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Cranbrook-Toolbrunup : catchment appraisal report 2001

Tim D. Overheu

Western South Coast Catchment Appraisal Team (WA)

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CRANBROOK-TOOLBRUNUP

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CRANBROOK-TOOLBRUNUP

CATCHMENT APPRAISAL REPORT 2001

Compiled by Tim Overheu
for the
Western South Coast Catchment Appraisal Team

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The Western South Coast Catchment Appraisal team:

Tony Cremin, Spatial Information Manager, Albany

Lisa Crossing, Extension Hydrologist, Albany

Ruhi Ferdowsian, Groundwater Hydrologist, Albany

Kelly Hill, Community Support Officer, Cranbrook

Ronald Master, Community Support Officer, Albany

Clare McCarron, formerly Hydro-analyst, Albany

Nick Middleton, Spatial Resource Analyst, Albany

Michael O'Connell, Regional Economist, Albany

Timothy Overheu, RCA Team Leader, Albany

Bruce Radys, Revegetation Officer, Albany

Arjen Ryder, Farming Systems Officer, Albany

Cindy Stevens, Farming Systems Development Officer, Gnowangerup

Angela Stuart-Street, Soil Resource Officer, Katanning

Summary

The Cranbrook–Toolbrunup area covers about 81,395 hectares in the Pallinup North Stirling (and part Kent-Frankland) sub-region, on the South Coast. It occupies 46,290 ha of the Tambellup Shire; 33,973 ha of Cranbrook Shire; about 729 ha of Gnowangerup Shire; and 403 ha of Broomehill Shire. The town of Cranbrook is included and Tambellup is directly adjacent to the west.

Geology is dominated by the granite and gneiss of the Yilgarn Craton. Hydrology is strongly influenced by the broad and often stagnant flats that are found mostly in the north. The soils are dominated by deep and shallow sandy duplexes, while gravelly soils with saline wet soils are also common.

Poorly drained sandy duplex, sandy duplex and gravel slopes and ridges are the three most widespread land management units.

Areas of current degradation and hydrological risk (rising watertables up to 2 m below the surface) are estimated at 9,017 ha (11%) with 28,400 ha facing potential risk.

Other land degradation risks include susceptibility to soil acidity (54% of catchment) and wind erosion (40%). About 48 km of sealed road, 65 km of unsealed roads and 23 km of railway line faces damage from high watertables.

Strategies from the best available information to address reduction of recharge and land degradation, as well as protection of remnant vegetation have been included.

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1. Introduction

The Cranbrook-Toolbrunup study area (Figure 1.1) is situated at the eastern junction of both the Pallinup North Stirling and Kent Frankland sub-regions and covers a total of 81,395 hectares. It comprises six amalgamated sub-catchments:

- Pingelup Creek
- Solomons Creek
- Racecourse Lake
- Lake Toolbrunup
- Twolganup Brook
- Hamilla Hill (west).

The study area was one of the first areas to be selected and reviewed for the appraisal process because of its high susceptibility to degradation by salinity and rising watertables.

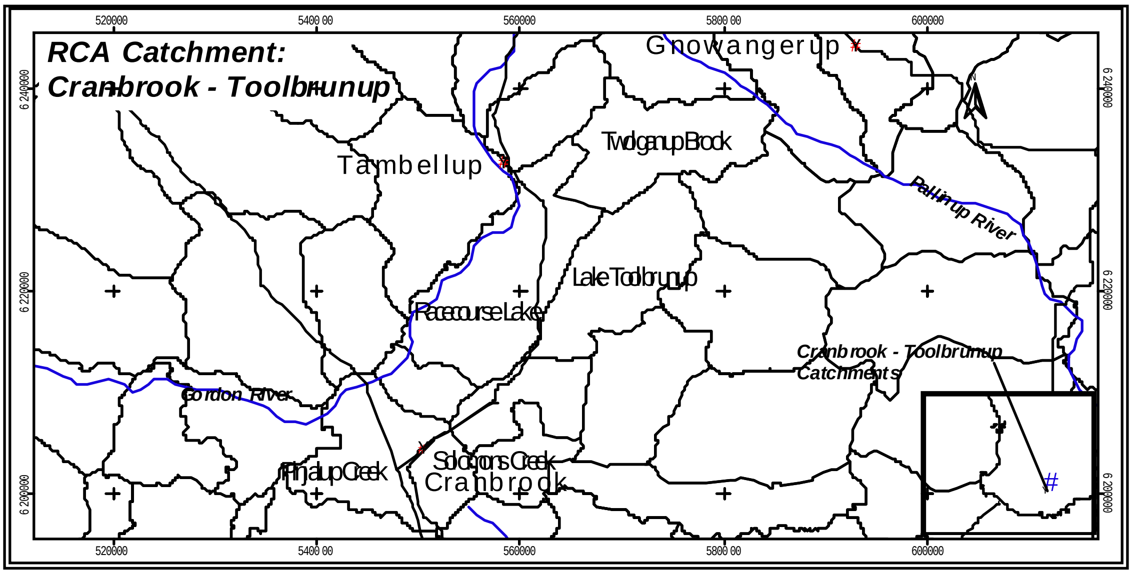


Figure 1.1. The Cranbrook–Toolbrunup area; north of Cranbrook in the North Stirling basin

With average annual rainfall varying from about 450 mm to less than 400 mm, there is a diversity of farming systems ranging from broadacre cropping to sheep production (wool and meat). In recent years, production has included viticulture in the west, aquaculture and commercial farm forestry.

This report primarily focuses on the agricultural and natural resources at risk and attempts to identify options to manage the potential risks.

2. Catchment resource analysis

2.1 Climate

Clare McCarron, (formerly) Department of Agriculture

Rainfall

The Cranbrook-Toolbrunup catchment experiences a strong seasonal Mediterranean climate with cool, wet winters and dry hot summers. Most rainfall occurs in winter, when eastward moving low-pressure systems to the south of the continent generate cold fronts bringing fairly reliable winter rainfall. Rainfall is higher at the coast and decreases with distance inland, although the Stirling Ranges have a strong effect on local distribution. In summer there is sporadic rainfall from thunderstorms.

Rainfall variation is shown in Table 2.1.1. There is a 20% chance (or one in five) of rainfall below 322 mm (dry year) and a 20% chance of rainfall above 454 mm (wet year) for the area.

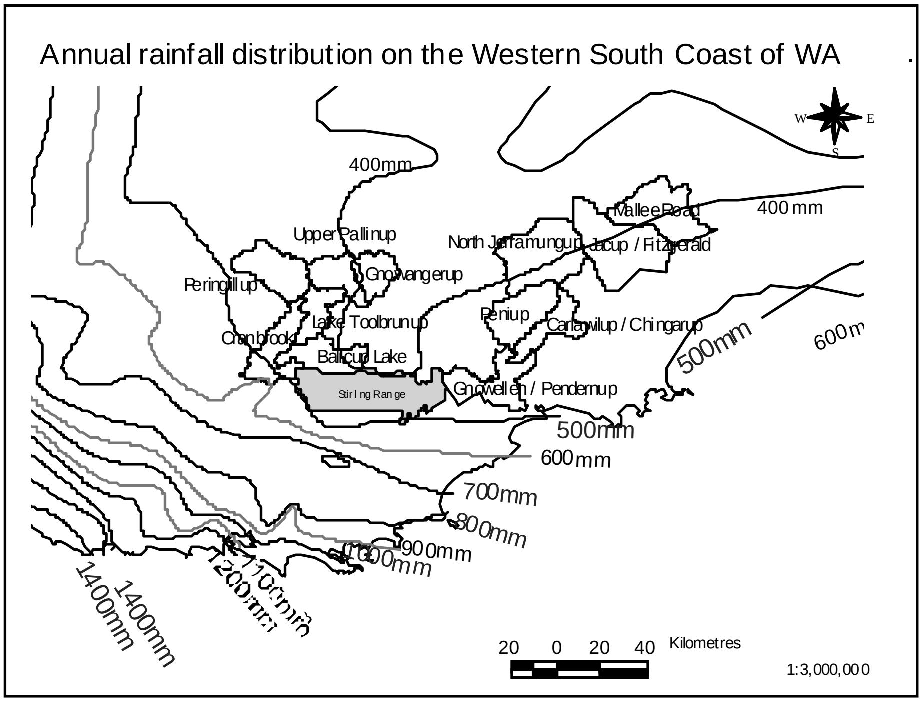


Figure 2.1.1. Average annual rainfall map from complete records to 1979 (Bureau of Meteorology)

Table 2.1.1. Statistics for annual rainfall for the Cranbrook-Toolbrunup catchment (interpolated data from Data Drill*)

Location	Mean (mm)	Deciles			Minimum (year)	Maximum (year)
		20% Dry Year	50% Median	80% Wet Year		
Lake Toolbrunup	393	322	394	454	240 (1987)	524 (1998)
Cranbrook	497	439	495	468	338 (1987)	631 (1963)

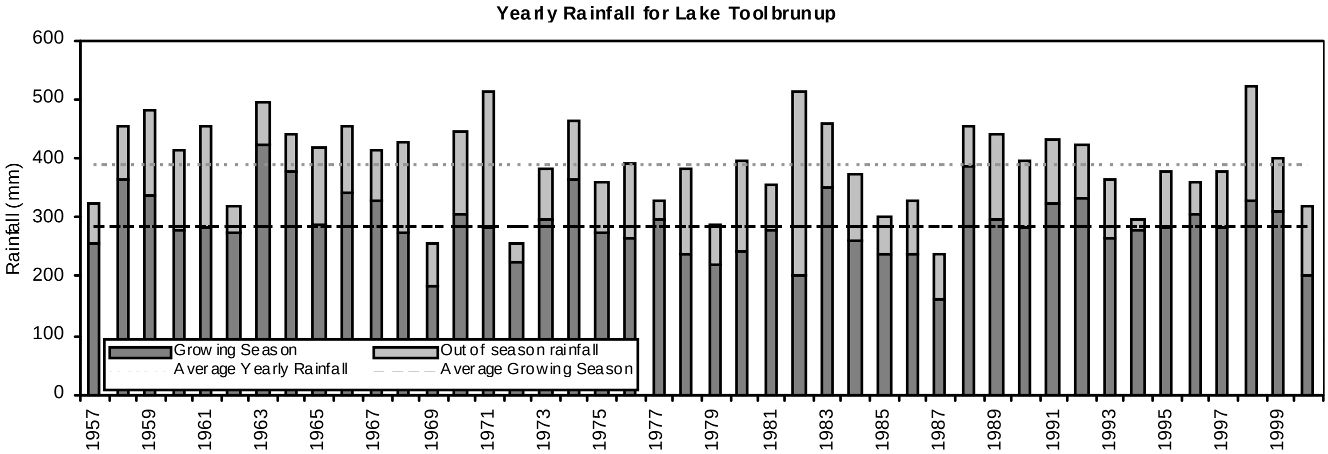


Figure 2.1.2. Annual rainfall within growing season (May to October) and out-of-growing season for Lake Toolbrunup (interpolated data from Data Drill)*

Temperature

Temperatures range from an average daily high in January of 28°C to average winter highs of 14 to 15°C*. When the recorded temperature drops below 2.2°C the ground temperature can fall to zero and frosts may occur. Frost also depends on low wind speeds and humidity. It may damage crops, especially in September to October (cf. Cereals Frost Identification Guide, Bulletin 4373, Department of Agriculture).

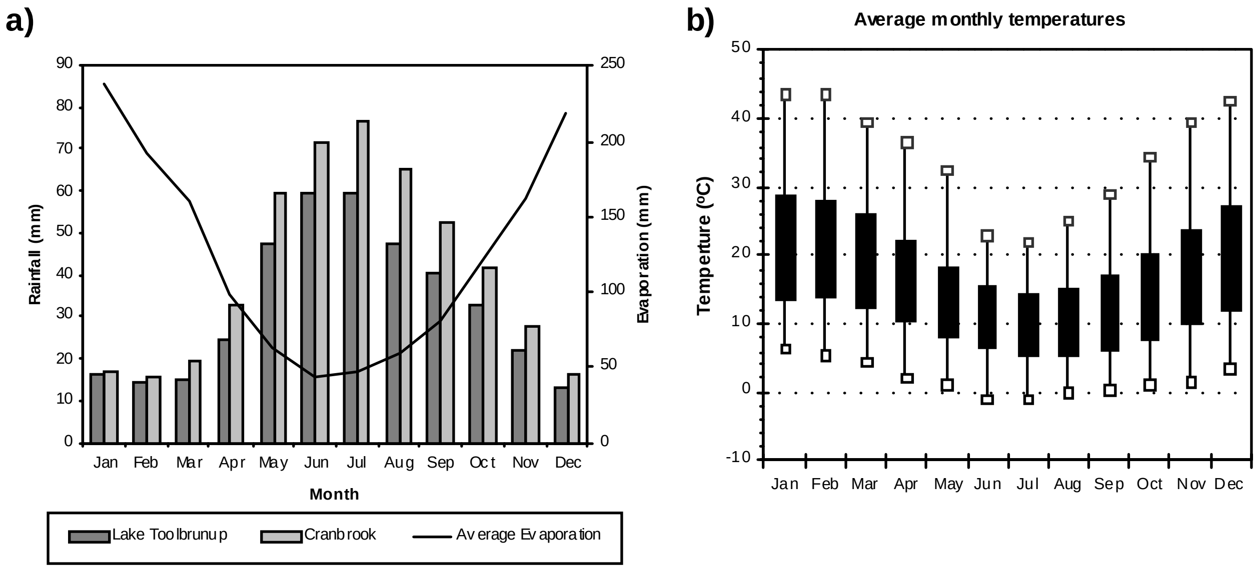


*Figure 2.1.1. Average monthly rainfall and evaporation (a); and average monthly temperatures for Lake Toolbrunup (b). The graph shows the highest recorded temperature for the month, the average maximum daily temperature, the average minimum daily and the lowest recorded temperatures since 1957 (*interpolated data from Data Drill).*

* These interpolated rainfall and temperature data were obtained from the Silo Data Drill website. The daily climate data are derived from Bureau of Meteorology climate stations. For more information see the website at www.bom.gov.au/silo (The Data Drill, Climate Impacts and Natural Resources Systems, Queensland Department of Natural Resources 2000).

Wind

The risk of wind erosion is higher when there is little or no ground cover. For crops this is mostly during autumn to early winter and for stock the risk is higher during late summer to autumn. Soil type is also critical with lighter soils much more susceptible.

2.2 Geology

Ruhi Ferdowsian, Senior Hydrologist, Albany

2.2.1 Geological history

The Cranbrook-Toolbrunup area lies within the southern margin of the Yilgarn Craton, which is a huge section of granitic bedrock underlying most of the wheatbelt. Most of the Yilgarn Craton forms the Darling Plateau, which starts about 12 km north of the study area. To the south, there is a gradual transition to the continental shelf, called the Ravensthorpe Ramp (Cope 1975). The northern precincts of the Ravensthorpe Ramp form the southern margins of the Yilgarn Craton.

The Ravensthorpe Ramp has a gradual southerly slope from about 350 m elevation near the southern edge of the Darling Plateau to sea level. The rivers draining to the South Coast are relatively short, and are incised into the tilted surface of this Ramp.

The Stirling Range forms the southern boundary of the study area. The sediments of this range were originally deposited in a basin (deep trough in the sea) more than 1000 million years ago but were uplifted much later. The rugged surface indicates that its latest uplifting was in recent geological periods.

About 40 million years ago, the continental margins sagged to form the Bremer Basin. The sea invaded and the shoreline moved inland. Most of the study area was then covered by sea (Eocene Sea). After this invasion, marine sediments (Tertiary sediments) were deposited in low areas above the basement rocks. These sedimentary materials are known as the 'Werillup Formation' and the overlying 'Pallinup Siltstone'. Later during the Tertiary period, the coastline was uplifted and former seabeds became the sandplains and stagnant flats of the study area. The lakes and dune systems were formed during very dry periods in recent geological times (past 2 million years). Wind eroded the depressions and dry lakebeds, forming the crescent-shaped sand dunes associated with the lakes. Fine sand from the Gordon River was also blown away and deposited, to form the elongated dunes that exist in the northern parts of the study area.

Basement rocks

Basement rocks in most of the study area, except its southern margins, are Archaean (>2,500 million years old). These rocks are generally igneous and metamorphic. This zone contains numerous dolerite dykes that have an east-west to north-west direction. Most of the dykes may be barriers to groundwater flow while their metamorphosed margins and contact zones with older rocks are usually carriers. Consequently they affect the hydrology, depending on their type, position in the landscape and topography. The basement rocks under the southern margins of the study area are mainly quartzites (metamorphosed sandstone), which are part of the meta-sediments of the Stirling Range Formation. Numerous shear zones and faults occur in both the Archaean rocks and the meta-sediments. These features have dictated the position of the creek and affect surface and groundwater flows.

Regolith

Regolith is the unconsolidated weathered or sedimentary material that overlies basement rock. In hilly areas, the regolith is shallow to moderately shallow (<20 m) and occasional rock outcrops (including dolerite) can be seen. It is mostly composed of *in situ* weathered material over basement rocks. The weathered profile contains lots of salt (up to 40,000 t/ha) and consists of sandy clay that changes to gritty sandy clay or clayey sand just above the basement rocks.

Regolith in the south, including Cranbrook townsite, is moderately deep (10 to 30 m). In most of this area, the *in situ* weathered profiles are covered by sediments of Tertiary age (Pallinup Siltstone) and overlying Quaternary alluvium. In the sandplain areas however there can be up to 40 m of Werrilup and overlying Pallinup formation. The Werillup formation consists of dark grey siltstone (lignite, brown coal), sandstone and claystone. The Pallinup Siltstone consists of siltstone and sponge-like materials (spongeolite). The spongeolite contains microscopic needles of silica called spicules that were laid down during a period of marine inundation.

The hydrology is strongly influenced by the broad and often stagnant flats that are found mostly in the northern parts of the study area. The regolith in these flats consists mainly of Pallinup Siltstone, a heavy clay profile that hinders the movement of groundwater. East of the Gordon River the flats have changed to swales and sand dunes due to wind erosion. Swales are linear, level-floored open depressions left between sand dune ridges built up by wind. The sand dunes interrupt the surface run-off and so affect the hydrology of the landscape.

2.3 Soil-landscape information

Angela Stuart-Street Soil Resource Officer, Katanning

The dominant soil-landscape unit is the internally drained basin of the North Stirling System which comprises just over a quarter of the area. The undulating Upper Pallinup (21%) and Jaffa (16%) Systems are widespread, together with the dunes of the Mooliup System (15%), which are blown from the bed of the Gordon River. Soils across the catchment are predominantly Grey deep sandy duplex. Other common soils include Grey shallow sandy duplex, Duplex sandy gravel, Pale deep sand and Salt lake soil.

2.3.1 Soil-landscapes

The Cranbrook-Toolbrunup area was surveyed as part of the regional land resource survey between 1992 and 1999. The results are in the *Tambellup Borden Land Resources Survey* (Stuart-Street *et al.* in prep) and the *North Stirling Land Conservation District Soils Manual* (Hardy & Tille 1993). The area lies in the Avon and Stirling Provinces within the Southern Zone of Rejuvenated Drainage, the Pallinup Zone, the Stirling Range Zone, and the Warren Denmark Southland Zone. Nine soil-landscape systems and their subsystems have been identified and are shown in Table 2.3.1.

Soil groups (Schoknecht *et al.* 1999) were developed to assist with the communication of information collected through the land resource mapping programs, especially in areas where detailed soil information is limited or incomplete. These provide a simple, standardised way of recognising the most common soils in Western Australia and are included in the table.

Table 2.3.1. Description of soil-landscape units

Soil-landscape	Landscape description and major soil groups
Carrolup (Ca) *5,505 ha (7%)*	Gently undulating to undulating rises, with low hills and narrow alluvial plains
Ca1	Upper slopes, hillcrests and breakaways. Sandy gravels with minor areas of Gravelly pale deep sands
Ca2	Lower to upper slopes. Grey deep sandy duplex soils with minor areas of Grey shallow sandy duplex soils
Ca3	Mid to upper slopes with dolerite and granite outcrop common. Grey deep sandy duplex soils and Gritty brown deep sands
Ca4	Lower slopes, footslopes, and drainage lines. Grey shallow and Deep sandy duplex soil
Ca5	Valley flats, stream channels and lower slopes. Saline wet soils with minor areas of Grey deep sandy duplex soil
Ca6	Valley flats and narrow plains with small dunes. Grey deep and shallow sandy duplex soils with Saline wet soil
Gordon Flats (Gd) *4,151 ha (5% of area)*	Broad, poorly drained alluvial plain with low sandy and gravelly rises
Gd1	Broad alluvial plains. Grey deep sandy duplex with Semi-wet soil and Duplex sandy gravel
Gd2	Low sandy rises and dunes. Grey deep sandy duplex and Pale deep sand are dominant
Gd4	Swampy terrain. Pale deep sand and Semi-wet soil are dominant with saline wet soil
Gd5	Saline drainage lines and flats. Saline wet soil and Grey deep sandy duplex are dominant.
Gd6	Broad drainage lines of major rivers. Grey deep sandy duplex is dominant with saline wet soil and semi wet soil.
Jaffa (Jf) *12,848 ha (16%)*	Undulating rises interspersed with undulating broad plains. Rock outcrop is a feature
Jf1	Lower to upper slopes and hillcrests. Duplex sandy gravel and grey deep sandy duplex are common
Jf2	Footslopes and undulating plains. Grey deep sandy duplex is dominant with Grey shallow sandy duplex and Semi-wet soil
Jf3	Mid to upper slopes and hillcrests. Grey deep sandy duplex and Grey shallow loamy duplex are common with bare rock outcrops
Jf4	Drainage lines and footslopes. Grey deep sandy duplex and Semi-wet soil is common with Saline wet soil

Table 2.3.1. (cont'd).

