Farm water for the north-eastern and eastern wheatbelt of Western Australia (Zones 2 and 5)

Susan Murphy-White
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FARM WATER
FOR THE NORTH-EASTERN AND
EASTERN WHEATBELT
OF WESTERN AUSTRALIA

Susie Murphy-White

May 2007
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( Zones 2 and 5)

Susie Murphy White
Dryland Research Institute, Merredin

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Summary

Large proportions of Western Australia’s dryland farms suffer from water supply problems in the form of shortages, poor quality or combinations of these two factors. The affected area relates to farmland receiving less than 600 mm average annual rainfall and encompasses most of the State’s commercial dryland farms. Continuing farm water supply problems throughout the north-eastern and eastern wheatbelt have highlighted the need for the development of an integrated approach to on-farm and off-farm water supply.

The ‘Water Planning and Management for Sustainable Dryland Agriculture’ project for the North-eastern and Eastern Wheatbelt was funded by the Natural Heritage Trust for three years (July 1996-July 1999). The research was based at the Merredin Dryland Research Institute and focused on developing strategies for Zone 5 and the north-east of Zone 2 that covers the north-eastern and eastern parts of the wheatbelt. The Sustainable Rural Development project and the Sustainability of Wool Production Systems supported the integration of farm water planning into focus catchment planning and the development of agricultural water supply areas to form a Regional Farm Water Plan.

Agricultural water supply areas were identified as part of the Regional Farm Water Plan developed for the project. The description of the water supply areas for the north-eastern and eastern wheatbelt will assist landholders in the development of new supplies and guide maintenance strategies and improvement of existing water supplies.

A regional study for the North-eastern and Eastern Wheatbelt was undertaken to assist in the development of new and existing water supplies and to define a landform-based approach for surface water management. Five farm water supply areas were identified using natural resource management units that relate to different types of water supply development potential. The base data used to develop water supply areas included soil type, landscape units, geology, hydrogeology, native vegetation and existing farm water resource infrastructure.
FARM WATER FOR THE NORTH-EASTERN AND EASTERN WHEATBELT

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1. Introduction

The area covered by this report is Zone 5 (North-eastern and Eastern Wheatbelt) and the north-eastern part of Zone 2 (Reticulated Scheme Area) of the Western Australian Farm Water Plan as shown in Figure 1. Although the reliability of water supply in Zone 2 is generally superior to Zone 5, there is ample scope for on-farm water supply development in Zone 2. The Local Government Areas (LGAs) in Zone 5 are Dalwallinu, Koorda, Mt Marshall, Mukiudin, Westonia, Yilgarn and Narembeen covering 2 million hectares. The LGAs in Zone 2 considered are Trayning, Nungarin, Merredin, Bruce Rock and Kellerberrin. This represents a total of 2.9 million hectares.

The Yilgarn catchment consists of 5.66 million hectares of land that extend from Kellerberrin to Southern Cross, east and north of Mukinbudin. The catchment is part of the Swan-Avon drainage system and includes the salt lakes which are part of the Zone of Ancient Drainage. These salt lakes exist as a linear chain that are interconnected, but rarely flow as they experience high evaporation and a shallow profile. The Yilgarn catchment was the area that overlapped with Zones 2 and 5 and studied in this project (Figure 2). Four focus catchments were studied from the Yilgarn catchment: Bodallin (Yilgarn LGA), Wallatin Creek (Kellerberrin LGA), Yeelanna and Yarragin TangPlang (Trayning LGA).

The study area has a Mediterranean climate with cool wet winters and hot dry summers. Average annual rainfall varies between 280 and 360 mm with approximately two-thirds falling in the growing season (May to September). Average monthly maximum temperature ranges from 16 to 36°C with the average annual evaporation exceeding 2,000 mm. Farming systems are dominated by winter cereal production and grazing of livestock, primarily Merino sheep for wool.
Water supplies are described as either low quality (livestock) or high quality (domestic) sources. Low quality water from dams and bores is generally used for livestock, garden, laundry and toilet facilities. High quality water is used for drinking, domestic purposes and for specific needs in farm operations such as crop spraying. The main sources of high quality water are tanks connected to roofed structures and bores.

A Farm Water Strategy Group was initiated in 1992 to advise on strategies that would reduce the severity and extent of supply problems. The Farm Water Plan 1994 (Farm Water Strategy Group 1994) describes the north-eastern and eastern wheatbelt to be the area where the greatest difficulty for development of reliable on-farm water supplies is experienced (Laing et al. 1988, Hauck 1992, Casey and Laing 1993).

The development of water supply areas was proposed as a methodology that would assist with the implementation of appropriate on-farm supply, design and technology. This approach was viewed as an effective method of reducing the occurrence of water deficiency declaration and thereby the associated costs to farmers and the State Government.

Zone 5 has been successful in securing community farm water grants to construct extensions to the government-reticulated scheme. Given the extension of the piped scheme from Zone 2 into Zone 5 and the general trend towards decreased stocking rates, the development of reliable water supplies was given low priority by the farming community during the project.
1.1 Historical development of farm water resources

The importance of reliable farm water supplies in the eastern wheatbelt was first realised in the 1830s when the country east of the Darling Range was explored for suitable agricultural land. The first explorer, Ensign Robert Dale (1830) circumnavigated an area east to Mt Stirling and Mt Caroline. During his journey he described the salt lake country and some fresh water sites of limited potential. The general absence of suitable surface water restricted the expansion of pastoral and agricultural pursuits (Main 1993). Other expeditions were mounted with the hope of finding grassy plains and an inland sea, but these reported a lack of useful surface water supplies.

In 1863, Lefroy discovered good agricultural land that lacked water apart from possible wells. This resulted in the expansion of sheep eastward onto pastoral leases. The eastward migration continued into the Kellerberrin and Doodlakine areas, with water holes and rocky outcrops used as catchments to support livestock and settlers. Numerous ‘gnamma’ holes and shallow wells were associated with granite outcrops (Laing and Hauck 1997). With the introduction of corrugated iron in the 1880s, homesteads were improved and the useable water catchment was doubled for domestic supplies.

The discovery of gold in Coolgardie and Kalgoorlie in 1892-93 placed greater importance on water supplies as populations increased. CY O’Connor started a pipeline to the goldfields in 1898, and when completed in 1903, was able to supply five million gallons of water on a daily basis. The main source of the water was the Helena River in the Darling Range. This water was used exclusively for the goldfields until it was realised that the demand for water was not equal to the supply of the scheme (Anon 1925). Agricultural districts made demands for the water supplies, and in response the government extended the pipeline to those along the routes engaged in tilling the soil.

The pipeline to the goldfields opened up the agricultural area adjacent to the line as far east as Southern Cross. In the early 1900s stocking rates increased on the pastoral leases and further improvements to domestic life were made. Springs and soaks near granite outcrops aided agricultural development in areas not connected to the pipeline. Small excavated tanks were constructed in what is now known as the wheatbelt (Laing and Hauck 1997).

Plate 1. Original roof and tank connection used by early pioneers

In the early 1900s large scale land clearing began for wheat production. An experimental farm was set up at Nangeenan in 1906, now the Merredin Dryland Research Institute. Research and development began into wheat varieties and other cereal and legume cropping systems. The first priority of most settlers was to provide water for families and horses using some form of earth dam or constructed water storage. For land opened up in the Mukinbudin area in 1910, the Agricultural Bank provided a loan of £150 for dam building. The money could either be used for two 1000 cubic metre dams or one of 2000 cubic metres (Maddock 1987). In 1911, the northern railway loop was completed (Dowerin to Merredin).
and greatly improved the transport of produce and water. Extension of the comprehensive
scheme to Nungarin was proposed in 1913 and sparked concern from farmers further north.
A letter from the Dandanning and Wattoning Farmers and Settlers Association dated
10/9/1913 resulted in the following reply from the Water Supply Engineer: “The Dandanning
and Wattoning area was too far out for inclusion, that it was only ‘a proposal’ at that stage
and that the development of local supplies was the best alternative” (Maddock 1987).

At the turn of the twentieth century dam sinking usually involved two to five horse teams,
while smaller teams were required to cart water for the horses and men. A single furrow
plough was used to mark and rip the surface over an oblong area for the dam. A scoop was
then used to remove the loose soil, and the area was re-ripped and scooped again. This
continued to a depth of 10 to 12 feet to make a 1000 cubic yard dam with construction taking
about 10 working days. The dams were reported to fail in dry years because of low rainfall
and high evaporation rates.

Further expansion occurred into the wheatbelt (after the First World War) with the Soldier
Settlement Scheme in the 1920s. Farms around Bonnie Rock and Southern Cross were
allocated between 1927 and 1929 as part of the ‘3500 Farms Scheme’ (Development,
Migration, and Agreement with Great Britain, Maddock 1987). By 1929 most of the
North-eastern and Eastern Wheatbelt had been settled.

