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West Mortlock catchment appraisal 2002

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WEST MORTLOCK

CATCHMENT APPRAISAL 2002

Compiled by Don Cummins

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West Mortlock Catchment Appraisal

Compiled by Don Cummins

for the Central Agricultural Region RCA team

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Summary

This report describes the soils, hydrology, natural vegetation and farming systems of the West Mortlock catchment and provides information on the threats to agriculture, infrastructure and natural resources caused by land degradation.

West Mortlock covers almost 700,000 hectares in the central wheatbelt. The catchment drains into the Avon River, which becomes the Swan River, before flowing into the Indian Ocean. The climate is Mediterranean with cool wet winters and hot dry summers and the annual rainfall is approximately 350 mm.

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

Soils and landscapes are variable, with sandy earths, loamy earths and deep sands comprising 48% of the catchment. Soil degradation issues include acidification, soil structure decline, erosion, waterlogging and water repellence.

Salinity currently affects 9.6% of the catchment (65,000 ha). Twenty nine per cent (197,000 ha) could be threatened by shallow watertables in the future.

Waterlogging, seepage and rising watertables present risks that can be controlled by constructing well-planned and designed earthworks. Grade banks on sloping land provide an important tool to manage surface water, which should be treated as a resource and used on-farm. Safe disposal of surface water to waterways should be considered a secondary alternative.

The catchment has a very low proportion of remnant vegetation – approximately 5.1% or 35,000 ha, of which shallow watertables affect about 4,000 ha (11.7%). Maintaining, enhancing and expanding remnant vegetation would deliver biodiversity, landscape and farming systems benefits.

Contents

1. Introduction

Rapid Catchment Appraisal aims to document salinity risk and management options by addressing all threats to the natural resource base, rather than isolating salinity as a separate issue.

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

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

- Don Cummins (Team Leader, Northam)
- Sacha Fielden (GIS Research Officer, Northam)
- Paul Galloway (Soil Research Officer, Narrogin)
- Shahzad Ghauri (Groundwater Hydrologist, Northam)
- Trevor Lacey (Development Officer, Farming Systems, Northam)
- Harry Lauk (Land Conservation Officer, Northam)
- Josh Smith (GIS Officer, Northam)

The report has been divided into three sections: the agricultural resource base, catchment risks and management options and impacts. It is important to cross-reference between sections to gain an understanding of how different risks and management options affect the agricultural resource base.

The appraisal process was completed with funding assistance from an Avon Catchment Council/Department of Agriculture, Natural Heritage Trust partnership project.

2. Agricultural resource base

2.1 Catchment description

The catchment is the drainage basin of the north branch of the Mortlock River, which is a tributary of the Avon River. It occupies 681,901 ha and covers the majority of the shires of Wongan-Ballidu and Goomalling. Shires with lesser areas in the catchment include: Dalwallinu, Cunderdin, Dowerin, Moora, Northam , Toodyay and Victoria Plains. Major towns are Wongan Hills, Goomalling, Ballidu and Dalwallinu. Much of the surface drainage is dominated by broad valley floor systems and salt lake chains in the north and well defined drainage in the south-west.

The catchment is bounded by the latitudes 425654.14 and 526787.04 (E) and 6667411.07 and 6502378.28 (W). The location is shown in Figure 2.1.

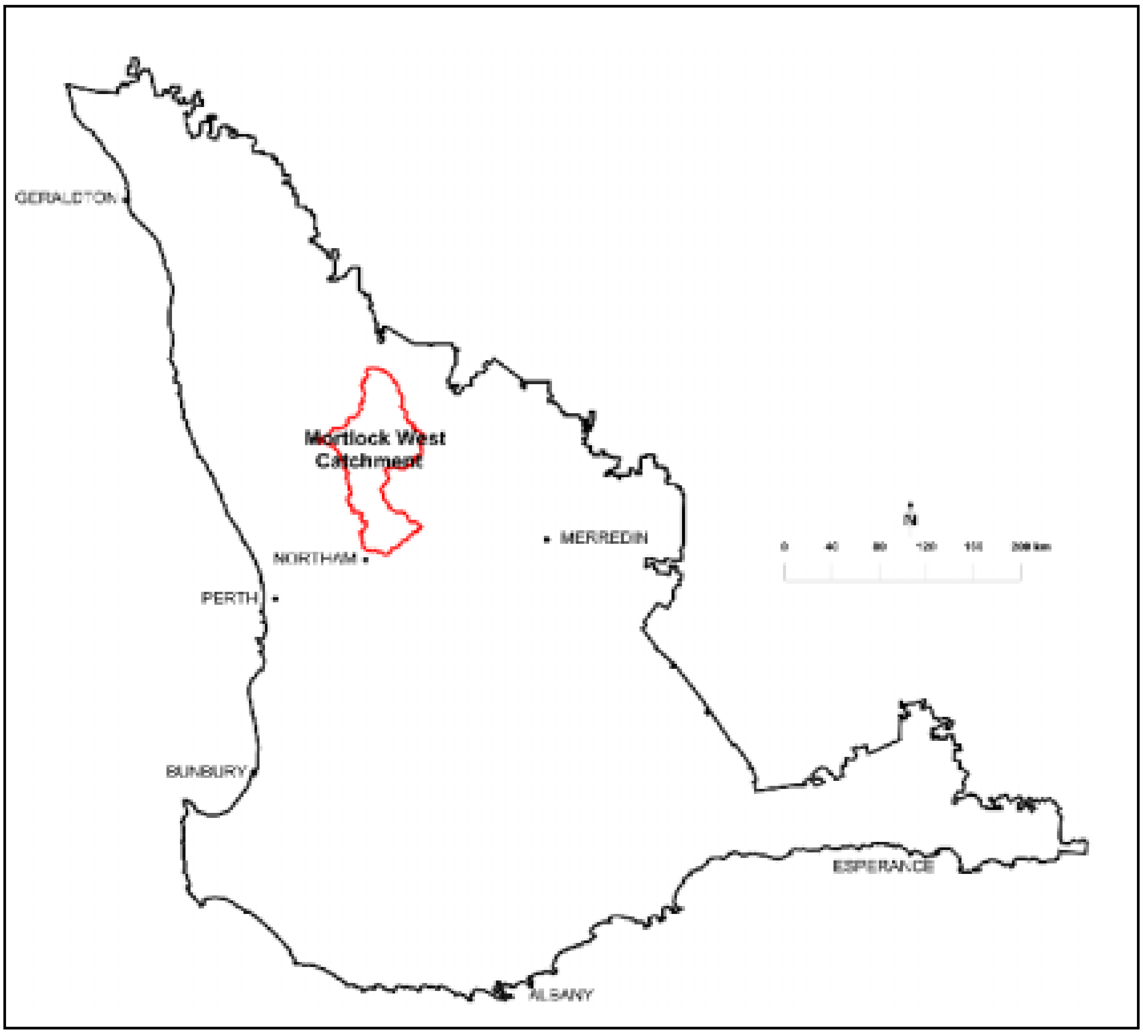


Figure 2.1. West Mortlock catchment location

2.2 Climate

Harry Lauk and Trevor Lacey

The catchment has a Mediterranean climate, with hot dry summers (Figure 2.4) and mild wet winters with rainfall peaking sharply in mid-winter. Moisture deficit over summer limits the growing season for traditional, annual agriculture systems to between May and September (Figure 2.3). On average about 70% of annual rainfall occurs through the growing season (Figure 2.2). Winter and spring rainfall is associated with the passage of cold fronts across the State. Strong northerly winds are often generated as the fronts approach, providing the potential for wind erosion particularly in late autumn and early spring when ground cover is at its lowest.

Summer thunderstorms are sporadic and cause intense rainfall in some years, such as the rains of February 2000. These storms can cause major run-off, erosion and recharge events. Wetter than average summers present opportunities for summer cropping, particularly forage crops.

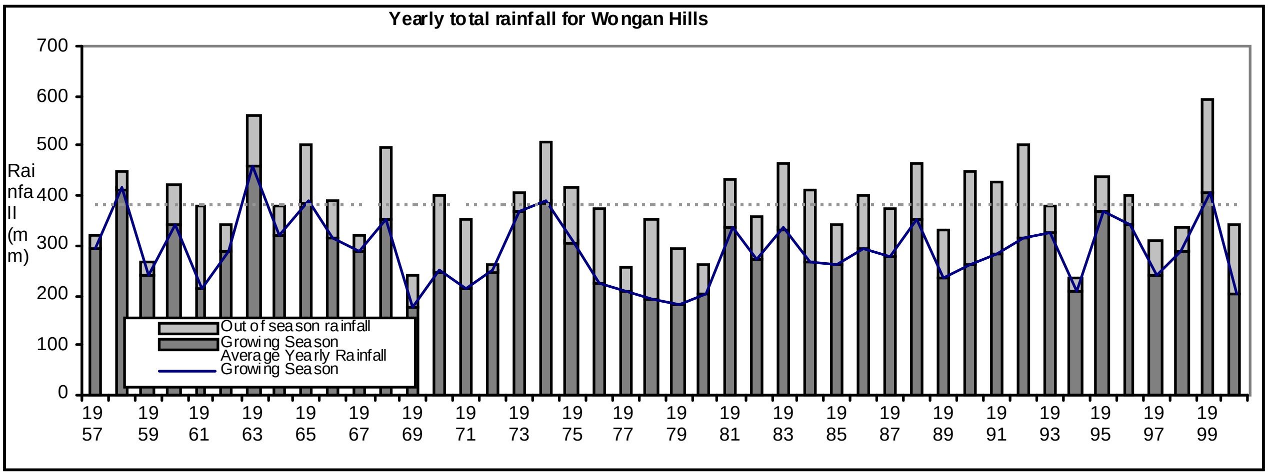


Figure 2.2. Annual rainfall patterns

Figure 2.3 shows that evaporation during summer months (December-February) can be very high (rates for Wongan Hills can reach 10 mm/day with an annual average of 2,400 mm). High evaporation rates affect the potential of most farm dams to sustain water supplies throughout the summer/autumn period.

Frost is most likely after fronts have passed and a new high-pressure system establishes. The combination of events from the preceding cool days and cold southerly air flow followed by clear skies and low or light winds can cause the land surface to cool rapidly. Cold air flows to the lowest points in the landscape with potential to cause damaging frosts (as experienced in 1998 and 1999). The level of damage is related to the minimum temperature, the period over which the frost persists and the sensitivity of the crops. The most damaging frosts are often in mid to late spring around the time crops are flowering.

