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Sustainable Land Management in the Ellen Brook Catchment

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Helping Communities Helping Australia

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INTRODUCTION

The Ellen Brook Catchment is a key catchment in the overall health of the Swan-Canning estuarine system. It has been identified as a major source of nutrients entering the estuary, exporting an average of approximately 77 t of nitrogen and 26 t of phosphorus per year. It is these nutrients that contribute to the periodic outbreaks of potentially toxic algal blooms in the Swan and Canning Rivers.

The Ellen Brook Catchment is also experiencing an increase in various forms of land degradation including soil salinity, wind erosion, water erosion, waterlogging and flooding. All of these forms of degradation have the potential to compromise the environmental, economic and social well being of the Catchment.

There are many different land uses within the Catchment including rural uses (such as cattle and sheep grazing), horticulture, commercial and industrial uses, an Air Force Base and urban and special rural residential areas.

The majority of these uses have been located in the area for a long time and all contribute to the export of nutrients from the Catchment to the Swan Canning estuary. In order to address the issues of land degradation and nutrient export, land uses, soil types, and management practices leading to land degradation need to be identified and modified through a shift towards sustainable land management practices.

A Catchment Management Plan has been developed for the Ellen Brook Catchment by the Ellen Brook Integrated Catchment Group outlining specific land management principles to help address each of the land degradation issues in the Catchment. Twelve Environmental Management Units have been identified within the Catchment according geomorphic province and soil landscape systems to provide land capability considerations and land management guidelines. The 12 Environmental Management Units provide a basis for this manual to describe best management information on:

- wind and water erosion;
- nutrient management;
- water and drainage management;
- water course and wetland management;
- salinity;
- acidity;
- agricultural and horticultural production and management; and
- vegetation and tree planting.

BACKGROUND

General

The Ellen Brook Catchment has a gauged area of 720 km^2 and is situated approximately 20 kilometres northeast of Perth (see **Figure 1**). It is the largest coastal sub-catchment of the Swan-Canning estuary, and is aligned roughly north-south. The central portion of the Catchment has been extensively cleared, primarily for agricultural use as well as some urban and industrial development.

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The main landuses within the Ellen Brook Catchment include grazing, forestry, annual and perennial horticulture, mining and extractive industries together with an expanding region of urban and rural residential development to the south. Townships include Ellen Brook, Bullsbrook and Muchea.

The Ellen Brook, which is winter flowing and summer dry, discharges into the upper Swan River. Discharge from the Ellen Brook represents 6% of the total water input into the Swan River estuary from all of the sub-catchments combined. Although this contribution is relatively quite small, the Ellen Brook contributes 36% of the total phosphorus load and 7% of the total nitrogen load annually into the Swan River estuary. This is particularly relevant to managing and preventing potentially toxic algal blooms in the upper Swan River system and the Swan-Canning estuary.

Climate

The Ellen Brook Catchment has a Mediterranean climate, with hot dry summers and cool wet winters. Average annual rainfall for the southern region of the Catchment is approximately 820 mm and this decreases to less than 660 mm in the northern region. The break of season usually occurs between mid April to mid May and the growing season typically lasts for about seven months. On average, ninety percent of the average annual rainfall falls between May and October.

Average daily temperatures typically range between 17°C (minimums) and 29°C (maximums) in summer and between 9°C (minimums) and 18°C (maximums) in winter. Annual pan evaporation is 934 mm, and the average daily evaporation ranges from 10.8 mm in January to 1.8 mm in June.

Geology and geomorphology

The geology of the Ellen Brook Catchment is dominated by the presence of the Darling Fault, a major regional fault line which separates the old crystalline rocks of the Yilgarn block to the east and the deep sediments of the Perth Basin to the west. The regional geology has been a significant factor affecting the geomorphology and soils developed throughout the Catchment across geological time.

Figure 1. Location map.

The Ellen Brook Catchment consists of three distinct geomorphological regions[1], the Darling Plateau, the Dandaragan Plateau and the Swan Coastal Plain (see **Figure 2**). Each region is defined mainly on broad geological differences and very broad landform types.

Each region can be further subdivided into sub-regions. Each of these sub-regions exhibit differing landform elements to the extent that different geomorphological sub-regions (which posses different combinations of landforms and soils) will require different land management styles and practices to prevent degradation, depending on the characteristics of the landform type and soils.

Table 1 below details the geomorphological regions and sub-regions that exist within the Ellen Brook Catchment.

Table 1. Geomorphological regions and sub-regions within the Ellen Brook Catchment

Geomorphological region	Geomorphological sub-region	Dominant land management unit
Darling Plateau	• Lateritic uplands. • Dissected valleys, spurs and valleys below the scarp surface; and • Minor valleys and drainage depressions.	• Gravel slopes and uplands. • Shallow slopes. • Sandy duplex slopes.
Dandaragan Plateau	• Gentle scarp area. • Sandy lateritic uplands; and • Relatively shallow incised valleys.	• Steep slopes. • Red sandy slopes and uplands. • Yellow to brown sandy slopes and uplands. • Pale sandy rises and slopes.
Swan Coastal Plain	• Aeolian deposits, mainly to the west; and • Fluvial deposits associated with the Ellen Brook drainage line running along the central axis of the Catchment.	• Gravel slopes and uplands. • Pale sandy rises and slopes. • Muchea limestone flats. • Winter wet flats and footslopes.

[1] Geomorphology is the science concerned with the development of the land surface over time and the processes that create it. Geomorphology groups areas of land into similar units called landforms, which share similar landform elements such as surface slope angles, underlying parent geology (underlying hard rock), soils, hydrological processes (how water reacts to the landform) and vegetation communities, and the development or evolution of different landforms is different over time. Groupings of similar landforms are often referred to as geomorphological units or geomorphological regions.

Figure 2. Geomorphological regions of the Ellen Brook Catchment.

Soils and landforms

A number of Land Resource Surveys have been carried out across the Ellen Brook Catchment area, and the soils found within the Catchment have been grouped according to the geomorphic setting in which they exist. **Table 2** details the Land Management Units (LMUs) found within the Ellen Brook Catchment.

A LMU is an area of land that can be separated from other areas based on its soil type and/or other physical characteristics. Agricultural productivity or the way you manage it is the same over its entire area. Management is the key factor when delineating LMU's. Although this is usually related to soil types, other factors such as landform or hydrological characteristics may be significant. For example, even though two areas may have different soil types, they may be categorised as the same LMU due to other landform related issues such as salinity or waterlogging.

Table 2. LMUs found within the Ellen Brook Catchment

Land Management Units
• Shallow gravels and ironstone
• Gravel slopes and uplands
• Steep slopes
• Shallow rocky slopes
• Loamy slopes
• Sandy duplex slopes
• Red sandy slopes and uplands
• Yellow to brown sandy slopes and uplands
• Pale sandy rises and slopes
• Pale sandy duplex flats
• Muchea limestone flats
• Loamy flats and terraces
• Winter wet flats and footslopes
• Salt affected land
• Swamps and drainage lines

YOUR PROPERTY, THE LAND DEGRADATION RISKS AND OPPORTUNITIES

Step 1: Where is your property?

Use the Environmental Management Unit (EMU) maps (**Figures 3, 4 and 5**) to determine where your property is in the Ellen Brook Catchment. These maps identify the LMUs likely to be found on your property. Ensure that you also look at nearby LMU's as the scale of the mapping means they are indicative only. Once you have roughly determined what LMUs you are dealing with, refer to the LMU Summary Sheets and take a look around your property and confirm what your LMU's are. The summary sheets contain information on where in the landscape the LMU is found, typical soil attributes, land degradation issues, general management guidelines associated with the unit and where to find further information in this document.

Step 2: What are the causes and management options for the land degradation risks?

Section 3 outlines the causes of and general management options for the major land degradation risks that are likely to be relevant on cleared land within the Ellen Brook Catchment. By using the table of land degradation risks in the Catchment and the LMU summary sheets you can determine what degradation issues are likely to face you and how you can manage them. (Check with your neighbours to confirm this.)

Step 3: What are the current key agricultural, horticultural and environmental management practices for managing the land degradation risks on your property?

Sections 4-7 outline the key management practices that can be adopted to address the land degradation risks on your property. Each management practice is a summary of current best practice information. The contact list informs you where further information can be obtained.

Figure 3. LMU Map 1.

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Figure 4. LMU Map 2.

Figure 5. LMU Map 3.

SHALLOW GRAVELS AND IRONSTONE

WA Soil Groups: Shallow gravels

Description and attributes

Landform

- Flat to gently undulating terrain with common surface ironstone gravel, stone or boulders.
- Occurs mainly within upland areas of the Darling and Dandaragan plateaux, and less commonly within their foothills and within minor portions (bog-iron ore areas) of the coastal alluvial plain.

Soils

- Shallow gravels - ironstone gravelly soils with cemented gravel at < 80 cm; often < 30 cm.
- Yellow, brown or reddish coloured in top 30 cm.
- High gravel content (> 20%, but often much higher) throughout.
- Sandy, or less commonly loamy, matrix.
- Overlies cemented gravels (duricrust or bog-iron ore).
- Water-holding capacity is generally low.
- Gravel and stone limits workability.
- High phosphorus absorption ability due to iron content.
- Generally limited available shallow groundwater.
- Restricted soil depth and rooting conditions.

Land degradation issues	Management guidelines	Section for further information
• High groundwater recharge hazard through fractured ironstone if cleared. • Any extensive rocky areas can create rapid runoff with risk of water erosion downslope. • Commonly associated with areas of remnant vegetation. • Rock outcrop hinders weed control, particularly for Patterson's Curse.	• Fence off remaining bushland to enable regeneration of understorey species. • Where already cleared, stocking rate for annual pasture is 0-2 DSE/ha. • Generally not suitable for perennial pasture or horticultural uses.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4)

GRAVEL SLOPES AND UPLANDS

WA Soil Groups: Duplex sandy gravel, Loamy gravel and Deep sandy gravel

Description and attributes

Landform

- Gentle to moderately sloping terrain (gradients < 15%) with common surface gravel, but few stones or boulders.
- Dominant land type of the Darling Plateau and Foothills.
- Some opportunities for siting dams in areas of duplex soils.

Soils

- Yellow brown gravels usually with variable amounts of duricrust and laterite. Cemented gravel is commonly present at a depth of 1 to 2 m.
- Duplex sandy gravels (dominant) have greater than 20% gravel within surface 15 cm and a predominantly sandy matrix over gravelly sandy clay loam to gravelly light clay at 30-80 cm.
- Deep sandy gravels (see photograph) and deep loamy gravels also occur.
- High gravel content limits soil water-holding capacity.
- High phosphorus absorption ability associated with iron rich soils.
- Soil depth may be restricted in minor areas.

Land degradation issues	Management guidelines	Section for further information
• Moderate water erosion risk on steeper portions (10-15% gradient). • A perched watertable may occur for limited periods within duplex sandy gravels on lesser gradients. • Sandy gravel slopes are susceptible to water repellence, particularly during 'break-of-season' rains. • These are often areas of significant water recharge.	• Fence off any remaining bushland. • Extensively used for grazing of annual pastures but also suitable for perennial grasses which would sustain higher stocking rates. • Potential stocking rate is 10 DSE/ha for annual pasture; 25 DSE/ha for perennial pasture. • Horticultural uses often restricted by lack of readily available water supply. • On slopes greater than 5% with duplex sandy gravels, use earthworks to store runoff or direct it to vegetated waterways.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4) • Key Horticultural Management Practices (Section 5)

STEEP SLOPES

Description and attributes

Landform

- Moderate to steep slopes with gradients in excess of 15%.
- Occurs within minor portions of the Darling and Dandaragan Plateaux.
- Machinery access restricted due to slope gradients and rock outcrop in some areas.
- Opportunities for siting dams.

Soils

- Predominantly loamy earths (loamy surfaced soils); either loamy throughout or grading to clay by 80 cm.
- Less commonly, loamy duplexes with texture contrast at < 80cm.
- White kaolin clays often at depth.
- Red or brown within top 30 cm.
- Neutral to acid pH.
- Generally friable topsoil and porous throughout.
- Minor gravel (ironstone and non-ironstone) may be present
- Generally productive soil with good physical properties.

WA Soil Groups: Friable red-brown loamy earth, Brown loamy earth and Red shallow loamy duplex

Land degradation issues	Management guidelines	Section for further information
• High risk of water erosion and phosphorus export due to slope gradients. • Particularly susceptible to water erosion under heavy grazing pressure when surface permeability is reduced and rapid runoff generated. • Although the soil is capable of retaining nutrients, run-off rates exacerbate the risk of nutrient loss. • Possibly susceptible to landslips near seepages or on cleared slopes with gradients greater than 25%.	• Manage stock numbers to retain surface cover. • Low stocking rates due to risk of erosion - 6 DSE/ha for annual pasture and 10 DSE/ha for perennial pasture. • Generally unsuitable for horticulture due to erosion risk and machinery access difficulties. • Increase deep rooted vegetation cover where possible. • Use earthworks to store runoff or direct it to vegetated waterways. • Control of nutrient loss will be affected through maintenance of vegetative cover, and control of surface runoff and erosion. • Establish sediment and nutrient filter buffer zones (vegetative) adjacent to nearby watercourses.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4) • Protecting and Enhancing your Living Stream (Section 6)

SHALLOW ROCKY SLOPES

WA Soil Groups: Rocky or stony soils

Description and attributes

Landform

- Moderately sloping terrain within Darling and Dandaragan Plateaux with locally common exposure of basement rocks.

Soils

- Variable shallow soils, predominantly red-brown earths, loams and clays within upland terrain.
- Rocks and stones occur throughout the profile.
- Neutral to acid pH.
- Low to moderate water-holding capacity due to limited depth.
- Access and use of machinery for cultivation is restricted by rock outcrop in some areas.
- Agricultural use commonly restricted to grazing.

Land degradation issues	Management guidelines	Section for further information
• Localised rocky areas within valleys and foothills can create rapid runoff with risk of water erosion downslope. • Although the soil is often capable of retaining nutrients, run-off rates can exacerbate the risk of nutrient loss.	• Fence off any remaining bushland. • Rocky slopes generally poorly suited to grazing; potential stocking rates - 0-2 DSE/ha for annual pasture. • Generally not suited for perennial pasture. • Control of nutrient loss will be affected through maintenance of vegetative cover and control of surface runoff and erosion.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4)

LOAMY SLOPES

Description and attributes

Landform

- Gentle to moderately sloping terrain with gradients less than 15%.
- Occurs within valleys of the Darling, and less commonly, Dandaragan Plateau.
- Opportunities for siting dams.
- Groundwater availability will be site-specific.

Soils

- Predominantly loamy earths (soils with a loamy surface and either loamy textures throughout or grading to clay by 80 cm).
- Less commonly, loamy duplexes with texture contrast at < 80 cm.
- Generally well drained with brown or reddish topsoil.
- Neutral to acid pH.
- Minor gravels may be present in subsoil.
- Versatile agricultural soil, productive for both grazing and horticulture (subject to water availability).

WA Soil Groups: Brown loamy earth, Friable red-brown earth and Brown deep loamy duplex

Land degradation issues	Management guidelines	Section for further information
• Moderate risk of water erosion and phosphorus export (particularly where slopes are 10-15%). • Areas subject to excessive stocking can develop a hardsetting surface which can increase surface runoff and risk of erosion.	• Manage stock numbers to retain surface cover. • Potential stocking rates - 10 DSE/ha for annual pasture; 25 DSE/ha for perennial pasture. • Use earthworks to store runoff or direct it to vegetated waterways. • Fence off remaining bushland to exclude stock. • Increase deep rooted vegetation where possible. • Establish sediment and nutrient filter buffer zones (vegetative) adjacent to nearby watercourses. • Control of nutrient loss will be affected through maintenance of vegetative cover and control of surface runoff and erosion.	• Land Degradation Risks (Section 3) • Pasture Management (Section 4) • Vegetation and Remnants (Section 6) • Water Course Management (Section 6)

SANDY DUPLEX SLOPES

Description and attributes

Landform

- Slopes (< 15% gradient) within moderately dissected terrain of the Darling or Dandaragan Plateau.
- Opportunities for siting dams.

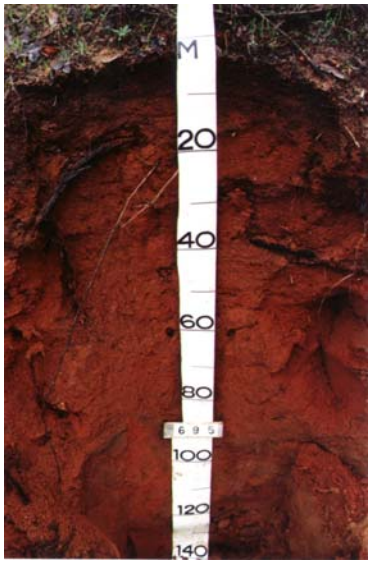
Soils

- Sandy duplex soils with greyish sandy surface layers over a sandy clay loam to light clay at < 80 cm, and sometimes < 30 cm depth.
- Usually yellowish coloured subsoil, and mottling is common.
- Neutral to acid pH subsoil.
- Ferruginous or quartzitic gravel may be present, especially above clay.

WA Soil Groups: Grey shallow sandy duplex and Grey deep sandy duplex

Land degradation issues	Management guidelines	Section for further information
• Sandy surfaces can be susceptible to wind erosion. • Lower slopes may be susceptible to salinity. • Seasonal waterlogging may occur above the clay on lower slopes. • Moderate risk of phosphorus export since grey sandy topsoils are only weakly retentive of nutrients applied as fertiliser. • Moderate risk of soil acidification.	• Fence off remaining areas of natural bush. • To avoid wind erosion, manage stock numbers to retain surface cover. • Potential stocking rate - 6-10 DSE/ha for annual pasture; 15-20 DSE/ha for perennial pasture. • Soil acidification, if present, should be addressed through liming. • Develop fertiliser management programme based on soil testing and: – applying only specific nutrients needed; – applying nutrients at a more strategic time; – using a slow release fertiliser source. • Use earthworks to store runoff or direct it to vegetated waterways. • Establish sediment and nutrient filter buffer zones (vegetation) adjacent to any nearby watercourses. • Increase deep rooted vegetation where possible.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4) • Fertiliser Application (Section 4) • Soil and Tissue Testing (Section 4) • Water Course Management (Section 6)

RED SANDY SLOPES AND UPLANDS



Description and attributes

Landform

- Undulating uplands and gentle slopes (less than 10% gradient) within subdued dissected portions of the Dandaragan Plateau and on very minor areas of the Coastal Plain.

Soils

- Red sands or earthy sands, greater than 80 cm deep.
- Well drained, permeable soils.
- Neutral to acid pH.
- Minor gravel may be present in subsoil.
- Fair to poor water-holding characteristics.
- Moderate nutrient (phosphorus) retention ability.
- Well suited to horticultural use (subject to availability of water for irrigation).

WA Soil Groups: Red deep sand

Land degradation issues	Management guidelines	Section for further information
• Prone to wind erosion in exposed positions. • Moderate groundwater recharge hazard under annual agriculture.	• To avoid wind erosion, manage stock numbers to retain surface cover. • Potential stocking rate - 7 DSE/ha for annual pasture; 20 DSE/ha for perennial pasture. • Strategic location of windbreaks to protect from wind erosion. • Increase use of deep rooted vegetation cover where possible. • Fence off any remaining areas of natural bush. • Develop fertiliser management programme based on soil testing and: – applying only specific nutrients needed; – applying nutrients at a more strategic time; – using a slow release fertiliser source.	• Land Degradation Risks (Section 3) • Pasture Management (Section 4) • Windbreaks (Section 5) • Vegetation and Remnants (Section 6) • Fertiliser Application (Section 4) • Soil and Tissue Testing (Section 4)

YELLOW TO BROWN SANDY SLOPES AND UPLANDS

WA Soil Groups: Yellow deep sand and Brown deep sand

Description and attributes

Landform

- Undulating uplands and gentle slopes (less than 10%) within the Dandaragan Plateau and in the foothills adjacent to the Coastal Plain.

Soils

- Yellow or brown sands or earthy sands, which are greater than 80 cm deep, are dominant. A pale or bleached subsurface layer can occur within the soil profile.
- Well to rapidly drained sands. Dry in summer with maximum watertable usually > 1.5 m from surface.
- Variable amounts of gravel, and often with a small, but noticeable increase in clay content deeper in the profile.
- Neutral to acid pH.
- Generally poor water-holding characteristics.
- Moderate nutrient (P) retention ability due to depth of sand and amount of iron oxide (geothite).
- Well suited to horticultural use (subject to availability of water for irrigation).

Land degradation issues	Management guidelines	Section for further information
• Prone to wind erosion in exposed positions. • Moderate groundwater recharge hazard under annual agriculture.	• To prevent wind erosion, manage stock numbers to retain surface cover. • Potential stocking rate - 6 DSE/ha for annual pasture; 20 DSE/ha for perennial pasture. • Strategic location of windbreaks to protect from wind erosion. • Increase use of deep rooted vegetation cover where possible. • Fence off any remaining areas of natural bush. • Conservative use of fertilisers given the rapid permeability of sandy soils. • Develop fertiliser management programme based on soil testing and: - applying only specific nutrients needed; - applying nutrients at a more strategic time; - using a slow release fertiliser source.	• Land Degradation Risks (Section 3) • Pasture Management (Section 4) • Wind Breaks (Section 5) • Vegetation and Remnants (Section 6) • Fertiliser Application (Section 4) • Fertiliser Use in Horticulture (Section 5) • Soil and Tissue Testing (Section 4)

PALE SANDY RISES AND SLOPES

Description and attributes

Landform

- Low relief dunes and sandplain on Coastal Plain, and less commonly within the Dandaragan Plateau.

Soils

- Pale leached or bleached deep sands which are white, grey or pale yellow within the top 30 cm and greater than 80 cm deep.
- Neutral to acid pH.
- Rapidly drained, highly permeable, leached soils.
- Minor ironstone gravel may be present in subsoil.
- Coffee rock, clay or duricrust may occur at greater than 80 cm.
- Very dry in summer with highest watertable normally greater than 2 m from surface in winter.
- Inherently poor fertility and water-holding characteristics.

WA Soil Groups: Pale deep sand

Land degradation issues	Management guidelines	Section for further information
• Moderate potential for phosphorus export due to high permeability and very low ability to retain nutrients. (Note. not high due to depth of soil before watertable.) • Provides rapid recharge to underlying shallow groundwater systems. • Moderate to high potential for wind erosion particularly in exposed positions. • Prone to water repellence, especially after legume cropping.	• Fence off any remaining areas of natural bush. • Increase use of deep rooted vegetation cover where possible. • Clearing and stocking not recommended. • Shallow rooted pasture species cannot persist on these sands. • Deeper rooted perennial grasses required, although commonly it is not economic to fertilise. • Generally not recommended for irrigated horticultural use due to significant risk of nutrient leaching and groundwater recharge. • If used for horticulture, soil amendments and careful scheduling of fertiliser applications are needed. • Other potential uses include commercial timber production (*Pinus pinaster*), tagasaste establishment for beef production, or wildflower production. • Strategic location of windbreaks required to protect from wind erosion.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4) • Key Horticultural Management Practices (Section 5) • Soil Amendments (Section 4) • Alternative Industries (Section 7) Windbreaks (Section 5)

PALE SANDY DUPLEX FLATS

Description and attributes

Landform

- Sandplain associated with the oldest inland dune system, and portions of the alluvial plain.
- Commonly occur in association with wetland depressions.

Soils

- Grey deep sandy duplex soils dominant with pale greyish sandy surface layers over mottled grey or yellowish brown clay at 30-80 cm. Less commonly sand over a ferricrete hardpan, shallow duplex (clay subsoil at less than 30 cm) or gravelly brown duplex soils.
- Moderately well drained with neutral to acid pH subsoil.
- Minor ironstone gravel may be present on top of clay layer.
- Sandy topsoils are inherently infertile.

WA Soil Groups: Grey deep sandy duplex, Yellow brown deep sandy duplex and Shallow variants of above

Land degradation issues	Management guidelines	Section for further information
• Prone to wind erosion if left bare of surface cover. • Seasonal waterlogging may occur for short periods. • High potential for nutrient losses particularly phosphorus. • Any drainage channels used to alleviate waterlogging may rapidly transport leached nutrients. • Prone to water repellence and soil acidity. • Partial or low risk of salinity.	• Develop fertiliser management programme based on soil testing and: - applying only specific nutrients needed; - applying nutrients at a more strategic time; - using a slow release fertiliser source. • Annual pasture may have a stock carrying capacity of 5 DSE/ha or 15-20 DSE/ha when combined with perennials. • Reduce topsoil acidity by liming. • To avoid wind erosion, manage stock numbers to retain surface cover. • Not recommended for irrigated horticultural use due to significant risk of nutrient leaching and groundwater recharge. • If used for horticulture soil amendments and careful scheduling of fertiliser application are needed. • Fence off any remaining areas of natural bush.	• Land Degradation Risks (Section 3) • Fertiliser Application (Section 4) • Fertiliser Use in Horticulture (Section 5) • Soil and Tissue Testing (Section 4) • Pasture Management (Section 4) • Wind Breaks (Section 5) • Key Horticultural Management Practices (Section 5) • Soil Amendments (Section 4) • Vegetation and Remnants (Section 6)

MUCHEA LIMESTONE FLATS

Description and attributes

Landform

- Flat to very undulating terrain over marl (limestone) on alluvial portions of the Coastal Plain and with locally common patches of Muchea limestone outcrop.

Soils

- Pale shallow sands (less than 80 cm deep) over marl on the Coastal Plain.
- Alkaline pH.
- Low water-holding capacity.
- Access and use of machinery for cultivation is restricted by rock outcrop in some areas.
- Agricultural use commonly restricted to grazing.

WA Soil Groups: Pale shallow sand and Rocky or stony soils

Land degradation issues	Management guidelines	Section for further information
• Limestone or underlying calcareous clays restrict drainage. • Depressions are subject to waterlogging and are prone to salinity. • High alkalinity and prolonged waterlogging are precursors to soil nutrient deficiency.	• Well managed pasture on better drained portions can have a carrying capacity of 8-10 DSE/ha and are also suitable for perennial pasture with a carrying capacity of up to 20 DSE/ha. • Fence off any remaining bushland.	• Land Degradation Risks (Section 3) • Pasture Management (Section 4) • Vegetation and Remnants (Section 6)

LOAMY FLATS AND TERRACES

WA Soil Groups: Brown loamy earth, Brown deep loamy duplex and Yellow loamy earth

Description and attributes

Landform

- Alluvial terraces and flood plains associated with major watercourses.
- Generally well drained with only minor perched watertables on flatter areas each winter.

Soils

- Predominantly loamy earths (soils with a loamy surface and either loamy throughout or grading to clay by 80 cm).
- Less commonly, loamy duplexes with texture contrast at < 80 cm.
- Generally well drained with brown or reddish topsoil.
- Nutrient retentive soils.
- Neutral to acid pH.
- Minor gravels may be present in subsoil.
- Often formed on recent alluvium.
- Versatile, productive agricultural soil.