The development of water supplies away from the piped scheme and isolated granite
outcrops began to improve. Wells and soaks were found at the footslopes of the light land
and mallee, but these supplies often became brackish with continued use. Boring for water
was also undertaken in heavy land on the broad valley floors between 10 and 30 metres and
the water was found to be saltier than seawater (Burvill 1979). Domestic water was collected
from roof rain tank connections and used very sparingly for domestic purposes. The
excavated earth tanks or dams were often covered to prevent evaporation. In 1929, the first rock catchment water supply in Australia, the No. 1 District Water Scheme,
was opened. This enclosed an area east of Lake Brown to west of Trayning, south to
Knungagin and about 12 miles north of Muckinbudin. Three reservoirs, Waddouring (22.5
million gallons capacity), Barballin (40 million gallons) and Knungagin (8 million gallons) all
using granite rock outcrops as catchment, were used to supply eight towns, 332 farms and
two rail loops - Dowerin to Merredin and Mt Marshall (Maddock 1987). After a series of dry
years the scheme was connected with the Goldfields Water Supply Scheme in 1937.

The modified comprehensive scheme was connected to Kellerberrin, Trayning and
surrounding areas in 1946 by the northern pipeline from the Goldfields mainline. Those
farmers who were not connected continued to improve their on-farm water supplies. Field
experience suggested that the more catchment on a farm dam, the more reliable the supply.

In 1947 Burvill (Soil Commissioner of Department of Agriculture) and Allison (Public Works
Department Engineer) investigated the use of graded areas (like earth roads) on small areas
of catchment. At the same time a farmer from North Pingrup constructed a corrugated earth
catchment by exposing the clay subsoil in the furrows (Burvill 1979). The extension of the
comprehensive water scheme north from Kellerberrin and Doodlakine occurred in 1958, and
led to an increase in livestock carrying capacity in the Trayning area.

A special farm water supply loan was made available in the 1960s by the State Government
to farmers not served or not likely to be served by the piped water scheme (Burvill 1979).
This continued the improvement in farm dam and roaded catchment design and reliability.
The same limitations in water supply development exist today as for the early pioneers:
inadequate depth due to shallow rock; permeable soils; rising groundwater; and high
evaporation rates.
1.2 Water deficiency

In 1995 the WA Government introduced the Farm Water Grants Scheme. This is based on the partitioning of the dryland agricultural area into seven zones (see Figure 1). The zones were defined according to the source of water supply, frequency and extent of deficiencies and the length of time required correcting the problem. The zone boundary map indicates the boundaries which coincide (where possible) with existing shire boundaries.

The Water Corporation estimates indicated that the provision of piped water supplies to wheatbelt farms in 1998 would cost approximately $100 per hectare. Owing to the huge cost, extensions to the Agricultural and Goldfields piped scheme is likely to be limited to those areas with special requirements and where none of the regular farmland water supply options are available or practical.
2. North-eastern and Eastern Wheatbelt biophysical environment

2.1 Climate

This area has a Mediterranean climate with hot dry summers and cool winters. Light winter rains dominate the rainfall and occasional summer thunderstorms. The annual average rainfall ranges from 286 to 359 mm. Class A pan evaporation exceeds rainfall in all months and by approximately 2000 mm over a whole year.

2.1.1 Rainfall

Rainfall is the most important variable that impacts on productivity and land degradation. Rainfall arises from two general climatic systems: southern frontal systems, which pass from west to east; and rain from tropical air with general pattern that tends to be a mosaic of wet and dry localities, which shifts from year to year.

The growing season rainfall from April to October accounts for 75% of annual rainfall. Rainfall differences result mainly from the growing season period. The summer rainfall period of November to March shows only small variation, however it does differ in intensity with the north of the region having more prevalent intense thunderstorms than the south.

![Average annual rainfall](image_url)

**Figure 3.** Average annual rainfall (Bureau of Meteorology1998, Farm Water Supplies 1996)
2.1.2 Rainfall variability

Mean annual rainfall and other details for five centres in the North-eastern and Eastern Wheatbelt are shown in Table 1.

Table 1. Rainfall variations for selected sites of the North-eastern and Eastern Wheatbelt
(Source: Bureau of Meteorology 1998)

<table>
<thead>
<tr>
<th>Location</th>
<th>MAR</th>
<th>Deciles</th>
<th>Min</th>
<th>Max</th>
<th>Rain days</th>
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<td>430 318 207</td>
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<td>441 345 219</td>
<td>177</td>
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<td>286</td>
<td>388 277 178</td>
<td>-</td>
<td>-</td>
<td>68</td>
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2.1.3 Temperature and evaporation

There is little variation in average temperatures throughout the year, however the north and east have a slightly higher average. Dalwallinu highest recorded temperature in January of 46.8 °C followed by Bencubbin, Merredin, Southern Cross and Narembeen at 45 °C (Table 2).

Table 2. Temperature records for selected sites (Source: Bureau of Meteorology 1998)

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<td>1.4</td>
<td>4</td>
</tr>
<tr>
<td>Southern Cross</td>
<td>8.2</td>
<td>8.1</td>
<td>5</td>
<td>0.6</td>
<td>-3.3</td>
<td>-3.8</td>
<td>-3</td>
<td>-2.7</td>
<td>-1.6</td>
<td>-1.1</td>
<td>1.1</td>
<td>3</td>
</tr>
</tbody>
</table>
Reliable water supplies for livestock must be stored over the summer. The volume of water required to support livestock depends on the evaporation as well as demands. The north and east have recorded slightly higher evaporation than the southern and western shires. These evaporation trends correlate with temperature trends.

Table 3. Mean monthly evaporation and annual evaporation (mm) from dams for selected sites (Coles and Hauck 1996)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Merredin</td>
<td>315</td>
<td>260</td>
<td>231</td>
<td>138</td>
<td>82</td>
<td>52</td>
<td>55</td>
<td>67</td>
<td>96</td>
<td>165</td>
<td>214</td>
<td>292</td>
<td>1,967</td>
</tr>
<tr>
<td>Mukinbudin</td>
<td>319</td>
<td>270</td>
<td>240</td>
<td>146</td>
<td>87</td>
<td>56</td>
<td>62</td>
<td>75</td>
<td>101</td>
<td>172</td>
<td>221</td>
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<td>2,046</td>
</tr>
<tr>
<td>Narembeen</td>
<td>297</td>
<td>239</td>
<td>209</td>
<td>125</td>
<td>75</td>
<td>50</td>
<td>62</td>
<td>51</td>
<td>90</td>
<td>150</td>
<td>195</td>
<td>270</td>
<td>1,813</td>
</tr>
<tr>
<td>Southern Cross</td>
<td>313</td>
<td>252</td>
<td>226</td>
<td>139</td>
<td>86</td>
<td>57</td>
<td>65</td>
<td>78</td>
<td>108</td>
<td>175</td>
<td>220</td>
<td>294</td>
<td>2,013</td>
</tr>
<tr>
<td>Wialki</td>
<td>324</td>
<td>280</td>
<td>245</td>
<td>151</td>
<td>94</td>
<td>60</td>
<td>65</td>
<td>82</td>
<td>107</td>
<td>179</td>
<td>228</td>
<td>205</td>
<td>2,120</td>
</tr>
</tbody>
</table>

2.2 Geology

The South-West of Western Australia is defined by two major tectonic units, the Yilgarn Craton and the Perth Basin and associated orogens. The Yilgarn Craton is separated from the Perth Basin by the Darling Fault to the west along the Western Gneiss Terrane, and subdivided into the Southern Cross (south-eastern margin), Murchison (northern margin) and the eastern Goldfields Provinces (eastern margin). The Yilgarn catchment is within the confines of Yilgarn Craton (Figure 4).
The Yilgarn Craton is a geologically stable mass of granite and gneiss of Archaean origin, some 4600 to 3000 million years old (Grealish and Wagnon 1995). Archaean granites outcrop throughout the wheatbelt and can be subdivided into three major sub-groups:

(i) Mafic, ultramafic and metasedimentary enclaves
(ii) Recrystallised granitoid gneiss
(iii) Young granite and adamellite.

These sub-groups form the underlying basement geology. Intrusions of dolerite, gabbro, diorite and quartz feldspars dykes are common and result from high pressure, temperature (metamorphism) and deformation that occurred during the Proterozoic Era (3000 to 600 million years ago). The dykes strike in an easterly or north-easterly direction (Blight et al. 1984). Dolerite appear to be influential in the development of topographic crests and ridges. The dykes have also influenced the development of soil, landforms and drainage patterns within the wheatbelt.

The basement geology is covered by saprolite or laterites of various depths and often covered by colluvium. Tertiary and Quaternary sediments of the Cainozoic Era 60 million years ago overlie the granite and gneiss bedrock (basement geology). The Tertiary Period (60 to 1.8 million years) sediments are formed from materials eroded from the older land surface (McArthur 1992). The sediments of the Quaternary Period (<1.8 million years) comprise aeolian, lacustrine, alluvial and colluvium deposits, derived from the breakdown of the Tertiary and Archaean bedrock.

High rates of weathering occurred when the climate was moist, temperate to tropical (Grealish and Wagnon 1995). As a result of the extended weathering with no volcanic eruptions, glaciation or rejuvenation, the landscape has very low relief with a profile of strongly weathered material. Soil particles consist of sandy or gravelly (ironstone) surface, underlain by mottled and pallid horizons of weathered material, sitting on weathered rock (saprolite) and bedrock.

