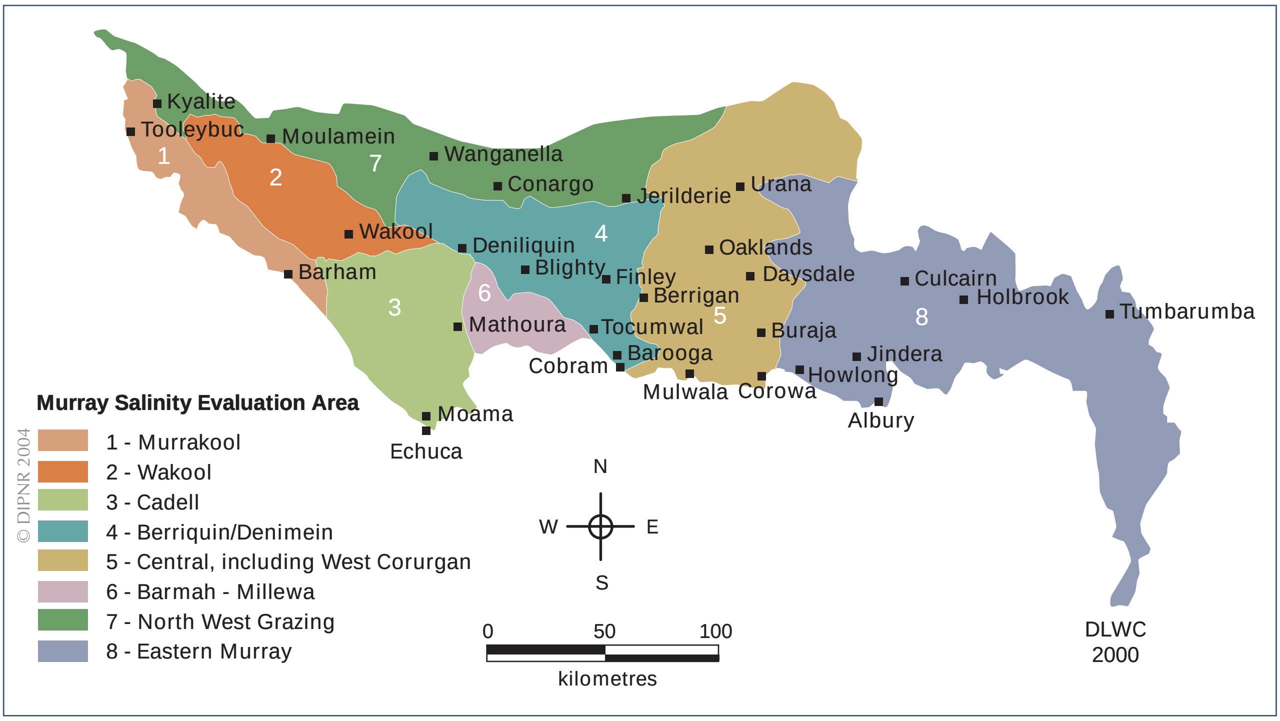


Figure 2: Salt load evaluation areas identified in the NSW Murray Catchment Salinity Report (Watson, 2002).

A brief description of each of the 'evaluation areas' and methods used to estimate salt loads is provided as follows.

- **The Eastern Murray** consists of the South West Slopes and Upper Murray. It receives the highest average rainfall of the region (approximately 500 to 1200 mm/year) and supports a range of agricultural activities including grazing, cropping and agro-forestry. Salt load and trend predictions for the Eastern Murray were based on an analysis of measurements taken in the Billabong and Jingellic Creek catchments. The average land area contribution of each of these catchments to down-stream salt load was calculated, then extrapolated to the whole Eastern Murray.

- **Wakool, Cadell and Berriquin/Denimein** are primarily irrigation areas for which Land and Water Management Plans (LWMP) have been developed. Salt loads from LWMP areas are measured according to Murray Irrigation Limited licensing conditions and the specified upper permissible limits were used in the salt load analysis. The importation and accumulation of salt to the LWMP areas via irrigation water from the Murray River was not included in the analysis as it was considered insignificant given the study's regional scale.

- **Central and West Corurgan, Barmah/Millewa, and North West Grazing** areas consist of dryland farming, minor irrigation and arid grazing in the plains and the native forests of the Barmah/Millewa area. DLWC assessed the likely salt load from these areas based on measured and modelled water table characteristics. It was concluded that salt export from these areas was unlikely to be significant in the next thirty years (Joseph, 2000).
- **Murrakool** is at the western end of the catchment and supports dryland and irrigation farming. An analysis of ground water and topographic characteristics by DLWC identified the potential for rising saline ground water to be intercepted by incised naturally occurring drainage lines. Salt loads were predicted based on modelling of this process (Joseph, 2002).

The results of the salt load study are reported in Watson (2002) and are shown in Figure 3. They indicate that approximately eighty percent of the total salt load contributed by the NSW Murray Catchment to the Murray River originates from the Eastern Murray, an area that includes the South West Slopes. A rising salt load trend between the years 2000 and 2020 is also indicated.

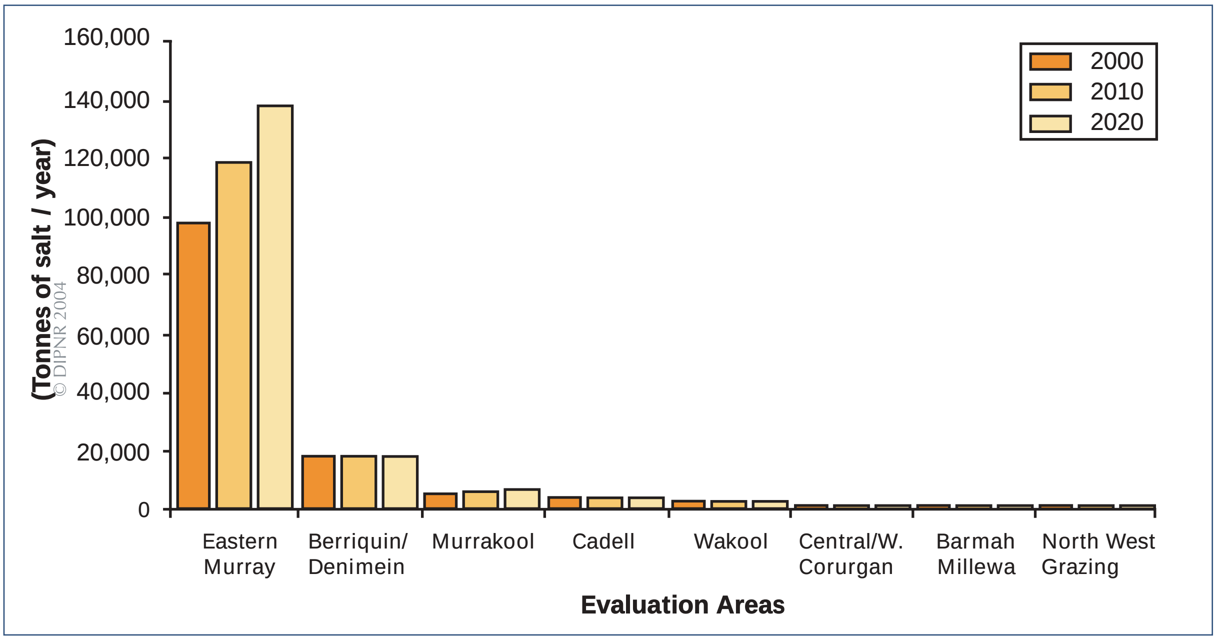


Figure 3: Predicted salt loads exported from the NSW Murray Catchment to the Murray River in 2000, 2010 and 2020 (Watson, 2002).

Salinity risk

A further analysis by DLWC (Watson, 2002) was undertaken to determine the relative salinity risk of subcatchments within the Eastern Murray. Salinity risk was defined for the purpose of the analysis as the potential of a subcatchment to suffer land salinisation and export salt in high concentration relative to other parts of the catchment.

The salinity risk of subcatchments in the Eastern Murray was determined empirically using a Geographic Information System (GIS) based model. The model overlayed three ‘salinity hazard’ layers: salt source potential based on geology and soils; wetness based on topography; and leakage potential implied from estimates of subcatchment perenniality.

The result was a map showing that the highest salinity risk is in the western half of the area, which is generally the South West Slopes (Figure 4).

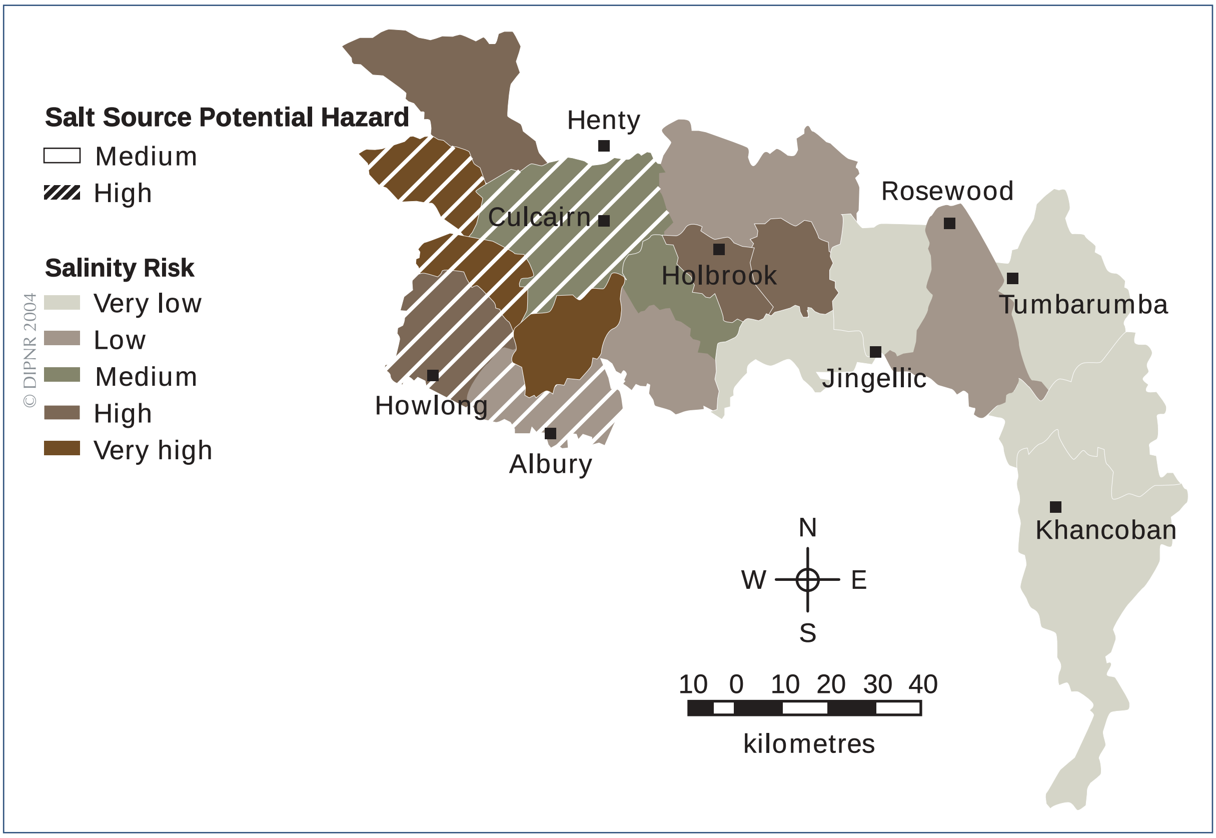


Figure 4: Salinity risk of the subcatchments of the Eastern Murray (Watson, 2002).

Ground water flow systems

The term ‘ground water flow system’ refers to the geographical extent and physical characteristics of a particular ground water unit. A ground water flow system is defined by its related recharge and discharge areas, water and salt stores, flow paths, geology, regolith and topography. Ground water flow systems of the NSW Murray Catchment were identified through *Catchment Categorisation*, a ‘tool’ of the National Dryland Salinity Project (MDBC, 2000) and are described by Humphries (2003).

