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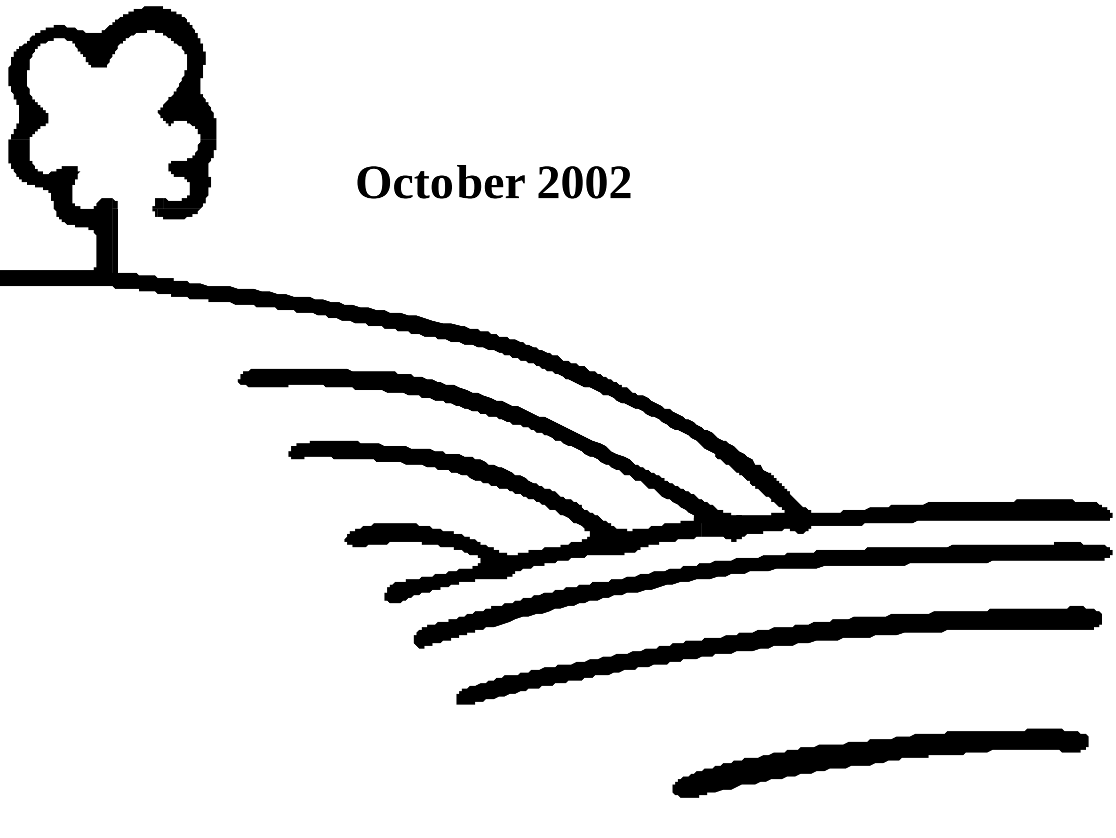
Phillips Brook catchment appraisal

Paul D. Galloway

Department of Agriculture
Government of Western Australia

PHILLIPS BROOK CATCHMENT APPRAISAL

Editor: Paul Galloway



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Edited by Paul Galloway

for the Central Agricultural Region RCA team

October 2002

Summary

This report describes the soils, hydrology and natural vegetation of the Phillips Brook catchment and provides information on the threats to agriculture, infrastructure and natural resources from salinity, waterlogging, erosion and other land degradation processes.

The 13,303 hectare catchment in the western wheatbelt near Toodyay drains into the Avon River, which becomes the Swan River before flowing into the Indian Ocean. The climate is Mediterranean with cool wet winters and hot dry summers and an annual rainfall of approximately 520 mm.

The agricultural systems are primarily broad-acre with winter cropping and livestock the main industries. Crops include wheat, barley, lupins, oats and canola, and the livestock focus is primarily on wool and prime lamb production. Crop rotations and production mix vary between farms depending on soil types, capital structure and expertise in the business.

Soils and landscapes are variable, with ironstone gravels, deep sandy duplexes, deep loamy duplexes and rocky and stony soils comprising 69% of the catchment. Major soil degradation issues are erosion, acidification, compaction and structural decline.

Salinity currently affects less than 0.1% of the catchment (40 ha), but about 9% (1,200 ha) could be threatened by shallow watertables if they rise as in other catchments. However, little is known about the depth to groundwater and its rate of rise, so monitoring with bores is recommended.

Water erosion and waterlogging present risks to the catchment that can be controlled by constructing well-planned and designed earthworks. Grade banks on sloping land are an important tool to manage surface water, which should be treated as a resource and used on-farm. Safe disposal of surface water to waterways should be considered a secondary alternative.

The catchment has a high proportion of remnant vegetation – approximately 4,300 ha (32%) – mostly in public reserves. About 420 ha (10%) of remnants remain on private land, but 65% of these are degraded. Shallow watertables could affect about 410 ha of the remaining remnant vegetation in the future. Maintaining, enhancing and expanding remnant vegetation are expected to deliver biodiversity, landscape and farming systems benefits, although these are unquantified.

Parts of the catchment are highly subdivided, so conservation works may need to be integrated across title boundaries with the cooperation of landholders. Soil and land conservation works should be considered before further subdivision occurs, as planning becomes more difficult with increased subdivision.

Contents

1. Introduction

Rapid Catchment Appraisal (RCA) is included in the State Salinity Strategy (2000) to document salinity risk and to manage that risk where possible. It aims to do this by addressing all threats to the natural resource base, rather than isolating salinity as a separate issue.

This report summarises current information on risks and impacts to agricultural production and natural resources within the Phillips Brook catchment. It also identifies suitable options to manage such risks. Land managers are urged to use this report as a starting point and to gather further information and support from the sources listed in the report.

The Department of Agriculture team responsible for implementing the RCA process and this report comprised:

- Shelley Cooper (Development Officer, Landcare, Northam)
- Don Cummins (Project Manager, Northam)
- Sacha Fielden (GIS Research Officer, Northam)
- Paul Galloway (Soil Research Officer, Narrogin)
- Shahzad Ghauri (Groundwater Hydrologist, Northam)
- Alex Hollick (Development Officer, Revegetation, Narrogin)
- Trevor Lacey (Development Officer, Farming Systems, Northam)
- Harry Lauk (Land Conservation Officer, Northam)
- Keith Ohlsen (Development Officer, Economics, Merredin)
- Josh Smith (GIS Administrator, Northam)
- Ian Wardell-Johnson (Land Conservation Officer, Narrogin)
- Tilwin Westrup (Development Officer, Narrogin)

Other who assisted in the production of this report were Ned Crossley, Research Hydrologist and Dr Bill Verboom, Soil Research Officer, both at Narrogin.

2. Natural resource base

2.1 Catchment description

The catchment occupies 13,303 hectares of the Shire of Toodyay, in the west of the central wheatbelt of Western Australia, north and west of the town of Toodyay. The catchment is most easily accessed from Toodyay via the Bindi Bindi-Toodyay Road and then the Bindoon-Dewars Pool Rd, which traverses the catchment east-west.

Phillips Brook flows into the Toodyay Brook at the bottom of the catchment, in the east. This ultimately flows into the Indian Ocean via the Avon and Swan Rivers.

The catchment is bounded by the latitudes of -31:33:58 and -31:23:41(S) and longitudes 116:29:21 and 116:20:29 (E) and shown in Figure 2.1.

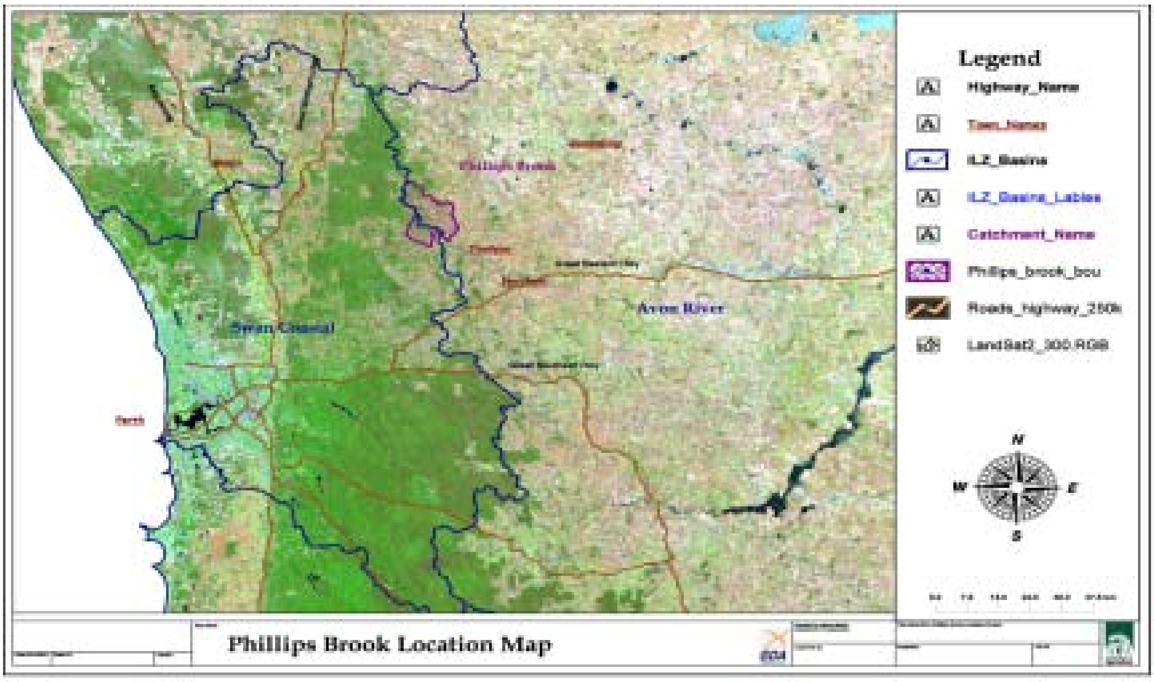

Figure 2.1. Catchment location

Approximately 92% of the catchment is privately owned and CALM manages the remaining 8% (largely jarrah-marri forest). There are many small lifestyle blocks in the west of the catchment and the east is dominated by traditional farming lots.

2.2 Climate

Tilwin Westrup

The catchment has a Mediterranean climate with hot dry summers (Figure 2.2) and mild wet winters (Figure 2.3). On average, 430 mm of the annual total of 520 mm falls during the growing season. Moisture deficit over summer limits the growing season for traditional annual agriculture to between May and September (Figure 2.4). Summer thunderstorms can cause intense rain in some years.