The major drainage systems developed in the Late Cretaceous Period (135 to 65 million years ago) and regular river flow inland had ceased by the mid-Miocene, 10 million years ago (Chin 1986). The old river channels or palaeodrainage lines form a series of evaporative salt lakes. Surface water very rarely flows between the lakes and groundwater movement beneath the lake system is very sluggish due to the lack of relief and the relatively impermeable clay soils.

The landscapes within the Yilgarn catchment were produced by a combination of geomorphological processes. The landscape has low relief, with slopes that are long and gentle. The drainage divides are wide and convex, with the main valleys very wide and often containing saline lake systems. These lake systems include Lakes Seabrook and Deborah which drain westerly into Lakes Brown and Wallambin of the Yilgarn catchment.

2.3 Hydrogeology

Dawit Berhane (formerly hydrologist, Merredin)

The Avon River Basin consists of four main flow systems: the salt lakes in the east Yilgarn and Lockhart catchments; the Salt River System in the central region Avon catchment; the rejuvenated Avon River Avon catchment; and the Swan River on the west of the Darling Scarp (Figure 5).

The majority of Farm Water Plan Zones 2 and 5, with its sluggish lake system, is in the eastern Zone of Ancient Drainage. Mulcahy (1967) identified a line (the Meckering Line) by which he separated this zone from the Zone of Rejuvenated Drainage down stream.
Upstream stream-bed gradients can be as low as 1:1500. Downstream of the Meckering Line, streams can have gradients up to 1:250.

The Salt River System and salt lakes are dominated by a linear chain of salt lakes, generally following the paths of the older palaeodrainage system. The lakes rarely flow as an interconnected system due to low seasonal rainfall, high evaporation rates and shallow lake profiles. Rather, they act as a series of evaporation sumps to surface run-off.

Figure 5. The Swan-Avon river system and Yilgarn and Lockhart catchments

Most of the eastern wheatbelt is situated on an Archaean craton with a flat landscape underlain by predominantly igneous rocks. Intrusions by Proterozoic-age dolerite dykes and more recent deformation by major faults, minor faults, and shear zones, have resulted in a strongly structurally controlled basement-aquifer complex. Aeolian, colluvial, fluviatile and lacustrine sediments of Holocene to Eocene age overlie deeply weathered saprolite, which consists of Cainozoic age, iso-volumetrically weathered felsic and mafic rocks.

The geological history has produced a complex fractured-rock and regolith system through which water is transported slowly (Lewis 1991). Three main aquifer types have been identified: fractured crystalline basement; saprolite; and sedimentary.

Due to the high costs of drilling and the high salinity of most groundwater, few holes have been drilled to determine the hydraulic properties of the fractured basement aquifer system. Nevertheless, the aquifer potential of the fractured system depends on the density of fractures, degree of connectivity and whether the fractures are open or filled with clay minerals. The fractured aquifer systems have low porosity and high permeability.
The bedrocks of the study area are normally overlain by alluvial deposits (soil) and regolith developed in situ by weathering of the underlying granite. The transition zone between unweathered bedrock and the overlying saprolite is often more permeable than the bulk of the saprolite. The regolith thickness varies greatly, ranging from zero, to tens of metres in the lower catchment (valley floor).

The alluvial deposits in the eastern wheatbelt have been classified into three distinct units: Recent alluvium; Tertiary alluvium; and Palaeochannel deposits (Salama et al. 1993). The most recent alluvium occurs in the upper reaches of the drainage system in narrow creeks and channels with moderate gradients. Alluvial materials consist of sediments ranging from clays to coarse gravel. The most areas for on farm groundwater supplies are in the alluvium, colluvium and sandplain areas.

About 1000 piezometers have been installed in the eastern wheatbelt to monitor variation in groundwater levels. Nulsen (1998) suggest that water levels have risen following clearing of native vegetation. Water level fluctuations have been characterised by few distinct patterns:

- Seasonal fluctuation that occurs in the lower reaches of catchments where aquifers have direct hydraulic contact with creeks. Water levels rise during winter and fall during summer in response to rainfall.
- Monotonically rising water levels occur in the upper reaches of catchments where water levels are relatively deep and rates of recharge are high. The rate of rise ranges from 0.2 to 0.5 metres per annum.
- Continuously rising water levels with seasonal fluctuations may occur in mid-slope areas. The water levels normally exhibit a sinusoidal pattern with a rising trend.
- Continuously falling water levels with seasonal fluctuations occur in catchments where revegetation has occurred. For example, in revegetated areas of the Merredin catchment water levels have declined by about 2 m over five years.

### 2.4 Soil and landscapes

The study area is within the Zone of Ancient Drainage (see Figure 7 of Grealish and Wagnon 1995). Four separate land resource surveys have been conducted there (Figure 6). While there are differences in the styles of these surveys, they are all regional scale mapping that recognises areas of similar soils, landform, geology, climate and native vegetation.

Zone 5 has been mapped for the Bencubbin and Southern Cross-Hyden map sheets. Zone 2 covers part of the Bencubbin and Southern Cross-Hyden map sheets to the north-east and the Kellerberrin and Merredin map sheets to the south-west.

In the Bencubbin area, Grealish and Wagnon (1995) described 14 land systems in terms of landform and soil variations. The Southern Cross-Hyden area (Frahmand draft, unpublished 1996) consists of 16 soil-landscape systems. Land resources of the Kellerberrin region (McArthur 1992) include eight land surfaces with similar landforms, soils and vegetation. Soils of the Merredin area (Bettenay and Hingston 1961) comprise nine associations.

The land system concept has been used to define the water supply areas. These occur in similar positions in the landscape, and have comparable landscape units, native vegetation and hydrological characteristics. The results of these correlations are presented in Table 4.
Figure 6. Land resource surveys for the study area
Table 4. Correlations between agricultural water supply units and landscape systems from four surveys

<table>
<thead>
<tr>
<th>Agricultural Water Supply Areas</th>
<th>Land resources of the Bencubbin area, 1:250,000 (Grealish &amp; Wagnon 1995)</th>
<th>Land resources of the Kellerberrin region, 1:100,000 (McArthur 1992)</th>
<th>Soils and land use of the Merredin area, 1:126,720 (Bettenay &amp; Hingston 1961)</th>
<th>Land resources of the Southern Cross-Hyden area, 1:250,000 (Frahmand 1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morrel</td>
<td>Land system</td>
<td>Land surfaces</td>
<td>Soil associations</td>
<td>Soil-landscape system</td>
</tr>
<tr>
<td>Kununoppin</td>
<td>Baladjie</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mukinbudin</td>
<td>Nangeenan</td>
<td>Hines Hill</td>
<td>Garrett</td>
<td></td>
</tr>
<tr>
<td>Wallambin</td>
<td>Baandee</td>
<td>Baandee, Stirling</td>
<td>Lagan</td>
<td></td>
</tr>
<tr>
<td>Salmon Gum</td>
<td>Cleary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gabbabin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trayning</td>
<td>Merredin</td>
<td>Merredin, Belka</td>
<td>Hope, Ghooli</td>
<td></td>
</tr>
<tr>
<td>Wialki</td>
<td></td>
<td></td>
<td>Daman</td>
<td></td>
</tr>
<tr>
<td>Mallee</td>
<td>Nembudding</td>
<td>Booraan</td>
<td>Coffin, Yeerakine</td>
<td></td>
</tr>
<tr>
<td>Nungarin</td>
<td>Coligar</td>
<td>Coligar</td>
<td>Nesheeb, Narembeen, Greenmount</td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>Kwelkan, Yetelling</td>
<td>Danberrin (&amp; rock)</td>
<td>Burngup, Karlagarin, Mt Speen</td>
<td></td>
</tr>
<tr>
<td>Tamma</td>
<td>Koorda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yelbeni</td>
<td>Ulva</td>
<td>Ulva</td>
<td>Buladagie</td>
<td></td>
</tr>
</tbody>
</table>

2.5 Vegetation

Farm Water Plan Zones 2 and 5 cover the South-West Botanical Province and lie within the Avon Botanical District. Vegetation systems represented in Zones 2 and 5 include Mt Caroline, Muntadgin, Moorine Rock and Jibbering (Beard 1979). Each system consists of a series of plant communities occurring in a mosaic pattern that are closely linked to topography and soil features (Table 5).

Table 5. Plant communities and their relevance to Water Supply Areas

<table>
<thead>
<tr>
<th>Water Supply Area</th>
<th>Plant community</th>
<th>Landscape</th>
<th>Soil association</th>
<th>Water comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock</td>
<td>Granite outcrops</td>
<td>Upper pediment</td>
<td>Weathered granite and granite colluvium</td>
<td>Shallow rock for dam depth</td>
</tr>
<tr>
<td>Tamma</td>
<td>Kwongan thickets</td>
<td>Interfluve</td>
<td>Sands high in ironstone landscape, yellow sandy soils</td>
<td>Hardpan dams</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good improved catchments</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Perched aquifers</td>
</tr>
<tr>
<td>Mallee</td>
<td>Mallee</td>
<td>Pediment slope</td>
<td>Sandy salmon gum to duplex soils</td>
<td>Clay dam sites in mallee patches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good roaded patches</td>
</tr>
<tr>
<td>Salmon Gum</td>
<td>Woodland</td>
<td>Upper valley</td>
<td>Heavy grey and red brown sandy loams</td>
<td>Saline groundwater</td>
</tr>
<tr>
<td>Morrel</td>
<td>Woodland/salt country</td>
<td>Lower valley</td>
<td>Alkaline fine powdery red loams to clay</td>
<td>Dams don’t hold</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nodules indicate permeable soils</td>
</tr>
</tbody>
</table>
The Mt Caroline Vegetation System covers all of the Kellerberrin LGA and parts of Bruce Rock, Merredin and Trayning. The Muntadgin Vegetation System includes the Merredin LGA. This system is slightly drier, higher in the landscape and less reduced by erosion than Mt Caroline. It consists of large areas of residual sandplain which have been dissected by shallow valleys leading to the west and north-west. Moorine Rock Vegetation System has less rainfall than Muntadgin and the country is more dissected. There are four parallel north-draining valley systems which join Lake Seabrook, which flows into the Swan-Avon catchment. The Jibbering Vegetation System borders Mt Caroline in the south and Moorine Rock in the east. The area consists of sandplain on the interfluves and red loams in the valleys.