Ground water flow systems may be categorised according to the time it takes for the system to respond to management interventions such as landuse change. Response time is largely inferred from the geographic extent of the system and categories include local, intermediate and regional. Local ground water flow systems extend only a few kilometres and their response to management intervention is rapid. Intermediate ground water flow systems are more extensive and have significantly greater response times. Regional ground water flow systems are thought to have response times in excess of 100 years.

The following table and diagram (Figure 5) demonstrate the geographical extent and response time of local, intermediate and regional ground water flow systems.

Category	Length of Flow	Response Time
local	<5km	5 - 30 years
intermediate	5 - 50km	30 - 100 years
regional	>50km	>100 years

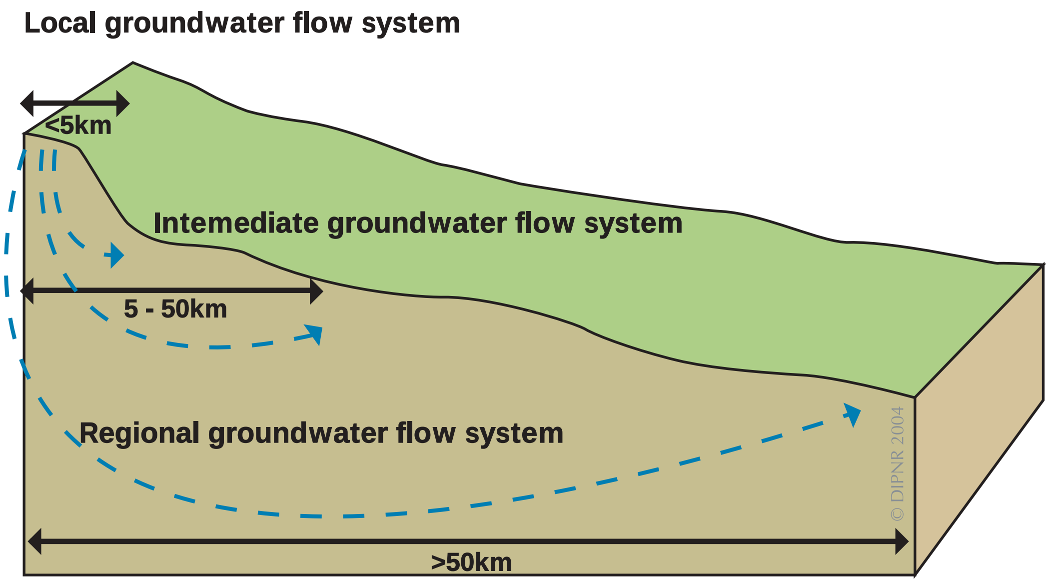


Figure 5: Extent and predicted response time of local, intermediate and regional ground water flow systems (Table: after Murray Darling Basin Commission, 2000; Diagram: adapted from Smithson, A. 2003).

The South West Slopes consists mainly of local and intermediate ground water flow systems. The *Murray Catchment Blueprint* (Murray Catchment Management Board, 2002) recognises that an observed salinity outcome resulting from changes applied to these systems may take decades and accordingly provides for lag time in its salinity target. The impact that landuse has on regional ground water systems is not fully understood, although it is assumed that landuse change to local and intermediate systems will also impact on regional systems.

Climatic influences

Climate and particularly the amount of water that is available in the landscape throughout the year is, along with other factors, significant in defining the South West Slopes as a salinity priority area.

To the west of the South West Slopes, average monthly rainfall in winter is generally exceeded by evaporation (Figure 6). Consequently there is seldom a surplus of water in the landscape and opportunities for leakage are irregular and best correlated with exceptional flooding events or wet years. The contribution of these areas to salinity via dryland processes is low.

The Upper Murray which is east of the South West Slopes has a high surplus of water in winter when average monthly rainfall greatly exceeds evaporation (Figure 6). Leakage opportunity is accordingly high yet the area has a low salinity risk; ground water flow systems are steep, well drained and fresh. Consequently it is more important for salinity management to maintain clean diluting runoff from the Upper Murray than it is to reduce leakage.

In the South West Slopes there also exists a regular opportunity for leakage in winter (Figure 6), though it is not as great as that of the Upper Murray. Unlike the Upper Murray however, salt stores are high and easily mobilised. Consequently the combined factors of climate and high salinity risk in the South West Slopes make it a salinity priority area.

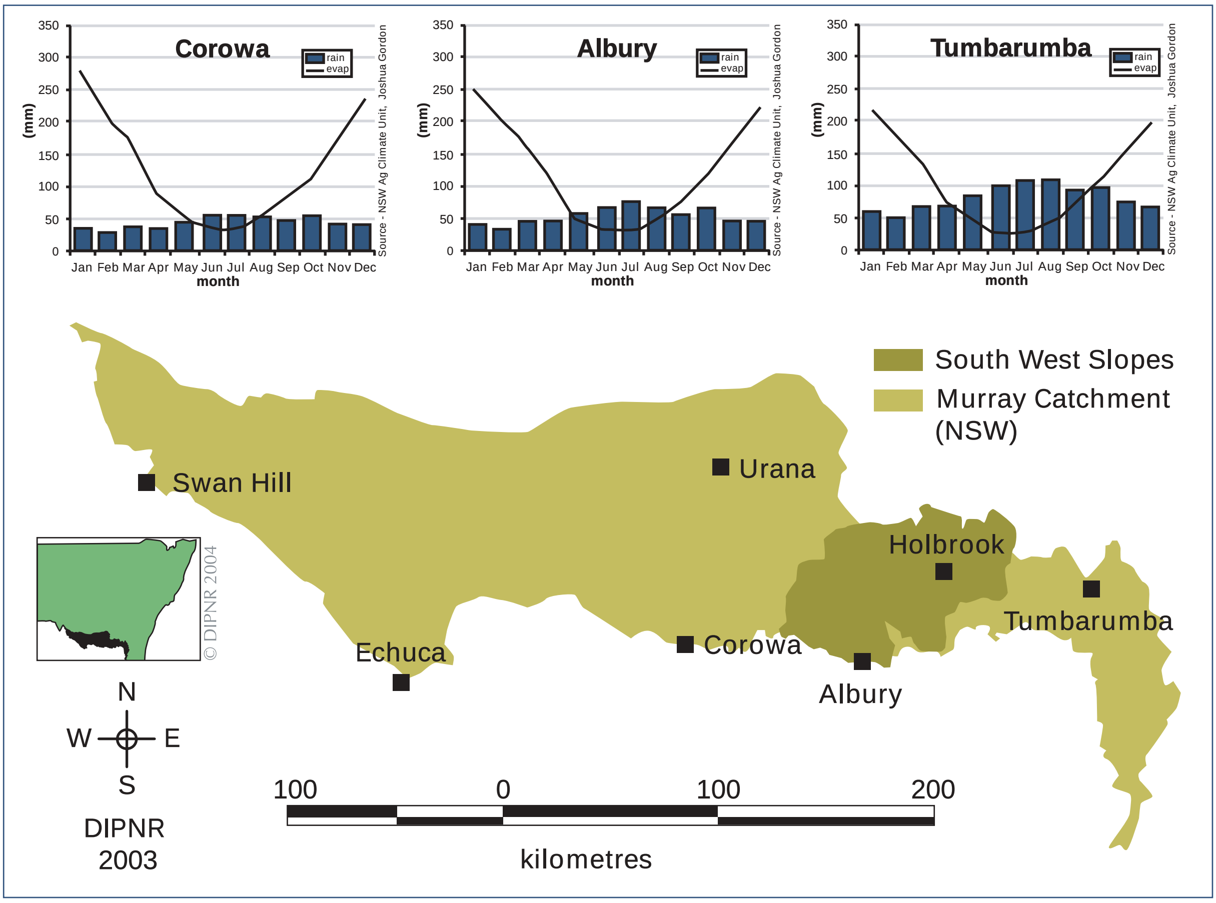


Figure 6: Monthly average annual rainfall and evaporation for Tumbarumba, Albury and Corowa.

Dryland salinity - processes, treatment

Overview

The South West Slopes contributes significantly to the elevated salt load and concentration in the Murray River and its tributaries, and currently suffers approximately 300 hectares of land salinisation (Spiers, 2003). Salt enters waterways when it is washed from salinised land and to a greater degree as direct discharge where deeply incised streams intersect shallow saline aquifers (Cresswell, 2003).

These salinity problems will be addressed in the South West Slopes by applying vegetation practices that both reduce the amount of water leaking past the root zone and allow sufficient clean runoff to dilute salt in waterways. Engineering measures may also be applied to achieve short terms targets.

An integrated approach to land management is required that values environmental, social and economic opportunities and limitations. This includes both improving the productivity of agricultural practices to optimise water use, and the strategic placement of high water use perennial and woody vegetation systems to address leakage and intercept lateral ground water flow.

The role of vegetation

Salinity occurrence depends on a complex interaction between vegetation, soil, geology, topography and climate. In the South West Slopes there is a continued effort through data collection and modelling to understand these interactions, though the ability to accurately quantify cause and effect is still some time away. This guide compares the potential influence of various vegetation types on salinity, based on an interpretation of their leakage and other hydrological impacts reported in the literature.

Most leakage in the South West Slopes occurs in winter, the wettest time of the year, when available water exceeds the usage requirements of plants. In spite of a frequent surplus of water at this time, leakage may be minimised by ensuring that the soil profile is as dry as possible prior to winter; a dry soil profile will store infiltration and act as a buffer. The degree to which soil acts as a buffer to leakage depends on two main variables, soil water holding capacity (SWHC) and autumn soil water deficit (ASWD), which are described below.

- **Soil water holding capacity (SWHC)** is the amount of water that a soil profile retains after drainage (Charman & Murphy, 1991). It indicates how great a buffer to leakage the profile will provide when fully dry. SWHC is influenced by soil texture and depth (which are generally constant) and soil structure which can be improved by increasing organic content and removing compacted layers. (Compaction is caused by cultivation, traffic and soil sodicity; it restricts water and root penetration, thereby reducing the effective depth of the soil profile).
- **Autumn soil water deficit (ASWD)** describes the dryness of a soil profile prior to winter and its associated capacity to store infiltration. The degree to which the ASWD of a profile develops in dryland areas depends largely on the water use characteristics of the plants that it supports.

Deep-rooted perennial vegetation tends to allow less leakage than annual shallow-rooted vegetation; it utilises more of the moisture reserve within the soil profile throughout the year leaving it drier prior to winter. Summer active perennial vegetation is favoured in areas where other perennial species become dormant at this time.

The way that vegetation is managed also has a significant influence on water use and leakage. For example, a consistently overgrazed and therefore growth-inhibited perennial pasture may use less water in a single year than a well-managed annual pasture.

Landuse in the South West Slopes is dominated by agriculture that is based on annual, shallow rooted plants. These plants are generally not as effective as perennial plants at buffering against leakage. This does not mean that all agricultural practices should be replaced to treat salinity. There is a great benefit from a salinity perspective in improving agricultural productivity, utilising for increased plant growth the water that otherwise becomes leakage.

To compare the relative amount of leakage that is likely to occur under various vegetation types, the predictions of several authors are combined and presented in Figure 7. The predictions for lucerne, annual pastures and cropping are from Ridley *et. al.* (2001); phalaris, cocksfoot and annual pastures from Ridley *et. al.* (1997); native pastures from Ridley (2003) and trees from White *et. al.* (2003). A range of soil types is assumed as well as best management practice for the vegetation types considered.