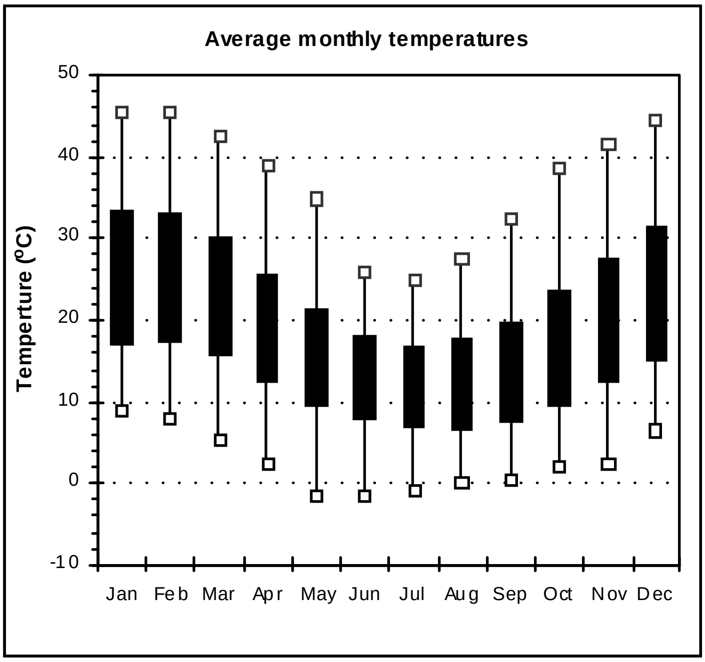

Figure 2.2. Monthly temperature ranges for the Phillips Brook catchment
(The bars represent the monthly average range for daily temperatures and the lines represent recorded monthly absolute minima and maxima)

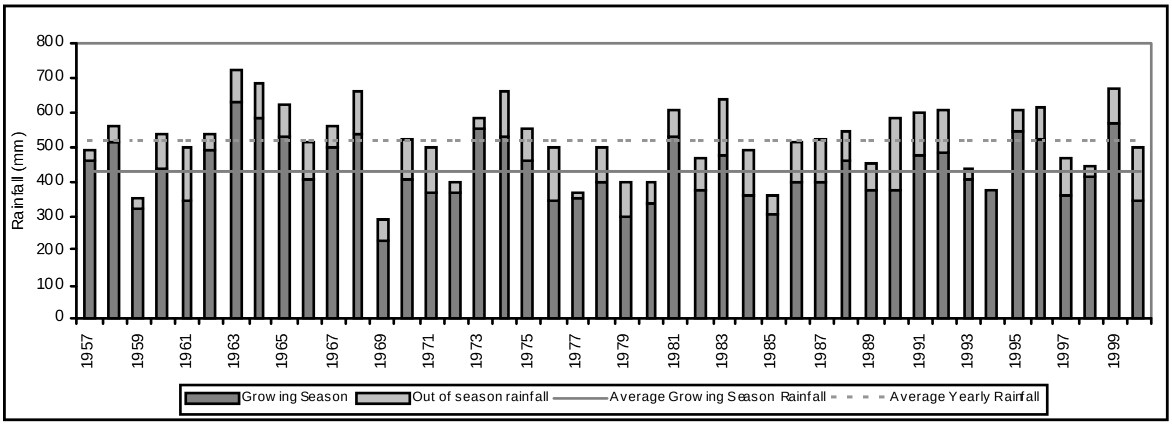

Figure 2.3. Annual rainfall patterns

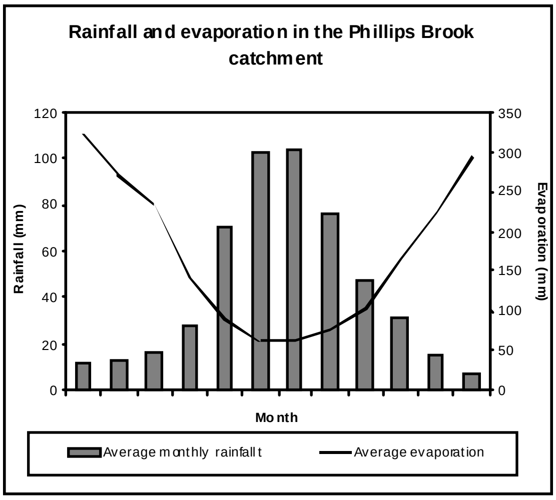

Figure 2.4. Monthly rainfall and evaporation

2.3 Geology

Shahzad Ghauri and Paul Galloway

Phillips Brook catchment is located on the Yilgarn Craton, which formed over several hundred million years during the Archean eon, more than 2,500 million years ago. It is a remnant of continental crust from a major land-forming period and it forms the nucleus from which the rest of Australia grew.

The catchment lies on the western edge of the Jimperding Metamorphic Belt, which contains ancient sediments that have been altered by pressure and heat. The metamorphic rocks of the catchment are primarily migmatites and gneisses (Wilde & Low 1978) that generally weather faster than surrounding rocks and hence are often found in valleys or eroded gullies.

Numerous dolerite and diorite dykes form linear features composed of dark-coloured, mostly fine-grained rocks and display a general northerly trend. These often cross the catchment's main flow direction and can form barriers to groundwater movement.

Physical, biological and geo-chemical processes differentially weather the minerals and fabric of the underlying geology. These processes alter hard rock to soft weathered and transported materials, known as 'regolith'. Regolith is usually thickest where rock is deeply weathered and sediments accumulate, such as in valleys.

Dominating features of the landscapes are laterites and ironstone gravels. These were once thought to have formed due to geo-chemical processes but are now believed to have formed because of south-western Australia's stable climate, geology and unique vegetation. Climate has remained relatively stable for the past 40 million years because continental drift from the cooler southern latitudes towards the equator compensated for global cooling (see the Paleo-Map Project on website www.scotese.com for details). The stable climate has favoured vegetation that secretes compounds that mobilise iron and other metals. Soil biota use these compounds and then accumulate iron, aluminium and other metallic elements in the rooting zone, thus forming laterites and ironstone gravels (Verboom and Galloway 2000, Pate *et al*. 2001).

The landscapes we see today result from differential erosion and weathering, which has left undulating landforms including rock outcrop, soil overlying unweathered rock, soil overlying weathered regolith and lateritic residuals (mesas). Valley alluvia have been deposited from slopes, and soil has formed on these materials.

2.4 Soils

Paul Galloway

The major soil types are ironstone gravelly soils (36% of the catchment), deep sandy duplexes (15%), rocky or stony soils (9%) and deep loamy duplexes (9%). Eleven other soil types have been identified but occur over small areas. The seven main soils comprising 85% of the catchment, are described in more detail in Table 2.1 (see Schoknecht 2002, for further details).

Table 2.1. Major soil types and areas*

Soil Supergroup	Description	Soil group components
Ironstone gravelly soils 4,880 ha 36% of catchment	Soils that have an ironstone gravel layer (>20% and greater than 20 cm thick) or duricrust/cemented gravels within the top 25 cm, and ironstone gravels are a dominant feature	Deep sandy gravel (19%) Loamy gravel (9%) Duplex sandy gravel (7%) Shallow gravel (2%)
Deep sandy duplexes 2,010 ha 15% of catchment	Soils with a sandy surface and a texture or permeability contrast at 30 to 80 cm	Red deep sandy duplex (8%) Grey deep sandy duplex (7%) Alkaline grey deep sandy duplex (<1%)
Rocky or stony soils 1,220 ha 9% of catchment	Soils, generally shallow, with more than 50% of coarse fragments >20 mm in size throughout the profile. Includes areas of rock outcrop	Bare rock (9%) Stony soil (<1%)
Deep loamy duplexes 1,150 ha 9% of catchment	Soils with a loamy surface and a texture contrast at 30 to 80 cm	Red deep loamy duplex (9%) Brown deep loamy duplex (<1%)
Shallow sands 820 ha 6% of catchment	Sands less than 80 cm deep over rock, hardpan or other cemented layer	Yellow/brown shallow sand (3%) Pale shallow sand (2%) Red shallow sand (1%)
Non-cracking clays 650 ha 5% of catchment	Soils that have a clay surface at least 30 cm thick and do not crack strongly when dry	Red/brown non-cracking clay (4%) Grey non-cracking clay (<1%)
Cracking clays 600 ha 5% of catchment	Soils that have a clay surface at least 30 cm thick and crack strongly when dry	Self-mulching cracking clay (5%)

* Some rounding errors may occur in individual totals

2.5 Hydrogeology

Shahzad Ghauri, Ned Crossley and Paul Galloway

2.5.1 Aquifers

An aquifer is a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients (Freeze and Cherry 1979). The main forms present are unconfined, semi-confined, and fractured rock aquifers (Figure 2.5).

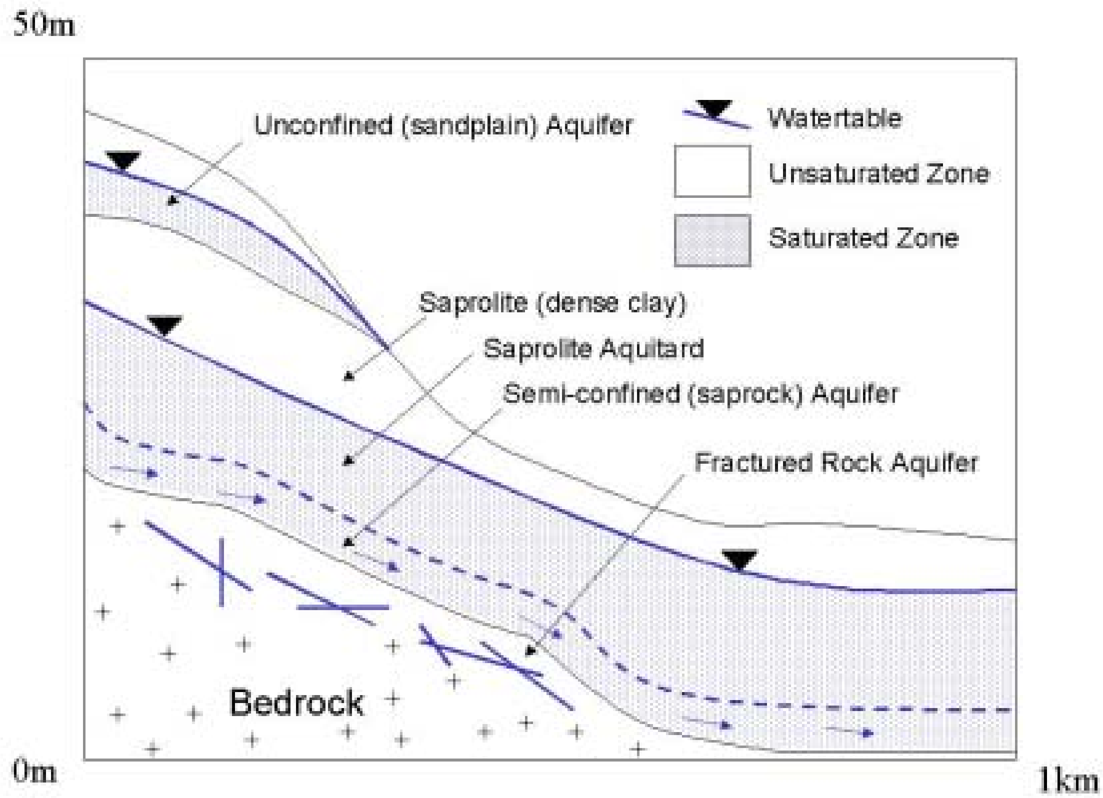

Figure 2.5. Schematic representation of typical aquifers

Confined aquifers are held between impermeable regolith layers called aquitards. In Phillips Brook, they usually occur in the actively weathering zone between bedrock and saprolite. Unconfined or perched aquifers occur in permeable surface materials where an unconstricted watertable forms the upper boundary. Aquifers are also likely to exist in alluvial sediments. Structurally controlled aquifers can be unconfined to semi-confined and occur at local scales, such as at the contact between intrusive mafic dykes and surrounding granitic country rock, and at regional scales in extensive fault systems. Following clearing, aquifers have increased in volume, number and extent.