Soil-landscape	Landscape description and major soil groups
Kent (Ke) ***88 ha (0.1%)***	Gently undulating plains and poorly drained flats with undulating gravelly rises scattered throughout
KeCMw	Lakes with swamps and lunettes. Wet soil, semi wet soil and Duplex sandy gravel are dominant
KePP	Broadly undulating plains. Duplex sandy gravel is dominant with Semi-wet soil, Shallow gravel and Grey deep sandy duplex
Mooliup (Mp) ***12,511 ha (15%)***	Undulating low rises and swampy plains overlain by areas of linear dunes which have blown from the bed of the Gordon River
Mp1	Hillcrests. Grey deep sandy duplex with Duplex sandy gravel and Shallow gravel
Mp2	Undulating rises. Grey deep sandy duplex is common with Duplex sandy gravel and Grey shallow sandy duplex
Mp3	Linear dunes and sand sheets. Pale deep sand is widespread with Grey deep sandy duplex
Mp4	Swampy plains. Semi-wet soils are common with Pale deep sand and Grey deep sandy duplex
Mp5	Saline drainage lines. Saline wet soil is dominant with Grey deep sandy duplex
North Stirling (Nt) ***21,235 ha (26%)***	Level to gently undulating broad, internally drained plain abutting the northern boundary of the Stirling Range
Nt1	Basin floor, including lakes and minor lunettes. Salt lake soil, Alkaline grey deep sandy duplex and Grey deep sandy duplex are common
Nt2	Lower slopes above basin floor. Grey deep sandy duplex and Alkaline grey deep sandy duplex are dominant
Nt3	Mid to upper slopes and broad crests. Grey deep sandy duplex and Alkaline grey shallow sandy duplex are common
Nt4	Large lunettes. Pale deep sand is dominant with Grey deep sandy duplex also common
Nt5	Sand sheets. Grey deep sandy duplex and Pale deep sand are dominant
Stirling Range (St) ***5,572 ha (7%)***	String of prominent peaks and undulating hills which form the Stirling Range
St1	Ridge crests, peaks and talus slopes. Stony soil is dominant with bare rock outcropping
St2	Upper slopes and undulating hills. Stony soil is dominant with duplex sandy gravel and shallow gravel
St3	Undulating rises and low hills. Duplex sandy gravel is common with stony soil and grey deep sandy duplex
St4	Level to gently undulating footslope plain. Grey deep sandy duplex with grey shallow sandy duplex
St5	Sand sheet.. Pale deep sand is dominant with Alkaline grey deep sandy duplex
St6	Drainage lines. Shallow gravel, Pale deep sand and Brown loamy earth are common with Semi-wet soil

Soil-landscape	Landscape description and major soil groups
Yaraleena (Ya) *2,128 ha (3%)*	Gently undulating and undulating rises with broad, gravelly hillcrests
Ya1	Crests and upper slopes. Duplex sandy gravel is dominant with Shallow gravel and Grey deep sandy duplex
Ya2	Lower to upper smooth slopes. Duplex sandy gravel is dominant with Grey deep sandy duplex
Ya3	Minor valleys, footslopes and lower slopes. Duplex sandy gravel is dominant with Semi-wet soil
Ya4	Drainage lines and valley flats. Duplex sandy gravel and Saline wet soil are common with Grey deep sandy duplex
Upper Pallinup (Up) *16,853 ha (21%)*	Gently undulating and less commonly, undulating rises. Dolerite and gabbro dykes feature prominently
Up1	Hillcrests and upper slopes. Duplex sandy gravel is dominant with grey deep sandy duplex
Up2	Lower to upper slopes. Grey deep sandy duplex is dominant with Grey shallow loamy duplex
Up3	Mid and upper slopes and hillcrests, featuring rock outcrops. Red deep sandy duplex and Grey deep sandy duplex common
Up4	Footslopes and lower slopes. Alkaline grey shallow sandy duplex is dominant with grey deep sandy duplex
Up5	Narrow valley flats. Saline wet soil is dominant with minor areas of alkaline grey shallow sandy duplex
Up6	Valley flats and narrow plains. Alkaline grey shallow sandy duplex and Saline wet soils are common

Table 2.3.2. Major soil groups in the Cranbrook-Toolbrunup area in order of abundance

Soil Group	Area (ha)	Area %
Grey deep sandy duplex	21,227	26
Grey shallow sandy duplex	7,589	9
Duplex sandy gravel	6,697	8
Pale deep sand	6,160	8
Grey shallow loamy duplex	4,786	6
Salt lake soil	4,437	6
Semi-wet soil	4,433	5
Alkaline grey shallow sandy duplex	4,180	5
Saline wet soil	4,065	5
Alkaline grey deep sandy duplex	2,951	4
Alkaline grey shallow loamy duplex	2,708	3
Shallow gravel	2,117	3
Stony soil	867	1
Other unallocated soils	9,178	11
Total	**81,395**	**100**

2.3.3 Land management units

Land management units are defined as "parcels of land, with common soils and landforms, which should be managed similarly in order to maximise their production and minimise land degradation" (Lloyd 1992). The details provided in Table 2.3.3 show the abilities of each different land management unit. It broadens the information base for future decision making about each area of land to better achieve sustainable production. See Section 4.1 for best management options for each land management unit.

Each unit exhibits varying degrees of susceptibility to different forms of land degradation. Risks are outlined for each land management unit in Section 3.6 and Table 3.6.1.

A cross-sectional diagram has also been created, showing typical positions within the landscape where each land management unit will be situated (Figure 4.1.1).

Table 2.3.3. Land management units in the Cranbrook-Toolbrunup area

Land management unit	Approx area (ha)	Remnant vegetation	Landscape position and major soil type
1. Sandy duplex soils (moderately drained)	24,487	Mallee heath (*E. tetragona*)	Well-drained sand or sandy loam over clay at 10-80 cm. Hillslopes, sandplain, lunettes, dunes and basin floor.
2. Poorly drained sandy duplex soils	11,769	Yate woodland or mallee heath (*E. decipiens*)	Sand or sandy loam over clay at 10-60 cm; clay may be blue-grey colour or very mottled; very wet in winter; generally seen on lower slopes, sandplain and basin floors.
3. Gravel ridges and slopes	9,544	Wandoo or mixed wandoo woodland	Ironstone gravel >60% overlying clay or hard ironstone at varying depths. Generally seen on hillcrests and slopes.
4. Lakes and swamps	9,258	Paperbark low woodland or melaleuca thicket	Salt lake soil, wet soil and semi wet soil. Associated with salt lakes, swamps, dune swales and minor lunettes.
5. Grey/greyish brown loams and clays	8,177	Moort woodland (*E. platypus*) or yate	Hardsetting grey clay loam and clay; grey to greyish brown loamy surface layers over clay at <30 cm, or clay at surface. Mid to lower slopes, flats and depressions and includes crabhole clays.
6. Pale deep sand	6,870	Mallee–heath (*E. decipiens, E. incrassata Nuytsia*)	Pale grey or bleached sand over clay or other hard layer at >80 cm. May be gravelly. Upper and lower slopes, as dunes and on lunettes, basin floor and lake and swamp margins.
7. Salt-affected land	4,065	Paperbark woodland, samphire, dead yates	A range of soils is affected. Seen on basin floor, drainage lines, crabhole country and seeps on hillslopes.
8. Red to red-brown soils	3,798	York gum/ wandoo/ jam woodland	Reddish brown sandy loam over clay at 10-20 cm; red or reddish brown clay loam over red clay at <10 cm or grading to red clay at depth. Upper and lower slopes, often associated with dolerite dykes.
9. Stony and rocky soils	867	Mixed York gum, wandoo, sheoak woodland	Rocky, stony or coarse gravelly (not ironstone) >50%. Generally seen on hillcrests and slopes.
10. Yellow and brown deep sand	726		Yellow or brown sand deeper than 80 cm. Generally seen on mid to lower slopes and valley floors, and as dunes.
11. Rock outcrops	663	Sheoak/ jam woodland	Outcrops of granite, dolerite, hard ironstone, sandstone and quartz.
12. Mallet hills	381		Pink or reddish water repellent soils, maybe gravelly, often acidic. Isolated hillcrests and breakaways.

2.4 Hydrogeology

Ruhi Ferdowsian, Hydrologist, Albany

2.4.1 Aquifers in hilly areas

Aquifers in the hilly areas have local scale flow systems. This means that the top and bottom of the flow systems are no more than a few kilometres apart. Here, the hydraulic head surfaces conform to local topography, and recharge areas are close to and upslope of the discharge sites. In these areas, every hillside has a local scale aquifer and their boundaries coincide with the ridge tops.

Depth to bedrock in these areas is <20 m, so aquifers are generally thin and shallow. Most of the profile would be low yielding due to clays in the regolith (often kaolinitic white clays) but a thin layer of coarser material usually exists just above bedrock.

In these areas salinity and rising groundwater are on-site issues. Therefore, management practices outside the influence of the aquifer will have little or no effect on the extent of salinity. However, the management of land with a local aquifer will affect others downstream. Salinity i affects creeklines and hillside seeps.

- Well-defined and narrow creeklines will become salt-affected because they become discharge sites as well as the carriers of saline baseflow.
- Hillside seeps occur in the lower parts of dissected landforms where basement rock highs or dolerite dykes obstruct the saline groundwater and bring it close to the soil surface.

Prior to clearing it is likely there would have been no aquifer or saturated zone on the upper slope areas. Data to 2001 indicates that there is a seasonally fluctuating watertable that is very close to the surface in low-lying areas and where particularly shallow bedrock obstructs flow on the hillsides. Bores in the hilly areas have salinities ranging from 1000 mS/m (milliSiemens per metre) probably in a shallow perched system, to 4000 mS/m, which is highly saline. The salt content is due to accumulation in the soil profile (predominantly from rainfall) over thousands of years. Clearing of remnant vegetation and excessive recharge under cropping and annual pastures have caused the rising water levels to mobilise the salt.

2.4.2 Aquifers in sandplain with salt lakes

The aquifer under the sandplain is very large (>30 km) and extends to neighbouring catchments. It is a regional scale flow system with numerous saline lakes intercepting and forming windows to the groundwater.

Prior to clearing, there was a permanent and hypersaline aquifer in the study area. Salinity of the groundwater was, and still is, very high (up to 10,000 mS/m; twice the salinity of seawater). The hydraulic gradient is very low and the groundwater is stagnant. The lakes have become discharge sites due to rising groundwater levels. As groundwater discharges into the lakes and evaporates, the hydraulic gradient increases around the lakes, maintaining groundwater flow towards them. As such, the area is internally drained, given that there are no continuous drainage channels to remove surface run-off out of the area.

Depth to bedrock in the sandplain areas could be less than 40 m so the aquifer is reasonably thick. Most of the profile would be high yielding because of coarser material (usually Werillup) at depth.

Lack of lateral groundwater flow in this stagnant regional aquifer makes salinity and rising groundwater significant on-site issues. Despite the existence of a regional aquifer, the management practices on each farm can influence the extent of salinity on that property. Salinity i is in the form of salt scalds on the flats between salt lakes. As groundwater levels rise, the number and the extent of the affected areas will increase gradually until most low-lying and flat areas of the paddock become unworkable.

2.4.3 Aquifers in broad flats

Aquifers in the broad flats have intermediate scale flow systems. They extend >10 km and discharge sites may be affected by recharge >3 km away. Depth to bedrock could be between 20 and 40 m. The regolith has high clay content but a thin layer of coarser material may exist just above bedrock.

Salinity occurs on broad valley floors plus patches in flats. The broad valley floors have become permanent discharge areas. These flats have become target areas for deep drain construction in recent years. Performance of these drains has been dependent on the presence or absence of coarse material within the drain profile.

Prior to clearing there would have been an aquifer or saturated zone in these broad flat areas below the root zone of the natural vegetation. After clearing as groundwater levels rose, the remaining natural vegetation died and the floors became bare, salt-affected ground. Bores in the broad flats have high salinities (>2000 mS/m). The high groundwater salinity as well as excessive waterlogging has become increasingly detrimental to the health of these flats.

2.5 Natural vegetation

Bruce Radys, Revegetation Officer, Albany

Vegetation communities vary throughout the landscape and usually reflect soil type and landscape position. Their names usually refer to the dominant species and their structure (or shape). The natural vegetation is described for the whole catchment, though much of the original vegetation has been cleared. Remnant bush and pre-clearing anecdotes indicate the original vegetation for each soil-landscape type.

The study area is situated across the boundaries of several Botanical regions and Vegetation systems (mapped by J. Beard 1976). These include:

- **AVON Botanical District** (Cranbrook to Tambellup)
  Tambellup vegetation system; wandoo, yate and York gum
- **ROE Botanical District** (east of Tambellup)
  Pallinup vegetation system; mallee
- **EYRE Botanical District** (adjoining Stirling Range National Park)
  Qualup vegetation system; mallee-heath
- **DARLING Botanical District** (Menzies sub-region; between Kendenup and Cranbrook). Kendenup vegetation system; jarrah and wandoo woodlands

Within each vegetation system, the communities vary according to soils and landscape position. The main vegetation communities are described in Table 2.6.1 below.

Table 2.6.1. Vegetation communities in the Cranbrook-Toolbrunup area

Name (dominant species/ structure)	Beard's notation	Common species	Soil type / landscape	Location (example)
Wandoo and yate woodland, sometimes with river gums	e5/7Mi	*E. wandoo,* *E. occidentalis, E. rudis* *Acacia acuminata (jam) and Allocasuarina huegeliana*	Hardsetting loams Creeks, rivers Rocky	North of Cranbrook
Wandoo, yate and York gum woodland	e5/6/7Mi	*E. loxophleba, E. wandoo, E. occidentalis*	As above	North of Lake Toolbrunup
Jarrah/ marri/ wandoo woodland	e2/3/5Mi	*E. marginata, E. calophylla, E. wandoo.* *E. occidentalis, E. decipiens*	Upper slopes Depressions, creeks	Tenterden
Tallerack mallee-heath	e26sZc	Blue mallee *(E. tetragona), E. decipiens, E. angulosa, Lambertia* spp.	Sandplain in south-east	Hamilla Hill
Mallee	e27Si	*E. uncinata, E. gardneri, E. occidentalis, E. flocktoniae, Melaleuca understorey*	Sandplain in north-east	Toolbrunup siding
Jarrah low forest	e2Li	*E. marginata,* *E. calophylla,* *Banksia grandis,* *Hakea nitida*	Ironstone, gravelly	West of Albany Hwy, Tenterden
Paperbark low woodland	mLi	*Melaleuca cuticularis*	Adjacent to lakes	Racecourse Lake
Paperbark low forest	mLc	*Melaleuca cuticularis*	Adjacent to lakes	Oorongerup swamp
Tea-tree and samphire	mLi.k3Ci	*Melaleuca viminea, Sarcocornia* spp., *Arthrocneum* sp.	Saline/wet	Salt lakes, saline flats
Heath (patches)	XZc	*Leptospermum erubescens?*	Sandplain	Tambellup

3. Catchment condition and future risk

3.1 Salinity and groundwater

Lisa Crossing, Hydrologist, Albany

Effective management of salinity requires an understanding of the processes that are causing the problem. This is a brief introduction to the key concepts and terms used in hydrology.

The hydrological cycle and catchment water balance

Water is continually being cycled through our environment at catchment and even global scales. Soils, geology, climate, landforms and vegetation all play a role in this hydrological cycle so a change in any one factor will inevitably affect the hydrology.

The concept of a **catchment water balance** is a simple accounting exercise: What comes in (*rainfall*) must be balanced by what goes out (*run-off, evapotranspiration, groundwater flow and discharge*) and any change in storage (*soil water, surface water and groundwater*).

$$P = R + G + (E+T) + \Delta S + U + \Delta D$$

Rainfall in	=	surface run-off	+	groundwater discharge	+	evaporation transpiration (soil & plant)	+	change in soil water storage	+	groundwater recharge	+	change in surface storage

Prior to clearing, the catchment water balance equation (above) was in balance, with rainfall inputs roughly equalling outputs. The change from native vegetation to agricultural crops and pastures has dramatically decreased evapotranspiration and upset the balance. This results in increased **recharge**, the component of rainfall that drains below the root zone of vegetation causing rising groundwater levels. In areas with <500 mm rainfall there is 1 mm or less recharge under native vegetation, but 10-50 mm in agricultural areas with similar rainfall (Tille *et al.* 2001). When the groundwater nears the surface, naturally occurring salts in the water are concentrated and deposited. This increase in soil salinity affects plant growth.

In medium to low rainfall areas it is reasonable to assume that *groundwater flow* (G) and the seasonal *changes in surface* (ΔD) and *soil water storage* (ΔS) are negligible; Therefore, the water balance can be simplified to:

$$P = (E+T) + U + R$$

Rainfall in	=	evaporation transpiration (soil & plant)	+	groundwater recharge	+	surface run-off

By measuring or estimating the values for run-off, evapotranspiration and rainfall, the water balance can be used to estimate the amount of water that is recharging to the groundwater. Using the groundwater calculator AgET (refer to the Farming Systems

- Section 4.2), recharge under current land use was estimated to be 51 mm or 11% of rainfall in the study area.

In catchments where there is very little run-off or groundwater drainage out of the system (stagnant, internally draining areas), the evapotranspiration prior to agricultural development would have almost equalled rainfall. These systems are therefore more sensitive to changes in evapotranspiration and it is more difficult to halt or reverse rising groundwater levels as there is no natural drainage to help prevent the catchment 'filling up' with water.

Salts in our landscapes

The salt responsible for salinity in Western Australia originated from the ocean. Wind and rain pick up small amounts of salt from the ocean and carry it inland where it has been deposited on our soils for tens of thousands of years. Salt accumulation depends on location, rainfall, *regolith* (the sediments or weathered material that occurs between the soil and the bedrock) and soil type but range from 100s to 10,000s of tonnes/ha in the Great Southern. In Cranbrook, salt storage of 2,729 t/ha was measured where there was a deep (26 m), heavy silty clay profile and only 171 t/ha in a shallow coarse sandy profile (Ferdowsian and Ryder 1997). Airborne salts continue to be deposited at a rate of around 30 kg/ha/yr on catchment (calculated at 450 mm rainfall, 100 km from the coast using a chloride concentration in rainfall of 4 mg/L; Hingston and Gailitis 1976).

Where does recharge occur?

Although recharge occurs over most of the landscape, the rate of recharge that occurs varies quite significantly depending on slope of land surface, waterlogging, soil type, land use etc. This means that zones of higher recharge may be targeted for high water use management options but changing land use in these areas alone is not sufficient to address the rising groundwater levels in the whole catchment. In some catchments recharge can occur in an area during winter and the same area can be a discharge site in summer (e.g. valley floor).

Where does salinity occur?

Although the water balance gives us an idea of why salinity may occur, the rate of spread, area and position of the saline areas is controlled by a wide range of factors. Salinity occurs wherever the groundwater reaches within approximately 1-2 m of the soil surface and salts can be concentrated by evaporation. Therefore, topography is very significant, with the valley floors, depressions, lakes, creeks and other areas of low relief being most affected. A much smaller proportion of salinisation can occur in other parts of the landscape where groundwater has been forced to the surface.

Groundwater flows

The storage and movement of groundwater through the landscape is a complex process. Groundwater moves through the gaps or pores in the soil and regolith. The ability of groundwater to move in the landscape is controlled by:

- The ability of the regolith to transmit water; referred to as **hydraulic conductivity**
- Hydraulic or **groundwater gradient** or pressure to drive the water flow

- Regolith and **aquifer thickness** controls the *area* of flow and any constriction of this area such as a granitic high, will reduce the overall volume of flow.

Wherever one of these factors is reduced, it slows the water flow and results in a build-up of groundwater at the restriction, which forces the watertable to rise.

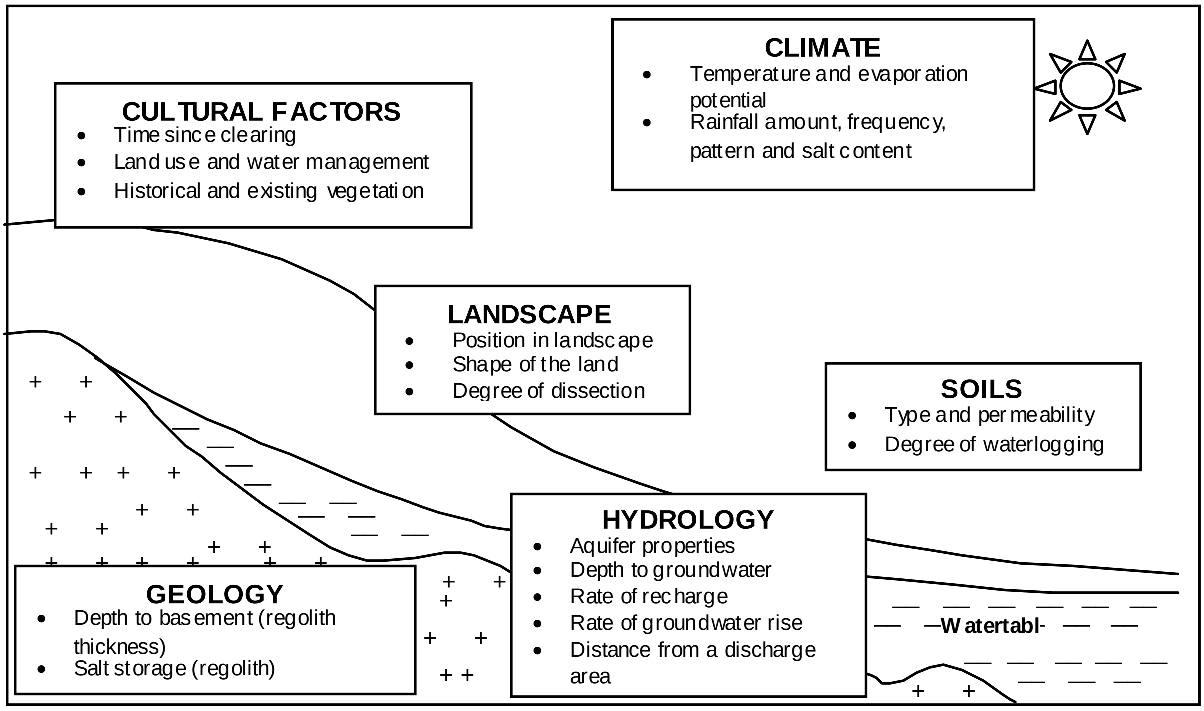


Figure 3.1.1. Factors that affect the process of land salinisation

3.1.2 Current salinity

Land Monitor used satellite imagery on six different dates from 1988 to 1998 to identify areas that showed consistently low productivity and indicated that 11.1% was affected by salt. In general, areas with either salt-tolerant pastures or other vegetation cannot be identified as saline in the satellite image, resulting in significant under-estimation of salinity extent.

3.1.3 Groundwater trends

Underlying trends in groundwater vary depending on position in the landscape. Much of the study area has local flow systems into lakes and stagnant flats.

A typical cross-section along a flow line for study area is shown in Figure 3.1.2. This traverses a gently undulating rise down to stagnant flats.

Hydrographs are graphs showing the water level in a piezometer or monitoring bore over time. HARTT (Hydrograph Analysis using Rainfall and Time Trends) is a method that identifies the effect of above or below average rainfall during the period of monitoring (cf. Appendix 5). This effect can then be removed and the underlying groundwater trend that would occur in an average rainfall year can be determined.

All the hydrographs in the study area were analysed with HARTT. Some typical examples are shown with respect to their position in the landscape (refer to Figure 3.1.2). In this area there are limited bores on the upper to mid-slopes and rises. Hydrographs 1 and 2 are from similar areas in adjoining catchments and hydrograph 3 is from within the Cranbrook townsite.

Hydrograph 1: In this monitoring bore on the gently undulating plains groundwater is at a depth of two to three metres. The groundwater in these areas is rising at a rate of 10-20 cm per year and shows seasonal fluctuations due to rainfall.

Hydrograph 2 & 3: Further down the slope on the stagnant flats, groundwater can come within a meter or two of the surface. These sites may be permanent or seasonal discharge sites. The hydrographs in these areas do not show significant long-term trends because evaporation and groundwater discharge maintain the water level below the ground surface even if levels are rising further up the slope.

Table 3.1.1. Accuracy assessment of salinity maps (after Evans 2001a and 2001b).