For this study four broad plant communities are recognised:

- Granite outcrops
- Kwongan thickets
- Mallee
- Woodland.

### 2.5.1 Granite outcrops

The granite outcrop plant community consists of shrubland and low woodland with dominant species including rock sheoak (*Allocasuarina huegeliana*), jam (*Acacia acuminata*) and York gum (*Eucalyptus loxophleba*). These species occur where soil profiles have developed in and around the edge of granite outcrops. Woodlands adjacent to the outcrops consist of rock sheoak, jam and inland wandoo (*E. capillosa* white gum). The white gum areas tend to indicate permeable soils, and clay dams constructed in these areas often leak. The plant community associated with granite outcrops contain soil pockets, which are vegetated with small trees of jam, caterpillar wattle (*Acacia lasiocalyx*), rock sheoak and weeping pittosporum (*Pittosporum phyiraeoides*) of the Muntadgin and Moorine Rock Vegetation Systems. Areas covered with broom bush honey myrtle (*Melaleuca hamulosa*) indicate wet patches and potential for groundwater supply development. Clay dam sites can be found near the edge of the granite outcrops and are indicated by larger shrubs and mallee.

### 2.5.2 Kwongan thickets

The kwongan community commonly takes the form of heath, thicket and scrubland. Tamma (*Allocasuarina campestris*) thickets are found on sands high in ironstone gravel and may be associated with scattered emergent inland wandoo (*Eucalyptus capillosa*). On the yellow sandy soils mixed thickets and heath consist of tamma and associated species of *Acacia* and *Melaleuca*. On poorly drained areas broom bush honey myrtle (*Melaleuca uncinata*) thickets with scattered York gum grow. Other species in the Muntadgin and Moorine Rock Vegetation Systems include black tamma (*Acacia acutivalis*) with *A. signata*, *A. stereophylla* and *A. neurophylla* and jam or grey tamma (*Allocasuarina corniculata*). The Burracoppin mallee (*Eucalyptus burracoppineisis*) occurs throughout the kwongan plant community.

### 2.5.3 Mallee

In the Muntadgin and Moorine Rock Vegetation Systems the plant community includes patches of pure mallee. Areas of woodland and mallees occur in the upper reaches of the main valleys. The common mallee is black marlock (*Eucalyptus subangusta*) and grows in association with white mallee (*E. cylindriflora*) or redwood (*E. transcontinentalis*). The understorey consists of scattered shrubs of the kwongan plant community where the soil is sandy, and woodland species where the soil is clayey. The Jibbering Vegetation System contains patches of mallee York gum (*E. loxophleba*) and redwood (*E. transcontinentalis*) in various mixtures throughout the reddish sandy duplex soils.
2.5.4 Woodland

Woodland areas are found on the lower valley slopes and flats and consist of associations of York gum, salmon gum (*Eucalyptus salmonophloia*) and gimlet (*E. salubris*). Small trees represented are jam, rock sheoak or mallee of black marlock (*E. subangusta*) and redwood (*E. transcontinentalis*). The shrub and ground layers are usually sparse. In the Muntadgin Vegetation System, morrel (*E. longicornis*) occurs near saline flats and on the calcareous soils, and can indicate a porous subsurface layer. Clay dams are prone to leaking. Inland wandoo occurs on lighter coloured soils, with sandy surfaces and is often found bordering kwongan. The understorey consists of scattered shrubs and occasional grasses and herbs. The valley floor of the Moorine Rock Vegetation System contains pure woodland with a mixture of salmon gum, gimlet and morrel according to the soil type. The understorey consists of saltbush (*Atriplex hymenotheca*) when morrel is present or near salt lakes. The Woodland plant community of the Jibbering Vegetation System includes York gum declining towards the east, yorrel (*E. yilgarnensis*) only on salt country and can be associated with salmon gum or gimlet on the heavier soils.

2.5.5 Salt country

Salt flats during summer are dry, covered with salt crystals and lack vegetation. Samphire (*Halosarcia* spp.) communities cover the extensive flats. The vegetation around the beds of salt lakes is sometimes overgrown with small stem-succulent samphires (*Arthrocnemum* sp.), boree (*Melaleuca lateriflora*) and yorrel (*Eucalyptus yilgarnensis*). The woodland areas in the salt flats consist of York gum, tea-tree (*Leptospermum* spp.) and samphire. Saltbush (*Atriplex* spp.), boree bush and other melaleucas cover the sandy dune ridges. Some grasses (e.g. *Stipa elegantissima*) and small trees of weeping pittosporum (*Pittosporum phylliraeoides*) are present.
<table>
<thead>
<tr>
<th>Vegetation system</th>
<th>Plant community</th>
<th>Granite outcrop</th>
<th>Kwongan</th>
<th>Mallee</th>
<th>Woodland</th>
<th>Salt country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Caroline</td>
<td></td>
<td>Rock sheoak (<em>Allocasuarina huegeliana</em>), jam (<em>Acacia acuminata</em>), York gum (<em>Eucalyptus loxophleba</em>)</td>
<td>Tamma (<em>Allocasuarina campestris</em>), inland wandoo (<em>Eucalyptus capillosa</em>), broom bush (<em>Melaleuca uncinata</em>)</td>
<td></td>
<td></td>
<td>Samphire (<em>Halosarcia</em> spp.), teatree (<em>Leptospermum</em> spp.)</td>
</tr>
<tr>
<td>Muntadgin</td>
<td></td>
<td>Jam, rock sheoak, caterpillar wattle (<em>Acacia lasiocalyx</em>), weeping pittosporum (<em>Pittosporum phyliraoides</em>)</td>
<td>Black tamma (<em>Acacia acutivalis</em>), jam, grey tamma (<em>Allocasuarina corniculata</em>), Burracoppin mallee (<em>Eucalyptus burracoppineisis</em>)</td>
<td></td>
<td></td>
<td>Salmon gum (<em>Eucalyptus salmonopholia</em>), gimlet (<em>E. salubris</em>), Inland Wandoo (<em>E. capillosa</em>)</td>
</tr>
</tbody>
</table>
2.6 Agricultural systems and water demand

The agricultural systems in the study area are based on winter cereal production and grazing. Approximately 60 per cent is cropped each year. Wheat is the major crop and grown in rotation with pulses, oilseeds, other coarse grains and pasture. The main livestock enterprise is Merino sheep for wool with some crossbreds for the prime lamb market.

![Figure 7. Variations in sheep numbers from 1980 to 1997, 2001 (Bureau of Statistics)](image)

General farm water requirements can be defined in relation to water use, quantity, quality and reliability criteria. The available resource is then divided based on the requirements for domestic, garden, crop-spraying and livestock supplies. Good quality (<55 mS/m TSS) is required for domestic purposes and the maximum for livestock range from 546 mS/m (pigs) to 1820 mS/m (sheep). The quantity of water required for each activity also varies, with livestock supplies coming under increased pressure during summer. Therefore, landholders using on-farm supplies are exposed to greater risk than those able to draw water directly from the government reticulation scheme.