2.5.2 Catchment hydrology

Because crops and pastures use less water than the original vegetation, clearing has increased the size and number of aquifers in the catchment. This is most clearly explained with a catchment water balance model.

A catchment water balance is an accounting exercise: what comes in (*rainfall*) is 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)**	**+**	**ΔS**	**+**	**U**	**+**	**ΔD**
Rainfall in	=	Surface run-off	+	Groundwater flow	+	evaporation transpiration (soil & plant)	+	change in soil water storage	+	Groundwater recharge	+	Change in surface storage

Before clearing, the components of the water balance equation were relatively stable. Rainfall has not changed much since clearing, but the hydrological balance has, because of changes to the components on the right-hand-side of the equation. The change from native vegetation to agricultural crops and pastures has decreased evapotranspiration (E+T), causing soil profiles to remain wetter for longer (ΔS), resulting in waterlogging, more run-off (R) and faster groundwater recharge (U). In Phillips Brook, groundwater recharge is balanced by evapotranspiration (E+T) and groundwater flow (G) to streams moving water – and salt in stream flows - out of the catchment.. Where groundwater flows to streams reduce and inputs remain, groundwater will tend to rise to the surface, evaporate and deposit salt. It appears unlikely that salinity will be a significant problem, because there is only a small area of valley flats with fairly sluggish groundwater drainage, and groundwater systems localised by bedrock highs and dolerite dykes affect only small areas. However, this has not been tested because of a lack of data.

No accurate data exists for salt store in the Toodyay area. However, based on de Broekert's 1996 relationship between rainfall and salt store, the regolith of Phillips Brook is likely to contain average salt storage concentrations of ~20 kg/m^2 (200 t/ha).

2.5.3 Groundwater

Groundwater characteristics have not been measured. Salinity in the deeper saprock aquifer is likely to vary from brackish to saline, causing some salinity in the valley floors. As in similar catchments to the south (Mokine Brook, Kokendin and Kettle Rock), Phillips Brook may have groundwater of suitable quality for livestock.

Local flow systems are typically unconfined (perched) aquifers in the more porous, sandy soils, causing some waterlogging and seeps in the lower slopes and valley floors. In addition, semi-confined (saprock) aquifers are localised by bedrock highs or dolerite dykes, and the intermediate flow systems in the deeper continuous saprock aquifer extend over most of the catchment. The upper slopes are steep with a thin permeable regolith that can generate free flowing artesian wells with stock-quality water.

2.6 Native vegetation

Alex Hollick

About 26% of the remnant vegetation is managed by CALM, 45% is privately-owned, and the rest is public land such as shire reserves or vacant Crown land.

Three types of woodland covered 98% of the catchment prior to clearing: York gum and flooded gum woodland occupied half on the most fertile loamy and clayey soils of the river flats, lower slopes and around rocky outcrops; marri and wandoo occupied almost 30% on sandy duplex soils and deep sands near rock outcrops and in depressions in lateritic terrain; jarrah, wandoo and powderbark woodland occupied almost 20%, mostly on the ironstone gravels in the west.

Since settlement, 68% of the catchment has been cleared. Only 13% of the original York/flooded gum country is left. It now covers 7%, mostly on private land in small, scattered remnants. The other two vegetation communities are still well represented, with 46% of the marri-wandoo woodland and 66% of the jarrah complex remaining. Together, these communities cover 25% of the catchment, mostly in the west. It is concerning that remnant vegetation only covers 7.5% of the eastern sub-catchment of Toodyay Brook, mostly in small and scattered remnants.

In comparison, the Shire of Toodyay retains 49% of its pre-European vegetation, 31% in reserves and on public land and 18% on private land, a better situation than most shires in the wheatbelt (Connell and Ebert 2000).

Vegetation-soil associations are complex. Table 2.2 compares pre-European vegetation with the present remnant vegetation within the major soil supergroups.

Table 2.2. Vegetation-soil associations and areas of vegetation

Soil Supergroups	Vegetation association*	Original extent** (%)	Percentage remaining**	Present extent** ha
Ironstone gravelly soils, Shallow sandy duplexes (wandoo)	Medium woodland: jarrah, wandoo and powderbark	19%	66%	1,580 (12%)
Rocky and stony soils, Deep sandy duplexes, Shallow sandy duplexes (wandoo)	Medium woodland: marri and wandoo	29%	46%	1,830 (13%)
Loamy earths, Loamy duplexes, Deep and shallow, deep sandy duplexes, Non-cracking clays, Cracking clays	Medium woodland: York gum and flooded gum	50%	13%	850 (7%)
	Total area of remnant vegetation			**4,250 (32%)**

* From Beard (1980)
** From Hopkins *et al.* (2002)

Almost 500 remnants remain in Phillips Brook catchment, but only 61 are more than 5 ha in size (see Table 2.3). Most remnants are small and isolated, with 376 patches smaller than 2 ha. Several of the areas in the west are part of larger remnants that extend beyond the catchment boundary. They have significant ecological value due to their size, connectivity and the fact that they link many different vegetation communities, including all three representative communities present in Phillips Brook.

Table 2.3. Characteristics of remnants represented in Phillips Brook catchment

Remnant size (ha)	Number of remnants within or overlapping catchment area	Proportion of area of patches within Phillips Brook catchment (%)
>1000	2	1.7
1000-100	3	15.9
100–50	3	55.1
50-20	8	92.5
20–10	11	63.2
10–5	34	90.0
5–2	58	93.6
<2	376	98.1
Total	**495**	**100.0**

3. Catchment condition and future risk

3.1 Salinity and groundwater

Shahzad Ghauri

Phillips Brook has only a very small area of saline land and has steep terrain and streams that remove groundwater from the catchment, so the risk of salinity spread is relatively low. Surface water and soil management issues should take priority. Reducing recharge is encouraged to improve the condition of the catchment and to lessen salinity and nutrient impacts on downstream rivers and streams.

As no groundwater records or monitoring bores are available to determine groundwater quality and trends, it is suggested that a network of bores be installed to determine what action, if any, is required.

3.1.1 Current extent of salinity

Phillips Brook catchment has only 40 hectares of saline land (<0.1%), based on Land Monitor data. For more information about Land Monitor, visit the website on www.landmonitor.wa.gov.au.

Salt accumulating from evaporation of surface water at breaks in slope and geological constrictions is the main cause.

3.1.2 Groundwater trends

The catchment is highly dissected, with high relief and strong seasonal stream flow variation. No records are available but groundwater is expected to rise rapidly following rainfall and to drain rapidly when not topped-up by rain. Shallow piezometers in low-lying positions may show only seasonal rainfall variation in water levels. Deep piezometers intercepting semi-confined aquifers in similar locations commonly show rates of rise in the order of 10-30 cm/year. This may ultimately increase discharge area.

3.1.3 Potential salinity risk

Land Monitor predicts that approximately 1,200 ha or 9% of the catchment could ultimately be affected by shallow watertables. However, this is a worst case scenario and because of the topography and location close to the Avon River, is unlikely to be realised. The prediction compares favourably to other catchments in the region, which have at least 15% classed as ‘at risk’. The area affected by shallow watertables will remain lower than other catchments because the steep topography causes rapid drainage. However, run-off during rainfall has increased since clearing causing surface water problems including erosion and waterlogging in the lower catchment.

Localised seeps from sandplain, bedrock highs and dykes are not considered in Land Monitor data. These seeps are often saline and sometimes acid, and although they affect only a small proportion of the catchment, may significantly affect individual landholders.

3.1.4 Recommendations

To determine whether the catchment is at risk from rising groundwater and salinity, the following measures are recommended:

1. Construct piezometers and observation bores remote from discharge sites and where recharge could put areas down-slope at risk.

   Justification - Groundwater trends can be observed without confounding factors by placing observation bores at sites remote from direct discharge influences.

2. Monitor groundwater levels, salinity and acidity in bores regularly (e.g. monthly)

   Justification - The future salinisation rate, extent and impact can be better modelled with direct data. Modelling can assist future catchment management planning and direct remediation strategies. The effectiveness of recharge reduction strategies can also be ascertained by monitoring bores if they are located proximal to treated areas (e.g. 10-50 m).

3.2 Soils risk summary

Paul Galloway

The major issues for the sandy-surfaced soils are:

- recharge susceptibility
- subsurface compaction
- soil acidification.

The major issues for the loamy and clayey-surfaced soils are:

- soil structure decline
- water erosion.

The physical and chemical properties of the soil can be changed to improve:

- the ability of plant roots to explore the soil and extract nutrients and water
- biological activity in the root zone
- aeration
- water infiltration rates
- water-holding capacity.

Improving the soil water storage contributes to salinity management.

Table 3.1 indicates the area and main soils that are potentially susceptible to various soil degradation processes and summarises management options that may fix a problem or improve a farming system. Options will vary for different sites and farming systems. A site analysis and farming system appraisal should be undertaken before recommending one option over another.

The best way to determine existing degradation is by observing and measuring soil characteristics directly. For example, waterlogging extent should be determined by site inspections during a wet period, while surface acidification is difficult to visualise, so accurate and timely soil testing is the best way to monitor its extent and severity.

Table 3.1. Recommended management options for major soil supergroups of Phillips Brook catchment

Degradation issue	Susceptible area (moderate risk)	Susceptible area (high to extreme risk)	Soil supergroups potentially affected	Management options
Subsurface compaction	74%	1%	Deep sandy duplexes Deep sands	Plant species with deep, strong taproots Controlled traffic farming Deep-ripping if sand is very deep. Site conditions will determine economic viability.
Soil structure decline	56%	1%	Deep loamy duplexes Non-cracking clays Shallow loamy duplexes	Increase organic matter Remove stock and do not work soil when wet Minimum tillage/ no-till Phase farming Stubble retention Deep-rooted species (perennials, serradella).
Acidification	40%	6%	Ironstone gravelly soils Deep sandy duplexes Deep sands Shallow sands	Monitor pH Lime applications Plant acid-tolerant species Manage nutrient/product export Manage nutrient requirements
Water erosion	41%	2%	Shallow loamy duplexes Deep loamy duplexes Non-cracking clays	See Surface water management section
Wind erosion	27%	2%	Deep sandy duplexes Shallow sands Deep sands	Retain stubble(50% ground cover) No-till Grazing management Perennials Windbreaks
Water-repellence	26%	2%	Ironstone gravelly soils Deep sands Deep sandy duplexes	Clay spreading Furrow sowing

3.2.1 Further reading

Farmnotes

32/85	Gypsum improves soil stability
57/90	Identifying gypsum-responsive soils
87/94	Stubble needs for reducing wind erosion
4/95	No tillage sowing minimises soil erosion
35/96	Preventing wind erosion
61/96	No-till sowing machinery to control wind erosion
65/96	Soil management options to control land degradation
66/96	Stubble management to control land degradation
110/96	Assessing water repellence
14/97	Claying water repellent soils
70/00	Looking at liming – consider the rate
78/00	The importance of soil pH
80/00	Management of soil acidity in agricultural land

3.3 Vegetation condition and risk assessment

Alex Hollick

Almost 500 areas of native vegetation remain in Phillips Brook catchment. Large tracts of the western portion are uncleared and in good condition. However, in the eastern sub-catchment many remnants are small and geographically isolated. These small remnants are less ecologically viable because they are fragmented and have a large perimeter-to-area ratio. This allows edge effects, such as weed and pest invasion, spray drift and other degrading processes, to affect a greater proportion. It also limits their value as habitat.