Land degradation issues	Management guidelines	Section for further information
• Moderate risk of phosphorus export, despite nutrient retentive nature of soil due to proximity to rivers, rare flooding, and associated erosion risk. • Partial or low risk of salinity due to landscape position and underlying sediments. • Moderate risk of soil structure decline and subsurface compaction.	• To avoid wind erosion, manage stock numbers to retain surface cover. • Potential stocking rates are - 10 DSE/ha for annual pasture; 25 DSE/ha for perennial pasture. • Maintain vegetated buffer zones along nearby watercourses to minimise risk of phosphorus export through soil erosion. • Restrict stock access from these areas to any adjacent waterways. • Apply appropriate setbacks from nearby watercourses for any horticultural use on these areas.	• Land Degradation Risks (Section 3) • Pasture Management (Section 4) • Water Course Management (Section 6) • Protecting and Enhancing your Living Stream (Section 6)

WINTER WET FLATS AND FOOTSLOPES

WA Soil Groups: Semi-wet soil and Wet soil and clays

Description and attributes

Landform

- Imperfectly to poorly drained flats and slight depressions within the Coastal Plain, or footslope seepage areas, with watertables at or near the surface throughout winter.
- Includes significant areas of cleared or degraded 'palusplain' wetlands.

Soils

- A wide variety of soils which are characteristically waterlogged to 30-80 cm for much of the year.
- Acid to neutral pH and usually with dark grey, brown or black topsoil.
- Variable clay subsoils are only slowly permeable and may contain bog iron.
- Clayey soils hold water strongly, restricting the amount available for plant growth.

Land degradation issues	Management guidelines	Section for further information
• Waterlogging and seasonal inundation limit agricultural land use options to grazing. • Prolonged inundation limits pasture growth, although summer pastures are highly productive on the periphery of the wetter areas. • High potential for nutrient loss. • Drainage channels generally required to alleviate waterlogging. However such channels can rapidly transport leached nutrients into natural drainage systems. • Moderate risk of salinity and soil acidification.	• Fence off any remaining areas of natural bush. • Manage stock numbers to retain surface cover. • Potential stocking rates - 10 DSE/ha for annual pasture; 25 DSE/ha for perennial pasture. • Address soil acidification (if present) through liming. • Establish waterlogging-tolerate legumes and grasses. • Develop fertiliser management programme based on soil testing and: – applying only specific nutrients needed; – applying nutrients at a more strategic time; – using a slow release fertiliser source.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Pasture Management (Section 4) • Fertiliser Application (Section 4) • Soil and Tissue Testing (Section 4)

SALT AFFECTED LAND

WA Soil Groups: Saline wet soil and Undifferentiated saline soils

Description and attributes

Landform

- Minor portions of the poorly drained flats on the Coastal Plain and, less commonly, narrow valley floors or lower valley slopes within the Dandaragan Plateau.

Soils

- Various soils which are characteristically seasonally waterlogged and currently subject to salinity.
- Seasonally wet to within 80 cm for a major part of the year.
- Commonly duplex soils although also sands, loams and clays, often over a hardpan layer.
- Limitations associated with salinity and waterlogging prohibit cropping or horticultural uses.

Land degradation issues	Management guidelines	Section for further information
• Waterlogging and high salinity severely limits growth of most plants, except halophytes. • These areas are also frequently subject to water and/or wind erosion due to lack of protective surface vegetation. • High risk of phosphorus export (if fertilised) due to poor vegetative growth, subsequent risk of erosion, and susceptibility to waterlogging and inundation.	• Establish waterlogging and salt tolerant species. • Fence off from grazing stock. • Fencing remnant vegetation such as *Allocasuarina obesa* and *Eucalyptus rudis* may encourage self-seeding. • Improve surface drainage (subject to ensuring 'downstream' waterbodies or land uses are not adversely affected).	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6)

SWAMPS AND DRAINAGE LINES

Description and attributes

Landform

- Drainage lines and swamps (basin wetlands) which form a functional part of the natural drainage system.

Soils

- Various soils depending on position within catchment and nature of underlying geology.
- Predominantly wet or semi-wet soils characterised by extensive periods of waterlogging and susceptibility to erosion and sediment transport.

WA Soil Groups: Wet soil and Semi-wet soil

Land degradation issues	Management guidelines	Section for further information
• High risk of phosphorus export (particularly from stock faeces) within drainage lines. • Very high risk of waterlogging and inundation precludes agricultural uses. • High risk of erosion associated with destruction of fringing vegetation along banks of watercourses. • Reduction in biodiversity and habitat values. • Some areas subject to salinity.	• Fence off and protect from stock. • In degraded areas re-establish fringing vegetation using native species. • Eradicate exotic weeds.	• Land Degradation Risks (Section 3) • Vegetation and Remnants (Section 6) • Weed Control (Section 4)

VEGETATION OF THE ELLEN BROOK CATCHMENT

The diversity of vegetation in the Ellen Brook Catchment prior to settlement (see **Figure 6**) has been mapped by Heddle *et al.* (1980) using landform and soils as a basis for identifying the major vegetation complexes.

Swan Coastal Plain Vegetation

The Swan Coastal Plain once supported a rich flora of Jarrah (*Eucalyptus marginata*), Marri (*Eucalyptus calophylla*) and *Banksia* woodland. The low-lying plain has been extensively cleared by early settlers to establish pastures, market gardening and other uses. West of the Brand Highway the Bassendean Dune system consists of low hills interspersed with low-lying poorly drained areas. *Banksia* low woodland occurs on the hills, with Tee Tree and Paperbarks (*Melaleuca* spp.) and Swamp Sheok (*Casuarina obesa*) occurring in the low-lying swampy areas and drainage lines.

Dandaragan Plateau vegetation

On the southern portion of the Dandaragan Plateau, bounded by the Darling Fault to the east and the Gingin Scarp to the west, the original cover was woodland of Marri and Wandoo (*Eucalyptus wandoo*) with patches of Jarrah forest. North of the Great Northern Highway, the plateau becomes sandier and supports *Banksia* woodland with scattered Marri and Jarrah thickening in patches to a Jarrah-Marri forest.

Darling Plateau vegetation

On the Darling Plateau, Jarrah occurs on the laterite uplands and associated scree slopes, although there is more open vegetation where granite outcrops protrude through the lateritic mantle. While Jarrah is the dominant tree it is usually accompanied by Marri and on some sites will also be associated with Blackbutt (*Eucalyptus patens*), Wandoo and Powderbark (*Eucalyptus accedens*).

Remnant vegetation

Satellite imagery of remnant vegetation in the Ellen Brook Catchment indicates that a vast proportion of land has been cleared. The main areas of clearing appear to be on the western margin of the Darling Plateau where nearly all of the land is cleared, the Dandaragan Plateau where nearly 50% of vegetation is cleared, and large tracts of the southern segment of the Ellen Brook valley.

Remnant vegetation is still present in the following areas:

- State forests.
- Foothills of the Darling Scarp.
- Local streamlines and wetlands; and
- Nature reserves and national parks.

Figure 6. Vegetation.

A3 SIZE PAGES FOR FIGURES 6 AND 7

There are also areas of remnant vegetation that appear in System 6 Reserves, as well as those that are included in *Bush Forever* (Western Australian Government, 2001). Other areas of remnant vegetation are contained within Crown Land and areas reserved for military purposes.

Bush Forever

Bush Forever (Western Australian Government, 2001), formally known as *Perth's Bushplan* (WAPC 1998), is intended to bring a whole-of-government approach to the setting aside of natural vegetation areas to meet the community's needs for conservation and compatible recreation as Perth continues to grow into the 21st century. *Bush Forever* is concerned with the protection of regionally significant bushland, however it does not include areas which may be locally significant.

The Ellen Brook Catchment contains approximately 26 regionally significant *Bush Forever* sites. Examples include the Ellen Brook Nature Reserve, the Twin Swamps Nature Reserve and Melaleuca Park.

FAUNA

Appendices B to **F** list the mammals, frogs, birds, reptiles and fish that may exist, or previously existed, in the general region around Perth. Introduced feral foxes and cats, loss of habitat through clearing of native vegetation, filling of wetlands and other water related impacts have had a severe impact on the distribution and abundance of native fauna. Small mammals in particular have been adversely affected, and a number of these species are now locally extinct.

The Department of Conservation and Land Management's (CALM) Western Shield program (fox baiting) in State forests and large conservation reserves has resulted in populations of small mammals reappearing (e.g. Chuditch, Woylies and Tammars). Private organisations have established wildlife sanctuaries at Chidlow (Karakamia) and near the Avon Valley National Park (Paruna).

The Ellen Brook Catchment is home to one of the most endangered animals in Australia, the Western swamp tortoise *(Pseudemydura umbrina)*. A captive breeding program involving the Perth Zoo has been very successful in recent years and CALM is now embarking on the next stage, involving the release of animals into new areas. Good water quality, suitable habitat, fox and cat control and catchment health are critical issues for the animal's long term survival.

Protection and management of remnant vegetation, creation of wildlife corridors, revegetation, streamlining, and planting local species of trees, shrubs, sedges and rushes are ways in which you can help to improve conditions for local fauna species and increase their abundance and diversity.

Frog populations around the world are under threat from many pressures, most recently a serious viral disease. Our Western Australian frog populations have not escaped harm. FrogWatch has

been established to raise the awareness of this threat and to provide advice to people about what they can do to protect frog populations.

RANGE OF LANDUSES IN THE ELLEN BROOK CATCHMENT

Figure 7 shows the range of land uses within the Ellen-Brook Catchment.

These landuses can broadly be grouped into:

- grazing;
- horticulture;
- fodder production;
- timber production;
- mining/basic materials extraction;
- industrial; and
- urban.

Below is a description of some of the major landuse groups (by area) and the opportunities that exist for sustainable land management practices to be adopted.

Grazing

Grazing of legume based annual pastures is the most common land use in the Catchment. Beef cattle for yearling production and horses for the racing industry and other equestrian activities are the main grazing livestock, followed by sheep and smaller industries such as emus, ostriches and alpacas.

Annual pastures commonly contain a mixture of various legumes, annual ryegrass and capeweed.

Subterranean clover is the main legume used. Other legumes such as balansa and Persian clover are common in waterlogged areas. Crimson, arrowleaf and serradella also have a place in pastures.

The Catchment also contains large areas of perennial grasses such as kikuyu, paspalum, couch, Veldt grass and more recently Rhodesgrass, which can be highly productive once well established.

The greatest gains in productivity can be made by careful pasture management. Careful pasture management involves using strict rotational grazing based on the emergence of ‘the third leaf’ in pasture grasses and accessing the feed on offer and moving livestock to fresh areas within a few days.

Small areas of irrigated perennial pastures can often be found on horse properties in the Catchment, this form of intensive agriculture can treble the stocking rate of most LMU’s.

Figure 7. Landuse.

A stocking rate is defined as the number of stock, e.g. sheep, cattle, horses or any other type of animal that can consistently be kept on a piece of pasture all year round with minor additional feed and without causing environmental degradation. Stocking rates are shown as Dry Sheep Equivalents (DSE) which are the number of adult sheep (wethers) that can be sustained on each hectare all year round. See 'Stocking rate guidelines for rural small holdings' (Misc. Publication 02/00) for more information on stocking rates and a table of animal equivalents for the calculation of stocking rates.

Likely degradation hazards

- All pastures require fertilising and if care is not taken to only apply the nutrients that are required for good production, excess nutrients will leach into the Ellen Brook.
- Increasing acidification can be a consequence of legume based pastures.
- Over watering of irrigated pastures can cause excessive leaching of nutrients.
- LMU'S grazed beyond their livestock carrying capability can be prone to wind erosion.
- Perennial grasses can be toxic to livestock (e.g. phalaris and panicum).
- Cape tulip, which is commonly found in pastures, is toxic to livestock.
- Annual ryegrass toxicity, which was formally a problem in the wheatbelt, can now be expected to increasingly occur in this region.
- Pasture grass species are often environmental weeds off site. This is particularly so for perennial grasses.

Further reading

Stocking rate guidelines for rural small holdings (Misc. Publication 02/00)

Perennial grasses - their role in the Ellen Brook Catchment (F/N No. 20/99)

Sprinkler irrigated pastures for small holdings (F/N No. 6/90)

Horticulture

In the Ellen Brook Catchment, intensive vegetable, strawberry and turf production is carried out on soils that often have an inherently low fertility. Most of these activities were established prior to the awareness that nutrients applied to the sandy soils in the Catchment could leach into the Swan-Canning estuary, which in turn lead to eutrophication and algal blooms.

Other less intensive forms of horticulture carried out in the Catchment include viticulture, citrus and stone fruit. At present, any landholder considering a change of landuse from grazing to intensive horticulture is required to forward a development proposal to their local government. The local government would then refer the proposal to the Department of Environmental Protection (DEP) for advice. As nutrient export is currently a major issue within the Catchment, intensive horticultural proposals are not often supported.

In the past, vegetable production on the infertile sandy soils of the Catchment has been poorly managed. The relatively low price of fertiliser compared with other production input costs encouraged excessive fertiliser use. Research is currently being conducted into fertigation methods, which will allow landholders to achieve efficient water and fertiliser use for growing various vegetable crops and reduce the total quantity of nutrients leaching into local waterbodies.

Research is also being directed at the role of organic matter for growing vegetable crops, as a means of increasing the capacity of the soils to retain nutrient elements, and as a source of nutrients for plant production. This research may in time overcome the present limitations preventing further development of intensive horticulture within the Catchment.

Likely degradation hazards

- Leaching of nutrients from most soils within the Ellen Brook Catchment.
- Inefficient use of water for irrigation.
- Soil acidity.
- Inappropriate use of agricultural chemicals namely fertilisers, insecticides, fungicides and herbicides.

Fodder production

The eastern, less waterlogged part of the Catchment is very suitable for cereal hay production. Landholders mainly produce oaten hay for sale to the equestrian industry. Good quality hay can be produced when the plant is cut at the 'milky' stage. Plants cut after this stage are of poor feed quality therefore it is critical to sow the crop so that it's development reaches the 'milky' stage at hay cutting and baling time, which is mid October.

Meadow hay is produced from better pasture areas, which often includes the winter waterlogged flats that are too wet for cereal growing and/or pug if grazed in winter. Meadow hay made from pasture with a high legume content and has not been grazed for 10 to 12 weeks has a higher stock feed value than cereal hay and is mainly used on-farm.

Silage made in rolls for on-farm use is a source of good quality stock feed. The advantage silage has over hay is that it can be made earlier to ensure good quality feed and is not reliant on fine weather.

Specialist growers carry out commercial lucerne hay production within the Catchment. Near neutral soils (pH), ample water supply and refined management skills are essential. Small, 2 to 5 hectare properties are normally not viable for growing lucerne. Producers, who have identified a market, can value add by converting hay to chaff.

Likely degradation hazards

- Agricultural weeds such as double gee, Paterson's Curse and cape tulip can be exported off farm in hay.
- Cape tulip is toxic to livestock. Dense patches of cape tulip existing in the paddock during hay cutting and baling can result in bales of meadow hay containing a considerable cape tulip content and hence may result in livestock death.
- Annual ryegrass in hay should be tested for annual ryegrass toxicity.
- Nitrogen based fertilisers applied when sowing cereal crops may leach below the root zone of the plants.
- Plants do not take up water at night, water applied at night on irrigated lucerne can be a waste of resources and increase leaching of nutrients.

Further reading

Fodder conservation as silage (F/N No 98/99).

Timber production

Farmers on the Swan Coastal Plain have grown *Pinus pinaster* or maritime pine for over 70 years. *P. pinaster* is a proven timber species as research and development has already been carried out. *P. pinaster* can be grown in sandy soils that have a low phosphorus retention index and low capability for pasture production. Growing of *P. pinaster* is the preferred landuse on these soils in relation to managing nutrient loss.

High-grade sawlogs can be produced on farms to provide additional farm income. Landholders can grow trees on farmland to produce hardwood sawlogs targeted at domestic and export markets. Trees are best grown in alleys and need to be grown quickly and efficiently, and in suitable quantities. The top performing species within the Catchment are *Eucalyptus saligna*, *E. botryoides*, *E. grandis* and *C. maculata*. *E. cladocalyx* is a suitable tree species for firewood production.

The growth rate and form of plantation trees is partly inherited from their parent trees. To maximise profitability from commercial plantings, it is highly recommended that seed sources should be obtained from superior parent trees. All species require a minimum of 1 to 2 metres soil depth.

Paulownia is a fast growing, deciduous tree capable of reaching in excess of 7 m in height in its first growing season. *Paulownia* requires a well drained soil at least 1.5 metres deep. The recommended pH range is 5.5 to 8. *P. fortunei* is the preferred variety. Market opportunities in Western Australia are currently non-existent, however, several companies are importing *Paulownia* timber and are working with local millers and furniture makers to assess the timbers' qualities. *Paulownia* is a summer growing tree that requires substantial amounts of water. Generally, Paulownia should be treated similarly to other horticultural tree crops grown in Western Australia.

Likely degradation hazards

- Soil preparation includes deep ripping which can erode if rip lines are continuous and sloping.
- Irrigation of *Paulownia* can result in leaching of excess nutrients on sandy soils.
- Growing of commercial timber trees is likely to increase the risk of fire.

Further reading

Farm Forestry Advisory Service Tree Notes series (see **Useful Addresses and Websites**).

SECTION 2: FARM AND CATCHMENT PLANNING

INTEGRATION OF LAND MANAGEMENT OPTIONS

Sitting on your property within the Ellen Brook Catchment, it might be easy to forget that you are part of a much bigger picture - that your piece of land is just one of many that make up the fabric of the region. What happens on your property is affected by what else is going on in the Catchment, and likewise, what you do, can and often does, have an effect on other properties in the region.

Catchment level planning

You can take into account the properties above and below (in the catchment sense) and either side of you to develop solutions to your land management issues, and where possible involve the surrounding owners into your solutions. This may involve links to existing catchment groups and catchment management plans.

For instance:

- You may jointly fence of a larger piece of bush and manage it as a whole.
- The contour banks on your property may connect to others next door for a better solution to fill his/her dam or to discharge water to a safer location.
- Control of weeds and feral animals can best be done on a collaborative basis so that a whole area is cleaned up rather than concentrating on one small block which is then reinfested from neighbouring properties.
- Native fauna may be able to move in vegetation corridors connected through your properties.
- Stabilisation of creek lines is easier if large lengths are done at once.

More often than not the combined work may mean reduced costs when contractors are used or bulk supplies are purchased. If nothing else the social interaction with your neighbours will be a big plus.

Property level planning

However there is another level of integration of management options apart from at the catchment level. This is at your own property level.

Here you can look at all the land management issues that exist on your property and/or on nearby properties and then develop solutions that address all of these. It is easy to concentrate on one aspect that particularly appeals to you and leave other equally important issues untreated, so you should try and deal with all of the issues identified in a manner that prioritises issues via a cost/benefit approach.

For example, if your property has:

- very few trees;
- an eroded creek and erosion on the firebreaks;

- salt showing in waterlogged flats;
- an algae problem in a down stream dam;
- massive Paterson's Curse infestations;
- rabbits in the sandy areas; and
- a shortage of water for your horses.

What can you do? Planting a few trees makes the area look good but will not solve all the problems.

The complete management can be staged but would include reducing the movement of water down firebreaks by placing grade-banks which feed a dam, you could plant your trees on the same line as the banks and develop both a windbreak and fauna corridor or habitat. Soil testing for nutrients will allow you to minimise the nutrient movement into the dam, which will in turn reduce the algae growth. Planting perennial pastures will give you more feed but will also help dry up the salt affected areas.

Once the area is stabilised, fencing off and repairing creek line and creating a fish/frog habitat with appropriate vegetation will help improve the resilience of the creek and improve the water quality in the dam. The vegetation will act as a nutrient filter as well. Controlling weeds will improve the pastures and also help prevent their spread. Rabbits will need to be controlled for tree survival. The end result is a more resilient/sustainable landscape and property that is a pleasure to live on and at the same time improve the well being of the Catchment.

There is a lot of work carried out by others to help you identify the broader issues.

The landcare movement has seized on the 'interconnectedness' of the land, and now strives to get landholders to work together at improving the region by fixing their properties, mindful of how this can have positive spin-offs for the rest of the Catchment.

The Ellen Brook Catchment has an 'Integrated Catchment Management Plan' (ICM). It is a 'blue print' and a tool for guiding the repair of the whole Catchment through the systematic improvement of individual properties, all of which build together to stitch back the torn fabric of the entire landscape.

This unique plan has been put together with the combined knowledge, advice and expertise of local landholders, landcare experts, scientists and officers from the main government land management agencies like Agriculture Western Australia (AGWEST), CALM and the Water and Rivers Commission (WRC). As such it is a detailed range of strategies and techniques to systematically improve the environment. It provides details on how to best reduce waterlogging, salinity and erosion, protect and retain bushland, revegetate, improve the quality of streams and wetlands, plant improved cropping regimes and lift the overall health, productivity and value of the region as a whole. As such your Ellen Brook ICM plan will help you to identify the best strategies that you can undertake to improve your property.

So where do you fit in?

Your property is a vital 'cog in the wheel' of the Ellen Brook ICM. Every landholder can play their part and improve not only their property but also others in the region. Your local landcare officer or AGWEST officer in Midland will have copies of the Ellen Brook ICM and will be only too happy to explain it to you and how you fit into the bigger picture.

So where do I start?

The Ellen Brook ICM and this associated manual will encourage you to look at your various landcare problems, not in isolation, but as a range of integrated issues. By looking at your land and it's problems in this way you can maximise the benefits and positive spin-offs from any one land improvement action.

For instance, you may be plagued by strong and hot easterly winds in the summer and may decide to screen these out with trees. Instead of just planting a single line of fast growing eucalypts, you could try putting in a wider strip including middle and under storey plants. This can include colourful and/or bird attracting plants and even fodder shrubs for your horses. You can align this belt to not only block out those wretched winds, but perhaps include a patch of bush that is struggling in the paddock. You may even be able to talk to your neighbour to see if he will combine with you to link his bush to yours through this belt of plants. Planning your work this way won't cost much more, but it will provide a wider range of benefits (e.g. potential fodder and fence posts), and to top it off, such a project could attract funding assistance and advice from your local landcare officer. That's 'big picture' landcare and that is the cheapest, most effective way to improve your 'patch of paradise' as well as the rest of the region.

FARM MANAGEMENT PLANS

Whether your property is 1 hectare or 10,000 hectares, the process of creating a farm management plan will help enormously to streamline activities and deliver better land management outcomes. This is because a farm management plan takes detailed information about the property (e.g. soils, water, geology, environment and existing features), and builds on this to create a long term vision and associated 'how to do it' plan for your property.

As such your farm management plan can be a powerful tool, and across the country landholders have been using this very system to:

- *transform their farms* through step by step landcare improvements;
- *integrate various activities* - a sensible design will, by its very nature, better allow you to achieve multiple benefits and streamline activities;
- *prioritise actions* - making sure their efforts are better directed; and
- *attract funding and assistance* - a good farm management plan is an essential requirement of most funding bodies, it will also be essential for primary producer status tax rulings.

The planning process

The process will typically involve the following steps:

1. Obtain an aerial photograph of your property.

   This provides the baseline information on your property and it provides a 'big picture' view of your land. It allows you to see clearly the layout, natural patterns of the landscape as well as the health of the land and bushland areas. These days an aerial photo can be simply and cheaply purchased from the Central Mapping Agency at the Department of Land Administration (DOLA), in Midland. They will require the location and size of your property and usually the scale of the photo that you would require (if you're not sure ask for it to be as big as possible for farm planning).

2. Gather information about the property.

   With a series of clear plastic sheets overlaid onto the aerial photo you can mark on:

   As the 'first overlay':

   - Existing features, e.g. house, sheds, fences, roads, bush areas and erosion scours.
   - North point, prevailing winds, major fire threats, frost areas, etc.

   As the 'second overlay':

   - 'Land Management Units' (LMUs). See **Table 2** and **Figures 3, 4 and 5** for the Land Management Units on your property.

   As the 'third overlay':

   Proposed changes and improvements to the property. This is your chance to dream and inspire yourself with how you would like your property to look in the future. You may want a series of shelterbelts, new fence alignments, orchards, maybe even a new lake or a new house! All of this should be put on the plan and as such it becomes the 'blue print' for your property - a plan to follow and something to aim towards. It will be vital to get details on strategies and techniques to implement any proposed works as the success of these ventures proposed will depend on it.

In combination the three overlays give you what exists now, what management changes should be made and your inspired visions for your property into the future.

3. Implementation and prioritisation

   A property plan is one thing but a strategy for its effective and efficient implementation is another altogether. As such a management plan should include details on:

   - prioritisation of work;
   - how this work is to be undertaken;
   - what steps to follow and when;

- how this work is to be managed; and
- how you will monitor this work and refine future works.

This can be a detailed document that is used in combination with the farm plan or it can simply be a calendar with points to follow to implement any chosen works. The choice will depend on your time, budget and existing skill level.

And remember …

Many people won't have the time or the money to tackle everything at once. A good plan, by it's very nature will allow you to work within your various constraints to ensure that when the time is right you have the tools and the information to get the job done cheaply and effectively.

The Swan Canning Catchment Cleanup Program – a chance to make it all happen!

Through the Swan Canning Catchment Cleanup Program (SCCP), Agriculture Western Australia is committing resources to help landholders in your region create their own farm management plans. The project arose out of the need to ensure that the Catchments feeding into the Swan and Canning rivers were better managed so as to improve health of these two important rivers. The project aims to ensure that the land and environmental resources contained within these areas are sustainably managed into the future by giving landholders, through a wide range of subsidised workshops and field days, both the skills and the confidence to make real improvements needed on their properties.

The project will be of immense benefit to landholders in the region.

- It will provide a wide range of subsidised courses and field days over the next 4 years.
- These activities will cater for demand and will be structured to meet local needs and interests.
- Timing will be flexible to meet peoples heavy time commitments.
- All courses and field days will be run by specialists and experts with years of land management experience.

Who to contact for more details?

Contact your local landcare officer or the Midland Agriculture Western Australia office (ph: 9274 5355) to find about up and coming courses and to book your place.

SECTION 3: LAND DEGRADATION RISKS

CAUSES AND KEY MANAGEMENT OPTIONS

Land degradation is the decline in quality of natural resources (soils, vegetation and water), commonly caused through the change of land use, for example from remnant vegetation to developed pastureland. However, in some cases some degradation of natural resources occurs as a result of extreme 'natural' events such as floods, droughts and bushfires.

Over time land degradation has become a major issue within the Ellen Brook Catchment. The most significant impact is the excessive loss of nutrients, predominantly nitrogen and phosphorus, which has contributed to regular, potentially toxic algal blooms in the upper reaches of the Swan-Canning estuary.

In addition to this problem, there has been an increase in the frequency and severity of soil salinity, wind erosion, water erosion and waterlogging. If improved management techniques are not implemented, these degradational processes have the potential to compromise the economic, environmental and social well being of the Catchment, and threaten the ongoing viability of certain activities and lifestyles.

The predominant land degradation issues for each of the land management units within the Ellen Brook Catchment are summarised below in **Table 3**. Following this table each of the degradation issues are defined and management practices to address the issues are summarised.