2.6.1 Livestock water consumption

Trends of sheep numbers in each of the local government authorities for Zones 2 and 5 since 1991 are shown in Figure 7 with sheep numbers in 1997 and 2001 shown in Table 7. Variations in sheep numbers can reflect changes in available water and fodder within the district associated with below-average rainfall years. The average stocking rates for each shire can be calculated from the livestock numbers and the percentage of farmland pasture.
Table 7. Total sheep numbers for 1997 and the change since 1991 along with sheep numbers in 1997 and 2001 (data courtesy of Curtis and Coss 1999; Source: ABS Census 1997, 2001)

<table>
<thead>
<tr>
<th>Local Government Authority</th>
<th>Change 1991-1997</th>
<th>Total sheep numbers including lambs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1997</td>
</tr>
<tr>
<td>Dalwallinu</td>
<td>Down 25%</td>
<td>310,000</td>
</tr>
<tr>
<td>Koorda</td>
<td>Down 30%</td>
<td>130,000</td>
</tr>
<tr>
<td>Mt Marshall</td>
<td>Down 27%</td>
<td>210,000</td>
</tr>
<tr>
<td>Mukinbudin</td>
<td>Down 34%</td>
<td>130,000</td>
</tr>
<tr>
<td>Westonia</td>
<td>Down 26%</td>
<td>100,000</td>
</tr>
<tr>
<td>Yilgarn</td>
<td>Down 12%</td>
<td>300,000</td>
</tr>
<tr>
<td>Narembeen</td>
<td>Down 11%</td>
<td>340,000</td>
</tr>
<tr>
<td>Bruce Rock</td>
<td>Down 26%</td>
<td>230,000</td>
</tr>
<tr>
<td>Kellerberrin</td>
<td>Down 23%</td>
<td>140,000</td>
</tr>
<tr>
<td>Merredin</td>
<td>Down 24%</td>
<td>200,000</td>
</tr>
<tr>
<td>Nungarin</td>
<td>Down 32%</td>
<td>60,000</td>
</tr>
<tr>
<td>Trayning</td>
<td>Down 23%</td>
<td>90,000</td>
</tr>
</tbody>
</table>

The basic livestock water consumption rate for each shire is given in Table 8. The requirements are given for both annual (kL/yr) and daily consumption rates (L/day). Peak factors are based on the driest months (January-February) and the annual DSE minimum is based on a 2 L/day requirement. The 2-litre minimum was imposed to account for hand-feeding during winter because of lack of pasture in a dry year. The drinking rates were derived from:

\[ DR = 0.19T - 2.88 \]

where DR is the drinking rate (L/day) and T is the mean daily maximum temperature (°C). Although the minimum consumption rate (of 2 L/DSE/day) is above average in most years, the design criteria must consider the worst case scenario.

Table 8. Total livestock consumption rates for Farm Water Plan Zones 2 and 5

<table>
<thead>
<tr>
<th>Location</th>
<th>Livestock water consumption kL/100 DSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bencubbin</td>
<td>11.5</td>
</tr>
<tr>
<td>Merredin</td>
<td>11.0</td>
</tr>
<tr>
<td>Mukinbudin</td>
<td>11.8</td>
</tr>
<tr>
<td>Narembeen</td>
<td>10.9</td>
</tr>
<tr>
<td>Southern Cross</td>
<td>11.6</td>
</tr>
<tr>
<td>Goodlands</td>
<td>12.2</td>
</tr>
<tr>
<td>Wialki</td>
<td>11.8</td>
</tr>
</tbody>
</table>

(Conversion of livestock to dry sheep equivalents or DSE: cattle x10, pigs x2, intensive piggery x15)
2.6.2 Crop spraying requirements

The crop spraying requirements each year vary according to the distribution of crop/pasture on each farm within each shire. Requirements are based on the number of applications per year (usually three): The rate of water mixed with the pesticide (35-50 L/ha) is multiplied by the area of land sprayed (hectares) each year. Figure 8 shows the variation in cropped area for shires in Zone 2 and 5. The quality of water used for spraying varies depending on the pesticide.

Figure 8. Variation in total cropped area excluding pastures and grasses (ha) from 1980 to 1997 and 2001 (Source: Australian Bureau of Statistics).

2.6.3 Domestic water consumption

Domestic water covers all amenities including showers, toilet, laundry and kitchen and roughly 150 L/day per person is required. The most efficient way to collect high quality water is to harvest rainwater from the roofs of buildings into storage tanks. The amount of water that can be harvested is dependent on the available roof area and storage tank size. Other sources such as groundwater (bores, soaks, wells) and dams can be used for laundry, toilet flushing and gardens. Domestic water constitutes less than 15% of that used in agricultural areas, but is generally the last water resource to be optimised.

Table 9. Average proportions of domestic water, based on data from 1985 survey of Perth water use

<table>
<thead>
<tr>
<th>Water use</th>
<th>%</th>
<th>Appliance usage</th>
<th>Litres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>10</td>
<td>Dishwasher per load</td>
<td>28-50</td>
</tr>
<tr>
<td>Showers and baths</td>
<td>40</td>
<td>Shower per minute</td>
<td>8-24</td>
</tr>
<tr>
<td>Laundry</td>
<td>20</td>
<td>Washing machine per load</td>
<td>64-70</td>
</tr>
<tr>
<td>Toilet flushing</td>
<td>30</td>
<td>Full flush</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Half flush</td>
<td>6</td>
</tr>
</tbody>
</table>
3. Agricultural water supply areas

Susie Murphy White and Peter Lacey

Agricultural water supplies and surface water management strategies have been developed for five water supply areas. The areas have similar climate, vegetation associations, land systems (land surfaces), slope, hydrological characteristics and position in the landscape.

The biophysical datasets used to define water supply areas were: soil type, landscape units, geology, native vegetation and existing water resource infrastructure. Hydrologic characteristics were interpreted and grouped into units that formed the basis for the water supply areas. A significant limiting factor for the development of water supplies was the depth to watertable and the amount of salt stored in the soil profile.

Soil type and vegetation patterns have a similar distribution patterns throughout the catchments in the region. The landscape units used to define water supply areas are shown in Figure 9. Landscape position and soil properties that influence catchment run-off and ease of establishing storage structures influence hydrologic characteristics and risks associated with water supply development.

![Figure 9. Landscape position and Water Supply Areas (adapted from Bettenay & Hingston 1961)](image)

A further refinement in the definition of Water Supply Areas was achieved through interpretation of combined spatial datasets, to produce a 1:250,000 scale map (Figure 10). Similar units from the soil-landscape systems of the Bencubbin (Grealish and Wagnon 1995) and Southern Cross-Hyden areas (Frahmand 1996), the land surfaces of the Kellerberrin region (McArthur 1992) and the soil associations from the Merredin area (Bettenay and Hingston 1961) were grouped to form the water supply areas. The process of defining areas gave prime consideration to soil type, the position in the landscape, landform and significant hydrological features.
The success rate of developing groundwater, dams and catchments was interpreted following assessment of 217 Farm Water Supply reports and local knowledge. Table 10 indicates the type of water supply development and likely success rate for each water supply area. A low success rate indicates high risk of failure where failure is defined as the inability to establish a supply that meets the demand for water in nine out of 10 years. A high success rate indicates a low risk of failure and in most cases a reliable water supply is achievable.

Table 10. Success rates of establishment in water supply areas

<table>
<thead>
<tr>
<th>Water supply area</th>
<th>Groundwater</th>
<th>Dams</th>
<th>Catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regional</td>
<td>Perched aquifer</td>
<td>Clay</td>
</tr>
<tr>
<td>Tamma</td>
<td>medium</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Rock</td>
<td>high</td>
<td>low</td>
<td>medium</td>
</tr>
<tr>
<td>Mallee</td>
<td>low</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Salmon Gum</td>
<td>low</td>
<td>low</td>
<td>medium</td>
</tr>
<tr>
<td>Morrel</td>
<td>low</td>
<td>medium</td>
<td>low</td>
</tr>
</tbody>
</table>
3.1 Tamma: Area 1

The Tamma Water Supply Area occurs on gently undulating plains and rises in the uplands of catchments. This land encompasses large areas of interfluve that may include small valleys with minor channels. Slopes are very gently inclined (1 to 3 per cent) with low relief (less than 30 metres). The unit is dominated by heath and native shrubland. The area was named after the dominant vegetation, tamma (*Allocasuarina campestris*). Soil textures at the surface are predominantly loamy sands. The regional groundwater level is generally 12 to 44 m below ground. Numerous perched water tables with limited to moderate storage have developed. Estimated annual recharge is between 0 and 24 mm (McConnell 1996).

Plate 2. Dominant species is tamma (*Allocasuarina campestris*)

3.1.1 Soil and water conservation issues

Tamma Water Supply Areas are highly susceptible to wind and water erosion. Paddock rilling and sheet erosion are common where paddocks are heavily stocked. Multiple watering points should be provided to allow even grazing pressure over entire paddocks. Grazing pressure should be reduced where possible to minimise the potential for erosion. Contour working lines and grade banks can be used to manage surface water run-off and where possible grade banks can feed water into dams or grassed waterways. The severity of wind erosion can be reduced by maintaining vegetative cover and keeping soil disturbance to a minimum.

Tamma is considered to be a high recharge area and is well suited to alley farming and growing perennial pastures such as lucerne. Grade banks should have trees planted below them to use any water that seeps through, and prevent development of sandplain seeps and salt scalds.

The Norpa and Cunderdin soils consist of deep yellow sandplain. Sheet and rill erosion can be a problem where run-on spills over the sandplain from the upper slopes. Grade banks or contour working may prevent further erosion downslope on these soils. Roaded catchments perform well, whereas natural farmland catchments produce limited run-off. In general, the soils are unsuitable for clay dams, but siliceous hardpan sites may exist.

Ulva soils consist of gravelly sand to 1.5 m deep. Natural farm catchments are not successful, however, improved catchments succeed where sufficient clay exists. New farm dam sites should be test bored to determine whether the subsoil contains the appropriate dam construction material and to ascertain the hardness of materials. Overburden should be pushed out 5 m from the final inside batter.
Holleton soils consist of the acid sands commonly known as the wodjil sandplain. This is prone to sheet erosion due to limited pasture and crop growth caused by soil acidity. Construction of grade banks and contour working can reduce run-off and thereby minimise erosion. Improved catchments for dams can increase run-off (water harvesting) satisfactorily but natural catchments provide little run-off. Clay dams are unsuitable on this soil. However, siliceous hardpan dam sites may exist. This soil may contain perched water aquifers suitable for developing groundwater supplies.