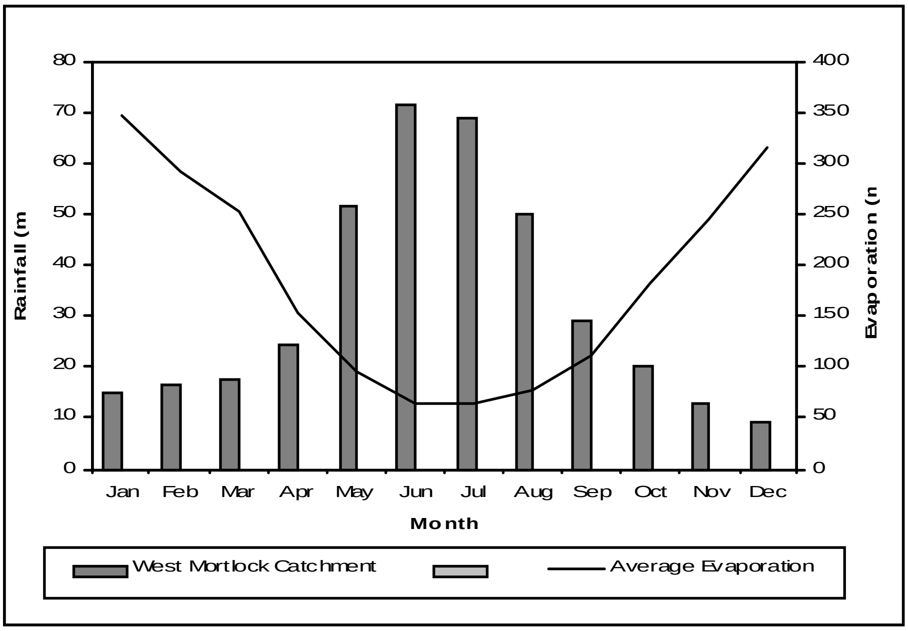
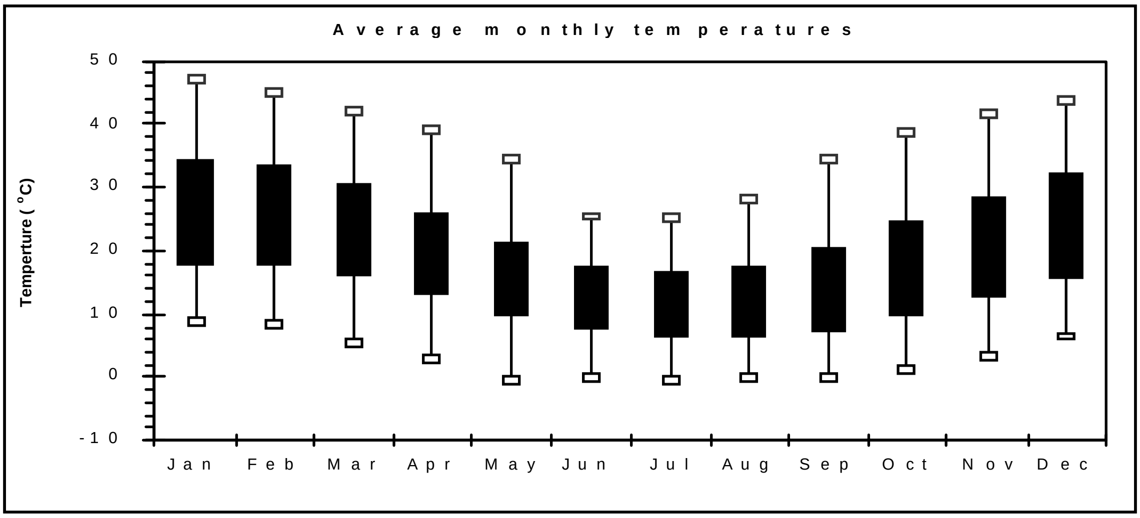


Figure 2.3. Monthly rainfall and evaporation



(The bars represent the monthly average range for daily temperatures and the lines represent recorded monthly absolute minima and maxima)

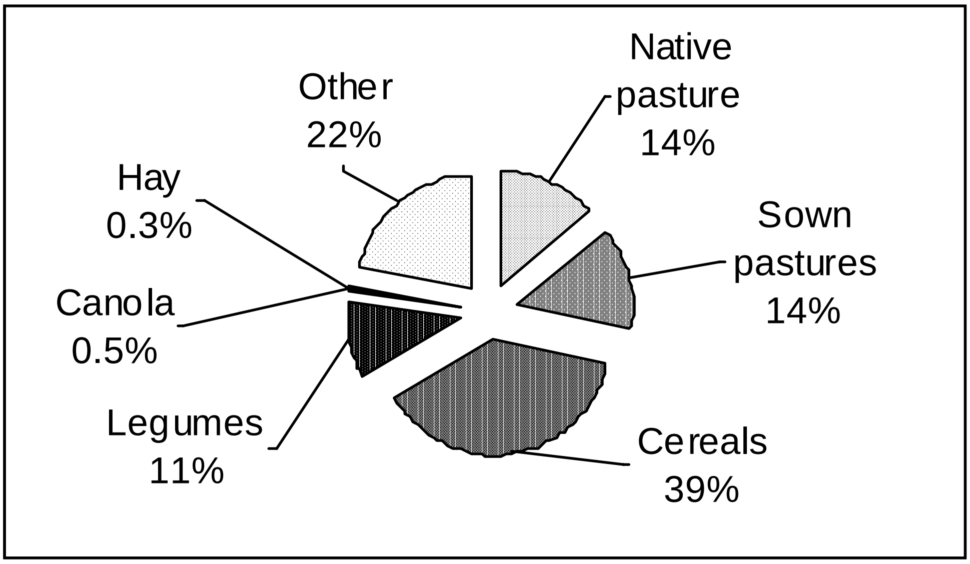
Figure 2.4. Monthly temperature ranges for the catchment

2.3 Farming systems

Trevor Lacey

2.3.1 Current farming systems

Farming systems are dominated by annual crop/pasture rotations and to a lesser extent by continuous cropping rotations. The main crops are wheat, barley, oats, lupins, canola, peas and chickpeas. Within these rotations, pastures account for 28% and crops 51% of the total farmed area as indicated in Figure 2.5. The main pasture species are subterranean clovers, medics and serradellas.



Based on averages 1983-99, for Goomalling, Wongan-Ballidu and Dalwallinu Shires

Figure 2.5. Enterprise distribution as percentage of farmed area

Crop yields show a great deal of variability from year to year but have an underlying upward trend of 50 kg per year (Figure 2.6). This can be attributed to technological improvements in weed control, varieties, fertilisers, rotations and machinery. Crop water use efficiency (yield per millimetre of rainfall) has generally increased over the period 1983-99. Average annual wheat yields range from just over 1 tonne per hectare in 1983 to just under 2 tonnes per hectare in good seasons in the late 1990s.

Average GVP is estimated at $213 million with crops contributing 83%. In the late 1980s to early 1990s the GVP from crops was at its lowest, dropping to 60% in Goomalling in 1988. Wongan-Ballidu and Dalwallinu shires have consistently had a 5 to 10% higher GVP from crops than Goomalling. Production from cropping increased through the 1990s reaching of 90% of GVP in Wongan-Ballidu and Dalwallinu in 1999.

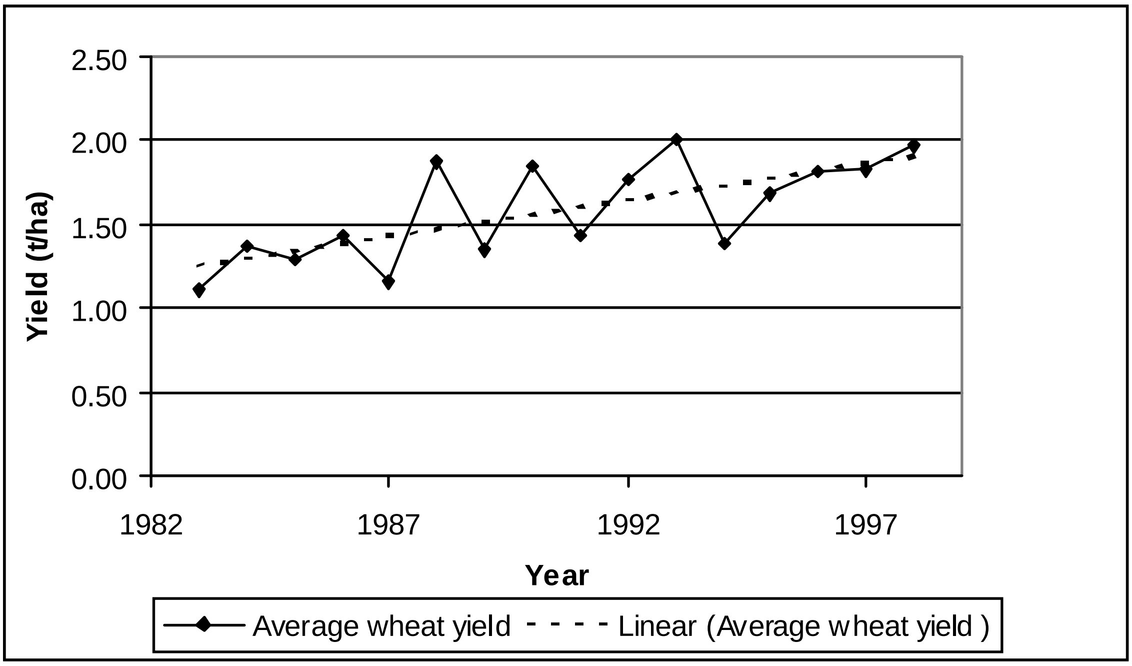


Figure 2.6. Average wheat yields for West Mortlock catchment based on Goomalling, Wongan-Ballidu and Dalwallinu Shires

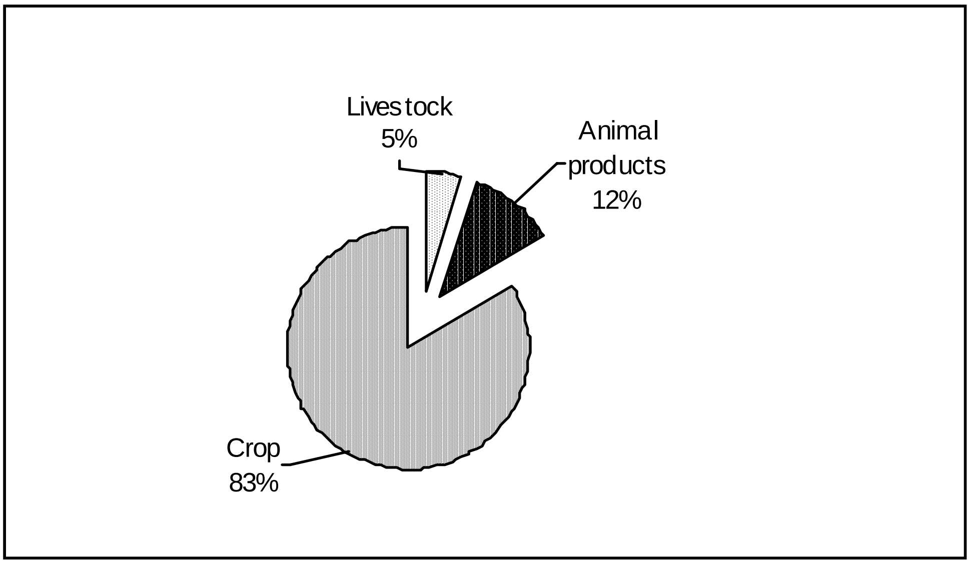


Figure 2.7. Average gross value of production (GVP) for agricultural production in the shires of Goomalling, Wongan Ballidu and Dalwallinu

2.3.2 Farmer survey

Twenty eight farmers, representing 14% of the area, provided information on farming systems. The survey results were:

- farm businesses largely comprise mixed stock (mainly sheep and some cattle) and crop enterprises;

- crop/pasture rotations and continuous cropping rotations are common on most soils throughout the region;
- wet and waterlogged areas have a predominance of permanent annual pastures or perennial vegetation, including some perennial-annual mixes such as alleys and phased lucerne rotation;
- serradella was by far the most widely adopted higher water use option, sown onto 1.6% of the area farmed by 43% of farmers. Although farmers plan to increase this to 2.5% this is significantly less than the area suited to serradella (approximately 40% of the catchment);
- lucerne is grown by 29% of farmers and was the next most commonly grown high water use option, covering 0.5% of the catchment;
- saltbush and tagasaste are grown by 25% of farmers on 0.3% of the catchment, falling well short of the potential area suited to them (approximately 50%). Information on lucerne, perennial grasses, balansa or Persian clovers and saltbush was sought by 20% of farmers.

