# Hydrogeology and Groundwater Resources of the Wilga Basin, Western Australia

Water Resource Management Division

DEPARTMENT OF WATER

HYDROGEOLOGY RECORD SERIES

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# Summary

The Wilga Basin, located 30 km south east of Collie, contains at least 300 metres of Permian sediments. The sequence consists of variably thick sandstone units interbedded with coal seams, mudstone, conglomerate and shale. The sediments are structurally preserved in two small fault-bounded grabens (Wilga Basin West and Wilga Basin East) situated on the Yilgarn Craton, and form a multi-layered, largely confined aquifer system. Groundwater stored in Wilga Basin West is brackish, and in Wilga Basin East is generally fresher. The watertable in both sub-basins is a subdued reflection of the topography and becomes shallower at the downstream reaches of the Collie River South Branch.

Since 1996, groundwater levels appear to have declined by an average of 0.38 m in Wilga Basin West. Water level decline has been greater in Wilga Basin East. Field evidence suggests there is currently no groundwater discharge to streams in Wilga Basin East. The likely cause of reduction is a persistent declining rainfall trend since the late 1960s; however, the reason for the greater water level decline in Wilga Basin East is unclear.

The lack of groundwater discharge to the surface and the continued declining rainfall suggests a reduction in groundwater storage in the Wilga Basin under the current low-rainfall climate regime. There are however large stored groundwater resources in the Wilga Basin of up to 490 GL that are regionally significant.

Potential development of the resource would be restricted by saline and acidic groundwater in Wilga Basin West. Greater opportunities for development are present in Wilga Basin East where there is a greater depth to the watertable and the groundwater is fresher and of near neutral pH. The groundwater resources could be developed for human and livestock consumption, irrigation and general industrial needs. Further work is required to determine whether there are any ecosystems dependent on the groundwater resources.

# 1 Introduction

## *1.1 Overview*

The Wilga Basin is located in the southwest of Western Australia, 14 km south of the Collie Basin and 30 km south of the township of Collie. The basin is lenticular in shape and comprises two sub-basins, Wilga Basin West and Wilga Basin East, which cover an aggregate area of about 31 $km^2$ (Figure 1).

The basin is filled with Permian sediments, including coal seams and sandstones, that have been structurally preserved in fault-bounded grabens on the Archaean Yilgarn Craton, similar to the Collie Basin. Extensive investigation has identified significant groundwater resources in the Collie Basin (Varma, 2002). The purpose of the investigation was to determine if similar groundwater resources exist in the Wilga Basin, which is in an area of poor groundwater resources.

This report describes the general basin stratigraphy and hydrogeological characteristics of the Wilga Basin. These descriptions are based on the results of three groundwater investigation programs instigated by the Geological Survey of Western Australia in 1993 and completed by the Water and Rivers Commission in 1996. Extensive and detailed borehole logs, produced by Western Collieries Ltd., were also used to supplement the existing data and previous reports on the Wilga Basin were reviewed.

## *1.2 Previous Work*

The earliest work in the Wilga Basin dates from 1918 when Michael O'Grady first discovered coal in a mineshaft. Subsequently, exploration bores were drilled by the Government to determine the stratigraphy and extent of the coal deposits in the basin (Blatchford, 1918; Maitland, 1920; Wilson, 1922), primarily focusing on Wilga Basin West. Numerous coal seams were intersected and analysed, with the initial results encouraging further exploration (Wilson, 1922; Montgomery, 1925).

The basic geometry and structure of the Wilga Basin were determined by Western Aluminium NL (1960) by a gravity survey of the region and a single deep bore. From 1968, Geotechnics (Aust) Pty Ltd partially cored several drill holes and obtained some geophysical data. A series of bores and geophysical surveys were carried out in Wilga Basin East by CRA Exploration in 1983 and 1984 (Ellis, 1984; 1985). Western Collieries derived general basin geometry based on these surveys. From 1982 to 1985 Western Collieries Ltd. undertook an extensive drilling program in both sub-basins generating geophysical logs and detailed stratigraphic logs correlating coal seams, which contributed to the current understanding of the Wilga Basin stratigraphy (Le Blanc Smith, 1990b). The regional geology is summarised in the Collie 1:250 000 geological sheet and explanatory notes (Wilde and Walker, 1982).

Laws (1992) synthesised all of the existing geological and hydrogeological data on the Wilga Basin and concluded that the geology of the basin suggested sufficient potential groundwater resources to warrant further investigations. Based on Laws' review, a three-phase drilling program was proposed in 1994, to better quantify the groundwater resource potential of the basin. The drilling program was completed in 1996 and the results are outlined in this report. Wilga Basin is also included in the exploratory notes of the Hydrogeology of the Collie 1:250 000 Sheet (Rutherford, 2000).

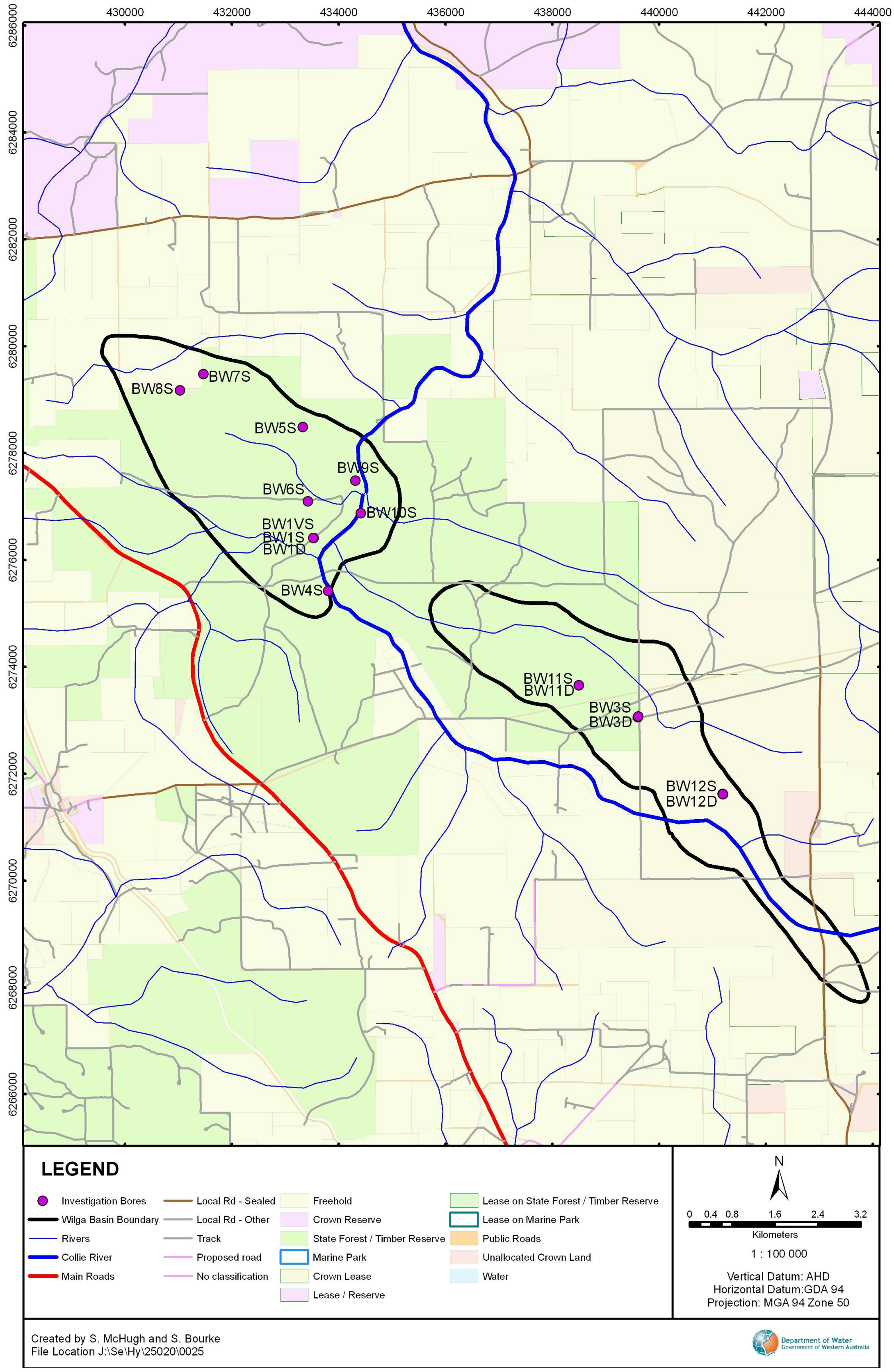


Figure 1. Location map of the Wilga Basin and investigation bores

# 2 Regional Setting

## *2.1 Climate*

The southwest of Western Australia experiences a temperate, Mediterranean-type climate. Summer is dry and hot with mean daily maximum temperatures recorded at Collie (the closest monitoring station to Wilga Basin) about 30°C during December to February. Winter is mild with the majority of annual rainfall, around 80%, received between May and September (Varma, 2002). The long term average annual rainfall for Collie is 944 mm (Bureau of Meteorology, 2004). It is likely that average annual rainfall for the Wilga area is about 700 mm in Wilga East and about 800 mm in Wilga West. Mean evaporation rate for the Wilga area is about 1500 mm/yr, which exceeds rainfall in most months of the year.