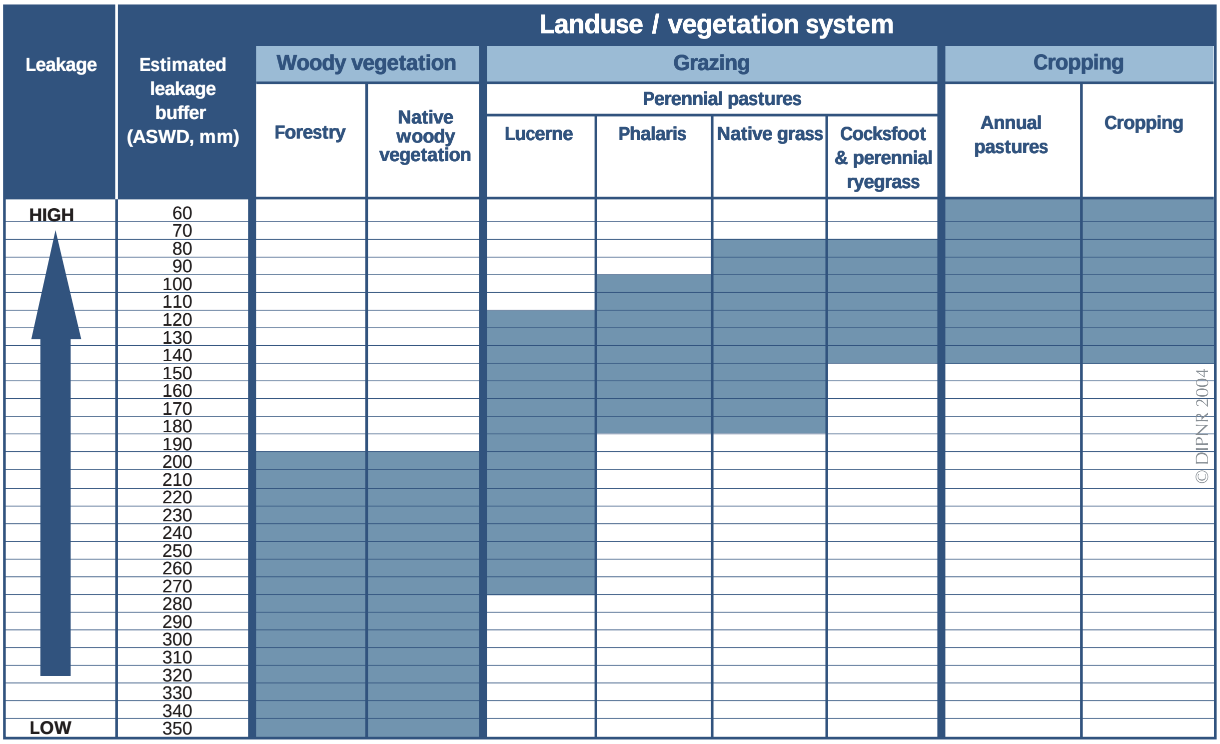


Figure 7: Estimated leakage under various vegetation types assuming a range of soils and best management practice, (after Ridley *et. al.* 1997), Ridley *et. al.* (2001), Ridley (2003) & White *et. al.* (2003).

Our current understanding of the treatment of salinity may be complimented by investigating the placement of vegetation according to its interaction with various soil types (Ridley, 2003), the influence of cultivation practice on runoff and infiltration (Johnston, 2003) and the influence of vegetation structure (canopy etc) on the water balance.

Treating salinity in an agricultural context

Salinity treatment to date has mainly focussed on fencing and establishing salt tolerant plants on discharge areas, as well as localised planting of woody vegetation and lucerne on recharge areas. This guide presents a broader and more integrated approach to reflect our contemporary understanding of the extent and offsite effects of salinity.

As part of this holistic landscape approach to addressing salinity, both targeted and extensive vegetation management activities are required across the South West Slopes. These are defined as follows:

- **Targeted activity** describes the application of intensive landuse at a site to specifically address a high recharge risk or intercept lateral ground water flow. Targeted activity may include the establishment of high water use vegetation including lucerne, biodiversity planting or agro-forestry.
- **Extensive activity** describes changes made to agricultural practice over large areas that result in improved vegetation health, productivity and water use. Extensive activity may include for example establishing perennial pasture, incorporating a perennial phase into a cropping rotation or increasing the efficiency of a grazing program. The environmental effects of extensive activity, though locally subtle, may bring significant regional salinity benefits.

The extensive vegetation changes that are required in the South West Slopes to address salinity are likely to be motivated by a range of indirect benefits that are environmental, social or economic in nature. In the case of agriculture, for example, economic gain may be achieved by increasing the use of available soil moisture for plant growth, an often-wasted resource that contributes to leakage.

A truly integrated approach to salinity will consider both targeted and extensive approaches to vegetation management at a property scale. For example, if plantation forestry were advocated on part of a property it would appropriate to take the opportunity to recommend improvement in the composition and management of surrounding agriculture including crops and pastures. In most cases vegetation that is promoted for salinity purposes will achieve a range of other benefits that constitute a healthy catchment including improved productivity, soil and water quality and biodiversity.

Prescribing vegetation for salinity outcomes

This section recommends options for placing vegetation within the South West Slopes to achieve salinity outcomes. Landscape interpretation is discussed as a means of identifying the groundwater and salinity process of an area of interest, then how this interpretation may be applied to determine options for vegetation-based salinity control.

Interpreting the landscape

Landscape interpretation provides a general understanding of the groundwater and salinity processes that occur within an area. An interpretation involves categorising an area according to its topography, ground water flow system association and other physical information, into one of a number of combinations that are typical of the South West Slopes. Landscape interpretation is undertaken in the field; it may be aided by local knowledge and relevant spatial data, and can contribute to decisions about vegetation placement for salinity outcomes.

Topography

Three broad topographic features need to be recognised when interpreting the landscape: plain, slope and hilltop. These categories are reasonably self-explanatory and their identification in the field is aided by the application of the land capability classification system described by Emery (1985), (see Figure 8).

Class	Land use	Description
I	mainly cropping	deep fertile soils, low slope, no erosion
II	mainly cropping	low sloping fertile soils and little erosion hazard; slopes up to 5%
III	mainly cropping	sloping country requiring runoff control; coarser textured and erosion-sensitive soils; slopes 2 - 10%
IV	mainly grazing	slopes up to 25% and land subject to minor erosion; unsuited to regular cropping due to any of a number of limitations
V	mainly grazing	similar to class IV but requiring more careful management due to erosion hazard
VI	grazing	slopes not exceeding 33%; includes limitations such as rock outcrop; shallow soils and severe soil erosion hazard
VII	tree cover	slopes exceeding 33%, having physical limitations that prevent any form of cropping or grazing
VIII	unsuitable for agriculture	swamps, cliffs etc

Figure 8: Land capability classes, (after Emery, 1985).

Topographic features in the South West Slopes can be broadly inferred from the previous table in the following way (see Figure 9):

- **Plains** are generally represented by the land capability classes I and II, with gradients of up to 5%. Plains are commonly used for regular cropping.
- **Slopes** are generally represented by the land capability classes III to V, with gradients of between 2% and 25%. Slopes are commonly used for grazing and opportunistic cropping; some regular cropping occurs on the lower slopes.
- **Hilltops** are generally represented by the land capability classes VI and above, with gradients sometimes exceeding 33%. They are the tops of ridges, knolls etc, consisting of shallow soils and often rock outcrop, which if cleared and not well managed may be characterised by bare sheep camps and annual weeds.

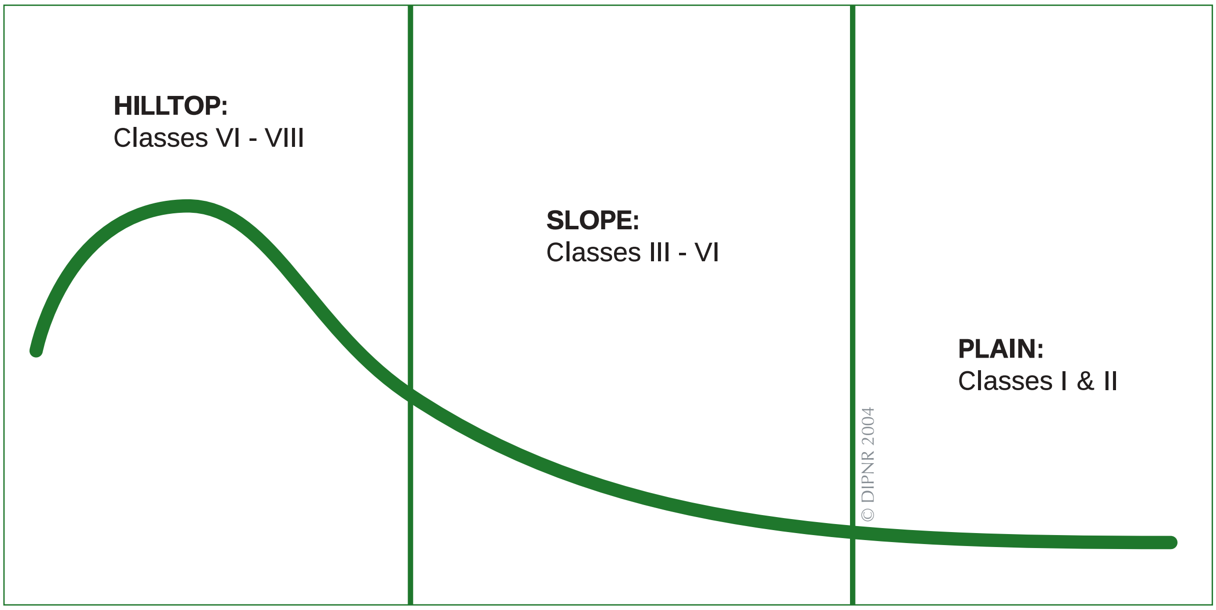


Figure 9: Topographic features broadly inferred from land capability classes (after Emery, 1985).

Break of slope is also an important topographic feature that is characterised by a change in gradient, usually between land classes. Deepening soil profiles that often occur here may suit establishing high water-use perennial and woody vegetation to intercept lateral ground water flow derived from higher in the landscape. Break of slope can also coincide with subsurface constrictions to water movement and saline discharge.

The land capability classification system is useful when applied at a property scale, to help guide recommendations for sustainable landuse options.

Ground water flow systems

Part of 'interpreting the landscape' requires a recognition of ground water flow characteristics. Three ground water flow landscape categories are defined: granite, meta-sedimentary and unconsolidated (alluvial). Their distribution in the South West Slopes is shown in Figure 10 and their primary characteristics are summarised as follows:

- **Granite landscapes** are generally massive (non-fractured). Consequently ground water penetration into parent material is minimal and it instead moves laterally through the soil profile above the rock. Granite systems tend to be localised meaning that related recharge and discharge generally occur within the extent of the surface water catchment.
- **Meta-sedimentary landscapes** tend to be fractured, meaning that the parent material can contain and transport water to other parts of the landscape via fractured rock aquifers. The scale of a meta-sedimentary system is consequently local to intermediate and can traverse one or more surface water catchments.
- **Unconsolidated (alluvial) landscapes** are intermediate to regional in their scale and generally consist of deep soils. Soil characteristics in these systems are more important than is underlying geology when considering leakage management.