A subset of 66 of these remnants accessible by road was assessed for condition according to criteria described in Appendix 2; 65% of those surveyed were rated as degraded or very degraded. The major causes of degradation are grazing pressure and weed infestation. Table 3.2 documents the remnants sampled.

Table 3.2. Condition of the sampled set of remnants

Degradation rating	Number of remnants	% of sample
Very good	17	26
Good	6	9
Degraded	24	36
Very degraded	19	29
Total	**66**	**100**

4. Management options and impacts

4.1 Farming systems

Trevor Lacey

4.1.1 Farmer survey

Farmers were surveyed to provide information on the farming systems practised within the catchment. There were only 10 responses, mostly from lifestyle holdings, so the results should be treated with caution.

Farm businesses in this area largely comprise mixed stock (mainly sheep and some cattle) and cropping enterprises. Crop-pasture rotations and continuous cropping are common on most soils. Deep sand and rocky stony soils, which are often difficult to crop, tend to be in permanent pasture or perennial vegetation. These soil types represent an opportunity for perennial pastures, forage crops and woody perennials. Perennial pastures are well-suited to stock enterprises as they can provide a better distribution of feed throughout the year, thus removing or reducing the need for supplements and enabling high-priced markets to be targeted.

Water supplies are all derived from on-farm sources and adequate, according to respondents, although several did request more information for developing water supplies.

About half the respondents expressed interest in high water use crops and pastures but only a few are currently using them. The respondents did not show much interest in oil mallees, tagasaste and pines, but these should be considered to improve farm sustainability.

Soil ameliorants such as lime and gypsum, reduced tillage and contour banks featured as areas of future interest but had a low level of adoption. These options can improve crop agronomy and help manage hazards associated with various soils. Suitable options for each soil type are indicated in Table 4.1. Addressing these issues will have an immediate impact on production, profit and recharge. Information on green and brown manuring was requested.

4.1.2 AgET and Catcher analysis

AgET and Catcher models highlight the relative differences in water use of annual and perennial species by estimating deep flow. AgET estimates the amount of water flowing beyond the roots for farming rotations on different soil types. Catcher estimates the impact of changing farming rotations on the whole catchment water balance. The rotations used on each major soil are described briefly below and presented in more detail in Appendix 4.

Altering farming systems to phased crop and perennial pasture rotations can significantly reduce recharge without major changes to the total area of crop and pasture. However, changing from continuous annual pasture to crop-annual pasture rotation or continuous cropping will only reduce recharge slightly.

Lucerne and woody perennials use almost all of the rainfall. Annual crops permit 5–15% of rainfall to flow past the plant root zone and clover/medic pastures permit 15–30% of annual rainfall past, depending on soil type. Heavier clay soils have less deep flow than lighter sandier soils, under waterlogging-free conditions.

Recharge under existing rotations is estimated to be 9.7% of annual rainfall. This could be reduced to 8.5% by increasing the proportion of perennials from 32 to 39% - a modest intervention and small result. McConnell (2001) considers this level of intervention will be the standard rotational system in 2020.

A more optimistic rotational system increases the perennial component and introduces phase farming to reduce recharge rates to 2.9% of annual rainfall. This would slow the rate of rise of groundwater, reducing the area affected by shallow watertables within the catchment. It would also reduce downstream erosion and salinity beyond the catchment. Increasing the perennials in the catchment from 32 to 65% only reduces pasture area from 45 to 39% and increases cropped area from 19 to 22%. The total production from this optimistic intervention should be at least as good as from current rotations. Stock carrying capacity is likely to be similar or increased, with a better spread of feed throughout the year providing the opportunity to target higher-priced markets for out of season stock.

Deep sands and ironstone gravels are high recharge soils that occupy a large part of the catchment. The best way to manage recharge on them is by planting permanent perennials (e.g. revegetation with natives, tagasaste, .shelter belts etc.) and phase cropping with perennial pastures, or less effectively, deep-rooted annual pastures (e.g. serradella).

Sandy duplexes are a major soil type that contributes significantly to recharge via preferred pathways such as large cracks and root channels, particularly when the soil profile is saturated or waterlogged. Recharge will reduce by improving surface water management and altering the farming system to increase perennials and improve crop and pasture water use.

Run-off is relatively high on rocky or stony soils and likely to contribute to recharge when it enters coarse decomposing rock, which often links rock outcrops with valley floor watertables. As areas surrounding rock outcrops often receive more than annual rainfall due to run-off, they provide an opportunity for planting perennials or establishing surface water management structures to divert water that can be used elsewhere (e.g. house water, stock water, aquaculture or horticulture ventures).

4.1.3 Farming systems options

4.1.3.1 Annual crop rotations and best farming practices

Best practice annual crop and pasture agronomy will marginally improve water use. Doubling crop yields only increases water use by 5%, and annual crops use more water than traditional annual pastures. Summer crops use similar amounts of water to traditional annual winter crops, but are able to use summer rainfall and moisture stored in soil. This has a net positive impact on year-round water use if winter crops or pastures follow summer crops.

Best agronomy practice includes:

- avoiding crop failures
- fixing soil conditions that hinder growth
- incorporating longer cropping phases into rotations
- using deep-rooted annual pasture species (e.g. serradellas) on suitable soil types
- using warm season crops in specific circumstances
- early sowing
- selecting suitable species and varieties for specific sites
- good rotations
- good nutrition
- effective weed management.

However, effective surface water management and perennial species are needed to reduce recharge rates significantly.

4.1.3.2 Integrating perennial pastures into the farming system

Perennials use water year-round and are generally deeper-rooted than annuals, so are better at drying the soil profile. Perennial pastures do not use as much water as woody perennials, but can be used on a large scale without changing land use and without major changes to farming practices. Lucerne is a perennial legume that can successfully be incorporated into farming systems. Some sub-tropical and temperate perennial grasses (including sorghum, which can grow as an annual or perennial) are being evaluated.

Rotations using perennial pastures have farming benefits including:

- managing herbicide-resistant weeds
- increasing the range of enterprises
- extending green feed
- finishing stock out of season
- providing ground cover
- reducing the need for supplementary feeding of stock.

Sites where fresh water accumulates provide perennial vegetation with the opportunity to maximise water use and production. ‘Best bet’ sites to maximise the production from lucerne include:

- above break-of-slope positions
- at soil changes where the up-slope soils are lighter than the down-slope soils

- in gritty soils around rock outcrops
- above dykes and faults.

Lucerne dryland grazing systems:

- grow on various soil types and environmental conditions
- produce feed with quality and quantity equal to or better than sub. clover
- Produce green feed from April to December and later throughout summer, depending on moisture availability
- provide opportunity to finish meat sheep out of season for premium markets
- require rotational grazing management.

Further reading for lucerne

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4.1.3.3 Integrating woody perennials into farming landscapes

Woody perennials use more water than perennial pastures. They best fit into the system in landscape or soil niches, in alleys or block plantings. Possibilities include:

- **tagasaste** for feed, in blocks on unproductive Pale deep sands
- **oil mallees**, in alleys across sloping land and valley flats to intercept water
- **pines** (*Pinus pinaster*), on Deep sands in blocks to maximise production
- **blue gums**, in blocks on loams and duplexes not prone to salinity, to maximise production
- **melaleucas** on waterlogged areas and marginally saline areas for production
- **saltbush** and **bluebush**, on saline sites to provide ground cover and some feed
- **acacias**, to provide alternative feed.

Specialty crops and timbers including **olives**, **sandalwood** and **native trees** for woodworking have merit for diversifying farming enterprises.

4.2 Surface water management

Harry Lauk, Ian Wardell-Johnson, Tilwin Westrup and Paul Galloway

Surface water management in the catchment should focus on the following problems:

- gully erosion below mallet hills
- sheet and rill erosion on longer slopes
- small areas of waterlogging
- conservation planning in some subdivision required
- hillside seeps present problems in wet years
- inadequate maintenance of existing surface water control earthworks
- inappropriate design of some earthworks.

4.2.2 Land management principles

Conservation land management options reduce the velocity and erosiveness of surface water. Four options that should be used are:

- vegetative cover to protect the soil from raindrop impact and reduce surface water
- working land along the contour to hold surface water in the furrows
- grass strips and permanently grassed waterways to slow surface water concentrated by natural landforms and earthworks
- management according to Land Management Units.

4.2.3 Surface water control

The amount of surface water run-off from the four main soil types is affected by slope, grade and landscape position (e.g. valley floor, footslope, upperslope, crest). A quick assessment of these slope classes can be made using ortho-photomaps overlaid with 2-metre contours. Earthworks can then be planned, considering soil type, to reduce the recurrent waterlogging (see Table 4.1).

Phillips Brook catchment is near the Avon and Darling catchment divide. The upper catchment has steep slopes and limited safe disposal points for surface water, so should not be cultivated. Artificial waterways may be required on footslopes grading to narrow valley floors.

Table 4.1. Possible earthworks for slope classes and landscape elements

Slope Class (%)	Landscape element	Suitable earthworks
0-1	Valley floors/ lower footslopes	Shallow relief drains Levee and Levied waterways
1-3	Long slopes / footslopes	Seepage interceptor drains Reverse bank seepage interceptor drains Levee and Levied waterways Diversion bank Broad-based bank (not less than 2%)
3-6	Mid-slopes/ minor upper slopes	Grade bank Seepage interceptor drains Reverse bank seepage interceptor drains Levee and levied waterways Diversion bank Broad-based bank
6-10	Upper slopes	Grade bank Level / adsorption banks directly below steep slopes of Mallet Hills Levee and levied waterways Diversion bank
>10	Steep slopes / Mallet Hills / rock outcrop	No earthworks recommended – use conservation land management practices

4.2.4 Surface water earthwork options

Earthworks require careful planning because inappropriate designs can cause more problems than they solve. The following should be considered:

- **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. For more information visit the Department of Agriculture website (http://www.agric.wa.gov.au/progserv/natural/assess/index.htm).

- **Average Recurrence Interval (ARI) -** describes the average period in years between the occurrence of a rainfall event of specified magnitude (duration and intensity) and an equal or greater event. For example, a 20 year ARI rainfall event would occur, on average, five times in 100 years and would have a 5% probability of occurring in any year. Earthworks should be designed and built to fill, or safely fail, when subjected to a specified ARI. Important earthworks, such as dams, waterways and absorption banks should be designed for at least a 20 year ARI. The minimum design of most surface drains and banks is a 10-year ARI.

In the Phillips Brook catchment, grade banks, absorption banks and waterways may be used with slopes between 1 and 10% depending on the site. The most suitable soils for these earthworks are loams, sandy-surfaced duplexes and clays. Shallow surface drains may be used on less than 1% slopes. The most suitable soils for shallow drains are duplex and clay soils.

The range of appropriate engineering options for the four main soil supergroups of Phillips Brook catchment are described in Table 4.2.