## *2.2 Physiography*

The study area lies on the Yilgarn Craton is the Darling Plateau, a weakly dissected undulating surface with an average elevation of about 300 metres. The Wilga Basin lies within the Collie River Catchment and is drained by the Collie River South Branch (Figure 1). Tributaries of Collie River South drain from the southeastern corner of the Wilga Basin East, where surface elevations are highest (270 m AHD), to the northwest. Drainage then flows northeast, bisecting Wilga Basin West. The salinity of streams in Wilga Basin West measured in September 2004 were 50 mg/L TDS.

## *2.3 Regional Geology*

The Wilga Basin lies within the Yilgarn Craton, which is composed of Archaean granites, migmatites and gneiss (Figure 2) that outcrop within and around the basin (Wilde and Walker, 1982). The Wilga Basin comprises an interbedded sedimentary sequence that is discussed in more detail in Chapter 4. The low-lying areas are comprised of alluvial and colluvial deposits of variable thickness.

## *2.4 Vegetation*

The majority of the Wilga area is covered by native vegetation; however, the most northerly area of Wilga Basin West has been cleared for farming. The southern area of Wilga Basin East is leased Crown land that has been partially cleared. Vegetation assemblages in the region have been mapped by Heddle *et al.* (1980) and Mattiske (1998) including the Wilga, Pindalup, Stockton and Collie complexes.

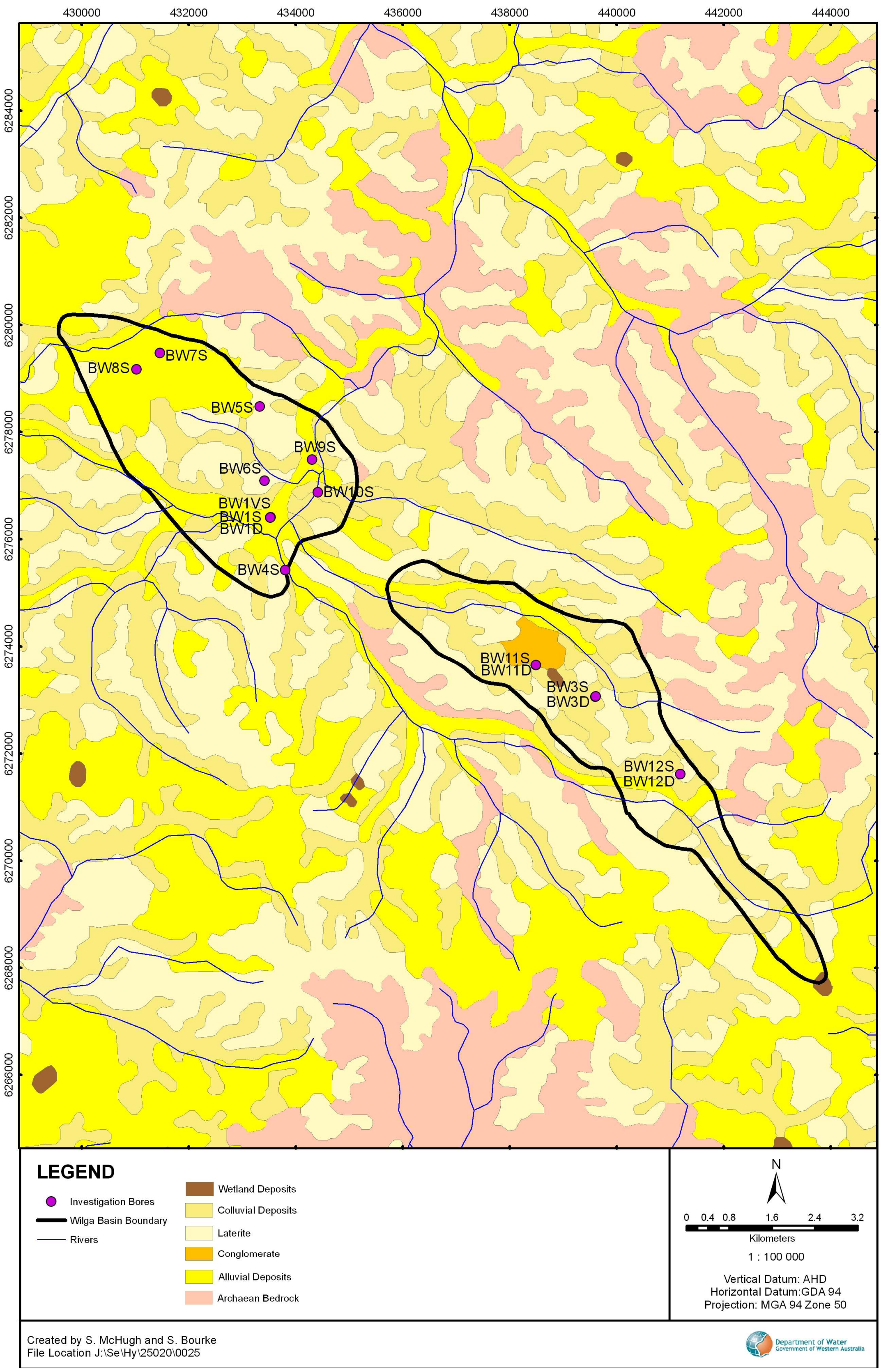


Figure 2. Surface geology of the Wilga Basin region.

# 3 Investigation Program

Drilling to evaluate the groundwater resources of Wilga Basin, based on the recommendations of Laws (1992) was carried out in three phases. The initial drilling program commenced in 1993/94 in Wilga Basin West with the drilling of one deep observation bore BoyupWilga (BW)1 (Prangley, 1994a; Waterhouse, 1994). In May 1995, a single deep observation bore was drilled in Wilga Basin East (BW3D) to test for presence of low salinity water, and seven shallow bores were drilled in Wilga Basin West (BW4 to BW10) to determine the depth to the water table and water quality in the shallow aquifer (Prangley, 1994b, 1996a). The final stage of the drilling program was to assess groundwater salinity in both the shallow and deep aquifers of Wilga Basin East (Prangley, 1996b) with two shallow (BW11S and BW12S) and two deep bores (BW11D and BW12D) drilled. BW2 was drilled in the Boyup Basin (Yesertener, 1996).

The first and second stages of the drilling were carried out by Yellowstone Holdings using a Gardner Denver 1400 mud rotary drill rig. The third stage of the drilling was carried out by Collie Drilling using a Gardner Denver 1000 rig.

Full details of the monitoring bores are provided in bore completion reports (Prangley, 1994a, 1996a, 1996c). Monitoring bores in Wilga Basin West were levelled to Australian Height Datum by licensed surveyors Harley, Hedderwick and Webber Pty Ltd in December 1995, and Wilga Basin East monitoring bores were levelled by K.J. Moir in May 1996. Chemical analysis of water samples were carried out by Analabs Pty Ltd, and Australian Environmental Laboratories. A summary of the drilling data, including bore location, bore depth, screened intervals, ground elevations and depth to water are shown in Table 1 and includes water table measurements taken in September 2004.