3.1.2 Best management practice

Groundwater

Productive bores have been established in regional aquifers at points in valleys and depressions in the landscape. Bores are generally reliable when successfully located. However, finding a suitable site can be difficult. Test drilling with a small rig is often worthwhile to ascertain whether or not a suitable supply exists, as a number of test holes can usually be drilled for the price of one production bore.

Perched aquifers are common within the Tamma Water Supply Area. Bore water quality is generally suitable for livestock with it often having an electrical conductivity of less than 1,500 mS/m. Localised expressions of shallow groundwater can be observed in soaks and sandplain seeps. Some perched aquifers can be identified in areas where crops stay green or lupins die due to soil salinity and waterlogged root systems.

A thorough assessment of perched aquifers is important before constructing a supply. To determine whether the supply will be suitable:

- The aquifer should have at least 3 metres of water above the impervious layer
- It should be on a slope not in a basin formed by the impervious layer
- It should have a suitable area of catchment
- If a salt scald exists it should be located at least 50 metres above the scald

A bore may be suitable in broken rock and coarse gravel, whereas a well would be better in sand. Drainpipe may be laid with a backhoe in some cases to increase the available draw on a supply. However, it should be noted that these supplies are often unsustainable. Trees should be established downslope from seepage areas to prevent recharge.

Dams

Although small pockets of clay occur in these soils, dams are generally not recommended on account of low to moderate clay content in sandy soils.

Siliceous hardpans and silcretes can be used to construct hardpan dams (Frith 1985). Soft subsoil materials tend to become permeable and leak. Soils that are discoloured dark brown or red often indicate water movement through the matrix. If soil materials are too hard and excavation is not possible without the aid of explosives, dam construction becomes very expensive. However, many siliceous hardpans and silcrete materials can be broken up and mixed with excavated soils to create dams with low leakage rates. Hardpan dam sites are usually associated with grey, yellow or white soils that have a gritty texture. Clays associated with hardpan dams tend to have very low plasticity compared to soils used to construct traditional clay dams.

Catchment

Farmland catchments generally have high infiltration rates and provide little run-off to dams in the Tamma Water Supply Area. Run-off generally occurs after intense thunderstorms or
very heavy winter rains. Farmland catchments in the Tamma Water Supply Area generate insufficient run-off for a reliable water supply.

Engineered or improved catchments provide a reliable source of run-off during lower intensity rainfall events and with greater frequency than farmland catchments. Improved catchments include farm tracks, roads, compacted areas around sheds and houses, flat compacted catchments and roaded catchments. Improved catchments are considered necessary to increase the reliability of dams. The effectiveness of roaded catchments depends on the clay content of the soil, the slope (preferably 1 to 1.5 per cent) and the construction techniques employed.

3.2 Rock: Area 2

Rock Water Supply Areas include granitic rock outcrops and the soils formed from weathered granite or granite colluvium. This area is associated with the upper pediment and along undulating to rolling low hills. Rock outcrops generally have low relief and occur on gently to moderately inclined slopes. The dominant vegetation is York gum (*Eucalyptus loxophleba*), jam (*Acacia acuminata*) bushland and rock sheoak (*Allocasuarina huegeliana*) (Beard 1979a,b, 1980a,b). The soils include shallow sands, grey sandy duplexes and sandy loams. The depth to watertable and the estimated recharge have not been determined. Rock Water Supply Areas generate large amounts of run-off that can cause erosion and gully formation downslope.

3.2.1 Soil and water conservation issues

Rock outcrops distribute large amounts of run-off onto the soils below, which can result in the formation of gullies due to erosion. Stabilised creeks or waterways and grade banks to prevent erosion are required. This water supply area is a good source of natural and improved catchment for harvesting rainfall into dams to promote reliable surface water supplies. However, dam sites in areas associated with white gums tend not to hold water, and on the whole, dam sites do not have sufficient depth due to shallow rock. Pockets of clay can be found and the weathered granite materials may be suitable for dam construction. Good quality but limited localised groundwater supplies are often located near granite outcrops. The areas below rock catchments are high recharge zones, with many soils around the rocks highly permeable; therefore, it is recommended that trees be planted to reduce recharge and stabilise the soil profile.

3.2.2 Best management practice

*Groundwater*

Some of the best groundwater supplies occur in the Rock Water Supply Area, particularly around granite outcrops. The main visual indicators for locating favourable sites are faults or fractures in rocks, and eroded gullies or drainage lines that lead away from the outcrops. Most successful bore sites are located at the base of granite outcrops where the water sits on the bedrock overlain by weathered granite and saprolite grits. Some of these aquifers have limited storage and may dry up after an initial pumping period. However, most bores used for livestock supplies are reliable. Although most successful bore sites are associated with granite outcrops, a number of good supplies are located in breakaway country derived from the remains of the old dissected landscape after weathering.

Aquifers are commonly close to the surface, although they are generally regional (water sitting on granite bedrock close to the surface) and should be treated in a similar way to perched aquifers. Water is often found at the surface in the form of soaks or seeps and may be covered by reeds or lush vegetation that take advantage of ready access to water.
Dams

Clay dam sites are difficult to locate, however, with adequate subsoil investigation, can be found often in pockets around rocks. These pockets often support larger shrubs and trees such as the mallee vegetation. Granite rock throughout this region is comparatively soft and in many cases a large bulldozer can rip and excavate material without blasting. When blasting is required, the cost of construction can easily double or triple.

Catchment

Natural rock catchments are very efficient water harvesting structures although run-off usually needs to be directed to storage structures through lined channels or piped inlets. Improved catchments are often not required as rock catchments generate run-off from low intensity rainfall events. Where improved catchments are required, it is important to note that soils tend to be erodible and the slope of the roads should be less than 1 per cent and the length should be less than 200 metres.

Plate 3. Berrinbooding rock catchment

3.3 Mallee: Area 3

The Mallee Water Supply Area is associated with the pediment slope that is situated between the valley and the uplands and occurs on undulating rises to low hills. It has low relief and gently inclined slopes. Native vegetation consists of mallee and some mixed woodland. Soil types vary from sandy salmon gum soils to duplex soils. The groundwater level ranges from 5 to 20 m below ground and the estimated recharge from 2 to 14 mm/yr. Salts stored in the soil profile were estimated at 600 tonnes of chloride per hectare (McConnell 1996).
3.3.1 Soil and water conservation issues

The Booraan and Korbel soils are often described as sandy salmon gum soils. They have hardsetting surfaces with a sandy loam topsoil, greyish to reddish brown. Construction of improved catchments and the use of natural catchments have been successful. Farm dams generally succeed if preceded by test drilling for saline groundwater, and suitable depth of clay. Deep sandy subsoils are generally unsuitable.

The Collgar soil type is a duplex of loamy sand over sandy clay and occurs on lower slopes adjoining the valley floor. The soil is susceptible to water erosion and waterlogging. Reverse bank seepage Interceptors can be effective to manage waterlogging and water erosion. Improved and natural catchments perform well due to the clay content of the subsoil. Farm dams are generally successful and this area is considered to be the best location to look for clay dam sites.

3.3.2 Best management practice

Groundwater

Good water supplies are difficult to locate in the regional aquifer as the groundwater is generally saline. The best supplies tend to be found where Rock or Tamma Water Supply Areas adjoin Mallee areas or where drainage lines descend from these areas. Perched aquifers with livestock quality water are rare in the Mallee Water Supply Areas.

Dams

Clay dams are the most common type in this area and although good pockets of clay exist, the subsoils tend to be highly permeable. Test drilling of sites is often overlooked but it is very important, to prevent wastage on shallow rock, highly permeable subsoils or saline watertables. Hardpan dams are much less common but the potential for a hardpan site should be investigated if a suitable clay site cannot be found.
Catchment

Natural farmland catchments on the Mallee Water Supply Area can provide good run-off, however with moves to minimum tillage, stubble retention and high water use systems, farmland run-off is reduced and improved catchments are often necessary. Improved catchments work well in the Mallee Water Supply Area, but erosion will occur where slopes are too steep. The slopes of roads on roaded catchments should be between 0.5 and 1.5 per cent.

3.4 Salmon Gum: Area 4

Salmon Gum Water Supply Areas are located in upper valleys where the landscape consists of undulating plains that form broad valley floors with extremely low relief and very gently inclined slopes (Grealish and Wagnon 1995). These areas usually lie adjacent to salt lake drainage systems. The native vegetation cover is salmon gum \((Eucalyptus salmonophloia)\) and gimlet \((Eucalyptus salubris)\) woodland with a shrub understorey. The soil varies between coarse textured grey soil and red-brown sandy loams. Hydrologic characteristics include groundwater 0 to 17 m below ground and an estimated recharge of 2 to 12 mm/yr.
3.4.1 Soil and water conservation issues

The Merredin soil type is commonly called a salmon gum-gimlet or heavy soil, and has sandy clay loam to loam topsoil that maybe hardsetting. Farm dams can be constructed successfully in this soil as long as no saline watertable is encountered. The white kaolin subsoils are avoided north of Bruce Rock, as these have a tendency to leak or remain permeable after dam construction. Natural and improved catchments are successful if required slope to run the water is available. W-drains may be necessary in areas where water ponds on the surface due to the presence of gilgais.