Catchment /Study Area	Salt-affected land detected	Non-saline land labelled as salt-affected
Ryan's Brook	72%	1%
Kent	82%	9%
South Stirling	68%	5%
South Coast	71%	7%
Toolibin	80%	1%
Fence Rd	65%	3%
Cridland	80%	0%
Doradine	77%	4%
Mills Lake	71%	5%
Tambellup	73%	0%
Cranbrook	74%	2%

For more information on the products, methods and accuracies go to the Land Monitor website: http://www.landmonitor.wa.gov.au

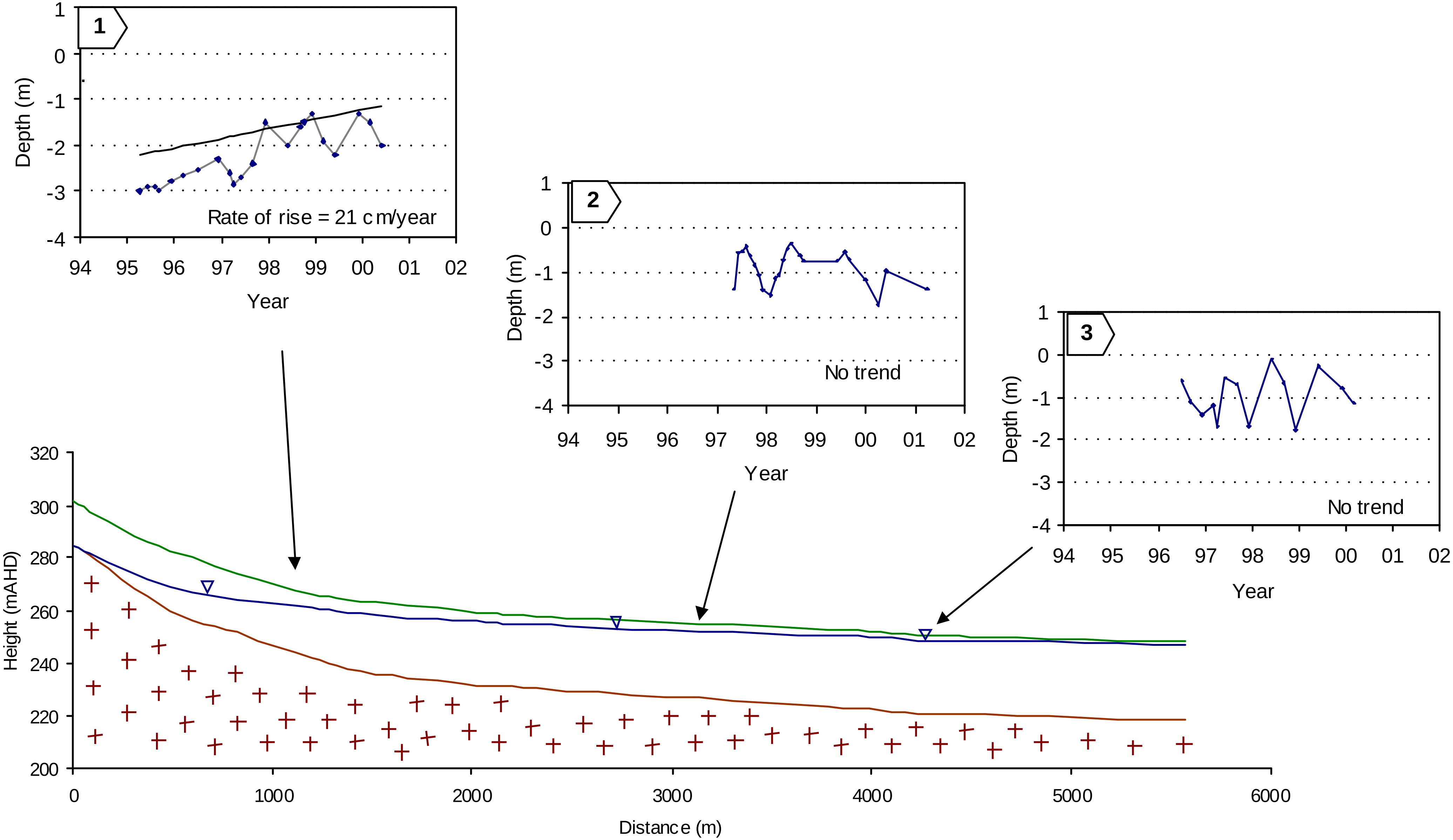


Figure 3.1.2. Typical groundwater hydrographs from monitoring bores in the Cranbrook–Toolbrunup study area in relation to landscape position

3.1.4 Potential salinity risk (Flowtube and Land Monitor)

Flowtube is a 2-D groundwater calculator designed to predict long-term groundwater trends along a groundwater flow path and examine the effects of recharge and discharge management options. Flowtube can estimate both long-term trends in groundwater levels, and length of the flowtube at risk of experiencing shallow watertables in any given number of years.

Warning!

The graphs below illustrate the likely trends in groundwater levels and have been calibrated with actual bore measurements. However, as with all models results should be treated with caution, as many simplifications, assumptions and estimates are included in the calculations.

Surface topography was taken from 2 m contours of the area generated by DOLA (see Appendix 1.1) while depth to bedrock and the initial groundwater levels are based on bores in the catchment.

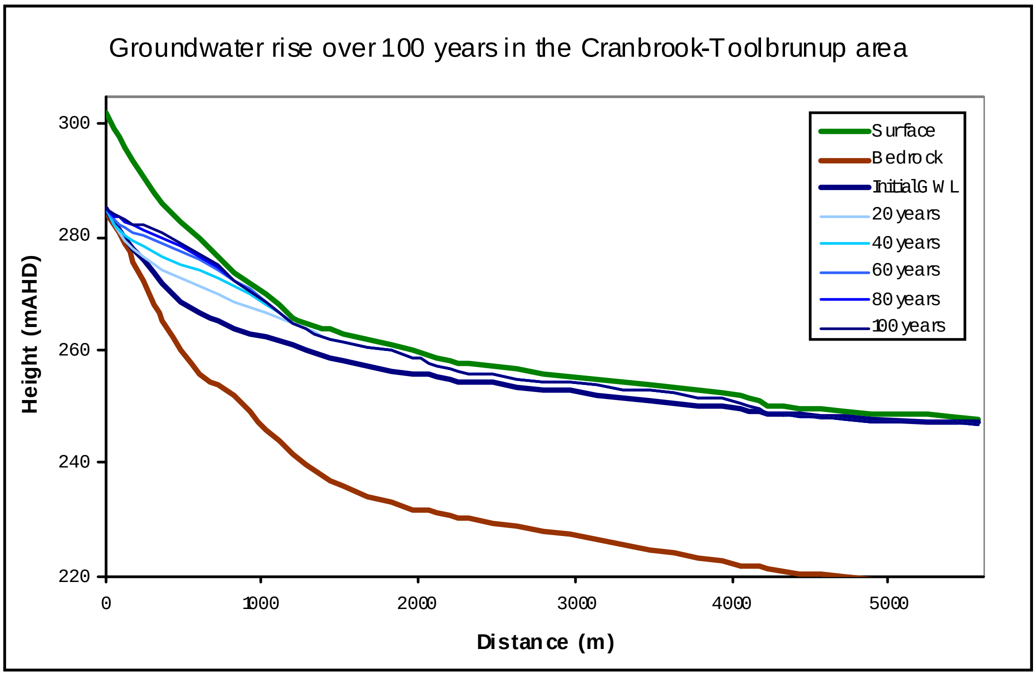


Figure 3.1.3: Expected groundwater rise over 50 years in a flow path typical of the Cranbrook-Toolbrunup area. This scenario was calculated using Flowtube.

The main areas at risk of becoming saline are the stagnant flats, creekline and lakes. Hillside seeps can also occur where there is shallow bedrock or other geological obstructions to flow. These areas then become groundwater discharge (saline) areas, which help to control the rate of rise in the rest of the catchment. However, it is not known how far the watertable will rise before an equilibrium is reached where extra recharge is matched by increased discharge to streams and evaporation.

Equilibrium is reached much faster in higher rainfall areas. In the scenario modeled above, the flow path reaches equilibrium in 50 years.

Eighty-seven per cent of the cross-section is affected by shallow watertables within 50 years. However, the cross-section follows a groundwater flow path that mirrors surface flows and these areas are lower than the surrounding land. Figure 3.1.2 showing 'low lying areas at risk of shallow watertables' illustrates this potential spread of salinity up the valleys if groundwater levels rise 0.5-2 m from the valley floor (which would only occur when there was much greater rises higher in the catchment).

Low lying areas at risk of shallow watertables

This map is generated using the detailed topography data (Digital Elevation Model) surveyed by Land Monitor. As low lying areas are more at risk of being affected by shallow saline watertables this map was generated to illustrate this potential. This map does not include areas where the watertable is brought close to the surface by geological features such as hillside seeps.

Appendix 1.3 shows the low-lying areas identified by Land Monitor within the Cranbrook-Toolbrunup catchment. The areas and percentage in each category are shown in Table 3.1.3.

Table 3.1.3. Low-lying areas within the Cranbrook–Toolbrunup study area

Rising shallow watertables	Area (ha)	Percentage
0-0.5 m above flow path	14,934	18.3%
0.5-1 m above flow path	5,487	6.7%
1-1.5 m above flow path	4,353	5.3%
1.5-2 m above flow path	3,626	4.5%
>2 m above flow path	52,995	65.1%
Whole catchment	81,395	100%

3.2 Flooding

Comprehensive information associated with water resources information covering the Cranbrook area, (including the internally drained lake system encompassing the Balicup Lake catchment) can be sourced from:

- **The Salinity and Hydrology of Cranbrook** (Ferdowsian and Ryder 1997, Resource Management Technical Report 170. Department of Agriculture, Western Australia, Perth
- **The Salinity and Hydrology of the Tambellup Townsite and Jam Creek Catchment** (Ferdowsian and Ryder 1998), Resource Management Technical Report 172. Department of Agriculture, Western Australia, Perth
- **Soils Manual for the North Stirling Land Conservation District** (Hardy and Tille 1993). Miscellaneous publication No. 42/92. Department of Agriculture, Western Australia. Perth
- **The Water and Rivers Commission's Information Centre** also offers flooding information via an online search using the following internet web page link. http://www.wrc.wa.gov.au/waterinf/wrdata/FLOW

The web page provides a link to historical datasets for various gauging stations (some no longer in operation) across the south western agricultural area. The page also provides an explanation on how to interpret the data.

The data records provide:

- Site location details
- Catchment area
- Rating tables used to convert from 'raw' variables collected at the site to converted variables; (e.g. from stage to discharge)
- The number of gauging (discharge measurements) done at the site
- Total monthly rainfall
- Total annual rainfall (and plotted graph illustration)
- Stream flow reports
- Rainfall statistical summary
- Stream flow sites
- Total monthly discharge
- Total annual discharge
- Discharge statistical summary
- Flow statistical summary.

- **Land Monitor** data presented in Appendix 1.4 also provides information on potential flooding concerns.

3.3 Biodiversity assets

Bruce Radys, Revegetation Officer, Albany

3.3.1 Remnant vegetation

The most significant biodiversity resource is the remaining natural bush. These areas contain a variety of native plants, animals and ecosystem processes. The value of remnant vegetation as a biodiversity asset will depend on factors like condition, size and isolation. The current pattern can be seen in Appendix 1.2. The main components include:

- Stirling Range National Park, Hamilla Hill and Sukey Hill (public reserves)
- Along the Gordon River and around Tambellup (some on farms)
- Vegetation around salt lakes and swamps (some on farms)
- Numerous other areas on farmland and roadsides but usually small and isolated.

Species of rare flora are located on private land, roadsides and the reserves. For further information, contact Sarah Barrett at the Department of Conservation and Land Management, Albany.

3.3.2 Biodiversity assets at risk

Table 3.3.1 illustrates the area of remnant vegetation at risk of potential loss and species decline from rising shallow watertables.

Table 3.3.1. Remnant vegetation at risk in the Cranbrook-Toolbrunup area

Height above flow path (valley floor)	Area of remnant vegetation (ha)	Percentage of total area of remnant vegetation (%)
0 to 0.5 m	2,839.8	25
0.5 to 1.0 m	1,091.4	9.6
1 to 1.5 m	759.6	6.7
1.5 to 2m	579	5
>2 m	6,102	53.7
Total area remnant	11,372.4	

- 25% of remnant vegetation is less than 0.5 m above the valley floors and 35% is 1 m or less. A significant proportion occurs because swamps and creeklines were often left uncleared. Natural communities risk death due to salinity if watertables continue to rise. Yate swamps, river gum and paperbark woodlands in these zones will be able to cope with changing conditions to different degrees. For revegetation, these species need to be planted further upslope than previously.
- A large proportion (>50%) of remnant vegetation is greater than 2 m above valley (or swamp) floors and is therefore at low risk. This would include mallee-heath communities on sand dunes, found higher up the slope on well-drained soils.
- To protect these areas, catchment water balance needs to be addressed by increasing water use (refer to Section 4.2).

This analysis presented in Table 3.3.2 suggests that:

- At least 20% of remnant vegetation is protected by Nature Reserves. This is considered to be in good condition.
- 10% is on vacant Crown land, mostly around townsites or along rivers.
- The greatest proportion of bush is on private farmland. The condition of remnant bush on private land varies considerably, depending on coverage, location in the landscape and whether or not it has been fenced to prevent livestock damage.

Table 3.3.2. Land tenure in the Cranbrook-Toolbrunup area

Land tenure type	Example of locations	Area (ha)	Percentage of total vegetation (%)
Closed road		51.7	0.38
Other reserve	Nature reserves	2754.08	20.43
Railway	Railway reserve	124.42	0.92
Road	Roadsides	6.47	0.05
Vacant crown land	Townsites	1367.42	10.14
Water feature	Water reserves /lakes	31.38	0.23
Assumed freehold land	Farm bush	9146.27	67.84
Total area (ha)		1,3481.68	

3.4 Infrastructure assets: roads and rail

Nick Middleton, Spatial Analyst, Albany

The study area has almost 369 km of gazetted roads, most unsealed gravel or tracks. Sealed roads total 140 km and 229 km unsealed.

The sealed road includes a 50 km stretch of the Great Southern Highway. Land Monitor height above valley floor data (HAVF) suggest shallow watertables. This information is summarised in Table 3.4.2 below.

Table 3.4.1. Length of road at risk of shallow watertables in the Cranbrook–Toolbrunup area

Rising shallow watertables (HAVF)	Sealed Roads (km)	Sealed Roads (%)	Unsealed Roads (km)	Unsealed Roads (%)
0 to 0.5 m	19.91	5.40%	26.91	7.29%
0.5 to 1 m	10.189	2.76%	14.38	3.90%
1 to 1.5 m	9.30	2.52%	12.25	3.32%
1.5 to 2 m	8.84	2.40%	11.55	3.13%
>2 m	91.55	24.82%	163.97	44.45%
Total length under threat (km)	139.79	37.91%	229.05	62.09%

A 58 km section of railway line also passes through the study area, part of Great Southern freight link and roughly parallel to the Great Southern Highway. he line is of considerable importance for grain freight from Katanning through to Albany. Table 3.4.3 summarises the length of line susceptible to decline because of rising shallow watertables. The maps presented in Appendix 1.3 and 1.4, also illustrate current and potential risks to infrastructure assets.

Table 3.4.3. Length of railway line at risk from rising shallow watertables

Rising shallow watertables (HAVF)	Railway line (km)	Railway line (%)
0 to 0.5 m	8.73	15.06
0.5 to 1 m	4.97	8.59
1 to 1.5 m	4.63	7.98
1.5 to 2 m	4.92	8.49
>2 m	34.70	59.88
Total length under threat (km)	57.95	

3.5 Natural resource risks other than salinity

Angela Stuart-Street Soil Resource Officer, Department of Agriculture, Katanning

Perceptions of land degradation are often influenced by visibility. Salinity, waterlogging and rising groundwatertables are accepted as being the most widespread and severe land degradation concern for many portions of the area.

The 'invisible' forms of land degradation such as soil acidity affect vastly larger areas but often go unnoticed and untreated (Nulsen 1993). These risks to the land resource threaten its natural and cultural assets and reduce agricultural productivity. The three primary types of land degradation risk within the study area are outlined below. These are linked to the land management units (LMUs) described in Section 2.2.2 of the report to refine the understanding of areas of the landscape at risk from various forms of degradation.

Table 3.5.1 outlines the main land degradation hazards across the catchment, for each land management unit.

3.5.1 Soil acidity

The soils most susceptible to subsoil acidification are sandy, highly leached soils (Dolling 1995). The areas most at risk are the Poorly drained sandy duplex, Sandy Duplex and Pale Deep Sand land management units. Approximately 44,233 ha (54%) is highly susceptible to this form of land degradation.

3.5.2 Wind erosion

Wind erosion events are infrequent, but can leave a major impact. Areas of unprotected loose dry soil in higher landscape positions are most at risk (Moore *et al.* 1998). The LMUs most at risk (particularly on crests and upper slopes) include the Sandy Duplex and Pale Deep Sands. Approximately 32,083 ha (40% of the study area) is highly susceptible to wind erosion.

Table 3.5.1. Assessment of land degradation hazards for land management units in the Cranbrook-Toolbrunup area

Land Management Unit	Approx area (ha)	Salinity risk	Waterlogging / inundation risk	Susceptibility to water erosion	Susceptibility to wind erosion	Susceptibility to subsurface (10-20 cm) acidification	Susceptibility to water repellence	Susceptibility to topsoil structure decline	Susceptibility to subsurface compaction (10-30 cm)
Sandy duplex (moderately drained)	24,487	Low to moderate risk*	Low to very low	Moderate	Moderate to high **	High	Moderate	Low	Moderate
Poorly drained sandy duplex	11,769	High	Moderate to high for lower slopes	Moderate	Low	High	Moderate	Low	Moderate
Gravel ridges and slopes	9,544	No risk	Nil to very low	Moderate	Low	Moderate	Moderate	Low	Low
Lakes and swamps	9,258	Presently saline or high risk	Not rated	Low	Low	Not rated	Not rated	Not rated	Not rated
Grey to greyish brown loams and clays	8,177	Low risk	Moderate to high on valley flats	Moderate (on slopes)	Generally low	Low	Low	Moderate to high	Low to moderate
Pale deep sands	6,870	No risk or partial risk	Very low on valley flats	Moderate	Moderate to high**	High	High	Low	Low to moderate
Salt-affected land	4,065	Presently saline	Very high	High	Low	Variable ***	Low	Not rated	Not rated
Red to red brown soils and dykes	3,798	Low risk*	Low	Moderate	Low	Low	Low	Moderate	Low
Stony and rocky soils	867	No risk	No risk	Low	No risk	Variable	Low	Low	Low
Yellow and brown deep sands	726	Moderate risk	Very low	Moderate	Moderate to high**	Moderate to high	High	Low	Low to moderate
Rock outcrops	663	Variable	Nil	Low	Low	Low	Low	Low	Not rated
Mallet hills	381	No risk****	Nil	High	Low	Presently acid	High	High	Low

* Low risk , salinity likely to develop as hillside seeps on the units where shallow bedrock forces saline groundwater close to the surface

** Highly susceptible to wind erosion on crests and upper slopes

*** Soil pH on saline soils is highly variable but they may not be economic to lime

**** Many Mallet Hills have acid clay subsoils that are often saline

4. Management options and impacts

4.1 Options for land management units

Following is a series of tables based on the land management units (discussed in Section 2.3.3). These recognise the degradation and management problems associated with the each dominant LMU in the Cranbrook-Toolbrunup area and suggest best practice'management options.

These options have been suggested on the basis of minimising recharge and land degradation as effectively as possible. The information can be used as a guide; however users are strongly encouraged to regularly seek further (current) information.

How to use the best bet option tables

The best option tables are divided into three columns of description, risk and management information.

Land management units

The first column shows a representative soil profile description and diagram identifying the land management unit. The brief description highlights some of the major soil properties such as soil layer depth, texture, and drainage. It may also include the landscape position, occurrence and proportion of gravel and presence of salt.

Water and soil problems

The second column contains a brief description of the water and soil properties associated with potential problems likely to occur within each land management unit. The information presents an assumed level of risk.

Each comment demonstrates where the greatest management risk or challenges lie for each unit. The problems may not be obvious currently, but the assumed level of risk for each problem to develop in the future is very real and is stated in this section. The comments should act as a reminder to address each possible risk in a practicable and economical way to increase catchment and farm health as well as reduce groundwater recharge.

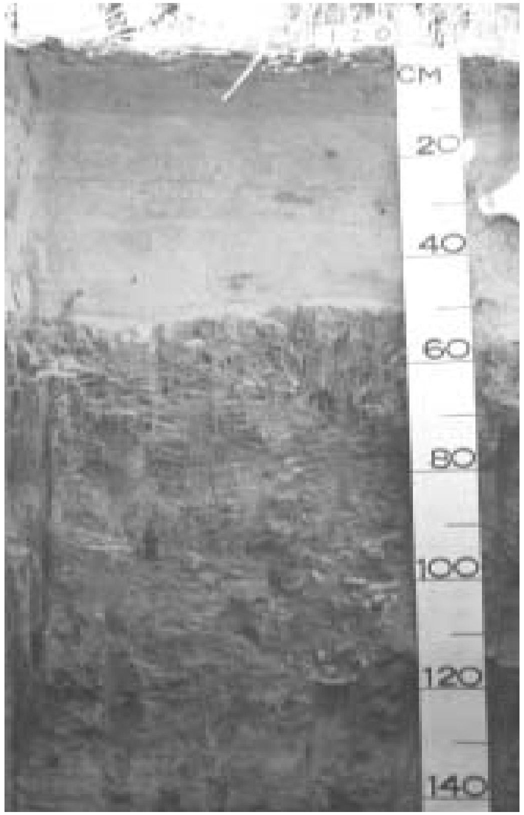
Management options

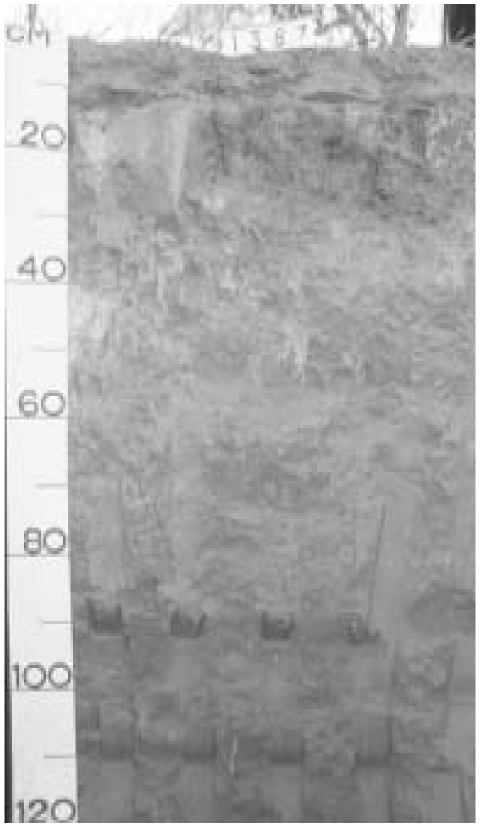
To assist in over coming existing problems and prevention of possible future landscape degradation problems, recommended management options are included for each LMU in the third column. These options deal directly with the potential and existing problems described in the second column of each LMU table. As stated previously, these broad management options and recommendations are aimed at landholders, rural community groups, regional planners, and others involved in the provision of technical advice to land users. The information will assist in the value judgments leading to the development of environmentally responsible and sustainable agricultural systems for rural production within the study area.