Table 1 Summary of Wilga Basin Bore Data

| Bore No | SWRIS Ref | Easting | Northing | Bore Depth (m) | Ground level (m) | TOC (m AHD) | Screen section (m) | SWL (mbtc) | SWL (m AHD) | Date measured | Airlift yield (m3/day) | SWL (mAHD) 23/09/04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BW1VS | 60919152 | 433536 | 6276412 | 24 | 227.13 | 228.41 | 15-21 | 9.08 | 219.33 | 06/05/94 | 75 | 219.15 |
| BW1S | 60919151 | 433535 | 6276409 | 49 | 227.1 | 227.97 | 42-48 | 8.8 | 219.17 | 28/04/94 | 32 | 219.07 |
| BW1D | 60919150 | 433531 | 6276409 | 199 | 227.16 | 228.35 | 173-179 | 11.33 | 217.02 | 27/04/94 | 43 | 216.68 |
| BW3S | 60919156 | 439606 | 6273060 | 39 | 256.82 | 257.76 | 33-39 | 15.15 | 242.61 | 10/04/95 | 65 | 240.72 |
| BW3D | 60919155 | 439611 | 6273069 | 227 | 256.82 | 257.72 | 193-199 | 18.29 | 239.43 | 10/04/95 | 54 | 238.61 |
| BW4S | 60919157 | 433810 | 6275423 | 52 | 227.55 | 228.55 | 44-50 | 8.48 | 220.07 | 10/04/95 | 27 | - |
| BW5S | 60919158 | 433333 | 6278486 | 53 | 234.52 | 235.37 | 44-50 | 15.1 | 220.27 | 10/04/95 | 32 | 219.8 |
| BW6S | 60919159 | 433427 | 6277096 | 61 | 232.03 | 232.85 | 53.5-59.5 | 13.07 | 219.78 | 10/04/95 | 80 | 219.36 |
| BW7S | 60919160 | 431472 | 6279480 | 61 | 241.7 | 242.55 | 54-60 | 21.72 | 220.83 | 10/04/95 | - | 220.49 |
| BW8S | 60919161 | 431033 | 6279176 | 63 | 240.37 | 241.41 | 57-63 | 20.43 | 220.98 | 10/04/95 | 104 | 220.62 |
| BW9S | 60919162 | 434314 | 6277485 | 67 | 219.45 | 220.61 | 42.5-54.5 | 6.09 | 214.52 | 10/04/95 | 118 | - |
| BW10S | 60919163 | 434419 | 6276875 | 61 | 217.69 | 218.95 | 37-49 | 4.57 | 214.38 | 10/04/95 | 6 | 213.57 |
| BW11S | 61230401 | 438499 | 6273655 | 38.5 | 261.48 | 262.08 | 32.5-38.5 | 21.01 | 241.07 | 06/05/96 | 1.4 | 239.11 |
| BW11D | 61230400 | 438498 | 6273658 | 114 | 261.48 | 262.1 | 102-108 | 21.7 | 240.4 | 06/05/96 | 37 | 239.16 |
| BW12S | 61230403 | 441194 | 6271622 | 42 | 261.84 | 262.6 | 36-42 | 16.58 | 246.02 | 20/05/96 | 86 | 244.63 |
| BW12D | 61230402 | 441196 | 6271619 | 263 | 261.8 | 262.57 | 232-238 | 15.5 | 247.07 | 20/05/96 | 58 | 246.48 |

# 4 Geology

## 4.1 Overview

The structure and stratigraphy of the Wilga Basin is based largely on the extensive deep drilling and gravity surveys conducted by Western Collieries Ltd (since there are few deep bores drilled under the current program), and the data review by Laws (1992).

The geometry of the two sub-basins has been derived from the modelling of gravity survey data (Western Colleries, 1990). The basin is a wedge-shaped, northwest trending, graben-like structure, bounded and cross-cut by north and northwest trending faults (Western Collieries, 1990). The maximum depth of Wilga Basin West is estimated to range between 300 and 500 m deep (Le Blanc Smith, 1990a; Western Collieries, 1990) shallowing towards the southeast. Boreholes in the deeper section of the basin did not intersect basement, therefore it can be inferred that greater than 330 m of Permian sediments are preserved in Wilga Basin West. Strata dip to the west at about 8 degrees (Le Blanc Smith, 1990b). Modelling of gravity data and borehole data shows the geometry of Wilga Basin East to be similar to Wilga Basin West, with an estimated maximum depth of least 260 m based on a Western Collieries bore that penetrated granite basement at 260 m.

The basin is bounded by Archaean granitoid rocks, which outcrop at the margins. Basement in Wilga Basin East also includes some mafic intrusives and metamorphic rocks. The stratigraphic succession of Wilga Basin (Table 3) appears to be broadly similar to the Collie Basin. Generalised cross-sections of each sub-basin are shown in Figures 3 and 4. There is no seismic data for the Wilga Basin region and the faults shown are illustrative only.

Table 2 Generalised Stratigraphy of the Wilga Basin

| Age | Unit | Thickness (m) | Lithology |
|---|---|---|---|
| Cainozoic | Residual deposits | 0 - 5 | Sandy laterite on ridges, lateritic clay in depressions, ferruginous sand/gravel |
| Permian | Weathered Permian sediments | 0 - 30 | Clay/sandy clay with sand interbeds, commonly iron stained. |
| Permian | Coal Measures | Up to 330 | Sandstone with dark grey mudstone, shale, silt and coal seam interbeds |
| | Moorhead Formation | 0 - 20 | Dark grey mudstone |
| | Shotts Formation | ? | Tillite |
| Archaean | Basement | N/a | Granite |

## 4.2 Archaean

The Archaean basement underlying and surrounding the Wilga Basin consists primarily of granite. Partially weathered granite was intersected in BW11D (Wilga Basin East) at a depth of 110 m. No Wilga Basin West boreholes in the current drilling program penetrated basement. However, a Western Collieries hole (W36) intersected Archaean basement at a depth of 162 m. Mafic intrusives and metamorphic rocks were also intercepted by Western Collieries in hole WRC3 at 218 m in Wilga Basin East.

### *4.3 Permian*

A largely continuous tillite unit of unknown thickness unconformably overlies Archaean basement in Wilga Basin West. Western Collieries drillhole W31 in Wilga West intersected tillite at 256 m. The tillite does not appear continuous in Wilga Basin East, as Western Collieries drillhole WRC3 did not penetrate tillite before encountering basement. Bore WCH1 penetrated tillite at a depth of 258 metres. The tillite is assumed analogous to the Shotts Formation of the Collie Basin (Laws, 1992; Varma, 2002).

A dark grey mudstone unit devoid of coal seams overlies the tillite unit in Wilga Basin West. The estimated thickness of the unit is approximately 23.5 m based on Western Collieries drillhole W31 that penetrated through the mudstone and into granite basement. Le Blanc Smith (1990a) correlated the mudstone unit to the Moorhead Formation of the Collie Basin. The mudstone unit appears discontinuous in Wilga Basin East. Borehole BW11D and Western Collieries drillhole WRC3 both penetrated through to Archaean basement but did not intercept mudstone. Although, observation bore BW3D and bore DDH1 in the northern region of the sub-basin penetrated mudstone.

A multi-layered sequence of sandstone, coal seams, mudstone, conglomerate and shale conformably overlies the mudstone unit in Wilga Basin West and the tillite unit in Wilga Basin East. The deeper part of this sequence is mainly sandstone interbedded with claystone, conglomerate and shale. The thickness of the basal sandstone unit appears variable in Wilga Basin East with up to 65 m in the southwestern part of the basin and thinning towards the southeast. In Wilga Basin West, the basal sandstone is about 65 m thick estimated from the stratigraphy of drillhole W32.

Coal sequences in the Wilga Basin consist of two main groups of coal seams. In Wilga Basin East, a lower 20 m thick sequence of closely spaced coal seams overlies the basal sandstone unit, from approximately 170 to 193 m. The lower coal seam sequence is thicker in Wilga Basin West (50 m thick). These lower coal seams have been correlated with the Ewington Member of the Collie Basin (Laws, 1992; Le Blanc Smith, 1990a). Separating the lower and upper coal seam sequences are sands and sandstone, interbedded with mudstone, conglomerate, shale and carbonaceous shale. The thickness of the interbedded sandstone unit ranges from 110 to 130 m in Wilga Basin East, and from 40 to 130 m in Wilga Basin West.

The Coal Measures are weathered to a depth of up to 35 m in both Wilga West and Wilga East basins. The lithology is consistent with a deeply weathered lateritic profile. The upper 5 m consists of sandy laterite and ferruginous sand on ridges and lateritic clay in depressions. From 5 to 30 m depth is predominantly clay and sandy clay with sand interbeds. The clay is commonly iron-stained near the surface and is whitish cream at depth. Previous reports have correlated this upper part of the sequence with the Cretaceous Nakina Formation of the Collie Basin (Laws, 1992; Le Blanc Smith, 1990a, 1990b).