Table 4.2. Recommendations for surface water control on soils of the Phillips Brook catchment

Soil supergroups	Management issues	Appropriate earthworks
Ironstone gravel (36% of catchment)	Water management rarely a problem unless gravels are over clay subsoil	Grade bank systems to stable waterway Leveed waterways
Deep sandy duplex soils (15% of catchment)	Surface water erosion rarely an issue	Grade banks to intercept sheep tracks
Rocky/stony soils (9% of catchment)	Recharge management on sandy soils surrounding rock Water erosion control on loamy and clayey soils around rock outcrops	Grade bank systems
Deep loamy duplex soils (9% of catchment)	Water erosion Flooding on valley flats Waterlogging	Grade bank systems Shallow relief drains Conventional or reverse bank seepage interceptor

4.2.5 Earthworks for water conservation and management

Earthworks, including grade banks, diversion banks, grassed waterways, roaded catchments and dams, are the primary method of water conservation and storage (see Appendix 4). The works described earlier can often be used to divert water into storage. Effective water storage structures increase the surface water storage (ΔD) component of the water balance. However, earthen storage structures are rarely 100% efficient, so usually contribute to recharge via preferred pathways and matrix flow, particularly given the significant hydraulic gradient under such structures.

Roaded catchments are designed to capture rainwater and provide an efficient method of increasing run-off into farm dams. Matching the roaded catchment area to dam volume can be done using computer programs such as Damcat II (see http://www.agric.wa.gov.au/environment/drainwise/tools.htm - Surface).

4.3 Remnant vegetation management

Alex Hollick

Approximately 26% of the remnant vegetation is managed by CALM, 45% is privately-owned, and the rest is public land such as shire reserves or vacant Crown Land. Methods of protecting remnants include fencing to exclude stock, weed and feral animal control, encouraging understorey regrowth, buffer planting to reduce edge effects (e.g. spray drift, weed invasion) and linking with corridors. For further information on these strategies, see Appendix 6.

4.3.1 Strategic revegetation

Revegetation can be strategically placed at water-gaining sites including:

- break of slope

- change of soil type
- creeklines/riparian zones
- where groundwater accumulates due to geological features.

These are the only places to revegetate. Where road verges act as corridors, boundary plantings adjacent to the verges will enhance their corridor quality, especially if the firebreak is moved inside the revegetation area. Corridor plantings can be placed anywhere to link remnants, and typical locations include fencelines and surface water control structures, where they don't interfere with farming operations.

It is important to consider planting understorey species when rehabilitating remnants and revegetating areas. Canopy trees use about 70% of the rainfall at a site, leaving the other 30% to infiltrate and perhaps contribute to groundwater recharge. This is especially so with summer rainfall when the understorey is comprised of annual grass weeds. Replacing these weeds with perennial shrubs or native grasses will use this rainfall.

Appendix 7 lists species useful for biodiversity revegetation on specific soil types. This list is useful if planting purely for recharge, salinity control or rehabilitation. If the planting is to have biodiversity or ecological value, then using local provenance species (those that occur naturally on-site) is strongly recommended.

Revegetation options with commercial potential include oil mallees, melaleucas, pines, cut flowers, nuts (pistachio or macadamia) and sandalwood.

4.4 Economics

Keith Ohlsen

4.3.1 Economics summary for Phillips Brook catchment

- Gross Value of Production (GVP) contribution to the local economy is estimated at $1.63 m*
- In response to market pressures, areas cropped have increased and winter-grazed hectares have reduced
- Farm operating profits have declined over the last few years
- Increased farm debt has resulted in very poor result in terms of return on capital.

4.3.2 Agricultural systems

- Primarily broad-acre with winter cropping and livestock the main industries
- Crop rotations and production mix vary between farms depending on soil types, capital structure and expertise in the business
- Livestock focus is primarily on wool with some prime lamb production
- Crops include wheat, barley, lupins, oats and canola.

4.3.3 District production*

For this catchment it is estimated that the GVP was:

- $1.63 m in 2000/01; operating return was $0.57 m
- Approximately 71% ($1.16 m) of GVP from grain production
- The balance was 18% ($0.29 m) sheep/wool
- 11% ($0.18 m) from other products.

(* Based on 2000/01 BankWest Benchmarks for the Northam District)

4.3.4 Economic performance

- Performance measures over the State indicate considerable variability in farm income over the last few years
- Indications are that greater focus on grain production resulted in greater return on capital
- Operating profits for mixed farming tended to be insufficient to sustain a positive return on capital.

4.3.5 Economic outlook

- Current impacts of risks concentrated in the lower slopes and drainage lines. These are the most productive areas within this catchment.
- Any losses in production in these areas would have significant impacts on GVP.
- Existing land management activity indicates a willingness to take action. This will be essential to maintain productivity into the future.

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6. Appendices

A1. Detailed soil-landscape map legend

Paul Galloway

Soil-landscape mapping undertaken by the Department of Agriculture identifies repeating patterns of landscapes and associated soils. This approach doesn't map individual soils or Land Management Units (LMUs). Instead, it maps landscape elements and describes the distribution of soils within each element. The soil-landscape map units reflect processes of soil and landscape development. These units are delineated by the interpretation of remotely sensed information such as air photos and satellite images.

The information for Phillips Brook catchment derives from data intended for publishing at a scale of 1:100,000 (Lantzke and Fulton 1993). It is useful for regional planning and provides only a preliminary basis for catchment planning. This mapping was based on black and white 1:50,000 aerial photography and is considered of average quality for the intended scale, given the resources available.

No further soil-landscape mapping is anticipated in the near future. However, more detailed mapping is required for catchment and farm planning purposes, and should be conducted by defining the spatial extent of LMUs. To assist this process, preliminary LMUs for Phillips Brook catchment have been defined by extracting soil supergroups (Schoknecht 2002) from the soil-landscape mapping information.

Soil supergroups comprise a suite of soils with similar characteristics and can be regarded as preliminary LMUs. They have not been explicitly mapped. Rather, their spatial extent has been calculated from the proportion that each occupies in the soil-landscape map-units present. The results are presented in Table A1.1.

It is important to understand that LMUs should comprise both soil and landscape elements to best partition the landscape for effective and sustainable management. Presently, the preliminary LMUs only relate soil type to landscape position through the broad description of the soil-landscape units.

Mapping the preliminary LMUs will not differentiate several important landscape-related LMUs. Of particular note are the mallet hills, and some landscape and slope differentiation of the duplex soils.

Mallet hills have Acid shallow duplex, Shallow loamy duplex, Shallow sandy duplex, and Non-cracking clay soils and are vegetated by mallet (*Eucalyptus astringens*). These steep and easily eroded areas should be mapped as a separate LMU to enable effective management. They are generally located around the 253WnYA, 253WnYA3, 253WnYA4, 253WnYA5, 253WnYA6, 253CcLV, 256JcYA and 256JcLV soil-landscape units described in Table A1.2.

Table A1.1. Soil supergroups (preliminary LMUs) in the Phillips Brook catchment in order of abundance

Soil supergroups (suggested preliminary Land Management Units)	Area (ha)	% of catchment
Ironstone gravelly soils	4,779	36
Deep sandy duplexes	2,012	15
Rocky or stony soils	1,220	9
Deep loamy duplexes	1,151	9
Shallow sands	819	6
Non-cracking clays	648	5
Cracking clays	601	5
Shallow loamy duplexes	540	4
Deep sands	396	3
Shallow sandy duplexes	364	3
Shallow loams	356	3
Wet or waterlogged soils	293	2
Loamy earths	95	1
Miscellaneous soils	21	<1
Sandy earths	8	<1
Total	**13,303**	**100.0**

It is considered necessary to separate some of the duplex soil supergroups into different landscape positions, for example, upper and mid-slope (10-6% and 6-3%), lower slope (3-1%) and valley floor (1-0%) landscape components. This division is considered important to create LMUs that address surface water management issues including water erosion and waterlogging.

The concept of landscape elements, in terms of grade of slope and landscape position (e.g. upper slope, lower slope, valley floor), is explored in more detail in surface water management, where it is most relevant.

This legend (Tables A1.2 and A1.3) is intended to be viewed concurrently with the Phillips Brook soil-landscape map in the back cover. It provides a summary description of soil-landscape units present and the area that each map unit occupies, in hectares and percentage of the catchment.

The soil supergroups present in each map unit have been documented according to Tables A1.3 and A1.4. Division into soil supergroups allows Land Management Unit mapping based on existing soil-landscape mapping.

Table A1.2. Description and area of map units

Map unit symbol	Name	Description	Area	
			(ha)	(%)
256JcYO	Jelcobine York Subsystem	Areas of soil derived from freshly exposed rock. Typified by the red soils of the Avon Valley but also includes areas of similar, but often greyer and lighter textured soils to the east.	4,179	31
256JcR2	Steep Rocky Hills 2 Subsystem (Jc)	Areas of steep, rocky hills.	3,135	24
253CcLV	Clackline Leaver Subsystem	Gravelly slopes and ridges found in the western part of the study area where streams and rivers have dissected the Darling Plateau.	2,536	19
253WnYA	Yalanbee Subsystem	Residual plateau at the top of the landscape shallowly dissected by Pindalup valleys. Pisolitic gravelly, yellowish brown soils that vary in texture from loamy sands to clays, with pockets of pale sands and areas of outcropping laterite.	2,352	18
256AfAV	Avon Flats	Alluvial terraces and floodplains that occur adjacent to the Avon, lower Mortlock and lower Dale Rivers.	362	3
253CcR1	Clackline Steep Rocky Hills 1	Areas of rock outcrop and steep rocky hills.	240	2
256JcHM	Hamersley Subsystem (Jc)	Narrow, minor drainage lines that occur predominantly within the York unit and lead down to major drainage systems such as the Avon and Dale Rivers.	140	1
253WnYA6	Wundowie YA6	Very gentle to gentle hill slopes (<10%). Deep uniform medium textured and duplex pisolitic gravelly earths.	105	1
256AfW_RIVER	Avon flat water, river phase	Narrow river valley.	71	1
253WnYA3	Wundowie YA3	Very gentle to gentle upper slopes (<10%) and crests.Shallow, pisolitic clayey sands of varying depths overlying laterite. Some outcropping laterite.	45	0
253WnKO	Wundowie Kokeby Subsystem	Very gentle sloping areas located in small pockets on summits and at breaks of slope. White and deeply bleached sand over laterite at greater than a metre depth.	39	0
256JcLV	Leaver Subsystem (Jc)	Gravelly slopes and ridges in the west of the study area where streams and rivers have dissected the Darling Plateau.	36	0
253WnYA4	Wundowie YA4	Very gentle to gentle upper slopes (<10%) and summits. Deep pisolitic gravelly clayey sands.	31	0
253WnYA5	Wundowie YA5	Very gentle to gentle hill slopes (<10%). Shallow pisolitic gravelly loams and clay loams over laterite.	16	0
253WnPN	Pindalup Subsystem	Shallow upper gently to sloping valleys. Alluvial red and yellow duplex and uniform fine soils which are often gravelly. Salinity prone especially in upper reaches.	14	0
256JcYA	Yalanbee Subsystem (Jc)	Undulating, Darling Range upland which contains predominantly 'buckshot gravel' soils.	3	0
253CcMN	Michibin Subsystem	Hillslopes containing soils formed by the weathering of fresh rock. Rock outcrop is common.	0	0

Table A1.3. Map units described in terms of presence and relative abundance of soil supergroups