2.4 Hydrogeology

Shahzad Ghauri and Paul Galloway

2.4.1 Geology and geomorphology

The catchment straddles the eastern margin of the Yilgarn Craton and the Greenstone belt, which formed over 2500 million years ago. Most outcropping rock is granite and adamellite (Chin 1986). Depth to bedrock is generally shallower in the west, particularly along stretches of the east branch of the Mortlock River, adjacent to Great Eastern Highway. Numerous dolerite dykes that have intruded the bedrock display an east-north-easterly trend and often delineate fractures and possible faults. These dykes are dark-coloured, mostly medium-grained and often cross the catchment's main flow direction, sometimes forming barriers to groundwater movement.

Physical, biological and geo-chemical processes differentially weather the various minerals and fabrics of the underlying geology. These processes alter hard rock to soft, weathered and transported materials known as ‘regolith’. Regolith is usually thickest where rock is deeply weathered and where sediments accumulate. Regolith depth across the catchment is variable but is generally thicker in the south and west and throughout the valleys.

The northern half of the catchment lies in the Zone of Ancient Drainage where primary salt lake chains occupy the lowest parts of valley floors (Mulcahy 1967; Bettenay and Hingston 1961,1964; Grealish and Wagnon 1993; Frahmand, unpublished data). The valley floor drainage is mostly internal, with salt lake chains only joining and flowing in wetter years. These salt lake chains join streams in the southern half of the catchment, which has rejuvenated drainage (Lantzke and Fulton 1993).

Lateritic landscapes dominate uplands of the catchment and their presence influences hydrology, soils, vegetation distribution and farming systems. Their origins are contentious. Early researchers attributed their formation to geo-chemical processes (Campbell 1917; Jutson 1934; Prescott and Pendleton 1952; Mulcahy 1967). However, new studies refute these views and link laterite formation to biological interactions (Verboom and Galloway 2000; Pate *et.al*. 2001; Verboom and Pate 2002).

2.4.2 Groundwater quality

The salinity of groundwater varies considerably depending on recharge sources, aquifer types and landscape positioning. Salinity levels near Goomalling, Gabbi Quoi Quoi sub-catchment and Wongan Hills townsite range from 360 to 2,710 mS/m. However, groundwater quality is generally between 1,000 and 1,500 mS/m, making it suitable for stock. As surface water and groundwater moves towards drainage lines, salts are dissolved from regolith material and salinity levels increase.

Perched (sandplain) aquifers exist in many areas, attributed to the high percentage of Sandy earths (22%) and Deep sands (11%). Groundwater with low salinity levels is found in such areas and is directly replenished by annual rainfall.

Groundwater pH varies from slightly acid to slightly alkaline (~ pH 5 to 8). Recent data collection has revealed that highly acid groundwater (pH <4) is widespread in the central and eastern wheatbelt. Acid groundwater has the potential to affect agricultural production and its disposal is problematic.

2.4.3 Water resources

The majority of landholders have access to scheme water, although just over half of those who responded to the farmer survey indicated their water supplies were adequate.

Fresh to brackish water has been found in many shallow piezometers though most are likely to be freshwater lenses overlying saline water. Piezometers were often placed in areas with obvious signs of salinity or shallow watertables during the 1990s and this is evident from water level and quality analysis. Good quality groundwater is present at depth just south of the Northam-Pithara Road and Jennacubbine East Road intersection.

In general, perched aquifers require good rainfall to be replenished after dry periods. Deeper aquifers maintain supplies for longer periods and are less reliant on short-term rainfall events. Deep groundwater in the higher yielding saprock aquifer is of unknown quality, however ‘sumps’ or depressions formed in small to moderate-sized (20 to 100 ha) areas of sandplain are features worth noting for test drilling.

2.5 Soils

Paul Galloway

Soils of the catchment are inherently variable, often changing over tens of metres. They can be grouped for similar management under broadscale agriculture (Schoknecht 2002) and to create the simplified soil map (see soils map).

2.5.1 Catchment soils

Two main soils and four common soils together account for 77% of the catchment. Major soils are:

- Sandy earths which occupy 22%, on freely drained slopes and crests;
- Shallow loamy duplexes, which occupy 16%, mostly on valley floors and lower to mid-slope positions.

The common soils are Deep sands (12%), Deep sandy duplexes (10%), ironstone gravels (10%) and Deep loamy duplexes (7%). Table 2.1 describes their abundance and location and defines typical soil profiles and the soil map overleaf shows the spatial distribution of soils in the catchment.

Other less prevalent but still significant soils are Loamy earths (5%), Shallow sands (5%) and Shallow sandy duplex (5%). Six other groups occupy small areas and can be identified in Appendix 1.

The soils provide a basis for Land Management Unit mapping. More detail about the soil-landscape mapping process is provided in Appendix 1, to assist mapping at farm scale.

Table 2.1: Major soils

Soils and abundance	Profile description Dominant location	Soil components (Per cent of catchment)
Sandy earths 149,000 ha 22%	Soils with a sandy surface grading to loam by 80 cm. May be clayey at depth Freely drained slopes and crests	Yellow sandy earth (9%) Brown sandy earth (8%) Acid yellow sandy earth (3%) Red sandy earth (2%) Pale sandy earth (<1%)
Shallow loamy duplexes 106,000 ha 16%	Soils with a loamy surface and a texture contrast at 3 to 30 cm Valley floors and lower to mid-slopes	Alkaline red shallow loamy duplex (6%) Red shallow loamy duplex (3%) Yellow/brown shallow loamy duplex (3%) Grey shallow loamy duplex (2%) Alkaline grey shallow loamy duplex (2%) Acid shallow duplex (<1%)
Deep sands 84,000 ha 12%	Sands greater than 80 cm deep Depressions in lateritic terrain; associated with sandy earths and Ironstone gravels	Yellow deep sand (7%) Gravelly pale deep sand (3%) Pale deep sand (2%) Brown deep sand (<1%)
Deep sandy duplexes 68,000 ha 10%	Soils with a sandy surface and a texture or permeability contrast at 30 to 80 cm. Colluvial slopes, around granite outcrops and sometimes in valley floors	Grey deep sandy duplex (7%) Alkaline grey deep sandy duplex (2%) Red deep sandy duplex (1%) Yellow-brown deep sandy duplex (<1%)
Ironstone gravelly soils 66,000 ha 10%	Soils that have ironstone gravels as a dominant feature of the profile Crests and rises	Loamy gravel (6%) Shallow gravel (3%) Deep sandy gravel (1%) Duplex sandy gravel (<1%)
Deep loamy duplexes 47,000 ha 7%	Soils with a loamy surface and a texture or permeability contrast at 30 to 80 cm Mid-slopes and near rock outcrops	Brown deep loamy duplex (5%) Red deep loamy duplex (2%)
Other minor soils 161,000 ha 23%	Loamy earths (5%), Shallow sands (5%), Shallow sandy duplex (5%), Wet or waterlogged soils (3%), and five others comprising 2% or less.	Calcareous loamy earth (4%) Grey shallow sandy duplex (4%) Yellow/brown shallow sand (3%) Saline wet soil (2%)

2.6 Surface water

Harry Lauk

The following information was drawn from the farmer survey:

- Earthworks are widely used, with 53% of farmers surveyed using contour banks, 50% using deep drains and 14% using other forms of surface drainage for waterlogging management. Farmers indicated a potential increase in deep drains and surface drainage.
- All farmers surveyed are connected to scheme water which supplies an average 39% of water used on-farm (ranges from 0 to 100%).
- Over half the farmers considered their water supplies to be adequate, while 30% would like further information on developing reliable water supplies.
- Dams generally rely on banks or natural catchments to help them fill with only 4% having roaded catchments.

In summary, improvements could be made in water harvesting techniques to reduce reliance on scheme water. Potential also exists for farmers to expand and improve earthworks for surface water management.

2.7 Remnant vegetation

Don Cummins

Only 5.1% of the original vegetation remains. This is comparable to most central wheatbelt catchments, which retain between 5 and 10% remnant vegetation. The important factor is the representation of vegetation associations across the catchment as a whole. Loss and fragmentation can have major impacts on genetic diversity and associated ecosystems.

Prior to clearing for agriculture, mallee and casuarina thicket covered 37% of the catchment. This vegetation association now occupies 1.8% of its original coverage. Other significant factors are:

- Medium woodland, salmon gum and morrel has disappeared since the establishment of agriculture. While these species are represented elsewhere, they no longer exist as a group. Statewide, this association has been reduced by almost half since European settlement.
- Average remnant size is 7.3 ha.
- Only 3.8% of the York and salmon gum vegetation association remains. This formerly covered 32% and its decline has a direct correlation to a range of soil types suitable for agriculture.
- Scrub heath on yellow sandplain, banksia-xylomelum alliance has declined from 11 to 2.2%.
- Most remnant vegetation is found on hill tops and along drainage lines. Granite outcropping in the south of Wongan-Ballidu Shire and in Goomalling Shire generally has medium-sized remnants dominated by low woodland. Saline

drainage lines in the north and the North Mortlock River channel are generally well vegetated, although fringing woodland is usually highly disturbed. These areas are clearly shown in association with vegetation type in the map overleaf. Road reserves are poor (in size and composition) across the entire catchment, notably in the Goomalling Shire.

2.7.1 Catchment wetlands

Lake Walyormouring (150 ha) is in the Walyormouring Nature Reserve (290 ha) in the Shire of Goomalling, 19 km north-east of Goomalling townsite. The lake is both saline and seasonal and has some surviving swamp sheoaks in shoreline areas (Weaving 1999). The vegetation of the lake fringe is highly degraded and the reserve at the northern end has mature trees but very little understorey due to weed invasion.