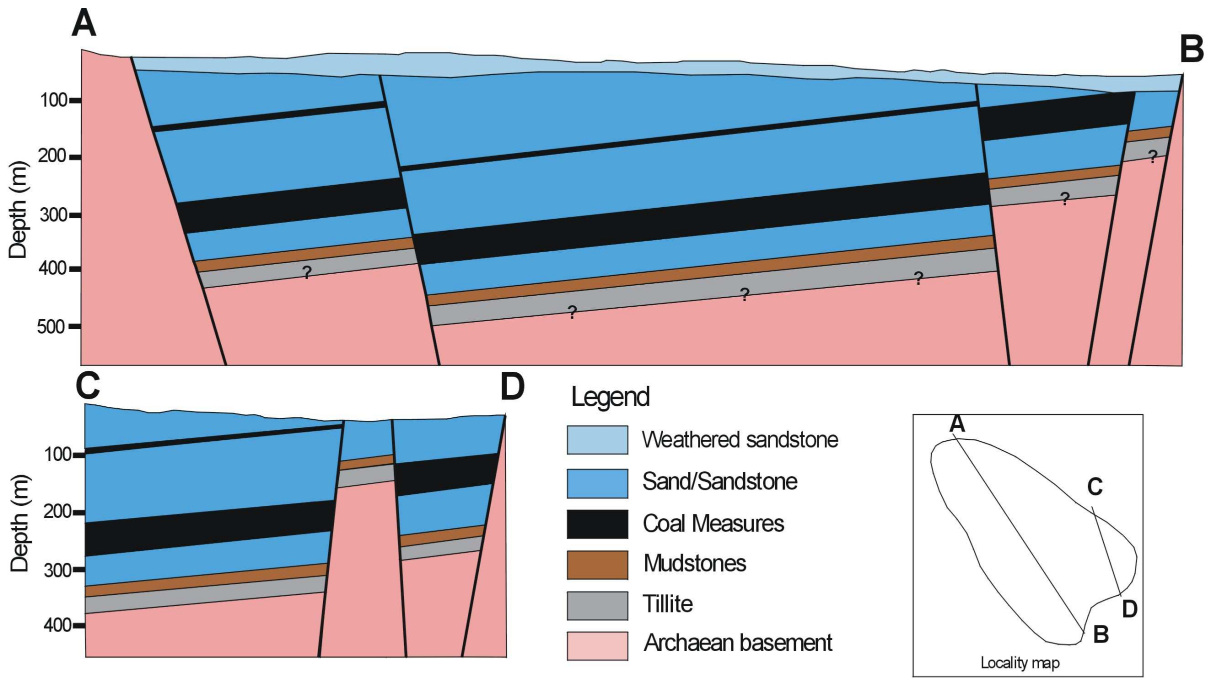


Figure 3. Geological cross-section of Wilga Basin West

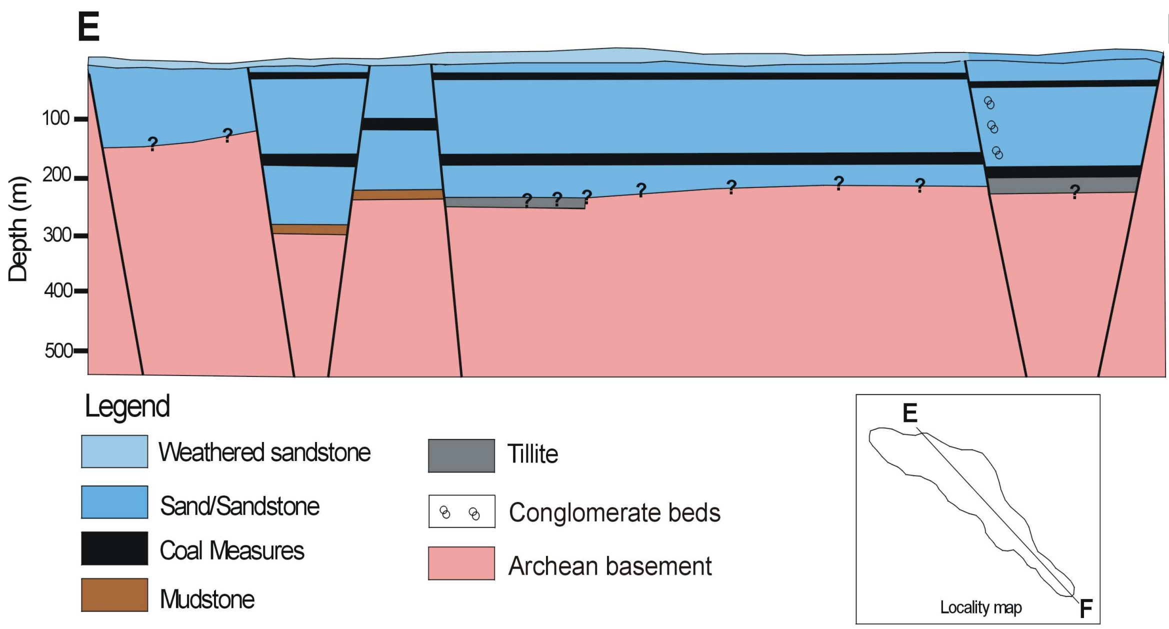


Figure 4. Geological cross-section of Wilga Basin East

# 5 Hydrogeology

## 5.1 Groundwater Occurrence

Groundwater in the Wilga Basin is contained within the sand and sandstone units of the Permian sediments (Figure 5). The sediments form a multi-layered aquifer that is unconfined in some areas of the basin where the surface sediments are sandy (eg. BW1D in Wilga Basin West and BW12 in Wilga Basin East). In the majority of the basin, the aquifer is confined by impermeable or low permeability clay and by coal seams between the deeper sandstone units.

## 5.2 Groundwater Flow System

Watertable contour maps for Wilga Basin West and East, derived from data obtained in May 1994 and April 1995 (Wilga West) and May 1996 (Wilga East) are shown in Figure 6 and 7. The configuration of the watertable in Wilga Basin West is relatively flat across most of the basin. Watertable elevations range from 221 m AHD in the west where ground elevations are highest (250 to 245 m AHD), to 214 m AHD in the eastern region near the main channel of the Collie River South Branch (Figure 6). Groundwater flows in a generally south-eastern direction towards the Collie River South Branch. The steepening of the water table contours suggest that groundwater is possibly discharging into more permeable sediments beneath the river.

The watertable elevation in Wilga Basin East slopes from 246 m AHD in the south east to 241 m AHD in the northwest region of the sub-basin (based on 1994 to 1996 data) and groundwater flow is in this general direction (Figure 7). The limited available data indicates that the potentiometric head distribution at the base of the aquifer is highly variable (Figure 5).

Groundwater recharge is from rainfall and from streams that lie above the water table. Based on the 1994, 1995 and 1996 data, groundwater discharge is likely to occur along the lower reaches of the Collie River South Branch and along the northernmost tributary in Wilga Basin East. However, water table elevations measured in September 2004 showed a regional decline in both sub-basins (Table 1) and field evidence suggested there was no visible groundwater discharge to the northern tributary in Wilga Basin East. The salinity at three sites along the lower reaches of the Collie River South Branch in Wilga Basin West (shown in Figure 5) measured in September 2004 was the same (50 mg/L TDS). This suggests that the groundwater contribution to streamflow is very small in relation to the contribution from rainfall runoff. Although, it is possible that groundwater may be discharging in the subsurface via more permeable sediments beneath the river.