Table 3. Land degradation risks* associated with the Ellen Brook Catchment LMUs

Land Management Unit	Wind erosion risk	Water erosion risk	Phosphorus export	Flood risk	Waterlogging /inundation risk	Salinity risk	Water repellence	Sub-surface (10–20 cm) acidification risk
Shallow gravels and ironstone	Low	Low	Low	Nil	Very low	No risk	Low - Moderate	Low - Moderate
Gravel slopes and uplands	Low	Low - Moderate	Low - Moderate	Nil	Very low	No risk - Partial risk	Moderate	Moderate
Steep slopes	Moderate	High	High	Nil	Very low	No risk	Low	Low
Shallow rocky slopes	Low	Moderate	Low - Moderate	Nil	Low	No risk - Partial risk	Low	Low - Moderate
Loamy slopes	Low	Moderate	Moderate	Nil	Low	No risk	Low	Low
Sandy duplex slopes	Low - Moderate	Low - Moderate	Moderate	Nil	Low - Moderate	No risk	Moderate	Moderate
Red sandy slopes and uplands	Moderate - High	Low	Low - Moderate	Nil	Nil	No risk	Moderate	Low
Yellow to brown sandy slopes and uplands	Moderate - High	Low	Low - Moderate	Nil	Nil	No risk	Moderate	Low
Pale sandy rises and slopes	High	Low	Moderate	Nil	Nil	No risk	High	Low - Moderate
Pale sandy duplex flats	High	Low	Moderate - High	Nil	Low - High	Partial risk	High	Low - Moderate
Muchea limestone flats	Moderate	Low	Moderate	Nil	Moderate	Partial risk	Moderate	Low
Loamy flats and terraces	Moderate	Low	Moderate	Nil - Low	Low	Partial risk	Low	Low
Winter wet flats and footslopes	Low	Low	High	Nil - Low	High	Partial risk (High in places)	Low - Moderate	Moderate
Salt affected land	Low - Moderate	Moderate	High	Nil - Low	High	Saline land	Low	Low
Swamps and drainage lines	Low	Low - High**	High	Nil - Moderate**	Very high	Partial risk - Saline land	Low - Moderate	Moderate

* Refer to van Gool and Moore (1998) for definition of risk factors and qualitative terms used.

** Higher risk for drainage lines.

Wind erosion

An investigation into the physical resources contained within the Bulls Brook Catchment (Misc. Publication 60/99: Agriculture Western Australia, 1999) identified wind erosion as a problem, occurring in areas with deep pale sands that have a very low capability for grazing, but were never the less still being grazed by cattle.

Wind erosion is not restricted to the Bulls Brook Catchment. It occurs throughout the Ellen Brook Catchment, mainly in the western areas on the Swan Coastal Plain where the coarse, pale, dry sandier soils occur. Landholders may over estimate the capability of these soils for grazing or, more often, fail to invest in fencing that restricts herds to areas of suitable pasture.

The causes of wind erosion

Wind erosion results when there is insufficient vegetation or ground cover to bind and protect the surface soil allowing the loose soil particles to be mobilised in strong winds. Bare soil patches often result in paddocks that are overstocked or in areas where stock congregate and remove vegetation or pasture cover.

Deep sandy rises on the coastal plain and mid and lower slope sandy pockets that occur in the foothills are most at risk. The major erosion causing winds are strong easterlies in summer and the northwesterly winds that occur with frontal systems in late autumn. The wind erosion problem is more of an issue in late autumn due to the lack of protective pasture cover and crop residues.

Management of wind erosion

The best way to manage wind erosion is to maintain plant material, be it stubble, dry pasture residue, or perennial grasses on the soil surface. This can be achieved by not grazing at rates above the capability and carrying capacity of the particular LMU.

Management methods can include:

- reducing stocking rates or removing stock from susceptible areas in autumn;
- preventing (by temporary fencing) the congregation of stock on susceptible soils;
- re–establishing native vegetation on the areas subject to erosion;
- establishing an agroforestry enterprise (for timber, firewood, fence posts, etc.) on susceptible soils;
- soil amendment by the addition of clay or other materials;
- physically measuring the amount of ground cover provided by growing pastures and pasture residue and use this information to adjust stocking rates;
- establishing a fodder shrub grazing system; and/or
- developing deep-rooted vegetation windbreaks and screens.

Implementation of one or more of the above management measures can also achieve multiple benefits. For example a windbreak could comprise species suitable for agroforestry or floriculture, re-establishment of native vegetation may achieve your biodiversity or nature conservation objective, and a shelterbelt could be incorporated with a grade bank that may have been planned for surface water control.

Water erosion

Water erosion occurs within the Ellen Brook Catchment as three principle types, namely:

- erosion caused by overland flow;
- stream bank erosion caused by flow events within the Ellen Brook or its tributaries; or
- poorly designed farm drains and farm drains not protected from stock damage.

Water erosion caused by overland flow is usually restricted to the eastern regions of the Catchment where soils are less sandy, and therefore a higher proportion of rainfall 'runs off' the soil surface rather than infiltrating. Severe water erosion can occur on the water-repellent sandy slopes following high rainfall events in autumn. Steeper slopes compound this as they increase the velocity of run off which results in erosion.

Stream bank erosion occurs in areas where riparian vegetation (vegetation aligning rivers and streams) has been cleared, leaving the stream bank vulnerable to high velocity flows during and after storms. Allowing stock access to streams will accelerate stream bank erosion. Cattle in particular generally prefer areas close to streams because of lush pasture, shade and easy access to water. Cattle destroy the vegetation around unfenced streams by soil compaction and removal of herbage, and trample and destabilise the stream banks.

Poorly designed farm drains have generally been constructed on unsuitable grades where the velocity of the flow is so rapid that the drain actively erodes. Farm drains not protected from stock damage by streamlining will continually collapse due to hoof damage.

Categories of water erosion

Water erosion occurs when soil particles are mobilised by the action of water. There are different water erosion 'types', including:

- Sheet erosion is the removal of a fairly uniform layer of soil from the land surface by raindrop splash and/or runoff.
- Rill erosion is erosion in numerous small channels, generally less than 30 cm in depth that can be obliterated by normal tillage. Rills often form under 'sheet' erosion events as water movement, inevitably, becomes concentrated due to irregularities in the land surface.

- Rills that are large enough to interfere with normal farm operations and cannot be filled by normal cultivation are termed gullies. Formation of gullies is related to the interaction of soil type, landform (slope), land use and climate. Erosion often occurs at the head and along the sides of gullies.
- Tunnel Erosion or piping is the removal of subsurface soil by water under the surface, while the soil on the surface remains relatively intact. Sub-surface tunnels often collapse, resulting in the formation of gullies. **NOTE:** This form of erosion is rare in the Ellen-Brook Catchment.

Areas where water is concentrated due to farm operations are most at risk from water erosion, e.g. stock pads or tracks, cultivation, firebreak and farm tracks.

Factors that generally influence erosion by water include:

- soil type;
- non-wettable sands;
- lack of vegetation cover (bare soil); and
- slope of the land.

Management of water erosion

The prevention of soil erosion by water is particularly important in the Ellen Brook area. Much of the nutrients (particularly phosphorous) that are washed into drains, streams and rivers (and which ultimately end up in the Swan Estuary) are attached to fine soil and clay particles. Minimising water erosion will have an important impact in reducing nutrients in these water bodies.

Equally important to you, is that the prevention and control of soil erosion by water can return benefits by:

- preventing loss of valuable topsoil and fertiliser;
- eliminating the need to repair gullies and rills; and
- reducing the need to clean farm dams and drains.

Prevention is the best cure. Management measures to reduce the risk of erosion by water include:

- construction of grade banks;
- fencing off creeks and waterways;
- re-establishing vegetation and sedge and rush beds along the edges of creeks and waterways;
- maintaining grassed waterways in paddocks;
- cultivating on the contour of the land;
- redesigning firebreaks which are located on a slope and/or consider chemical firebreaks; and
- increasing the infiltration of water by maintaining healthy, well structured soils.

Management of erosion should be considered in the context of the whole property. Other benefits can be gained if treatments to manage erosion are carefully considered (a WIN - WIN situation).

For example, gully erosion can often be managed by the well-planned use of grade (or contour) banks. A well-planned network of these banks can provide you with an asset to capture and harvest water. At the same time, because you are capturing and redirecting water movement down the landscape, grade banks can reduce waterlogging in areas below the banks and result in better production in previously waterlogged areas.

Nutrient export

Excessive nutrient loss (particularly phosphorus and nitrogen) is a major land management issue within the Ellen Brook Catchment. The export of nutrients increases the nutrient loading in receiving water bodies (in this case the Ellen Brook and subsequently the Swan River estuary). This process of nutrient enrichment is called eutrophication. Nitrogen and Phosphorus enter the river (in soluble form, as organic matter, or attached to sediment particles) directly, in runoff, or via groundwater.

Nutrient enrichment can result in algal blooms, especially during spring and summer. Algal blooms are unsightly and can involve toxic algae. Toxic blue-green algae have caused death to stock and wildlife and serious sickness in humans.

Causes of nutrient export

Nutrients, be they native or from fertiliser, can be lost into waterways through processes such as soil erosion and leaching. Of these nutrients it is phosphorus and nitrogen which contribute most to eutrophication.

Sources of nitrogen and phosphorus include commercial fertilisers applied to crops and pastures in rates that exceed plant requirements, effluent from animal feedlots, intensive animal industries (e.g. piggeries) and grazing areas, and wastes from agricultural industries (e.g. food processing factories).

Nitrogen is needed in large quantities by plants (more so than any other nutrient) and it must be available constantly through the growing cycle. It is the nutrient that determines the quality of crops and pastures because it is the essential element for protein production.

Phosphorus is an essential nutrient for plant growth. It has a key role in the energy function of the plant. In the Ellen Brook Catchment, the areas most susceptible to losing applied phosphorus are the low lying regions that have soils with very low P binding capacity and may be seasonally wet or inundated. The majority of the sandy, low-lying areas along the central axis of the Catchment on the coastal plain are highly susceptible to nutrient loss, leading to contamination of ground water, drainage water and possibly surface waters.

Management of nutrient export

Given the need to apply fertilisers to maintain the fertility of productive farmland, it is essential that nutrients are not wasted. The protection of stream banks is one of the most important ways of reducing nutrient addition to waterways. Nutrients attached to sediment are carried into the water through the erosion of banks. Unless fencing is adequate, stock will defecate in the water and break down banks, further adding to the sediment load.

Nitrogen loss can be minimised by:

- applying nitrogen fertilisers in small amounts over the growing season, and using only recommended rates (soil and plant testing for nitrate-nitrogen can indicate high levels);
- applying nitrogen fertilisers as close to sowing as possible, and again only when needed by the crop;
- sowing summer growing perennial pastures to take up nitrogen;
- using organic or controlled release nitrogen fertiliser on sandy soils; and
- using temperate perennial grasses where possible to use up available soil nitrogen at the 'break of season', before it is leached beyond the root zone or used by undesirable weeds such as capeweed.

Phosphorus loss can be minimised by:

- matching the supply of phosphorus to the needs of the plant by soil and plant tissue testing and correct timing of phosphorus applications;
- incorporating rather than broadcasting fertiliser where possible;
- avoiding bare areas when fertilising, especially when storms are likely;
- not fertilising close to or across dams and waterways; and
- keeping records on fertiliser use.

Waterlogging and inundation

In the Ellen Brook Catchment, waterlogging usually occurs on previously cleared swamps, seasonal swamps or flat to very slightly falling permanently moist areas, now utilised for agriculture. It can also occur on soils where water movement is inhibited due to structural decline of the soil or natural barriers to water movement such as clay subsoils on the Coastal Plain or dolerite dykes on the Darling Plateau.

The causes of waterlogging and inundation

Waterlogging is too much water in the root zone of a plant. The roots cannot absorb oxygen to breathe, so the plant stops growing within a few days and may die. Other gases, such as carbon dioxide and ethylene, may also accumulate and affect the plant's health.

Inundation is water ponding on the ground surface. Those parts of the plant that are submerged cannot breathe or photosynthesise. Short plants, such as young crops or heavily grazed pastures, may be completely covered, and usually die. Inundation is often associated with waterlogging.

Many farmers do not realise that a site is waterlogged until water appears on the soil surface. However, by this stage, plant roots may already be damaged and the yield potential severely affected.

Waterlogging and inundation slow pasture growth in winter and delay the spring flush. Pasture growth in winter is at least five times more valuable than extra production in late spring. Waterlogged pasture legumes grow more slowly than waterlogged grasses, so waterlogged pastures become grassy and weedy.

Waterlogged and inundated areas contribute recharge to saline aquifers, are very susceptible to water erosion and are prone to soil structure decline if cultivated or stocked when too wet.

Symptoms of waterlogging include:

- yellowing of crops and pastures;
- the presence of weeds such as toad rush, cotula, dock and Yorkshire fog grass;
- grey or greenish coloured soil; and
- the presence of orange mottles in soil profiles (although some mottles may have been caused by waterlogging in previous climates).

Areas that are most susceptible to waterlogging and inundation are those where:

- the soil has a shallow clay subsoil (particularly on flat land or in water-gaining areas such as rock outcrops, roads, lower slopes and areas where water converges); and
- the soil allows water to infiltrate only slowly, such as clays, loams, and soils that set hard and/or soils with a surface seal.

Waterlogging is very obvious on salt-affected land. Unless salt levels are very high, most plants growing in well-drained soils can keep salt out of their roots. Since waterlogging prevents the roots making enough energy to keep the salt out, the salt enters the roots and the plants die.

Management of waterlogging

A combination of improved shallow surface drains and the introduction of more waterlogging tolerant plant species are the best way to overcome waterlogging and inundation. In many cases, drains have paid for themselves within a few years of installation. Water and nutrients can be harvested by simple earthworks design prior to any outlet entering major flow lines.

Surface water control on flat clayey soils (a minor soil type Ellen-Brook Catchment)

Waterlogging and inundation are also common on flat, clayey soils used for pasture production. Poor soil structure often prevents the rain from soaking into the soil or the land may be too flat for adequate runoff.

Soil structure can be improved on some soils by:

- using gypsum (see Farmnote 32/85 Gypsum improves soil stability); and
- preventing stock pugging the area in winter.

Surface water management can be improved by connecting low areas with spoon or W drains. The low areas need to be pegged out in winter (see *Farmnote 120/84: Spoon and W Drains*). Make sure that the drains empty into a well-defined waterway. Consider the introduction of improved, waterlogging tolerant legume pasture species and earthworks design to harvest nutrients and water prior to exit from the property.

Legal responsibilities for drainage

'Landholders are required to notify the Commissioner of Soil and land Conservation in writing at least 90 days before draining or pumping commences if it is proposed to drain or pump water from under the land surface because of the salinity of the land or water'.

It always pays to check with your local shire before you undertake any drainage activities.

Grazing management and weed control

Waterlogged soils also have little strength, and sheep and cattle can easily destroy the soil structure by pugging them. This further restricts water infiltration and so inundation becomes more serious. Farms with a large percentage of soils prone to pugging need special grazing management. Stock can also uproot plants from waterlogged soils.

Desirable pasture species that grow well late in the season are an advantage if the area is sufficient to provide late feed for stock. However, on many farms in high rainfall areas, some of the wet parts should be drained to also increase early pasture production.

Fencing

The Ellen-Brook Catchment contains large areas of flat winter wet sands that even when drained remain too waterlogged for vehicle travel most of the winter months. These areas require fencing to separate them from the more winter dry areas so improved management can be applied. Often the wet sands can be left ungrazed and can then be cut for meadow hay.

Salinity

Previous surveys carried out by Agriculture Western Australia indicate that there are large areas of waterlogged flats immediately to the east of the Ellen Brook and a lesser area immediately to the west (either side of the main Ellen Brook drainage line) susceptible to salinity.

Agriculture Western Australia undertook an investigation into salinity within the Shire of Chittering (Agriculture Western Australia, 1997). This investigation confirmed that soil and stream salinity was common in the Shire of Chittering and is most severe in the north east of the Shire.

Salinity is evident in the Bulls Brook sub-catchment (*Misc. Publication 60/99,* Agriculture Western Australia, 1999), on either side of and in close proximity to the Ellen Brook channel. There is a serious outbreak in an area east of the Ellen Brook and adjacent to Rutland Road. Other severe outbreaks occur in the Rocky Creek, Wandena and Muchea east sub-catchments.

Figures 3, 4 and 5 show where salt affected land managements units are found within the Ellen Brook Catchment.

The causes of salinity

Dryland salinity is a problem caused by rising groundwater, which in turn is the result of the clearing of deep-rooted native vegetation.

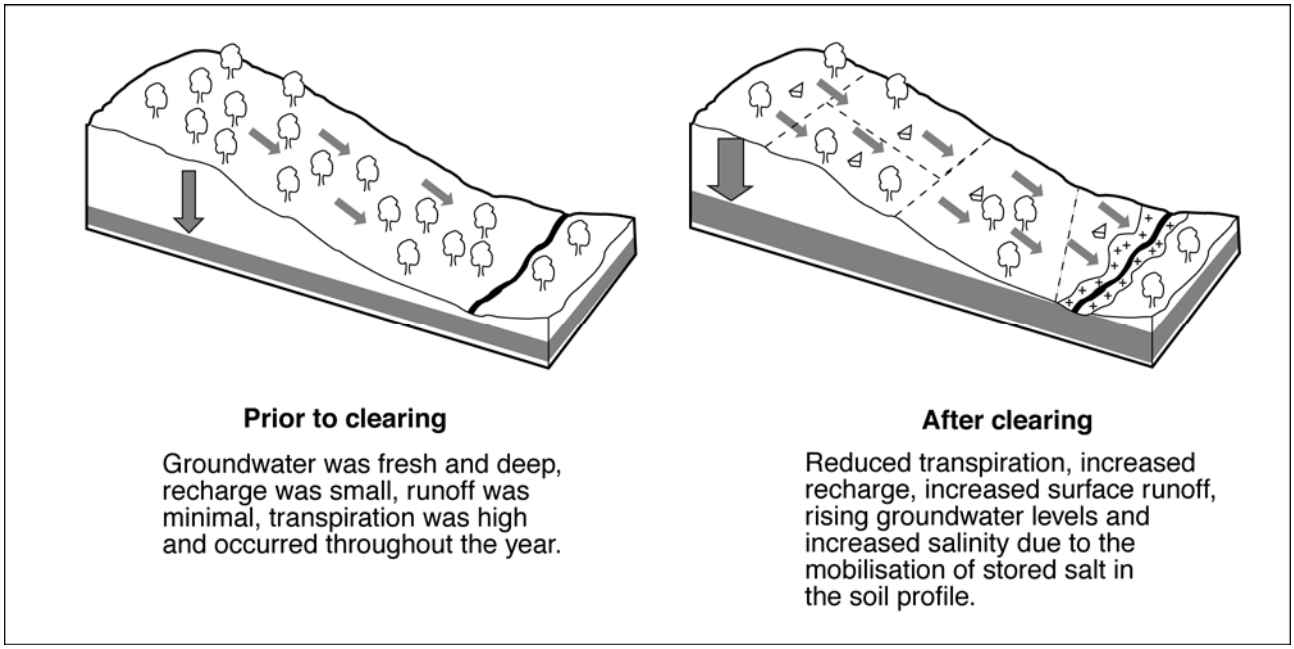
In certain soil types salt has accumulated within the soil over thousands of years. This accumulation is the result of a number of factors, namely:

- rainfall, which carries with it a small amount of salt;
- a high seawater level in past geological ages (the marine influence) which flooded many parts of the coastal plain and adjoining areas; and
- a level of rainfall which has been insufficient to wash the salt through and out of the soil.

Prior to clearing for agriculture, the water cycle was in balance due to the vegetation physically intercepting rainfall and preventing it from reaching the ground, and the vegetation using most of the water which fell to the ground and infiltrated into the soil.

When native vegetation was cleared for agriculture, and replaced with annual pastures and crops, there was not the same ability for this system to use all of the water that infiltrated into the soil. The groundwater levels then rose, dissolving the salts stored in the soil, and eventually bringing the salt to the surface.

Figure 8. Water cycle prior to and after clearing.



In the Swan-Canning region, salinity problems are common in valley floors of the northern and eastern (lower rainfall) catchments, some areas of foothills (closer to the edge of the Darling Scarp) and on isolated parts of the coastal plain.

When rising groundwater actually breaks out at the surface it is related to the geology of the area (i.e. what's happening beneath the surface of the soil). For example, underground extrusions of hard rock (dolerite dykes), a rise in the underlying bedrock (bedrock high), and a layer of clay close to the surface can all result in salt areas (salt scalds) emerging higher in the landscape than just the valley floor. However, within the Ellen Brook Catchment, valley floor salinity is by far the most common type of salinity.

Waterlogging often precedes and is associated with the outbreak of salinity. Symptoms evident in areas affected by waterlogging and then salinity include:

- deterioration of crop, pasture and/or native vegetation growth and health;
- species such as barley grass and button grass will become evident, and then dominant in salty areas;
- water seeps will be evident at the soil surface (often well after rainfall events) indicating groundwater is discharging in the area; and
- the land surface becoming completely bare, or supporting only high salt tolerant plants, and salt crystal patches being noticeable on the surface in late-spring and summer.

Management of salinity

Management is a long-term prospect and is best tackled by the cooperative efforts of groups of neighbours and others living in your sub-catchment area. As with most problems, careful planning is required to ensure that you and your neighbours select the best long-term management and production options for your situation.

The critical principles for managing salinity at your farm and catchment scale include:

- develop strategies as part of an overall property plan;
- identify land and soil types best suited to certain types of land management activity;
- redirect and hold your surface water away from waterlogged and saline area and increase the water use capability of your farm (water harvesting);
- establish high water use, deep rooted, perennial vegetation [native and commercially viable species should both be considered];
- protect and rehabilitate areas of remnant vegetation;
- protect areas already degraded by vegetation loss, water discharge and salt scalding;
- investigate different pasture, crop and horticulture options that will maximise both farm income and water use;
- investigate funding support from Government and private schemes [these focus on activities that have a high public benefit];
- plan initiatives in close collaboration with your neighbours and other landowners in the 'catchment'. Mostly funding is available though groups, not individuals;
- investigate the productive use of saline lands; and
- don't waste time and money on attempting to restore the most degraded areas, as these areas will be subject to increasing degradation for some time. Wait until other measures begin to take effect.

There are a number of funding programs available to help you manage salinity. These involve both public (government) funds like the Western Australian Salinity Strategy, the Natural Heritage Trust and the Swan Canning Cleanup Program and private or corporate funds like the Swan Catchment Urban Landcare Program (mainly supported by Alcoa Australia) and programs sponsored through the WA Landcare Trust. To take advantage of these it is crucial that your property plan is part of a larger catchment plan and that you are actively involved in a catchment group or Land Conservation District Committee. (See **Useful Contracts** for details of your landcare and catchment coordinators.)

Your property plan should involve one or more of the following actions to address salinity:

- Protection of remnant vegetation.
- Surface water management (grade banks, interceptor banks, dams). Remember your legal responsibilities, you must notify the Commissioner for Soil and Land Conservation at least 90 days before draining water from land affected by salinity.
- Agroforestry options in recharge areas.
- Revegetation areas incorporating trees, shrubs, sedges and rushes, planted in recharge areas (biodiversity plantings).
- Alley farming in both recharge and discharge areas.
- Perennial pastures.
- Perennial fodder shrubs.
- Improved pastures especially in the waterlogged, mildly saline areas; and
- New fencing to protect areas planted to trees and shrubs and to define areas requiring particular management regimes (LMUs).

Water repellence

Water repellent behaviour in soil is caused by dry coatings of hydrophobic (that is, water hating) material on soil particles or aggregates, as well as hydrophobic organic matter, such as fungal strands and particles of decomposing plant material. Methods of assessing repellency are explained in *Farmnote No. 110/96: Assessing water repellency*. It occurs mainly in sandy soils with less than 5% clay content, which is typical of many of the soils found within the Ellen-Brook Catchment (especially on the coastal plain).

If any of the following symptoms are evident, the soil is likely to be water repellent:

- During opening rains, water ponding occurs on dry sandy soils in patches and runoff may occur from sandy soils on sloping sites.
- Dry patches of soil between moist depressions.
- Patches of dust in a ‘wet’ soil when cultivating.
- Staggered emergence (pasture, crops, weeds - especially capeweed), with early growth in depressions.
- Patchy crop or pasture growth, with failure to germinate in areas of dry soil.

Following significant rainfall, water repellence can be confirmed by examining a cross-section of the soil underlying these areas of uneven growth. The bare patches should correspond with zones of dry soil.

Patchy emergence early in the autumn typifies pastures on water repellent soils. Light rains accumulate in hollows and hoof prints and wet the soil sufficiently for plants to survive for a few weeks. The pasture may have patches of plants on wetted areas with dry, bare ground in between.

Subterranean clover is at a competitive disadvantage to aerial seeding plants. Its runners do not preferentially place the seeds in the hollows, and seeds placed just below the soil surface may or may not be wet by light rains. When they do germinate, the roots may find only dry soil underneath the seed, so the seedling dies. This can lead to a decline in the cover and productivity of clover pastures.

The causes of water repellence

Coarse textured soils with a loamy or clayey sand surface (for example, yellow-brown clayey sands and sandy earths with 5 to 10% clay) can be considered an intermediate category. In practice, they rarely develop enough water repellence to affect their management, but moderate to severe repellence has been measured under long-term blue lupin pastures.

There is some circumstantial evidence to suggest that with changing farming practices (increased production, less soil disturbance and mixing), a shallow (less than 5 cm) surface layer of fluffy soil which is difficult to wet is developing on some of these soils. The content of fine material in the surface soil could have been reduced to less than 5% through clay movement and/or by increases in organic matter through conservation farming.

Hydrophobic organic matter (waxy-like compounds) is produced by the decomposition of plants, but some plants grow larger and produce more waxy residues than others. This is the main reason why some land uses or rotations induce greater degrees of water repellence, especially rotations including legumes.

Water repellence is strongly influenced by past management and land use history. A paddock with inherently susceptible soils may or may not be water repellent at present, depending on the paddock history and the time of the year.

Field observations can be made to verify whether water repellence is a significant problem. A paddock with susceptible soils and a past history of clover-based pasture, blue lupins, perennial pasture or regular legume crops is more likely to develop water repellence to some extent. The timing of observations is important, and in some years, water repellence is negated by an even rainfall pattern early in the season.

Management of water repellence

Possible management solutions depend on the location, landscape and agricultural enterprise in question.

Claying

Claying is currently the best long-term solution to correct the problem for better cropping and pastures. Suitable top-dressed or delved clay can cover the repellent soil particle surfaces and improve soil water retention and nutrition, but is often relatively expensive initially. *See Farmnote No. 14/97: Claying water repellent soils* for more details.

Permanent pastures

Permanent pastures are a potential option. If care is taken with the method of establishment, permanent pasture and fodder shrubs such as tagasaste often prosper on water repellent soils, as do trees such as *Pinus pinaster.*

When revegetating areas

Rip all planting lines to allow water entry; use a soil wetting agent in a narrow band on the planting/rip line; or use a scalper or furrow plough to collect water. Be careful of water erosion, do not scalp or furrow very long lines and operate along the land contour.

Soil acidity

The causes of soil acidity

In the medium rainfall region of Western Australia, many light textured soils were slightly acidic before they were cleared. With the introduction of agriculture, these soils are becoming increasingly acidic because of:

- the leaching of nitrogen out of the root zone; and
- removal of produce (hay, grain, seed, grazing) from the paddock.

The nitrogen can come from growing legumes or from applied fertiliser. When produce is removed it is like removing lime, leaving the soil more acidic.

Causes of yield loss

As the soil becomes more acidic, aluminium becomes more available and can become toxic to plants. With increasing acidity, some nutrients such as phosphorus and molybdenum become less available and may be deficient in the plant. Acidity also reduces yields by adversely affecting the nodulation, and hence nitrogen fixation of legumes. Therefore yield is affected by a combination of nutrient deficiency and toxicity.

Measuring soil acidity

Soil pH is a measure of how acidic the soil is, and the lower the pH, the higher the acidity. Soil testing laboratories use a number of methods to measure pH, usually making the measurements on a suspension of soil in water or in a calcium chloride ($CaCl_2$) solution.

The calcium chloride method is the more reliable measure of soil acidity. Add 0.7 of a pH unit to roughly convert calcium chloride pH to pH in water.

Management of soil acidity

There are two main solutions to soil acidity, namely applying lime and using tolerant crops.