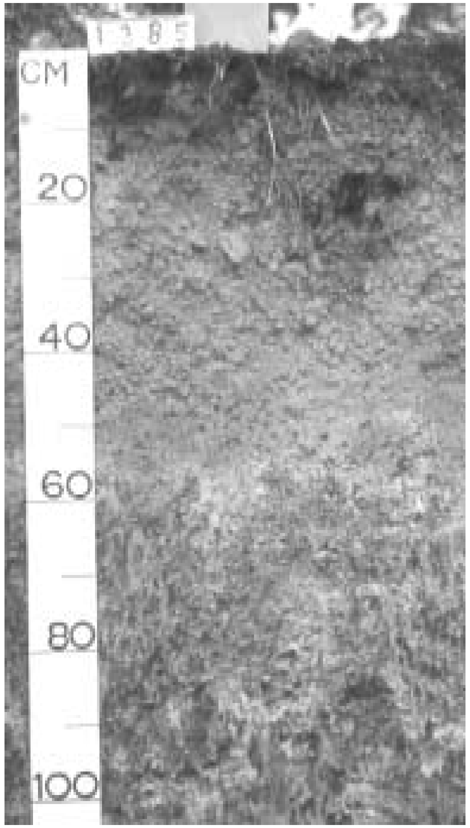
The management choices are listed in point form under the sub-headings of soil management, surface water control, cropping and pasture options, recharge reduction and revegetation options. However, to address all of the management options for each LMU in one go would be a large and possibly expensive task and in many circumstance unfeasible. Therefore, the recommendation would be to spread the management tasks over a suitable number of years. The ongoing development of a farm business plan and management action plan will assist in targeting the opportunities to achieve the management recommendations presented in the LMU tables and highlighted elsewhere in this report.

However, even though comprehensive information is presented throughout the various sections of this report, **land managers are encouraged to regularly seek further information** from the Department of Agriculture or other reliable sources of information.

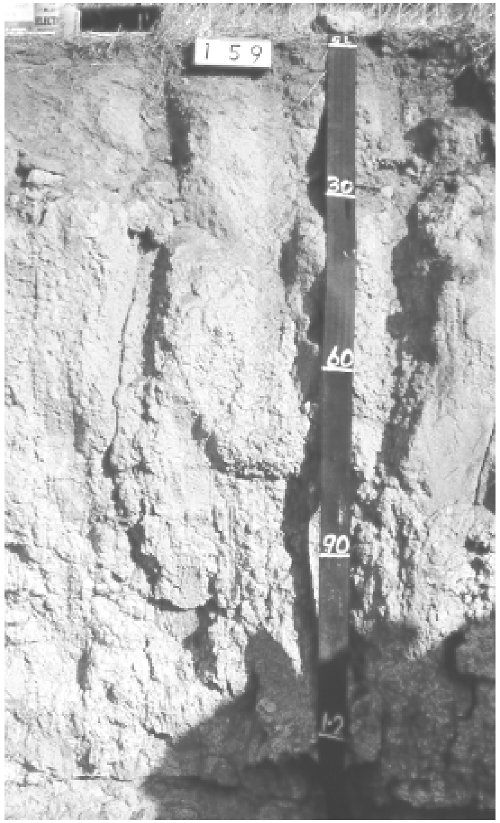
Cranbrook-Toolbrunup: Identifying LMUs and their best management options

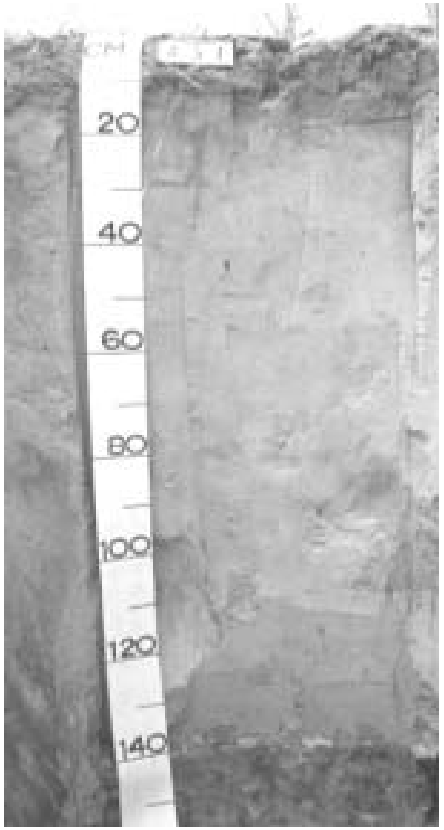
Land Management Unit	Water and Soil Problems	Management Options
SANDY DUPLEX SOILS **(Moderately drained)** (24,487 ha) Pale grey sand or sandy loam over clay at 10–80 m, seasonally perched watertable common. Mainly on mid to upper slopes as well as some areas of the sandplain and basin floor. 	• Generally a moderate groundwater recharge risk; this may increase to a high risk in winter months, associated with perched watertables. • High risk of wind erosion on exposed crests and upper slopes, otherwise the risk is moderate. • Highly susceptible to subsoil acidification. • Water erosion is a high risk on exposed upper slopes. • Traffic and plough pans can be a risk. • Sandy topsoils may display water repellence, low soil water storage and poor nutrient availability. • Low to moderate risk of soil structure decline (surface crusting and hardsetting soils).	**SOIL MANAGEMENT** • Minimum tillage and no-till. • Any working up on slopes should be carried out on the contour. This is generally economically beneficial and should be standard best practice to improve water conservation for crops and to minimise erosion. • Liming may be necessary to achieve crop and pasture production potentials and assist in the establishment of lucerne; regular monitoring of soil pH levels is advised. • Practise stubble retention or aim to maintain >50% ground cover to control risk of wind and water erosion. • Clayey subsoils may be sodic – surface sealing and hardsetting problems may result from clay being brought to the surface by cultivation. **CROPPING /PASTURE OPTIONS** • Crops highly suitable to this soil type where subsoil pH is acid to neutral include oats, barley and canola. • Other suitable crops include wheat and lupins (though prefer the deeper sandy duplexes). • Annual clovers, veldt grass, *casbah biserrula* and serradella mix would suit the sandier areas, which are prone to wind erosion. In wetter areas try balansa clover. **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Phase cropping with lucerne and cereals will help reduce recharge rates. • Grade banks are effective in controlling water erosion and waterlogging where interception of clay is possible. **REVEGETATION OPTIONS** • Veldt grass and serradella mix would suit the sandier areas, which are prone to wind erosion. • Belts of oil mallees (four to eight rows) below grade banks, separated by crop pasture areas (suitable machinery width).

Land Management Unit	Water and Soil Problems	Management Options
POORLY DRAINED SANDY DUPLEX SOILS (11,769 ha) Sand or sandy loam over (often greyish coloured) clay at 10-60 m; clay may be blue/grey in colour or very mottled; very wet in winter. Generally occurs on lower slopes and footslopes, sandplain, and valley and basin floors. 	• Moderate to high groundwater recharge - highest where water ponds. • High risk of salinity developing usually along drainage lines, on ponded areas and on the basin floor. • Moderate waterlogging risk. Waterlogging is the major limitation in this area – boggy soils in wet years may hinder trafficability. • Flooding can occur on the basin floor. • Highly susceptible to sub-surface acidification. • Moderately susceptible to wind and water erosion, traffic and plough pans. • Clay subsoil may present a barrier to some deep-rooted species	**SOIL MANAGEMENT** • Liming may be necessary to ensure good establishment of lucerne, and to enable good growth of pastures. Regular monitoring of surface (0-10 cm) and subsurface (10-20 cm) pH is advised. • Reduced traffic movement when soil is wet minimises soil compaction risk. • Minimum tillage and no-till operations. • Practise stubble retention or aim to maintain >50% ground cover to control risk of wind and water erosion. • Clayey subsoils may be sodic; surface sealing and hardsetting problems may result from clay being brought to the surface by cultivation. **CROPPING /PASTURE OPTIONS** • Highly suitable for oats, and where waterlogging is not a problem, barley and canola. • Suitable for wheat and lupins (pH acid to neutral), and faba beans and field peas where pH is alkaline. • Summer crops. • Pasture options include annual sub clovers, crimson clover and serradella, casbah biserrula mixtures. Medics suitable on the alkaline soils. • In waterlogged, mildly saline areas tall wheat grass and balansa clover can be grown. **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Lucerne on the deeper soil and on areas with low risk of flooding. Productivity may not be as good as soils, which are well drained. • Grade banks are effective in controlling water erosion and waterlogging where interception of clay is possible. Shallow relief drains ('W') can be used to reduce ponding and promote drainage from valley floors. **REVEGETATION OPTIONS** • Revegetation areas will need to be mounded - aligned parallel to banks. • Belts of oil mallees (four or eight rows) separated by crop pasture areas (suitable machinery width)..

Land Management Unit	Water and Soil Problems	Management Options
GRAVEL RIDGES AND SLOPES (9,544 ha) Ironstone gravel >60% overlying clay or hard ironstone at varying depths. Occurs generally on hillcrests and upper slopes. 	• High groundwater recharge if cleared. • Sandy topsoils are moderately susceptible to sub-surface acidification, traffic and plough pans. • Mild wind and water erosion on exposed sites where ground cover is <50%. • Low soil water storage. • May be susceptible to water repellence Generally good rooting depth.	**SOIL MANAGEMENT** • Liming may be necessary; regular monitoring of soil pH levels is advised. • Maintenance of active growing plants is important here to prevent rapid drainage of soil water to below the root zone, contributing to problems lower in the landscape. • Cultivation should be carried out on the contour to reduce erosion risks and improve water conservation for crops. • Minimum tillage or no-till is encouraged to reduce the incidence of traffic and plough pans, improving soil structure, and maintaining soil organic matter. • Practise stubble retention or aim to maintain >50% ground cover to control risk of wind and water erosion. **CROPPING /PASTURE OPTIONS** • Crops suitable to this soil type include wheat, barley, lupins & canola (they will perform satisfactorily on shallow gravels, though prefer deeper loamy & sandy phases). On the shallow gravels feed barley is more suitable than malting barley. • Oats are only suitable on the gravels with deep loamy & sandy phases. • Pasture options include annual clovers, serradellas and casbah biserrula. **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Alley farming/strip planting systems to reduce recharge rates. • Soil profile and depth to clay need to be checked prior to commencing earthworks. Earthworks with grades should be used to move water off, prevent ponding and recharge. • Alley farming/strip planting system to reduce recharge rates. **REVEGETATION OPTIONS** • Direct seed native species - scalp areas with grader, scraper or chatfield. • Farm forestry species (eucalypt sawlogs) in four row belts (max. 30 m wide);- plant an extra row of hardy shrubs to maintain windbreak value (see mallett hills). • Oil mallee alleys - unfenced four or eight row belts. • Fence off remnant vegetation and allow to regenerate.

Land Management Unit	Water and Soil Problems	Management Options
LAKES AND SWAMPS (9,258 ha) Salt lake, semi-wet and wet soils. Associated with salt lakes, swamps, dune swales, plains and minor lunettes. 	• High salinity or high risk of becoming saline. • Seasonal waterlogging, inundation and flooding render this soil unsuitable for the growth of most plants. • There may be degradation by sheet, rill and wind erosion and be devoid of vegetation in many areas.	**SOIL MANAGEMENT** • Much is non-agricultural land, or not suited to agricultural production and where possible should be fenced off and managed separately, with emphasis on maintaining ground cover on surrounding associated areas to reduce risk of erosion. **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Earthwork options are limited and site specific. • Shallow relief drainage and herringbone planting/drainage in support of revegetation may be beneficial around lake and swamp margins. **REVEGETATION OPTIONS** • Saltbush and puccinellia. • Fence and allow to regenerate. • See saline areas for revegetation techniques.

Land Management Unit	Water and Soil Problems	Management Options
GREY to GREYISH BROWN LOAMS AND CLAYS (8,177 ha) Hardsetting grey clay loam and clay. Grey to greyish brown loamy surface layers over clay at <30 cm, or clay at surface. Mainly on mid to lower slopes, flats and depressions. Also includes crab hole clays (‘cup and saucer’ or crab hole country). 	• Moderate groundwater recharge, highest where water ponds. • Hardsetting topsoil limits root penetration and establishment of seedlings. • Salinity may develop on valley floors and drainage lines with shallow watertables, or on ponded areas. • Soil can be worked only over a narrow moisture range as it becomes too boggy when wet, and too hard when dry. • Moderate to high risk of waterlogging and inundation, highest on flats and low-lying areas. • Gilgai can be an obstacle to machinery • These clays are highly dispersible and sodic, and conditions are often made worse by cultivation.	**SOIL MANAGEMENT** • Green manuring of a high legume pasture or legume crop such as lentils or peas may improve organic matter, soil structure and aid in improving yields. • Minimum tillage or no-till is preferred to maintain soil structure. • Adding gypsum may help improve soil structure and increase productivity. Investigate with a gypsum test and test strips first. • Avoid working the soil when excessively wet. • Activities that cause rapid loss of organic matter, e.g. long fallow in crop rotation and stubble burning, should be avoided. **CROPPING/ PASTURE OPTIONS** • Highly suitable for wheat, oats and barley (oats will be the better option in wet years). • Suitable for canola, faba beans, field peas, chickpeas and potentially lentils. • Pasture options include medics and in wet areas Persian and balansa clover. • Where soils are sodic tall wheat grass and balansa clover pasture is a good option. If it must be cropped, barley then wheat will do better than oats and legumes but yields will still be significantly reduced on these soils. **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Raised beds may improve surface drainage and enable plant species to persist. • Shallow relief drains (‘W’) can be used to reduce ponding and promote drainage from valley floors. • Hardsetting clay can be reliable run-off source for dam catchments. **REVEGETATION OPTIONS** • Saline areas with barley grass can grow tall wheat grass and balansa clover mix. • Tall fescue does well in waterlogged and flooded conditions. • Belts of oil mallees (four or eight rows) below banks, separated by crop pasture areas (suitable machinery width). • Fence off remnant vegetation/swamps and allow to regenerate, plant a buffer of suitable native/farm forestry species.

Land Management Unit	Water and Soil Problems	Management Options
DEEP SANDS (6,870 ha) Pale grey or white sands deeper than 80 cm. Gravel (<20%) may be present through profile. Generally seen on mid to lower slopes, as dunes, and on lunettes on lake edges. 	• High groundwater recharge. • High risk of wind erosion on exposed crests, lunettes and upper slopes, otherwise the risk is moderate. • These soils are very highly leached, do not retain nutrients, and are highly prone to sub-surface acidification. • Moderately susceptible to water erosion, inundation on flats, traffic and plough pans. • Water erosion is a high risk on exposed upper slopes. • Sandy soils may display water repellence. • Soil water storage is generally low.	**SOIL MANAGEMENT** • Practise stubble retention, brown manuring or maintain approximately 50% ground cover to control wind and water erosion and maintain soil organic matter. • Liming is likely to be uneconomical due to the characteristically low productivity of this soil. • Claying water repellent soils may be an option to consider where the problem is widespread. **CROPPING /PASTURE OPTIONS** • Suitable for wheat, barley and lupins. Stubble retention will protect seedlings from wind erosion. • Lucerne with annual pasture to minimise soil erosion. • Veldt grass and serradella mix. Also an annual sub clover and casbah biserrula mix. **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Grader built earthworks may alleviate soil erosion on slopes or inundation on flats, but have a high maintenance requirement. Interception of shallow seepage unlikely to be effective on downslope waterlogging. Waterlogging period may be reduced on valley floors by the placement of shallow relief drains ('W', 'U' etc). **REVEGETATION AND TREE PLANTING OPTIONS** • Maritime pine plantation over entire area. • Plots of tagasaste planted in rows three to six metres apart. Manage as fodder for cattle (will need to be cut for sheep) *Acacia saligna* can be direct seeded, but as a fodder is questionable value. • Some pastures (e.g. serradella) may be sown between rows if wide enough. • Fence off low production areas and remnant vegetation; allow regeneration or plant suitable banksias, acacias. • Seedlings usually grow best on deep sands, plant as early as possible. • Ripping is recommended, mounding is not. Scalping a narrow area may remove non-wetting layer.

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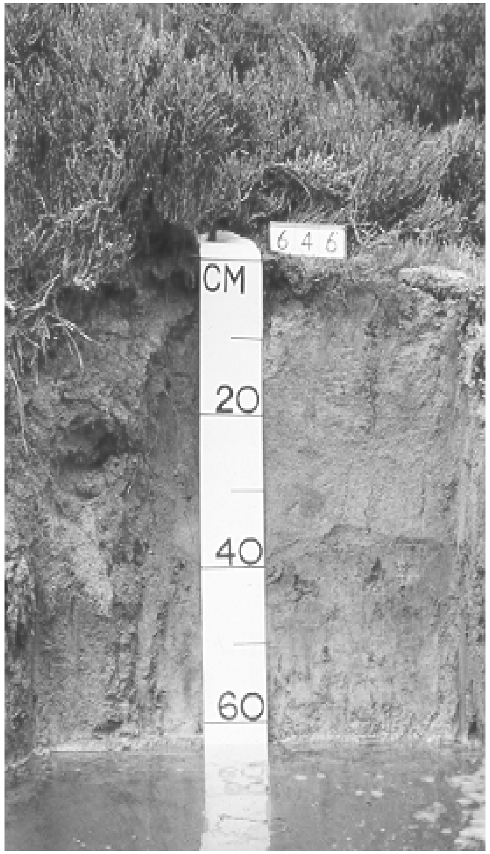
SALT-AFFECTED LAND

(4,065 ha)

A range of soils is affected by salt. They are usually w aterlogged and may be subject to flooding. It is usually seen on valley and basin floors, crab hole country, drainage lines, and occasionally on hillsides as saline hillside seeps.



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- Presently saline.
- Mainly groundwater discharge but recharge may occur during winter.
- Very high risk of waterlogging, inundation, and in some areas, flooding.
- Highly susceptible to serious water erosion problems (gully and rill), particularly along saline drainage lines.

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SOIL MANAGEMENT
- Where possible, fence affected area to protect from compaction and erosion by stock and traffic.
- Maintenance of ground cover to reduce risk of water erosion is recommended.
- Many of these areas are not suited to agricultural production due to waterlogging and salinity problems.

CROPPING /PASTURE OPTIONS
- Salt and waterlogging tolerant perennials such as tall wheat grass, tall fescue and puccinellia are suitable.
- Perennial shrubs such as bluebush (tolerates salinity and short periods of waterlogging), saltbush (tolerates salinity and waterlogging) and samphire (highly tolerant to salinity and waterlogging).

RECHARGE REDUCTION & SURFACE WATER CONTROL
- Shallow surface drainage is recommended (e.g. W-drains, grade banks, herringbone drainage and revegetation establishment). Notification of Intent to drain may be required. Grader built intercepting banks to clay installed above the salt affected area may aid by draining water flowing on the clay subsurface before it contributes to saline areas.
- Increase water use off-site as well as on-site.

GROUND WATER OPTIONS
- Drains to relieve groundwater and groundwater pumping are expensive. Good design is essential and should be site specific.
- Drainage effluent should be disposed of without degradation.
- A Notice of Intent to drain will be required.

REVEGETATION OPTIONS
- Bare saline areas are suitable for saltbush species and samphire in mildly waterlogged conditions.
- All revegetation areas should be mounded at 0.5 to 1% slope to reduce waterlogging - mounds with a distinct 'V' work best.
- Mild saline areas - 4 row belts of tolerant oil mallees, with tolerant pasture species (balansa etc) sown between - maintain grazing.
- Single rows of saltbush species (direct seeded or seedlings), separated by alleys of saltland pastures - managed for fodder.

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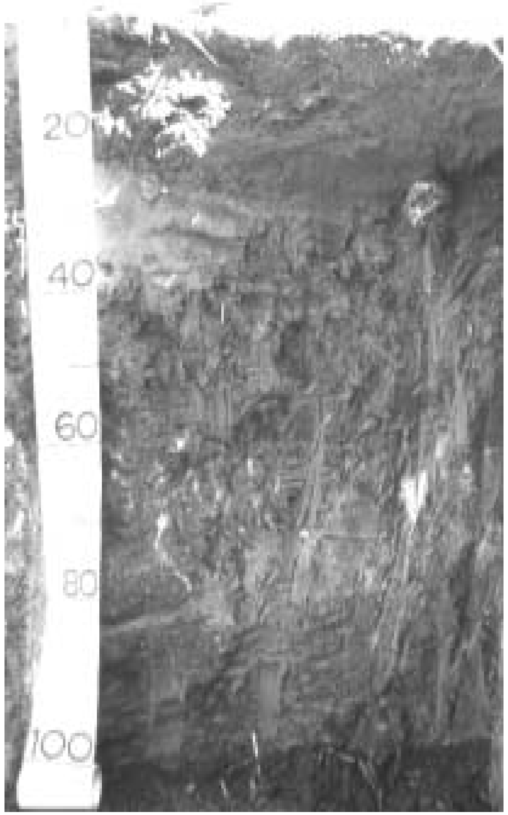
RED to RED BROWN SOILS and DYKES (3,798 ha)

Reddish brown sandy loam over clay or grading to clay at 10-20 cm (red loam); red or reddish brown clay loam over red clay at <10 cm or grading to red clay at depth (red clay). Seen mainly on slopes and ridges, and often associated with dolerite dykes.



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- Low to moderate groundwater recharge.
- Good water availability in most years – dry seasons may cause water stress.
- Fresh or saline hillside seeps may occur on or near these soils as they are formed on dolerite dykes.
- Surface cracking may make stock and vehicle movement difficult
- Low risk of waterlogging. Lighter soils upslope from this LMU may exhibit waterlogging due to the heavier red soils acting as a textural barrier to lateral water movement.
- Moderately susceptible to water erosion and decline of topsoil structure.
- Surface and subsurface soils may be alkaline and unsuitable for some crops and pastures, and may exhibit nutrient toxicity and deficiencies.

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SOIL MANAGEMENT

- Cropping operations should occur on the contour and minimum tillage or no-till operations and stubble retention should be considered to aid in improvement of soil structure.
- Reduction of traffic in paddocks and avoidance of traffic movement when soil is wet minimises soil compaction.

CROPPING/PASTURE OPTIONS

- Highly suitable for wheat, oats, barley and canola.
- Where pH is alkaline, also suitable for faba beans, field peas, chickpeas and lentils.
- Pasture options include annual sub clovers, *casbah biserrula*, and in the wetter areas, balansa clover. Medics are an option in alkaline areas.