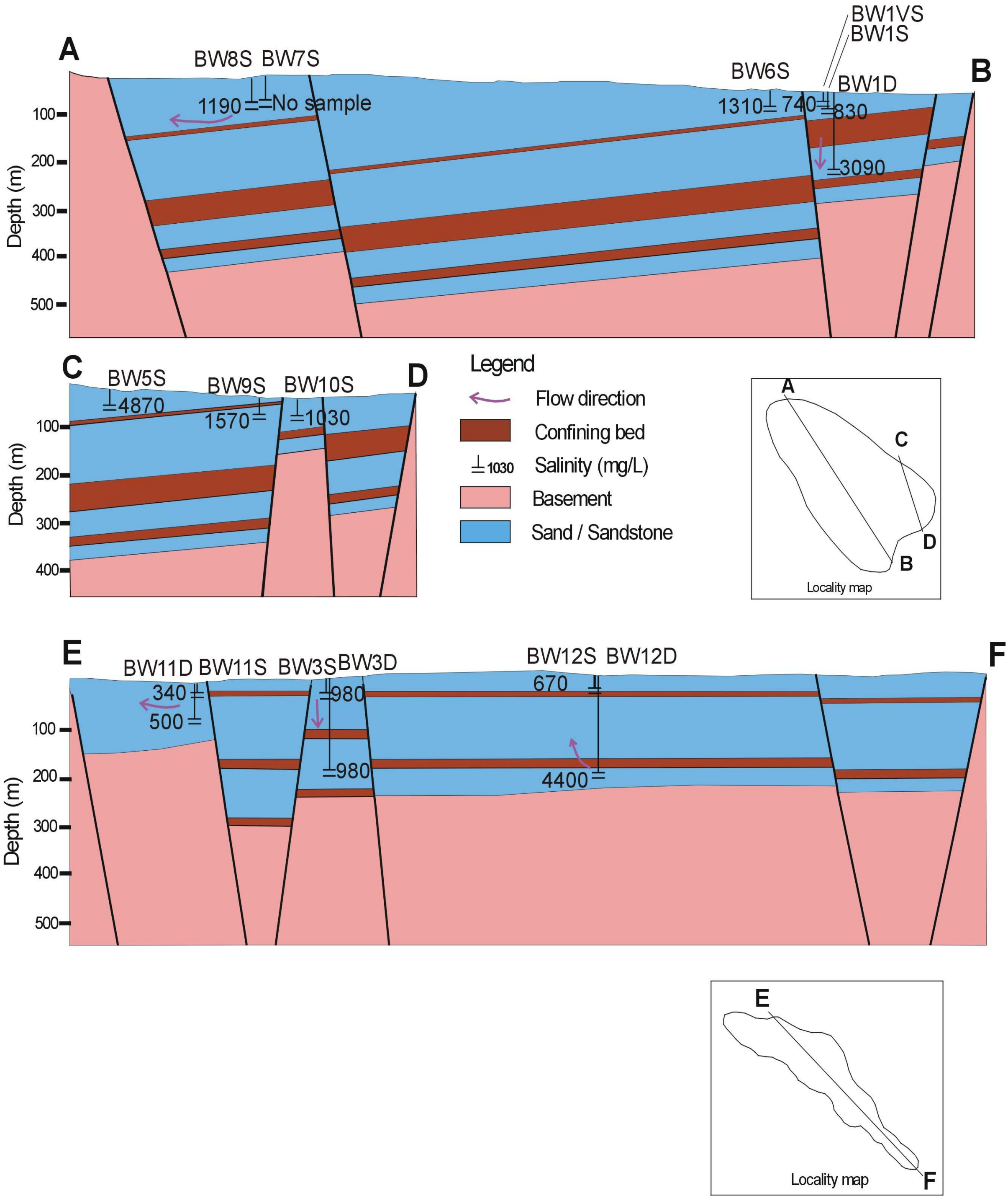


Figure 5. Hydrogeological cross-sections of Wilga Basin West and East

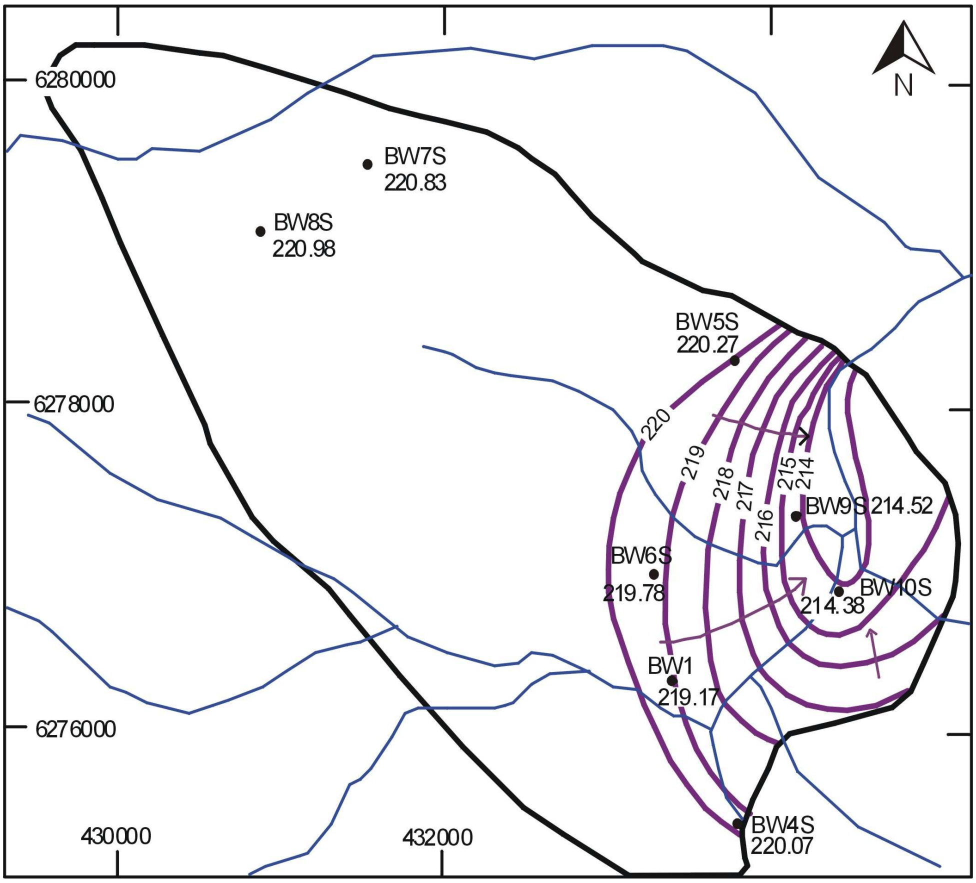


Figure 6. Watertable contours for Wilga Basin West

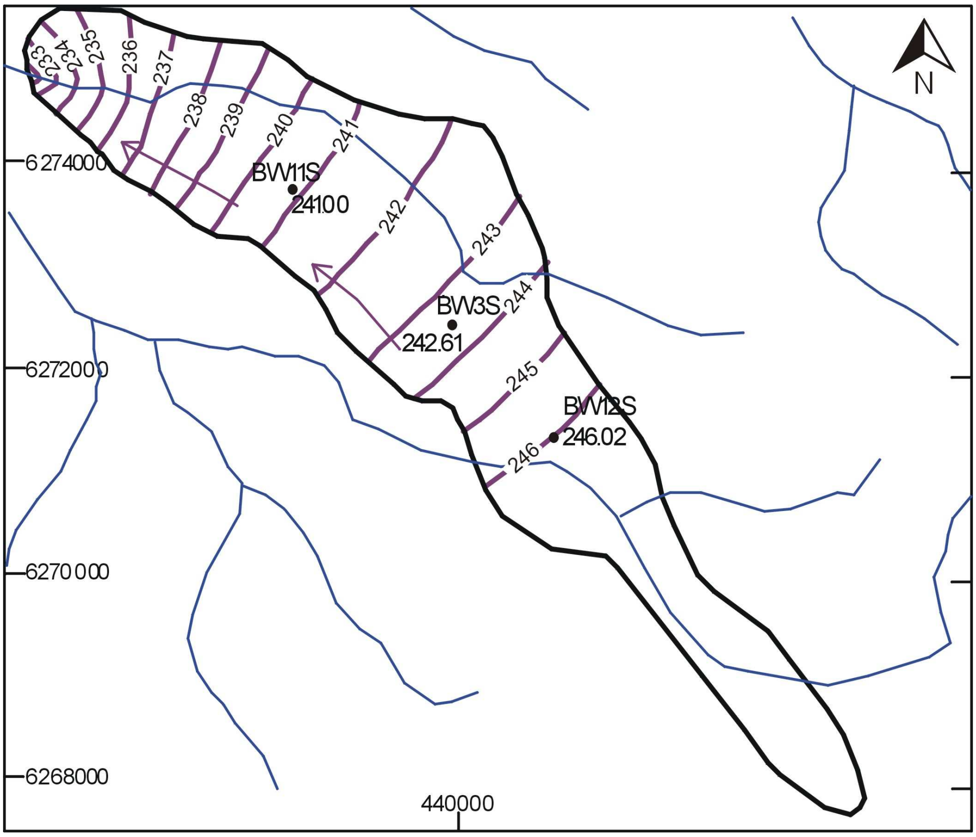


Figure 7. Watertable contours for Wilga Basin East (m AHD)

## *5.3 Groundwater Quality*

Groundwater samples were taken for chemical analyses during the three drilling programs. The concentration of major ions, pH, colour and salinity were determined for each sample. The results of the analyses are summarised in Table 3.

### *5.3.1 Major ions*

As shown on the piper trilinear diagram (Figure 8), most groundwater in the Wilga Basin is generally of the sodium chloride type indicating that the source of groundwater is rainfall. The deeper bores (BW1D, BW3D, BW11D and BW12D) have a slightly higher concentration of calcium. There are no other discernible trends in groundwater quality.

### *5.3.2 Salinity*

The groundwater salinity in the Wilga Basin West as measured from shallow observation bores ranges from marginal (740 mg/L Total Dissolved Solids, TDS) to saline (4870 mg/L TDS) (Figure 5 and Figure 8). The lowest salinity groundwater is found in the western region of the sub-basin and salinity generally increases in the direction of groundwater flow, due largely to the evaporative concentration of salts where the water table is shallow. The highest salinity was measured in BW5 (4870 mg/L TDS). It is highly likely that groundwater salinity is stratified with increasing salinity with depth.