Map unit symbol	Wet or Waterlogged soils	Rocky or stony soils	Ironstone gravelly soils	Deep Sandy duplexes	Shallow Sandy duplexes	Shallow sands	Deep sands	Sandy Earths	Deep Loamy duplexes	Shallow Loamy duplexes	Shallow loams	Loamy earths	Cracking clays	Non-cracking clays	Other soils
253Cc	-	Minor	Major	-	Major	Major	-	Minor	-	Common	-	Minor	-	-	-
253CcLV	-	Minor	Dominant	-	-	-	Minor	-	-	Minor	-	-	-	-	-
253CcMN	Minor	Minor	Minor	Major	Minor	Major	Other	-	Common	Minor	Minor	-	Minor	Minor	-
253CcR1	-	Major	-	Major	Minor	Common	Minor	-	Minor	Minor	Minor	-	Minor	Minor	-
253Wn	Minor	-	Dominant	-	-	-	Minor	-	-	-	-	Other	-	-	-
253WnKO	Other	-	Common	Major	Other	-	Dominant	Other	-	-	-	-	-	-	-
253WnPN	Dominant	-	Minor	Minor	-	-	Other	Minor	-	-	-	Minor	-	Minor	-
253WnYA	-	-	Dominant	-	-	-	Minor	-	-	-	-	-	-	-	-
253WnYA3	-	Minor	Dominant	-	-	-	Common	-	-	Minor	-	-	-	-	-
253WnYA4	-	Minor	Dominant	-	-	Minor	Common	-	-	-	-	-	-	-	-
253WnYA5	-	Minor	Dominant	-	-	-	-	-	-	-	-	-	-	-	-
253WnYA6	-	Minor	Dominant	-	-	-	-	-	Minor	Minor	-	-	-	-	-
256Af	-	-	-	Minor	-	-	Common	Minor	-	Other	-	Major	Minor	Major	-
256AfAV	Common	Minor	-	Minor	Minor	Minor	Common	Minor	Other	Other	Other	Major	Minor	Common	-
256AfW_	-	-	-	Minor	-	-	Common	Minor	-	Other	-	Major	Minor	Major	-
256AfW_RIVER	Dominant	-	-	-	-	-	-	-	-	-	-	-	-	-	Major
256Jc	Minor	Common	Common	Common	Minor	Minor	Minor	-	Common	Common	Minor	-	Minor	Minor	-
256JcHM	Dominant	Common	-	Common	Minor	Minor	-	-	Minor	Minor	Minor	-	-	-	-
256JcLV	-	Minor	Dominant	-	-	-	Minor	-	-	Minor	-	-	-	-	-
256JcR2	-	Major	-	Major	Minor	Common	Minor	-	Minor	Minor	Minor	-	Minor	Minor	-
256JcYA	-	-	Dominant	-	-	-	Minor	-	-	-	-	-	-	-	-
256JcYO	Minor	Minor	-	Major	Minor	Common	Other	-	Major	Minor	Minor	-	Minor	Minor	-

Table A1.4. Relative abundance of soil supergroups by map units

Soil supergroup proportion	Area percentage range
Dominant	>50%
Major	20-49%
Common	10-19%
Minor	2-9%
Other	<2%

It is important to remember that the soil supergroup breakdown of the map units refers to all occurrences. Any single area of a map unit may encompass different proportions of the supergroups, or a subset of the total supergroups.

A2. Remnant vegetation degradation ratings

Rating	Criteria
4. Very good	Evidence of localised low level damage to otherwise healthy bush. Recruitment should be apparent. Weed and grazing damage is confined (20% of area). Some modification of vegetation structure due to changes in fire regimes may be apparent. Little evidence of logging or firewood collection.
3. Good	Evidence of localised high level damage to otherwise low-level damaged bush. Recruitment is localised and the populations of some species may be senescent. Weed and grazing damage is apparent in <50% of the area. Modification to vegetation structure due to changes in fire regimes may be apparent. Gall and mistletoe damage may be apparent. Evidence of logging or firewood collection.
2. Degraded	Widespread high level damage. Recruitment is disrupted and most woody species appear senescent. Weed and grazing damage may be apparent throughout the area. Modification to vegetation structure due to changes in fire regimes may be apparent. Locally some strata may be absent. Gall and mistletoe damage may be apparent. Evidence of logging or firewood collection.
1. Very degraded	Widespread high level damage. Recruitment is disrupted and most woody species appear senescent. Weed and grazing damage may be apparent throughout the area. Modification to vegetation structure due to changes in fire regimes may be apparent. Widespread loss of vertical strata. Gall and mistletoe damage may be apparent. Evidence of logging and firewood collection.

Damage types

High level Grazing (domestic or feral), logging, clearing and excavation, dieback, salinisation or other watertable modifications, roadworks, flower picking, major structures (e.g. sheds), mowing, car bodies.

Low level Dumping (household, garden, etc.), minor structures (e.g. managed or fenced areas), firewood collection, weed infestation, modified fire regime.

A3. AgET and Catcher analysis for Phillips Brook catchment

AgET calculates average deep flow and run-off based on a series of buckets that fill and overflow into the next bucket. It should be kept in mind that:

- The lateral movement of water, waterlogging, perched watertables and preferred pathway recharge is not catered for and will lead to higher rates of recharge.
- Average deep flow and run-off do not reflect yearly or seasonal variation that occurs.
- There is limited data across Western Australia to calibrate the model, leading to reduced accuracy of predictions. However, trends will remain fairly constant and thus enable comparisons.

Rotational deep flow is proportional to the number of years of crop or pasture in the rotation and can be calculated as follows. For example a pasture, pasture, wheat, lupin, wheat, barley rotation on a sandy duplex would be two years of pasture and four years of crop.

$$\text{Deep Flow} = \frac{((2 \text{ years X pasture deep flow**}) + (4 \text{ years X crop deep flow**}))}{\text{Total years in rotation}}$$

$$\text{Deep Flow} = \frac{((2 \text{ X } 17\%) + (4 \text{ X } 13\%))}{6} = 14.3$$

(** % deep flow from Table A3.1.)

The deep flow as a percentage of annual rainfall has been estimated using a water balance model for a number of farming options on the major soil groups in the catchment. These results (Table A3.1) are not expected to accurately predict water use occurring in the catchment due to unpredictable natural variation. However, they highlight the relative differences in water use of annual and perennial species as outlined.

The results from AgET were used to run Catcher, a model that calculates the catchment water balance (see Aquifer dynamics) based on the percentage of soil types and options being used within the catchment. Catcher was run with three scenarios: current practice, predicted practice in 2020 and an optimistic option for 2020 with a higher level of recharge intervention including phased perennial pastures and woody perennials (Table A3.2). Current and predicted 2020 rotations were taken from McConnell (2001).

Table A3.1. Predicted deep flow for some options on main soil supergroups in the Phillips Brook catchment

Soil type	Options	Predicted deep flow as percentage of annual rainfall (%AR)
Rocky or Stony	Clover/medic pastures	14
	Continuous crop	0
	Lucerne	0
	Woody perennials	0
Ironstone gravels	Clover/medic pastures	22
	Crop	9
	Lucerne	0
	Woody perennials	0
Loamy earths	Clover/medic pastures	18
	Crop	14
	Lucerne	2
	Woody perennials	0
Sandy duplexes	Clover/medic pastures	17
	Crop	13
	Lucerne	1
	Woody perennials	0
Deep sands	Clover/medic pastures	27
	Serradella	15
	Crop	5
	Lucerne	0
	Woody perennials	0

Some soils have been grouped for this analysis (e.g. Loamy earths were included with Loamy duplexes) as McConnell (2001) did not use all soil groups. As such, the percentage of soils used for the Catcher modelling may vary from those reported elsewhere.

Table A3.2. Percentage of soil types allocated to land use options in the current, 2020 and optimistic 2020 rotations modelled in the catchment

Soil type and percentage of catchment	Rotation	Land use (%)				
		Sub. clover	Lucerne	Commercial trees	Crop	Pre-clearing vegetation
Rocky stony 9%	Current	42	-	-	7	21
	2020	31	7	4	7	21
	Optimistic 2020	21	14	7	7	21
Ironstone gravel 34%	Current	42	-	11	14	33
	2020	34	0	14	19	33
	Optimistic 2020	0	34	14	19	33
Loamy earth 10%	Current	59	-	6	29	6
	2020	59	0	5	30	6
	Optimistic 2020	29	30	5	30	6
Sandy duplex 21%	Current	43	-	6	29	22
	2020	44	10	10	14	22
	Optimistic 2020	10	29	10	29	22

The optimistic rotation outlined is but one example of a combination of options that might be adopted. Individual farming enterprises should consider different combinations of these options in conjunction with other management options outlined in this report.

A4. Description and placement of conservation earthworks

4.1 Valley floors and lower slopes

Shallow relief drains

Shallow relief drains are channels constructed to remove water from flooded areas, regulate the depth of water in ponds or define flows through low lying ill-defined areas. A shallow relief drain can be a number of designs including a 'W', 'V', 'U' 'flat bottomed' or spoon drain.

They are generally sited on flat areas where ponding and waterlogging occurs because of poorly defined drainage. Water that normally ponds on the surface enters the drain and flows along a gentle grade (less than 0.3%) to a suitable disposal point. This reduces the impact of waterlogging and inundation. Shallow relief drains should only be used where a stable outlet capable of disposing the quantity of water collected is available. Drains should be clear of floodplains.

Levee and leveed waterways

Often called a grassed waterway, a leveed waterway is a natural or constructed channel shaped to required dimensions and established with a vegetative cover. They can be broad shallow natural waterways or constructed channels. They are designed to convey run-off from grade banks, diversions, dam overflows or other water concentrations without causing erosion or flooding.

Leveed waterways are usually constructed where no suitable natural waterway exists, to dispose of surface water to a safe point. Outlets should be stable and of sufficient capacity to prevent ponding and erosion.

Lower to mid-slopes

Seepage interceptor drain

A seepage interceptor drain is a 'V' shaped channel designed to remove surface water flows and subsurface seepage from sloping land and lead it to a waterway. A traditional seepage interceptor drain has the bank formed from spoil downhill from the channel. A reverse bank seepage interceptor has spoil uphill forming the bank, which allows surface and subsurface flows to be separated. Reverse bank seepage interceptors are recommended as they are not prone to erosion and channel scouring as traditional seepage interceptor drains. However, they are unsuitable in some situations.

Seepage interceptor drains will not control watertables beneath salt areas where water is rising under pressure from a deep aquifer.

Note: Reverse bank seepage interceptors have been adapted to the Upper Great Southern and are very site-specific (like all earthworks). As their grades are steeper than the conventional interceptor, caution is required if considered elsewhere.

Mid to upper slopes

Diversion and broad-based banks

These are channels with spoil banks formed below the channel. They are constructed to intercept and divert surface water. They can be designed to protect a cultivated area, a gully, an eroded area and infrastructure from erosion, flooding and waterlogging. They can also be used to divert surface water on sloping land to or from a dam or waterway.

Broad-based banks are designed with a broad cross-section and gentle batters. They have advantages over conventional banks because the battered spoil does not create an obstacle to vehicle travel. The shape enables travel or access across them and tillage along their length if the soil types are suitable. There are examples of both the channel and bank being cropped.

Diversion and broad-based banks operate similarly to grade banks except they are wider and have a larger capacity and can therefore transport larger quantities of water.