RECHARGE REDUCTION & SURFACE WATER CONTROL

- Lucerne on areas that are not prone to waterlogging or seepage.
- Hillside seepage areas may become saline with barley grass appearing. Tall wheat grass and balansa clover may increase the grazing value.
- Grade and seepage interceptor banks can reduce erosion and waterlogging. Care should be taken in siting of banks as striking rock may lead to increased recharge.

REVEGETATION OPTIONS

- Lucerne on areas that are not prone to waterlogging or seepage.
- Hillside seepage areas may become saline with barley grass appearing. Tall wheatgrass and balansa clover may increase the grazing value of these areas.
- Farm forestry species (eucalypt sawlogs) in four row belts - plant an extra row of hardy shrubs to maintain windbreak value (*Eucalyptus cladocalyx, E. loxophleba ssp. loxophleba, E. occidentalis, E. tricarpa, E. astringens, Allocasuarina huegeliana).*
- Native species - hosts for sandalwood production - direct seed or seedlings.
- Rip into clay layer to assist root penetration of seedlings.

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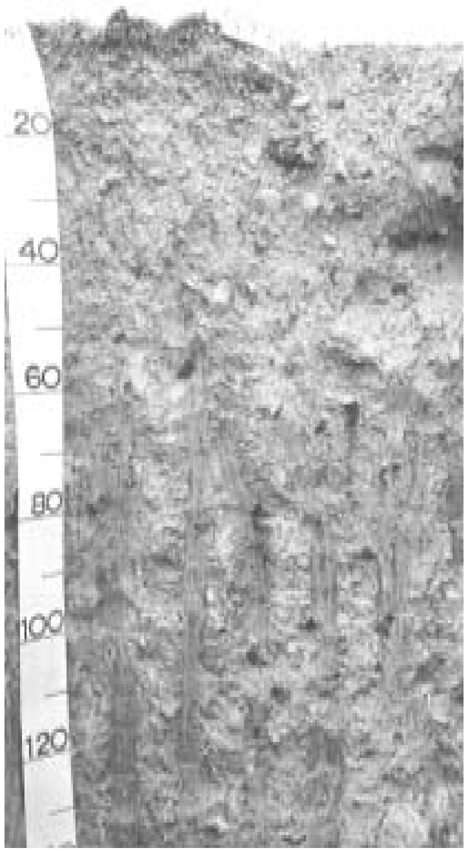
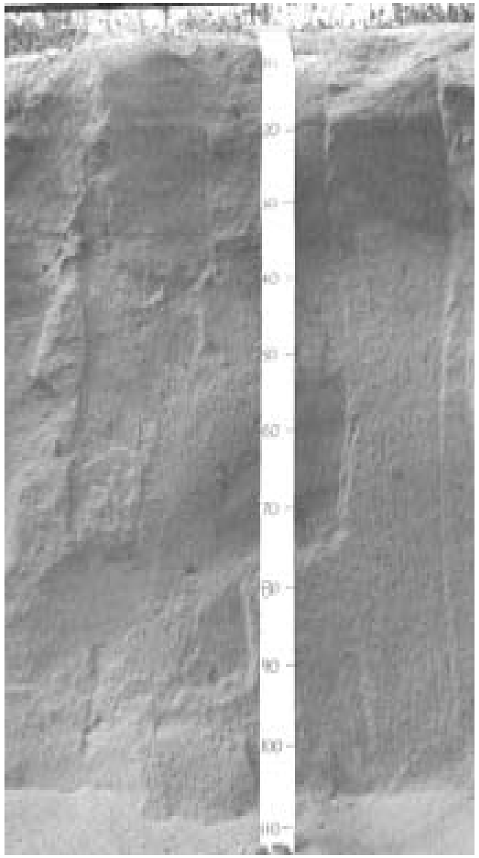
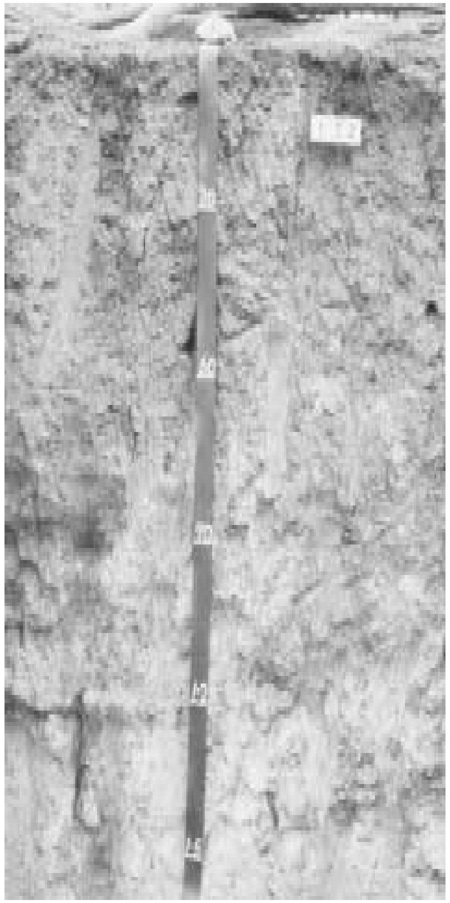
Land Management Unit	Water and Soil Problems	Management Options
STONY AND ROCKY SOILS (867 ha) These soils are identified by the large amount of sandstone rocks on the ground surface and through the topsoil. They are common on the hills of the Stirling Range, but can be found lower down in the landscape. 	• Very high groundwater recharge. • Water erosion is a high risk on exposed upper slopes. • Water availability varies, depending on depth to clay • Rocks may hinder cultivation and reduce trafficability • Moderate risk of wind erosion – rocks on surface lessen risk • Generally good rooting depth but stones may hinder roots.	**SOIL MANAGEMENT** • Maintenance of active growing plants is important here to prevent rapid drainage of soil water to below the root zone, contributing to problems lower in the landscape. • Cultivation should be carried out on the contour to reduce erosion risks and improve water conservation. **CROPPING/PASTURE OPTIONS** • Moderate performance of cereals and annual pastures **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Veldt grass and serradella mix in areas with deep sandy soil. • Lucerne. • Phalaris and strawberry clover in seepage areas. • Placement of earthworks is highly dependent on soil structure and clay depth. Grader built earthworks may alleviate soil erosion on slopes or inundation on flats, but have a high maintenance requirement. Unless the clay layer is reached, banks will be ineffective for waterlogging control. **REVEGETATION OPTIONS** • Fence off and allow any existing vegetation to regenerate. • Sandalwood plantation - hosts required. • Revegetate with a mixture of native species around the rock areas - direct seed sandalwood after hosts are established. • Use direct seeding or seedlings as a method of establishing a buffer zone and extra habitat around these important nature conservation areas.

Land Management Unit	Water and Soil Problems	Management Options
YELLOW AND BROWN DEEP SAND (726 ha) Yellow or brown sand deeper than 80 cm. Generally on mid to lower slopes and valley floors, and as dunes. 	• High groundwater recharge. • High risk of wind erosion on exposed crests and upper slopes, otherwise the risk is moderate. • These soils are very highly leached, do not retain nutrients, and are highly prone to sub-surface acidification. • Moderately susceptible to water erosion, inundation on flats, traffic and plough pans. • Water erosion is a high risk on exposed upper slopes. • Sandy soils may display water repellence. • Soil water storage is generally low.	**SOIL MANAGEMENT** • Practise stubble retention, brown manuring or maintain approximately 50% ground cover to control wind and water erosion and maintain soil organic matter. • Liming may be necessary to achieve crop and pasture production potentials and assist in the establishment of lucerne; regular monitoring of soil pH levels is advised. • Claying water repellent soils may be an option to consider where the problem is widespread. **CROPPING/PASTURE OPTIONS** • Highly suitable for wheat, oats, barley, lupins and canola. • Phase cropping with lucerne. • Pasture options include annual sub clovers, serradella and casbah biserrula **RECHARGE REDUCTION & SURFACE WATER CONTROL** • Generally not suitable for surface water control earthworks due to slumping of the structures. • Minimise water retention with good soil management practices such as working to the contour and maintaining a good pasture cover. • Grader built earthworks may alleviate soil erosion on slopes or inundation on flats, but have a high maintenance requirement. Interception of shallow seepage unlikely to be effective on downslope waterlogging. Waterlogging period may be reduced on valley floors by the placement of shallow relief drains ('W', 'U' etc). **REVEGETATION OPTIONS** • Belts of oil mallees (four to eight rows) below banks, separated by crop pasture areas (suitable machinery width). • Eucalypt sawlogs -sugar gums (*Eucalyptus occidentalis*). • Maritime pine as belts or plantation over entire area.

Land Management Unit	Water and Soil Problems	Management Options
ROCK OUTCROPS (663 ha) Includes outcrops of granite, dolerite, sandstone, quartz and hard ironstone. Generally seen on ridges, peaks and mid to upper hillslopes. 	• Very high recharge through soil at the edge of outcrops. • Variable recharge can occur through fractures in the rock. • Hillside seeps can develop where outcrop forces saline groundwater to the surface. • Outcrops may shed water resulting in water erosion downslope.	**SOIL MANAGEMENT** • This is non-agricultural land, but where possible should be fenced off and managed separately, with emphasis on revegetation to maximise water use. **SURFACE WATER CONTROL** • Grade banks below a water shedding areas can alleviate erosion problems. Absorption banks can be used where no safe disposal point can be located, as a last resort due to the increased recharge risk. Absorption banks should be used in conjunction with tree planting along bank. • Larger granite rocks can be a good run-off source for dams. **REVEGETATION OPTIONS** • Fence off and allow any existing vegetation to regenerate. • Sandalwood plantation – host plants required. • Revegetate with a mixture of native species around the rock areas - direct seed sandalwood after hosts are established. • Use direct seeding or seedlings as a method of establishing a buffer zone and extra habitat around these important nature conservation areas.

Land Management Unit	Water and Soil Problems	Management Options
MALLET HILLS (381 ha) Pink or reddish water-repellent soils, may be gravelly, often acidic. Isolated hillcrests and breakaways. 	• Generally low recharge because water runs off. • Highly susceptible to water erosion, particularly on breakaways with slopes >10%. • Highly susceptible to water repellence and topsoil structure decline. • Subsoils are often acid and saline, and if exposed remain bare and unproductive.	**SOIL MANAGEMENT** • Maintenance of ground cover is important to reduce water erosion risk. **SURFACE WATER CONTROL** • Grade banks below a water shedding area can alleviate erosion problems and may be a good water source for dams situated nearby. • Dams should not be constructed due to the poor water holding capability of the subsoil. • Grade and seepage interceptor banks can reduce erosion and waterlogging. Care should be taken in siting of banks as striking rock may lead to increased recharge. **REVEGETATION OPTIONS** • Fence off and revegetate with species native to the catchment. • Difficult to revegetate. Mounding and putting native tree species branches with seed at the base of the mounds has given good stands of seedlings. • Oil mallees - contact Oil Mallee Company for suitable species. • Eucalypt sawlogs - brown mallet for posts, sawlogs. • Fence and allow to regenerate.

Land Management Unit	Mallet hills	Pale deep sands	Gravels	Rock outcrops	Red – red/brown soils and dykes	Poorly drained sandy duplex	Salt affected land	Grey/greyish brown loams and clays	Yellow and brown deep sand	Lakes and swamps	Sandy duplex soils	Stony and rocky soils
Landscape Position	Isolated hillcrests and breakaways	Upper to lower slopes, dunes, basin floor, lake and swamp margins	Crests and upper slopes	Outcrops of granite, dolerite, and hard iron-stone, on ridges and upper slopes	Upper and lower slopes, often associated with dolerite dykes	Lower slopes and basin floor	Basin floor and seeps on hill slopes	Mid to lower slopes, flats and depressions	Mid to lower slopes and valley floors, and dunes.	Seen mainly on the basin floor	Hillslopes, sandplain, lunettes, dunes and basin floor	Hillcrests and upper slopes
Profile No.	1	2	3	4	5	6	7	8	9	10	11	12

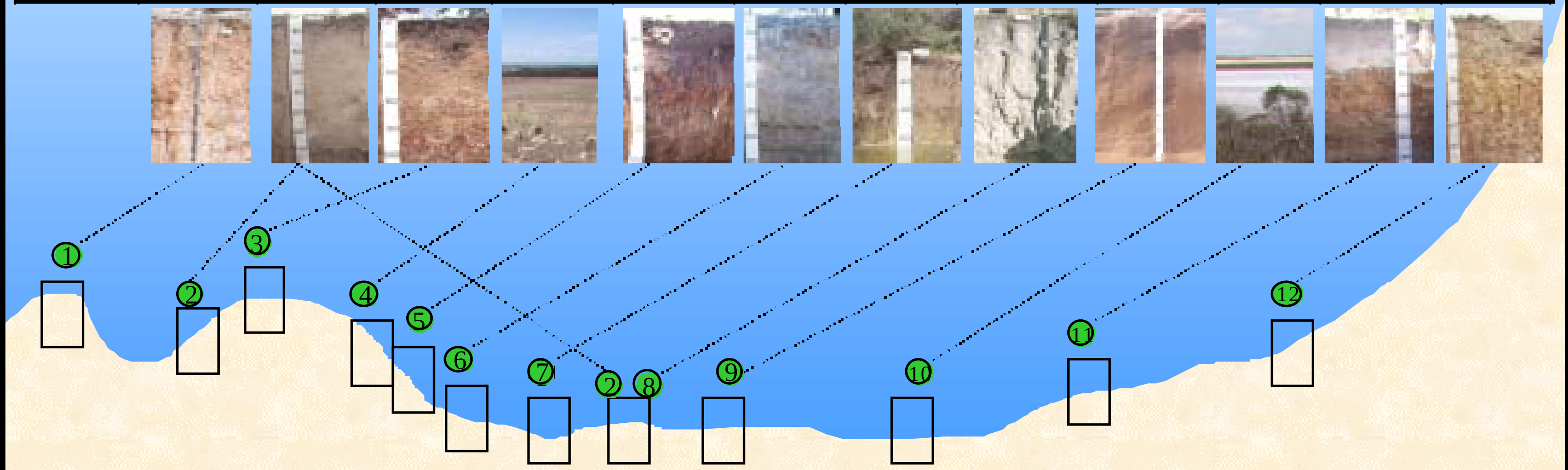


Figure 4.1.1. Schematic cross-section of land management units in Cranbrook-Toolbrunup area

4.2 Farming systems

Arjen Ryder, Low Recharge Farming System Officer, Albany and Cindy Stevens, Development Officer, Gnowangerup

Farming systems across the North Stirling comprise annual crops grown in rotation with annual pastures, with farm income predominantly from grain, sheep and wool production. In recent years farming systems have headed towards longer cropping phases which have been beneficial in reducing the risk of herbicide resistance, maximising returns on grain. They have become possible with more cropping options such as canola, chickpeas, field peas, faba beans, lentils and vetches. The recent revival of minimum and no-till farming and its gradual adoption has reduced the effects of erosion and soil structural decline.

Yield range for common crops, and sheep numbers in an average year in the Gnowangerup, Tambellup and Broomehill Shires:					
Wheat	Barley	Oats	Lupins	Canola	Sheep
1.75-2 t/ha	1.75-2 t/ha	2-3 t/ha	1-1.25 t/ha	1-1.25 t/ha	300,000-800,000 hd

Lake Toolbrunup area

Current farming systems comprise mostly no tillage with knifepoints with an increasing use of press wheels. A few farmers still use discs and conventional methods. Typical rotations may include a three to six year cropping phase, followed by a two to three year pasture phase. The general nutritional status of the soils includes satisfactory nitrogen levels, trace element deficiencies (Zn, Cu, Mn) and an increasing trend in the application of potassium. Herbicide resistance is an issue for most growers (Group A and B herbicides).

Considerable research has been undertaken on the effect of standard agricultural systems on the hydrological cycle, especially recharge and discharge areas, groundwater levels and salinity. Under current practices, it has been estimated that salinity across the South West agricultural area could increase to 8 million hectares (Short & McConnell 2001).

A large proportion of this potential recharge can be reduced by:

- Increasing the area under perennials
- Introducing phase cropping with perennials
- Applying management options to improve the productivity of crops and pastures.

These systems are generally known as low recharge farming systems. Research is currently underway to assess various perennial pasture species and determine how they may be used more effectively within the current annual farming systems.

Lucerne phase farming as an option

The economic and environmental benefits are important considerations before introducing perennials into the farming system. Phase farming with lucerne (three to four years crop, three to four years lucerne) is becoming widely accepted for its profitable contribution to the grazing and cropping systems with the added benefits of reducing recharge, increased soil nitrogen and providing winter cleaning to manage herbicide resistance.

Estimating recharge through the AgET model

AgET provides an estimate of recharge based on soil, rainfall and plant species.. As with all models and mathematical assumptions, it is important to note that the model provides an estimate. Variations in the estimates will occur in the field.

A generalised scenario example (calculated using the AgET model) is given below showing the estimated reduction in recharge across a 2,010 ha property, when lucerne plantings were increased from zero to 20% of the property.

Property details

Property size:	2,010 ha	
Average rainfall:	400 mm (AgET rainfall records used from 1974 to 1993)	
Soil Groups:	Deep sandy duplex	46%
	Shallow sandy duplex	25%
	Shallow loamy duplex	20%
	Deep sand	5%
	Saline soil	4%

Property detail summary

Under the existing land use of annual pasture and crop:

Annual pasture	1,006 ha	52%
Crop	904 ha	48%
Total arable land	1,910 ha	100%
Remnant bush + non-arable	100 ha	
Total land area	2,010 ha	

Recharge under the above system is 51 mm (12.5% of annual rainfall).

The above system then compared to having 20% of the property under lucerne with the same land area cropped is observed as follows:

Annual pasture	604 ha	32%
Lucerne	402 ha	20%
Crop	904 ha	48%
Total arable land	1,910 ha	100%
Remnant bush + non-arable	100 ha	
Total land area	2,010 ha	

Recharge is reduced to 39 mm (or 9.5% of annual rainfall)

When introduced into the existing annual farming systems, lucerne and other perennial species have the capacity to reduce recharge by increasing the depth of soil profile explored (lucerne roots have been found growing down to 3.5 m) as well as surviving over summer. Production benefits include (i) additional green feed after annuals have dried off, thereby reducing autumn hand feeding; (ii) increasing the potential to fix 60 kg of soil nitrogen /ha /yr; and (iii) increasing protein levels in following grain crops.

Figure 4.2.1 and Table 4.2.1 illustrate the possible effect of changing management to reduce recharge on long-term groundwater levels. Growing lucerne or other perennials can decrease the eventual extent of land at risk of becoming saline. However, in Lake Toolbrunup catchment there are only small differences in the area affected even with 50% perennials. This is due to the topography which has stagnant flats (<0.5% slope) that are already at risk of salinisation and then a sharp break of slope to the granitic rises. Rate of watertable rise under varying topography will change with management but there is little risk of salinisation (see Figure 4.2.1) above the break of slope except where shallow bedrock forces a hillside seep.

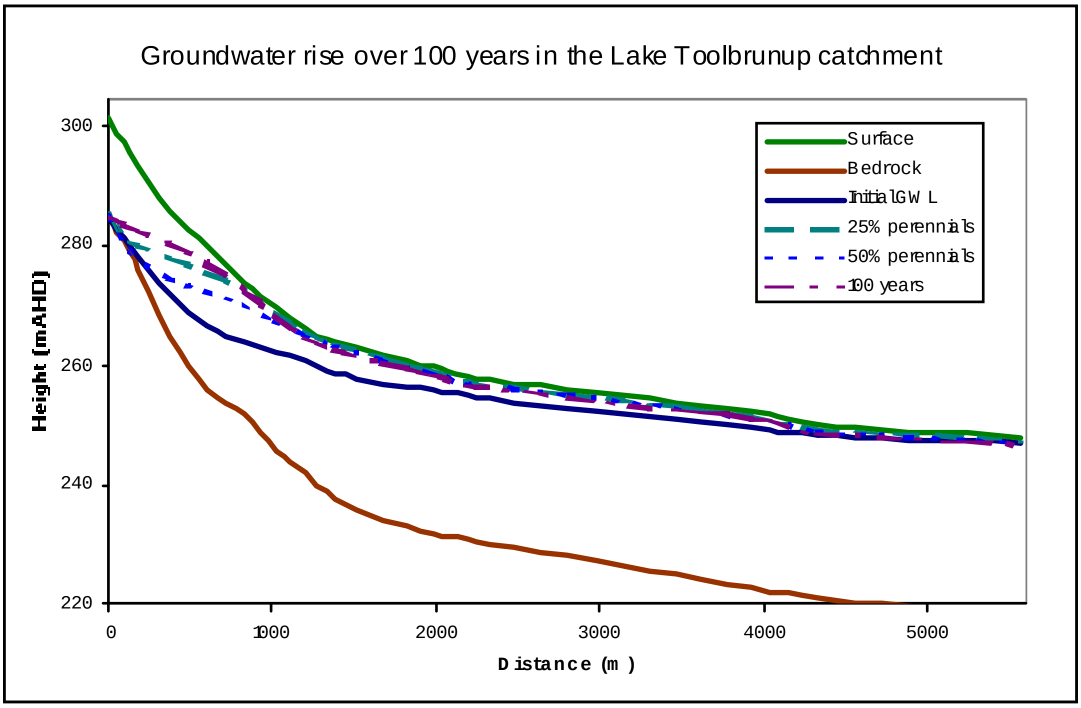


Figure 4.2.1. The effect of reducing recharge on groundwater levels over 100 years in the Lake Toolbrunup catchment.

Table 4.2.1. Possible effect of increasing perennial vegetation (assuming zero recharge under perennials) on the extent and rate of salinisation in the Lake Toolbrunup catchment

Flowpath affected by shallow watertables	50 years	100 years	At equilibrium	Number of years taken to reach equilibrium
current practice	89%	89%	89%	50
50% perennials	81%	89%	89%	100
25% perennials	81%	81%	81%	35

Options for introducing perennial systems

Lucerne can be introduced into a farm by establishing a whole paddock and grazing it according to growth. Further information on establishment and grazing of lucerne can be accessed through the Western Australian Lucerne Growers association (refer to Section 5 of this report for contact details).

Alley farm systems using trees or shrubs (oil mallees, pines, acacias, tagasaste or saltbush) in belts with either annual or perennial pasture between the belts has been adopted successfully in fresh to marginally saline areas (Ryder *et al. 20*00).

Tall wheat grass and balansa clover have been successfully grown on marginal to saline land (Robinson 2000, Ryder *et al.* 2000).

Block planting of trees or in belts of five rows have proved useful in reducing wind erosion (Ryder *et al.* 2000).

Farming systems 'in the future' will inevitably include an increased component of perennials either for recharge reduction or for increased whole farm productivity (such as weed and grazing management and strategic cropping cycles).

Another enhancement will be the improved coordination and delivery of precision agricultural systems. Information collected from individual paddocks at a detailed scale (using a GPS and yield monitor) will link to the better management and identification of soil types, fertility status, landscape position, areas of low productivity and marginal or potential saline areas. This level of technology will prove useful when deciding what the best (or most economically sustainable) land use will be per paddock together with maximising the potential for each agricultural system.