Lake Hinds (1592 ha) is a seasonal, hyper-saline lake 18 km north-west of Wongan Hills townsite. The lake fringes are dominated by *Haloscarcia lepidosperma*, *H. pergranulata* and *Sarcocornia quinqueflora* (Weaving 1999). The lake has very little fringing vegetation besides a small area of medium woodland to the south.

2.7.2 Significant reserves

The Wongan Hills area contains a number of reserves totalling about 1000 ha. Surveys show that more than 400 species of plants and 40 species of spiders, including a trapdoor and the Wongan Hills wishbone spider, are found in this area. The hills have a unique vegetation system due to the distinctive geology.

Table 2.2: Rare and endangered flora*

Name	Common Name	Found	Habitat
Acacia denticulosa	sandpaper wattle	Private property at Wongan Hills	N/A
Acacia pharangites	Wongan Gully wattle	Wongan Hills	Dense heath on greenstone gully slopes
Acacia semicircinalis	Wongan wattle	Wongan Hills	Lateritic slopes
Acacia vassalii	Vassal's wattle	Wongan Hills	Heath areas
Acacia pygmae	dwarf rock wattle	Wongan Hills	Lateritic sites
Conostylis wonganensis	Wongan conostylis	Near Wongan Hills	Mallee heath on sandy duplexes
Daviesia euphorbioides	Wongan cactus	Road, rail and nature reserves in Wongan-Ballidu, Dowerin and Goomalling shires	N/A
Daviesia spiralis	spiral-leaved daviesia	Near Wongan Hills	Open areas in mallee shrubland
Drakonorchis drakeoides (listed as critically endangered since 1995)	hinged dragon orchid	Private land and reserves in Wongan-Ballidu and Goomalling Shires	Low rises above saline flats, in tall to medium shrubland dominated by *Melaleuca* and/or *Acacia*
Eremophila ternifolia	Wongan eremophila	Wongan Hills	*Eucalyptus* woodland
Eriostemon wonganensis	Wongan eriostemon	Wongan Hills	Open *Eucalyptus* woodland
Gastrolobium glaucum	spike or Wongan poison	Wongan Hills	Gravelly rises
Rhagodia acicularis		Road reserves and private land in Wongan-Ballidu	Red soil on gravelly laterite slopes in *Eucalyptus* woodland
Stylidium coroniforme	Wongan trigger plant	Wongan Hills	Shallow sandy soil over laterite
Verticordia hughanii		Goomalling and Dowerin	Grey sandy soils on the fringes of salt lakes
Verticordia staminosa	Wongan featherflower	Wongan-Ballidu Shire	Confined to shallow soils on rocky outcrops
Grevillea dryandroides subsp. d*ryandroides*		Small area near Ballidu	Sandy clay loam in heath
Hemigenia viscida	sticky hemigenia	Road, rail and nature reserves and private land in Wongan-Ballidu	Low heath on gravelly soils
Melaleuca sciotostyla	Wongan melaleuca	Wongan Hills	Gravelly soils at the base of lateritic breakaways
Microcoyrys eremophiloides	Wongan microcorys	Wongan Hills	Shallow gravelly soils

**(Weaving 1999)*

3. Catchment risks

3.1 Salinity and groundwater

Shahzad Ghauri

3.1.1 Current extent of salinity

The catchment has 65,000 hectares of saline land (9.6%) based on Land Monitor data, shown in the following map. Accuracy statements of the data sets can be found in CSIRO Mathematical and Information Services (CMIS) Report No. 01/111.

Salinity is most common in the valley floors but farmers rated the change of slope as the biggest problem. This may indicate where salinity is currently developing or where management options are available. It is likely to expand in low-lying areas adjacent to existing salinity, however this expansion is highly dependent on elevation, slope and soil type.

3.1.2 Potential salinity risk

Land Monitor topographical models show that approximately 197,000 hectares or 29% of the catchment is located near valley floors. These low-lying areas could ultimately become waterlogged or saline if the groundwater rises sufficiently; however, because of the sandy soil types and proximity to large discharge areas, this prediction is unlikely to be realised.

3.1.3 Groundwater trends

Movements in groundwater level over time vary greatly with many bores rising, falling and remaining relatively static over short and long monitoring periods.

Goomalling network bores in the south-west show a predominantly falling trend of between 0.06 and 0.67 m/yr across all landscape areas. Most falling trends identified in middle or upper slope landscape positions can be attributed to below-average rainfall and the gradual reduction in the effects of the January 2000 flood event.

Trends in 25 bores in Gabby Quoi Quoi sub-catchment were analysed in 2001 and the following was determined:

- overall trends in water level indicate local small falls in depth to watertable. Falls varied between 0.02 and 0.14 m/yr throughout the catchment. Rainfall was not in decline during this period so the reduction in watertable may have been due to revegetation strategies;
- a single bore showed a rising trend, averaging 0.15 m/yr;
- many bores were located in lower slope and valley areas and peaks in water level correspond with peaks in rainfall;
- deep and shallow bores at most sites show similar seasonal patterns and some deep bores actually develop positive heads during winter;

- bores located in upper landscape positions responded to seasonal variation in a similar manner to those located in the valleys.

Observation bores in Wongan Hills town site have also shown consistent falling trends of around 0.25 m/yr, most likely due to below-average rainfall, as the bores have only been monitored since July 2000.

Many bores show both rising and falling trends of less than 0.05 m/yr over various monitoring periods. Most are located in lower slope or valley/discharge areas and are due to reductions in rainfall/run-off in recent years and/or discharge via capillary action.

3.1.4 Effect of rainfall

Analysis of all piezometer data was conducted using the Hydrograph Analysis and Rainfall Time Trends program (Ferdowsian *et al.* 2001). The program assists in explaining long-term groundwater trends by removing the effects of rainfall events from the underlying trend. When applied to Goomalling bores with a falling trend of 0.67 m/yr, this trend was adjusted to 0.52 m/yr.

HARTT illustrates two main differences compared to reporting ordinary linear groundwater trends. Bores with long monitoring periods resulted in linear rates of rise (m/yr) similar to those that were resolved by the program. This is because atypical rainfall events that impact for short periods are largely negated when an average is taken of the entire monitoring period.

3.2 Soil and land degradation risks

Paul Galloway

The major land degradation hazards are soil acidification and structural decline. Both are manageable but likely to affect large areas unless best management practices are adopted. Other hazards that could affect significant areas are subsoil compaction, wind and water erosion and water repellence. These less visible problems affect larger areas than salinity however often go unnoticed and untreated (Nulsen 1993).

Treatment options are varied, with some easily treated, some requiring significant time and/or money, while others are very difficult to reverse once apparent. From a production viewpoint, it makes sense to address those problems that affect large areas and are relatively easily treated.

Options for managing each degradation hazard vary depending on site characteristics and farming systems. A site analysis and farming system appraisal should be undertaken before recommending one option over another. Degradation hazards and management options are more fully described in Moore (1998) and in Farmnotes listed in further reading.

3.2.1 Soil acidity

Approximately 307,000 ha (45%) is moderately to highly susceptible to increased rates of acidification and 18,000 ha (3%) of this is naturally acidic. Testing soil pH in the surface (0-10 cm) and subsurface (10-20 cm) layers is the only accurate way of monitoring acidification. The common soils that are most susceptible to acidification are Deep sands, Sandy earths and Ironstone gravels. These occupy a total of 299,000 ha or 44% and are associated with lateritic landforms. They are leached sandy soils with low organic carbon content and little resistance (or buffering capacity) to pH change.

Liming is the most common method of halting and reversing acidity on these productive soils. The total annual lime requirement is calculated to range from 50,000 to 83,000 tonnes, based on acidification rates of between 75 and 125 kg Lime Equivalent/ha/yr. for the farming systems and soils (Porter and Miller 1998; Dolling unpublished). Lime application is currently between 25,000 and 35,000 tonnes, or 30 to 70% of estimated requirements (Figure 3.1). Furthermore, annual lime applications over the past four years average about 81% of the absolute minimum required (35,000 tonnes lime/yr). These rates vary significantly with the seasonal economic situation. Lime use across the catchment increased from 1996 when the "Time to Lime" campaign was introduced (Andreini and Dolling, unpublished).

Approximately 41% of the catchment was limed in 2001?, according to the farmers surveyed. The Lime and Nutrient Calculator can be used to calculate the lime requirements for individual paddocks. It is available from Top Crop administration, Department of Agriculture, Northam.

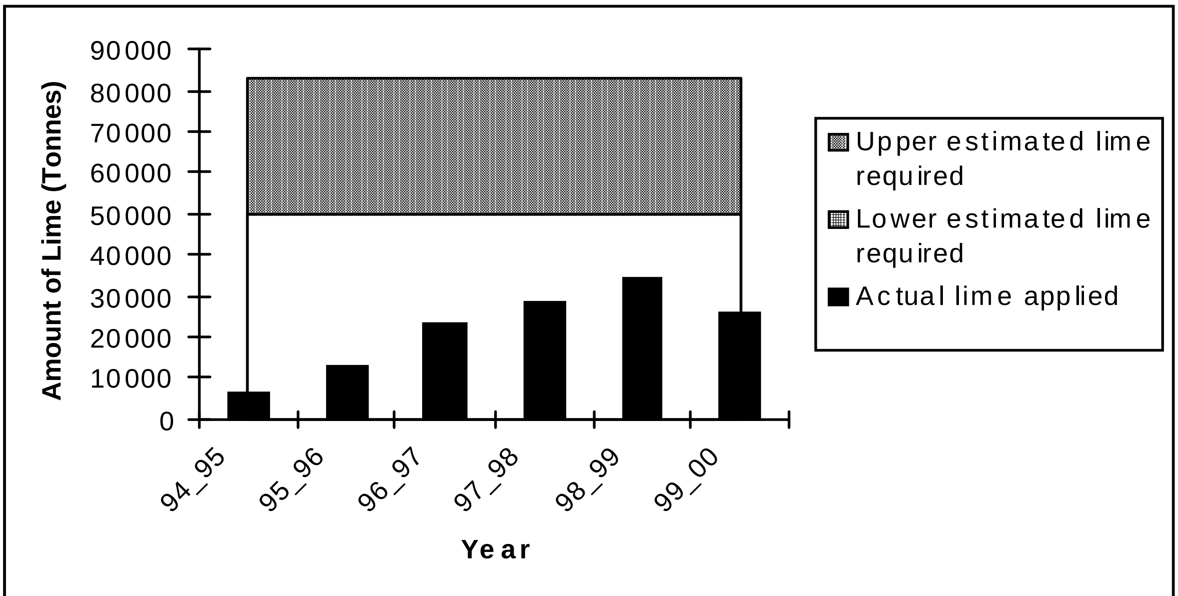


Figure 3.1. Lime use and catchment lime requirement

Lime responses are variable on the naturally acidic yellow sandy earths or Wodjil soils, which account for about 18,000 ha (3%), of the catchment. Andreini and Dolling (unpublished report) suggest that economic responses to liming are marginal or ineffective. However, some trial results suggest that lime applications are economically beneficial to production (Gazey, pers comm). Best soil acidity management on acid sandplain is a liming program in conjunction with planting acid-tolerant species and using less acidifying management practices (Gazey, pers comm). The other naturally acid soil is the agriculturally unproductive acid shallow duplex (2,000 ha or <1%) generally found below breakaways. These should be fenced and revegetated.