Contour grade banks

These are banks with an uphill channel and may be single or form part of a multiple bank system. They are constructed to control surface water flows from sloping land thus reducing the risk of surface erosion, flooding and waterlogging. The purpose of each bank is to increase the time of concentration of run-off and to control its volume and velocity so that serious erosion will not occur.

Channels can be designed with increased grade to help limit recharge. Increasing the velocity of the water in the channel (by increasing the grade) reduces the chance of it 'leaking' through the channel floor and contributing to groundwater through preferred pathway recharge. This design does slightly increase the risk of erosion in the channels.

Grade banks are most effective in duplex (sand over clay) or clay soils. In sandy soils or gravel, they have less impact on waterlogging, but can still control surface flow and are a useful guide to cultivation on the contour.

Improved trafficability and increased crop and pasture yields can occur by reducing the area affected by waterlogging and salinity. The water captured is usually relatively fresh and so i can be harvested and stored in dams or tanks.

Upper slopes

Absorption and level banks

Absorption (level) banks are surveyed with no grade (level) with uphill channels. They are usually constructed in an attempt to control surface water flows high in the landscape where there is no safe disposal option.

When water flows into these banks, a pressure head is created, and water is forced down any preferred pathways or weak points along the channel. This water may then cause waterlogging further down slope, groundwater recharge, or causes the bank to blow out, causing major erosion.

These banks should be avoided, unless absolutely necessary (e.g. where massive erosion is likely). Artificial waterways can be designed on slopes of up to 8%, so grade banks can actually be used on many of the areas where level banks were traditionally placed.

Steep slopes, where no natural or artificial waterways and grade bank systems can be installed, should be kept well vegetated and uncultivated.

Other earthworks

Dams

Dams are a barrier, embankment or earth structure, which has the primary function of impounding water. They are constructed to store rainfall run-off for short or long periods. Short-term storage (including piped water release systems) can be used to control surface water above gullies to alleviate erosion, below eroded areas to trap sediment, or as part of a down slope release system for controlling flooding.

Dams with long-term water storage could also be useful for aquaculture.

Generally, placing dams in valleys, drainage lines, on or just below laterite hilltops or mallet hills should be avoided as dams in these areas often leak. Efforts should be made to ensure dams are properly sealed.

Roaded catchments

Roaded catchments capture rainwater and provide an efficient method of increasing run-off into farm dams. They are formed, compacted, parallel ridges and channels of earth. Construction of roaded catchments is similar to that of earth roads, except they have a steeper camber. The surface is made as smooth and impervious as possible. A clay blanket over the surface of the catchment is required in sandy or gravelly soils.

Well designed and constructed roaded catchments can run water from short and low intensity rainfall events. Such water-shedding ability greatly extends the number of rains and the period of the year over which the dam collects water. This can reduce the size of the dam needed to ensure a permanent supply of water.

A5. Protecting remnant vegetation

Fencing

Fencing is needed to allow regrowth of understorey plants and trees from the seedbank in the soil or existing plants. By excluding stock, additional weed seed and nutrient import from droppings are also limited.

Weed control

Weed control is necessary because most weed and pasture species grow faster than the native understorey plants and have the potential to choke out natural regeneration. Fire can be used as an initial weed reduction method, but a number of factors need to be considered before making the decision to burn:

- Is there any native groundcover/understorey that will be killed by the burn?
- Is the weed burden in a condition (dry enough) to burn effectively?
- Will the fire get away and destroy further native bush or farmland?
- Do I have the time to return later and spray out emerging weeds?

If the fire will burn safely and effectively, the need for future spraying is paramount. The weeds generally grow faster and quicker than the natives after a fire, which means that after the dead weed burden has been removed, spraying can effectively remove the next generation of germinating weeds. If the area can't be easily accessed with a small utility or ATV-mounted boomspray, the options are reduced to either hand spraying or misting. If the weeds are mainly grasses, Fusilade™ can be misted into the remnant with care not to effect adjacent crops or pastures. Hand spraying can use either Fusilade™ or a knockdown targeting specific weeds and taking care to avoid natives. If a boomspray is useable, then Fusilade™ can be used over the top of native understorey, as it will not affect the broadleaf perennials and will be more effective than if misted.

Feral animal control

In general, the aim is to disturb the soil as little as possible in bush regeneration, but where rabbits are a problem, baiting, myxomatosis and shooting are unlikely to be completely effective, and burrow ripping will be necessary. The eradication of rabbits will enable the bush to regenerate much more easily without the grazing pressure.

Understorey replanting

Once the weed burden has been removed or greatly reduced, the understorey may start to regenerate by itself. If this doesn't happen, steps may need to be taken to encourage its return. This can take the form of scattering prepared seeds of understorey species, direct seeding, or planting of seedlings. Whatever strategy is used, it is necessary to wait until the weed seed bank has been sufficiently reduced so that further spraying over the top of the new understorey is either unnecessary or of a form that won't harm them (e.g. Fusilade™ for grass weeds).

Buffer planting

Buffer planting involves the use of hardier species like broombush (*Melaleuca* spp.) or oil mallees around the border of remnants to both expand the area, and reduce the effects of spray drift or nutrient import on the vegetation. Nutrient import will reduce the effectiveness of revegetation, as weeds can generally tolerate higher nutrient levels than native plants. Most natives are adapted to very nutrient-poor soils, and some nutrients can become toxic at levels well below those necessary for introduced crops. Nutrients can be imported by water and wind erosion, and in stock droppings.

Corridors

Corridor links are important for fauna habitat and biodiversity conservation. By linking remnants, birds and other fauna have access to larger areas of feeding and nesting habitat. The ideal minimum width for a corridor is 50 m.

A6. Revegetation species for land management units

The following table matches soil supergroups and species suitable for revegetation. Commercial species are listed first, with other species next.

Soil type	**Commercial woody species**	**Other trees, shrubs & perennials**
Wet or waterlogged	*Atriplex amnicola* (river saltbush) *Atriplex paludosa* (marsh saltbush) *Maireana brevifolia* (small-leafed bluebush) *Atriplex nummularia* (old man saltbush) *Atriplex bunburyana* (silver saltbush) *Melaleuca uncinata* (broombush)	***Trees*** *Casuarina obesa* (salt sheoak) *E. sargentii* (salt river gum) *E. kondininensis* (blackbutt) ***Shrubs*** *Halosarcia* spp. (samphire) ***Pasture perennials*** Puccinellia (tolerates waterlogging) Tall wheat grass (tolerates waterlogging) Salt water couch (tolerates inundation)
Cracking clays, Non-cracking clays, Shallow sandy duplexes	*E. salmonophloia* (salmon gum) *E. salubris* (gimlet) *Atriplex amnicola* (river saltbush) *Maireana brevifolia* (small leafed bluebush) *Santalum acuminatum* (quandong) *Santalum spicatum* (sandalwood)	***Trees*** *E. rudis* (flooded gum) *E. sargentii* (salt river gum) *E. loxophleba* (York gum) *E. ovularis* (small fruited mallee) *E. calycogona* (gooseberry mallee) *E. longicornis* (morrel) ***Shrubs*** *Acacia hemiteles* (tan wattle) *Acacia colletioides* (wait-a-while) *Acacia merrallii* (Merrall's wattle) *Cassia nemophila* (desert cassia) *Melaleuca adnata* ***Pasture perennials*** Lucerne Tall wheat grass (tolerates waterlogging) Strawberry clover (year-round moisture)
Sandy earths, Shallow loams, Loamy earths	*E. loxophleba* subsp. *Lissophloia* (smooth barked York gum) *Melaleuca uncinata* (broombush)	***Trees*** *E. wandoo* (wandoo/white gum) *E. accedens* (powderbark wandoo) *Acacia acuminata* (jam) *Allocasuarina huegeliana* (rock sheoak) *Acacia microbotrya* (manna gum) ***Shrubs*** *Kunzea pulchella* (granite kunzea) *Allocasuarina campestris* (tamma) *Leptospermum erubescens* (tea-tree) *Hakea recurva*

Revegetation species ….(continued)

Soil type	Commercial woody species	Other trees, shrubs & perennials
Shallow sands, Deep sands	*Melaleuca uncinata* (broombush) *Melaleuca acuminata* *E. astringens* (brown mallet on mallet hills)	***Trees*** *E. wandoo* (wandoo/white gum) *E. accedens* (powderbark wandoo) *E. loxophleba* (York gum) *E. sheathiana* (ribbon bark gum) *E. neutra* (redwood) *E. eremophila* (tall sand mallee) *E. erythronema* (white-barked mallee) *E. burracoppinenis* (Burracoppin mallee) *E. annulata* (open-fruited mallee) *E. calycogona* (gooseberry mallee) *E. argyphea* (silver mallet) *Acacia acuminata* (jam) *Melaleuca spathulata* (swamp mallet) *Xylomelum angustifolium* (sandplain woody pear) ***Shrubs*** *Acacia hemiteles* (tan wattle) ***Pasture perennials*** Lucerne Tall wheat grass (tolerates waterlogging) Strawberry clover (year-round moisture)
Ironstone gravelly soils	*Melaleuca uncinata* (broombush)	***Trees*** *Allocasuarina acutivalvis* (black tamma) *Allocasuarina corniculata* (grey tamma) *E. marginata* *E. calophylla* ***Shrubs*** *Allocasuarina campestris* (tamma) *Melaleuca conothamnoides* (wheatbelt honeymyrtle) *Leptospermum erubescens* (tea-tree) *Hakea scoparia* *Grevillea paradoxa* (bottlebrush grevillea)

Revegetation species ....(continued)

Soil type	Commercial woody species	Other trees, shrubs & perennials
Sandy duplexes, loamy duplexes	*E. marginata* *Allocasuarina huegeliana* (rock sheoak) *Acacia saligna* (golden wreath wattle)	***Trees*** *E. wandoo* (wandoo) *E. accedens* (powderbark wandoo) *E. calophylla* *Banksia attenuata* (slender banksia) *E. leptopoda* (Tammin mallee) *Acacia acuminata* (jam) ***Shrubs*** *Callistemon phoeniceus* (lesser bottlebrush) *Allocasuarina campestris* (tamma) *Melaleuca conothamnoides* (wheatbelt honeymyrtle) *Grevillea pritzelii* (black toothbrush grevillea) *Leptospermum erubescens* (tea-tree) ***Pasture perennials*** Tagasaste Veldt grass
Rocky or stony soils	*E. capillosa* (inland wandoo) *Melaleuca uncinata* (broombush) *E. astringens* (brown mallet)	***Trees*** *Acacia acuminata* (jam) ***Shrubs*** *Allocasuarina campestris* (tamma) *Grevillea huegelii*
Rock outcrop	*E. loxophleba subsp. Lissophloia* (smooth-barked York gum)	***Trees*** *Acacia acuminata* (jam) ***Shrubs*** *Leptospermum erubescens* (tea-tree) *Allocasuarina campestris* (tamma) *Borya nitida* (pincushions) *Grimmea* sp. *Pimelia* sp.

Oil mallees are an option on a number of these soil types. Further information can be obtained from the Department of Agriculture Revegetation on Farms information kit on Oil Mallees. Contact your local office for details.

A7. List of contacts and further information

Of the publications listed below, Farmnotes (FN), Bulletins, Miscellaneous Publications (MP), Factsheets, Treenotes, Technical Bulletins (TB) and Resource Management Technical Reports (TR) are from the Department of Agriculture.