The Australian Centre for Precision Agriculture website:
www.usyd.edu.au/su/agric/acpa/pag.htm has some useful information for the latest developments.

4.3 Salinity management – assessing economic feasibility

Michael O'Connell, Regional Economist, Albany

4.3.1 Guiding principles

Decisions about salinity management are often complex. Deciding on what to do, when, and how much, are big decisions. In order to minimise costly mistakes, the following process is recommended:

1. Identify the problem, its causes and impacts on the farm business
2. Identify the various courses of action that are technically feasible
3. Analyse the economic and financial feasibility of the available options
4. Implement the chosen solution(s) to the problem
5. Monitor, control and revise for unexpected developments.

The focus will be on assessing economic feasibility. Information relating to items 1, 2, 4 and 5 can be found elsewhere and by contacting the Department of Agriculture.

4.3.2. Assessing the economic feasibility of salinity management options

A cashflow budget will provide a lot of useful information about likely impacts of proposed changes on farm business profitability. Remember - mistakes made on paper cost a lot less than mistakes made in the paddock. The following steps are required to make a cashflow budget:

1. Identify the establishment costs
2. Identify ongoing maintenance costs
3. Identify benefits
4. Combine benefits and costs to create budget
5. Compare with current practice.

These steps will now be illustrated using oil mallees as an example. The numbers given are intended as examples only

Table 4.3.1a. Step 1: Identify establishment costs (year 1)

Ripping, mounding & planting					$150	
Trees	2,500	seedlings @	$0.40	each	$1,000	
Weed control	1.0	L/ha glyphosate @	$6.00	/ L	$6	
	4.0	L/ha simazine @	$5.25	/ L	$21	
Allowance for loss of stubble grazing					$20	
Firebreaks					$5	
Insurance					$5	
Total					$1,207	/ ha

Table 4.3.1b. Identification of establishment costs (year 2)

Establishment costs - year 2		
Weed control	$25	
Contingency item (e.g. insect control)	$10	
Allowance for loss of stubble grazing	$20	
Firebreaks	$5	
Insurance	$5	
Total	$65	/ha

Machinery operations are assumed to be done by contract or with hired equipment. Trees are assumed to be planted in hedges with conventional farming practice in the alleys. The hedges take up 15% of the landscape. It is assumed that the alleys are sown to crops in the first two years and that no stock are allowed in until year three. An estimate of the opportunity cost of lost stubble grazing is included. A contingency line is also included to account for unexpected costs that inevitably occur.

Table 4.3.1c. Step 2: Identify ongoing maintenance costs (year 3+)

Ongoing maintenance costs - year three onwards		
Allowance for rabbit control	$5	
Contingency item	$5	
Firebreaks	$5	
Insurance	$5	
Total	$20	/ ha

Table 4.3.1d. Step 3: Identify benefits

Harvest returns		
Number of trees (assumes 90% survival)	2,250	/ ha
Yield	25	kg / tree
Net price of biomass (after harvest & transport)	$15	/ tonne
Total benefit at harvest	$844	/ ha

Note: The final results will be highly sensitive to assumptions about yield and price. It is worth repeating the calculations for a best case and worst-case scenario. It is also necessary to estimate the number of years to first harvest and the frequency of harvests after that. In the cash flow budget (see below) it is assumed that the first harvest is in year five, with subsequent harvests every two years. Again, it is worth repeating the calculations for different scenarios.

Step 4: Combine benefits and costs to create budget.

The costs and benefits can now be entered into a computer spreadsheet or written out. An example format is given below. Having the budget in a computer spreadsheet is particularly useful in that is easy to change assumptions and see the impact on results. To reflect the long-term nature of oil mallees the budget has been extended out to 15 years. All figures are before interest and tax.

Table 4.3.2. Example of oil mallee cash flow budget

Year	Costs ($/ha)	Harvest returns ($/ha)	Cash flow ($/ha)
1	$1,207	$0	-$1,207
2	$65	$0	-$65
3	$20	$0	-$20
4	$20	$0	-$20
5	$20	$844	$824
6	$20	$0	-$20
7	$20	$844	$824
8	$20	$0	-$20
9	$20	$844	$824
10	$20	$0	-$20
11	$20	$844	$824
12	$20	$0	-$20
13	$20	$844	$824
14	$20	$0	-$20
15	$20	$844	$824

Note: The budget is presented in 'real' dollars with the effects of inflation removed. This is appropriate for an economic analysis where the relative profitability of a new enterprise is being assessed. However when it comes to actual financial planning it is important to account for inflation and work in 'nominal' dollars. In some economic analyses it may also be necessary to make adjustment for real changes in the value of inputs and outputs.

Step 5: Compare with current practice

The critical question to ask now is "How does this new activity compare with the current farming system?" For example, assume the existing crop and pasture program generates a year-in year-out gross margin of $125/ha. How can this be compared against the uneven cash flow pattern of the new activity, in this case oil mallees?

One approach would be just to add up all the expected future cash flow amounts. Don't! This will give the wrong answer because a dollar received today is worth more than a dollar received in the future. And this is true even when inflation is left out of our calculations, because a dollar can be invested today and earn a real return. For example $1 growing at 10% p.a. compounded will be worth $2 after seven years. Add to this the fact that most people have a "time preference" for money and it becomes obvious why it is so important to make some adjustments to the value of future cash flows. This is done by a process called discounting. In this example a discount rate of 7.5% p.a. is used.

After 15 years the cumulative value for oil mallees is slightly ahead of the current land use. However in all prior years the current practice is ahead. This is best represented in Figure 4.3.1.

Table 4.3.3. Discounted cash flow (DCF) for oil mallees compared to current land use

Year	Discount factor	Oil mallee: Cash flow ($/ha)	Oil mallee: DCF ($/ha)	Oil mallee: Cumulative DCF ($/ha)	Current land use: Cash flow ($/ha)	Current land use: DCF ($/ha)	Current land use: Cumulative DCF ($/ha)
1	0.93	-$1,207	-$1,123	-$1,123	$125	$116	$116
2	0.87	-$65	-$56	-$1,179	$125	$108	$224
3	0.80	-$20	-$16	-$1,195	$125	$101	$325
4	0.75	-$20	-$15	-$1,210	$125	$94	$419
5	0.70	$824	$574	-$636	$125	$87	$506
6	0.65	-$20	-$13	-$649	$125	$81	$587
7	0.60	$824	$497	-$153	$125	$75	$662
8	0.56	-$20	-$11	-$164	$125	$70	$732
9	0.52	$824	$430	$266	$125	$65	$797
10	0.49	-$20	-$10	$256	$125	$61	$858
11	0.45	$824	$372	$628	$125	$56	$914
12	0.42	-$20	-$8	$619	$125	$52	$967
13	0.39	$824	$322	$941	$125	$49	$1,016
14	0.36	-$20	-$7	$934	$125	$45	$1,061
15	0.34	$824	$278	$1,212	$125	$42	$1,103

Note: Discount factor = 1 / $(1 + r)^y$, where r is the discount rate expressed as a decimal (e.g. 7.5% becomes 0.075), and where y is the number of years into the future. Depending on the situation it may also be appropriate to factor in a yield decline due to land degradation with the current land use. However the effect of any land degradation (e.g. a salt-scald) could be at least partly offset by efficiency gains on the remainder of the landscape.

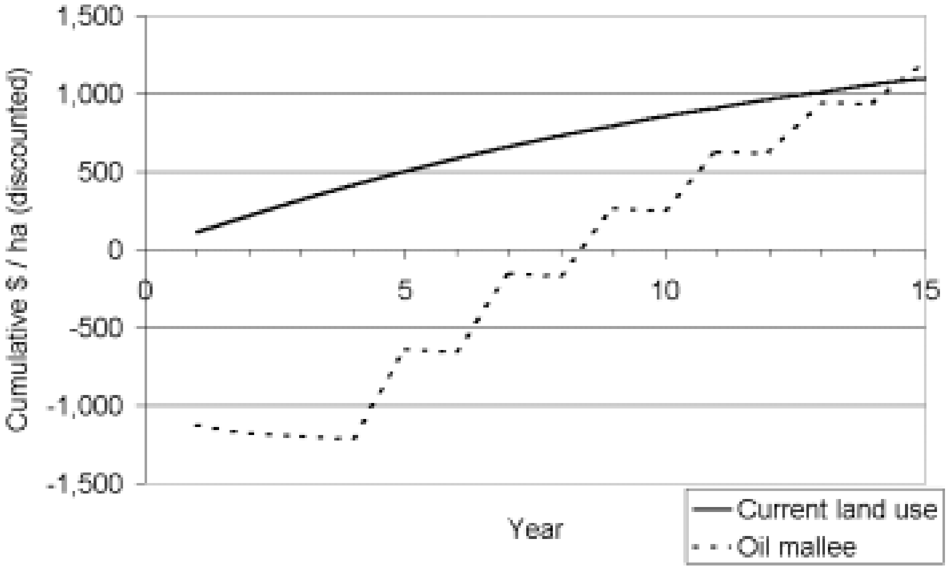


Figure 4.3.1. Example of cumulative cash flow for oil mallees and current land use

It is also important to see how sensitive profits are to changes in assumptions. Figure 4.3.2 shows discounted cash flow under two different harvesting schedules. The first scenario is for first harvest in year four, then every two years. The second, less optimistic, scenario is for first harvest in year five, then every three years. Other important assumptions to test are yield, price, establishment costs and discount rate. These all have a significant impact on results.

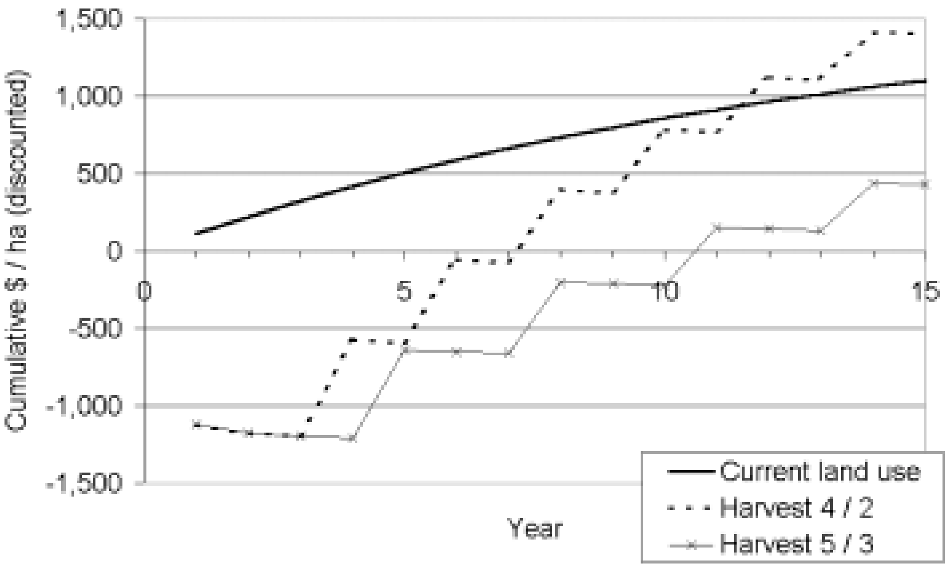


Figure 4.3.2. Impact of different harvesting schedules on the cumulative cash flow from oil mallees, compared with current land use.

4.3.3 What the results mean and how to use them

Putting the budget together is one thing, interpreting the results is another. The key is to work out which numbers are important and which are not. In the oil mallee example, establishment cost, yields, prices, harvest schedule and discount rate were identified as important. The important numbers in any budget should be identified and examined under a wide range of scenarios.

Related to this, it is also important to recognise that a lot of the figures that go into budgets will be 'soft'. History shows that the best estimates about the future will rarely, if ever, happen as expected. There is a need to regularly review projects, make revisions, and possibly even accept something that was previously rejected.

Remember also that a cash flow analysis does not give a definitive answer. A range of factors should determine the final decision, such as:

- Personal goals and ambitions. What are the implications for lifestyle etc?
- Practical considerations, e.g. what are the implications for the current farming system? Are modifications to plant and equipment required? What about timing of operations, and conflicts in the use of labour and machinery?
- Financial situation, e.g. does the financial position allow the luxury of a long-term investment with several years to cost recovery? If the new venture falls on its face what will this mean for the farm business?

- Alternative investment opportunities. For example, would it be better to invest capital off-farm? Or buy more land? Or take out a lease?
- Attitudes to risk and personal preferences. Is the new venture highly risky and, if so, is this acceptable?

Table 4.3.4. Some important costs, benefits and cash flow implications of selected enterprises for salinity management

Option	Costs / disadvantages	Benefits / advantages	Cash flow implications	Main profit drivers
Perennial pastures (e.g. lucerne, kikuyu)	• Establishment costs are usually similar to cost of planting a crop. • Ongoing costs are similar to annual pasture. • Removal can require several sprays and careful management. Dead plants can create problems for seeding following crops. • Soil profile will be very dry after a perennial pasture phase. Crop yields may suffer if growing season rainfall is low. • Potential for animal health problems on lush green feed, but risk can be managed.	• Reduced recharge. • Supply of quality feed during autumn feed trough. • Disease break for following crops. • Nitrogen fixation by legumes (e.g. lucerne).	• Usually negative cash flow in year 1, but cover cropping can help recoup costs. • Positive cash flow from year two onwards. • Anticipate full cost recovery after two to seven years.	• Livestock and wool prices. • Flock structure. • Success of establishment (failed establishment is expensive). • Quality and quantity of out of season feed. • Availability and cost of other feeds. • Yield and protein boost in following crops. • Area grown (average value declines as more area is sown).
Balansa clover	• Should cost less than a crop to establish. • Careful grazing management is required.	• Can be grown in areas where traditional pastures perform poorly. • Waterlogging allows growing season to be extended.	• A well-managed balansa pasture can be very profitable.	• Quality of dry feed in summer. • Livestock and wool prices. • Flock structure. • Area grown.
Saltbush pasture system (e.g. saltbush, puccinellia, tall wheat grass, balansa clover)	• Establishment costs vary enormously, typically ranging from $75/ ha to over $200 /ha. • A good supply of fresh water must be provided for stock. • New fences might be needed. • Mustering can be a problem. • Generally not suitable for lambing ewes and young sheep.	• Reduced recharge. • Reduced water erosion. • Saltbush dries soil profile enough to allow salts to be flushed from topsoil. Other pasture plants can then establish (e.g. balansa clover, grasses). These other pasture species form a large part of the grazing value. • Can last for many years if managed well.	• Some grazing available in the first year. • Cost recovery period will depend a lot on cost of establishment. • Have been demonstrated to be profitable, especially when a good understorey of highly nutritious pasture is established.	• Livestock and wool prices. • Success of establishment (failed establishment is expensive). • Quality and quantity of out of season feed. • Availability and cost of other feeds. • Area grown.

Table 4.3.4. (cont'd)

Option	Costs / disadvantages	Benefits / advantages	Cash flow implications	Main profit drivers
Tagasaste	• Establishment cost typically in the order of $100 -150 /ha. • Require ongoing management to prevent plants getting to big. • New fences might be needed. • Mustering can be a problem.	• Stabilises soil. • Reduced recharge. • Provides year round feed.	• Depends strongly on how well the plants are utilised. Well-managed stands can be profitable.	• Feed must be utilised in order to realise benefits. • Livestock prices. • Success of establishment. • Availability and cost of other feeds. • Area grown.
Tree crops in alleys, such as oil mallees	• Often costs over $1,000 /ha to establish, plus ongoing maintenance. • Modifications to machinery may be required in order to farm between alleys of trees. • Livestock must be excluded for at least the establishment phase. • Future prices and yields are uncertain. • Land is taken out of crop and pasture production.	• Reduced recharge. • Potential to generate future income. • Windbreak effect reduces soil erosion.	• Large up front costs. • Delay of several years at least before first income. • Typically 10 + years to full cost recovery.	• Cost of establishment. • Years to first harvest. • Frequency of harvest. • Price received and yields. • Profitability of alternative land use. • Discount rate (opportunity cost of alternative investments).
Tree crops in blocks, such as sandalwood	• Often costs over $1,000 /ha to establish, plus ongoing maintenance. • Livestock must be excluded for at least the establishment phase, often longer. • Future prices and yields are uncertain. • Recharge benefits restricted mainly to land on which trees are planted.	• As above.	• As above.	• As above.

4.4 Surface water management

Austin Rogerson, Land Conservation Officer, Albany

4.4.1 Conservation land management options

Conservation land management options seek to use excess water to minimise run-off, improve flat land drainage to reduce excess water and waterlogging, and protect against erosion by covering the soil with vegetation and reducing the speed (velocity) of surface water run-off.

Four land management options may be used within most of the study area:

- Vegetative cover to use the water (transpiration), protect the soil from raindrop impact and surface water run-off, and to slow down surface water flow
- Working land along the contour to contain surface water in the furrows
- Adopting minimum-tillage or no-till age cropping techniques to reduce damage to soil structure
- Appropriate designed conservation earthworks including permanently grassed waterways to slow water velocity whilst providing maximum drainage of all areas.

Surface water earthwork options

Surface water earthworks reduce the velocity and volume (peak flow) from run-off by diverting or retaining run-off flow. Table 4.4.1 shows the area of slope classes of five major soil landscapes, which represent most of the area currently used for agriculture. Subject to site survey, this represents a guide to the potential for surface water earthworks over 85% of the study area.

Table 4.4.1. Area of land presenting opportunities for surface water earthworks subject to soil and slope classes

Class	**Soil-landscape units (refer to Section 2.3)**	**Slope class**				**Total**
		0-1%	1-6%	6-10%	10+%	
1	Ca2+Jf1+Mp2+Nt3+Ya2+Up2	3,553	21,051	284	19	24,907
2	Ca4+Jf2+Nt2+St4+Ya3+Up4	5,531	11,895	186	20	17,632
3	Nt1	10,351	4,403	30	5	14,789
4	Gd2+Mp3+Nt4+Nt5	1,661	4,492	91	1	6,245
5	St3	110	2,437	455	107	3,109
6	Ca1+Mp1+Ya1+Up1	259	1,913	60	5	2,237
	Totals (km)	21,465	46,191	1,106	157	68,919

***** Legend to Classes (see Section 2.3. Soil-landscape information)***

1. Lower, mid and upper hillcrests of Carrolup, Jaffa, Mooniup, Nth Stirling and Upper Pallinup soils. Common soils are grey deep and shallow sandy and loamy duplex.
2. Lower slopes, footslopes and drainage lines of Carrolup, Jaffa, Nth Stirlings and Upper Pallinup soils. Common soils are grey deep and shallow sandy duplex.
3. Basin floor, including lakes and minor lunettes of North Stirling. Common soils are alkaline grey deep sandy duplex.

4. Sandsheets and large lunettes of the North Stirling, Gordon Flats and Mooliup soil landscape units. Common soils are grey deep sandy duplex and pale deep sands.
5. Undulating rises and low hills of the Stirling Range soils. Common soils are duplex sandy gravel, stony soils and grey deep sandy duplex.
6. Upper slopes, hillcrests and breakaways. Common soils are duplex sandy gravel and deep sandy duplex.

The deep sandy duplex soils of Classes 3, 4, 5 and parts of 6 would make the placement of grade banks difficult and depth to clay would need to be surveyed before commencement. Due to the deep sandy profiles, it is difficult to estimate the area that grade banks and waterways may be installed. Assuming that it is only practical (due to clay depth) to place earthworks in less than 50% of these areas, then an area of 55,629 ha with slopes between 0 and 10% might be available. The most suitable soil-landscapes for grade banks, absorption banks and waterways are Classes 1 and 2 making 42,500 ha suitable for earthworks subject to survey.

The most suitable soil-landscapes for drains are Classes 1, 2 and 3.

Areas of Classes 4, 5 and 6 that have less than 1% fall may benefit from shallow relief drains to alleviate waterlogging. While these deep sandy soils are highly permeable, if they are saturated and subject to ponding, crops will benefit from drainage.

The areas suitable for shallow relief drains and raised beds cannot be determined using Table 4.4.1, however 21,465 ha that have less than 1% slope and are subject to waterlogging would benefit from surface drainage and may increase production from raised bed cropping.

Structures with no land slope criteria (refer to Table 4.4.2) would need site-specific land assessment to determine their suitability. Based on slopes, 157 ha or 0.2% is unsuitable for banks and drains, i.e. >10%, and 107 ha or 68% of this falls within the Class 5 soil-landscape, which represents steeper undulating rises in the Stirling Range soil-landscape unit.

Earthworks require careful planning because inappropriate and poor designs can cause more degradation than what the structure was intended to alleviate. Suitably qualified people need to be consulted for the legal aspects, design and construction of earthworks. The following points need to be addressed in surface water earthwork planning:

- **Land assessment;** information on soil condition, vegetation cover, catchment area, annual average rainfall and slope is used to calculate maximum flows, safe grades and safe velocity. http://www.agric.wa.gov.au/progserv/natural/assess/index.htm
- **The annual recurrence interval (ARI);** is the frequency an earthwork is designed to fill or safely fail. Important earthworks, such as dams, waterways and absorption banks are designed for at least a 20-year ARI. The minimum design of most drains and banks is a 10-year ARI (Bligh 1989).
- **Legal aspects;** there are legal aspects that must be considered before earthworks are constructed. Diversion of flows, increasing flow velocities or increasing quantity of flow, could cause damage to neighbouring properties for which the drainage proponent may be responsible (Keen 1998). Catchment planning and discussing planned earthworks with potentially affected neighbours is recommended.

After defining the problem and carrying out land assessment, the type and design of earthwork to construct is selected. The design criterion for earthworks commonly used in Western Australia is listed in Table 4.4.1. Earthworks alone cannot halt the rising watertable and need to be used in conjunction with other Conservation farming strategies. For more information visit
www.agric.wa.gov.au/environment/land/drainwise/options/index.htm

Table 4.4.1. Design criteria for common earthworks used in Western Australia

Earthwork design	Land slope (%)	Soil type	Grade (%)	Landscape position
Grade bank	Up to 10	SD / L	0.2-0.5	Upper & mid-slope
Seepage interception bank	Up to 10	SD / DD / S		Lower & mid-slope
Absorption and level banks	Up to 10	SD / L	0	Breakaways & upper-slope
Broad-based banks	2-6	SD / L	0.15-0.3	Upper, mid & lower-slope
Shallow relief drains	Up to 0.2	C / SD	Up to 0.2	Valley floor
Levee waterways	Up to 10	C / S / DD / SD	Up to 10	Valley floors and hillslope
Raised bed	0.1-2		0.1-2	
Evaporation ponds	Site-specific		0	
Dams	Up to 10	C / SD / DD / L	Up to 10	Not in valley watercourse
Roaded catchment	Up to 6%	C / SD	Up to 6%	Good clay required close to surface

* Further information about all of the above structures can be found out by an on-line search through the following web page. **www.agric.wa.gov.au/environment/land/drainwise/options/engineering**

**** Key to Soil Groups**	
C: Clay	G: Gravel
S: Sand	SD: Shallow duplex
L: Loam	DD: Deep duplex

Conservation earthworks

Comprehensive information about various conservation earthworks and their placement in the landscape, is available on-line through the Department of Agriculture's Internet site (Table 4.4.3, Figure 4.4.1). Similar information can be sourced through other technical publications.