Lime

Lime incorporated in the topsoil can correct soil acidity and increase plant yield. High quality lime at 1 t/ha will increase the soil pH by 0.3 to 0.7 of a pH unit. The lime will last about ten years.

Lime must be well mixed with the soil to be effective. Cultivation before seeding rather than direct drilling will give best results.

Avoid applying lime at more than 2.5 t/ha, since too much lime can induce trace element deficiencies, particularly in relation to zinc and manganese.

Tolerant species

Subterranean clover is tolerant to soil acidity and will grow well in soils with a pH of higher than 4.5 in CaCl.

Groundwater contamination

We all have a responsibility on our properties to manage the resources available to us. This is critically important for our groundwater supplies that are used both locally and regionally to supply domestic or stock water needs. In the past, unregulated land use activities and inappropriate storage, use and disposal of chemicals has caused groundwater pollution, often with serious contamination effects.

As a landholder you can be responsible for the careful and safe management of your property and the important community groundwater resources by following the guidelines set out below:

- *Storage of chemicals* - Ensure that any chemicals you have on-site are safely stored in a cool dry area away from the elements.
- *Safe disposal of chemicals* - Under no circumstances should chemicals be disposed of into waterways, sewage systems or down drains. Your council will have safe disposal points that you can use for such chemicals. (See Useful Contacts for details of your local council.)
- *Safe use of chemicals* - In all cases, follow the instructions closely for any chemical that you use. As a general rule avoid using them within 100 m of waterways. Use reliable and safe equipment and only spray on clear still days with at least 12-24 hours of fine weather predicted.

- *Safe storage and use of manures* - Manures should be stored in a sealed facility to prevent leaching of nutrients from the site. Storage in a shed is ideal or storage on a concrete pad with sealed sidewalls and a cover is acceptable. Manures should not be stored within 200 m of waterways and in areas prone to winter waterlogging to avoid potential for groundwater contamination.
- *Location of stables and other animal yards* - Ideally any animal shelters should be located at least 100 m from waterways and well above areas prone to winter waterlogging to avoid potential for groundwater contamination. Your local council will, in most cases, require plans to be submitted for such structures.

In all cases, check with the Water and Rivers Commission and your local environmental health officer to ensure that the activities you propose meet with their guidelines.

SECTION 4: KEY AGRICULTURAL MANAGEMENT PRACTICES

PASTURE MANAGEMENT

Pasture production for grazing and feed conservation is the major land use within the Ellen Brook Catchment.

Farmers frequently need to re-seed their pastures. Pastures deteriorate and new, more productive species and cultivars become available, and improved techniques are continually developed to tackle land management problems like salinity, waterlogging and acidity. All these situations lead to a re-seeding operation.

A successful re-seeding operation can be highly profitable, and failure expensive. The reseeding operation itself may be faulty, being either poorly planned or poorly executed. Often a paddock is re-seeded because the pasture has deteriorated but the cause of the pasture deterioration has not been identified. Re-seeding, without tackling the underlying problem often leads to failure however competent and planned the re-seeding operation. Alternately a deteriorated pasture can often be restored to full production by changing paddock management.

So assessing the pasture, its botanical composition, health and productivity and the soil it is growing in are all important. This assessment helps you decide whether to re-seed the paddock or change paddock management practices. The following table lists some of the problems and some ways they can be identified.

PASTURE ESTABLISHMENT

Pastures are the backbone of any grazing enterprise. After identifying the underlying causes of why a pasture paddock has deteriorated, it is likely that the paddock will require re-seeding. Re-seeding is expensive, so it is important that any re-seeding operation be successful.

Beware that each paddock or LMU will differ, as will the seasonal conditions. Legume seeds not requiring inoculation should always be treated for redlegged earth mite and lucerne flea. Fertiliser type and rates should be dependent on soil test results.

Table 4. Common problems associated with establishing good pastures

Problem	Indicators and causes
Low soil fertility	• Unproductive pasture. • Pasture low in clover, grassy, and weeds (flatweed, sorrel). • Clover patchy. • Clover has nutrient deficiency symptoms (usually potassium and/or sulphur). • Tissue or soil test for trace elements.
Soil acidity	• ***Soil test*** (chloride pH below 4.3). • Pasture low in clover. • Clover nitrogen deficient and poorly nodulated. • Roots stunted (chloride pH below 4.0). • Sorrel present.
Soil salinity	• Unproductive low-lying (poorly drained) land. • Bare ground, barley grass, button weed, beard grass, little subterranean clover, white clover or capeweed present. Often grows ryegrass, balansa clover or lotus. • Confirm by soil test and an EM 38 survey.
Overgrazing	• Clover, flat weed, winter grass and chickweed present, little ryegrass. • Much bare ground, even in winter • Grazed hard to the ground.
Undergrazing	• Low density, grassy pastures. • Old decaying leaves near pasture base. • Uneven grazing. • Dead grass carried over into new season.
Waterlogging	• Watertable 30 cm deep. Soggy wet ground, rushes, dock, pugging by stock.
Inundation	• Even worse than waterlogging - puddles everywhere.
Soil compaction	• ***Heavy loams and clays.*** Stock pugging, poor water infiltration, shallow rooting. Responds to ripping and draining. • ***Sandy loams.*** Traffic hard pan at depth. Cereal hay crops respond to ripping 30 cm deep.
Weeds	• Sorrel/Guildford grass: Unthrifty pasture, acidic and/or low in nutrients. • Rank week growth: Undergrazing. • Flat weed growth: Low in nutrients (particularly potassium), overgrazing • Rushes: Waterlogging
Dock dominance	• High nitrogen status. • Needs a more productive grass. • Waterlogged, lax grazing, repeated hay cutting.
Capeweed dominance	• High nitrogen status. • Needs more productive, persistent grass. • False break or severe redlegged earth mite attack has killed clover. Sandy soils, disturbed or overgrazed in summer. Lax grazing in winter.
Couch/kikuyu dominance	• Undergrazing, high nitrogen use, salinity, waterlogging.
Loss of clover	• Low soil fertility levels (potassium, sulphur and trace elements), soil acidity, undergrazing. • Repeated hay cropping. • Insects (mite and flea) not controlled in hay crops. Toot rots and scorch in older clover varieties. • Viruses. • Non wetting. • Salt.

Source: *Productive pastures pay*, Agriculture Western Australia, 1995.

How to establish annual pastures

1. Summer - Soil test.
2. Autumn - Graze heavily to remove dry matter.
3. April - Burn if sufficient dry matter is present to carry a fire.
4. April - Topdress with grade one agricultural lime at 2.5 tonnes per hectare (subject to pH being less than 4.5 in CaCl).
5. April - Cultivate to 5 cm and harrow to prepare a final seedbed.
6. April/May - Wait for a complete germination of weeds.
7. Early May - Spray weeds with glyphosate at 2.5 litres per hectare. Add insecticide for control of redlegged earth mite and lucerne flea.
8. Early May - Mix seed and fertiliser in the fertiliser box of a combine and broadcast seed.
9. Harrow to cover the seed and roll to compact the soil around the seed on sandy soils.

The established pasture can be lightly grazed six weeks after germination.

How to introduce improved cultivars to existing annual pastures

1. Summer - Soil test.
2. Autumn - Graze heavily to remove excess dry matter.
3. April - Topdress with grade one agricultural lime at 2.5 tonnes per hectare (subject to pH being below 4.5 pH in CaCl).
4. April/May - Wait for a full pasture germination and clover to have four true leaves.
5. Early May - Spray with glyphosate (360 g/L) at one litre per hectare with added insecticide for redlegged earth mite and lucerne flea control - this spray will remove undesirable weeds but will only set back existing legumes.
6. Early May - Treat legume seed with insecticide for systemic control of redlegged earth mite and lucerne flea one day before seeding. Seed that requires inoculation and lime pelleting should not be treated.
7. Early May - Direct seed with drill two days after spraying with glyphosate.

Seed recommendations for annual pastures

The seed selected to be sown and the rate at which it is sown will vary according to soil type, species and cultivars already existing, species and cultivars potentially available and the current seed price. The lists below are a guide only.

Winter wet soils

Trikkala sub. clover
Paradana balansa clover
Prolific Persian clover
Palestine strawberry clover
Concorde annual ryegrass (one of many available)

Medium soils

Trikkala sub. clover
Seaton Park sub. clover
Frontier balansa clover
Caprera crimson clover
Cefalu arrowleaf clover (sandy gravels)
Cadiz serradella
Santorini yellow serradella
Avila yellow serradella
Annual ryegrass

Dry soils

Dalkeith sub. clover
Hykon rose clover
Cadiz serradella
Santorini serradella
Charano serradella
Annual ryegrass

How to establish summer growing perennial grasses

Perennial grasses cost more to establish than annual pastures because of increased cost of seed and the need to reduce stocking in the year of establishment.

1. Early winter - Graze for winter feed.
2. Late winter - Heavily graze to remove the bulk of vegetated material.
3. Mid August - Spray with 2.5 litres of glyphosate (360 g/L), add insecticide for redlegged earth mite and lucerne flea control.
4. Late August - Harrow or cultivate to obtain enough loose soil to form a seedbed. Do not cultivate deeply (< 2.5 cm).
5. Late August/early September - Sow by mixing seed and fertiliser in the fertiliser box of a combine. Set the disc or cultivators to 2.5 cm depth. Remove the hoses and drop the seed and fertilisers onto the surface then lightly harrow to cover the seed. Roll to compact the soil around the seed.
6. Spring/summer - Delay grazing as long as possible. It is important not to graze in the first summer.

Seed recommendations for summer growing perennial grasses

Rhodes grass is the preferred perennial to sow in the Ellen Brook Catchment. Callide, katambora, finecut, top cut or namkat are suitable varieties. Green, gatton and bambatsi panics may have a place but are not recommended on horse properties. Rates can vary from 2 to 5 kg/ha.

How to establish sprinkler irrigated pastures

Sprinkler irrigated pastures can play an important role on small properties. To ensure success, close attention needs to be paid to the establishment of pasture and subsequent watering, fertiliser application and grazing management.

1. Winter - Graze for winter feed.
2. August/September - Heavily graze to remove the bulk of feed.
3. Early September - Prepare a fine seedbed with few large clods. This can be done with a disc cultivator, a scarifier or a rotary hoe. Then harrow with tyne harrows to break up the clods, firm the seedbed and level the surface.
4. September - Weed control is essential. After the final seedbed has been prepared, water the area to encourage a full germination of weeds, then spray with glyphosate (360 g/L 0 at two litres per hectare) to kill weeds. Add insecticide for redlegged earth mite and lucerne flea control.
5. September - Inoculate and lime pellet the clover seeds.
6. Late September/early October - Mix the seed with the fertiliser in the fertiliser box of a combine and sow by dropping the mixture onto the surface (hoses out). Cover the seed with a set of light harrows and roll to compact the soil around the seed.

Seed recommendations for sprinkler irrigated pastures

Kikuyu
Rhodes grass
Haifia white clover
Palestine strawberry clover
Paspalum dilatatum
(inoculate and lime pellet the clover seed)

FERTILISER APPLICATION

The Ellen Brook Catchment discharges approximately one third of the total phosphorus load that ends up in the Swan River estuary each year. The Ellen Brook contribution to total nitrogen load is approximately 7%. These high nutrient loads encourage rapid growth of algae and weeds that are not needed in our river systems. Apart from causing this pollution and unwanted algal growth, the loss of these nutrients from your farm costs you money.

Different fertiliser strategies have been tested and adopted over the last decade by Agriculture Western Australia to obtain the most profitable (optimum) production of pasture and to achieve the most efficient use of fertiliser with minimum export or loss off site. Fertiliser efficiency is achieved when most of the nutrients are used by plants and little or none is wasted by leaching.

The following strategies refer mainly to the annual fertiliser requirement of legume based annual pastures.

Strategies to reduce leaching

Three strategies, adopted either separately or combined, are recommended:

1. *Apply only the nutrients actually needed.* Soil tests are the best guide to determine the phosphorus (P), potassium (K) and sulphur (S) status of your soil, and hence fertilisers needed (see section on Soil Testing below). Soil tests on most paddocks that have been fertilised for many years have shown that sulphur and potassium are the most important nutrients limiting optimum pasture production, especially for spring clover growth. With traditional use of superpotash fertilisers (applying all the fertiliser near the start of the growing season) high rates of superpotash are required to supply sufficient sulphur and potassium for optimum plant growth. This results in higher costs and excess use of P.

2. *Apply nutrients at a more strategic time.* To avoid leaching of major nutrients apply them at the best time to enhance plant uptake. If the nutrients are applied only once, application of phosphorus, potassium and sulphur at 3-4 weeks after germination is the best time for both pasture growth and the environment. This allows the plants time to develop their root system before fertiliser is applied, increasing the chances of uptake of nutrients by plants before the nutrients are leached out of the root zone.

   Leaching is greatest in winter (June to August) because rainfall is more intense and low temperatures and waterlogging reduce plant growth and nutrient demand. Do not top dress onto ‘soggy’ paddocks with water flowing across them. Both potassium and sulphur are mainly required for spring growth, therefore, application of fertiliser potassium and sulphur in August is vital for optimum growth. This can be achieved by a ‘split’ application, with phosphorus, potassium and sulphur being topdressed 3-4 weeks after germination, followed by a later application of mainly potassium and sulphur in August.

   Applying fertilisers when the plant has the best chance of being able to use them is important. There are a vast range of fertilisers now available and many can be used on a ‘mix and match’ basis or pre-mixed batches can be purchased.

   It is likely that in the Ellen Brook Catchment, sandy soils will need more potassium and sulphur whereas the heavier or loamy clay soils will need a higher level of phosphorus based fertilisers. However soil testing will sort this decision out for you.

3. *Use a slow release fertiliser source.* Less water-soluble sources of nutrients that dissolve slowly or break down gradually, can better match plant demand and so reduce losses through leaching. Amounts to apply and time of application need to be determined. Usually slow release sources can be applied near the start of the season to supply nutrients in spring, when temperatures are rising, rainfall is receding, and pasture growth is increasing towards its maximum.

Some slow release fertilisers are now becoming available commercially, but their eventual use will depend on their rate of dissolution to produce plant available forms of the element in the soil, their ability to be combined with other nutrient sources, and their cost.

Slow release sulphur sources that are already available commercially include:

- crushed rock gypsum (Jurien Bay Gypsum, CRG); and
- elemental sulphur, which as a fine powder is incorporated into single or triple superphosphate; examples are 'coastal superphosphate' and 'Summit Pasture'.

Recommended practice

The best, most efficient and economic fertiliser practice is to use soil tests to determine the amount of phosphorus, potassium and sulphur required, and to apply fertilisers at the right time of year (see section on Soil Testing below).

The preferred option is the application of superphosphate (subject to a soil test), or slow release phosphate sources, 3 to 4 weeks after germination, followed by a second application of muriate of potash and gypsum in August when spring growth increases. Soils vary in their capability of responding to added nutrients. Sandy soils for example will reach their potential at lower phosphorus levels than will loamier clay soils, however they will require higher applications of sulphur and potassium than will loams or clays.

It should always be remembered that the level of production will be constrained by the most limiting nutrient.

Fertiliser application methods

Broadcasting

This method is used frequently before seeding a new pasture when large amounts of fertiliser are needed and the risk of burning the germinating seedling is high.

Fertiliser can be broadcast by machine or by hand. Fertiliser is first distributed evenly over the soil surface and either left for rain incorporation or mechanically incorporated. It is usual to apply phosphatic and potassium fertilisers this way. Nitrogen fertilisers such as urea and ammonia based should be incorporated as soon as they are applied to prevent gaseous losses especially on alkaline or high pH soils.

Top dressing

Top dressing of fertiliser onto established pastures is commonly carried out by broadcasting with a spinner machine. Fertiliser is distributed evenly over the soil surface and is left for rain incorporation. Different fertilisers are topdressed onto existing pastures at different times of the

year and at different growth stages of the plant. For example, the plants demand for phosphorus is higher in the early stages of development and not so much towards the end. Potassium is needed more in the spring when rapid plant growth can 'dilute' the existing potassium levels in the plant and cause a deficiency. It is usual to top-dress potassium fertilisers and sulphur fertilisers in spring if possible.

On waterlogged or wet sands where machinery is unable to travel or where machinery creates undesirable furrows, sulphur is top-dressed in early winter using slow release sources such as ironman or crushed rock gypsum.

When re-seeding pasture, fertilisers are often top-dressed onto the soil surface using a drill or combine which has the hoses pulled out. This way of top-dressing is more precise than broadcasting using a spinner.

SOIL AND PLANT TISSUE TESTING

In any agricultural system it is important to know exactly what your plants need to avoid wastage and to maximise both profit and production. For example in the Ellen Brook Catchment it is likely that on sandy soils using superphosphate, to meet the plant's sulphur and potassium requirements, the amount of phosphorus that is applied is in excess of plant needs.

The question to ask then is why apply expensive phosphorus fertilisers when the plant needs sulphur and potassium? Deciding on exactly what the plant needs will reduce the chances and severity of nutrient losses and reduce the nutrient loads being dumped into the Swan River estuary via the Ellen Brook.

To determine nutrient needs for the crops and soils on your land you must learn two things:

- What nutrients are needed in the fertiliser; and
- How much of each nutrient is needed to get the most profitable yield.

There are several ways to obtain this information:

- Look for hunger signs in the plant or deficiency symptoms.
- Test the soils to estimate their nutrient availability.
- Test the plant to determine the plant's need; and
- Conduct fertiliser trials.

Knowing accurately what your soil needs and what different fertilisers contain enables money saving decisions to be made. For example, superphosphate contains both phosphorus and sulphur and other things such as calcium and oxygen. A soil test may tell you that you don't need phosphorus and the response you are obtaining from applying superphosphate is from the sulphur

content in the fertiliser. Therefore money can be saved by buying less expensive sulphur based fertilisers instead of superphosphate. This action is both beneficial to you and the environment.

The following sections discuss how to take soil and plant tissue samples.

Soil testing

Soil testing is the most effective way of assessing the fertility of your soils. Soil tests alone do not provide a complete answer to working out how much and what type of fertiliser to use but they do help in deciding on a fertiliser program.

Soil tests can:

- reduce the guesswork in soil management and fertiliser use;
- guide decisions on types and amounts in most situations;
- indicate where soil amendments such as lime may be needed;
- assist in calculating profits and investment returns; and
- enable soil fertility trends to be measured and established as a result of management practices imposed on the different land management units.

It is important to realise that the chemical test is only one part of the process. How the sample is taken and the method of analysis is very important.

Collecting samples

The collecting of the soil sample is extremely important, especially when it is realised that each hectare of land contains about 1500 tonnes of soil in the top 10 centimetres. Of a 500 gram soil sample taken from the top 10 centimetres, only about one teaspoon is actually analysed.

Sample dryland pastures when annual species have dried off, which is usually during December through to March. Soil samples are taken from the top 10 centimetres of the soil profile. To be representative, sampling requires an assessment of the soil type and plant growth in the area to ensure it is typical of the area being sampled and any differences in plant growth are not due to soil type changes. Different soils from the same area should not be sampled together since the results would not be same for different soil types, and as such different soils should be sampled separately. Some areas such as stock camps, drainage lines, fence lines and headlands should be avoided.

Notes of where the samples were taken will give valuable information on your management of the different land management units. It is a good idea to mark the sampling transects on your property plan and stick to that transect in future years. Note if the samples were from slopes, different soil types, wet areas or areas of different stages of development.

Collect 20 to 30 cores from each sampled transect and bulk these together to make one sample. Collecting the soil sample to the precise 0-10 centimetres profile is critical.

Who do I take my samples to?

Agriculture Western Australia can provide a list of companies who can carry out detailed soil analysis for nutrient availability and other chemical properties.

Method of analysis

A good soil test chemically extracts and measures the amount of nutrient available to the plant from a small sample of soil.

Different methods of analysis can give different results requiring different interpretation. Methods used that reflect the 'plant availability' of the particular element are preferred. The most common methods used by the major agricultural analytical laboratories in Australia are set out below in **Table 5**.

Table 5. Common soil nutrient analysis techniques

Element	Method
Nitrogen	Nitrate Ammonium Total N
Phosphorus	Colwell
Potassium	Colwell
Sulphur	Potassium chloride
Exchangeable cations	Barium chloride, ammonium chloride
Trace elements	EDTA + ammonium acetate. Hot water (Boron) Manitol + CaCl2, CaCl2 (boron), Ammonium oxalate + ammonium acetate
pH	pH can be measured in water and calcium chloride
Salinity	Electrical conductivity measured in either a saturated extract or a 1:5 soil water solution
Organic matter	Walkley Black oxidisable carbon
Aluminium	Potassium of calcium chloride

It may not be necessary to get samples analysed for all elements and there will be occasions when only basic testing for salinity or pH will be necessary.

Interpretation

Most landowners carrying out soil testing are interested in increasing yields and profits. They are interested in building and maintaining soil fertility and protecting the environment.

The soil testing laboratory results should therefore be considered along with other information such as:

- Recommendations to optimise plant yield so that all nutrients will be maintained at non-limiting economic levels throughout the life of the plant.
- 'Adequate' soil nutrient levels need to be maintained. Frequently in order to provide 'adequate' levels of one particular nutrient another is applied to excess.
- If soil tests show a high or excessive level of nutrient, little economic benefit will be gained by applying more of that nutrient. Economic responses are greater when nutrient levels are in the low range.
- Maintaining adequate soil and plant nutrient levels allows the plant to resist stress conditions of heat, cold and waterlogging.

Agriculture Western Australia has produced *Bulletin No 4357: Fertilisers for pastures on sandy soils of the Swan Coastal Plain* and **Tables 6, 7, 8** and **9** below (taken from the document) can be used to help interpret soil test results. The optimum soil test level depends on enterprise profitability. Beef and sheep farms are less profitable than dairy farms so optimum soil test levels on beef and sheep farms are lower than on dairy farms. These levels are a guide only.

Table 6. Nutrient status level of soil

Nutrient status level	Response to fertiliser	Nutrient need
Low	Large growth response over 15%	High nutrient need
Medium	Small growth response about 15%	Maintenance dressings only
High	Little to no growth response	No need for fertiliser other than to replace nutrient losses

Table 7. Soil phosphorus status

			Soil phosphorus levels (ppm)		
Phosphorus fixing level	**Reactive iron* (ppm)**	**PRI***	**Low**	**Medium**	**High**
Very low	1- 100	Below 2	Below 7	7-10	10+
Low	101- 200	Below 2	Below 8	8-13	13+
Low/medium	201- 400	2- 7	Below 15	15-20	20+
Medium	401- 800	8-15	Below 20	20-25	25+
Medium/high	801-1600	16-35	Below 25	25-35	35+
High above	Above 1600	Above 35	Below 30	30-45	45+

* Reactive iron and phosphorus retention index (PRI) are chemical tests used to measure the soil's ability to hold or fix phosphate.

Table 8. Soil potassium status

	Potassium levels (ppm)		
	Low status	**Medium status**	**High status**
Beef farms	Below 80	80-100	100+
Dairy farms, hay and silage	Below 80	80-120	120+

Table 9. Soil sulphur status

Reactive iron (ppm)	PRI	Sulphur retention	Sulphur response
1- 200	Below 2	Very low	33%+
201- 400	2- 7	Low	25-33%+
401- 800	8-15	Medium	12-33%
801-1400	16-30	High	12-25%
1400-1600+	Above 30	Very high	Nil

NB If no S is applied, even on soils with reactive iron of > 1160-2000 a S need will develop over time.

Reactive iron and PRI both give a rough measure of the soil's ability to retain sulphur and, hence, its responsiveness to sulphur fertilisers.

Plant tissue testing

By plant tissue testing we are actually 'asking the plant' if the soil and fertiliser supplied enough of each nutrient tested. The nutrients can be tested in the plant sap or in the dry matter. The concentrations of the various nutrients can be determined chemically. If a nutrient is below the standard minimum concentration, which varies with each nutrient, it is likely that the application of a fertiliser containing that nutrient will increase yields.

Analysis of dried plant material should be viewed separately from results of rapid plant sap tests.

The major uses of plant tissue analysis are to:

- confirm visual nutrient deficiency diagnosis;
- identify hidden problems where plants do not exhibit 'hunger signs' but are not producing well;
- identify areas where deficiencies of one or more nutrients may occur;
- determine if applied nutrients have been taken up by the plant;
- assess feed quality and use as a guide to animal health issues; and
- determine trace element requirements.

Collecting samples

Collecting the appropriate plant part is important. The concentration of any particular nutrient will vary with the plant part, the plant's age, variety and weather conditions. Most reputable testing laboratories will assist in providing information on sampling procedures.

Nutrient deficiency symptoms

Plants suffering from a nutrient deficiency or multiple nutrient deficiencies often exhibit visual symptoms. There are many books and charts describing and illustrating these symptoms and care must be taken to avoid some of the traps because:

- multiple deficiencies are difficult to detect and may be masked by leaf diseases or other non-nutritional factors;
- growth and yield may be retarded long before symptoms become visible;
- symptoms of different deficiencies can be easily confused; and
- 'hidden hunger' may exist where there are no symptoms but yield is reduced.

General and simplified descriptions of some nutrient deficiencies are contained below in **Table 10**.

Table 10. Some common nutrient deficiencies in plants and symptoms

Nutrient	Symptoms
Nitrogen	Yellowing of the whole plant occurs often with reddening in cold weather; older leaves are affected first.
Phosphorus	Plants have dark green foliage, reddening or purpling of leaves or petioles; older leaves affected first.
Potassium	Older leaves of plants may be chlorotic and dying near the margins or marginal burn; younger leaves may develop red colours or show interveinal chlorosis with shiny surfaces.
Sulphur	Whole plants may develop chlorosis, with the younger leaves being the first affected. Can be distinguished from N deficiency where deficiency first appears in older leaves.
Calcium	Growing point of plants dies. In fruit crops disorders develop such as bitter pit in pome fruit, blossom end rot in tomato and capsicum.
Magnesium	Marginal or interveinal chlorosis in older leaves of plants; green area of the leaf of woody plants may develop an 'arrow head' appearance. Usually occurs on older tissue first.
Copper	Young leaves die, chlorosis, failure to set fruit. Expanding leaves may become twisted and cupped and leaf margins may be irregular.
Zinc	Small bunched leaves, chlorotic mottling in less severe cases.
Boron	Death of growing points and development of a 'witches broom' effect. Leaf distortion in some species (e.g. grapes) fruit may be distorted in some cases, petioles may crack in celery; distortion of stems and branches in pine trees with development of speed wobble effect.
Molybdenum	In legumes a greater paleness develops. In non-legumes, a mottled pale appearance. Marginal leaf burn of mature leaves in rock melon, maize, sunflower, whiptail in cauliflower.

For complete diagnostics, if plant nutrient deficiencies are suspected, check pH and salinity levels in the soil and irrigation water. Low pH can reduce the availability of calcium, magnesium, sulphur, phosphorus, potassium and molybdenum. A low pH can also increase the availability of iron, manganese, boron, copper, zinc and aluminium, so ideally a balanced pH that suits both the plant and the soil type is required.

WEED CONTROL

Weeds and weed control is a problem common to every part of the Swan-Canning area, and the Ellen Brook is no exception.

Responsibility for weed control rests with the landowner. This includes individuals, corporate owners and State Government agencies or Local Governments with vesting authority over crown land. Agriculture Western Australia maintains and updates a list of agricultural weeds and their control on its website (www.agric.wa.gov.au). Use the alphabetical search facility for 'Weeds - declared plant list'. There are currently no known declared weeds in the Ellen Brook Catchment.