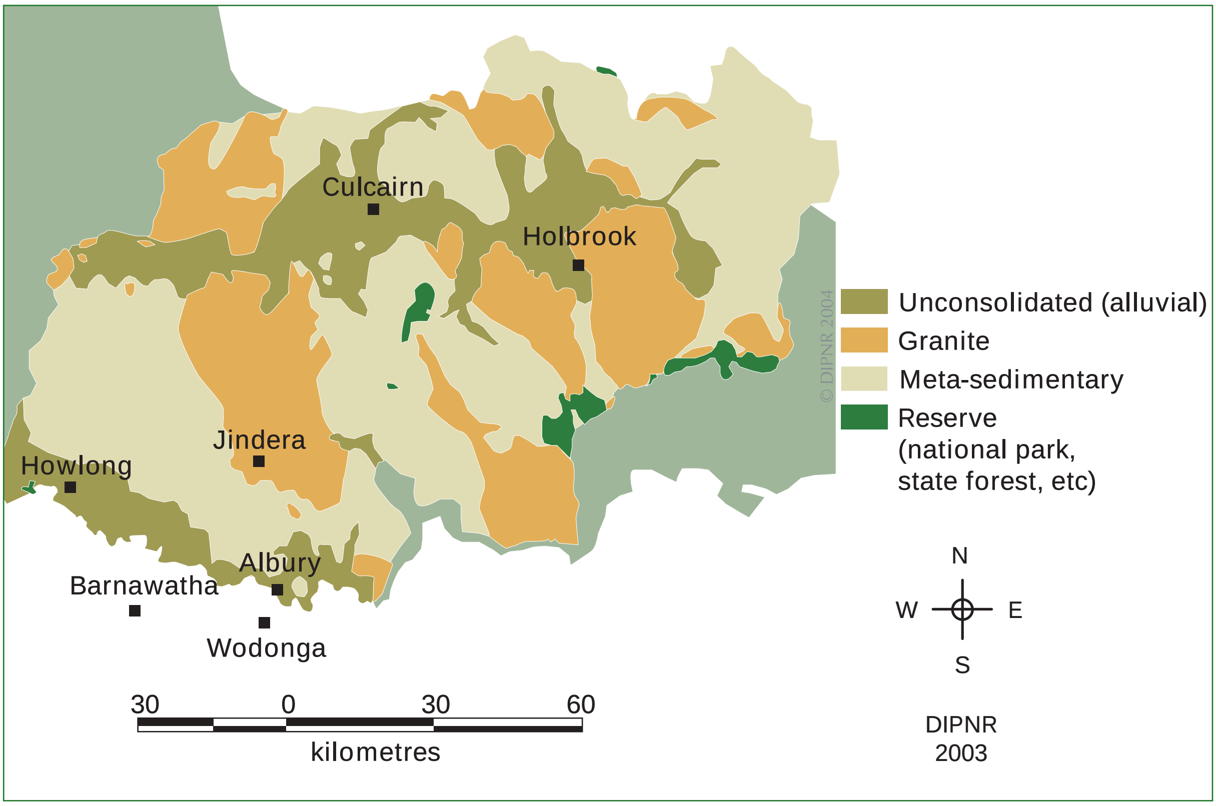
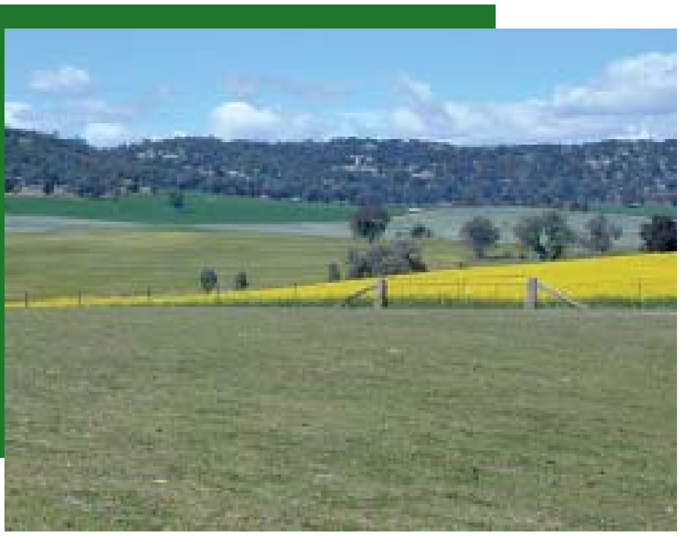


Figure 10: The distribution of granite, meta-sedimentary and unconsolidated (alluvial) landscapes in the South West Slopes (source: Department of Infrastructure, Planning and Natural Resources 2003).

Matching vegetation to landscapes

This section provides recommendations for placing vegetation to achieve salinity outcomes in the South West Slopes. The recommendations are given in relation to typical combinations of topographic position and ground water flow system (granite, meta-sedimentary or unconsolidated (alluvial)). They favour maximum leakage reduction and ground water flow interception, and reflect consideration of the impacts on runoff volume, practicality and economic viability.



Granite landscapes

Granite landscapes consist of two types of ground water flow systems, which are described in the appendices:

1. Local flow systems in high relief granite
2. Local flow systems in low relief granite

Granite landscapes are common in the Eastern Murray and are identified most clearly by outcrops of parent rock that appear as rounded boulders, particularly on hilltops (Figure 11). Granite landscapes vary considerably according to the degree of weathering, rainfall, landform shape, slope, colluvium depth, water movement within the landform and erosion processes.

Granite, though sometimes fractured, is mostly massive (not fractured). This plays an important role in the way that water moves in granite systems. Vertical ground water movement through the parent material is restricted so ground water instead moves laterally through the regolith around and over the parent material. Soil depth increases down slope and soil texture becomes heavier. This can impede water movement causing water logging and sometimes land salinisation. Salt storage in these landscapes is thought to be low to moderate, with saline expressions usually being in the form of salt indicator species and reduced productivity.

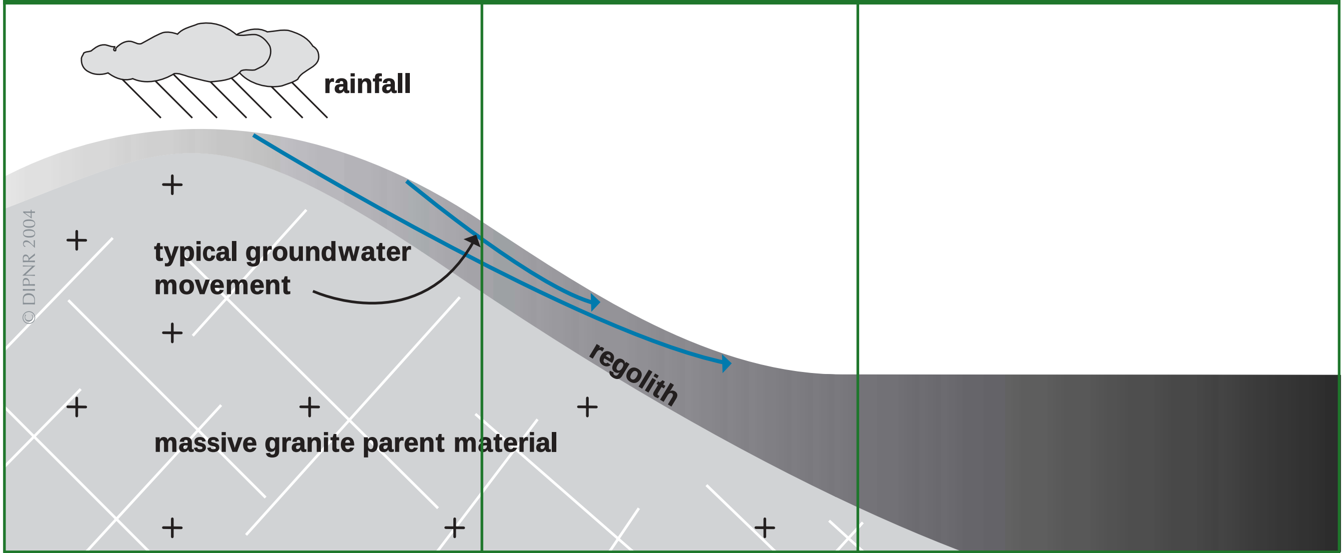
Granite systems are categorised as 'local' meaning that recharge and discharge are contained within the one defined catchment area, usually less than 1000ha. The response time of these systems to management interventions is rapid.

Leakage occurs throughout this landscape, particularly on the coarsely textured soils of the hilltops and slopes (Figure 12). Laterally flowing ground water may be intercepted by strategically placed high water use vegetation.

Figure 11: Typical granite landscape (T. Dawson). Inset: granite rock (M. Mitchell)

Management Recommendations for Granite Landscapes

Hilltops	Slopes	Plains



	Hilltops	Slopes	Plains
Highly Recommended	Ground water interception: • woody vegetation in strips, on the contour and above saline discharge areas	Ground water interception: • woody vegetation in strips, on the contour and above saline discharge areas • high-water-use pastures such as lucerne, strategically placed	
General Best Practice	Leakage control: • native perennial pasture • native woodland	Leakage control: • perennial pasture • native woodland	Leakage control: • perennial pasture • native woodland • perennial phases in cropping rotations
Comments	Strip planting of native woody vegetation may, to best intercept lateral groundwater flow, be placed on the convex change of slope where soils deepen.	High-water-use pasture such as lucerne may, in addition to controlling leakage, be strategically placed to intercept lateral ground water flow.	Significant leakage control may be achieved due to deep soils and a wide range of vegetation options, though lateral ground water flow interception may not be possible due to deep flow paths. Saline land should be managed so that groundcover is maintained.

Figure 12: Management recommendations for granite landscapes.

Meta-sedimentary landscapes

Meta-sedimentary landscapes consist of three types of ground water flows system, which are described in the appendices:

1. Local flow systems in high relief non-granite fractured rock
2. Local/intermediate flow systems in low relief non-granite fractured rock
3. Local flow systems in upper Devonian sandstone and surrounding plains

Meta-sedimentary landscapes are very common in the Eastern Murray (Figure 13) and are most clearly identified by the exposure of parent material, which has a layered appearance. The parent material is of a sedimentary origin and has changed appearance due to the metamorphic processes of heat and pressure. Individual sediments can be identified in more coarsely textured rocks, while finer mudstone is common in weathered profiles.

The displacement of rocks from fracturing and faulting has resulted in highly complex rock structures that can readily transmit water. Recharge typically occurs on hilltop outcrops and within the colluvial material generated from these rocks. Ground water flow is at both local and intermediate scales with a great deal of connectivity between, even across catchment boundaries.

The fractured and transmissive nature of meta-sedimentary rocks contrasts with the massive granite rocks described earlier, where ground water tends to only move laterally. In meta-sedimentary country the parent material provides the opportunity for water to move vertically and into deeper intermediate and regional aquifers. Consequently it is considered best to address excessive leakage at the point at which water enters the landscape rather that relying entirely on the interception of lateral flow (Figure 14).

Figure 13: Typical meta-sedimentary landscape (T. Watson). Inset: meta-sedimentary rock (M. Mitchell).

Management Recommendations for Meta-sedimentary Landscapes

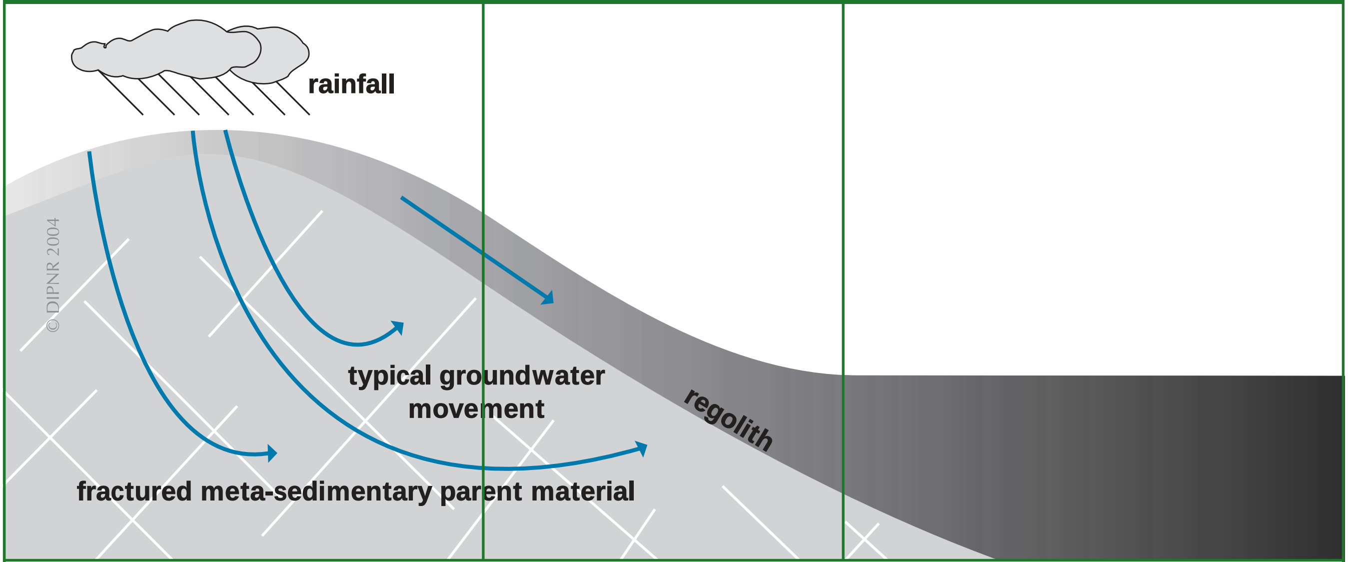
Hilltops	Slopes	Plains
		
Highly Recommended		
Leakage control: • native perennial pasture • native woodland • forestry	Leakage control: • perennial pasture • native woodland • forestry	
General Best Practice		
Ground water interception: • woody vegetation in strips, on the contour and above saline discharge areas	Ground water interception: • woody vegetation in strips, on the contour and above saline discharge areas. • high-water-use pasture such as lucerne, strategically placed	Leakage control: • perennial pasture • native woodland • perennial phases in cropping rotations
Comments		
Leakage management is a high priority due to its potential direct accession to underlying fractured rock aquifers. Native woody vegetation may be most appropriate, as land use options are limited.	Increased soil depth allows a greater range of vegetation options to control leakage than on hilltops.	Significant leakage control may be achieved due to deep soils and a wide range of vegetation options, though lateral ground water flow interception may not be possible due to deep flow paths. Saline land should be managed so that groundcover is maintained.