The Beacon soil type is a red soil with a hardsetting surface and red loam topsoil (Grealish and Wagnon 1995). Dams constructed in this soil suffer from leakage problems particularly where calcium carbonate nodules are present.

The Mollerin soil type is commonly called a red-brown hardpan soil, and has a reddish brown, loamy sand topsoil that is hardsetting on the surface. Waterlogging can be a problem owing to the presence of shallow hardpan.

The Neening soil can be called a grey clay valley soil, with well-structured, greyish brown, sandy clay loam topsoil. Groundwater supplies are not generally associated with it.

All of the soils are found in the valleys leading into the salt lakes and at times can have large volumes of water flowing over them, resulting in large scale gully erosion. Grade banks and grassed waterways are two methods used to prevent erosion. Salmon Gum Water Supply Areas are not considered to be high recharge areas although moderate recharge can occur.

3.4.2 Best management practice

Groundwater

Bores in regional aquifers have an extremely low success rate when trying to locate groundwater with electrical conductivity less than 1,000 mS/m. Normally groundwater has electrical conductivity in excess of 2,000 mS/m. Perched aquifers are uncommon in these soils but where they do exist, groundwater is invariably very saline.

Dams

As with the Mallee Water Supply Area, clay dam sites can be found in the Salmon Gum Water Supply Area. However, there are a few problems. Many soils have a very porous subsurface layer that is often identified with a silky smooth texture, white or pink subsurface clays and soils with excessive calcium nodulation. All potential dam sites should be test drilled prior to construction. Hardpan dam sites are very rare.
Natural farmland catchments vary from good to poor and landholders generally rely on creeks to fill their dams. The regularity of flow is often overestimated and suitable improved catchment should be constructed if streamflow frequency cannot be reliably determined. Improved catchments work well on these soils but it may be difficult to find a catchment site with sufficient slope. Building an improved catchment requires due consideration of both catchment and dam sites.

3.5 Morrel: Area 5

The Morrel Water Supply Area is located on the lower slopes of valley floors and has very little relief with virtually level slopes that often fringe salt lake drainage systems. The native vegetation includes morrel (*Eucalyptus longicornis*) and salmon gum (*Eucalyptus salmonophloia*) woodland with a saltbush understorey (Beard 1979a,b, 1980a,b). The major soil types are alkaline red loams to clay. Hydrologic characteristics include very high watertables within 5 m of the surface, and an estimated recharge of 2-7 mm/yr. The soil profile contains around 1,200 tonnes of chloride per hectare (McConnell 1996) and high levels of calcium carbonate.
3.5.1 Soil and water conservation issues

The Hines Hill and Nangeenan soil types have similar topsoil characteristics. The Nangeenan soil type has well structured subsoil, although both can be called morrel soils. The soil profiles have fluffy greyish brown, sandy loam topsoil, often formed from wind-blown material adjacent to salt lakes. Farm dams in this area do not hold water and natural and improved catchments do not perform well.

The soils are highly susceptible to erosion, particularly wind erosion. The area often has poor vegetative cover and is commonly eroded by winds generated by summer and early winter storms. Working the soil should be kept to a minimum and alley farming with the aim of using trees to prevent wind erosion is suggested. Morrel soils are considered to be low recharge sites, although moderate recharge may occur.

3.5.2 Best management practice

*Groundwater*

Regional aquifers are highly saline and unsuitable for water supplies. Perched aquifers are very difficult to locate, however, some success has been achieved by drilling in dunes around the salt lakes. These dunes were blown from ancient lakes and may be difficult to locate.

*Dams*

Clay dam sites are difficult to locate in the Morrel Water Supply Area. Difficulties are encountered with high saline watertables and the permeable nature of the subsoils. Test drilling and in-hole water tests are very important in these areas. Success rates for suitable sites are very low. Hardpan materials are generally not suitable for the construction of hardpan dams.

*Catchment*

Natural farmland catchments generally have very low slopes and do not provide sufficient run-off to dams. Improved catchments generally perform poorly and may suffer from erosion.
4. Farm water resources development

Adequate water supplies are an essential component of any farming enterprise. The development and provision of reliable supplies should meet present and future needs, ensure productivity, enable returns to be maximised and living standards improved. Water supplies which meet these needs must be carefully designed to ensure the required outcomes are met.

Water supply planning initiatives should be implemented in conjunction with soil conservation design to maximise integration.

4.1 On-farm water supply planning

By employing an integrated planning approach, it is possible to develop reliable on-farm water supplies in most agricultural areas. An *ad hoc* approach to water supply development can result in inadequate or ineffective water supplies. A planned approach allows design of a system to cater for needs and conditions efficiently and effectively. A basic approach to farm water supply planning is:

- Calculate enterprise water requirements, both quantity and quality
- Assess the available options to achieve those requirements
- Determine the technical and economic feasibility of these options
- Develop a farm water plan
- Design and construct the appropriate system
- Monitor the success of the system.

By assessing the on-farm water resource development potential, areas of the farm may be targeted as key sites for water supplies. This may involve accessing groundwater or the design of water harvesting structures to store or collect rainfall. Once the water requirements have been calculated, the next step is to assess existing water supply structure to determine the capacity and reliability. By assessing the reliability of existing structures and calculating the shortfall, a water plan can be developed that will include refurbishment of existing supplies and construction of new infrastructure and distribution systems.

4.1.1 The concept of reliability

Reliability is a term used to express how often the user of a system is prepared to allow that system to fail. The nature and timing of the system failure is determined by equating the costs associated with developing and maintaining that system to a level of reliability and to the cost associated with system failure.

Reliability is normally expressed as a percentage or as an expected failure frequency. For example, a system with reliability of 50% has a 50% chance of success in any given year; it also has a 50% chance of failure in any year, and may be expressed as a one in two failure rate (i.e. 1:2 years). However, a system with 90% reliability has a 90% chance of success in any given year or a 10% chance of failure, and may be expressed as a one in 10 failure rate (i.e. 1:10 years). Note that it is possible for a system with 90% reliability rating to fail more than one year in succession (when we get two or three, one in 10 year events in succession), but in the long-term it will average out to once every 10 years.

The level of reliability required by a system often depends on the impact that system failure has on those affected and the cost associated with failure. Some may be prepared to accept
a failure of a system once every five years where others will only accept failure once every 20 years. The more reliable a system becomes, the greater the rigour in design and construction, and consequently the more expensive it is to install and maintain. Consideration is also being given to the type of agricultural enterprise with the importance of water resource reliability increasing as the degree of agricultural intensification rises. In an intensive system, such as cattle feedlots or piggeries, where water consumption is high and forward contracts or other business agreements exist, access to a secure reliable water supply is paramount.

Farm water supplies for broadacre enterprises are designed with a nominal reliability rating of at least 90%. However, many on-farm water supplies are only rated as 50 to 70% reliable, resulting in a heavy draw on the public scheme, during relatively low rainfall years. Carting water generates high costs to the public to maintain the supply and a high cost to the farmer in terms of both dollars and time. A 20% improvement in the reliability of on-farm water supplies will generate a net gain to the public and the farming community, releasing public funds to create and maintain community and emergency off-farm water supplies.

4.1.2 Assessing the enterprise requirements
There are three main water demands on the farm: domestic (house and garden); crop spraying; and livestock. Water quality requirements vary with demand type and may range from fresh to brackish depending on use. Systems used to capture, store and convey water within the farm vary according to use, volume required, rainfall and farm location.

4.2 Best management practice in water supply design
The Department of Agriculture and Food can provide information on the design, construction and maintenance of water supplies through Farmnotes, bulletins and ‘freeware’ software to assist farmers in assessing the reliability of their water supplies. Water Management for Dryland Agriculture kits are available in both hardcopy and on CD from regional offices or by emailing farmwaterinfo@agric.wa.gov.au.

4.3 Farm Water Grants Scheme
The Farm Water Grants Scheme (FWGS) is available to commercial broadacre farming businesses to plan and invest in improvements to farm water supplies in zones not connected to a government piped water supply. The aim is to improve the reliability of on-farm water supplies, thereby minimising the dependence on off-farm supplies during low rainfall years. This alleviates problems arising from water deficiency declarations as well as decreasing the length of the deficiency declarations. Financial incentives are available for domestic, livestock and crop-spray requirements.

Under the scheme:
- Priority is given to applicants with the greatest calculated water supply deficiency. A point system was initiated to determine an applicant’s priority based on locality and the degree of water deficiency
- A maximum grant of $20,000 is available for expenditure on water supply works
- Farmers can claim 70% of expenditure on approved water supply improvement work up to the maximum grant approved
- Applicants have 18 months from the date of approval to complete the water supply works indicated in the application
- Grants are not awarded retrospectively
Farms connected to a piped water scheme are not eligible for the grant, however, the program provides subsidies for these farms as a contribution towards the cost of preparing a farm water supply plan by an accredited farm water planner.

The effectiveness of the FWGS is measured by the extent to which eligible farmers with serious water deficiencies utilise the scheme to improve their on-farm water supplies. Some advantages of the scheme are:

- No recurrent cost to government
- Environmentally sound
- Offers a more economical alternative to costly pipeline extensions.