The golden rule is 'know thine enemy' - how the weed grows, how it reproduces or spreads (seeds, corms or bulbs, rhizomes), when it flowers and when it sets seed.

Weeds can be a problem in pastures and crops, and where the weed occurs will often determine the most appropriate method of control.

The more common pasture weeds in the Ellen Brook area include Paterson's Curse, Cape Tulip, dock, double gee, barley grass and sorrel. In pasture some weeds are only a problem when they dominate e.g., a small proportion of capeweed in the pasture is not a problem.

Weeds on your property need to be identified and further information obtained in regard to the potential control or eradication options. Agriculture Western Australia has many Farmnotes on weed control in agricultural situations.

Common methods used for weed control include:

- biological control;
- hand and mechanical removal;
- scalping and / or cultivation and slashing; and
- herbicide application, either manually operated spray packs at the small scale or boom sprays at the broad scale.

Take care when using herbicides - seek expert advice, read instructions and use safety equipment. Ensure the correct herbicide is being used for the weed and situation.

There is continuing research into biological control of weeds (e.g. bridal creeper, leaf hopper, rust, dock moth and others). Maintain contact with Agriculture Western Australia offices for latest updates on various biological weed controls.

It is best to control weeds when they are young and small, as they are most susceptible to both herbicide and manual operations at this stage.

SOIL AMENDMENTS

In many areas of the Ellen Brook Catchment, soils perform below the ideal, making traditional agriculture and land use difficult. Some sites have low production potential, and often these are the poor sandy soils that are prone to erosion and seem unable to hold onto water and nutrients. Others, whilst having some productive potential, are prone to waterlogging and become 'gluggy' in winter, bake hard in summer and at all times are difficult to work by machine or by hand.

In all cases the soil is missing some 'key' ingredients that, if added at the correct rate, could improve the soil balance, fertility, productivity and hence its value on the property.

Today there are a range of materials and strategies that can be used to improve the soils on a property. In all cases action should start with a detailed soil test of the site to get a clear understanding of the soil and what exactly is required and in what quantities. Using the soil test results, improvements can then be made with greater accuracy according to the soil type. The major forms of improvements are set out as follows:

Improvements for sandy soils

For the sandy soils, the problems are usually low fertility, water repellency and low moisture retention. Improvements can be made using one or more of the following additives:

Compost, mulch and cover crops (e.g. straw)

These can be spread and incorporated into the problem soils. They will provide nutrients for plant growth and will help to improve soil structure by feeding microorganisms, which in turn will generate natural fertility to sustain plant growth. An ongoing program to apply these materials will be required, particularly for very poor soils.

Zeolite, Bentonite and Gypsum

When these three naturally occurring elements are mixed together and incorporated into the soil they form a powerful mixture that will improve the sandy soils ability to grab hold of water and nutrients. They have the advantage that they can be used in all areas.

Improvements for heavy clay soils

For the clay soils, the problems are usually associated with poor drainage and soil structure. Improvements can be made using one or more of the following additives:

Gypsum and crushed limestone

Most clay soils will respond to either gypsum or crushed limestone. Both will act on the clay to break it up into manageable and workable clumps and as both add valuable nutrients to the soil they ensure that there is an improvement in soil structure, drainage and productivity.

Compost, mulch and cover crops (e.g. straw)

These can be spread and incorporated into these types of soils. They will help to build up soil structure and break up the clays into workable clumps. An ongoing program to apply these materials will be required, particularly for very heavy clay soils.

A word of caution!

In all cases the materials to be used should be spread when the soil is dry and trafficable. They can be incorporated into the soil to a depth of 5-10 centimetres by cultivation or with a rotary hoe, or if there is a risk of soil erosion, they can be spread on the top where they will infiltrate into the soil over time. In all cases, check with the Water and Rivers Commission and your local environmental health officer to ensure that these materials will not cause pollution to waterways and residential areas. As a general rule they should not be spread within 50 metres of waterways.

Who can help me?

Your local landcare officer or Agriculture Western Australia office should be able to provide details on these products and where they can be sourced. Often rural suppliers and large garden supply centres will have useful information and have access to these products. In some cases materials maybe difficult to purchase or they will be available only seasonally. It may pay to work as a group of landholders to purchase the materials required, particularly if your property is small and the minimum amount available for sale is more than your own property requirements.

SECTION 5: KEY HORTICULTURAL MANAGEMENT PRACTICES

FERTILISER USE

Control of nitrogen and phosphorus pollution from horticulture

Horticultural activities on the Swan Coastal Plain can be classified according to their relative phosphorus and nitrogen use and the amount of residual nutrient remaining in the soil after harvest.

Table 11. Relative nitrogen and phosphorus pollution risk of different horticultural activities

	Nitrogen	Phosphorus
High	Market gardens, greenhouse flowers	Market gardens, greenhouse flowers
Medium	Orchards, vineyards, turf, native flowers, nurseries	Orchards, vineyards, turf
Low	-	Native flowers, nurseries

Source: Lantzke, N. (1997). Phosphorus and Nitrate loss from horticulture on the Swan Coastal Plain.

Ways to reduce nitrate leaching from horticulture

(Source - Farmnote 02/95: Nitrates in the groundwater beneath horticultural properties.)

- Apply no more nitrogen fertiliser than the crop needs for good growth. Refer to Agriculture Western Australia for nitrogen recommendations for different crops.
- Do not over-water. Excessive applications of water infiltrate through the soil and leach nutrients away. Small, frequent waterings are best on sandy soils, keeping the root zone moist without excessive water loss below the root zone.
- Ensure that your irrigation system applies water evenly. Uneven application leads to over-watering in some areas in order to supply enough water to the drier spots. This excess water drains below the root zone, leaching nitrogen with it.
- On sandy soils, apply nitrogen fertiliser in small, regular doses throughout the life of the crop. This will limit leaching (caused by heavy rain or over watering) to the most recent small application.
- Slow-release nitrogen fertilisers can reduce leaching, because they supply nitrogen at a steady rate over an extended period. This can result in efficient nitrogen use by crops, with less nitrogen available for leaching. At present these forms of nitrogen are more expensive and generally uneconomic.
- Match nitrogen application rates with crop growth stage. Young crops require lower rates of nutrients than crops in mid-growth. However, apply nitrogen in more frequent, smaller doses when crops are young, because their root systems are smaller. Reduce nitrogen applications as the crop approaches maturity.

- When plants are young, place nitrogen fertiliser with droppers immediately adjacent to plants. When crops develop more extensive roots they are better able to extract nitrogen spread over the whole garden, orchard or vineyard.
- Do not apply high rates of poultry manure, which will increase soil nitrogen levels far beyond what the plant can use and lead to nitrogen leaching. All nitrogen contained in poultry manure is leached within about four weeks of application. The maximum recommended rate for vegetables is 30 m^3/ha per crop.
- Conduct plant testing to determine whether the crop has sufficient nitrogen and adjust nitrogen applications.
- Sap testing kits provide a quick method to determine the nitrogen status of a crop.
- Adding nitrogen daily in the irrigation water rather than weekly or fortnightly as a side dressing can reduce the amount of nitrogen being leached in the groundwater.

Ways to reduce phosphorus leaching from horticulture

(Source: Draft Environmental Code of Practice for Market Gardens on the Swan Coastal Plain and Best Practice Guidelines for Growing Vegetables, NSW Agriculture, 1997.)

- Slow release phosphorus fertilisers should be used wherever possible.
- If soluble phosphorus fertilisers are used, their application rates should be drastically reduced but with more frequent applications. Rather than add all the crops requirements before the crop is planted, it is recommended that the amount added pre-planting is halved and the remaining phosphorus added weekly or fortnightly as a side dressing to reduce the amount leached to the groundwater.
- The phosphorus requirement of the soil should be determined periodically to establish the amount of phosphorus in the soil so that surplus phosphorus is never added.
- Organic matter or clay soils should be blended into sandy soils to improve phosphorus retention.
- The long held view is that phosphorus does not move very much in the soil, so it needs to be applied a few weeks before planting. Side dressing phosphorus is of little benefit to crops that are already established.
- Apply phosphorus fertiliser to the area where plant roots will grow. Banding is preferable to broadcasting as the fertiliser is placed in the root zone where it is needed by young plants

Fertiliser application methods

Broadcasting

Broadcasting is used frequently before seeding a new crop when large amounts of fertiliser are needed and the risk of burning germinating seedlings is high.

Fertiliser can be broadcast by machine or by hand. Fertiliser is first distributed evenly over the soil surface and either left for rain incorporation or mechanically incorporated. It is usual to apply phosphatic and potassium fertilisers this way. Nitrogen fertilisers such as urea and ammonia based should be incorporated as soon as they are applied to prevent gaseous losses especially on alkaline or high pH soils.

Side-dressing

Row crops such as olives, grapevines and other tree crops usually receive side dressings of fertilisers applied either close to or between the rows after the crop is well established. Phosphatic fertilisers are usually side-dressed and should be applied early in the establishment phase and further dressings applied as a maintenance requirement. Side dressing of nitrogen fertilisers is common practice.

Fertigation

Fertigation is used when it is possible and appropriate to apply nutrients in irrigation water. Soluble fertilisers are injected into the irrigation water during the pumping stage. Highly accurate applications of the required nutrients can be applied using this method.

Fertigation is commonly used on perennial tree and row crops such as olives and grape vines where applications of nitrogen are regularly needed to maintain high growth rates. In general, nutrients with poor mobility such as phosphorus are added at the beginning of the season, and usually applied direct to the soil and not through the irrigation system. More mobile nutrients are usually added later in the plant's growth cycle. Remember that nutrients need to be soluble to be used in a fertigation system. Soluble phosphatic fertilisers are quite expensive.

Drip irrigation systems should be flushed at the end of each fertigation cycle to prevent blockages and algal build up.

IRRIGATION

How much water do plants need? Most irrigators tend to underestimate the plants water needs. Water is needed to irrigate the crop, cool the crop (for example lettuces), prevent sandblasting, wash in fertilisers, prevent frost damage, wet the soil before planting and to apply chemicals.

In the Ellen Brook Catchment irrigation is used to produce both annual and perennial horticultural crops. Crops of grapes, olives, flowers such as proteas and vegetables are irrigated each year.

Landowners need to remember that although irrigation usually increases production it does not always increase profit. Irrigation can increase the landowner's ability to diversify into a range of alternative crops, which were previously limited by the availability of natural rainfall.

It is important to consider many other factors such as the type of plant (annual or perennial), the soil type and its water storage capacity, the rainfall and evaporation rates, and the actual efficiency of the type of irrigation system you are intending to use.

Agriculture Western Australia has a Crop Irrigation Requirement Program that can help you decide how much water your crop needs. Deciding on what your crop needs on a day to day basis or actually scheduling irrigation requires measurement of climatic data such as rainfall and evaporation. An understanding of crop factors, soil factors and the efficiency of the various types of irrigation are needed to accurately determine plant water needs.

The cost of an irrigation system will vary according to the:

- amount of ground preparation and fencing needed;
- type and amount of water available;
- soil types and landforms slopes infiltration rates, etc.; and
- total amount of water needed per year.

Types of irrigation

There are four broad types of irrigation systems. Each has its own characteristics and uses. The categories are:

- over head sprinkler systems (which requires high water pressures);
- flood irrigation methods using either bays or furrows (which requires very flat or gently sloping land and large volumes of water);
- trickle and micro sprinkler systems (which requires medium to low pressures and smaller volumes of water); and
- sub-irrigation methods.

The two types of irrigation systems that are commonly used in the Ellen Brook Catchment are trickle irrigation and sprinkler spray systems. Of these, trickle irrigation is the most efficient and the recommended irrigation system for the Ellen Brook Catchment.

Trickle irrigation

Trickle irrigation is possibly the most efficient method of irrigation available in the Ellen Brook Catchment. The desired rate of water can be applied accurately. Pressure compensation to allow for accurate application over the length of a trickle line can be achieved. Installation costs are lower since total water volumes per unit of time are less, pressure and friction parameters are more easily managed resulting in lower capital, and have lower running and maintenance costs.

Efficiency values of above 90% can be achieved from trickle irrigation systems where there is very little water lost to evaporation or passes through the root zone to the watertable. Micro-sprinkler

systems can be used on high infiltration soils where lateral spread of water does not readily occur and a wider wetted area is needed.

Most irrigation practiced in the Ellen Brook Catchment is based on trickle irrigation methods. It is commonly used for watering tree crops such as olives, citrus fruit, flowering shrubs, vineyards and can be adapted to most row crops where a cooling effect is not required.

Sprinkler spray systems

Sprinkler spray systems can be either fixed or moveable and are used predominantly on pastures and small areas of annual vegetable crops. The efficiency is less than that of trickle systems, but more than flood or furrow irrigation systems. An efficiency factor of about 75 to 85% is commonly used for sprinkler systems.

The slope of the ground, infiltration rates, applications rates and the salinity of the water are all issues that need to be considered. Generally vegetable crops are produced on sandier soils where infiltration rates are not an issue. However, nutrient losses from over watering are an important consideration in the Ellen Brook Catchment. Sprinkler irrigation of small areas of perennial grass pasture for animal studs is typical of small area irrigation where water supplies may be limiting.

Factors contributing to crop growth

Sustainable crop production depends on the irrigator's knowledge of the factors contributing to crop growth under irrigation. These factors are:

- The water requirements of the crop.
- Soil type.
- Soil preparation.
- Soil fertility.
- Weed control.
- Pests and diseases; and
- Varieties used.

Water requirements of horticultural crops

Soil moisture needs to be kept at a level that allows optimum growth of plants. The main considerations here are:

- evaporation rates;
- crop factors;
- soil types;
- infiltration rates;
- root depth; and
- rainfall.

Appendix G describes each of the considerations above and outlines how to calculate the water requirements of various horticultural crops grown in the Ellen Brook Catchment.

Water quality

The quality of the water may determine how it is applied and what it can be used for. Saline water should be kept off the leaves of plants to avoid 'burning'. Water of marginal quality for the particular crop needs to be carefully managed to avoid plant damage. Lists of plants and their relative tolerances to salinity are readily available.

Another important measure of irrigation water quality is the iron content. Toxic levels frequently occur in both groundwater and surface water. High iron content water may damage trickle irrigation systems by combining with an alga and causing pipe blockages. The use of algicides and disinfectants can assist in overcoming these potential problems.

Agriculture Western Australian Farmnotes are available to assist with these problems.

Timing or scheduling of irrigation

The timing of water applications is a crucial part of managing irrigation. Some tree species respond to dry periods by flowering earlier, others need dry spells and then a large water application to break dormancy. Olives for example need water to assist in flowering and fruit filling. Wine quality from vines subjected to controlled irrigation is higher than wine produced from vines receiving maximum irrigation.

Estimates of when the crop requires water can be made from measuring evaporation and rainfall and knowing your soils Readily Available Water (RAW) holding capacity. The amount of RAW available to the plant is that which the plant can extract or 'suck out'. Evaporimeters can be easily made and calibrated from drums.

More sophisticated methods of determining when to irrigate are available. Tensiometers, moisture probes, and computerised weather stations can all be used to assist in making these decisions. Many large vineyards use moisture probes and radio transmitters to send RAW information from the vineyard soil to a receiver based at the office, which is connected to a computer where information can be down-loaded into a program that is capable of controlling solenoid valves to start watering cycles automatically.

On a smaller and less technical scale, simple instruments such as the evaporimeter, rain gauge and a soil auger can be used to estimate soil moisture storage.

Periodic inspections during irrigation will allow the landowner to see how far the irrigation is penetrating the soil and wetting the root zone. This will allow a judgement to be made as to whether over or under watering may be occurring. Apart from actually weighing and drying out a

soil sample, a rough estimate of the moisture content can be obtained by the soil's appearance and 'feel'.

Efficient irrigation

In summary, efficient irrigation management requires knowledge of the crop, irrigation methods and system, soil and water quality as well as methods of monitoring the soil and water status.

To be able to maintain a healthy and profitable environment on your land, care needs to be taken and suitable nutrient and irrigation management measures put in place.

WINDBREAKS - BUFFERS FOR HORTICULTURE

High wind velocity (speed) causes problems for most horticultural properties on the Swan Coastal Plain. The establishment of a well-designed windbreak will help achieve higher yields and improve the quality of most horticultural crops. Windbreaks will also help you to maximise resource use, particularly water, but also fertilisers and chemicals. The main problem winds in summer come from the east in the morning and the south west in the afternoons. In autumn and winter strong northwesterly winds associated with the on-set of frontal systems can also be a problem.

The advantages of windbreaks

1. *Reduced plant damage* - Vegetable crops are protected from sandblasting; and the percentage of fallen and blemished fruit is reduced. The incidence of broken stems, leaf loss and lodging of plants is also reduced.
2. *Increased yield* - Trials have shown that protection from wind will increase yield. This is true for broadacre crops and livestock production as well as horticultural crops. Strong, hot winds increase plant evapotranspiration resulting in moisture stress and the requirement for more frequent irrigation. In winter, cold dry winds cool the soil, which slows plant growth and delays crop maturity. Wind will also reduce the activity of insect pollinators.
3. *Increased sprinkler uniformity* - Windy conditions will greatly reduce the uniformity of sprinkler irrigation resulting in significant yield variations across a crop. Wind increases evaporation and therefore water use.
4. *Decreased wind erosion* - On vegetable growing properties, windbreaks will protect bare cultivated areas from erosion by wind.
5. *Increased spray efficiency* - Windbreaks reduce spray drift and will maximise the efficiency of pesticide applications. They will reduce the chance of accidental damage to other crops and increase the number of days when spraying is possible.

Windbreak design

The design of windbreaks is important if your investment is to be maximised. Poorly designed and sited windbreaks may interfere with farm operations, provide limited advantages and may need to be removed later. As with most situations time spent in planning will be paid off in the long run.

Important principles for windbreak design are:

- Position at right angles to the most dominant/damaging winds. On the Swan Coastal Plain they should run north-northwest to south-southeast.
- East-west windbreaks will result in significant shading to the south of the windbreak in winter, and cause a reduction in yield.
- Design your windbreak as part of an overall property plan so other requirements can be taken into account (e.g. re-positioning of fences, tracks and access ways).
- Avoid windbreaks on ridges as they may increase turbulence.
- Solid barriers create turbulence and eddies. The most effective windbreaks are those that allow the wind to flow through them; and ideally about 50% of the wind should flow through them.
- Gaps and access ways may cause the wind to tunnel. Short windbreaks, twice as long as the gap should be planted on the windward side of the access road to provide continuous protection.
- Windbreaks will provide downwind protection for a distance of up to ten times their height. In a horticultural situation, windbreaks over 6-8 metres can be difficult to manage and may cause excessive shading of crops. On larger properties a windbreak 6-8 metres high will require another windbreak about 60 to 80 metres downwind.
- Windbreaks should extend well beyond the edge of the crop being protected, as wind will curl around the edge of the windbreak causing turbulence.
- Windbreaks should be planted at least 10 metres from the horticultural crop to reduce shading and competition from tree roots. A greater buffer area is needed for tall windbreak species. Sufficient room should be left to allow ripping of the tree roots, vehicle access and turning space. A greater distance between crop and windbreak is required when trees are planted to the north of the cropping area so as to minimise shading in winter.

Suitable tree species for windbreaks in the Ellen Brook Catchment

Many species have been evaluated for their potential as windbreaks. No one species possesses all of the following beneficial criteria:

- Cheap.
- Fast growing.
- Upright habit.
- Retention of lower branches.

- Immunity to pests and diseases.
- 50 per cent porosity to wind.
- Non competitive or non intrusive root system.
- Branches which don't break in strong winds.
- Minimal suckering; and
- Easily trimmed or hedged.

The following species are most suitable for use as horticultural windbreaks on the Swan Coastal Plain.

Casuarina species

Demonstrations by Agriculture Western Australia have shown *Casuarina* species to be one of the best species for windbreaks on horticultural properties on the Swan Coastal Plain. The best performing *Casuarina* species in most cases is *Casuarina cunninghamiana* (river sheoak).

On heavier soil types *Casuarina glauca* (swamp oak) and *Casuarina obesa* (also called swamp oak) have performed well, though they are more prone to splitting in high winds. On white and pale grey sands *Casuarina equisetifolia* (coastal sheoak) performs well, though the tree shape is fairly open possibly allowing too much wind to pass through. All *Casuarina* species are resistant to almost all pests and diseases (including weevils). Rabbits like to eat young *Casuarina* seedlings, and if present, should be controlled before planting.

Particular care must be taken when using *Casuarina* windbreaks for drip irrigated perennial crops. If the tree's roots are not adequately pruned they will grow into the production area, seriously competing with the crop and even entering into the drippers. The setback distance from the windbreak may need to be increased when growing drip irrigated, perennial crops.

Eucalyptus species

A number of eucalyptus species have been used for windbreaks on horticultural properties. Limb breakage on mature trees during high winds can be a problem and with many taller species an additional, lower growing species is needed to fill in holes in the base. Eucalyptus trees are prone to attack by a range of insects. Spacing between trees should be 3 to 4 m. Species that may be suitable are listed in **Table 12** below.

Table 12. Eucalyptus species that may be used in windbreaks

Small trees	Large trees
Eucalyptus decipiens	*Eucalyptus botryoides* (southern mahogany)
Eucalyptus platypus (coastal moort)	*Eucalyptus gomphocephala* (tuart)
Eucalyptus lehmannii (bushy yate)	*Corymbia maculata* (spotted gum)

Eucalyptus cladocalyx (dwarf sugar gum)	*Eucalyptus grandis* (rose gum)

Exotic deciduous trees

The three main deciduous tree groups that are suitable for boundary and internal orchard windbreaks are *Populus* (poplars), *Salix* (willows) and *Alnus* (alders). All are moderate to fast growing species and respond well to intensive management and side trimming. Deciduous trees provide less wind protection during the winter months. This is a disadvantage for annual vegetable cropping and evergreen perennial crops.

Pinus radiata

Pinus radiata is fast growing species and reaches a height of 15 to 20 metres. Pines are suitable for planting as windbreaks on horticultural properties though they have some limitations. Older radiata trees become too open at their base and often require an under planting of a shade tolerant, lower growing species. This lower growing species should be planted at the same time as the pines.

Other problems with radiata trees include a canopy which is too dense when young, too wide a circumference when older and a poor ability to form a hedge. Limited side pruning just before the spring flush is useful in younger trees. *Pinus pinaster* is more suited for planting on white sands.

SECTION 6: KEY ENVIRONMENTAL MANAGEMENT PRACTICES

WATER COURSE MANAGEMENT

From drains to living streams

Your watercourse is part of an extensive water catchment network, made up of depressions, wetlands, drains, streams and rivers that branch out to remove excess rainfall from the surrounding landscape. Water does not flow in a straight line, so natural streamlines generally 'snake' or meander across the land on their way to the ocean.

Unfortunately, most waterways are being used simply as a drain, with little thought to the consequences. Practices such as the clearing of fringing vegetation, uncontrolled grazing by livestock, removal of natural debris such as logs and branches, the building of piped culverts, the straightening channels to name a few have altered the natural waterway systems. Extensive networks of poorly designed, artificial drains are contributing to excessive quantities of nutrients, sediment and other types of pollutants entering our waterways.

Activities on your property are linked to others via this network of drainage. Waterways need your help. A great way to start is by wrapping them in a protective layer of vegetation.

BENEFITS OF HEALTHY RIPARIAN VEGETATION

Healthy vegetation on the banks of your waterway will provide many benefits. Referred to as the 'Riparian Zone', the area adjacent to your waterway is vitally important to its health and provides a range of benefits as outlined below.

Erosion control

Multiple layers of vegetation protect the soil within the riparian zone of natural watercourses. A mixed canopy of trees, shrubs and other vegetation form a protective umbrella over the soil, shielding it from the direct impact of heavy rainfall. Fallen leaves and other debris mulch the soil and add another layer of protection on the surface of the soil.

Like the steel reinforcing bars in concrete, the roots of trees and large shrubs create an extensive underground structure to hold and support the banks of your watercourse together. Within this underground framework the soil is bound together by the fibrous roots of the small shrubs, sedges, rushes, herbs and grasses.

Biological nutrient filter

The erosive force of rainfall run-off entering the waterway from adjacent areas is reduced by the filtering effect of healthy riparian vegetation. This vegetative maze reduces the speed of the run off, filters out debris, manure and sediment, and increases infiltration into the soil. Once in the soil,

dissolved nutrients can be utilised by the extensive root systems of the plants or bound up by soil particles.

Habitat for wildlife

The combination of water and thick protective vegetation provides the ideal conditions for a wide range of wildlife. Riparian plants provide food and shelter for both land and water-based creatures. Insects such as Dragonflies and Mayflies are drawn to the water to breed, as they must spend their larval stages in water. The sedges and rushes that often line the shore of a waterway provide a home to freshwater shrimp, beetles and small fish. The leafy vegetation on the bank is alive with insects on which spiders, lizards, birds and mammals can feast.

Food for aquatic creatures

Leaves falling into the water are the primary source of food for the waterways herbivorous macro-invertebrates, who in turn become food for carnivorous invertebrates such as marron, fish, frogs and birds. Overhanging trees and shrubs provide shade to keep the water cool in the hotter summer months. Many of the aquatic creatures are sensitive to high temperatures and die without the cooling shade that the trees provide. Woody debris such as fallen trees and branches provide underwater habitats, protection from predators, shelter from fast flowing water and fish spawning sites.

Wildlife corridors

Well-vegetated waterways provide protective corridors along which small birds and animals can move. In largely cleared areas, these ribbons of green are becoming increasingly important, as they are often the only links to other semi-isolated patches of remnant vegetation. Without them, populations of birds and animals are trapped and vulnerable to predation, inbreeding, food shortages, fire and other threats.

Human sanctuaries

We often forget the recreational value of a healthy living stream. Every waterway is different with regional differences being provided by its unique blend of local native vegetation. People like to relax in these areas, enjoying a shady tree and admiring the scenery and associated wildlife.

Basically, healthy riparian vegetation provides many environmental, economic and social benefits.

PROTECTING AND ENHANCING YOUR LIVING STREAM

If your riparian zone is degraded, subject to grazing or is being damaged in any way, the first step in its rehabilitation is to develop a plan of attack. Your waterway restoration project must be

integrated into your Property Plan**.** Think of your property as a living, breathing organism that must have all its component parts working in harmony to function properly.

Remember your waterway is only part of a branching watery network, surrounded by many influences, so consider the wider picture when planning your work.

Step 1. Who's waterway is it?

Before you do anything you need to know who owns or manages the waterway. Even if it passes through your own property it may be a government proclaimed waterway. In general the bigger it is, the more likely that you will need permission. Your local shire council will be able to advise you on the level of permission required.

Step 2. Seek help

There is a wealth of knowledge on waterway restoration built from many years of trial and error. Seek advise from others such as experienced locals, landcare groups, your local landcare coordinator, environmental consultants and government organisations such as the Swan Catchment Centre. Your local shire council will be able provide you with a list of contacts.

Did you know?

Your project is likely to be eligible for landcare funding, providing up to 50% of your project costs. Think ahead and apply early (up to 12 months ahead of implementation), as these funds are often limited.

Step 3. Don't forget the tributaries

It may not be practical to revegetate all the minor drainage lines that empty into your waterway but they have the potential to clog your restoration with a continual supply of sediment and nutrients if not considered. Consider realigning internal fences so that it coincides with minor drainage lines. Maybe establish a wider revegetation zone where the minor drain empties, filtering the water before it enters your waterway, effectively creating a wetland.

Step 4. How wide do I fence?