Figure 14: Management recommendations for meta-sedimentary landscapes.

Unconsolidated (alluvial) landscapes

Alluvial landscapes consist of one ground water flow system, which is described in the appendices:

- Local/intermediate flow systems in upland alluvium

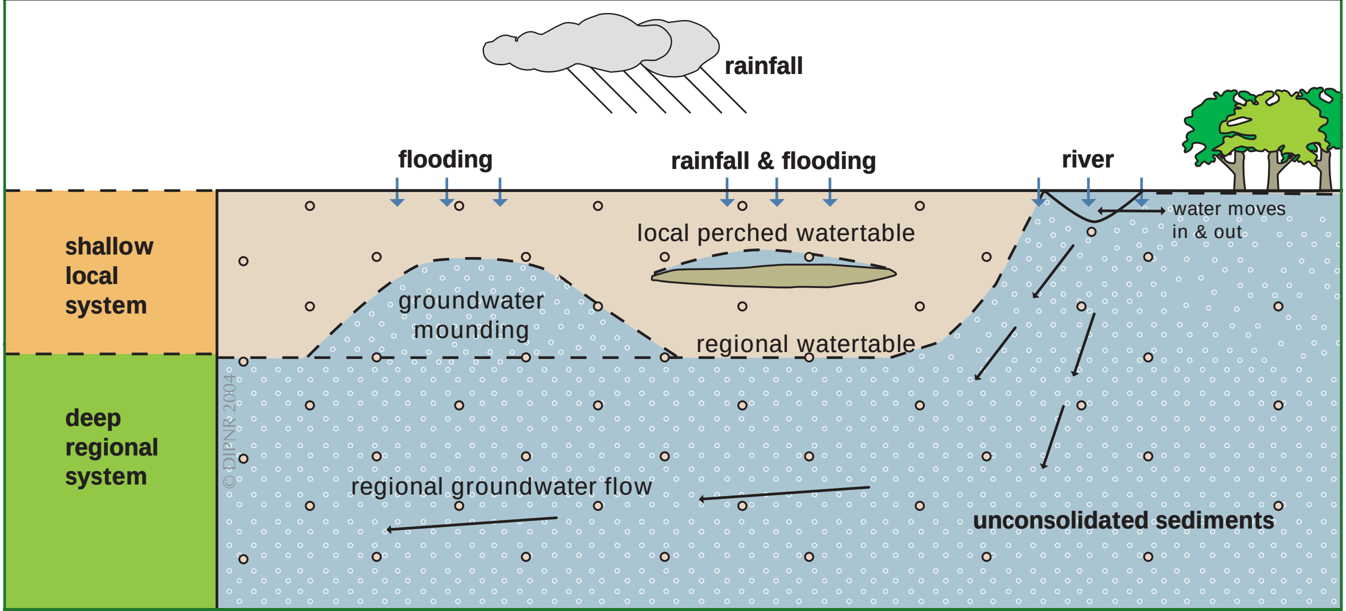
Unconsolidated (alluvial) landscapes are found throughout the Eastern Murray and correspond with the plains of the Murray River and Billabong Creek drainage lines (Figure 15). The Billabong Creek is the longest creek in Australia and extends westward from the hilly terrain of the Upper Murray, to enter the Edward River at Moulamein.

Unconsolidated (alluvial) landscapes are characterised by flat plains, deep soil profiles and complex drainage networks. They typically occur in broad open linear river valleys where significant thicknesses of alluvium have accumulated.

Shallow aquifers may receive recharge from both the upward pressure of underlying aquifers and from leakage. This may result in the mobilisation of stored salt to the ground surface, or laterally to intersecting drainage lines. The mobilisation of salt in shallow aquifers in unconsolidated (alluvial) landscapes may be reduced by pumping water from the deeper aquifers to relieve upward pressure where a relationship between the aquifers is established, and by reducing leakage via improved vegetation management.

Figure 15: Typical unconsolidated (alluvial) landscape (T. Watson).

Management Recommendations for Unconsolidated (alluvial) Landscapes



Plains

General Best Practice

Leakage control

- perennial pasture
- native woodland
- perennial phases in cropping rotations

Comments

The highly permeable colluvium and alluvium that exist throughout the plains, which are often concentrated in lenses, favour recharge. It is important that any vegetation applied to these landscapes has maximum perenniality and summer activity.

Soil structure and health should be managed to maximise SWHC; factors to consider include organic matter, pH and waterlogging due to compaction or sodicity. Conservation farming practices such as direct drill, stubble retention and minimum tillage are recommended.

Lucerne in cropping rotations is also strongly recommended to increase farm perenniality.

Occasionally, where it is demonstrated that lateral ground water flow interception will reduce known saline discharge, then targeted woody vegetation may be applied as a high priority.

Figure 16: Management recommendations for unconsolidated (alluvial) landscapes. (Diagram: adapted from Smithson, A. 2003).

Vegetation – definitions, management, impacts

This section describes five vegetation types and their potential role in addressing salinity in the South West Slopes. The vegetation types considered are:

- Forestry
- Native woody vegetation
- Native pasture
- Introduced pasture
- Cropping

The information in this section can be used to develop recommendations for land management and should be balanced with expert advice tailored to each situation.

Forestry

Definition

Forestry refers to the growing and harvesting of trees for commercial purposes.

Salinity Impact

Forestry readily develops maximum ASWD as it is comprised of deep-rooted and usually summer-active perennial plants. Infiltration and runoff is less under trees due to the interception and direct evaporation of precipitation by foliage, which can reduce effective rainfall by 10-35% according to Johnston (2003).

To be most effective in addressing salinity, forestry should be located in areas of high leakage potential or where there is an opportunity to intercept significant lateral ground water flow.

Issues

Forestry in the South West Slopes is often 'sub-commercial' due to annual rainfall limitations and related slow growth rates, which can limit the viability of its implementation. Factors that affect the viability of a forestry enterprise include:

- access for planting
- management and harvesting issues
- soil type and depth
- distance to processing
- rainfall and planting density

Social impacts are also central to decisions on forestry. Although softwoods (Figure 17) appear to hold the greatest attention in the South West Slopes, other options continue to be explored including specialised timbers, firewood, seed orchards, alley farming and oil extraction.

Figure 17: Forestry plantation (N. Myer).

Native woody vegetation

Definition

In the South West Slopes the structure of woody vegetation is 'woodland', which under natural circumstances includes widely spaced trees, shrubs and a variety of perennial ground covers and grasses (for example Yellow Box woodland, Figure 18). The biodiversity and habitat values of native woody vegetation are severely effected due to over-clearing in the South West Slopes so their restoration and regeneration is strongly encouraged (Murray Catchment Management Board, 2002). Remnant native woody vegetation often occupies parts of the landscape that are unable to support productive agriculture.

Salinity Impact

Native woody vegetation readily develops maximum ASWD as it is comprised of deep-rooted and usually summer-active perennial plants. Infiltration and runoff is less under trees due to the interception and direct evaporation of precipitation by foliage, which can reduce effective rainfall by 10-35% according to Johnston (2003).

Issues

Issues in establishing and or managing native woody vegetation include, for example, weed and pest animal management, economic and social benefits and costs. Grazing can often form an important part of native vegetation management and strategies should be designed to optimise growth and water use while allowing natural regeneration. A good reference for the establishment and management of native woody vegetation in the *South West Slopes is the South West Slopes Revegetation Guide for Holbrook, Hume and Urana Districts* (Stelling, 1998).

Figure 18: Native woody vegetation (C. Miles).

Native pasture systems

Definition

Native pastures (Figure 19) are those dominated by locally native plant species. They are often an under-utilised resource, which if properly managed can be a useful and productive part of farming. Managing native pasture in certain ways is consistent with maximising farm income' (Crosthwaite & Malcolm, 1999). Native pastures are particularly useful for grazing when located in areas where the establishment of introduced pastures is uneconomic or impractical, for example on rocky or steep land. Native pastures may also have a biodiversity benefit.

Salinity Impact

Native pastures are able to survive and thrive in relatively low soil fertility and acid soils, respond to summer rainfall and yield greater volumes of clean runoff than other pastures (Johnston 2003). From a salinity perspective, native pastures are extremely important. If well managed they will provide optimal soil drying (ASWD) in locations where options for high water use vegetation, eg hilltops and steep slopes are limited.

Issues

Native grasses are difficult and expensive to re-establish and their removal is discouraged. Practices that may be appropriate to best manage native pasture include:

- Active grazing management to favour 'seed-set' of desirable species, control weeds and optimise growth and utilisation.
- Inclusion of trees in some cases in an open woodland structure to maximise grass growth.
- Cautious and informed application of fertiliser and incorporation of legumes, with attention to the sensitivity and viability of the native plants.

Figure 19: Native pasture (Red Grass *(Bothriochloa* sp) and Weeping Grass *(microlaena* sp) (C. Allen). Inset: Weeping Grass *(Microlaena* sp) (C. Allen).

Introduced pasture

Definition

Introduced pastures are those typically dominated by naturalised or non-native species.

Salinity Impact

Improving the mix and management of introduced pasture in the South West Slopes has perhaps the greatest potential for managing leakage and salinity at a catchment scale. This is due to the significant cumulative effect that results from changes applied extensively across the landscape. The improved management of pastures is a major salinity priority, which fortunately can also be justified from the point of view of improving productivity and profitability.

Introduced pastures can be manipulated in both content and management to optimise their soil moisture utilisation and consequently ASWD. In terms of pasture content, two categories are compared: annual based and perennial based.

Annual/perennial

There are two broad categories of introduced pasture: 'annual' which are those dominated by shallow rooted plants that have a short growth season and annual life cycle, and 'perennial' which contain plants that survive from one year to another (though they may not be active for this entire period). A robust perennial pasture may have an annual component including legumes to maximise herbage and production.

Perennial pastures are preferred to annual pastures for salinity management. Well-managed perennial pastures use more soil moisture throughout the year and tend to be deeper rooted, so develop a greater ASWD and accordingly minimise leakage.

Lucerne (Figure 20) is a highly promoted introduced pasture species. It is perennial, active for most of the year including summer and has a very long taproot that allows it to utilise water from significant depth. Lucerne is encouraged wherever topography and other practical limitations permit as a productive landuse option to address identified high leakage potential.

Management

Pasture management is just as important to water use and ASWD development as is its composition. For example a perennial pasture that is overgrazed may use less water in one year than a well managed annual pasture in the same situation. Pasture management also has some bearing on the structure and health of a soil. A well managed pasture is likely to have good structure and higher levels of organic material, which equates to higher SWHC and potential buffer size.

Pastures that are composed and managed for optimal water use and ASWD development are inevitably the most productive, as they utilise rather than waste the soil moisture resource.