Other sandy-surfaced soils such as gritty sands formed on fresh granite and sandy duplexes are susceptible to acidification, but generally have better buffering capacity than those discussed above due to their composition and clay content.

3.2.2 Soil structure decline

Approximately 290,000 ha (43%) has loamy and clayey-surfaced soils that are moderately to highly susceptible to structural decline. Of these, the Shallow loamy duplex soils (106,000 ha or 16%) are most at risk, due to their clay mineralogy, chemistry and past management.

Soil structure decline can be minimised and reversed by applying gypsum, increasing organic matter, blanketing the surface with stubble, practising minimum tillage and removing stock during wet periods. Gypsum will only temporarily improve structure, so should be regarded as an initial step in moving towards conservation tillage methods, rather than a solution to decline. Gypsum has been used on 5% of the area farmed by those surveyed. The farmers did not expect to increase the area.

3.2.3 Subsurface compaction

Sixty seven per cent of the catchment is moderately to extremely susceptible to compaction, but the Sandy earths (22%) and Deep sands (12%) should be targeted first, as they are most susceptible and most likely to respond if no other root limiting layer is encountered. Sandy duplexes are also prone to prone to subsoil compaction, but economic responses are variable and depend on the depth of other root-limiting layers.

Controlled traffic farming minimises the extent of compaction after pans are removed by deep ripping. It also delivers other benefits to the farming system. Deep ripping has been used by approximately 36% of farmers on 19% of the area farmed by them.

3.2.4 Wind erosion

Areas of bare loose dry soil in higher landscape positions are most at risk of wind erosion (Moore *et al*. 1998). The most susceptible are Deep sands, Sandy duplexes and Sandy earths on crests and upper slopes. About 38% are moderately susceptible and 20% are highly to extremely susceptible to wind erosion, but areas at risk are usually much less because of landscape factors and effective management.

Wind erosion can be controlled by maintaining cover, stock management and planting windbreaks to protect susceptible areas. The minimum requirement is 50% cover on paddocks to prevent wind erosion, which translates to 750 kg/ha of cereal crop residue and 500 kg/ha of dry matter in pasture paddocks.

3.2.5 Water repellence

Water repellence mostly occurs on sandy-surfaced soils that have hydrophobic organic matter present. It is most common on the highly productive sands, sandy earths and gravelly soils that are managed under a cereal-legume rotation. About 41% is moderately to highly susceptible but actual occurrence is unknown.

Water repellence is most commonly managed by clay spreading and furrow sowing.

3.2.6 Waterlogging

Waterlogging varies in extent and severity from season to season, and occurs as a complex interaction of weather conditions, soil type, soil moisture status and landform. Weather conditions during winter generally limit waterlogging to small areas of water accumulation, even though 18% of the catchment is moderately to severely susceptible in wet winters. The main soils affected are shallow sandy and shallow loamy duplexes on lower slopes and valley floors. Waterlogging management is addressed in the surface water management section.

3.3 Surface water

Harry Lauk

The catchment has many broad flat valley systems – the map overleaf shows that thirty one per cent of the catchment has slopes of less than 1%. Rising watertables are likely to cause widespread waterlogging and salinity in the valley floors. In wet years, surface flooding will also be a problem.

Fifty five per cent has slopes between 1 and 3% where 80% of the soils are sandy or loamy types. In these areas, runoff would be insufficient for stock/farm water supplies with below-average or even average rainfall. In above-average rainfall years, erosion and waterlogging would affect these sandy/loamy duplex soils.

Surface water management should be a higher priority than subsurface water/moisture control in this catchment. .

3.4 Vegetation risk assessment

Don Cummins

3.4.1 Remnants at risk from salinity

The salinity risk to remnant vegetation is limited because:

- the succulent steppe (*Melaleuca thyiodes* and samphire association) is established mainly in areas already saline. This association is highly adapted to saline conditions and would continue to thrive as salinity increases;
- while shires such as Dalwallinu and Goomalling have relatively large areas of vegetation affected by salinity, much is confined to vegetation fringing existing salt lake chains and saline drainage lines.

Table 3.1: Salinity and remnant vegetation by shires

Shire*	Area of vegetation		Area affected by salinity	
	(ha)	%	(ha)	%
Cunderdin	168	0.8	15	9.2
Dalwallinu	9,506	8.0	1,638	17.2
Dowerin	1,262	4.7	108	8.6
Goomalling	6,984	4.8	1,377	19.7
Moora	1,345	4.6	107	8.0
Northam	545	2.6	44	8.2
Toodyay	0	0	0	0
Victoria Plains	1,123	3.1	118	10.5
Wongan-Ballidu	14,135	5.0	702	5.0
All shires	**35,067**	**5.1**	**4,109**	**11.7**

portion of shire in the catchment

3.4.2 Fragmentation and biodiversity loss

Fragmentation of remnant vegetation can disrupt ecological processes and remnants may become too small to maintain viable breeding populations of species. Table 3.2 shows that the catchment has vegetation associations that are fragmented into a series of small remnants, the majority of which are below 10 ha.

The York and salmon gum vegetation association once covered 32% of the catchment. Such woodlands are now found in isolated islands of mature trees, often with grazed understorey and little or no regeneration. Both species are slow maturing and fragmentation/isolation probably means long-term loss.

Of positive significance is the management of predominately saline systems in valley floors. Such areas are dominated by succulent steppe, which exists in average-sized remnants. The main drainage channel of the North Mortlock River from Lake Hinds to Lake Ninan, and the North Mortlock River, where it crosses Beecroft Road in Goomalling Shire, are good examples of this type of vegetation. Unfortunately the majority of such sites remain unfenced, and bordering shrubland and woodland on low dunes is at risk from grazing and weed invasion. The long-term effects of ongoing salinisation on this vegetation association remain to be seen.

A critical threshold of 30% of the landscape occupied by woodland has been suggested as essential for sustaining bird and mammal populations (McAlpine and Loyn 1998). This catchment contains less than 1.5%, making this vegetation generally unsuitable for many fauna species. Critical thresholds for individual species need to be determined before management decisions are made locally. For example a study at Wyalkatchem has shown that wrens have a range of up to 15 km but will rarely cross gaps in vegetation greater than 60 m wide (Brooker 1999). Similarly trapdoor spiders are known to aggregate around matriarchal nest spaces and rarely disperse (Lambeck 1999).

Table 3.2: Fragmentation of remnants in the catchment

Vegetation association		**Area (ha)**	**Average remnant (ha)**
Medium woodland	York and wandoo.	952.8	3.5
	York gum and salmon gum	8456.4	3.9
	York gum	774.8	4.9
	Wandoo	42.7	2.2
	Salmon gum	96.3	3.5
	York gum, wandoo and salmon gum	36.5	6.0
	Wandoo, York gum, salmon gum, morrel and gimlet	8.4	0.7
Shrubland	*Acacia neurophylla*, *A. beauverdiana* and *A. resinomarginea* thicket	2613.6	8.4
	Scrub-heath on yellow sandplain and banksia-xylomelum alliance	1679.4	3.5
	Tamma and dryandra thicket	1056.9	50.3
	Mallee and Casuarina thicket	12,641.2	4.5
	Melaleuca thyoides thicket	17.1	8.5
	Melaleuca uncinata thicket and scattered York gums	17.0	3.4
Succulent Steppe	*Melaleuca thyoides* over samphire	5,146.2	5.4
	Mallee and *Melaleuca uncinata* thickets on salt flats	78.2	2.7
Other e.g rock		1442	6.3
Total		35,059.5	7.3

** This is the average total remnant size of each vegetation association. Remnants may contain several vegetation associations.*

4. Management options and impacts

4.1 Farming systems

Trevor Lacey and Shahzad Ghauri

4.1.1 Catchment modelling

Two computer models were applied to determine the impacts of farming systems based management options on groundwater recharge. The Flowtube model utilises real bore data gathered across a local sub-catchment transect. The bore data used in the construction of this model were collected during April 2000 and scenarios are presented representing differing levels of intervention by all landholders within the entire catchment. AgET concentrates on estimating the amount of water flowing beyond the roots for different farming rotations on different soil types. AgET data had a further layer of analysis applied at catchment scale via the Catcher model, which estimates the impact of changing farming rotations on the catchment water balance.

Combined modelling results have developed the following recharge scenarios:

1. **Do nothing**. Recharge under existing rotations is estimated to be 11% of annual rainfall.

2. **Low intervention**. Could see a reduction of recharge to 10% of annual rainfall by increasing perennials from 6 to 15% of catchment area.

3. **Moderate intervention**. This would involve increasing perennials to 19%, through the introduction of phase farming and could reduce recharge to 8.7% of annual rainfall. Significantly, these perennial systems may provide the basis for profitable production from areas with shallow watertables. Increasing the level of perennials from 5 to 19% only reduces pasture area from 30 to 28% and cropped area from 64 to 61%. The total production from this optimistic intervention should be at least as good as from current rotations. Stock carrying capacity is likely to be similar or increased, with a better spread of feed throughout the year (from 8% perennial pastures), providing the opportunity to target higher-priced markets for out of season stock.

4. **High intervention**. A reduction of recharge by 50% could be achieved through widespread adoption of perennial pastures, alley farming, tagasaste and oil mallees.

It is important to note that altering farming systems to include some phased crop and perennial pasture rotations can significantly reduce recharge without major changes to the total area of crop and pasture. However, changing from continuous annual pasture to crop-annual pasture rotation or to continuous cropping will only reduce recharge slightly.

The use of lucerne and woody perennials in farming systems is considered highly beneficial as they use almost all of the annual rainfall. While annual crops permit approximately 5-15% of rainfall to flow past the root zone and clover/medic pastures allow 10-30% of rainfall past the plant root zone, depending on soil type.

When recharge is examined from a soil and landscape perspective, the following should be noted (see Figure 4.1):

- Deep sands, Sandy earths and Ironstone gravels are major soils with high recharge potential. The best way to manage recharge on them is by planting permanent perennials (e.g. revegetation with natives, tagasaste, rows of shelter belts etc.) and phase cropping with perennial pastures, or less effectively, deep-rooted annual pastures (e.g. serradella) or continuous cropping.

- Shallow sandy duplexes are minor soils that contribute significantly to recharge via preferred pathways such as large cracks and root channels, particularly when the soil profile is saturated or waterlogged. Recharge will reduce on this soil by improving surface water management (reducing waterlogging) and altering the farming system to increase perennials and improve crop and pasture water-use.

- General results show that middle and lower slopes are at risk of salinisation within 20 years and that the onset of salinity in middle slopes can be delayed by many years, depending on the level of intervention. However, lower slope and valley areas must not be seen as completely unproductive in future, as many areas within salinised paddocks will remain highly productive for salt-tolerant pastures.