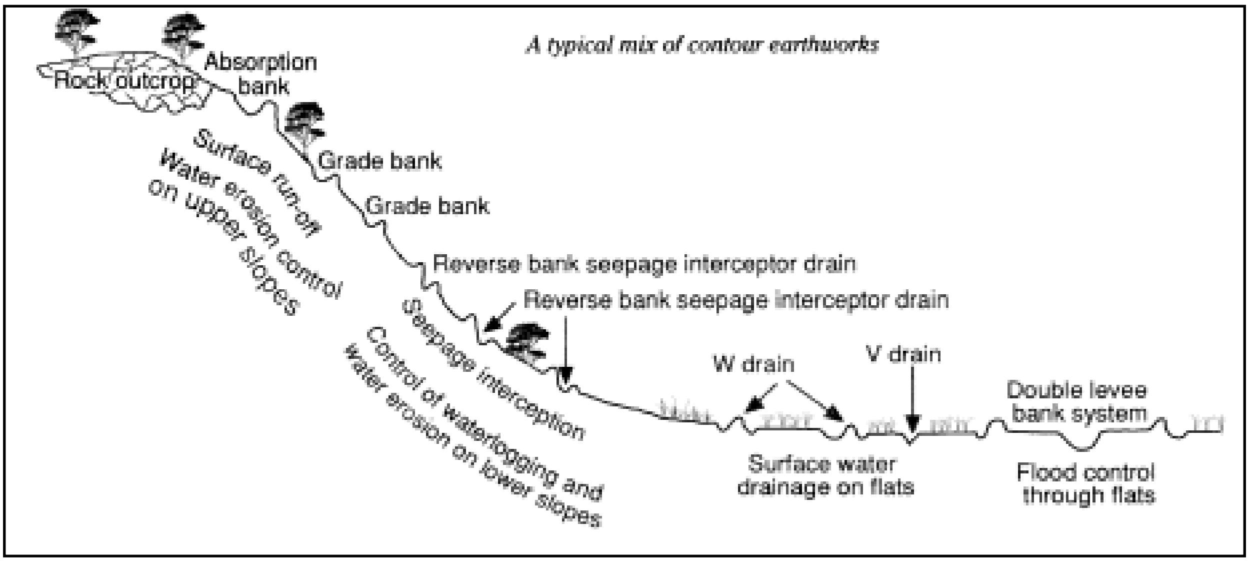


Figure 4.4.1: Schematic representation of some typical contour earthworks (after Negus unpub & Lefroy n.d.)

Table 4.4.2. Web links on design, description and placement of conservation earthworks

Valley floors and lower-slopes	
Shallow relief drains	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Sh_relief.htm
Levee and leveed waterways	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/levees.htm
Raised beds	
Lower to mid-slopes	
Seepage interceptor drain	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/seepge.htm
Mid to upper-slopes	
Diversion and broad-based banks	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Div_bbks.htm
Contour grade banks	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Gr_bnk.htm
Upper-slopes	
Absorption and level banks	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Ab_bank.htm

4.4.4 Other earthworks

Dams
www.agric.wa.gov.au/environment/land/drainwise/options/engineering/dams.htm
No dam site should be selected without drilling for soil suitability.
Roaded catchments
www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Rdd_cmnt.htm
Evaporation basins and ponds
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Evap_Bsns.htm
Evaporation basin design is based on the criterion that no leakage occurs to any groundwater that has an existing beneficial use or a potential beneficial use, nor should there be any overflow to environmental sensitive areas.

4.5 Groundwater management

John Firth and Austin Rogerson, Land Conservation Officers

There are only a few options for managing groundwater before it contributes to waterlogging and salinity. The effectiveness of these options is limited due to the local and intermediate groundwater flow systems that typically have low permeability and gradients and therefore low ability to move groundwater. Table 4.5.1 offers some options that may be suitable in the study area.

Table 4.5.1. Groundwater management options

Open deep drains
Deep drains are used to lower the watertable close to the surface, reducing waterlogging of the topsoil while allowing rainfall to leach salt from the upper profile. Construction of deep drains is a relatively expensive option. Open drains remove land from production and their effectiveness is variable according to soil type. Careful planning and site assessment is required to ensure deep drains are effective. Farmers must notify the Commissioner of Soil Conservation of their intention to construct deep drains at least 90 days before undertaking the earthworks.
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/deep_drains.htm
Groundwater pumping
Pumping is most often used to protect sites in recovery catchments (nature conservation), rural towns and other areas where high value assets are at imminent risk. Groundwater pumping is most effective in permeable aquifer systems. These include deep sandy profiles, thick saprock over basement rocks with coarse material and in some geological faults and shear zones. The Commissioner of Soil Conservation must be notified at least 90 days before undertaking groundwater pumping with associated earthworks.
Farmnote 20/2001 Agriculture Western Australia.
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Gwtr_pump.htm

Relief wells (artesian bores)
A relief well is a 'free flowing' groundwater bore driven by artesian pressure. When planning to install relief wells, a notice of intent (NOI) is required to be submitted to the Office of the Commissioner for Soil and Land Conservation at least 90 days prior to installation.
Farmnote 42/2001 Department of Agriculture Western Australia.
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Rlf_wells.htm
Legislation: Notice of intent to drain or pump
Management of surface and sub-surface water through constructed drainage is recognised, as one of the legitimate tools available to fighting salinity, waterlogging and inundation, although increased use of water through vegetation or farming systems remains the preferred option. Regulations established under the Soil and Land Conservation Act require that, 'When an owner or occupier of land proposes to drain or pump water from under the land surface because of salinity of the land or water and to discharge that water onto other land, into other water or into a watercourse, the owner or occupier shall, at least 90 days before the draining or pumping commences, notify the Commissioner in writing inn the manner set forth in Form 2 Schedule 2' Landholders need to understand that they have a duty of care to ensure their management actions do not lead to land degradation. A penalty will apply to the owner or occupier who fails to notify the commissioner.
http://www.agric.wa.gov.au/environment/land/drainwise/legal/index.htm

4.6 Salt-affected agricultural land

4.6.1 Management of salt-affected agricultural land

Western Australia has about 2 million hectares of salt-affected and variably waterlogged land. If nothing is done, this area is predicted to reach 3 million ha by around 2020, before rising to more than 6 million ha when groundwater equilibrium is reached.

The level of intervention required to substantially reduce the rate of rise in watertables (and related extent of salinity) is significant. New farming systems need to be developed, demonstrated and adopted. In the interim recharge will continue and salinity will inevitably expand.

Some of this land can be productive, some not, but all needs to be managed to minimise on-site erosion and off-site impacts such as sedimentation and flooding.

Not all saltland is the same. Based on plant growth responses, saltland can be divided into three general capability classes with respect to their productive potential.

- <u>Land of 'low' productive potential</u>. This category dominated by clays and shallow duplex soils of the valley floors, especially in areas less than 600 mm/yr. This land is subject to regular inundation, waterlogging and/or high concentrations of salt in the soil profile. Sodic subsoils in many areas reduces the opportunity for drainage and related sub-soil conditions restrict plant growth. The soils will be bare, support self-sown samphire (*Halosarcia spp*.) or contain a patchy cover of highly salt-tolerant annual grasses and forbs. These soils may be planted to halophytic forage shrubs like saltbushes (*Atriplex sp*), however their productivity (leaf production) will be low (mostly less than 0.5 tonnes per hectare per annum). Planting and other interventions (e.g. engineering) on these sites are likely to be uneconomic. These sites should be stabilised by controlling grazing and allowed to regenerate naturally.

- <u>Land of 'moderate' productive potential</u>. This category dominated by deeper duplex and 'morrel' soils and supporting patchy stands of barley grass. Extreme salt accumulation in the root-zone may occur in clayey B-horizons, but not in the more leachable A-horizons. These areas may grow trees for several years; however it is expected that they will either die (or grow poorly) in the longer term (approx. 5-20 years) because of the irreversible accumulation of salt in the deeper root-zones. These sites are most suited to the growth of saltland pastures. In the <600 mm rainfall zone, *Atriplex sp*. and *Maireana brevifolia* can be established by niche seeding or the planting of nursery raised seedlings. These plants have value as forages, but more importantly will act to lower watertables when grown in association with annual legumes such as balansa clover. Perennial 'partnerships' or associations of plants such as *Acacia saligna* and tall wheat grass, or puccinellia and a legume on duplex soils, are also likely to be profitable in higher rainfall areas (400-600 mm).

- Land of 'high' productive potential. This category, dominant over the low valley slope areas is characterised by deeper duplex soils carrying thick stands of barley grass with some rye grass but an absence of clovers. Salinity levels are relatively low but the land area is highly susceptible to waterlogging. Further upslope this class may feature a sandplain landscape with related seeps (areas where sands and gravels shelve out onto clays). This land is primarily affected by waterlogging. It will grow a range of moderately salt and waterlogging tolerant trees (*e.g. Eucalyptus camaldulensis*, *E. occidentalis*, *Melaleuca* and *Casuarina* species). Sandplain seeps are also readily reclaimed using strategic tree planting.

The options for management of each of these classes vary with climate. However, a first step in the management of any areas of saltland should be to reduce waterlogging and inundation. Surface water management above the area of saltland using appropriately designed and constructed grade banks will minimise the flow of water onto the area. In some instances it will be necessary to reduce ponding and inundation of the saline area using 'W' drains or spoon drains.

Depending on the value of the saline land and associated assets, some engineering options may be appropriate for the prevention or reclamation of saline land. Engineering may also be used to change the status of an area (improve a moderate to a high 'productive potential' area) to either increase the productivity of saline pasture systems or improve the land to the point of cropping with cereals.

Management recommendations common for all classes of saline land are:
- Fence to control grazing and manage erosion
- Prevent inundation
- Manage waterlogging and encourage leaching
- Ensure maximum plant cover (restrict evaporation and manage soil loss)
- Change land use to a saltland system as soon as salinity is apparent.

These classifications do not take account of the potential for the productive use of saline groundwater or industries that may develop as a result (aquaculture, solar energy through evaporation ponds, etc).

Table 4.6.1 lists some of the generic options available for each saltland category in 400 to 600 mm rainfall zone (i.e. Cranbrook-Toolbrunup area). Costs and benefits are a general guide only and will vary between farm businesses and current costs and prices.

Table 4.6.1. Options for managing salt-affected land in the 600-400 mm rainfall zone

Category	***Options***	***Costs and benefits***	***Comment***
Low	Fence, control surface water and let regenerate naturally.	Cost of fencing. Some minor direct economic benefit in long term.	Exclusion of stock, regeneration, reduce erosion, use water and provide wildlife habitat, amenity.
	Establish to 'low input' saltbush/bluebush or similar (no legumes possible).	Establishment costs (excluding fencing and water supplies) of $100-150 /ha. Production likely to be low (~ 1 t/ha/yr) and uneconomic.	Opportunistic grazing; Reduced erosion, some increased water use, some wildlife habitat and improved appearance.
Moderate	Control surface water (run-on) to improve site conditions and reduce waterlogging and inundation (on-site).	<$100 /ha, benefits from improved productivity (below).	Required to prevent inundation and excess waterlogging.
	Establish saltland pastures (saltbush-balansa or bluebush systems if not waterlogged).	Establishment cost of $100-150/ha (not including water supplies and fencing); benefits from meat/wool income; deferred grazing. Return variable but may be $30-75 /ha.	
	Revegetation of *Eucalyptus* (e.g. oil mallee), *Casuarina*, *Melaleuca*, and related species.	Establishment costs could be >$500/ha, Benefits (oil mallees, melaleucas) from oil and associated products; few if any timber products, seed; unlikely to be productive (short term).	Break-even option included sale of timber, added grazing. Very few businesses using these options at present (long term; high risk).
	Groundwater drainage options.	Installation costs >$1000 /ha. Benefits dependant on salt leaching and extent of watertable lowering.	Most applicable in highly permeable soils and high value assets at risk. Safe disposal required.
High	Install permanent raised beds and crop with barley and oats.	$1000 /ha; increase crop yields.	Gives a cropping option. The fate of raised beds in a grazing situation not yet clear.
	Sandplain and related seeps can be reclaimed using strategic drainage and tree planting.	Up to $500/ha establishment; each ha established can reclaim 5-10 ha.	Salinity of water determines benefits (stock water, tree water use).
	High-risk tree-crops (*E. camaldulensis*, hybrids), others.	$1000/ha establishment. Longer term tree crops for specialty timbers or fibre	Increased salinity over time, distance, markets.
	Groundwater drainage options.	$1000+/ha to install. Benefits depend on salt leaching and extent of watertable lowering.	Most applicable in highly permeable soils and high value assets at risk. Safe disposal required.

4.6.2 Additional perennial recommendations for saline land

Lisa Crossing, Hydrologist, Department Agriculture, Albany

Table 4.5.2. Other options for salinised agricultural land in the Cranbrook-Toolbrunup area (after Malcolm and Swaan 1989)

Species	Tolerances	Attributes
River saltbush	Highly salt-tolerant, drought tolerant, moderately waterlogging tolerant. Has good long-term survival.	Good long-term survival. Palatable and recovers from grazing. Lowers shallow watertables. May be difficult to establish from seed.
Small leaf bluebush *(Maireana brevifolia)*	Well-drained slightly to moderately saline soils. Does not tolerate waterlogging.	Palatable and recovers from grazing. Contains oxalate – may need to be fed with hay. Volunteers readily.
Samphire *(Halosarcia* species)	Highly tolerant to salt and waterlogging.	Volunteers readily. Recovers from grazing. High salt content.
Wavy leaf saltbush *(Atriplex undulata)*	Highly salt-tolerant, moderately waterlogging tolerant.	Good long-term survival. Harvestable seed. Recovers from grazing. Susceptible to fungal attack.
Quailbush *(Atriplex lentiformis)*	Highly salt-tolerant, moderately waterlogging tolerant.	Gives good early growth. Provides good shelter. Does not persist.
Old man saltbush (*Atriplex nummularia*)	Highly salt-tolerant, lower tolerance to waterlogging than river saltbush.	Good long-term survival. Low recruitment. Low palatability.
Grey saltbush (*Atriplex ciliata*)	Highly salt-tolerant, moderately waterlogging tolerant.	Has an erect and prostrate form. Palatability varies. Does not persist.
Puccinellia (*Puccinellia ciliata*)	Tolerant of salt and waterlogging.	Palatable, recovers well from grazing. Responsive to N and P fertilisers.
Tall wheat grass (*Thinopyrum elongatum*)	Less tolerant than puccinellia to salt. Tolerates alkaline soils and moderate waterlogging.	Moderately palatable. Needs heavy rotational grazing. Responsive to N and P fertilisers.
Balansa clover (*Trifolium michelianum*)	Highly tolerant to waterlogging, tolerant to low salinity.	Very high feed value. Can grow as under-storey to saltbush. Responsive to P fertilisers. New short-season cultivars 'Frontier' suited to drier locations.

5. Further information and contacts

Kelly Hill, Coordinator, Social Impacts of Salinity, Cranbrook

The following section is a link to further contacts and supporting details. It can be used to assist with decisions and implementation options, as it contains details such as telephone numbers and addresses for local contacts, along with useful (and reliable) website addresses.

The following pages have been grouped into four categories, for easier access:

5.1 Farming systems contacts
5.2 Funding opportunities
5.3 Useful community contacts
5.4 Useful agricultural internet sites.

Much of the information presented here, are possible first points of contact to further the details already presented within this report. One other useful source of current and relevant information, such as Farmnotes, is the Department of Agriculture's website: www.agric.wa.gov.au/agency/Pubns

In particular, the site at www.agric.wa.gov.au/environment/ contains details on environmental management in Western Australia, but more importantly, the link to the Rapid Catchment Appraisal (RCA) page and its associated information.

5.1 Farming systems contacts

		Contacts	***Publications / Websites***
Cropping options	**Lower recharge farming systems**	Western Australian Lucerne Growers' Inc C/- Department of Agriculture Katanning 9821 3333	**Farmnote 135/2000** 'Lucerne in Pasture-crop rotations - Establishment and Management.
		Western Australian No-Tillage Farmers' Association (Inc) Ph/fax: 9622 3395 Mobile: 0427 223 395	www.wantfa.com.au
		Department of Agriculture Farming Systems Development Officers Katanning 9821 3333 Albany 9892 8444 Jerramungup 9835 1177	Department of Agric. 'Low recharge farming systems: Case studies on the South Coast.' Misc. Pub. 22/2000.
	Warm season crops	Western Australian Lucerne Growers' Inc C/- Department of Agriculture Katanning 9821 3333	**Farmnote 135/2000** 'Lucerne in pasture-crop rotations - establishment and management.
		Western Australian No-Tillage Farmers' Association (Inc) Ph/fax: 9622 3395 Mobile: 0427 223 395	www.wantfa.com.au
		Department of Agriculture Katanning 9821 3333 Albany 9892 8444 Jerramungup 9835 1177	
Pasture options	**Lucerne**	Western Australian Lucerne Growers' Inc C/- Department of Agriculture Katanning 9821 3333	**Farmnote 135/2000** 'Lucerne in pasture-crop rotations - establishment and management.
	Other perennial pastures	Department of Agriculture Katanning 9821 3333 Albany 9892 8444 Jerramungup 9835 1177	Bulletin 4343 'Soil Guide' this book is relevant for all cereal & oil seed crops, alternative grain legumes and perennial / annual pasture systems.
Fodder shrub options	**Tagasaste, Acacia saligna, and Saltbush**	Department of Agriculture Farming Systems Development Officers Katanning 9821 3333 Albany 9892 8444 Jerramungup 9835 1177	Dept of Agriculture Bulletin 4291, 'Tagasaste', 1994 FactSheet 37/2000 'Tagasaste'. The feed value of the perennial fodder shrub tagasaste **Farmnote 50/2000.** Department of Agric. 'Low recharge farming systems: Case studies on the South Coast.' Misc. Pub. 22/2000.

		Contacts	***Publications / Websites***
Commercial farm forestry	**Monterey pine *(Pinus radiata)*** & **Maritime pine *(Pinus pinaster***	*Forest Products Commission (FPC)* Albany 9842 4530 Katanning 9821 7022	www.fpc.wa.gov.au
	Tasmanian blue gum *(Eucalyptus globulus)*	Timber 2002 Albany 9892 8520	www.timber2002.com.au Contains details of all industry stakeholders and contacts.
		Joint venture companies: Bunnings Tree farms 9771 7222 Integrated Tree Cropping 9842 1389	
	Eucalypts for sawlogs	Farm Forestry Development Officer C/- Department of Agriculture Albany 9892 8418	
	Oil mallees	Oil Mallee Association of WA (Inc) 9478 0330	www.oilmallee.com.au
		Dept of Agriculture Narrogin 9881 0222	**Fact sheet 30/2000, 'Eucalyptus Oil Mallees'**
	Carbon credit trading	CALM Plantation Group Como 9334 0463	
Productive use of saline lands	**Saltland plants**	Saltland Pastures Association 9871 2041	Department of Agriculture Bulletin 4312 'Saltland Pastures in Australia: A Practical Guide' by E.G. Barrett-Lennard and C.V. Malcolm
			'Saltland Pastures – Options and constraints' – Michael Lloyd, and 'Saltland Pastures? They are feasible and sustainable – we need a new design' – E.G. Barrett-Lennard and M. Ewing. Papers from the 5th National PURSL Conference Tamworth NSW, Australia 9-13 March 1998.
Productive use of saline water	**Saline aquaculture: Rainbow trout**	Fisheries Western Australia Albany 9841 7766	www.wa.gov.au/westfish
	Black bream	Fisheries Western Australia Albany 9841 7766	www.wa.gov.au/westfish
Freshwater aquaculture	**Yabbies and marron**	Fisheries Western Australia Albany 9841 7766	www.wa.gov.au/westfish

		Contacts	Publications / Websites
Native vegetation management & revegetation	**Native vegetation management & revegetation for nature conservation**	Regional Bushcare Facilitators South Coast 9842 4519	CALM Wildlife Notes: 'How to manage your granite outcrops' (CALM) 'How to manage your Wandoo woodland' (CALM) 'Managing your bush land' (CALM) Land for Wildlife's 'Western Wildlife' quarterly magazine 'Managing Dieback in Bush land' (jointly produced by Shire of Kalamunda, Dieback Working Group, NHT, Bushcare and CALM)
		Department of Agriculture Revegetation Development Officers ***Albany*** 9892 8444	
		Land for Wildlife officers ***Alban*** 9842 4500	
		Greening Australia (WA) Bushcare Support Officer ***Tambellup*** 9825 3092	
	Protecting waterways and wetlands	Waterways WA Coordinator and Rivercare Officers Water and Rivers Commission Albany 9842 5760	www.wrc.wa.gov.au
Engineering options	**Surface water management**	Department of Agriculture Land Conservation Officers ***Albany*** 9892 8444 ***Katanning*** 9821 3333 ***Jerramungup*** 9835 1177	Department of Agriculture Technical Report 185: 'Common Conservation Works Used in Western Australia' (Martyn Keen 1998)
	Community landcare technicians	***Broomehill:*** Grant Taylor 9825 3062 ***Denbarker:*** Ross Roberts 9857 6024 ***Denmark:*** Angus MacKenzie 9840 9237 Robert Underwood 9840 9018 ***Jerramungup:*** Trevor Davey 9835 1103 ***Katanning:*** Norma Blyth 9821 1776 Norm Flugge 9822 1505 Tom Haddleton 9822 8037 ***Kojonup:*** Peter Coffey 9833 6268 Jenny Gardner 9831 1576 ***Many Peaks:*** Bill Rochester 9846 1230 ***Ongerup:*** Steve Newby 9828 2023 ***Plantagenet:*** William Press 9845 1247 ***Rocky Gully:*** Bill Waud 9855 1560 ***Wellstead:*** Jeff McTaggart 9847 3003	

	Groundwater management	Department of Agriculture Albany 9892 8444 Katanning 9821 3333 Jerramungup 9835 1177	Dept of Agriculture Bulletin 4391 'An assessment of the Efficacy of Deep Drains Constructed in the Wheatbelt of Western Australia'.
	Groundwater pumping, relief wells & siphons	Department of Agriculture Katanning 9821 3333	'Relief wells in south Western Australia' Farmnote 42/2001.
Soils	**Acid soils, soil structure & water repellence**	Department of Agriculture Soils Officers Albany 9892 8444 Katanning 9821 3333	'Management of soil acidity in agricultural land' Farmnote 80/2000. 'Looking at liming: comparing lime sources' Farmnote 69/2000.
Monitoring and evaluation	**Monitoring & evaluation**	Land Management Society Como 9450 6862	Farm Monitoring Kit – monitoring equipment for all aspects of your farming operations.