Issues

Issues with introduced pastures include, for example, the potential for some species to become environmental weeds; practical and economic limitations for establishment; and the potentially significant change in farm management that may be required to ensure they are managed to optimise growth and water utilisation. Advice to help achieve good pasture management through strategic grazing can be provided by agronomists.

Figure 20: Lucerne-based pasture undersown in crop (D. Costello).

Cropping

Definition

Cropping in the South West Slopes mainly consists of varieties of winter crops including wheat, triticale, canola, lupins and oats, grown on the better soils of land classes I, II and III. Crops are usually grown in rotation with pasture phases.

Salinity Impact

Almost all cropping in the South West Slopes is based on annual plants that grow slowly in winter, have a short burst in spring, seed set and then die in early summer. This is in contrast with the deep-rooted perennial plants that are preferred for addressing salinity. However it has been shown that various crop management techniques can be applied to optimise water use, which if applied extensively could have a beneficial cumulative effect at a catchment scale.

The management techniques advocated for salinity outcomes include the following:

The use of early season crops

The use of early season crops will effectively extend the growing season and so the period of time that soil moisture is being utilised.

Improved soil health

Conservation farming principles such as stubble retention, direct drilling, controlled traffic, incorporating organic material, and effective rotations will improve soil structure, biota and health. This will maximise the amount of moisture that the soil profile can hold and accordingly how great a buffer (ASWD) can be developed to minimise leakage. Other factors that may need to be addressed are soil acidity (pH) and removing hardpans caused by compaction or soil sodicity.

Improved crop agronomy

Improved crop agronomy to optimise plant growth and production such as soil fertility management, control of weeds, pests and disease and precision farming technologies will ensure that soil moisture use is maximised.

Direct or reduced tillage

Direct drilling or reduced tillage help to conserve soil structure and the associated macro-pores that are important for maintaining soil water holding capacity.

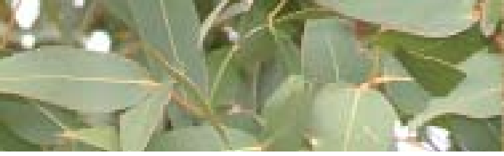
Incorporation of a perennial phase

Lucerne is an introduced perennial and summer active pasture species that is highly effective in drying out the soil profile. Incorporating lucerne into a cropping rotation will have a significant impact on ASWD while it is in place and a diminishing impact over subsequent cropping seasons. The average ASWD of a paddock and farm will be higher if this practice is adopted (Ridley et. al. 2001). Soil moisture prior to sowing crops is often critical to their performance and success, so the use of lucerne for soil drying and salinity outcomes must be considered in terms of this.

Issues

Cropping (Figure 20) is a necessary and important part of the economy and social culture of the South West Slopes. In some areas, particularly the fertile plains, it provides a major proportion of farm income. While annual crops are not ideal from a salinity management perspective, a positive salinity outcome can be achieved by maximising crop water use and incorporating or increasing perennial pasture phases in rotations.

Figure 21: Cropping (T. Watson)



Conclusion

This guide provides a foundation to understanding the relevance and processes of salinity in the South West Slopes. It also provides a means for prescribing vegetation as a treatment, based on and interpretation of the landscape and knowledge of the general impact of various vegetation types. Research and modelling continues to refine our understanding of salinity and the best ways to treat it. Consequently when planning actions to address salinity at all geographic scales, it is necessary to seek the most current and proven information for the area, and as the problem is complex, to consider a range of environmental, social and economic factors.

Glossary

This glossary contains terms included within and additional to those contained in the text.

agro-forestry	Land management practice in which farmers cultivate trees in addition to their other agricultural activities.
agronomy	Branch of agriculture dealing with pasture and crop production.
alluvial	Deposited by rivers in low-lying areas and flood plains.
annuals	Plants that live for one growing season.
aquifer	A layer of rock or sediment that allows water to move through it and from which water can be extracted. Confined aquifers have a layer of rock or clay above them, which is impermeable to water.
autumn soil water deficit (ASWD)	The degree of dryness of a soil profile prior to the onset of winter.
biodiversity	The variety of life forms, the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form.
break of slope	The zone across a landscape at which the surface slope changes and where the hydraulic conductivity of the underlying material or the hydraulic gradient decrease.
catchment	The area of land drained by a river and its tributaries.
colluvial (deposits)	Deposits of loose material that have been carried by gravity and are usually found at foot slopes of hills.
deep drainage	Water draining from below the root zone into underlying aquifers.
discharge	Flow of ground water from the saturated zone to the earth surface.
discharge area	The area in which there is upward movement of ground water and where ground water is discharged from the soil surface. Ground water escapes via springs, evaporation, transpiration and surface drainage (see recharge area).
electrical conductivity	The most widely used and convenient method of measuring the salinity of water is by electrical conductivity. One measure of electrical conductivity is 'micro-Siemens per centimetre'. The shorthand expression for this is the 'electrical conductivity unit', 'EC unit' or just 'EC'.
evapo-transpiration	The movement of water to the atmosphere from the combined sources of vegetation, soil and water bodies.
fallowing	The practices of leaving land without vegetative cover for a period of time before sowing another crop. Its purpose is to allow nutrients and water to accumulate in the soil.
fractured rock strata	These occur in rocks eg slate, phyllite and basalt, and allow water to move through broken joints, bedding plains or faults.
geology	Science of learning about the earth: its origin, structures, composition, historical changes and processes.
ground water	Water beneath the surface held in or moving through saturated layers of soil, sediment or rock.
ground water flow system	The term ground water flow system (GWFS) refers to the underground extent of a hydrological system, including places that water enters, is transmitted, stored and departs. It also refers to the particular physical attributes of that system, including geophysical characteristics, geology, regolith and topography.

hydrogeology	The science pertaining to ground water in or moving through soils and rock formations and the transport of materials that are either in suspension or dissolved in the water.
landscape	An area of land and its physical features. A term that we use to describe an area that has common features. For example Albury may be in a range of landscapes, depending on whether we are looking at the type of agricultural production, vegetation or landforms.
leaching	A process through which soluble salts and minerals are moved with the infiltrating soil water to lower levels in the soil profile.
leakage	Same meaning as 'recharge'.
native vegetation	Plant species that are indigenous to the subject location.
piezometer	A tube inserted into an aquifer to measure the ground water. When the ground water is under pressure the piezometer measures the hydraulic head or level.
perennial/perenniality	A plant that lives for several years (compared to annuals)/the degree to which a vegetation community or geographical area is composed of perennial vegetation.
permeability	The capacity of a substance (for example, soil or rock) to allow water to pass through it. Sand, for example, is said to have high permeability.
recharge	A component of rainfall that drains below the root zone of vegetation and joins the ground water. Same meaning as 'leakage'
recharge area	The area where water can enter and move downward to the ground water.
regolith	The layer of loose or cohesive material that includes soils which sits over bedrock and forms the surface of the land.
remnant vegetation	Native vegetation remaining after an area has been cleared.
runoff	The proportion of rainfall that flows across the ground surface, generally to enter drainage lines.
root zone	The area below the ground surface occupied by plant roots.
salinisation	The process by which land becomes salt-affected or salinised.
salinised land	Land affected by salinity.
salinity	The concentration of salts in land and water, usually expressed in EC units.
salinity hazard	Factor that contributes to salinity risk.
salinity risk	When applied to a subcatchment of the Eastern Murray Catchment; the relative risk of land salinisation, or saline discharge of a concentration that is high in comparison with the rest of the catchment.
salt concentration	Level of salts on the land surface or in soil, rocks or water.
salt load	The amount of salt carried in water flow in rivers, ground water or off the soil surface, in a given time period.
salt tolerant plants	Plants that are adapted to a saline environment.
soil profile	A vertical section of earth from the soil surface to parent rock material that shows the different soils horizons.
soil water holding capacity (SWHC)	Amount of water that remains in a soil profile after drainage.
subsoil	The layer of soil below the topsoil, generally deeper that 10cm.

topsoil	The surface or upper level of soil, generally within 10cm of the surface.
topography	The detailed description and analysis of the features of a relatively small area, district or locality.
wash-off	The process of salt being washed from salinised land to water courses in storm runoff.
water balance	A state of equilibrium when rainfall or irrigation water in a landscape is accounted for by the sum of runoff, plant water use, evaporation, recharge and changes in soil moisture content.
water logging	Where the surface soils is saturated with water from rising ground water of surface runoff collecting in low areas.
watertable	The watertable is the upper surface of ground water. The soil profile is fully saturated below the watertable and unsaturated above it.
weathering	Chemical, physical and biological decomposition of rocks. This can result in the formation of a soil profile.

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Appendices

Ground Water Flow Systems of the South West Slopes

Six ground water flow systems have been defined in the South West Slopes, and are described in detail in Humphries, (2003). The map below (Figure 22) shows the regional extent of GWFS in the Murray and South West Slopes and following is a summary of the individual systems.

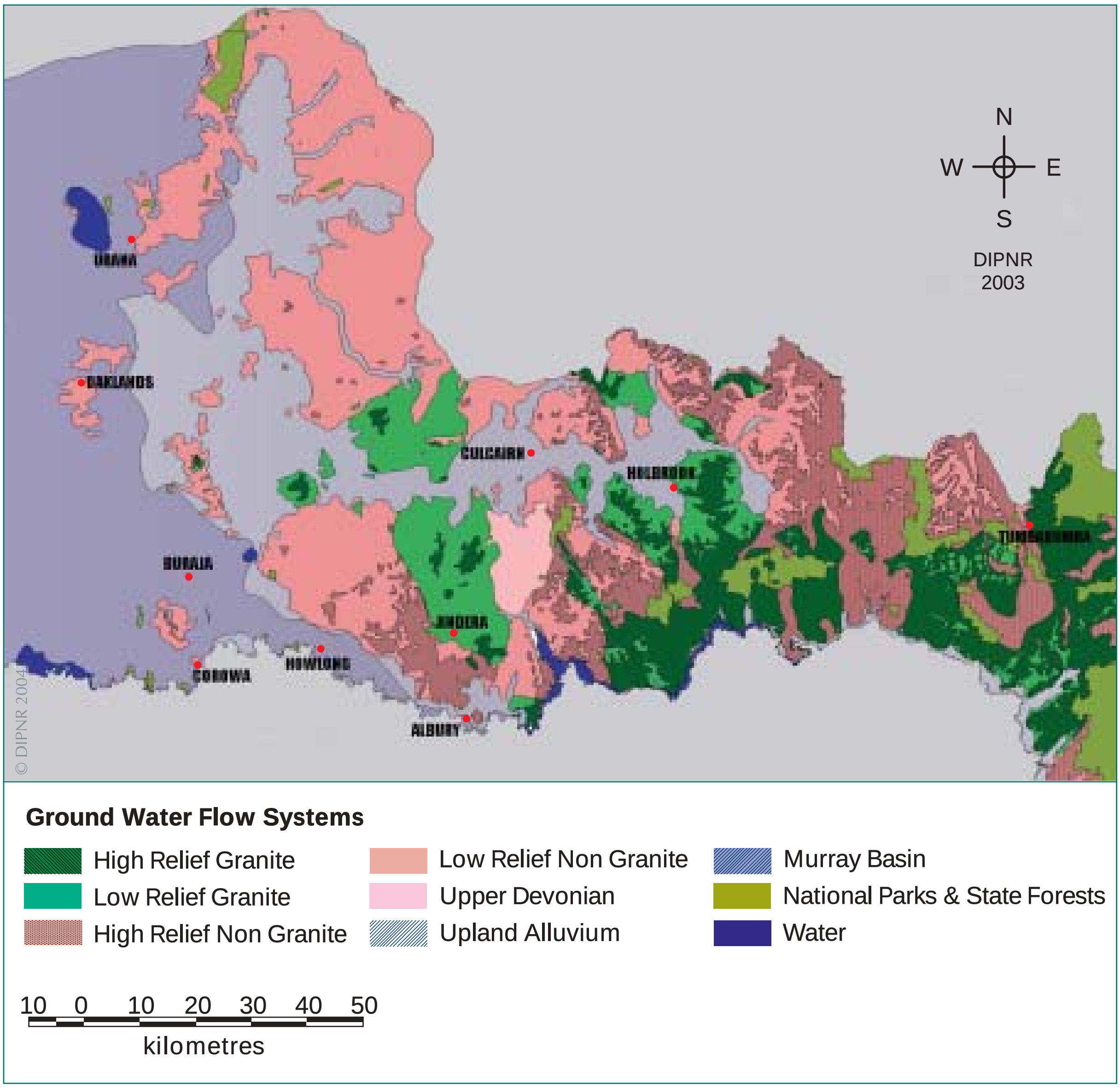


Figure 22: Ground water flow systems of the Eastern Murray.