Farming system contacts

Subject		***Contacts***	***Publications/websites***
Cropping options	Lower recharge farming systems and Warm season crops	WA Lucerne Growers' Inc c/- Dept of Agriculture, Narrogin 9881 0222 Western Australian No-Tillage Farmers' Association (Inc) Ph/fax: 9622 3395 Mobile: 0427 223 395 Dept of Agriculture Farming System Development Officer Narrogin 9881 0222 Centre for Cropping Systems Northam 9690 2000	WA No-Tillage Farmers' Assoc. www.wantfa.com.au "Low recharge farming systems, Case Studies on the South Coast" – MP 22/2000
Pasture options	Lucerne and other perennial pastures	As for cropping options above	"Perennial pastures for areas receiving less than 800 mm annual rainfall" - Bulletin 4253 "Establishing perennials in areas with less than 700 mm annual rainfall" FN 8/93 "Soil Guide" - Bulletin 4343. Relevant for wheat, barley, oats, lupins, canola, field peas, faba beans, chickpeas, annual clovers, serradella, medics, lucerne, phalaris, cocksfoot, tall fescue, perennial ryegrass, kikuyu, Rhodes grass, couch, paspalum, puccinellia, tall wheat grass, saltwater couch, tagasaste, saltland plants.

Subject		Contact	Publication/website
Pasture options	Lucerne		"Dryland lucerne – establishment and management" - FN 4/98 "Lucerne in pasture-crop rotations – establishment and management" - FN 135/2000 "Dryland Lucerne Information Booklet" Dept of Agric, Northam "Diseases and their control in lucerne" - FN 79/89 "Grazing sheep and cattle on dryland lucerne" - FN 36/2001 "Insect pests in lucerne" - FN 53/89 "Dryland lucerne: Getting it right every time" - Primary Industries of South Australia Bulletin 4/97 "Lucerne for pasture and fodder" - NSW Agriculture "Lucerne the queen of forages" –FN 65/94
Pasture options	Perennial grasses		"Puccinellia – perennial sweet grass" – brochure, Primary Industries of South Australia and Saltland Solutions "Puccinellia for productive saltland pastures" – FN 1/99 "Perennial grasses for animal production in the high rainfall areas of WA" - MP 2/98 "Use of native perennial grasses on farms in the wheatbelt of WA" – MP 8/99 "Green feed in summer – Case study" – FN 59/96
Fodder shrub options	Tagasaste and saltbush	Dept of Agriculture Farming System Officers Narrogin 9881 0222 Northam 9690 2000	"Tagasaste" - Bulletin 4291 "Tagasaste" - Factsheet 37/2000 "The feed value of the perennial fodder shrub tagasaste" - FN 50/2000 "Tagasaste" - FN 12/96

Subject		**Contact**	**Website/Publication**
Fodder shrub options	*Acacia saligna*	CALM Farm Forestry Unit Narrogin 9881 1113	
Commercial farm forestry	Radiata pine (*Pinus radiata*) Maritime pine (*Pinus pinaster*) WA eucalypts for sawlogs (for rainfall >450 mm) Eastern States eucalypts for sawlogs and other species Sandalwood Oil mallees	Forest Products Commission Guildford 9279 4088 Moora c/- Agriculture 9651 0526 CALM Farm Forestry Narrogin 9881 1444 Busselton 9752 1677 Como 9334 0333 Farm Forestry and Revegetation Team Dept of Agriculture Narrogin 9881 0222 Oil Mallee Company 9478 0340	"Agroforestry with widely-spaced pine trees" - Bulletin 4176 "Maritime Pine" - Revegetation on Farms Kit, Dept of Agric. Narrogin "Sandalwood" – Revegetation on Farms Information Kit, Dept of Agric. Narrogin "Eucalyptus Oil Mallee" - Revegetation of Farms Information Kit, Dept of Agric. Narrogin "Growing Pines for wood products" – Treenote 18/99 "Eucalyptus Oil Mallees" - Factsheet 30/2000 "Eucalyptus Oil Mallees" - FN 48/98 Forest Products Commission www.fpc.wa.gov.au Dept of Agriculture www.agric.wa.gov.au/programs/srd/farmforestry/ www.agric.wa.gov.au/progserv/natural/trees/ Dept of CALM www.calm.wa.gov.au/projects/tree_crop.html Oil mallees www.oilmallee.com.au
	Carbon credit trading	CALM Farm Forestry Unit Narrogin 9881 1113 Como 9334 0333	

Subject		***Contacts***	***Publications/websites***
Productive use of saline lands	Saltland plants	Saltland Pastures Association 9871 2041	"Saltland Pastures in Australia: A Practical Guide" - Bulletin 4312 "Saltland Pastures – Options and constraints" – Michael Lloyd & "Saltland Pastures? They are feasible and sustainable – we need a new design" – E.G. Barrett-Lennard and M. Ewing. 5th National PURSL Conference Tamworth NSW 1998. "Saltland management – revegetation" - FN 44/86 "Samphire for waterlogged saltland" FN 56/88 "Forage shrubs and grasses for revegetating saltland" - Bulletin 4153 "Saltland Pastures in Australia: A practical guide" - TB 4312 "Wheatbelt salinity – a review of saltland problems in south-western Australia" TB 52
Productive use of saline water	Saline aquaculture: Rainbow trout Black bream	Dept of Fisheries Narrogin (c/- Dept of Agric) 9881 0222	Dept of Fisheries "AQUAINFO" notes. www.wa.gov.au/westfish/aqua
Freshwater aquaculture	Yabbies and marron	Dept of Fisheries Narrogin (c/- Dept of Agric) 9881 0222	Dept of Fisheries www.wa.gov.au/westfish/aqua

Natural resource management

Subject		***Contacts***	***Publications / Websites***
Salinity	Salinity – general	Dept of Agriculture Narrogin 9881 0222 Northam 9690 2000	"Salinity at a glance" - FN 8/2000 "2000 State Salinity Strategy", State Salinity Council "Wheatbelt salinity – a review of the saltland problems in south-western Australia" - TB 52
Native vegetation management and revegetaion	Native vegetation management & revegetation for nature conservation	Greening Australia (WA) Bushcare Support Officers Northam c/o Avon Catchment Network 9690 2259 Land for Wildlife officers Coordinator, CALM Como 9334 0530 Narrogin 9881 9218 Mundaring 9295 1955 Revegetation on Farms Dept of Agriculture Narrogin 9881 0222	Bushcare technical notes CALM Wildlife Notes: "How to manage your granite outcrops" "How to manage your wandoo woodland" "Managing your bushland" Land for Wildlife's "Western Wildlife" magazine "Managing Dieback in Bushland" (Shire of Kalamunda, Dieback Working Group, NHT, Bushcare and CALM) "Fitting trees into the farm plan" - FN 102/88 "Reclaiming sandplain seeps with small blocks of trees" - FN 116/88 "Direct seeding native trees and shrubs" - FN 34/98
Rivers, creeks and wetlands	Protecting waterways and wetlands	Waterways WA Coordinator and Rivercare Officers Water and Rivers Commission Northam 9622 7055	Water and Rivers Commission www.wrc.wa.gov.au/protect/waterways Environmental Water Quality: A guide to sampling and measurement" – MP16/96
Engineering options	Surface water management	Land Conservation Officer / Hydrologist Dept of Agriculture Northam 9690 2000 Narrogin 988`0222 Water and Rivers Commission Perth 9278 0300 Northam 9622 7055	"Common Conservation Works Used in Western Australia" –TR 185 www.agric.wa.gov.au/environment/land/drainwise "Evaporation Basin Guidelines for Disposal of Saline Water" - MP 21/99

Subject		*Contacts*	*Publications / Websites*
	Groundwater management	Dept of Agriculture Hydrogeologist Narrogin 9881 0222 Northam 9690 2000	"An assessment of the Efficacy of Deep Drains Constructed in the Wheatbelt of Western Australia" - Bulletin 4391
	Groundwater pumping/Relief wells/Syphons	Dept of Agriculture Hydogeologist Narrogin 9881 0222 Northam 9690 2000	"Relief Wells in South Western Australia" – FN 42/2001 "Pumps: A method of financially assessing groundwater pumping used to mitigate salinity in South WA" – Resource Management TR 87 "Using pumps and syphons to control salinity at a saline seep in the Wallatin Creek Catchment" – TR 91
Soils	Acid soils, Soil structure & Water repellence	Dept of Agriculture Soils Officer Narrogin 9881 0222	"Management of Soil Acidity in Agricultural Land" – FN 80/2000 "Looking as Liming: Comparing Lime Sources" – FN 69/2000
Monitoring and evaluation	Monitoring and evaluation	Land Management Society Perth 9450 6862	Farm Monitoring Kit, Land Management Society

3 Funding opportunities

State Funding Opportunities	Natural Heritage Trust (NHT)	State NHT Coordinator Perth 9368 3168	Funding for projects including Bushcare, Rivercare, Landcare, farm forestry, fisheries, wetlands, and endangered species etc.
	Lotteries Commission/ Gordon Reid Foundation	Executive Officer, Gordon Reid Foundation for Conservation Perth 9340 5270 or 1800 655 270	Funding for non-profit groups in conserving and restoring indigenous plants, animals and micro-organisms and their natural environment
	Community Conservation Grants	Community Conservation Grants CALM Perth 9442 0300	Funding available for the conservation of flora, fauna and associated activities
	Dept of Fisheries – Aquaculture Development Fund	Aquaculture Development Council Perth 9482 7333	Funding available in Aquaculture Industry Development Projects and Marketing, Industry Promotion and Study tours.

Regional Funding Opportunities	Avon Catchment Council Biodiversity Program Funding High Value Public Assets Funding	PO Box 311, Northam 6401 9690 2250	Funding for fencing good quality bushland. Funding to protect public assets of high value e.g. river foreshores.

3. Useful community contacts

Agricultural Services & Contacts	Dept of Agriculture	Dept of Agriculture Narrogin 9881 0222 Northam 9690 2000 Cropline Freecall 1800 068 107	Access to technical information and staff, library resources, videos, publications and other current information and services
Landcare	Landcare Centres and Land Conservation District Committees (LCDC)	Landcare Centres: Pingelly 9887 0092 Brookton 9642 1106	Run by the community, to provide landholders with access to local natural resource management information and services.
Conservation and protecting the environment	Biodiversity	CALM District Offices	Information, material and advice on conservation and biodiversity issues.
	Regional natural resource management	Avon Catchment Council 9690 2000	Providing assistance to
	Land Management	Land Management Society PO Box 242 COMO WA 9450 6862	Land Management Society www.space.net.au/~lmsinfo
Support Services	Social Impacts of Salinity	Social Impacts of Salinity Coordinator Dept of Agriculture Narrogin 9881 0222	Offers community funding information, regional contacts, workshops and general follow up support
	Agcare	Central Agcare 9063 2037 Wheatbelt Office of General Practice Northam 9621 1530	Counselling to the farming community.

Useful agricultural internet sites

ABC Countrywide – http://www.abc.net.au/rural/news_states/trannm.htm

Transcripts of the ABC's daily National Rural News programs. 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 Department of Agriculture's AgFax service, which contains 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

Department of Agriculture – http://www.agric.wa.gov.au

Department of Fisheries – http://www.wa.gov.au/westfish/

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 –
http://www.rirdc.gov.au

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

The Woolmark Company – http://www.wool.com.au/

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