- Areas with steeper slopes and shorter distances to discharge points will be less affected by salinisation because the higher groundwater gradients and less constrictive flow, thus reducing groundwater rise. Examples include areas surrounding Dambouring and Ballidu.

The rotations used on each major soil, shown in the modelling are presented in more detail in Appendix 3.

NOTE: Flowtube modelling cited in this report assumes a constant annual rate of recharge. It does not take into account episodic recharge (high rainfall/flood events and often results in watertables rising and not lowering to their previous, deeper levels). Another major assumption is that all strategies implemented take effect immediately with full potential e.g. lucerne is transpiring water at its full potential from the moment it is included in the program.

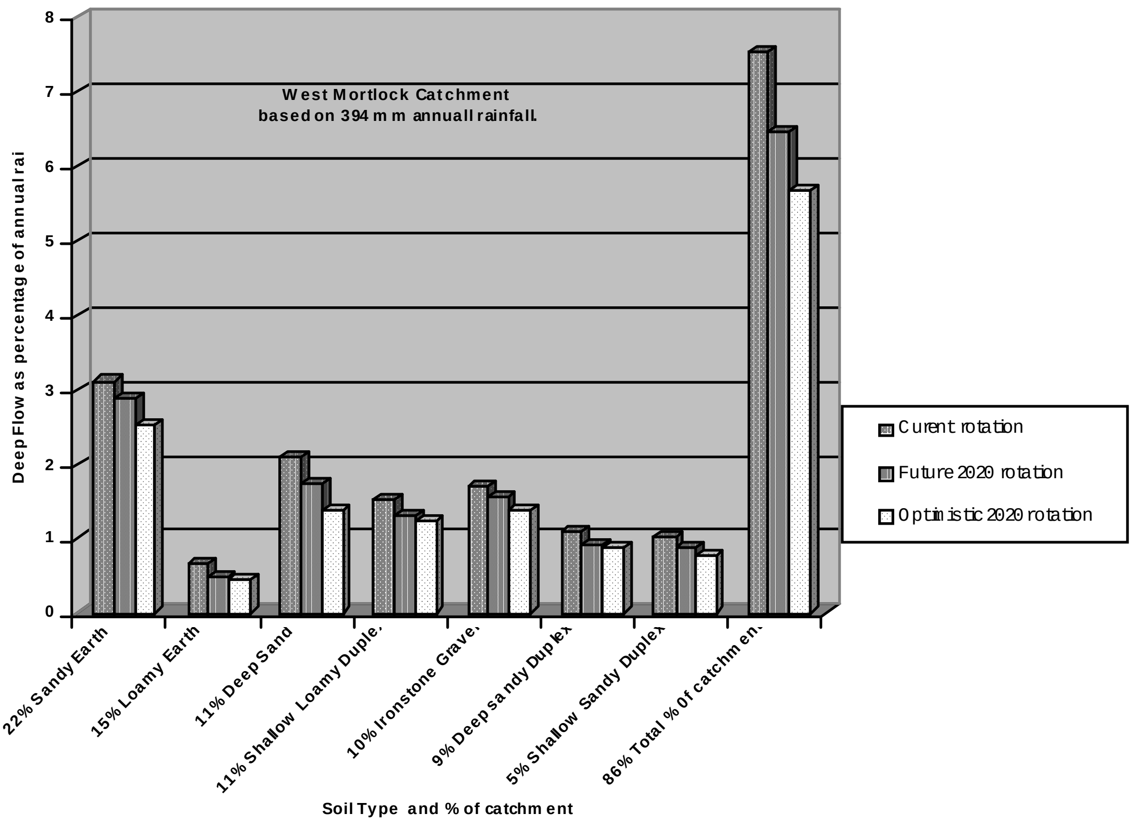


*Figure 4.1: Catchment recharge from current and future rotations**

4.1.4 Farming systems options

4.1.4.1 Annual crop rotations and use of best farming practices

Best practice annual crop and pasture agronomy will marginally improve water use. Doubling crop yields only increases water use by 5%, and annual crops use more water than traditional annual pastures. Annual summer crops use similar amounts of water to traditional annual crops but are able to use summer rainfall and moisture stored in soil. This has a net positive impact on year-round water use if winter crops or pastures follow summer crops. However, effective surface water management and perennial species are needed to reduce recharge rates significantly. Soils that are difficult to crop, or that have marginal economic returns, are a good opportunity for perennial pastures, forage crops and woody perennials. Perennial pastures are well-suited to stock enterprises as they can provide a better distribution of feed throughout the year, thus removing or reducing the need for feed supplements and enabling high-priced markets to be targeted.

4.1.4.2 Integrating perennial pastures into the farming system

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

Rotations using perennial pastures have farming benefits including:

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

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

- above break of slope positions;
- on soil changes where the upslope soils are lighter than the downslope soils;
- in gritty soils around rock outcrops;
- above dykes and faults.

Lucerne dryland grazing systems:

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

Integrating woody perennials into farming landscapes

Woody perennials use more water than perennial pastures. They best fit into the farming system in landscape or soil niches, in alleys or block plantings. For information on commercial woody perennials that fit into West Mortlock refer to Table 4.3.

4.2 Groundwater management

Shahzad Ghauri

4.2.1 Revegetation responses

The following is example of groundwater response to revegetation in West Mortlock (Hopgood 2001).

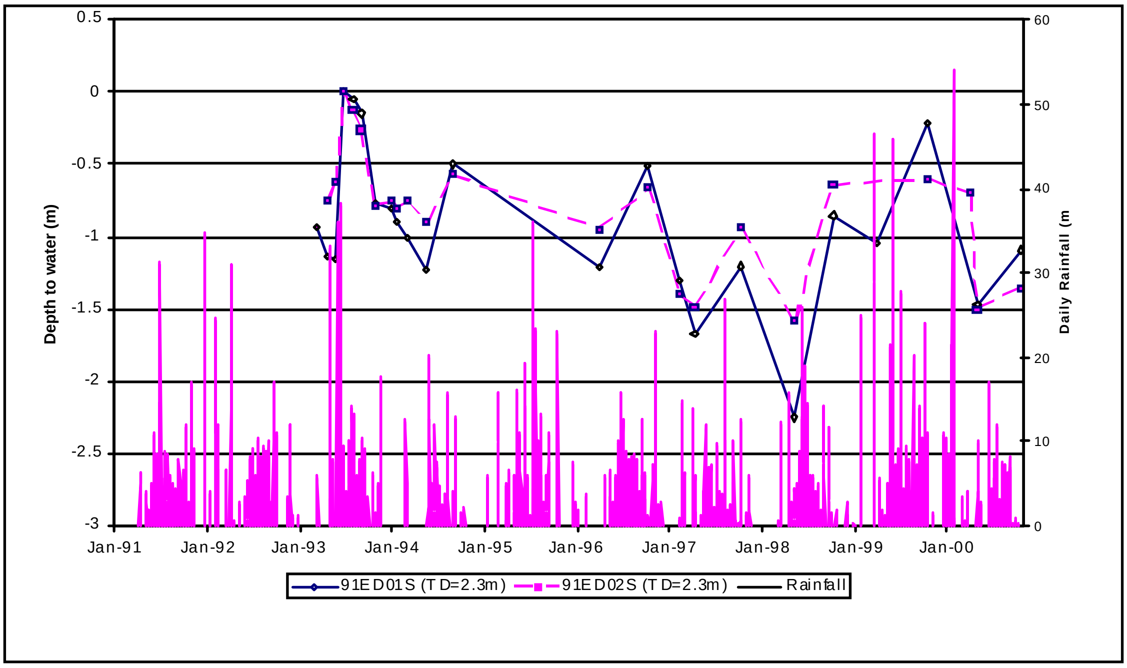


Figure 4.2. Dean Road water level and daily rainfall

The site is on Dean Road, east of Konnongorring. The landscape position is a lower slope and the soil is a loamy clay. The bores located at the site are surrounded by rows of salt-tolerant trees planted in 1993 and 1994 and there is samphire downslope in the valley. The trees have shown signs of stress due to dry conditions of June to December 2000.

Monitoring of the bores has shown a similar depth to the watertable, varying seasonally between the ground surface and 2.2 m below. High rainfall in 1999 and January 2000 has led to a sharp rise in the watertable with some lowering around April 2000. The bores show a falling trend in depth to groundwater of between 0.07 and 0.11 m/yr, indicating that the tree planting has some success in lowering the watertable. However this trend may not continue, as the trees are showing signs of stress. Additional decline in the watertable due to dry conditions since 2000 can probably be expected.

Similar revegetation work in the adjacent East Mortlock catchment has improved the condition of a mildly saline paddock. In 1989, multiple rows of four to five lines of trees were planted, with a strip of cultivated land (25 to 30 m) between. The area was dominated by barley grass prior to trees being established and had groundwater salinity of <2000 mS/m. Measurements show that groundwater EC had reduced by up to 40% over 10 years. The eucalypts, though salt-tolerant, are likely to have lowered the saline watertable and then transpired direct rainfall infiltration. The area now produces significant saltland pasture and can serve for stock to shelter.

4.2.3 Managing discharge

Deep drainage

Installing drains in soils with low hydraulic conductivity such as heavy clays, may only impact on as little as 10 m of land either side of the drain. However, deep drains can be effective where they intercept more permeable aquifers that have a hydraulic gradient, even when these are quite thin. These include clay overlying permeable saprolite, sandy sediments, clays with preferred pathways such as sand seams and old root channels. Proper design, land degradation potential and safe disposal of water should always be considered before constructing drains. Visit the following website for more information on deep drainage:

www.agric.wa.gov.au/environment/land/drainwise/options/engineering/deep_drains.htm

Groundwater pumping

Groundwater pumping is a valuable tool, particularly for controlling watertables under high value assets. Aquifer pump tests in Wongan Hills townsite achieved a small drawdown of 1 m at a monitored site 26 m away from the pumped bore. This pumping has achieved rapid drawdown, suggesting that water available for pumping was limited, probably due to the presence of barriers such as dykes (Deshon 2001). Qualified groundwater hydrogeologists should conduct site investigations to locate production bores, as groundwater systems are complex and variable.

For more information on groundwater pumping, visit the following website:

www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Gwtr_pump.htm

4.3 Surface water management

Harry Lauk

4.3.1 Introduction

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

- rising watertables in the broad flat valley systems;
- waterlogging on the slopes of the sandy/loamy duplex soils;
- large valley floors and smaller hillside seep areas of waterlogging;
- hillside seepages and flooding prone areas in wet years;
- inadequate maintenance of existing surface water control earthworks;
- on farm water supplies in below average rainfall years;
- inappropriate design of some earthworks and;
- lack of industry standards for deep drainage earthworks.

4.3.2 Land management principles

Conservation land management options reduce the velocity and erosiveness of surface water. Land management options that should be used in most areas of the catchment, are:

- vegetative cover to protect the soil from raindrop impact and reduce surface water, eg steep loam/clay slopes in upper catchment;
- working land along the contour to hold surface water in the furrows;
- grass strips and permanently grassed waterways to slow surface water that has been concentrated by natural landforms and earthworks, eg do not cultivate natural drainage lines or waterways and double fence major waterways and;
- managing your farm according to Land Management Units.