Environmentally speaking, the wider the vegetative buffer the better, but any buffer is better than no buffer at all. Economically speaking, your fence is a major investment so it makes sense to locate your fence higher than the potential flood height of your waterway. When building your fence don't be lured into following the meanders of the waterway closely in a bid to limit loss of grazing land. It is far easier and cheaper to keep bends, and hence expensive strainer posts, in your fence to a minimum. Revegetating wider sections will also provide valuable shelter for stock.

Figure 9. Towards a living stream.

Step 5. Revegetation

Depending on the degree of degradation some areas may have enough native species present to naturally regenerate once fenced. However, when the impact of uncontrolled grazing is eliminated, other issues are likely to arise to hamper the revegetation of the waterway.

Weeds and other pests

Weeds can pose a major threat to the successful regeneration of your waterway. To give the native vegetation a chance to establish, weed and pest control measures must be introduced. You may have to resort to physical removal of weeds or the careful use of herbicides. When using herbicides follow the instructions on the label carefully and seek out 'frog friendly' formulations to limit any harmful affects to the waterway. Rabbits and kangaroo numbers need to be monitored as they can eat a large number of your lovingly planted seedlings. Tree guards may be necessary to get your seedlings through the first couple of years.

Soil preparation - ripping and mounding

Some soil preparation will assist revegetation, but be careful as you can easily cause an erosion zone. Ripping is essential on all agricultural soils before planting. Ripping should be to about 0.5 m or deeper where impeding layers can be profitably broken. Ripping will increase soil aeration, and this increases plant growth. Mounding should always be done on soils that are salt affected or waterlogged. Even salt and waterlogging tolerant plants are sensitive to these conditions during

establishment. Limit mounds to 10 metres in length and leave at least a 2 metre undisturbed area on which to overflow. Mounding aerates the soil, allows nutrients to collect around the seedling and raises seedling roots above the saturated and salt affected soil.

Planting trees and shrubs

Select species that are native to your region in preference to species from elsewhere. Local native species are generally adapted to the local conditions and are most likely to support a wider range of local fauna. If trees and large shrubs are present, try to order mainly lower storey shrubs, as these are the species that need the most help. These shrubs will support ground living fauna and stabilise the soil along your waterway.

Direct seeding

You may be lucky enough to have an area of local bush that is relatively intact. Collecting local seed and sowing it into your regeneration site can be very cost effective. Be careful to choose your collection site wisely. Pick a site similar to your own and seek help with germination tricks. Be prepared for the need for follow up weed control. Results can be highly variable but when successful it is the most effective method of restoring riparian vegetation.

Sedges and rushes

Sedges and rushes are an important component of the riparian zone. They can be expensive, as they are often difficult to produce in nurseries. An alternative is to transplant from a location where they are abundant or not wanted. Some farmers regularly spray to reduce sedges and rushes in their paddocks. They are often delighted to allow you access to them. Different species have different requirements, but in general try transplanting them in late winter.

Step 6. Consider stock access

To ensure healthy riparian vegetation and protect revegetated areas, stock access must be tightly controlled. The key is to use the fence to control the level of grazing so as to allow the native vegetation to regenerate and to limit soil disturbance. If your aim is to encourage a diverse, natural ecosystem then total stock exclusion is required. However be prepared for a potential explosion of weeds when grazing is removed. A fair compromise is to allow opportunistic grazing by stock. If grass weeds need to be reduced (e.g. to minimise the potential fire risk) stock could be briefly introduced in spring. In time, the shade from the canopy of the trees and shrubs will eliminate many of the early-established weed species.

Stock watering points and crossings

Ideally, stock watering points should be located away from the waterway using windmills, soaks and dams. However if access to the waterway is required there are a few techniques that can limit degradation. In most cases rock will be needed to harden the approaches to the waters edge. A key

feature is to leave the ground rough. By making it uncomfortable for the stock they will tend to drink and quickly leave rather than linger and cause degradation.

Stock watering points should be located away from steep stream banks that are prone to erosion. A better access site would be on the inside of a bend in the river where sediment is naturally deposited. Perhaps there is a stony section that could be utilised. A combination stock watering and vehicle crossing point may be possible. It should be located on slow moving straight sections between bends in the channel. Hardened with rock, these structures must be carefully designed with particular attention paid to the downstream side where most crossing disaster stories occur. Well-designed structures can be built to imitate natural riffles or rapids and become a key habitat feature in the waterway. Crossings can also function as a fire control measure by creating a gap in the continuous line of riparian vegetation.

Pools and riffles

Unlike a newly constructed drain with a constant slope, a natural waterway will flow down a series of steps. Just as it is natural for water to meander, it also undulates up and down creating a stepped effect. Deeper pools will generally be formed on the bends during high flow events. In the straight sections between bends, boulders, rocks and logs will accumulate often creating riffle structures. Often the roots of trees, semi attached fallen logs, rocks and a well constructed stock crossing can provide a local pool/riffle effect in other sections of the waterway. The cascading effect caused by obstructions in the waterway will force air into the water. These riffle zones oxygenate the water and are essential for aquatic life downstream. In the deeper pools, the flow will slow and debris tends to settle. This is sometimes referred to as the stomach of the waterway because its primary role is trapping food to be digested by the resident macroinvertebrates.

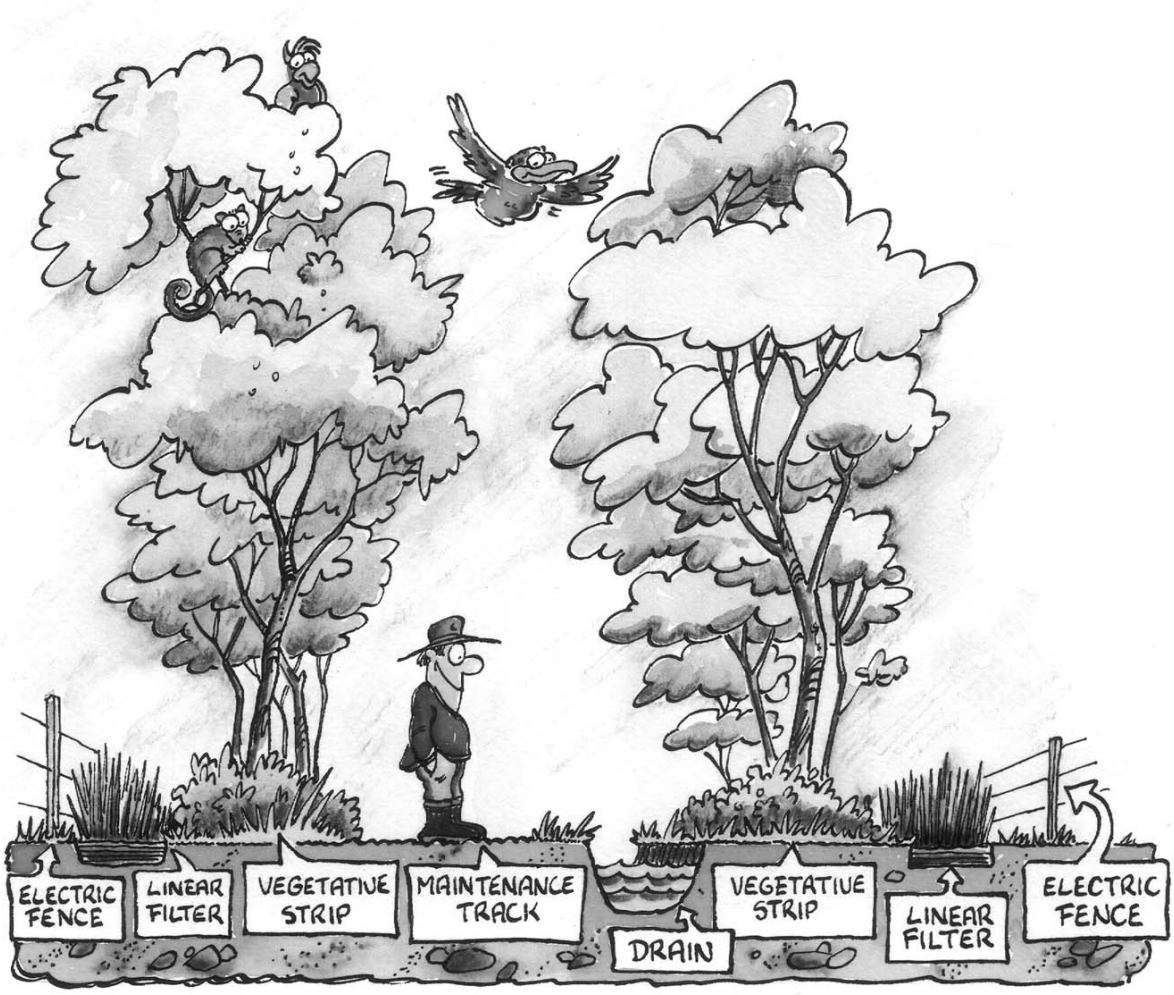
Large woody debris

Logs and branches can be placed in the waterway to create valuable fauna habitat, reduce erosion and oxygenate the water. Logs collected from the surrounding landscape can be placed in riffle zones. However seek advice before you commence this work as the potential to create havoc is real. The power of flowing water should not be underestimated, you might like to practice on small tributaries first.

Streamlining - Turning your drain into a living stream

There is no reason why drains on your property can’t be transformed into a network of babbling brooks. Streamlining is the process of modifying high maintenance artificial drainage into more natural watercourses. Comprising of fencing (only if required to control stock), revegetation, filtration systems and some in-stream structures, the process seeks to imitate natures recipe as previously outlined above. The result is a stream to be proud of, with clear water, reduced nutrient and sediment levels, reduced erosion and a return of local wildlife.

Figure 10. Cross sectional streamlining diagram.



Wetlands - Natures biological filtration system

Prior to clearing, all low lying areas were part of an extensive chain of heavily vegetated wetlands. Rainfall run-off would enter the wetland where it would be subject to processes of settling, filtration, plant uptake and infiltration into the soil. Once filled it would often overflow into an adjoining wetland to undergo a similar process until it reached a major watercourse. Natural wetlands are teaming with life and are an integral part of the catchment's waterway network. All wetlands on your property need to be protected and fenced. This will allow the control of grazing needed to enhance your wetland.

Creating artificial wetlands

Why not have a go at creating your own wetland? Existing depressions where water collects or the point in which drainage lines enter a waterway are ideal places to establish an artificial wetland. As a general rule, the more natural features you can add to your wetland the better it will function ecologically. So study natural systems, seek advice but have a go, as it can be very rewarding.

Water harvesting

It is ironic that we have developed a drainage network designed to remove rainfall run-off as quickly as possible. We effectively curse the rainfall for two months and spend the rest of the year wishing it would rain. Dams, detention basins and artificial wetlands can be used to retain water long after the winter rains have finished. This provides you with a valuable source of water, alleviates flooding by controlling the input of run-off water into our local waterways, provides an opportunity to clean rainfall run-off and offers a new potential habitat for wildlife.

Further information

General information on waterway management can be found in a wide range of sources and include the following:

Publications

Managing Our Rivers: A guide to the nature and management of streams of the southwest Western Australia, by Dr Luke J. Pen.

Streamlining: An environmentally sustainable drainage network for the Swan Coastal Plain (Peel Harvey Catchment), by G. Heady and N. Guise.

Living Streams: A guide to bringing watercourses back to life in south-west Western Australia, by Dr Luke Pen and Karen Majer.

Waternote Series: Advisory notes for land managers on river and wetland restoration, by the Water and Rivers Commission. Also available on Internet site: *www.wrc.wa.gov.au/public/WaterNotes.*

For more information contact:

Agriculture Western Australia
36 Railway Parade, Midland
Ph: (08) 9274 5355

Swan Catchment Centre
108 Adelaide Terrace, Perth
Ph: (08) 9221 3840

VEGETATION AND REMNANTS

Western Australia is one of the most biologically diverse areas on the planet. It boasts a unique suite of flora and fauna found nowhere else on earth. The Ellen Brook Catchment, with its diverse range of habitats is certainly one of the jewels in this crown. It contains a wide range of natural environments starting with the Jarrah forests of the Darling Plateau, to the *Banksia* woodlands of the Dandaragan Plateau and several others on the Swan Coastal Plain.

Did you know? ….

The humble Jarrah tree *(Eucalyptus marginata)* plays home and host to over 600 species of insects, more than 300 of which are found on no other plant anywhere in the world!

Sadly, much of this biodiversity has been lost through inappropriate land use activities such as clearing, overgrazing, draining and filling wetlands. This has left a mere patchwork of vegetation remnants, islands of biological richness in a sea of farms, roads, towns and other 'hostile' human activities.

This legacy of natural wealth must be protected and enhanced so that we can retain our vital natural heritage and ensure its place in our future landscapes.

The Federal Government, with the support of the WA Government, has embarked on an ambitious program to protect at least 10% of all ecosystems found in the state prior to European settlement. As much of this is now found on private properties this means assisting landholders to manage and restore the bush area.

Managing your bushland

Before you start any work it will be important to take stock of just what is in your bushland. This information will help you to better plan any work and so be more effective. The key things to look for are:

- Has it been recorded as a Bush Forever site?
- How big is the bush area? (an aerial photo may help with this)
- What is the level of disturbance? (e.g. grazing, dieback, weeds)
- Where are the closest bush sites? (to see if they can be linked)
- What are the soil types and their distribution? (this will help in choosing species)
- What species are found in your bush? (including rare and endangered ones)
- Are there any perceived threats to your bush? (e.g. grazing, rising watertable)

Armed with this information you will be in an excellent position to plan any management activities. You will be able to plan what areas are a priority for action (e.g. start with areas of that are of the highest value, protection is always more effective than restoration), which species to use in revegetation, what weeds to tackle and so on. Typically fencing is a first step if you have stock, as their presence will continue to degrade the bush and bring in weeds. Once the bushland is protected you may begin thinking about revegetation work. This will typically start with a thorough weed control program, seed collecting, followed by planting or direct seeding and then control of any vermin such as rabbits and grasshoppers. Your local Agriculture Western Australia office can provide advice on vermin control techniques.

A good plan should consider fire threats and include provision for suitable firebreaks to ensure emergency access is available for fire fighting crews. The bush will need to be carefully managed, in many cases as dieback is a real threat, capable of wiping out up to 25% of species found in WA bushland. Plans should include strategies to treat dieback affected areas (e.g. stem injection with preventative chemicals) and reduce the threat of spread (e.g. create defined paths, restrict access of animals and machinery).

Did you know? ….

Many landholders are working together to improve the bushland in their local area - they may agree for instance, to pool resources and join forces to tackle weeds, put up fences and do revegetation work. Working as a group means that they can also be in a better position than an individual landholder to access funds and advice to help with this work.

Above all else don't forget to enjoy your bush. Create defined paths through the bush and marvel at its beauty as it begins to recover under your sympathetic management. Take plenty of photos so you can compare progress and setbacks. In the end, with careful management your bush can become a unique and spectacular feature on your property and as such a valuable link in the chain of bushland that stretches across the Catchment.

Who can help me?

Your local landcare officer will be able to assist you to effectively protect and manage valuable remnant vegetation areas on your property. CALM, through its *'Land for Wildlife'* program, as well as Greening Western Australia, can assist in surveying, mapping and providing detailed management plans for your bushland. There are conditions to this help, but they encourage landholders to contact them to see if they can be assisted.

Revegetation techniques

Additional vegetation and trees can usually be readily included in farm plans without significant loss of productive land. The existing layout of paddock fences, access tracks, water supplies, and contour banks should be examined when you are considering where to revegetate or plant trees on a farm. Vegetation establishment in the Ellen Brook Catchment can have many benefits to individual properties, and the environment.

To have maximum impact, planning for establishment should ensure revegetation areas are located:

- where they have greatest effect in combating wind and water erosion or salinity;
- where they provide stock shelter or add to the landscape aesthetics;
- where they connect with other vegetation areas (remnant vegetation) to provide corridors and buffers of protection;
- where they conflict least with farm operation or productivity; and
- where they will grow quickly into healthy long-lived trees.

Vegetation belts need to be fenced to avoid stock damage. Fencing costs can be minimised by locating new plantings near existing fences, proposed new fence lines, near or between existing remnant vegetation areas and along formed farm tracks, laneways and contour banks. As fencing is a significant cost component of vegetation establishment, the investment needs to be worthwhile. In addition to the on farm benefits above, planning revegetation areas should also consider the medium and longer term commercial potential to the farm.

For large landholdings, Government and private schemes are available that provide a commercial return for little outlay by the landowner. For medium sized and smaller landholdings various tree species suited to the 'boutique' timber markets are worthy of investigation on how they may be fitted best into the farm plan.

State & Federal Government support is also available for landowners with plans to establish revegetation areas on a sub-catchment scale (that is, across a group of properties in a defined catchment area). Opportunities for funding support are available from:

- State Revegetation Scheme;
- Commonwealth Natural Heritage Trust;
- Gordon Reid Foundation (Lotteries Commission of Western Australia); and
- Swan Catchment Urban Landcare Program (Contact the Swan Catchment Centre).

Tree planting

Table 13 outlines the key activities, and timing, for revegetation using tubestock and direct seeding methods. Direct seeding provides the best opportunities for introducing a greater diversity of plants but in order to be successful, particular attention should be given to weed control.

Table 13. Key activities and timing for revegetation

Activity	Timing	Comments
Weed control	September/October prior to planned revegetation.	Revegetated area should be sprayed with knock-down herbicide (Roundup Biactive) to reduce seed set.
Ripping	November/December prior to planned revegetation (i.e. as the soil begins to dry out). Avoid ripping when soils contain a lot of moisture, especially heavy soils.	To shatter any hardpan to allow infiltration of water and roots deep into the soil profile. Ripping 8 months prior to revegetation gives time for air pockets, which may be created by the ripper, to settle out. A mounder creates a raised bed or waterlogged free zone to aid root development in the first season. *Tubestock planting* - Rip lines should be around 2 to 3 metres apart, and a ripper mounder should be used in waterlogged and saline sites. *Direct seeding* - Rip lines as close as possible.

Table 13 continued …

Activity	Timing	Comments
Seedling and seed order	Order seed the winter prior to planned revegetation; tubestock the December prior.	Seed suppliers collect in spring/early summer. Nurseries require at least six months to grow most species.
Weed control using herbicide (Tubestock)	Late autumn/early winter	Spray germinating weeds after opening rains.
Weed control using scalping (preferred method for direct seeding)	Late autumn/early winter	Scalp the area, using grader blade or similar, to remove top 5 cm of soil. Rows of mounded soil created from this process will need to be sprayed with both a knockdown and residual herbicide.
Planting	Early winter	Tubestock - Trees and shrubs should be planted into rip (and mounded) lines. *Direct seeding* - May be done by hand or by a mechanical seeder. Tubestock should be planted on the rows of mounded top soil.
Weed control	Early spring	Grass selective herbicide may be used to control subsequent germination of weeds. Broad leaved weeds may be controlled using selective herbicides (e.g. Lontrel), or even a knockdown herbicide at a low rate (e.g. Ally) but expert advice should be sought.
In-fill planting	During the next winter	May be necessary depending on survival and germination success. Further weed control may also be required in future years.

Use local species

Generally this principle applies to any project, especially when remnant bushland is being rehabilitated. Local species are best adapted to the soil and climate, they won't become weeds, and they will be a favoured habitat by the local fauna. Look at the species in remnant patches of bushland on or near your property. Any local catchment group in your area would also be worth talking to for advice.

However, when revegetating cleared farmland, where land use has resulted in severely altered soil and water conditions, local species may not be suited. In this case other species should be used which will tolerate the changed conditions. As a general rule try to select Western Australian plants from a region which is relatively close (say within 200 km).

There is a need to be careful, because some Australian species have become weeds if they are not indigenous to the area. *Acacia* species are one such group. Some acacias to avoid are Early Black Wattle, Flinders Range Wattle, Queensland Silver Wattle, Sydney Golden Wattle, and Golden Wattle. There are also lots of others, including some *Eucalyptus* species.

Seed collection

The most valuable seed sources are from local remnant patches. CALM's *Wildlife Note No. 4: Seed collecting from native plants* provides detail on how to collect seed. Most native seed can be collected between November and January. You'll need a permit from CALM if you are collecting seed from public land. Seeds with hard coats will need to be treated by heating, or scarifying. Smoke treatment has also been found to enhance native seed germination (contact Kings Park for information).

To collect seed from ground cover species, find a site with healthy ground covers during August-October. Return in late January and carefully sweep up the loose surface material (stones and leaf litter) where the seed will be. Use your seed directly on your site for direct seeding, or dry and store until you need it. You might use the seed to grow seedlings.

Prepare the area

If the area is degraded, you'll need to address the problem - control weeds and rabbits, fencing, control water flow, and so on. For seeds or seedlings, you need the soil to be soft, bare, and free of weeds. Deep ripping and ploughing softens the soil for easy root penetration. Waiting 6 to 12 months before planting seedlings is recommended (see above table).

Direct seeding

Seed may simply be thrown by hand over the site, sprayed onto larger areas with a hydro-mulcher or seeded using a combine (fertiliser box with a suitable material to bulk out the seed mix). Experiment a little. A specialist seeder can rip and sow seed and spread slow release fertiliser at the same time. Brush matting is useful to spread seed, and prevent erosion - lay branches of the plant across the area, and the seed will drop off as the branch dries out. Cover the seed, to improve germination, by dragging sacks over the site, or applying a thin layer of soil. Greening WA has published a useful book called *Direct Seeding of Trees and Shrubs*.

Planting

Planting can be done by hand or you can use a tree planter for large numbers. Tree planters are generally most efficient when the area is large and clear of obstacles such as remnant trees, fences, stumps etc. Use the occasion as a social get together for your catchment group. Follow the guide provided in **Table 13**. When ripping and mounding try to introduce meanders or curves, or if possible plant in groups and clusters - bush doesn't grow in straight lines!

Have a look at *Bush Regeneration* (Buchanan, 1989), *Managing your Bushland* (Hussey and Wallace, 1992), the *Farm Monitoring Handbook* (Hunt and Gilkes, 1992), and *Managing Perth's Bushland* (Scheltema and Harris, 1995) to begin with. Talk to local agencies and organisations, such as Greening WA and Agriculture Western Australia for advice and information.

Season

The site should be moist several weeks before planting, and for months after, so in this region May-July is generally the best time to plant and seed. Prolonged soil moisture is less critical for planting tubestock. If you're propagating seedlings from seed, seeds should be germinated in August-January, depending on the plant species, to be ready for planting in May-July.

Maintenance

Remember that weed control is essential! Weeds will compete for light, nutrients, water and soil space. Mulching can help control weeds, and also improves soil moisture and temperature. Local leaf litter is best, but newspaper, hay or straw is fine. Plant guards for seedlings can be useful to protect from grazing animals, children, frost and wind. Fencing is required to exclude grazing animals (feral, native and domestic). For projects in and around waterways, surround the area with a buffer of vegetation to reduce sedimentation and nutrients entering the waterway. This buffer should include trees, shrubs, sedges and rushes to provide the maximum possible vegetative cover on the soil surface and root development below the surface.

Vegetation buffers and tree belts may be located at the break of slope, perhaps in conjunction with grade banks, to maximise water use and reduce catchment recharge.

Fencing remnants

There is little point in trying to improve your bushland if grazing animals will continue to have free and open access to it. Stock will trample and destroy the understorey plants, reduce regeneration, bring in weeds and ring bark larger trees. Put simply, good management of bushland will require effective protection from all grazing animals. Usually that involves fencing, though individual tree guards may also be effective in some cases.

Fencing is often cited as the most expensive component of any bushland management strategy, but with some careful design, this need not be the case, particularly when viewed in the light of the benefits it will bring for your bushland. For the most effective fencing project it may well be useful to follow the steps set out below.

1. Use an aerial photo to plan the fence

This will give you an overall perspective on the project and with a plastic overlay you should be able to do some 'mock' fence layouts to come up with the best fencing design. Remember too, that it is the 'kinks' and bends in the fence layout that add the most to your costs, as these require strainer 'assemblies' which are time consuming and require more materials to make. Try to strike a balance between fence shape and cost. Sometimes it might be more useful, for instance, to have a straight section of fence, include more paddock and not put in the extra fencing needed to 'hug' an odd shaped bush area. This extra land may be used to create a vegetation buffer, grow fodder shrubs or maybe even locally native timber trees and fence posts.

2. Remember crossings and water access points

In many cases you will still need to put stock through bush areas to adjoining paddocks or perhaps give them access to water supplies. Your aerial photo can help decide the best location for these structures. As a general rule, locate crossings through the narrowest point and on the most stable areas of the bushland to reduce damage. If stock must have access to waterways in your bushland, restrict it to narrow points to reduce damage to vegetation and banks.

3. Fencing type

With a preferred layout in place, you can then decide which fencing system is best for you. It usually comes down to a choice between some kind of permanent fence (usually non-electric) and electric fencing. The benefits and disadvantages of each should be weighed up before you make your choice. Some things to consider when making this choice are out below in **Table 14**.

Table 14. Comparisons between different fence types

	Cost	Flexibility	Weaknesses	Maintenance	Use in rocky areas
Electric	Cheapest type, expect to pay $600-$1000/km.	Can accommodate 'odd' shaped areas easily.	Relies on electricity to deter animals. If supply is lost or circuit fails through 'short out' animals will easily get through.	Relatively high, need weekly checks to prevent 'shorting out' from branches, weeds, etc.	Suitable as uses less posts of smaller diameter so less digging.
Permanent	More expensive. Post/wire $1500-$3000/km. Post/rail at least $6000 km.	Needs expensive 'strainer assemblies' to accommodate 'odd' shaped areas.	Can be attacked by termites.	Little; once established, 1 or 2 check ups a year is sufficient.	Often very expensive as many holes must be dug for fence posts.

Who can help me?

Most rural hardware suppliers will have good ideas on both styles of fencing that suit the local conditions and who are the best fencing contractors and material suppliers. In many cases companies that produce fencing materials put out excellent (and usually free) fencing manuals to show fencing designs and things to consider.

The following points are well worth considering.

1. Who and what exactly are you keeping out?

It is vital at this stage to work out which animals you are up against. Is it sheep or cattle or maybe horses and kangaroos? Whatever the case your design will no doubt vary depending on your foe!

2. Do you want to let anyone in or out?

Sometimes it may be wise to let resident kangaroos in and out of your bush areas. After all, it is usually their home and if penned in or out they can damage your fence and themselves. They are notoriously territorial and will stubbornly try to use their existing paths, even if you've put a fence across it.

3. Don't be stingy

Allow plenty of room between your bushland and the fence to accommodate for the growth of young plants and may be even access tracks. Remember it can be costly and damaging if vegetation is actively growing and pushed up against your fence.

Assistance

If you are fencing off your bushland, there are a range of bodies that may be able to help. Your local landcare group may have Natural Heritage Funding (NHT) to assist fencing projects. They will usually need to see a plan of proposed works, but can provide useful subsidies. The State Government offers some fencing grants through its Remnant Vegetation Protection Scheme. Your local landcare officer should be able to fill you in on any opportunities that exist.

Weed control in remnants

With a fencing program in place it is time to look at the state of your bushland and, in particular the weeds present. Weeds are a major threat to your bushland, as they will silently and steadily overtake your bushland, smothering understorey and reducing the habitat for local animals. In many cases they can make the bush far less attractive, more of a fire risk and even less accessible.

Weed control strategy

Before you rush head long into a 'weed war' it will be wise to base your plan of attack on a well designed weed control strategy. This can be created following the steps set out below:

1. Start with a weed map

This should link into your original assessment of the bushland and should aim to identify the weeds present and their distribution over the site. You will find through such a process that the level of weed invasion will vary over the site. Areas near the edge of the bush and near tracks will have much higher numbers of weeds than more remote areas say within the heart of the bushland. This becomes a 'weed map' and it is an excellent tool to target weed actions.