Local flow systems in high relief non granite fractured rock

Occurrence

East of Holbrook in the Upper Billabong Catchment, Jingellic, south of Tumbarumba including parts of Mannus State Forest, areas adjacent and including Kosciuszko National Park, high relief areas northwest of Holbrook, Mullengandra, and areas west of Albury and Jindera.

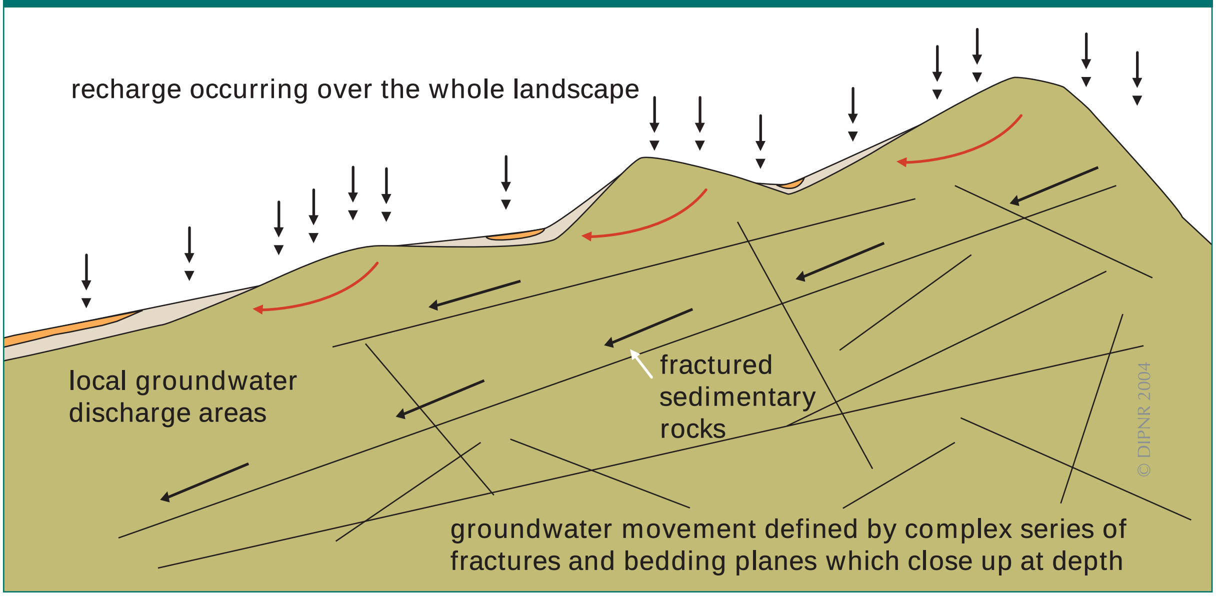
Attributes

Scale	local
Landform	steeply undulating country
Aquifer	fractured meta-sediments
Aquifer transmissivity	moderate
Ground water salinity	low
Land use	predominantly grazing, significant tree cover
Catchment size	small
Salinity manifestation	break of slope and drainage lines
Temporal recharge distribution	seasonal
Spatial recharge distribution	hilltop outcrops and within shallow soil profiles in upper parts of catchment
Type areas	Holbrook - Upper Billabong

Discussion

The systems are characterised by a large number of small local flow systems (between 3 - 5km in length) that correlate very closely with topographic catchments. They contain highly fractured meta-sediments and soils that are commonly shallow and coarsely textured. Recharge occurs seasonally on hill top outcrops and within colluvial material, and a distinctive filling and draining response is produced. Ground water discharge typically occurs at the break of slope and stream networks receive ground water discharge as base-flow or within drainage lines. Aquifers are found in fractured meta-sediments and are commonly unconfined or semi-confined. Salt storage in the system is usually low. Response times to changed ground water conditions can be rapid (5-50 years), with equilibrium conditions taking significantly longer to establish.

Local Flow Systems - High Relief Non-Granite



Source: After Humphries, (2003).

Local flow systems in high relief granites

Occurrence

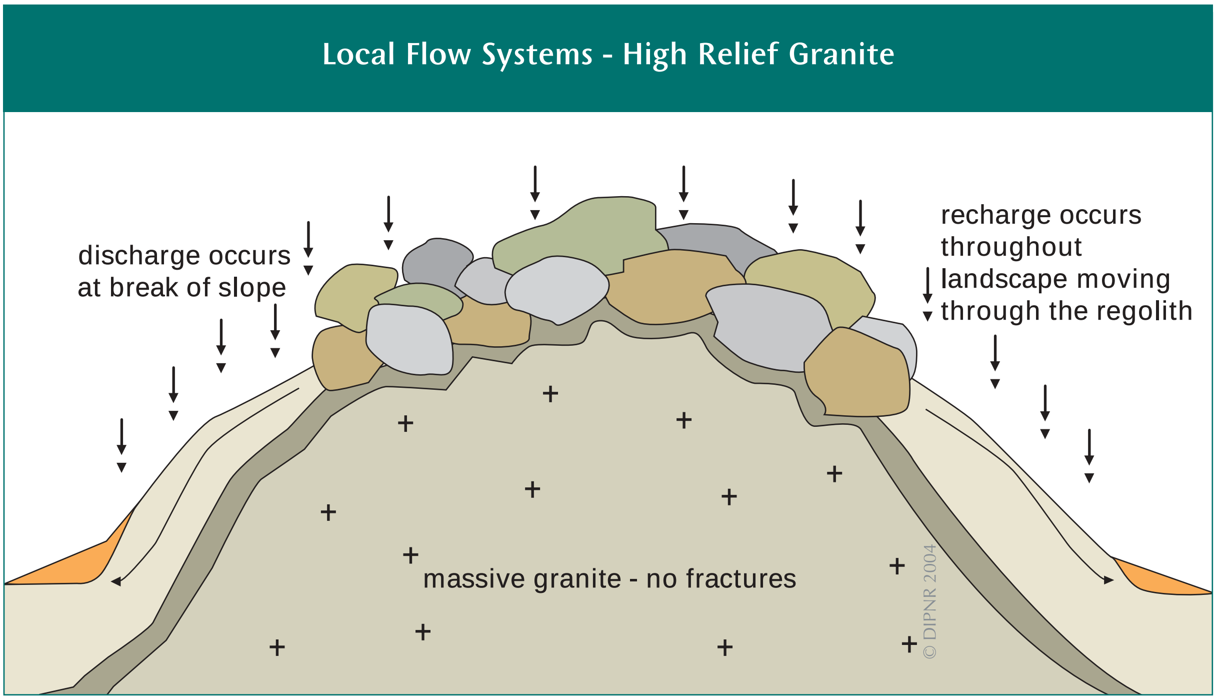
South-east of Mullengandra and Holbrook, including Lankeys Creek, alongside Kosciuszko National Park, south of Tumbarumba, and pocket areas north of Jindera.

Attributes

Scale	local
Landform	steep granite terrain
Aquifer	saprolite/colluvium
Aquifer transmissivity	moderate
Ground water salinity	generally low, some moderate
Land use	grazing
Catchment size	small
Salinity manifestation	break of slope and valley floor (at unit boundary)
Temporal recharge distribution	seasonal
Spatial recharge distribution	from run-on at midslope sites
Type areas	Wagra (near Wymah)

Discussion

These systems are dominated by deeply weathered granite bodies and have well developed colluvial slopes surrounding them. They typically comprise unconfined saprolite and colluvial aquifers, which are overlain by remnant clay and weathered bedrock surfaces on the mid and lower slopes. Recharge is seasonal and begins on the mid slope areas at the head of the colluvial material. Ground water mostly moves laterally, due to the massive nature of the parent material. Discharge and salinity typically occur in valley floors and at breaks of slope, and are evidenced by salt indicator species and reduced productivity. Salt storage in these systems is considered to be low to moderate.



Source: After Humphries, (2003).

Local flow systems in low relief granites

Occurrence

North of Jindera, Burrumbuttock region, Gombargana, Alma Park-Walbundrie regions, south of Berrigan, around Cookardinia and small outcrops south of Holbrook.

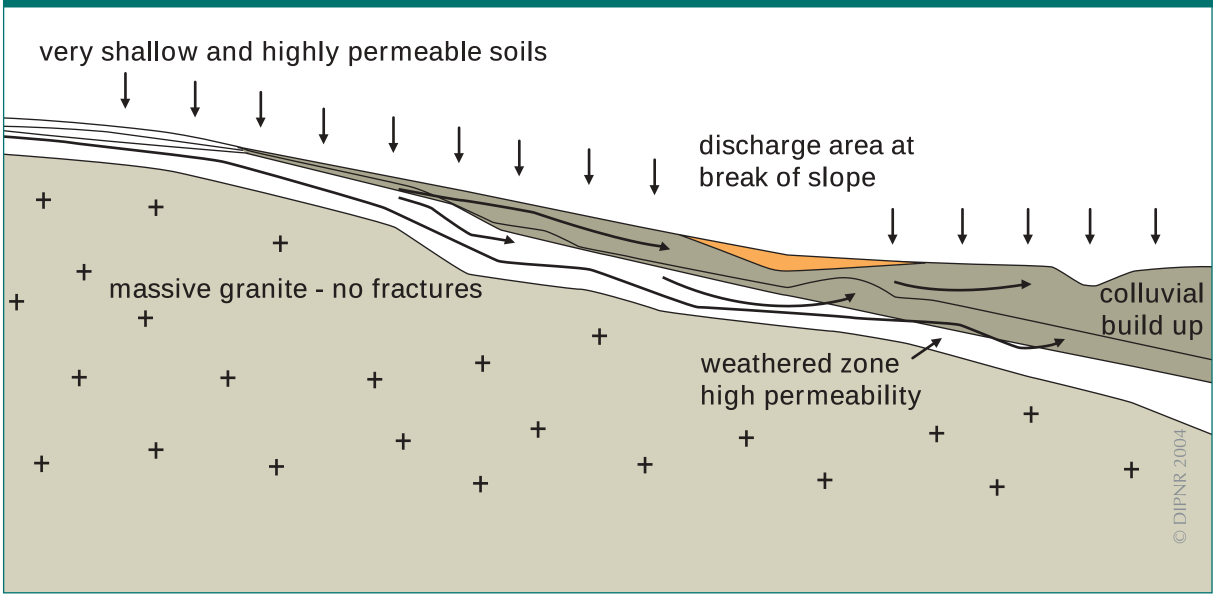
Attributes

Scale	local
Landform	gently undulating landscape
Aquifer	saprolite and saprolith
Aquifer transmissivity	low-moderate in the east, moderate in the west
Ground water salinity	generally low, some moderate
Land use	mixed farming
Catchment size	small
Salinity manifestation	valley floor and drainage lines
Temporal recharge distribution	seasonal and episodic
Spatial recharge distribution	slopes
Type areas	Gerogery

Discussion

These systems are characterised by a deeply weathered granite profile (40m - 50m) occurring on gentler slopes than the high relief granites. Aquifers of these systems are mainly unconfined saprolite/ saprolith with flow lengths in the order of 5km. Ground water salinity increases from east to west and can be up to 20dS/m. Recharge occurs generally across the systems and ground water flow is mainly lateral due to the massive nature of the parent material. Salt stores are moderate, again with concentrations increasing to the west. Salt expressions are usually evidenced by salt tolerant species with some scalding and erosion. The majority of the expressions can be found in drainage lines and valley floors.