4.3.3 Surface water control

The amount of surface water run-off from each of the four main soil types is affected by slope grade and landscape position (for example: valley floor, footslope, upperslope, crest). A quick assessment of these slope classes can be made using orthophotos overlain with 2-metre contours. Earthworks can then be planned, taking soil type into account, to help reduce waterlogging (Table 4.1).

Higher slopes (3% to10%) are mainly present in the southern part of the catchment , with nearly all of the northern half of the catchment having slopes of less than 3% to less than1%.

Table 4.1: Earthworks for the slope classes and landscape elements of West Mortlock catchment.

Slope Class (%)	Landscape element	Suitable earthworks
0-1% slope (31% of catchment)	Valley floors / lower footslopes	Shallow relief drains Levee and Levied waterways
1-3% slope (55% of catchment)	Long slopes / footslopes	Seepage interceptor drains Reverse Bank seepage interceptor drains Levee and Levied waterways Diversion bank Broad-based bank (not less than 2%)
3-5% slope (10% of catchment)	Mid-slopes / minor upperslopes	Grade bank Seepage interceptor drains Reverse Bank seepage interceptor drains Levee and Levied waterways Diversion bank Broad-based bank

Slope Class (%)	Landscape element	Suitable earthworks
5-10% slope (3% of catchment)	Upperslopes	Grade bank Level/adsorption banks directly below steep slopes of Mallet Hills Levee and Levied waterways Diversion bank
>10% slope (1% of catchment)	Steep slopes / Mallet Hills / rock outcrop	Use conservation land management practices Absorption banks if erosion a problem

4.3.4 Surface water earthwork options

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

- **Land Assessment –** information on soil condition, vegetation cover, catchment area, annual average rainfall and slope is used to calculate maximum flows, safe grades, safe velocity and safe disposal points. For more information visit the Department of Agriculture website (http://www.agric.wa.gov.au/progserv/natural/assess/index.htm).
- **Average Recurrence Interval (ARI) –** describes the average period in years between the occurrence of a rainfall event of specified magnitude (duration and intensity) and an equal or greater event. For example, a 20 year ARI rainfall event would occur, on average, five times in 100 years and would have a 5% probability of occurring in any year. Earthworks should be designed and built to fill or safely fail when subjected to a specified ARI. Important earthworks, such as dams, waterways and absorption banks should be designed for at least a 20 year ARI. The minimum design of most surface drains and banks is a 10 year ARI.

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

The range of appropriate engineering options for the main soils is described in Table 4.2.

Table 4.2: Recommendations for surface water control

Soils	Management issues	Appropriate earthworks
Sandy earths (22% of catchment)	Water management only a problem in wetter years – waterlogging main issue	Grade bank systems to stable waterway Levee waterways
Loamy earths (15% of catchment)	Surface water erosion may be issue on steeper slopes. Waterlogging may also be problem in wet years	Grade banks to intercept excess surface water Reverse bank interceptors if duplex soils
Deep sandy duplex (10% of catchment)	Usually no surface water issues	Not required Usually no surface water issues
Deep sands (10% of catchment)	Usually no surface water issues	Not required Usually no surface water issues
Ironstone gravelly soils (10% of catchment)	Usually no surface water issues unless on breakaways	Grade or level banks if erosion present
Deep loamy duplex (10% of catchment)	Water erosion Flooding on valley flats Waterlogging	Grade bank systems Shallow relief drains/w-drains Conventional or reverse bank seepage interceptor drains
Other (23% of catchment)	Usually erosion or waterlogging or flooding on valley floors	Various bank types per situation

4.3.5 Earthworks for water conservation and management

Earthworks, including grade banks, diversion banks, grassed waterways, roaded catchments and dams, are the primary method of water conservation and storage. The works described earlier in this section can often be utilised to divert water into storage. Effective water storage structures increase the surface storage component of the water balance. However, rarely are earthen storage structures 100% efficient, so they usually contribute to recharge via preferred pathways and matrix flow, particularly given the significant hydraulic gradient under such structures. Design is therefore important to maximise storage efficiency and to minimise recharge.

Roaded catchments are designed to capture rainwater and provide an efficient method of increasing run-off into farm dams. A well constructed and maintained roaded catchment can to start to shed water after only 4-6 mm rainfall, whereas grade banks will not. However, poorly maintained roaded catchments can require up to 10-15 mm of rainfall to produce run-off. There are few roaded catchments on farms in the catchment.

For more information see:

http://www.agric.wa.gov.au/environment/land/drainwise/tools.htm#Surface

4.4 Remnant vegetation management

4.4.1 Focal species for biodiversity

Fauna focal species can assist in planning for the preservation and expansion of remnant vegetation. The basic principles outlined by CSIRO (Lambeck 1999) in their focal species approach to maintaining and enhancing biodiversity in remnants are:

- Choose a focal species, preferably a bird, that has a habitat requirement similar to a range of birds found in the catchment e.g. the Rufous Whistler, which is found in nearly all vegetation associations, and typical of 95% of woodland birds in its requirements for a minimum of 10 ha of shrubby woodland.
- Understorey is essential, revegetation or grazed remnants that are composed of trees only are of little value to fauna.
- Large remnants, preferably around 100 ha, need to be part of any corridor. All other remnants in any corridor need to be at least 10 ha.
- Remnant 'stepping stones' are needed at least every 1 km.
- While roads can present a significant barrier to many species, they are still considered vital habitat for many birds.

For more information go to www.csiro.au

4.4.2 Case study for biodiversity protection/enhancement

In the south many remnants are on granite outcrops. Such vegetation is generally not fenced, may have an understorey dominated by weeds and often has little or no regeneration. Following are the basic requirements for protecting and enhancing such remnants, this information can also be applied to other remnants:

- Fence out remnants. Without protection from stock, mature trees will be all that remain in the patch of vegetation. Granite hill tops are difficult to revegetate, so the best bet is to fence and allow natural regeneration (some level of weed control may be necessary).

- Buffer remnants to ensure minimal weed encroachment from neighbouring paddocks and to provide a way of limiting the effects of agricultural fertiliser and spray drift on remnants (edge effects). 3-5 rows of oil mallees may be a suitable buffer. The secondary benefit of such a planting, will be to intercept water movement off hilltops and minimise waterlogging down slope; and

- Linking hill tops through the creation of fenced vegetation corridors to fill the gaps between remnants. Such corridors need to designed, in terms of width and vegetation composition, with a fauna species in mind. Bird species should be considered a priority and CSIRO has completed studies on optimal corridor composition to encourage species movement.

Suggested large scale catchment corridors are listed in Appendix A2.

4.4.3 Commercial options

The range of commercial revegetation options for low rainfall areas is generally limited. The recommendations are shown in Table 4.3. The key reference for revegetation information is www.agric.wa.gov.au. Further information regarding suitable revegetation species should be sourced from Lefroy *et al.* (1991).

Table 4.3: Commercial revegetation options

Species	**Soil Type**	**Annual Rainfall**	**Limitations**
Tagasaste	Deep sands, sandy earths	300 mm +	Preference for grazing by cattle, susceptible to pests, doesn't tolerate waterlogging, grazing with sheep requires rotational grazing and slashing.
Oil mallees	9 species available that suit a range of soil types from sands to loams and clays	200 mm +	Markets not well established, scale of production needs to be increased to meet biomass markets, harvesting and processing methods still being developed.
Sandalwood	Free draining ironstone gravels and loams	400-600 mm. Generally drought tolerant	20 years to reach commercial size, sensitive to fire and requires host plant (jam).
Banksias	Well drained sandy earths and deep sands	250+ mm	May require irrigation to encourage production, susceptible to dieback, will not tolerate waterlogging. Markets can be variable.
Broombush	Sands through to gravels and clays, can be waterlogging and salt tolerant	250+ mm	Economics of block plantings dubious, small market and suitable species for commercial use still being researched by CALM.
Maritime pine (Forest Products Commission offers share farming arrangements for this species.)	Deep sands, gravelly soils and sandy earths.	400+ mm	30 year+ rotation. Rainfall requirement limits this species to the western edge of the catchment. 150 km haulage limit to be profitable. May be growth/form problems in wheatbelt plantings.

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6. Appendices

A1. Soil-landscape information as a basis for Land Management Unit (LMU) mapping

Paul Galloway

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

The information for West Mortlock catchment derives from data intended for publishing at a scale of 1:100,000 to 1:250,000. It is useful for regional planning and provides only preliminary basis for catchment planning. More detailed mapping is required for catchment and farm planning purposes and should be conducted by defining the spatial extent of the LMUs. To assist this process soil groups have been extracted from the soil-landscape mapping information (Table A1.1). These are a suite of soils with similar characteristics and can be regarded as preliminary LMUs. They have not been explicitly mapped. Rather, their spatial extent has been calculated from the proportion that each occupies in the soil-landscape units present.

LMUs should comprise both soil and landscape elements to best partition the landscape for effective and sustainable management. Presently, the preliminary LMUs only relate soil type to landscape position through the broad description found in the existing soil-landscape maps held by the Department of Agriculture.

Mapping the preliminary LMUs of the catchment will not differentiate several important landscape-related LMUs. It is necessary to separate some of the duplex soils into different landscape positions to create LMUs that address surface water management issues including water erosion and waterlogging. Suggested divisions for the sandy duplex soils are upper and mid-slope (10-6% and 6-3%), lower slope (3-1%) and valley floor (1-0%) landscape components.

Regional scale soil-landscape mapping held by the Department of Agriculture can be used to initiate LMU mapping. Mapping line-work identifies initial subdivisions and map-unit descriptions define the relative abundance of LMUs within each map-unit. This information is available on request to the Department of Agriculture's regional soil resource or research officers.