The salinity measured in the shallow bores in Wilga Basin East is lower than Wilga Basin West and is fresh ranging from 340 mg/L to 980 mg/L TDS. Salinity is higher in the deeper confined aquifer (BW12D) where there is upward flow (4400 mg/L TDS). The salinity in bore BW3D (within the deeper aquifer) is similar to the shallow aquifer (BW3S). Salinity generally decreases in the direction of groundwater flow and with depth. The reasons for the unusual salinity distribution are unclear.

### *5.3.3 pH*

In Wilga Basin West, groundwater pH ranges widely from 2.8 to 10.4. The pH in the Wilga Basin East is generally higher than Wilga West, ranging from 5.2 to 9.9. The more acidic readings are probably related to the oxidation of sulphide minerals. This is the case in the Collie Basin where low pH groundwater is found near underground and open cut mines where carbon and sulphide rich sediments have undergone oxidation (Varma, 2002). The unusually high pH (greater than 9) in some of the bores (BW1VS, BW1S, BW11S and BW11D) may be due to cement contamination during bore construction.

Table 3. Chemical analysis of Wilga Basin groundwater chemistry (mg/L)

| Bore No | pH lab | Colour (TCU) | Electrical Conductivity (µS/cm) | TDS | Total Hard | Total Alk. | Ca | Mg | Na | K | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | $SiO_2$ | B | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BW1VS | 9.8 | <5 | 1400 | 740 | 210 | 62 | 28 | 34 | 198 | 13 | 25 | 25 | 392 | 20 | 1 | 16 | 0.02 | 0.1 |
| BW1S | 10.4 | <5 | 1380 | 830 | 107 | 70 | 33 | 6 | 246 | 14 | 26 | <2 | 370 | 49 | 1 | 78 | 0.02 | 0.4 |
| BW1D | 7.6 | <5 | 5530 | 3090 | 1190 | 147 | 165 | 190 | 690 | 62 | <2 | 179 | 1810 | 71 | 2 | 12 | 0.02 | 0.1 |
| BW3S | 6.9 | <1 | 1600 | 980 | 155 | 18 | 10 | 32 | 245 | 14 | <1 | 22 | 480 | 25 | 3.7 | 11 | <0.1 | <0.1 |
| BW3D | 8.3 | <1 | 1600 | 980 | 235 | 150 | 60 | 21 | 215 | 27 | <1 | 180 | 410 | 39 | 5.6 | 5.8 | <0.1 | 0.1 |
| BW4S | 2.8 | <1 | 3400 | 2050 | 230 | <1 | 17 | 45 | 445 | 14 | <1 | <1 | 920 | 25 | 2 | 9.3 | <0.1 | <0.1 |
| BW5S | 3.3 | <1 | 8100 | 4870 | 1100 | <1 | 27 | 250 | 1230 | 28 | <1 | <1 | 2750 | 165 | 1.3 | 14 | <0.1 | 0.9 |
| BW6S | 5.5 | <1 | 2200 | 1310 | 295 | 2 | 11 | 65 | 270 | 22 | <1 | 3 | 690 | 19 | 0.9 | 9 | <0.1 | <0.1 |
| BW7S | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| BW8S | 3.2 | <1 | 2000 | 1190 | 195 | <1 | 13 | 39 | 250 | 11 | <1 | <1 | 545 | 23 | 0.5 | 10 | <0.1 | 0.1 |
| BW9S | 6.6 | 1 | 2600 | 1570 | 305 | 42 | 51 | 43 | 345 | 26 | <1 | 52 | 785 | 38 | <0.2 | 5.5 | <0.1 | <0.1 |
| BW10S | 7.3 | 1 | 1700 | 1030 | 220 | 40 | 33 | 34 | 225 | 19 | <1 | 49 | 495 | 21 | 5.1 | 6.3 | <0.1 | 0.2 |
| BW11S | 9.2 | 30 | 600 | 340 | 40 | 75 | 28 | 6.1 | 72 | 4.8 | 20 | 45 | 120 | 30 | 0.5 | 8 | 0.17 | <0.1 |
| BW11D | 9.9 | <5 | 940 | 500 | 185 | 50 | 48 | 16 | 130 | 31 | 25 | 10 | 240 | 15 | 0.1 | 14 | 0.13 | <0.1 |
| BW12S | 7 | <5 | 1300 | 670 | 110 | 35 | 12 | 20 | 220 | 2.7 | nil | 45 | 350 | 29 | 0.3 | <0.1 | <0.03 | <0.1 |
| BW12D | 5.2 | <5 | 8000 | 4400 | 1400 | <5 | 120 | 270 | 840 | 50 | nil | 5 | 2500 | 38 | 3.9 | <0.1 | 0.04 | <0.1 |