2. Know your weeds well

Before you start your weeding program make sure you know about the weeds present on-site in your bushland. For example, you will have better success with weed control if you know:

- what they look like when they are young, (this is the best time to attack them);
- when they will flower and set seed (you want to have weeded them out before this time); and
- whether they can regenerate from bulbs or their roots or whether they rely on seed.

For best results all weeding should be done when the plants are young and actively growing.

Who can help me?

Your local landcare officer, Agriculture Western Australia office or CALM can help with weed identification and the best control strategies. They may even be able to provide a list of weed control contractors.

3. Tackle the better areas first

Believe it or not, it is the areas where weeds are at their *fewest* that should be tackled first. These areas will be the easiest to improve and through such work you can then systematically peg back the weeds on the site, moving eventually to the areas where the weeds are at their worst. Always try to ensure that weeded areas can actively regenerate themselves (through seeding by local plants), or that you can plant seedlings or scatter seed once the weeding is done.

Chemical versus non-chemical control?

There are wide range of weed control methods that you can use in your bushland. What you use will depend on your budget, the time you have available, the weeds involved and your own particular preferences. If you are going to use chemical control measures, remember safety and watch for the effect of sprays on nearby native plants in your bushland as well as waterways. Non-chemical methods such as hand weeding, smothering or scalping are fine but time consuming. Whichever system you use don't forget that follow up weeding is usually required to remove a weed once and for all.

Corridors to link bushland

Your bushland will benefit greatly by linking it to nearby bushland areas with a strip of new vegetation. Our bushland is fragmented and isolated therefore these vegetation links will provide valuable 'wildlife corridors' through which animals can move safely from one bushland patch to the next. They can also help the animals to escape from catastrophic events such as fire and floods etc. The corridors will allow animal populations from different bush areas to mix and breed, thereby expanding the 'gene pools' and so improving the whole integrity of the environment.

To be effective however, a 'wildlife corridor' should have the following design principles included:

1. Chose the right target

In the Ellen Brook Catchment there are many patches of bush that can be linked up. Check with your local landcare officer and LCDC group to find out what plans they have for corridor creation in your local area. They may have details on appropriate designs, species to use and even access to funds to help with this work.

2. Make it wide

The best corridors are as wide as you can allow. This will make them more resilient against weed invasions and more likely to be a continuous planting. As a minimum aim for a corridor 10-15 m wide.

3. Make it diverse!

Try to incorporate a wide range of *locally* occurring native species including trees, shrubs and even ground covers. This will ensure that a whole range of animals will find it safe to 'use' your corridor.

4. Make it safe

Ensure that your newly formed corridor is fenced off from stock so that it remains healthy and vigorous.

5. Talk to your neighbours

The best corridors will have cooperation between landholders to make them work. Often this will mean sharing ideas and the workload.

6. Make it work

Often this means keeping track of the project, doing ongoing weed and vermin control within the area and infill replanting as required. Keep records of what grows and is found there naturally. Soon you could be witnessing the first animal migration through your corridors.

Don't forget too, that a well designed corridor will not only link bush areas but it will provide shelter and shade in your paddocks, potentially feed for stock and even colour and beauty for the property. As such make your corridors a valuable and productive part of your property plan.

Dieback control

Phytophthora cinnomomi (dieback) is a serious fungal threat to our native bush. Dieback spreads quite easily through the movement of water, soil, machines and people. Particular native plants like some Eucalyptus, *Banksia* and *Dryandra* are at most risk. If you have dieback-affected vegetation on or near your property, then try to use hygiene measures to limit the spread.

Hygiene measures include:

- clean all the soil off your shoes after walking in the area;
- visit known dieback areas last;
- do any earthworks in drier months;
- limit soil disturbance;
- keep the area well drained;
- walk instead of using a vehicle (it's easier to clean your shoes than a vehicle);
- ensure machinery is clean before and after construction and maintenance of firebreaks and roads;
- try to limit stock access;
- protect the vegetation by injecting trees with Phosphite, and spraying all other vegetation; and
- let your neighbours know.

Phosphite can help vegetation fight off the disease for 3 to 5 years. Refer to *Managing Dieback in Bushland* prepared by the Dieback Working Group. Edition 2 of this publication is currently in preparation.

SECTION 7: OTHER MANAGEMENT PRACTICES

FIREBREAKS

Firebreaks are required by law, and each local council has its own general laws (see **Table 15** for requirements in the City of Swan and Shire of Chittering). Firebreaks can stop fires spreading, allow fire fighting vehicle access, and provide a break from which backburning can take place to control a fire.

If you live with or next to a large block of native vegetation you can also reduce the intensity of a fire with weed control (weeds increase the fire danger) and fuel reduction burning. If the bush is managed by CALM, call their Fire Protection Unit for advice. You may also need to liaise with your local Shire or City, the Bush Fires Board and your local fire brigade. You'll need a permit during 'Restricted Burning Periods' (see **Table 16**).

Table 15. Firebreak requirements with Swan and Chittering

City/Shire	Width of firebreak	Period of time (that firebreaks must be maintained)	Comments
Swan	3 metres	2 November-31 March	Firebreaks need to be clear of all flammable material. They should be placed inside all external boundaries and surrounding all buildings. In new subdivisions a cell firebreak system may be installed if a fire management plan is in place.
Chittering	3 metres	31 October-12 April	Firebreaks need to be clear of all flammable material. They should be placed inside all external boundaries and surrounding all buildings, haystacks and fuel storage areas. In special-rural sub-divisions a firebreak is required around all buildings, haystacks and fuel storage areas and a 3 metre perimeter access gate is required on each lot adjoining the sub-division perimeter.

Please check details with your local council as firebreak requirements are reviewed annually.

Table 16. Burning off requirements in Swan and Chittering

City/Shire	Restricted season - permit required	Burning prohibited
Swan	2 November to 14 December, and 15 March to 10 May	15 December to 14 March
Chittering	19 October to 30 November, and 1 March to 1 May	1 December to 28 February

Please check details with your local council as the burning season is reviewed annually.

Further reading:

Strategic firebreaks and fuel breaks Bushfire Prevention Note 4/97
Fighting fire with fire Fact Sheet by CALM

DIVERSIFICATION OF PRODUCTION SYSTEMS

Agricultural production and rural landuses are a major landuse in the Ellen Brook Catchment. Many landholders rely on agricultural production as their main occupation, while there is also an increasing proportion of rural lifestyle landuses. While rural lifestyle may have less of a reliance on agricultural production, many rural landholders do include agricultural systems into their property management. This can include pasture for stock, alternative industries as a second income, or managing a variety of cropping systems.

Conventional production systems

There is little doubt that most conventional agricultural landuses have contributed to land degradation in Australia. There is a continuing debate about the sustainability of current agricultural production, and a continuing search for agricultural systems that are sustainable in our landscape. Other sections in this manual detail some of the results of land management practices that have had a detrimental effect on the Ellen Brook Catchment's natural resources. Effects such as salinity, wind and soil erosion, decline in soil condition, loss of biodiversity and remnant vegetation and nutrient export have been associated with conventional agricultural systems.

Recognition of our impacts has resulted in significant changes to conventional agricultural systems. There is a greater understanding of the causes of land degradation and methods of rehabilitating those effects. Some examples are:

- Monitoring grazing pressure and actively managing stocking rates when the soil is in danger of being exposed to wind and water will help to reduce erosion.
- Conservation earthworks being used to control surface water erosion.
- Perennial, deep-rooted pastures and crop varieties and cropping rotations with significantly increased water use and reduced erosion.

- Soil sampling and analysis and the application of fertilisers in line with soil test results, or using slow release fertiliser can help decrease nutrient exports from the sandy soils, which contribute to algal blooms.
- Increasing the proportion of native vegetation in the landscape, and protecting remnant vegetation by fencing benefits agricultural systems by lowering groundwatertables, providing protection for stock, and minimising wind and soil erosion.
- Removing weeds and increasing fringing vegetation on streams, gullies and permanent and ephemeral wetlands helps to reduce nutrients entering the groundwater and waterways.

Whatever improvements are be incorporated into a conventional agricultural system, there are real benefits to the whole system if a planned approach is taken to the property and the management system. Further to these improvements, the popularity of alternative systems is increasing.

Some alternatives

There are many studies that show that consumers, especially overseas, are becoming increasingly concerned about chemicals and the environmental impacts of agricultural systems.

The markets are also changing. Consumer tastes are becoming more adventurous, both in Australia and overseas. To compete with the many technical advances in agriculture, a producer needs a competitive edge.

You may have, or plan to have, a productive horticultural or agricultural venture on your property. It might be your hobby, or you may be interested in producing commercially. It is worth considering some of the alternatives to conventional systems.

The alternative systems include (but are not limited to):

- organic farming;
- bio-dynamic farming; and
- permaculture.

The core principles behind these systems are quite similar. They involve a holistic approach to the property that considers soil and soil fauna, minerals, nutrients and production processes as part of a system, rather than in isolation.

Organic farming

Organic agriculture is farming without the use of artificial chemicals at any stage of production, from preparing the soil to marketing the produce. An artificial chemical is one that has been processed chemically or manufactured, and includes insecticides, herbicides and man-made fertilisers. These are replaced by natural or organic materials such as compost, crushed rock and

various natural preparations. The aim is to build sustainable management and a healthy soil. It is based on the principles of:

- crop rotations;
- nil artificial fertiliser;
- approved pesticides;
- the addition of organic matter to the soil;
- the careful monitoring of crops for pests and disease; and,
- free range animals.

Benefits of organic farming:

- Improved soil condition (chemically, physically and biologically).
- Utilises some recycled wastes.
- Avoids problems associated with many agricultural pollutants.
- Minimises the use of non-renewable resources.
- Enhances the natural biological cycles on the farm.
- Coexists with, and helps to protect, the environment.
- Plants become more resilient to pests and diseases.

Managing the system

Methods mimic the natural processes of ecosystems. Rather than feeding the plants, the soil is fed to build up its fertility. Use compost, manures, other organic wastes, green manure, mulch and worms to increase your soil's productivity. Organic wastes provide the required nutrients. Mulch protects the soil's surface, and also decays to provide nutrients. Worms and soil microbes break down organic matter which release nutrients, and worms aerate the soil as they tunnel.

Organic farming issues

- *Pest control:* Healthy plants cope with pests and disease much better. Effective pest control involves managing the whole system, not just the problem, using the methods outlined above. Encourage natural predators and use 'companion planting'.
- *Maintaining soil fertility*: It is not as easy as applying artificial fertilisers. Use a variety of organic materials in your compost to give a good balance of nutrients. Manure and blood and bone help to activate the decomposition of compost. Legume crops (e.g. clover) are also an option and a legume crop incorporated back into the soil (green manure) will increase soil nitrogen.
- *Soil acidity:* Crushed limestone can be used, and lower cropping rates will slow the acidifying process.

If you're planning on going commercial, think about how the land was used previously. To be more competitive, you'll need to be certified.

The certifying organisations are the:

Biological Farmers of Australia (BFA): ..... Ph: 07 4639 3299
Biodynamic Research Institute (Demeter): ..... Ph: 03 5966 7333
National Association for Sustainable Agriculture Australia (NASAA): ..... Ph: 08 8370 8455
Organic Food Chain (OFC): ..... Ph: 07 4637 2600
Organic Herb Growers of Australia (OHGA): ..... Ph: 02 6622 0100
Organic Vignerons Association of Australia (OVAA): ..... Ph: 08 8562 2122
Tasmanian Organic Producers (TOP): ..... Ph: 03 6383 4039

Requirements for certifying differ slightly between each organisation. Generally, it takes at least three years of using the new system to achieve certification, and you should expect a lower return during this time. Crop yields are also generally lower using organic systems but when certification is achieved you will get a premium price for your produce.

Bio-dynamics

This system sees the whole earth as a living entity and aims to remain productive within a closed, self-sufficient farm system. Further to the principles of organic farming, biodynamic methods are designed to biologically activate the life of soil and plants through specially prepared sprays and composts. Some practices also rely on the phases of the moon, the sun, the planets and stars for these preparations and for planting. Minerals and fertilisers must be non-water soluble, so that the plant obtains them via the work of microbes and worms in the soil and care is taken to ensure plant growth is not 'forced'.

Common problems and issues with biodynamic farming are similar to organic methods. Certification is also required if you want to sell commercially (see above contacts).

Permaculture

Permaculture is a way of planning your lifestyle to increase resources, conserve energy and reduce or eliminate pollution or waste. It is all about design. It is based on a holistic approach to food production and lifestyle that integrates plants, animals, buildings and people. The system aims to provide food and habitat for people and plants and animals.

A good Permaculture design:

- reduces wasted energy and materials, both human and environmental;
- maximises the sun, water, and other natural energies (such as wind, dust, leaves and bird droppings); and
- minimises the labour input of the landholder.

A big difference between Permaculture and the organic/biodynamic systems is that it reduces the energy wasted in transporting food to people. Permaculture systems are usually based on organic growing principles.

ALTERNATIVE INDUSTRIES

Niche marketing and specialist produce provide opportunities to diversify production. It may be worth considering a different product to the 'traditional' ones grown or reared in your area. Agriculture Western Australia is encouraging more diverse and sustainable agriculture in response to changes in consumer demand, commodity prices, technology and the environment.

Some examples of the potential and emerging new industries are:

- Native Floriculture
- Lavender
- Sandalwood
- Japanese Green Tea (trialing)
- Aquaculture in inland saltwater ('Outback Ocean')
- Bushfoods
- Jojoba
- Seed potatoes
- Bamboo shoots
- Pharmaceuticals
- Buckwheat
- Short Grain Rice
- Camels (for meat)
- Specialist stock breeds of goats, sheep and cattle.

While many of the above will not be suited to the Ellen Brook area, the list is provided to illustrate the work that is being done to develop alternative industries. Contact the New Industries Program in Agriculture Western Australia (ph: 368 3333) for more information.

USEFUL CONTACTS

Chittering Landcare Centre:

Old Gingin Rd
MUCHEA WA 6501

Raffy Andreoli
Chittering and North Swan Landcare Coordinator
Ph: 9571 0200

Damian Crilly
Ellen brook Catchment Coordinator
Ph: 9571 0300

City of Swan: 9267 9267

Fairbridge Village, Pinjarra: Telephone 9531 1177, sustainable landuse, water management, domestic effluent demonstrations and training.

Greening Australia, WA: Telephone 9335 8933, advice and publications on revegetation and bushland management.

Shire of Chittering: 9576 1044

Shire of Gingin: 9575 2211

Swan Catchment Centre: Telephone 9220 5300 for catchment group, LCDCs and environmental groups contacts, and funding and community training information in the Swan Canning Catchment.

The Land Management Society: Telephone 9450 6862, land management tool kits and farm tours.

The Men of the Trees, WA Inc.: Telephone 9250 1888, information on tree planting and revegetation, nursery and landcare education.

The Permaculture Association of WA: Telephone 9487 7376, courses and publications on organic farming and land management.

The WA Nut and Tree Crop Association: Telephone 9388 1965, information and publications on land management and fruit and tree crops.

USEFUL WEB SITES AND E-MAIL ADDRESSES

A good starting point …	
www.online.wa.gov.au	This is an excellent resource directory that will allow you to see and tap into a wide range of useful web sites associated with property management.
Agricultural issues	
www.agric.wa.gov.au	Agriculture Western Australia's site
www.agric.wa.gov.au/programs/srd/farmforestry/fftreenotes.htm	Farm Forestry Tree Notes
Waterway issues	
www.wrc.wa.gov.au	Water and Rivers Commission's site
www.wrc.wa.gov.au/public/WaterNotes	Lots of useful information that you can download on water, rivers and streams management techniques and strategies.
Conservation groups	
www.information.org	A WA based site that links you to a wide range of environmental organisations.
www.iinet.au/~treeswa	The Men of the Trees, WA
Training courses	
www.training.wa.gov.au	Department of Training Site. Information on training opportunities.
www.getaccess.wa.gov.au	Useful information on a wide range of careers.
Grskills@upnaway.com	Greenskills provide useful information on landcare training.
Maps, aerial photographs and other geographic information	
www.dola.wa.gov.au	DOLA provide a wide range of information and aerial photos.
Natural environment	
www.calm.wa.gov.au/	Conservation and Land Management's (CALM) site.
www.calm.wa.gov.au/science/florabase.html	On-line database on local flora.

Agroforestry	
http://www.mtg.unimelb.edu.au	Latest information on agroforestry.
Business development	
www.commerce.wa.gov.au	Department of Commerce and Trade's site.
www.agric.wa.gov.au/progserv/market/FINRADJ/	Farm Business Development Grants
Funding organisations	
www.lottery.wa.gov.au/corporate/commset.htm	Lotteries Commission Funding Site
www.nht/	Natural Heritage Trust (NHT)
www.calm.wa.gov.au	Land for Wildlife
www.wrc.wa.gov.au/swanavon/whats_new/sculp	Swan Canning Urban Landcare Program (SCULP)
Occupation Health and Safety	
www.safetyline.wa.gov.au	Farm Safe and a range of other safety initiatives.

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Bulls Brook Catchment physical resource assessment and reference for catchment planning and action	Miscellaneous Publication 60/99
Productive pastures pay	Bulletin 4302
Fertilisers for pasture on sandy soils of the Swan Coastal Plain	Bulletin 4357
Revegetation guide to the central wheatbelt	Bulletin 4321
Stocking rate guidelines for rural small holdings	Miscellaneous Publication 02/00
Streamlining: An environmentally sustainable drainage network for the Swan Coastal Plain (Peel Harvey Catchment)	Bulletin 4279
The land is in your hands	Miscellaneous Publication 58/99

Assessing water repellency	Farmnote 110/96
Claying water repellent soils	Farmnote 14/97
Direct seeding of native plants for revegetation	Farmnote 40/98
Erosion (firebreak, farm track, headland and stock pad)	Farmnotes 26/93 to 29/93
Fitting trees into the farm plan	Farmnote 102/88
Fodder conservation as silage	Farmnote 98/99
Gypsum improves soil stability	Farmnote 32/85
Importance of being sheltered	Farmnote 49/96
Livestock and water salinity	Farmnote 59/88
Managing waterlogging and inundation in crops	Farmnote 80/93
Managing waterlogging and inundation in pastures	Farmnote 79/93
Nitrates in the groundwater beneath horticultural properties	Farmnote 02/95
Perennial grasses - their role in the Ellen Brook Catchment	Farmnote 20/99
Preventing wind erosion	Farmnote 35/96
Scheduling for trickle, sprinkler and flood irrigation	Farmnote 22/90
Site assessment for successful revegetation for agricultural regions with less than 600 mm rainfall	Farmnote 36/98
Site preparation for successful revegetation for agricultural regions with less than 600 mm rainfall	Farmnote 37/98
Soil management options to control land degradation	Farmnote 65/96
Spoon and W-drains	Farmnote 120/84

Sprinkler and micro-irrigation systems for small farms	Farmnote 53/86
Sprinkler irrigated pastures for small holdings	Farmnote 06/98
Tolerance of plants to salty water	Farmnote 47/90
Water drainage: Responsibility of landholders under agricultural Acts	Farmnotes 09/91
Water supplies for irrigation on the small farm	Farmnote 73/94
Waterlogging and inundation: Why they could be costing you money	Farmnote 78/93
Weed control for successful revegetation for agricultural regions with less than 600 mm rainfall	Farmnote 47/98

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Tree Notes relevant to the Ellen Brook Catchment include:

Preparing sites for tree planting	Treenote No. 2
Pruning equipment for farm forestry	Treenote No. 5
Glossary of farm forestry terms	Treenote No. 6
Timber advisory notes	Treenote No. 7
Preserving round posts on the farm	Treenote No. 8
Paulownia	Treenote No. 9
Farm forestry definitions and designs	Treenote No. 10
Benefits of farm forestry	Treenote No. 11
Tree planting	Treenote No. 17
Growing pines for wood products	Treenote No. 18
Harvesting farm-grown trees: Three growers' experiences	Treenote No. 19
Weed control in eucalypts and pines	Treenote No. 20
Insect pests of eucalypts and pines	Treenote No. 21
Windbreak design and management	Treenote No. 22
Timber production from windbreaks	Treenote No. 23
Parrot damage in agroforestry	Treenote No. 26
Rectifying parrot damage in eucalypts	Treenote No. 29
Control of the Australian ringneck parrot by trapping in southwest Western Australia	Treenote No. 34

GLOSSARY

Acidity
An acidic soil is one where the pH of the soil is low. A soil with a pH below 7.0 is considered acid. Generally, when the pH drops below 5.5, plant and root growth is repressed.

Agroforestry
The integration of commercial tree growing into the operation of a farming enterprise.

Algae
A diverse group of aquatic plants containing chlorophyll and other photosynthetic pigments. Many are microscopic (often being single cells) but some can be large, including the large seaweeds. They grow as single cells or aggregations of cells (colonies).

Algal bloom
The rapid excessive growth of algae, generally caused by high nutrient levels and favourable conditions. Can result in deoxygenation of the water mass when the algae die, leading to the death of aquatic flora and fauna.

Alkaline
A pH of greater than 7.0 in water.

Aquifer
A porous soil or geological formation, often lying between impermeable sub-surface strata, which holds water and through which water can percolate slowly over long distances and which yields groundwater to springs and wells.

Arable
Describes land suitable for the economic production of crops, usually involving regular cultivation.

Bedrock
Solid rock underlying the soil profile or other surface materials. It does not necessarily represent the *parent material* of the overlying soil.

Biodiversity
The variety of all living things, including the different plants, animals, micro-organisms, the genes they contain, and the ecosystems they form.

Bio-dynamic farming
A system of agriculture that works with biological processes, based upon a growing awareness that the whole earth is a living entity. It aims to remain productive within a closed, self-sufficient farm system.

Biological weed control
Non chemical means of controlling weeds, e.g. leaf hopper, rust and dock moth.

Buffer zone
Any area of land used or designed to isolate one area of land from another so that adverse effects arising from one area do not affect the other.

Calcareous
Soil containing sufficient calcium and/or magnesium carbonate to 'fizz' (effervesce) visibly when treated with dilute hydrochloric acid.

Catchment
The land area from which rainfall flows into a river. **Sub-catchments** are the areas of land surrounding smaller streams and tributaries within a catchment area.

Conservation
The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations. Thus conservation is positive, embracing preservation, maintenance, sustainable utilisation, restoration and enhancement of the natural environment.

Contour bank
Ridge or bank of earth constructed across a slope to collect and direct water flow; usually constructed with small longitudinal gradient, e.g. 0.5% slope.

Degradation
Decline in the quality of natural resources commonly caused by human activities.

Dieback disease
A deadly plant disease caused by the pathogen *Phytophthora cinnamomi*, which feeds on the roots and stems of living plants, causing them to rot.

Direct drilling
A technique used to establish pastures without cultivation. The weeds are killed with a non residual 'knock down' herbicide and the pasture and seed sown with a suitable machine, usually a disc or narrow tyned seeder.

Direct seeding
Is a revegetation technique where the seed of native plants are scattered onto prepared ground and encouraged to establish themselves.

Drainage
The interception and removal of excess surface and/or sub-surface water from land, using artificial or natural means.

Ecosystem
A functioning unit formed by the relationships between the physical environment (e.g. the water cycle, soil processes) and the plants and animals.

Erosion
The process of gradual loosening and removal of the landscape by the weathering processes influenced by **water** and **wind**. Running water and the impacts of rainfall can induce several types of erosion. **Sheet erosion** is the removal of a uniform layer of soil by water runoff. **Rill erosion** occurs as a result of the formation of small water channels on the land's surface. **Channel** and **gully** erosion are more pronounced forms of rill erosion, where deeper channels are formed along drainage lines.

Human land use can cause soil to be lost at a much faster rate than the natural erosion process.

Eutrophication

The process of nutrient enrichment of water bodies by nutrient export of phosphorus and nitrogen from the land.

Fertigation

Soluble fertilisers are injected into the irrigation water during the pumping stage. Highly accurate applications of the required nutrients can be applied using this method.

Fertiliser

Any substance, natural or manufactured, added to the soil to supply essential plant nutrients for plant growth, and thereby either maintaining or increasing the general level of crop yield and pasture productivity.

Firebreak

Can stop fires spreading, allow firefighting vehicle access, and provide a break from which backburning can take place to control a fire.

Geomorphology

The science concerned with the development of the land surface over time and the processes that create it.

Green framework

An integrated network of vegetation corridors usually comprising of trees and shrubs that are strategically located on the property so as to produce multiple benefits.

Inoculation

The introduction of a pure or mixed culture of microorganisms into the soil. This is usually achieved by mixing the inoculant with the seed at sowing time or by coating the seed with it prior to sowing.

Inundation

Water ponding on the ground surface. Those parts of the plant that are submerged cannot breathe or photosynthesise

Integrated Catchment Management (ICM)

The coordinated planning, use and management of water, land, vegetation and other natural resources on a river or groundwater catchment basis. ICM is based on cooperation between community groups and government agencies at all levels to consider all aspects of catchment management.

Land capability

Is the ability of the land to sustain a land use without suffering long term damage. **Land capability assessment** compares the physical requirements of a land use with the qualities of the land.

Land degradation

Includes any activity or process which reduces the quality, nature or usefulness of land. Land degradation is defined by the *Soil and Land Conservation Act 1945* to include:

a) soil erosion, salinity, eutrophication, and flooding; and

b) the removal or deterioration of natural or introduced vegetation; that may be detrimental to the present or future use of the land.

Land Management Unit (LMU)
An area of land that can be separated from other areas based on its soil type and/or other physical characteristics. Agricultural productivity or the way it is managed is the same over its entire area.

Leaching/leachate
The process by which materials such as organic matter and mineral salts are washed out of a layer of soil or dumped material by being dissolved by or suspended in percolating rainwater; the material washed out is known as leachate. Leachates can pollute groundwater and waterways.

Legume
A plant that produces its own nitrogen in nodules on the roots in association with rhizobium bacteria.

Lime
A naturally occurring calcareous material used to raise the pH of acid soils and/or supply nutrient calcium for plant growth.

Living stream
A natural watercourse that is healthy and comprised of a range of native plants and associated animals.

Loam
A soil intermediate in texture between a sand and a clay, *containing significant quantities of organic matter* and approximately equal proportions of sand, silt and clay sized particles.

Monitoring
A process by which change can be identified and quantified.

Native vegetation
Indigenous pasture, bushland and/or timber species adapted to the prevailing environmental conditions including climate, soils and natural grazing patterns.

Nutrient
Any element essential to the growth of plants or which can be beneficially utilised by them. Such nutrients are supplied from the soil or from application of fertiliser.

Organic farming
Is a common alternative system of production that excludes the use of the chemicals at any stage, from preparation of the soil to marketing the produce.

Overgrazing
Continued grazing of pasture at a level which permanently and adversely affects its plant components often leaving the soil bare and open to erosion.

Perennial plant
A plant whose life cycle extends for more than two years and continues to live from year to year.

Permaculture
A design system that integrates food production and lifestyle, aiming to reduce wasted environmental and human energy and materials. The system aims to provide food and habitat for people, plants and animals.

pH
A symbol denoting the concentration of hydrogen (H) ions in solution. A measure of acidity or alkalinity in water in which pH 7 is neutral, values above 7 are alkaline and values below 7 are acid.

Photosynthesis
A process, which is driven by sunlight, whereby plants take up carbon dioxide (CO_2) from the atmosphere and make sugars and starches. These compounds are further combined to make the plant's structure.