Table A1.1: Soil groups (preliminary LMUs) of West Mortlock catchment

Soils (suggested preliminary Land Management Units)	Area (ha)	% of catchment
Sandy earths	149,300	22
Shallow loamy duplexes	106,100	16
Deep sands	84,000	12
Deep sandy duplexes	68,200	10
Ironstone gravelly soils	65,600	10
Deep loamy duplexes	47,400	7
Loamy earths	34,100	5
Shallow sands	33,300	5
Shallow sandy duplexes	33,200	5
Wet or waterlogged soils	21,800	3
Cracking clays	13,100	2
Non-cracking clays	12,800	2
Rocky or stony soils	7,800	1
Shallow loams	3,200	<1
Miscellaneous soils	1,200	<1
Total	**681,200**	**100**

A2. Remnant vegetation

Vegetation association	Associated soils	Original cover (ha)	Proportion of catchment (%)	Proportion remaining (% of catchment)	Proportion remaining (% of association)
Medium woodland					
York gum and wandoo	Sandy duplexes	17,280	2	<1	<1
York gum and salmon gum	Loamy duplexes and loamy earths	218,719	32	1.2	3.8
York gum	Sandy and loamy duplexes	11,066	1.6	<1	7
Salmon gum and morrel	Loamy earths and loamy duplexes	32	<1	0	0
Salmon gum	Loamy duplexes	625	<1	<1	15
Wandoo	Shallow sandy duplexes	728	<1	<1	5.8
York gum, wandoo and salmon gum	Sandy and loamy duplexes	134	<1	<1	27
Wandoo, York gum, salmon gum, morrel and gimlet	Loamy duplexes and loamy earths	1,564	<1	<1	<1

Vegetation association	Associated soils	Original cover (ha)	Proportion of catchment (%)	Proportion remaining (% of catchment)	Proportion remaining (% of association)
Shrublands					
Acacia neurophylla, *A. beauverdiana* and *A. resinomarginea* thicket	Sandy earths and deep sands	33,134	4.9	<1	7.9
Scrub heath on yellow sandplain banksia-xylomelum alliance	Sandy earths and deep sands	75,126	11	<1	2.2
Mallee and casuarina thicket	Shallow sands and ironstone gravelly soils	254,869	37	1.8	5
Melaleuca uncinata thicket with York gum	Loamy earths and deep loamy duplexes	79	<1	<1	21.6
Tamma and dryandra thicket	Ironstone gravelly soils	1,441	<1	<1	73.4
Melaleuca thyoides thicket	Shallow loamy duplexes and cracking clays	392	<1	<1	4.5
Succulent steppe					
Melaleuca thyoides over samphire	Shallow loamy duplexes and cracking clays	55,377	8.1	<1	9.3
Mallee and *Melaleuca uncinata* thickets on salt flats	Loamy duplexes	3,803	<1	<1	<1
Bare/salt lakes	Salt lakes	2,986	<1	<1	1.5
Bare/rock outcrops	Bare area and rock	4,545	<1	<1	30.1
Total		**681,901**	**100**	**5.1**	

Significant catchment corridors

1. North Mortlock River from north of Beecroft Road (Goomalling), following the drainage line south to the Southern Brook confluence. The dominant vegetation association is *Melaleuca thyoides* and samphire, however, as the drainage channel becomes more confined, sheoaks and York gums are more common. The size of riparian remnants is extremely variable but most are unfenced and disturbance levels are high. There is a 43 ha reserve in this corridor, where the Toodyay-Goomalling Road crosses the drainage line and the total corridor length is 25 km. This corridor could be expanded north east, to link to Mungilan Creek and a large remnant on Patterson Road, 13 km south of Goomalling.

2. North Mortlock River from Lake Hinds to Lake Ninan. This 21 km corridor is composed of generally well preserved vegetation in the river channel, with some fringing shrubland and woodland, notably salmon gum and gimlet close to Lake Hinds. The drainage line requires fencing and there may be further opportunities to expand the corridor north-east (still following the drainage line) to Kondut.

3. Linking the gaps in remnants from Wongan Hills townsite west to the Wongan Hills. These are relatively small gaps but a continuous corridor would link a number of well preserved remnants.

A3. AgET and Catcher analysis

AgET, formerly known as Wattle, calculates average recharge (Argent & George 1997).

Recharge under a crop rotational system is proportional to the number of years of crop or pasture in the rotation and can be calculated as follows: for example a pasture, pasture, wheat, lupin, wheat, barley rotation on a Shallow sandy duplex would be two years of pasture and four years of crop.

$$\text{Recharge} = \frac{(2 \text{ years X pasture recharge**}) + (4 \text{ years X crop recharge**})}{\text{Total years in rotation}}$$

$$\text{Recharge} = \frac{(2 \text{ X } 24\%) + (4 \text{ X } 15.5\%)}{6} = 18.3$$

(** West Mortlock % recharge from Table 15.)

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

Table A3.1: Predicted recharge for some options on main soils for shires

Soil type	Options	Predicted recharge as percentage of annual rainfall (%AR)			
		Goomalling 373 mm	Wongan-Ballidu 394 mm	Dalwallinu 362 mm	West Mortlock catchment
Sandy earths	Clover/medic pasture	22	21	17	19
	Continuous crop	15	14	10	12
	Lucerne	0	0	0	0
	Woody perennials	0	0	0	0
Loamy earths	Clover/medic pasture	12	12	9	10
	Continuous crop	7	7	5	6
	Lucerne	0	0	0	0
	Woody perennials	0	0	0	0
Deep sands	Clover/medic pasture	32	31	27	29
	Continuous crop	12	12	9	10.5
	Lucerne	0	0	0	0
	Woody perennials	0	0	0	0
Shallow loamy duplex	Clover/medic pasture	20	20	16	18
	Continuous crop	14	13	9	11
	Lucerne	1	0	0	.5
	Woody perennials	0	0	0	0
Ironstone gravels	Clover/medic pasture	24	24	20	22
	Continuous crop	16	16	12	14
	Lucerne	0	0	0	0
	Woody perennials	0	0	0	0
Deep sandy duplex	Clover/medic pasture	18	18	14	16
	Continuous crop	13	12	9	11
	Lucerne	0	0	0	0
	Woody perennials	0	0	0	0
Shallow sandy duplex	Clover/medic pasture	27	26	22	24
	Continuous crop	20	18	14	16
	Lucerne	2	2	1	1
	Woody perennials	0	0	0	0

Catchment water balances were estimated by running Catcher with three scenarios: current practice, predicted practice in 2020 and optimistic option for 2020, with higher level of recharge intervention including phased perennial pastures and woody perennials (Table A3.2). Current and predicted 2020 rotations were taken from McConnell (2001). Difficulties were encountered trying to compare soil types across zones and this information should be reviewed.

Table A3.2: Percentages of soils allocated to land use options in current, future 2020 and optimistic future 2020 rotations

Soil type and percentage of catchment	Rotation	Land use (%)					
		Sub clover	Lucerne	Commercial trees	Serradella	Crop	Pre-clearing vegetation
Sandy earths - 22%	Current rotation	40	0		0	49	11
	Future rotation 2020	35	5			49	11
	Optimistic rotation 2020	15	5	5	15	49	11
Loamy earths - 15%	Current rotation	25	0		0	75	
	Future rotation 2020	15	10			75	
	Optimistic rotation 2020	15	10	5		70	
Deep sands - 11%	Current rotation	40	0			49	11
	Future rotation 2020	30	5	5		49	11
	Optimistic rotation 2020	20	5	5	10	49	11
Shallow loamy duplex - 11%	Current rotation	25	0			75	
	Future rotation 2020	15	10			75	
	Optimistic rotation 2020	15	10	5		70	
Ironstone gravel - 10%	Current rotation	30				64	6
	Future rotation 2020	30	5	0		54	11
	Optimistic rotation 2020	20	10	0	0	59	11
Deep sandy duplex - 9%	Current rotation	25	0			69	6
	Future rotation 2020	15	10			69	6
	Optimistic rotation 2020		10	5	15	64	6
Shallow sandy duplex - 5%	Current rotation	25	0			69	6
	Future rotation 2020	15	10			69	6
	Optimistic rotation 2020	10	10	10		64	6

The optimistic rotation outlined is but one example of a combination that might be adopted. Combinations of options in conjunction with other management options outlined in this report should be considered.

A4. Shire summary

Table A4.1: Shire area in West Mortlock catchment

LGA	Area (ha)	Area in catchment	Per cent
Cunderdin	186,092	20,244	10.9
Dalwallinu	722,049	118,941	16.5
Dowerin	186,145	26,576	14.3
Goomalling	183,381	144,750	78.9
Moora	375,983	29,437	7.8
Northam	140,342	20,963	14.9
Toodyay	169,167	2	0.0
Victoria Plains	254,865	35,954	14.1
Wongan-Ballidu	336,307	285,034	84.8
All shires	**2,554,329**	**681,901**	**26.7**

Table A4.2: Roads and built-up areas in catchment

LGA	Length of roads (km)					Built-up area	
	Highway	*Main*	*Local*	*Other*	*Total*	*ha*	*%*
Cunderdin			92	22	114		0.0
Dalwallinu	28	133	570	279	890	493	0.4
Dowerin			140	44	184	82	0.3
Goomalling		104	494	149	747	431	0.3
Moora			121	107	228	3	0.0
Northam		11	113	35	158		0.0
Toodyay							0.0
Victoria Plains		11	148	52	212		0.0
Wongan-Ballidu		73	1,200	660	1,933	2,114	0.7
All shires	**28**		**2,878**	**1,349**	**4,468**	**3,124**	**1.8**

Table A4.3: Roads and built up areas affected by salinity

LGA	Length of roads (km)					Area affected (ha)	
	Highway	*Main*	*Local*	*Other*	*Total*	*Total*	*Built-up*
Cunderdin	0.0	0.0	2.9	1.1	4.0	1,002	
Dalwallinu	0.1	2.8	49.1	14.5	64.3	7,342	4
Dowerin	0.0	0.0	2.5	0.3	3.0	890	2
Goomalling	0.0	4.6	36.9	8.6	50.2	12,583	6
Moora	0.0	0.0	10.1	6.2	16.1	2,826	
Northam	0.0	0.1	5.9	1.1	7.2	930	
Toodyay							
Victoria Plains	0.0	0.8	9.3	2.4	12.8	2,494	
Wongan-Ballidu	0.0	6.5	159.5	54.9	211.2	37,201	8
All shires	**0.1**	**14.8**	**276.3**	**89.1**	**368.8**	**65,267**	**20**

A5. Contacts

The most important source of current agricultural resource management information is the Deparment's website at www.agric.wa.gov.au. Natural resource management information can also be found at: www.avonicm.org.au

Table A5.1: Contacts list

Area	Contact	Details
Farming systems	Trevor Lacey	Department of Agriculture Northam Ph 9690 2101fax 9622 1902 email tlacey@agric.wa.gov.au
Soils	Paul Galloway	Department of Agriculture Narrogin Ph 9881 0227 fax 9881 1950 email pgalloway@agric.wa.gov.au
Hydrology	Shahzad Ghauri	Department of Agriculture Northam Ph 9690 2102 fax 9622 1902 email sghauri@agric.wa.gov.au
Surface water management	Harry Lauk	Department of Agriculture Northam Ph 9690 2162 fax 9622 1902 email hlauk@agric.wa.gov.au
Remnant vegetation/revegetation	Don Cummins	Department of Agriculture Northam Ph 9690 2242 fax 9622 1902 email dcummins@agric.wa.gov.au

A6. Further reading

Farmnotes from Department of Agriculture on soils

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

Best practice agronomy

'The Wheat Book – Principles and Practices'. Bulletin 4443, Department of Agriculture

Department of Agriculture website at www.agric.wa.gov.au

Animal production Farmnotes

36/2001	Grazing sheep and cattle on dryland lucerne
135/2000	Lucerne in pasture-crop rotations: establishment and management

Revegetation Farmnotes

26/2000	Brown Mallet
30/2000	Eucalyptus oil mallees
33/2000	River red gum
24/2000	Banksias for cut flower production
25/2000	Broombush
29/2000	Maritime pine
35/2000	Southern sandalwood
37/2000	Tagasaste
38/2000	Wandoo