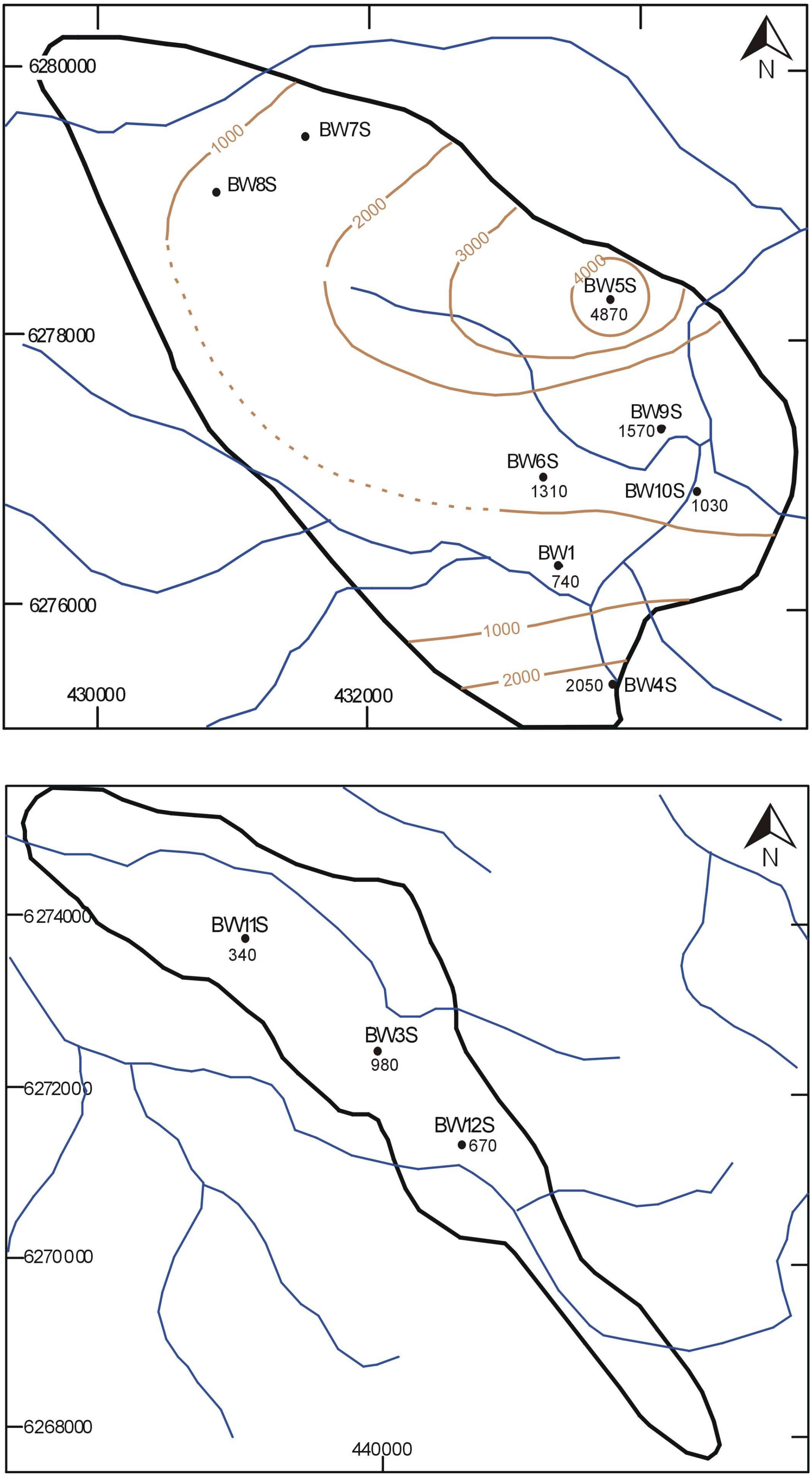


Figure 8. Watertable salinity (mg/L) in Wilga Basin West and Wilga Basin East

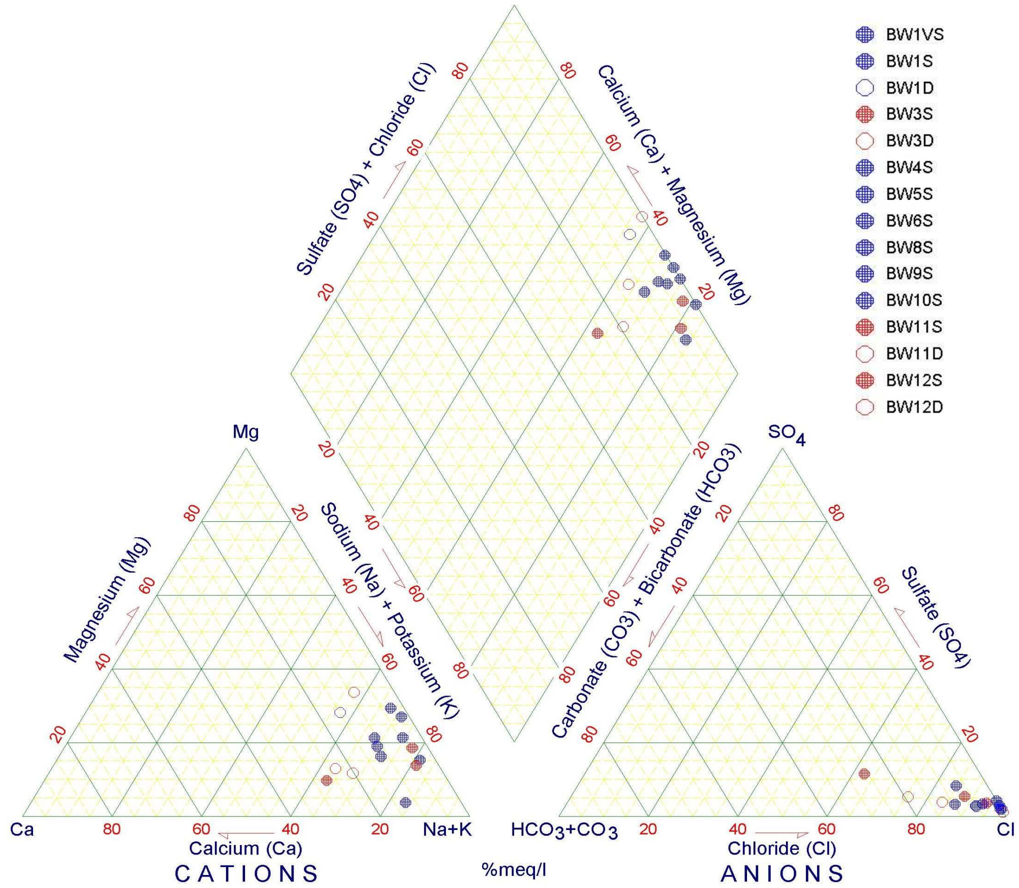


Figure 9. Trilinear diagram of major ion chemistry

## *5.4 Groundwater Resources*

### *5.4.1 Renewable*

An understanding of the renewable groundwater resources in the Wilga Basin can be inferred from the measured changes in groundwater levels from 1994 to 2004 (Tables 4 and 5). Groundwater levels were measured in September 2004 at the end of the winter rainy period. A comparison of these water level measurements with those taken at the end of summer in 1994 to 1996 show that levels in all observation have declined from 1994/96 to 2004. The decline in water levels may be greater by the end of the 2004/2005 summer, as such the change in water level over the ten-year period is probably an underestimation.

Groundwater levels have declined by an average of 0.38 metres in Wilga Basin West over the eight year period. The water level decline since 1996 has been greater in Wilga Basin East with the water table in shallow observation bores declining by about 0.9 metres and in the deeper bores by 1.75 metres. The decline appears to increase in a down-gradient direction towards the discharge area, where there is increased discharge to a permeable drainage feature.

The main cause of water level decline in the Wilga Basin is probably a reduction in rainfall, which is the primary source of groundwater recharge. Figure 10 shows the variation in daily rainfall for the Wilga area as a cumulative deviation from the mean, calculated from interpolated daily rainfall data from 1940 to 2004 (Queensland Department of Natural Resources, 2004). The steady reduction in rainfall from 1967 to the present can be correlated to the regional decline in groundwater levels in the Wilga Basin, as there is no groundwater abstraction or major change in landuse.

Based on 1994 to 1996 water table elevation and derived contours, groundwater probably actively discharged into downstream creek channels. Field observations in 2004 suggest that under the current low rainfall conditions, there is no visible groundwater discharge in Wilga Basin East and apparently very small discharge in Wilga West. Therefore, there is ongoing depletion of groundwater storage.

Table 4 Changes in groundwater levels in Wilga Basin West observation bores

| Bore No. | Potentiometric head (mAHD) 1994 to 1996 | Potentiometric head (mAHD) 2004 | Change (m) |
|---|---|---|---|
| BW1VS | 219.33 | 219.15 | -0.18 |
| BW1S | 219.17 | 219.07 | -0.10 |
| BW1D | 217.02 | 216.68 | -0.34 |
| BW4S | 220.07 | - | - |
| BW5S | 220.27 | 219.80 | -0.47 |
| BW6S | 219.78 | 219.36 | -0.42 |
| BW7S | 220.83 | 220.49 | -0.34 |
| BW8S | 220.98 | 220.62 | -0.36 |
| BW9S | 214.52 | - | - |
| BW10S | 214.38 | 213.57 | -0.81 |

Table 5 Changes in groundwater levels in Wilga Basin East observation bores

| Bore No. | Potentiometric head (mAHD) 1994 to 1996 | Potentiometric head (mAHD) 2004 | Change (m) |
|---|---|---|---|
| BW3S | 242.61 | 240.72 | -1.89 |
| BW3D | 239.43 | 238.61 | -0.82 |
| BW11S | 241.07 | 239.11 | -1.96 |
| BW11D | 240.40 | 239.16 | -1.24 |
| BW12S | 246.02 | 244.63 | -1.39 |
| BW12D | 247.07 | 246.48 | -0.59 |

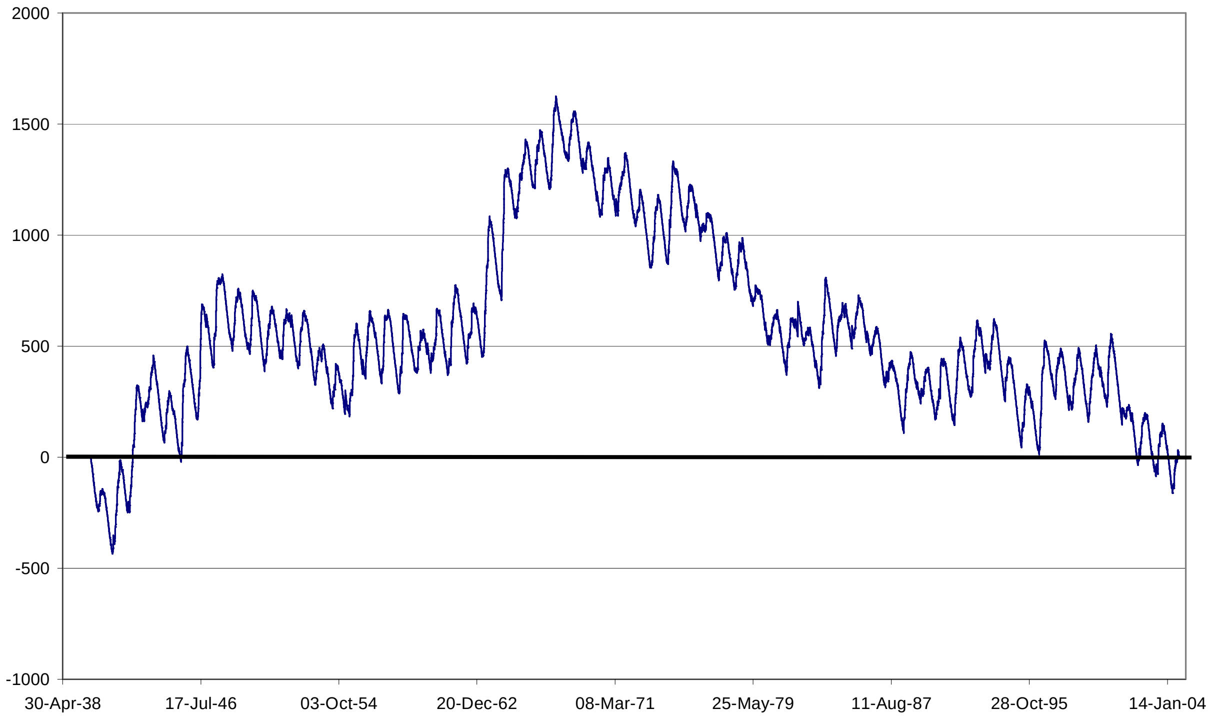


Figure 10. CDFM of daily rainfall for Wilga Basin based on SILO Data Drill (Queensland Department of Natural Resources, 2004).