4.4 Community Farm Water Program

The Community Water Supply Program provides funding for community water supply improvements in districts receiving less than 600 mm average annual rainfall. The objective is to identify communities in most need of better water supplies and to encourage local government to submit water supply development proposals which result in rural communities being better prepared for years of low rainfall.

Categories of work considered for funding include:

1. **Construction of Strategic Agricultural Area Supplies:** A strategic water source is identified within the Farm Water Plan as an essential part of the emergency network available to provide emergency water supplies for livestock in times of a declared water deficiency.

2. **Refurbishment of Agricultural Area Water Supplies:** Many of the existing strategic Agricultural Area water supplies are in a poor state of repair, and local governments with a desire to refurbish such supplies may be eligible.

3. **Construction of Community Water Supplies:** Local sites with good water supply potential, either on-farm or off-farm, may be suitable for development as community water supplies.

4. **Extension of Water Corporation Piped Water Supplies:** Funding may be available for the construction of pipeline extensions to towns, strategic community water points and farms, from the Water Corporation’s supply schemes.

Where improvements result in a significant direct benefit to individuals, a minimum contribution of one-third of the construction costs is required from the community. The remainder may be met by the program. Community groups and local government are invited to submit proposals to address identified water deficiencies for towns and farmlands. Proposals must be endorsed by the relevant local government authority. The Rural Water Advisory Committee has responsibility for assessing any proposals received, prior to making recommendations for funding to the Minister.
4.5 Community Water Supply Program

Some examples of rural water strategy projects initiated from the late 1980s to the late 1990s in the area are provided in Table 11.

Table 11. Examples of rural water strategy projects (OWR annual reports, Waterline December 1998, Farm Water Strategy Group 1994)

<table>
<thead>
<tr>
<th>Project title</th>
<th>Shire</th>
<th>Total expenditure ($)</th>
<th>Year started</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koonkoobing to Arnolds Etn</td>
<td>Mt Marshall – Mukinbudin</td>
<td>1,366,735</td>
<td>1988/89</td>
</tr>
<tr>
<td>Beacon Rock to N Cleary Etn</td>
<td>Mt Marshall</td>
<td>688,973</td>
<td>1988/89</td>
</tr>
<tr>
<td>Mt Walker – Augment supply</td>
<td>Yilgarn</td>
<td>342,755</td>
<td>1989/90</td>
</tr>
<tr>
<td>Warralakin – G&amp;AWS</td>
<td>Westonia</td>
<td>429,162</td>
<td>1989/90</td>
</tr>
<tr>
<td>Cleary Rock – G&amp;AWS Etn</td>
<td>Koorda</td>
<td>823,591</td>
<td>1990/91</td>
</tr>
<tr>
<td>Westonia – Secure supply</td>
<td>Westonia</td>
<td>57,576</td>
<td>1992/93</td>
</tr>
<tr>
<td>Mt Hampton dam</td>
<td>Yilgarn</td>
<td>275,938</td>
<td>1992/93</td>
</tr>
<tr>
<td>North Gabbin</td>
<td>Mt Marshall</td>
<td>246,000</td>
<td>1995/96</td>
</tr>
<tr>
<td>Petrudor</td>
<td>Dalwallinu Wongan-Ballidu</td>
<td>996,000</td>
<td>1995/96</td>
</tr>
<tr>
<td>Snake Soak</td>
<td>Mt Marshall</td>
<td>43,000</td>
<td>1997/98</td>
</tr>
<tr>
<td>Mt Collier</td>
<td>Koorda</td>
<td>227,000</td>
<td>1997/98</td>
</tr>
<tr>
<td>Berringbooding Pipeline</td>
<td>Mukinbudin</td>
<td>167,000</td>
<td>1998/99</td>
</tr>
<tr>
<td>Chown Tank Road Pipeline</td>
<td>Koorda</td>
<td>80,000</td>
<td>1998/99</td>
</tr>
<tr>
<td>Muntadgin Town Water Supply</td>
<td>Merredin</td>
<td>240,000</td>
<td>1998/99</td>
</tr>
<tr>
<td>Dalwallinu Town Dam</td>
<td>Dalwallinu Town Dam</td>
<td>40,000</td>
<td>1998/99</td>
</tr>
</tbody>
</table>
5. Water resources research: Needs and opportunities

5.1 Community issues and attitudes

The community issues for the North-eastern and Eastern Wheatbelt can be neatly divided into Zones 2 and 5 when assessing the issues and attitudes associated with on-farm water supplies. Zone 5, which is not connected to the scheme, is reliant upon the development of surface and groundwater supplies for livestock and spray water, and roof rain tank systems for domestic and spray water. Landholders in this zone experience water shortages in dry years or when run-off is reduced.

Zone 2 (reticulated scheme area) is reliant upon the scheme to provide almost 100 per cent of livestock, spray and domestic water. Although there are some on-farm water supply developments in the area, landholders are not eligible for the Farm Water Grants Scheme and, therefore, promoting further development of on-farm water supplies is difficult. As of 2006, the program provides subsidies for these farms as a contribution towards the cost of preparing a farm water supply plan by an accredited farm water planner.

5.2 Low adoption survey

An investigation into low adoption of on-farm water supply systems in water deficient areas of WA was conducted during 1991. About 100 landholders were surveyed from Zone 5. A series of questions was asked regarding the dam and roadded catchment in Plate 9. The majority of farmers’ attitudes towards roadded catchments revealed that the roadded catchment pictured is:

- Cheap and easy to maintain
- Practical on most soil types
- Fencing is necessary
- The dam and catchment are reliable in a drought year
- The roadded catchment will run water in light rains.

Plate 9. A standard design of farm water supply for 1000 sheep in the north-eastern wheatbelt

Most landholders surveyed believed that it was not cheaper to cart water, agist sheep or to sell livestock during dry years than install this type of catchment to improve water supply reliability.
The majority of landholders surveyed also believed that:

- A roller was essential for construction
- Contractors need independent supervision when constructing roaded catchments
- Contractors are available for this type of construction (Plate 9)
- Advice on catchment design is available.

5.3 Focus catchment surveys

Through the focus catchment process, a survey of the inventory of each landholder was completed. The focus catchments surveyed in 1997 were Yarragin TangPlang (Trayning LGA), Yeelanna (Trayning) and Wallatin Creek (Kellerberrin) in Zone 2 and all were connected to the comprehensive scheme. In 1998 the Bodallin Focus Catchment Group (Yilgarn LGA) completed the same survey. The Bodallin catchment has 53% of landholders in Zone 2 (connected to the comprehensive scheme) and 47% of the landholders in Zone 5.

The demand for livestock quality water for sheep accounts for 60% in Wallatin Creek, 50% Yarragin TangPlang, 45% Yeelanna and 52% of the demand in Bodallin. Garden water was the next biggest drain on low quality water.

Groundwater supplies in these catchments included soaks and bores. The number of groundwater supplies developed in each catchment was Wallatin Creek (16), Yarragin TangPlang (6), Yeelanna (3) and Bodallin (8). Dam sizes for all catchments show great variation, with the average size for Wallatin Creek, Yarragin TangPlang and Bodallin catchments between 1000 and 2499 cubic metres. In Yeelanna the average dam size was 2500-3999 cubic metres. Approximately 20% of the dams from each catchment leaked. Wallatin Creek had 13% of the dams with salinities too high for ewes and lambs, while Yarragin TangPlang had 5% and Yeelanna 2%. Most dams relied on farmland catchment to provide run-off and fill their dams. Yeelanna had 29% of dams with roaded catchments, Bodallin 10%, Wallatin Creek 8% and Yarragin TangPlang 5%.

Maintenance of dams and catchments is of low priority for these catchments. Most landholders maintained their dams when required with little expenditure on maintenance. Catchment maintenance also occurred when required with less than $1000 spent.

5.4 Community water day

A community water day was held in Bencubbin in February 1998 as a forum for exchange of information and to establish issues and needs relating to water supply and agricultural water management. A total of 43 landholders, agency, shire representatives and community landcare coordinators attended. The following issues were raised:

- Incentives were needed for self-sufficiency to reduce the reliance on the scheme
- Funding for landholders on the scheme to establish sustainable water supplies
- Integration of soil and water conservation
- Exploration for groundwater
- Acceptance of water harvesting techniques
- Research into decreasing evaporation
- Increased public awareness.
6. Conclusion

This project has identified natural resource constraints and opportunities as they apply to farm water supply development. An interpretation of suitable types of water supply and the associated risk of failure were developed for each of five farm water supply areas. A high success rate for water supply establishment can be achieved if water supply areas are identified and then options considered prior to applying design criteria for proposed improvements.

Water supply areas are directly relevant to the farm scale but are also valuable when applied at catchment or regional scale to resolve issues such as the assessment of public water supply needs in areas with a history of water deficiency.

Catchment planning processes that encourage landholders and planners to interpret natural resource attributes against the performance of existing systems will assist the development of the local knowledge needed for effective farm water management. The mapping products and landform interpretations developed in this project provide useful concepts for planning groundwater and surface water supplies in the north-eastern wheatbelt.
7. References


Coles NA, Hauck EJ (1996 but still in draft). Farm water supply planning information and statistics. Agriculture WA.