Local Flow Systems - Low Relief Granite



Source: After Humphries, (2003).

Local/intermediate flow systems in low relief non-granite fractured rocks

Occurrence

North and east of Holbrook, including Carabost, Rosewood, headwaters of the Little Billabong, Mangoplah, north-east of Morven, east of Lockhart, Urangeline, Rand, Pleasant Hills, Doodle Comer, north of Howlong including Balldale, around Daysdale, north of Corowa, Mt Boomanoomana, south of Berrigan, west of Cobram.

Attributes

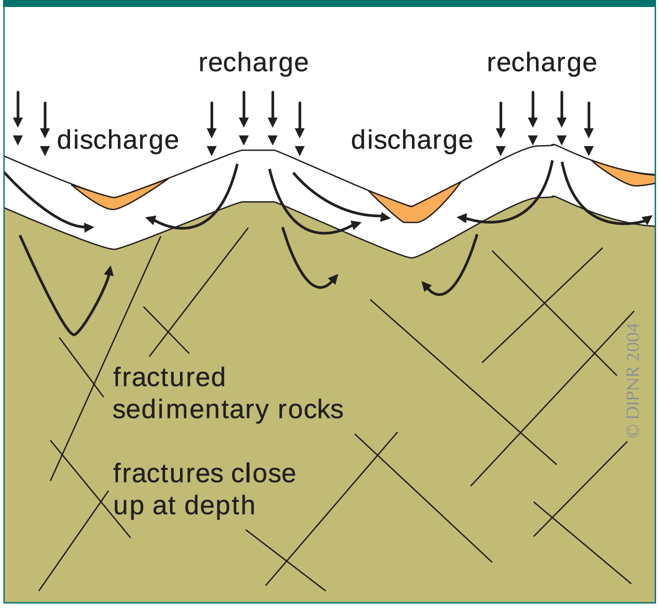
Scale	intermediate
Landform	gently undulating
Aquifer	fractured rock
Aquifer transmissivity	moderate
Ground water salinity	moderate
Land use	mixed farming (cropping and grazing)
Catchment size	moderate
Salinity manifestation	break of slope
Temporal recharge distribution	seasonal and episodic
Spatial recharge distribution	generally over landscape
Type areas	Lockhart

Discussion

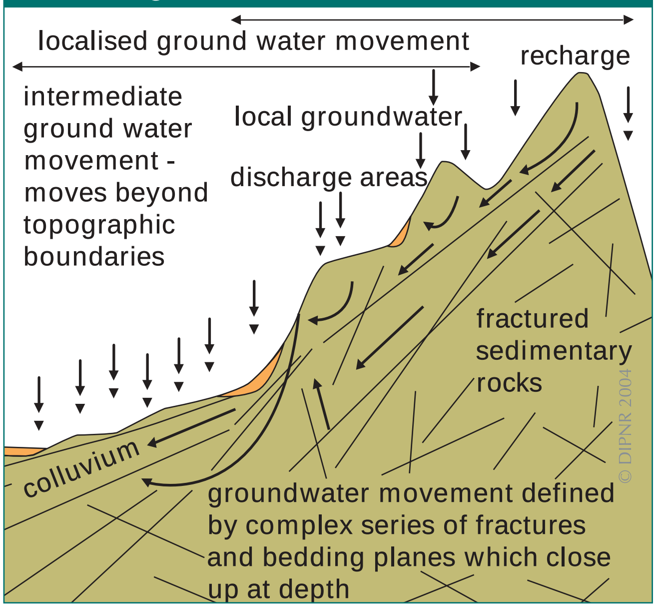
These systems are common within the Murray catchment and consist of gently undulating country with residual and colluvial material underlain by weathered and highly fractured meta-sediments including slate, phyllite, sandstone, schist and gneiss. Aquifers are unconfined and typically exist in fractured rock with good porosity. Catchment size is intermediate and in the order of 10 - 20,000 ha; flow lengths are usually between 5-10 km. Local relief is generally less than 20-30 metres and consequently ground water may flow underneath catchment boundaries.

Recharge occurs seasonally, mostly via fractured rock outcrops in catchment headwaters and generally throughout the system. Discharge occurs where there is a reduction in the hydraulic gradient consistent with major changes in the slope of the land and via base flow to streams. Salinity expressions also occur at the break of slope, evidenced by indicator species and scalding.

Local Flow Systems - Low Relief Non-Granite



Local & Intermediate Flow Systems - High & Low Relief Non-Granite



Source: After Humphries, (2003).

Local flow systems in upper Devonian sandstone and surrounding plains

Occurrence

Yambla Range (Table Top) and the plains to the west, bounded by Gerogery Creek.

Attributes

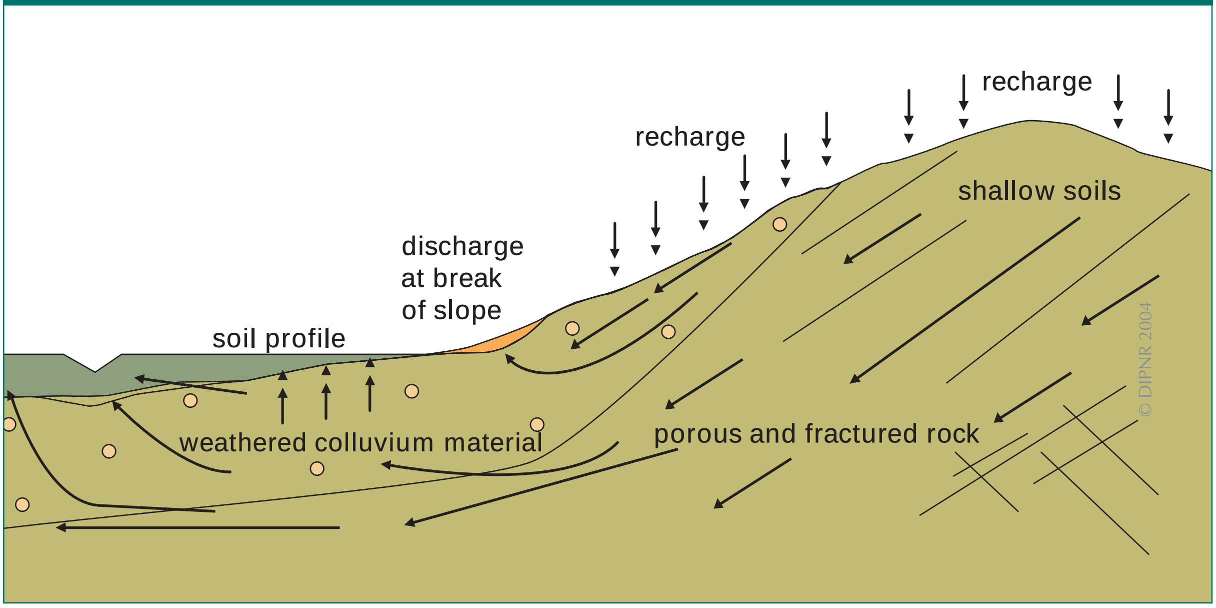
Scale	local
Landform	steep slopes and some plateaus
Aquifer	fractured rock and colluvial slope
Aquifer transmissivity	moderate
Ground water salinity	low
Land use	mainly grazing, timber on higher slopes
Catchment size	small
Salinity manifestation	break of slope and valley floor
Temporal recharge distribution	seasonal
Spatial recharge distribution	through colluvial slopes and rock outcrops
Type areas	Gerogery East

Discussion

This system is characterised by uplifted sedimentary rocks that dip to the west, with relatively coarse colluvial slopes that follow the direction of dip and give way to gently sloping adjoining valleys. Overall relief is up to 300 metres, which combined with relatively confined aquifers that flow for around 2 km, producing very high ground water pressures on the plains.

Recharge occurs seasonally, through the colluvial slopes and directly in the fractured rock outcrops of the range that have minimal soil cover. Ground water flow occurs via fractures in the sedimentary rocks and shallow flow in the colluvial material. Ground water trends are showing a steady rise in this area. Ground water discharge and salinity typically occur where higher permeability fractured rocks rest over less permeable materials, at the break of slope and in valley floors, as evidenced by salt indicator species and some scalding.

Local Flow Systems - Upper Devonian Sandstone and Surrounding Plain



Source: **After Humphries, (2003).**

Local/intermediate flow systems in upland alluvium

Occurrence

Mid catchment plains - alluvial and adjacent low colluvial foot-slopes, recent alluvial deposits of the Murray Plains and the Billabong Creek Plains, upstream of Corowa and Rand respectively.

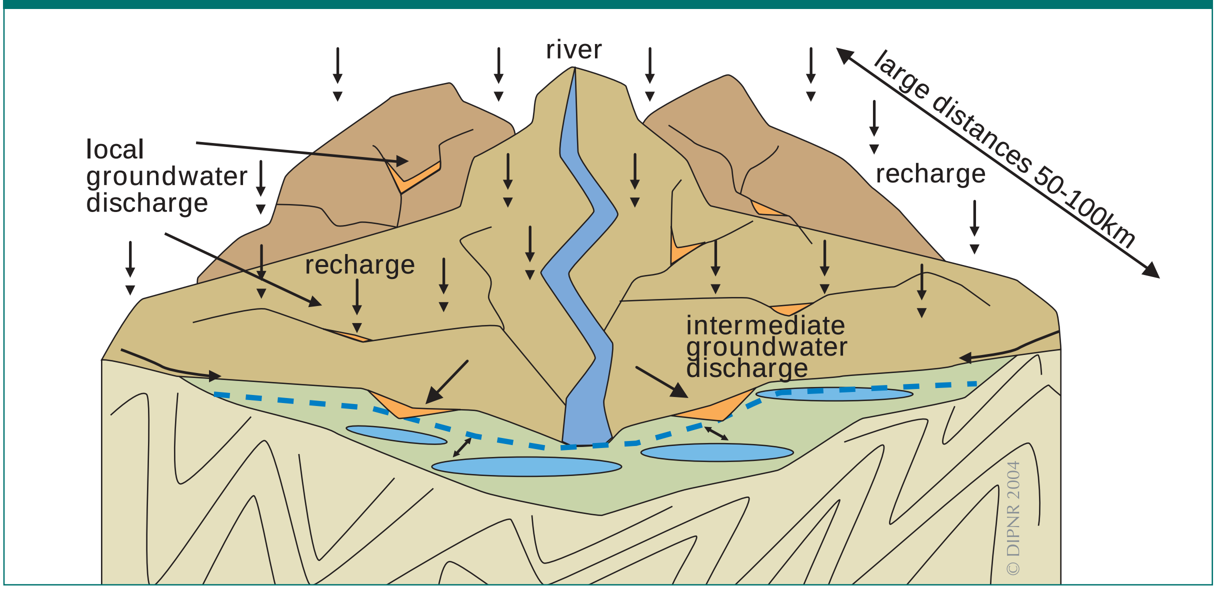
Attributes

Scale	local
Landform	alluvial plains and colluvial foot-slopes
Aquifer	alluvial material (sand/clay and gravel)
Aquifer transmissivity	high
Ground water salinity	low to moderate
Land use	cropping and grazing
Catchment size	large
Salinity manifestation	where tributaries reach the floodplain
Temporal recharge distribution	episodic
Spatial recharge distribution	recharge occurs over the landscape
Type areas	billabong upstream of Rand, Murray upstream of Corowa

Discussion

Broad open linear river valleys where significant thicknesses of alluvium have accumulated define this GWFS. Aquifers consist of alluvium (clay, sand and gravel) and are semi-confined and confined. Catchment size is in the order of 50-100,000 ha, with flow lengths over 100 km. Ground water salinities are low to moderate and increase from east to west. Salinity outbreaks usually occur where the tributaries reach the floodplains, and where narrowing of valleys leads to broad-scale discharge to surface water systems.

Local/Intermediate Flow Systems - Upland Alluvium



Source: After Humphries, (2003).

Department of
Infrastructure, Planning and Natural Resources