5.2 Funding opportunities

South Coast Funding Opportunities	Regional Wetlands Program	Regional Wetlands Program Coordinator C/- Water & Rivers Commission, Albany 9841 0114	Grants of $600 /km for priority wetland fencing (priority of wetlands already determined).
State Funding Opportunities	Coastwest / Coastcare WA	Regional Coastal Facilitator CALM Albany 9842 4500	Funding to encourage coastal protection through research, education, and associated recreation facilities.
	Community Conservation Grants	Community Conservation Grants Coordinator CALM Perth 9442 0300	Funding available for the conservation of flora, fauna and associated activities.
	Fisheries WA – Aquaculture Development	Executive Officer – Aquaculture Development Council, Perth 9482 7333	Funding available in two categories – Aquaculture Industry Development Projects and Marketing, Industry Promotion and Study Tours.
	Fisheries WA - Fishcare	Fishcare Officer, Perth 9482 7204	Funding available for the management of fish resources and their environment – rehabilitation, education & maintenance.
	Lotteries Commission / Gordon Reid Foundation	Executive Officer Gordon Reid Foundation for Conservation Freecall: 1800 655 270	Funding for not-for-profit groups in conserving and restoring indigenous plants, animals and micro-organisms and their natural environment in WA.
	Natural Heritage Trust (NHT)	South Coast NHT Executive Officer Dept of Agriculture Albany 9892 8444	Funding for projects in many areas, including Bushcare, Rivercare, Landcare, farm forestry, fisheries, wetlands, and endangered species, to name a few.

5.3 Useful community contacts

Agricultural Services & Contacts	Department of Agriculture District Offices	Albany 9892 8444 Jerramungup 9835 1177 Katanning 9821 3333	Access to technical information (& staff), library resources, videos, publications and other current information and services provided by the Department.
	Community Agriculture Centres (CACs)	Cranbrook 9826 1306 Denmark 9848 1756 Gnowangerup 9827 1587 Plantagenet 9851 2706	Community centres run and staffed by the Department of Agriculture, which offer all the services and resources of the District Offices.
	Indigenous liaison Officer	Albany 9892 8444	Access to landscape and cultural information associated with indigenous and cultural issues.
	Landcare Centres	Borden Landcare Centre 9828 1086 Gillamii (Cranbrook) 9826 1234 Jerramungup 9835 1127	Centres run by the community, which provide landholders with access to local Natural Resource Management information and services.
	Cropline	Freecall: 1800 068 107	Run by the Dept of Agriculture, 5 days a week – advice on all aspects of cropping systems.
	South Coast Regional Information Centre (SCRIC)	SCRIC Manager C/- Dept of Agriculture Albany 9892 8444 http://www.scric.org	Provision of information about natural resource management across the South Coast. Website offers regional information on news & events, a bulletin board, databases, maps, reports, help & education and links to other useful sites.
Regional Group	South Coast Regional Initiative Planning Team (SCRIPT)	SCRIPT Manager C/- Department of Agriculture Albany 9892 8444 http://www.script.asn.au/	SCRIPT is an independent, open organisation that brings people, organisations and information together so that the regional community drives sustainable management of natural resources with positive social and economic outcomes.
Support Services	Social Impacts of Salinity (SIS)	Social Impacts of Salinity Coordinator Cranbrook 9826 1306	Offers community funding information, regional support contact lists, 'Getting more from your group' workshops & general follow up support after the RCA process.
	Landcare Enterprise Officer (LEO)	Landcare Enterprise Officer Albany 9842 3717 http://www.script.asn.au/	Offers funding information for natural resource management, employment & enterprise development, an online list of funding compendiums, employment & training information and assistance with project development.
	Great Southern Area Consultative Committee (GSACC)	Albany 9842 5800 www.albanyworking.org.au/	GSACC supports initiatives in the Great Southern, by supporting the efforts of business & the community towards sustained economic growth, which maximises employment opportunities & skills development.
	Great Southern Development Commission	Albany 9842 4888 www.gsdc.com.au/	Promotes economic and social development in the Great Southern region of WA.

	Telecentres	Frankland 9855 2310 Jerramungup 9835 4012 Kojonup 9831 0256 Ongerup 9838 1216 Wellstead 9847 2078	Provide facilities for the local community such as photocopiers, **internet access**, faxes, laminators and other office equipment (all with a small fee). Telecentres can also organise community events, as required (such as training workshops).
	Business Enterprise Centres (BECs)	Albany 9841 8477 Jerramungup 9835 1998 Tambellup 9825 1220	Business Enterprise Centres provide information and support to local small businesses including value adding, diversification, training, and business/strategic/marketing plans, to name a few.
Counselling Services	Southern AgCare (Family and Financial Counselling Services)	***Financial*** Chris Wheatcroft (Gnowangerup) 9827 1559 David Poultney (Albany) 9842 2956 ***Family*** Pearl Draper (Gnowangerup) 9824 1036 Dorothy Bailey (Mt Barker) 9854 3045	Provide a free, confidential and mobile service to landholders in: Albany, Plantagenet, Cranbrook, Kojonup, Tambellup, Broomehill, Gnowangerup, Jerramungup, Kent, Katanning, Woodanilling, West Arthur, Wagin, Dumbleyung & Lake Grace.

5.4. Useful agricultural internet sites

Keep in mind when using the Internet, particularly with overseas information, that the Information is relevant to your farming practices. For example, are the chemicals described registered in WA? Are the pests the same? Are the soil types similar?

ABC Countrywide – http://www.abc.net.au/rural/news_states/trannm.htm
This site contains transcripts of the ABC's daily National Rural News program. This site also contains the latest national weather and satellite maps.

AgFax Information Retrieval System –
http://www.agric.wa.gov.au/customer_services/AgFax.htm
The home page of the Dept of Agriculture's AgFax service, which contain instructions on how to use the service.

AGNET – http://agnet.com.au/biglist.html
A list of Australian agricultural sites.

Agriculture, Fisheries and Forestry, Australia (AFFA) http://www.affa.gov.au/

Australian Wheat Board – http://www.awb.com.au/

Bureau of Meteorology (WA) – http://www.bom.gov.au/weather/wa/

CSIRO Land and Water – http://www.clw.csiro.au/

Department of Conservation and Land Management – http://www.calm.wa.gov.au

Fisheries WA – http://www.wa.gov.au/westfish/

Hydrogeological Atlas of WA -
http://www.wa.gov.au/westfish/aqua/broc/groundwater/index.html

Kondinin Group – http://www.kondinin.com.au/

Land and Water Resources Research and Development Corporation –
http://www.lwrrdc.gov.au/

Landcare Australia – http://www.landcareaustralia.com.au/

National Farmers Federation Australia – http://www.nff.org.au/

Natural Heritage Trust (funding program) – http://www.nht.gov.au/funds.html

Rural Industries Research and Development Corporation AgFact sheets –
http://www.rirdc.gov.au/agfacts & http://www.rirdc.gov.au/pub/shortreps/contents.html

State Salinity Council – http://www.salinity.org.au

Water and Rivers Commission – http://www.wrc.wa.gov.au

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6.1 References for alternative perennial pasture species

Lucerne

Farmnote 4/98 'Dryland lucerne – establishment & management'.
Farmnote 53/89 'Insect pests in lucerne'.
Farmnote 79/89 'Diseases and their control in lucerne'.
'Success with dryland lucerne' – contact Crop Monitoring Services 018 838 103.
WA Lucerne Growers Association, C/- Roy Latta, Department of Agriculture Katanning.

Kikuyu

Perennial Pastures, Sudmeyer *et al.* 1994, Bulletin 4253, Department of Agriculture.
Perennial pasture establishment technique, Buchanan *et al.* Esperance LCDC.
Perennial grasses for animal production in the high rainfall areas of WA, Greathead *et al.* 1998, Misc Pub 2/98, Department of Agriculture.
Farmnote No. 11/95 'Kikuyu – the forgotten pasture?'
Farmnote No. 11/98 'Well adapted perennial grasses for the Esperance sandplain'.

Rhodes grass

Perennial Pastures, Sudmeyer *et al.* 1994, Bulletin 4253 Department of Agriculture.
Perennial pasture establishment technique, Buchanan *et al.*, Esperance LCDC.
Farmnote No. 20/99 'Perennial grasses - there role in the Ellen Brook Catchment.'
Farmnote No. 12/98 'Niche perennial grasses for the Esperance sandplain.'

Tall fescue

Perennial Pastures, Sudmeyer *et al.* 1994, Bulletin 4253 Department of Agriculture.
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7. Glossary

Alluvium: Weathered material transported by water.

Alkaline: The soil has an alkaline reaction or pH. The pH measured in dilute solution of calcium chloride is more than 7.0. An alkaline soil alters the availability of some nutrients for plant growth and will affect the growth of certain crops (e.g. narrow-leafed lupins). If a soil is strongly alkaline (pH more than 8.5) it can indicate unfavourable conditions for most plants.

Alley farming: Used to describe farming systems where crops and pastures are grown between alleys of trees and shrubs. The layout can take various forms from straight north-south plantings with narrow areas between trees to widely spaced alleys following the contour of the land (e.g. along a grade bank system).

Aquifer: Water bearing/permeable rock formation; likely rock types are sands, gravels, sandstones, limestone and heavily fractured volcanic and crystalline rocks.

Artesian: An aquifer where the water is under sufficient pressure to flow freely from a bore without pumping; the hydraulic head is above the ground level.

Bedrock: Consolidated rock at the bottom of a profile, underlying soil and regolith material. Bedrock may be exposed at the surface as outcrops. Also referred to as 'basement rock'.

Claying: Adding clay to water repellent soils to improve water entry and retention. Clay particles will coat the non-wetting sand grains and produce a new wetting surface. Those clays that are spontaneously dispersed by rain are the ones to use (for example, kaolinite).

Colluvium: Weathered material transported by gravity.

Discharge: Groundwater flow from an aquifer. Evaporation from a shallow watertable by capillary rise is often referred to as passive or diffuse discharge.

Dolerite: A medium-grained mafic igneous rock, which occurs mainly as dykes, sills or small plugs
Duplex soil: A duplex soil is defined as a soil with a texture or permeability contrast layer within the top 80 cm of the profile.

Dyke: An intrusive body of igneous rock, which cuts across the bedding or structure of the host rock.

Fault: A fracture in the earth where movement has taken place.

Gneissic: A metamorphosed rock that, like granite, contains quartz, feldspars and mica, but in which the grains are organised along bands. Banding is due to recrystalisation during cooling.

Grade banks: A flat-bottomed bank with a grade of 0.5% (10 cm in 20m).

Granitoid: An igneous rock that falls within the granite range.

Hydraulic conductivity: A measure of the ability of a fluid to move through sediment or rock.

In-situ: Description of a material that occurs in the position it was originally formed or deposited in.

Interceptor drains: Constructed with a cut into the clay subsoil to collect subsoil seepage from perched watertables. There are 2 types; conventional interceptors have the spoil downslope whereas reverse interceptors have the spoil upslope.

pH (acidity/alkalinity) pH values taken as a guide only

	pH_{CaCl2}	pH_{water}
strongly acid	<4.5	<5.5
acid	4.5-5.5	5.5-6.5
neutral	5.5-7.5	6.5-8.0
alkaline	>7.5	>8.0

Moisture availability: The amount of moisture in soil that is available to be absorbed by plant roots

Relief: The difference in elevation between the high and low points of a land surface

Subsoil: Layer/s of a soil below the topsoil, which are usually higher in clay and lower in organic matter than the topsoil. Often called the B horizon/s of a profile.

Topsoil: Surface layer/s of a soil, which are usually higher in organic matter (at least at the surface) and lower in clay than the lower layers (subsoil). Often called the A horizon/s of a profile.

Water repellence: A condition that affects the wetting pattern of soils, especially sandy soils, and results in an uneven wetting pattern in autumn. In the paddock, patches of wet soil alternate with patches of dry soil, which results in poor germination of crops and pasture. It is caused by the build-up of organic coatings on the sand grains. A water droplet placed on the surface of a soil can demonstrate water repellence. If a soil is water repellent the water droplet will form a bead and not penetrate quickly.

Appendices

A1. Maps

Three maps are presented inside the back cover of this report.

A1.1. Soil-landscape map for the Cranbrook-Toolbrunup area

The mapping was compiled by field sampling, aerial photograph interpretation (at 1:50,000) and use of Landsat TM and Digital Elevation Models (at 1:100,000) to refine line work. Field sampling was undertaken with an observation density of approximately one site every 1.25 km. The publication scale is 1:150,000.

A1.2. Remnant vegetation through the study area, together with Beard's (1976) vegetation community mapping.

A1.3. Area of low productivity / waterlogging with remnant vegetation on an orthophoto scene covering the Cranbrook-Toolbrunup area.

*A2. Available bore data in the Cranbrook-Toolbrunup catchment. All the C***97 bores were drilled in and around Cranbrook as part of the Rural Towns Program*

Bore Name	Depth Drilled (m)	Last reading	Water level (m)	Salinity EC (mS/m)
C10D97	14	4/02/00	-0.55	3,910
C10I97	11.3	19/07/00	-1.1	3,740
C11D97	15.7	4/02/00	-1.16	2,750
C12S97	4	26/05/00	-1.93	3,720
C13D97	20	19/07/00	-2.36	2,250
C14S97	8	26/05/00	-2.41	2,260
C15D97	11	5/05/00	-1.82	3,310
C16D97	19.5	5/05/00	-1.75	3,590
C17D97	14	19/07/00	-2.63	2,260
C18D97	17	5/05/00	-2.95	1,886
C19D97		4/02/00	-1.77	3,220
C19S97		4/02/00	-1.49	380
C1D97	16.5	26/05/00	-3.63	2,860
C1S97	5	26/05/00	-3.66	224
C3D97	26.1	26/05/00	-2.05	2,020
C4D97	11	22/05/01	-2.78	549
C5S97	3.6	5/05/00	-2.15	436
C6D97	8	26/05/00	-2.86	1,557
C7S97	4	26/05/00	-2.77	796
C8D97	23	4/02/00	-1.18	3,050
C9S97	4	5/05/00	-2.1	2,860
ns10d86	33.1	23/12/88	-4.71	7,636
ns10i86	19	15/06/89	-4.17	7,636
ns10s86	5	15/06/89	-4.29	1,163
NS21D	6.5	1/01/00	-4.9	
NS22D	11.2	10/07/00	-3.9	

A3. Land Monitor data and methods

The Land Monitor Project covers the entire south-west agricultural area. Its products include:

- Maps of salt-affected/low productivity land and its change
- Predictions of areas at risk of high watertables
- Maps of perennial vegetation changes over time

The two main data sources are:

- Landsat satellite images collected from 1988 to 2000 (the sequence of images provides the history for monitoring changes)
- A new and accurate Digital Elevation Model (DEM) which provides data on the height of the land at every location in the region

Ground information on salinity, salinity risk and vegetation condition is also used for training and accuracy checking. A range of people, including hydrologists from the RCA program, provides this information.

Landsat images are collected by a satellite sensor every 16 days. The images record reflected energy from each 'pixel' on the ground. The sensor records visible and infrared reflected energy as digital images.

About Landsat images:	
How frequent?	: Every 16 days
Where?	: Everywhere
Pixel size?	: 30 m by 30 m (approximately 0.1 ha)
Data?	: Digital reflected energy in six channels [Three visible (blue, green, red), three Infrared

In a single image, different land cover types (e.g. bush, pasture) have different reflected signals; differences in condition (e.g. productivity, vegetation density) also affect the signal. The data can be displayed as a picture to highlight these differences. In particular, images from the spring growing season show productivity variations, and images from summer show variation in perennial vegetation type and density.

Changes in land cover and condition can be detected with careful processing of a sequence of images.

Landsat data *do not* measure salt concentrations in the soil directly, and do not see beneath the soil.

Land Monitor uses a series of spring images and the DEM to map 'salt-affected /low-productivity' land. The image data are processed using sample 'ground truth maps' of saline and non-saline land, to produce maps of similar cover types as seen by the sensor. This information is combined with landscape position, and the sequence of years is used to remove transient low-productivity areas resulting from management. Salt-affected areas generally show consistently low productivity over time and are in relatively low-lying parts of the landscape. Landscape position data is produced by mathematical processing of the DEM, and is used with the image data.

Saline land, which is well covered and appears productive in some years, may be missed. Non-saline areas of consistent low productivity may be erroneously mapped as salt-affected. In addition, small or narrow saline areas may be missed, particularly if they are covered with remnant vegetation.

An accuracy assessment is carried out to provide and estimate of the ‘error rate’ in the maps. The accuracy assessment involves an independent check on the ground for the true salinity status of a large number of points on the map. These are conducted in at least two areas within each processed scene. Typical accuracies of detection of salinity for Land Monitor maps are in the range of 75-90% by area.

By processing a whole sequence of Landsat Images, a sequence of ‘salt-affected/low-productivity maps is produced which can be compared to produce a map of change over time.

How is the areas-at-risk map produced?

The risk map is ‘trained’ using sample risk areas provided by hydrologists. These are only available for small areas within the region. The Land Monitor data (from the DEM and Landsat) are then mathematically processed to match the expert’s maps as accurately as possible. The results are then assessed for accuracy in comparison with independent predictions by hydrologists.

Factors which affect risk of high watertables and for which data are available:

- Relative landform position (a number variables derived from the DEM are used)
- Land cover (e.g. % clearing) derived from Landsat

Note that none of the variables measures the depth to watertable. All DEM variables are derived from the land surface shape given by the DEM. Many are derived from water-accumulation models, which calculate the ‘catchment’ or ‘upslope area’ for every point.

The ‘height-above-flow path’ variable can be used to assess degree of risk within the at-risk area. The ‘flow paths’ are not creeklines as traditionally mapped; they are features with a large upslope area, which include actual creeks. They are identified from the DEM processing by thresholding the water accumulation variable at a high value. Once these features are defined, the height-above is simply a vertical elevation from the flow paths (again done using the smoothed DEM), which defines an area on the ground.

More information on Land Monitor methods and results

More complete information on the methods, results and accuracy for different areas can be found on the website: http://www.landmonitor.wa.gov.au

The report ‘collecting ground truth data for salinity mapping and monitoring’ contains a full description of the salinity mapping process, including ground data.

A4. Brief description of the HARRT model for hydrograph analysis

By 1994, an estimated 1.8 million hectares of cleared land in Western Australia was affected by secondary dryland salinity to some extent, representing 9.4 per cent of agricultural land in the State. It was estimated that this area was likely to double in the coming 20 years (to around 3.3 million ha) and may double again before a new equilibrium is reached.

The cause of this salinity is excessive recharge under traditional dryland (non-irrigated) agriculture, leading to rising levels of naturally saline groundwater. As water levels come close to the soil surface, saline groundwater will discharge causing soil salinity and contaminating water resources. The rate of rise is not always consistent and increases during years with above average rainfall.

Monitoring changes in groundwater levels in response to management practices is helpful in indicating the degree of threat faced, and the necessary timing and scale of preventative treatments. It can also indicate the impacts of treatments implemented to reduce the rate of groundwater rise.

Hydrologists in the Department of Agriculture have developed a new approach called HARTT (Hydrograph Analysis: Rainfall and Time Trends). The method can differentiate between the effect of rainfall fluctuations and the underlying trend of groundwater levels over time. Rainfall is represented as an accumulation of deviations from average rainfall. Figure A5.1 is an illustrative example of Accumulative Monthly Residual Rainfall (AMRR). The AMRR is the difference between accumulative actual monthly rainfall and accumulative mean monthly rainfall.

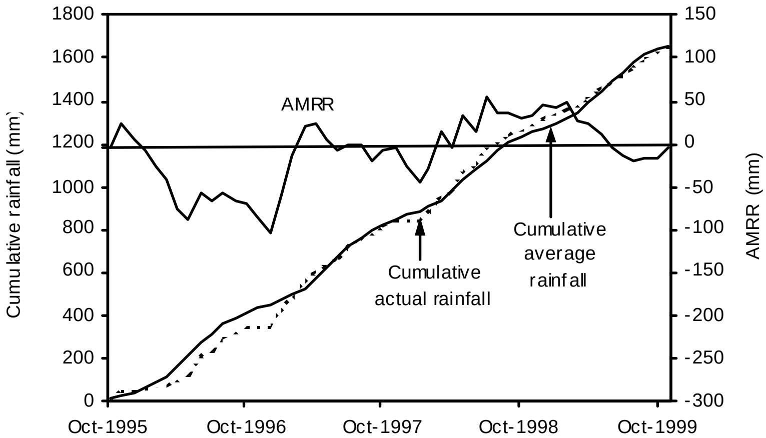

Figure A5.1. Example of accumulative monthly residual rainfall (AMRR)

The simplest version of the model to explain groundwater level changes was:

$$\mathbf{Depth}_t = k_0 + k_1 \times \mathbf{AMRR}_{t-L} + k_2 \times t$$

Where '**Depth**' is depth of groundwater below the ground surface, ***t*** is months since observations commenced, ***L*** is length of time lag (in months) between rainfall and its impact on groundwater, and k_0, k_1 and k_2 are parameters to be estimated. Parameter k_0 is approximately equal to the initial depth to groundwater, k_1 represents the impact of above- or below-average rainfall on the groundwater level, and $\boldsymbol{k_2}$ is the trend rate of groundwater rise or fall over time.

The new method for statistical modelling of hydrographs has some considerable strength. The HARTT method is simple to apply with standard regression methods. It provides high quality fits to observed data. It allows the separation of unusual rainfall events from the underlying time trend. Results are highly consistent with hydrological expectations.

For more information contact Ruhi Ferdowsian, Department of Agriculture, Albany, (08) 9892 8423.

A5. Vegetation types and estimated proportions of the catchment prior to clearing

Beard's vegetation association	Total pre-European (clearing) area (ha)	Percentage of total area (%)
e15,27Si: Shrubland; mallee scrub, *Eucalyptus eremophila* & black marlock (*E. redunca*)	52	0.06
e2,3,5Mi: Medium woodland; jarrah, marri & wandoo	4,848	5.96
e26SZc: Shrubland; tallerack mallee-heath	1,567	1.93
e27Si: Shrubland; mallee scrub, black marlock	7,780	9.56
e2Li: Low woodland; jarrah	8	0.01
e2SZc: Shrubland; jarrah mallee-heath	5	0.01
e5,6,7Mi: Medium woodland; wandoo, York gum & yate	6,269	7.70
e5,7,18Mi: Medium woodland; wandoo, yate & river gum	7,486	9.19
e5,7Mi: Medium woodland; wandoo & yate	42,866	52.65
e5Mr/xZc: Mosaic, medium open woodland; wandoo / Shrubland; mixed heath	5,406	6.64
e6,7,8Mi: Medium woodland; York gum, yate & salmon gum	220	0.27
e7Mi: Medium woodland; yate	813	1.00
e8,9Mi/e15,27Si: Mosaic, medium woodland; salmon gum & morrel / Shrubland; mallee scrub eucalypt	969	1.19
fl: Bare areas; freshwater lakes	81	0.10
mLi: Low woodland; paperbark (*Melaleuca* sp.).	1,123	1.38
mLi k3Ci: Succulent steppe with low woodland; myoporum over samphire	521	0.64
sl: Bare areas; salt lakes	1,401	1.72