Plant community
The plants that grow together naturally in a particular place. Characterised by the structure of the vegetation (the number of layers, their height and density), and the species composition.

Recharge area
An area where water is absorbed to be added to a geologic zone of saturation or aquifer.

Rehabilitation
The treatment of degraded or disturbed land to achieve an agreed level of capability and stability, preferably at least equal to that which existed prior to degradation or disturbance.

Revegetation
The re-establishment of plants on an area of ground that is depleted or devoid of vegetation.

Riffle
In the straight sections between bends, boulders, rocks and logs will accumulate often creating riffle structures. The cascading effect caused by obstructions in the waterway will force air into the water. These riffle zones oxygenate the water and are essential for aquatic life downstream.

Riparian zone
The land which adjoins a waterway. River banks, gullies and dips, and floodplains are all part of the zone.

Rotational grazing
Where the paddock or area is only grazed for a certain period of time before the stock are moved on to another area.

Runoff
That portion of rainfall not immediately absorbed into or detained upon the soil and which thus becomes surface flow.

Salinity
An increase in salt concentrations in the soil or water bodies. **Dryland salinity** has occurred as a result of replacing deep-rooted native vegetation with introduced vegetation that uses less water. Evaporation of water at the soil surface further concentrates the salt, and saltland develops. **Irrigation salinity** is caused by excess irrigation water seeping through the soil to the groundwater, drawing the watertable closer to the soil surface.

Water bodies become saline when runoff from these areas enters.

Sedimentation

The process of mineral and organic sediment transportation and deposition into water bodies from erosional processes. **Turbidity** occurs when sediments are suspended in the water column and impede light penetration.

Seedbed

The layer of soil which, when suitable prepared, receives sown seeds and provides for their subsequent germination and growth.

Seepage

The process by which water percolates downwards and/or laterally through the soil, often emerging at ground level lower down a slope.

Shelter belt

An area of living trees and/or shrubs established and maintained for the protection of grazing animals from adverse climatic conditions.

Silage

Fodder conserved by a process in which the green or partly dried crop or pasture is stored and air excluded.

Soil compaction

The process whereby the density of soils is increased by tillage, stock trampling and/or vehicular traffic. *This will lead to declines in soil structure and productivity.*

Soil degradation

Decline in soil quality commonly caused through its improper use by humans.

Soil fertility

The capacity of the soil to provide adequate supplies of nutrients in proper balance for the growth of specified plants, when other growth factors, such as light, moisture and temperature are favourable.

Soil horizon

A layer of soil approximately parallel to the surface:

O Horizon - is mainly organic material.

A Horizon (the topsoil) - has some organic material, and mostly minerals. It is generally darker than the deeper layers.

B Horizon (the subsoil) - can often be a very different texture and stronger colour (red, yellow) than the other layers.

C Horizon - often partly weathered rock.

Soil profile

The freshly exposed soil face in a hole or trench. The 3 main forms of profile are:

Uniform - Few changes in texture between the horizons.

Gradational - Boundaries between horizons gradual, and becoming increasingly clayey down the profile.

Duplex - Dramatic texture differences between horizons.

Soil structure

The arrangement of the silt (or loam), sand and clay particles, and the organic matter.

Soil texture
The physical characteristics of soil type. Determined by the amount of silt (or loam), sand and clay particles in the soil.

Spillway
An open or enclosed channel, or a combination of both, used to convey excess water from a dam or similar storage.

Stocking rate
The number of stock, e.g. sheep, cattle, horses or any other type of animal that can consistently be kept on a piece of pasture all year round with minor additional feed and without causing environmental degradation. Stocking rates are shown as **Dry Sheep Equivalents (DSE)** which are the number of adult sheep (wethers) that can be sustained on each hectare all year round.

Streamlining
The process of changing high maintenance, artificial drainage into a more natural watercourse. The process involves revegetation and instream modifications.

Sub. clover
An annual legume that normally prefers neutral to acidic soils. It produces seed along runners in burrs, which are buried beneath the soil surface.

Sustainable
A sustainable land use is one that can the land can support without suffering environmental degradation or irreversible damage. It does not jeopardise future generations of land users, and it maintains or enhances economic viability of production.

Topsoil
That part of the soil profile containing material which is usually more fertile and better structured than underlying layers.

Tunnelling
The removal of sub-surface soil by water while the surface soil remains relatively intact.

Water repellent soils
Soils which resist wetting when dry. Drops of water do not spread spontaneously over their surface and into pores. This characteristic is mainly a feature of some sandy soils (topsoils) and is generally attributed to organic coatings on the sand grains, which resist water entry into the soil.

Watercourse
A channel, having defined bed and banks down which surface water flows on a permanent or semi-permanent basis or at least, under natural conditions, for a substantial time after periods of heavy rainfall within its catchment.

Watershed
The dividing ridge between two catchments.

Waterlogging
A soil condition where the soil is saturated with water and lacking all, or most, air spaces. Occurs as a result of heavy rainfall, poor drainage, or excessive irrigation

Waterway

May be a narrow channel that flows only under certain conditions, a permanent creek, or a larger river. It may also be a wetland or dampland where a stream spills into a flatter part of the landscape. A waterway system includes the watercourse bed, the banks, the surrounding flood plain, and the water itself.

Wetland

Area of seasonal, intermittent or permanent waterlogged soils or inundated land, whether natural or otherwise, fresh or saline, e.g. lake, swamp, dampland.

Windbreak

A barrier of living trees and/or shrubs or other materials which reduces the velocity of the wind near the soil surface, thus protecting the soil from *wind erosion*.

APPENDIX A. PLANT SPECIES LISTS FOR THE SHIRES OF CHITTERING, GINGIN, MUNDARING AND SWAN

Scientific name	Common name	Gravels	Sands Loams Clays	Comments
Trees				
Acacia acuminata	Raspberry jam	yes		salt tolerant
Acacia cyclops	Coastal wattle		dry	seed, fast growing
Acacia saligna	Golden wreath wattle		wet/dry	salt tolerant, fast growing
Allocasuarina freseriana	Common sheoak	yes	dry	fast growing
Allocasuarina huegeliana	Rock sheoak	yes		on granite
Banksia attenuata	Candle banksia		wet/dry	seed, fast growing
Banksia grandis	Bull banksia	yes	dry	
Banksia ilicifolia	Holly leaf banksia		wet	
Banksia littoralis	Swamp banksia		wet	
Banksia menziesii	Firewood banksia		wet/dry	fast growing
Casuarina obesa	Salt sheoak		wet	salt tolerant
Eucalyptus accedens	Powderbark wandoo	yes		fast growing
Eucalyptus calophylla	Marri	yes		seed, fast growing
Eucalyptus laeliae	Buttergum	yes		granite
Eucalyptus lane-poolei	Salmon white gum	yes	dry	
Eucalyptus marginata	Jarrah	yes	dry	
Eucalyptus patens	Blackbutt	yes	dry	
Eucalyptus rudis	Flooded gum	yes	wet	for damp areas
Eucalyptus todtiana	Prickly bark, Coastal black butt		wet/dry	
Eucalyptus wandoo	Wandoo	yes		
Melaleuca cuticularis	Salt paperbark		wet	salt tolerant
Melaleuca preissiana	Stout paperbark		wet	
Melaleuca rhaphiophylla	Freshwater paperbark		wet	
Nuytsia floribunda	Christmas tree		wet/dry	seed requires a host plant, slow growing
Santalum acuminatum	Sandalwood	yes	dry	seed requires a host plant
Tall shrubs - 1.2 m high or more				
Acacia cochlearis	Rigid wattle		dry	
Acacia pulchella	Prickly moses		dry	1.0-1.2 m high
Acacia rostellifera	Summer scented wattle		wet/dry	cuttings only, salt tolerant suckers
Actinostrobus pyramidalis	Swamp cypress	*clay*	wet	seed
Adenanthos cygnorum	Woolly bush	yes	wet/dry	
Callistemon phoeniceus	Lesser bottlebrush	yes	wet/dry	
Dryandra sessilis	Parrot bush	yes	dry	
Grevillea vestita			dry	limestone
Hakea cristata	Snail hakea	yes		granite, vigorous
Hakea lissocarpha	Honey bush	yes	dry	
Hakea trifurcata	Two leaf hakea	yes	dry	vigorous
Hakea undulata	Wavy-leaved hakea	yes		
Jacksonia furcellata	Grey stinkwood		dry	coloniser of poor soils
J. sternbergiana	Green stinkwood		dry	
Kunzea ericifolia	Spearwood		wet	
Labichea lanceolata	Tall Labichea	yes		1.0-1.2 m high

Scientific name	Common name	Gravels	Sands Loams Clays	Comments
Leptospermum erubescens	Roadside tea-tree	yes		
Melaleuca thymoides			wet	salt tolerant
Persoonia elliptica	Snottygobble	yes		with jarrah cuttings only
Persoonia longifolia		yes		
Regelia ciliata			wet	1.0-1.2 m high
Regelia inops			wet/dry	
Viminea preissii	Swishbush		wet	autumn seeding
Xanthorrhoea preissii	Balga	yes	dry	transplants
Small shrubs - less than 1.0 m high				
Acacia drummondi	Drummond's wattle	yes		
Acacia nervosa	Rib wattle	yes		
Acacia shuttleworthii		yes	dry	
Acacia teretifolia		yes		
Acacia willdenowiana	Grass wattle	yes		
Anigozanthos spp.	Kangaroo paw	yes		
Calothammus sanguineus	Blood flower		dry	
Calytix aurea	Golden star flower	yes		cuttings
Chorizema dicksonii	Flame pea	yes		seed
Conostylis aculeata	Cone flower	yes	dry	perennial herb, seed
Conostylis candicans	Grey cottonhead		dry	perennial herb, seed
Conostylis juncea			wet	
Dampiera alata	Wing-stemmed Dampiera	yes		
Dampiera linearis	Common Dampiera	yes		
Daviesia rhombifolia		yes		seed
Dryandra nivea	Couch honeypot	yes		
Eremaea fimbriata			dry	
Eremaea purpurea			wet	
Eriostemon spicatus	Salt and pepper		wet/dry	
Grevillea bipinnatifida	Fuchsia grevillea	yes		
Grevillea pilulifera	Woolly-flowered grevillea	yes		
Grevillea synaphaea	Catkin grevillea	yes		
Gomphologbium tomentosum	Yellow pea			
Hardenbergia comptoniana	Native wisteria	yes	dry	
Hibbertia commutata	Buttercup	yes		cuttings
Hibbertia aff. *helianthemoides*	Buttercup		wet	cuttings
Hibbertia hypericoides	Buttercup	yes	dry	slow grower
Hibbertia polystachya	Buttercup	yes		slow grower
Hibbertia racemosa	Buttercup	wet		slow grower
Hovea pungens	Hovea	yes		
Hovea trisperma	Common hovea		dry	seeds in autumn
Hypocalymma angustifolium	White myrtle	yes		seeds in autumn
Hypocalymma robustum	Swan river myrtle	yes	dry	seeds in autumn
Isopogon asper		yes		
Johnsonia acaulis		yes		
Johnsonia pubescens	Pipe lily		dry	
Kennedia coccinea	Coral vine	yes		
Kennedia prostrata	Running postman		dry	
Laxmania grandifolia		yes		

Scientific name	Common name	Gravels	Sands Loams Clays	Comments
Small shrubs - less than 1.0 m high - continued				
Leucopogon australia	Spiked beard-heath		wet	
Melaleuca scabra	Rough honey myrtle		dry	
Melaleuca trichophylla		yes	wet	
Oxylobium capitatus	Eggs and bacon		dry	poisonous to cattle
Patersonia occidentalis	Patersonia		wet/dry	seed, cuttings
Petrophile linearis	Pixie mops		dry	
Pimelea suaveolens	Scented banjine	yes		
Ptilotus polystachyus	Mulla mulla		dry	seeds in spring
Scholtzia involucrata	Spiked Scholtzia			
Scaevola canescens	Grey Scaevola	yes		
Stirlingia latifolia	Blue Boy	yes		
Verticordia nitens	Morrison		wet	seeds or cuttings
Xanthorrheoa spp.		yes		

Recommended trees and shrubs for saltland

Scientific name	Common name	Origin	Comments
Casuarina obesa	Swamp sheoak	L	very salt tolerant
Melaleuca cuticularis	Saltwater paperbark	L	very salt tolerant
Eucalyptus sargentii	Salt river gum	WA	very salt tolerant
E. loxopheba	York gum	L	moderately salt tolerant
E. occidentalis	Flat topped yate	WA	moderately salt tolerant
E. spathulata	Swamp mallet	WA	moderately salt tolerant
E. camaldulensis	River red gum provenance Lake Albacutya	ES	moderately salt tolerant
Acacia saligna	Golden wreath wattle	L	moderately salt tolerant
Allocasuarina cunninghamiana	River sheoak	ES	moderately salt tolerant
Eucalyptus rudis	Flodded gum	L	mildly salt tolerant
E. robusta	Swamp mahogany	ES	mildly salt tolerant
E. cladocalyx	Sugar gum	WA	mildly salt tolerant
E. melliodora	Yellow box	ES	mildly salt tolerant
E. microcarpa	Grey box	ES	mildly salt tolerant
Acacia rostellifera	Summer-scented wattle	L	
Melaleuca thymoides		L	

L = Local

WA = Western Australia

ES = Eastern States

APPENDIX B. MAMMAL SPECIES OF THE DARLING SCARP AND RANGES

Echidna
Dasyuridae Mardo (Yellow-footed antechinus) Chuditch (native cat)# Brush-tailed Phascogale# Dunnart Fat-tailed Dunnart Western Quoll
Quenda (Southern Brown Bandicoot)#
Honey possum
Brush-tailed possum
Western Pygmy Possum
Kangaroos and wallabies: Western Grey Kangaroo Tammar Wallaby Brush or Black-gloved Wallaby#
White-striped Mastiff Bat Little Mastiff Bat
Vesper bats: Gould's Wattled Bat Chocolate Wattled Bat King River Eptesicus Lesser Long-eared Bat Gould's Long-eared Bat Greater Long-eared Bat Great Pipistrelle
Rats and mice: Rakali or Water Rat House Mouse* Black rat*
Rabbit*
European Red Fox*
Feral cat*
Feral pig*

* Introduced species.

\# Regional conservation significance.

APPENDIX C. FROG SPECIES IN THE REGION

Frog species		Plain	Scarp	Ranges	Wheat belt
Ground frogs:					
Quacking Froglet	*Crinia georgiana*	*	*	*	
Brown Froglet	*Crinia insignifera*	*			
Glauert's Froglet	*Crinia glauerti*		*	*	
Lea's Frog	*Geocrinia leai*		*		
Moaning frog	*Heleioporus eyrei*	*		*	
Chocolate Burrowing Frog or Western Marsh Frog	*Heleioporus barycragus*		*	*	
Whooping Frog	*Heleioporus inornatus*		*	*	
Marbled Burrowing Frog (or Sand Frog)	*Heleioporus psammophilus*		*	*	*
Pobblebonk (or Banjo Frog)	*Limnodynastes dorsalis*	*			*
Guenther's Toadlet	*Pseudophryne guentheri*			*	
Western Froglet	*Crinia pseudinsignifera*		*	*	*
Western Spotted Frog	*Heleioporus albopunctatus*				*
Turtle Frog	*Myobatrachus gouldii*	*			*
Crawling Frog	*Pseudophryne guentheri*	*	*	*	*
Humming Frog	*Neobatrachus pelobatoides#*	*	*		*
Tree frogs:					
Slender Tree Frog	*Litoria adelaidensis*	*	*		
Motorbike frog	*Litoria moorei*	*	*	*	*

The distribution indicated is only a guide.

On the Swan Coastal Plain the Humming Frog occurs in the Swan Valley only.

Sources: FrogWatch information sheets
Sanders and Harold (1991)

APPENDIX D. BIRDS IN THE DARLING SCARP AND RANGES

Emu	Crakes and rails (continued …):
Stubble Quail	Spotless Crake
Phalacrocoracidae	Dusky Moorhen #
Little Black Cormorant	Purple Swamphen
Little Pied Cormorant	Eurasian Coot
Podicipedidae	Black-winged Stilt
Black-throated Grebe	Lapwings and plovers:
Hoary-headed Grebe	Black-fronted Dotterel
Ducks, geese and swans:	Banded Lapwing
Australian Shelduck	Pigeons and doves:
Australian Wood Duck	Rock Dove*
Musk Duck	Spotted Turtle-Dove*
Pacific Black Duck	Laughing Turtle-Dove*
Grey Teal	Common Bronzewing
Herons and egrets:	Crested Pigeon
White-Faced Heron	Cockatoos:
White-Necked Heron	Short-billed Black Cockatoo #
Nankeen Night Heron	Red-tailed Black Cockatoo #
Ibis and spoonbills:	Carnaby’s Cockatoo
Australian White Ibis	Galah
Straw-necked Ibis	Lorikeets and parrots:
Yellow-billed Spoonbill	Purple-crowned Lorikeet
Kites, hawks and eagles:	Rainbow Lorikeet*
Black-shouldered Kite	Red-capped Parrot
Square-tailed Kite #	Western Rosella
Whistling Kite	Australian Ringneck (twenty-eight)
Brown Goshawk	Elegant Parrot
Collared Sparrowhawk	Cuckoos:
Wedge-tailed Eagle	Pallid Cuckoo
Little Eagle	Fan-tailed Cuckoo
Falcons:	Horsfield’s Bronze-Cuckoo
Peregrine Falcon #	Shining Bronze-Cuckoo
Australian Hobby	Hawk-owls:
Brown Falcon	Southern Boobook Owl
Australian Kestrel	Barking Owl #
Painted Button-quail	*Strigidae*
Crakes and rails:	Barn Owl
Buff-banded Rail	Boobook Owl
Baillon’s Crake	Tawny Frogmouth

Australian Owlet-nightjar
Fork-tailed Swift
Forest Kingfishers:
- Laughing Kookaburra*
- Red-backed Kingfisher
- Sacred Kingfisher

Rainbow Bee-eater
Rufous Treecreeper
Maluridae:
- Splendid Fairy-wren
- Red-winged Fairy-wren
- Southern Emu-wren

Pardalotes:
- Spotted Pardalote
- Striated Pardalote

Acanthizidae:
- White-browed Scrubwren
- Weebill
- Western Gerygone
- Inland Thornbill
- Broad-tailed Thornbill
- Western Thornbill
- Yellow-rumped Thornbill

Honeyeaters:
- Red Wattlebird
- Little Wattlebird
- Singing Honeyeater
- Yellow-plumed Honeyeater
- White-naped Honeyeater
- Brown-headed Honeyeater
- Brown Honeyeater
- New Holland Honeyeater
- Tawny-crowned Honeyeater
- White-cheeked Honeyeater
- Western Spinebill
- White-fronted Chat

Australian robins:
- Jacky Winter
- Scarlet Robin
- White-breasted Robin
- Red-capped Robin
- Western Yellow Robin

Varied Sittella
Zosteropidae:
- Grey-breasted White-eye

Ploceidae:
- Red-eared Firetail

Whistlers:
- Crested Shrike-tit #
- Golden Whistler
- Rufous Whistler
- Grey Shrike-thrush

Flycatchers:
- Restless Flycatcher
- Magpie-lark
- Grey Fantail
- Willie Wagtail

Cuckoo-shrikes:
- Black-faced Cuckoo-shrike
- Ground Cuckoo-shrike
- White-winged Triller

Woodswallows:
- Black-faced Woodswallow
- Dusky Woodswallow
- Grey Butcherbird
- Australian Magpie
- Grey Currawong

Corvidae:
- Australian Raven

Richard's Pipit
Mistletoebird
Swallows:
- White-backed Swallow
- Welcome Swallow
- Tree Martin

Old World warblers:
- Clamorous Reed-Warbler
- Little Grassbird
- Rufous Songlark
- Brown Songlark

Silvereye

* Introduced species.
\# Regional conservation significance.
Source: Dell (1983)

APPENDIX E. REPTILES OF THE DARLING SCARP

Geckoes:

- Clawless Gecko
- Wheatbelt Stone Gecko
- Speckled Stone Gecko
- Beautiful Gecko
- Tree Dtella
- Marbled Gecko
- Barking Gecko
- Spiny-tailed Gecko

Legless lizards:

- Granite Worm-lizard
- Fraser's Legless Lizard
- Gray's Legless Lizard
- Burton's Legless Lizard
- Common Scalyfoot

Dragon lizards:

- Western Bearded Dragon
- Rock Dragon

Monitors and goannas:

- Gould's Sand Goanna
- Black-tailed Tree Goanna

Skink lizards:

- New Holland Skink
- Fence Skink
- Dell's Skink#
- Red-legged Skink
- King's Skink
- Salmon-bellied Skink

Skinks continued:

- Spectacled Egernia
- Dwarf Skink
- Dusky Morethia
- Bob-tailed Skink
- Richardson's Sand Swimmer
- Five-toed Skink
- Southern-tail Flecked Morethia
- Loristas

Blind snakes:

- *Ramphotyphylops australis*
- *Ramphotyphylops pinguis*
- *Ramphotyphylops waitii*

Pythons:

- South-West Carpet Python#
- Stimson's Python

Poisonous snakes:

- Southern Death-adder (only on the Scarp)
- Reticulated Whip Snake
- Bardick Snake
- Bandi-bandi Snake
- Western Tiger Snake
- Mulga Snake
- Dugite
- Gwarder
- Gould's Snake
- Half-ringed Snake

Regional conservation significance.

NB: This is not a complete list, try Bush *et al*. (1995), and Sanders and Harold (1991).

APPENDIX F. FISH AND TORTOISE SPECIES IN THE SWAN-AVON SYSTEM

Western Minnow	*Galaxias occidentalis*
Western Pygmy Perch	*Edelia vittata*
Mosquito fish*	*Gambusia holbrooki*
Freshwater cobbler	*Tandanus bostocki*
Nightfish	*Bostockia porosa*
Western swamp tortoise#	*Pseudemydura umbrina*
Long-necked tortoise	*Chelodina oblonga*

* Introduced species.

\# Rare and Endangered Species.

Source: Pen, L.J. (1999) Managing our Rivers.

APPENDIX G. CALCULATING CROP WATER REQUIREMENTS

1. Evaporation rate is determined by measuring the amount of water evaporating from a free surface of water in different areas over time. Tables of evaporation losses are available. Assume the evaporation in the Ellen Brook Catchment is 2000 mm per year. This value has been used together with a rainfall value based on the RAAF airforce base to illustrate how irrigation requirements are calculated. See Appendix @ for an estimate of the water needs of a range of crops grown in the Ellen Brook Catchment.

2. Crop factors are an estimate of the ratio between the rate at which the crop (and the soil surface) loses water (evapotranspiration) compared to the evaporation rate. The rate at which the crop and the soil loose water is less than the evaporation rate. Crop factors are commonly between 0.2 and 0.8.

   Examples of crop factors are set out below:

Apples	0.55
Avocados	0.80
Citrus	0.55
Proteas	0.40
Grapes	0.20
Olives	0.50

Although these values are indicative, values vary according to time of year and are generally not constant and can vary according to growth stage.

3. Soil types differ on their ability to hold or retain moisture. The amount of moisture available to the plant is that which the plant can extract or 'suck out'. This available water is sometimes known as the readily available water or RAW value of the soil. Some RAW values for different soils are shown in the table below.

Table F1. The amount of available water held by soils of different textures

Soil texture	Range mm/m	Average mm/m
Coarse sand	33- 42	36
Medium to fine loamy sand	62- 83	67
Moderately coarse sandy loam, fine sandy loam	83-125	104
Medium fine sandy loam, sandy clay loam, silt loam	125-192	158
Moderately fine clay loam, silty clay	146-208	175
Fine sandy clay, silty clay, clay	133-208	167

4. Infiltration rate is a measure of the soil's ability to absorb the applied irrigation water. If the infiltration rate is exceeded, water will run off and be wasted and contribute to environmental damage to the watertable, nearby by wet lands or damage neighbouring properties. Efficiency decreases as the application rate increases above the infiltration rate.

5. Root depth must be known to prevent irrigation applications in excess of that needed to wet the root zone. Water applied in excess of that needed to wet the root zone is lost to the plant and contributes to the watertable adding nutrients and possibly pesticides. Several Government agencies may require a nutrient and irrigation management plan (NIMP) in order to make landowners aware of their responsibility in this regard.

6. Rainfall received in excess of the first millimetre is beneficial to the plant and is subtracted from the irrigation requirement.

Examples of infiltration rates are shown below:

Sand	30 mm per hour
Sandy loam	20 mm per hour
Loam	15 mm per hour
Clay loam	12.5 mm per hour
Clay	6.5 mm per hour

Infiltration rate can depend on soil structure and vary accordingly.

Root depths of some crops:

Apples	1 m
Grapes	0.5-1.0 m
Lucerne	2.0 m
Annual pastures	0.5 m
Perennial pastures	0.8 m
Cabbage	0.6 m
Potatoes	0.9 m
Tomatoes	1.0 m

Root depth depends on the presence or otherwise of restricting layers.

An example uses the above values to determine the irrigation requirements of a crop.

The area is Bullsbrook and the crop is olives. How much water is needed during January when the rainfall is nil?

Evaporation in January: 300 mm

Rainfall: 0 mm

Olive crop factor for January is 0.50

The effective evaporation is 300 mm – 0 mm = 300 mm

Water to apply for January is 300 mm x 0.50 = 150 mm (or an average of 5 mm per day)

It is obviously not practical to apply all this water at once as the root zone could not hold all this water. The frequency of application then needs to be determined.

The soil is a loamy sand, which will hold in the 1.0 m root zone 67 mm of water. We should now adopt a rule that the available water in the root zone does not drop below 50% of the RAW or readily available water. If this is the case, irrigation will need to be applied when the water content drops to say 33 mm of RAW. On average, this amount of water will be lost in 33 mm divided by 5.0 mm per day equalling 6.6 days. Therefore an irrigation of 33 mm per hectare will be needed every 6.6 days during January in the event of no rain falling.

Ellen Brook		**Estimated water needs for a range of crops**												
Climatic data	**Unit**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Evaporation (Class A Pan)	mm	300	280	235	125	80	60	55	80	105	165	215	300	2,000
Rainfall (RAAF Air base)	mm	6	13	14	38	89	145	142	105	64	37	26	9	689
No of rain days (average)		2	3	3	7	12	16	17	15	12	9	6	3	105
Effective rainfall	mm	4	10	11	31	77	129	125	90	52	28	20	6	584
Potential evapotranspiration														
Olives	mm	150	140	118	63	40	30	28	40	53	83	108	150	1,000
Wine grapes	mm	75	70	59	31	20	15	14	20	26	41	54	75	500
Avocado	mm	240	224	188	100	64	48	44	64	84	132	172	240	1,600
Irrigation requirement														
Irrigation requirement *Olives*	mm	146	130	107	32	0	0	0	0	0	55	88	144	700
Irrigation volume used *Olives*	cubic m	1,460	1,300	1065	315	0	0	0	0	0	545	875	1,440	7,000
Irrigation requirement for *Wine grapes*	mm	71	60	48	0	0	0	0	0	0	13	34	69	295
Irrigation volume used *Wine grapes*	cubic m	710	600	478	3	0	0	0	0	0	133	338	690	2,950
Irrigation requirement for *avocado*	mm	236	214	177	69	0	0	0	0	32	104	152	234	1,218
Irrigation volume used *avocado*	cubic m	2,360	2,140	1,770	690	0	0	0	0	320	1,040	1,520	2,340	12,180
Direct crop coefficient Crop factors														
*Olives**		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Wine grapes		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Avocado		0.80	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	