### *5.4.2 Groundwater Storage*

Groundwater storage can be estimated by multiplying the volume of sandstone aquifer by a specific yield. Varma (2002) adopted a specific yield of 0.1 for the Collie Basin and this is used for the Wilga Basin. The average thickness of sandstone beds in the Wilga Basin West is about 165 m and about 150m in Wilga Basin East. Applying the average specific yield to the area of each sub-basin (Wilga West is about 16 $m^2$ and Wilga East is 15 $m^2$) gives an estimated groundwater storage of 264 GL for Wilga Basin West and 225 GL for Wilga Basin East. Using an average aquifer thickness of 157 m for the whole basin, an aggregate basin area of 31 $km^2$ and a specific yield of 0.1 gives an estimated groundwater storage of about 490 GL. This amount represents about 7% of the groundwater in storage in the Collie Basin (Varma, 2002).

# 6 Groundwater development and management considerations

The Wilga Basin lies in a region of poor groundwater reserves, and as such the stored groundwater in the basin represents a significant groundwater resource. Groundwater could be used for a variety of purposes, including domestic, livestock, irrigation and industrial use.

Groundwater from the shallow aquifer in Wilga Basin West is brackish and acidic, except in the western parts of the sub-basin where it is near neutral. The acidic condition may limit development, as groundwater with pH lower than 5 may be detrimental to livestock and for use in irrigation. Groundwater from the deeper aquifer in Wilga Basin West has neutral pH and is saline in the southern area of the sub-basin, which may be adequate for livestock watering. In the northern parts of Wilga Basin West, groundwater salinity in the deeper aquifer is unknown.

The groundwater resources in the Wilga Basin of greatest potential occur within the shallow aquifer of Wilga Basin East. Groundwater quality is suitable for humans and livestock, for the irrigation of crops and for general industrial use. Groundwater in the deeper aquifers is fresh in the northern half of the sub-basin but is saline in the southern half. The use of groundwater from this region of the basin would restrict crop type for irrigation but groundwater salinity is still appropriate for livestock watering.

It is anticipated that should large-scale groundwater abstraction occur in the Wilga Basin groundwater storage would be gradually depleted. This managed depletion may be acceptable assuming there are no environmental impacts.

Abstraction of groundwater in the Wilga Basin, under the current climate regime, is likely to impact on ecosystems currently dependent on groundwater. Wilga Basin West is predominantly State Forest, comprising a mix of open forest of *Eucalyptus*, *Corymbia* and *Allocasuarina* on gravelly-sandy upland soils and *Eucalyptus* and *Banksia* woodlands associated with the river tributaries. The rooting depth of these vegetation assemblages and depth to the water table are important considerations in determining how sensitive vegetation is to watertable decline and where potential groundwater dependent ecosystems (GDEs) are distributed. The northern area of Wilga Basin West and most of Wilga Basin East are unlikely to support GDEs where the depth to watertable is between 15 and 21 m. The vegetation in these regions would be least sensitive to watertable drawdown due to abstraction.

The presence of acidic groundwater in the shallow aquifer would warrant further investigation if any groundwater production bores are installed. It is possible that acidic groundwater is due to the oxidation of sulphide minerals caused by a decline in the water table. Considering that hydrochemical results were obtained in 1994 to 1996, and that water levels have declined further since that time, more current data may be required to adequately assess water quality, particularly in Wilga Basin West.

# 7 Conclusions

The Wilga Basin contains at least 300 metres of Permian sediments preserved within two small, fault-bounded grabens (Wilga Basins West and East). The Permian sequence comprises variably thick sandstone units interbedded with coal seams, mudstone, conglomerate and shale, which form a multi-layered aquifer system. There are slight differences in basin stratigraphy and hydrogeology between Wilga Basin West and Wilga Basin East.

The Permian sediments in Wilga Basin West have an estimated maximum thickness of over 330 m. Sand and sandstone comprise up to 200 m and the average thickness is about 165 m of the sequence. The sandstone units are separated by two main groups of coal seams: a lower group about 50 m thick and a 10 m thick upper group. Groundwater stored within the sandstone units of Wilga Basin West is brackish, and slightly acidic near the surface owing to oxidation of sulphide-rich sediments.

Wilga Basin East contains a generally thinner sequence of Permian sediments (maximum of 260 m). The total thickness of sand and sandstone stored in the basin is at most 195 m and averages about 150 m. The sandstone units are separated by two relatively thin coal seam groups (a 20 m lower group and <10 m upper group). Near surface groundwater salinity is generally fresher in Wilga Basin East and at depth is highly variable. The controls on the groundwater salinity distribution are not well understood. Groundwater pH is near neutral.

Water levels in the Wilga Basin have declined on average about 0.4 m in Wilga Basin West and between 0.8 and 1.8 m in Wilga Basin East over an 8-year period. Water levels in Wilga Basin East show a greater decline over an eight-year period compared with Wilga West levels, however the reason for the greater decline in Wilga Basin East is unclear. The reduction in water levels is most likely due to the declining trend in rainfall since 1967.

Under the present low rainfall conditions, there is a reduction in groundwater storage in the Wilga Basin. Despite this, there is however significant storage (about 490 x $10^6 m^3$) that is a regionally important groundwater resource with development potential. Limitations to groundwater development include the saline and acidic groundwater and relatively shallow depth of the groundwater in the southern area of Wilga Basin West. The lower salinity, neutral pH and greater depth to the watertable in Wilga Basin East provide the greatest potential for groundwater development.

# 8 References

Blatchford, T., 1918. *The discovery of Coal 5$^{1}/_{2}$ Miles North-east of Wilga Siding on the Donnybrook-Katanning Railway*. Western Australia, Geological Survey, Annual Report, 1918, 12-13.

Bureau of Meteorology, 2004. *Digital average rainfall data for Collie* http://www.bom.gov.au/climate

Ellis, C., 1984. *Annual Report for 1983 on Wilga Coal Mining Leases 70/4643-4654: CRA Exploration Pty Ltd* (unpublished). Western Australia, Geological Survey, S-series Open File, microfiche SWC 2601 (C130).

Ellis, C., 1985. *Annual Report for 1984 on Wilga Coal Mining Leases 70/4643-4654: CRA Exploration Pty Ltd* (unpublished). Western Australia, Geological Survey, S-series Open File, microfiche SWC 2601 (C131).

Heddle, E. M., Loneragan, O. W. and Havel, J. J., 1980. *Vegetation Complexes of the Darling System, Western Australia*. *In*, Atlas of Natural Resources, Darling System, Western Australia, Department of Conservation and Environment.

Laws, A.T., 1992. *Review of Available Data on the Wilga, Boyup and Minor Basins, in Southwest Western Australia, and a proposed assessment program.* Western Australia, Geological Survey, Hydrogeology Report 1992/12.

Le Blanc Smith, G., 1990a. *Wilga and Boyup Basins*. *In*: Geology and Mineral Resources of Western Australia, Western Australia, Geological Survey, Memoir 3, 531-534.

Le Blanc Smith, G., 1990b. *A Review of the Coal Resources in Western Australia*. Western Australia, Geological Survey, Basins and Fossil Fuels Confidential Report, 1990/3.

Maitland, A.G., 1920. *Boring for Coal at Wilga*. Western Australia, Geological Survey, Annual Report, 1920, 10-11.

Montgomery, A., 1925. *The Wilga Coalfield: Western Australia*. Mines Department, Annual Report 1924, Appendix 23, 87-92.

Prangley, C.J., 1994a. *Wilga Basin Drilling Project Bore Completion Report 1994, Sites BW1VS, BW1S and BW1D,* Western Australia, Geological Survey, Hydrogeology Report No. 1994/22.

Prangley, C.J., 1994b. *Wilga Basin Drilling Proposal*. Western Australia, Geological Survey, Hydrogeology Report 1994/51.

Prangley, C.J., 1996a. *Wilga Basin Drilling Project Bore Completion Report, Sites BW3 – BW10*. Western Australia, Geological Survey, Hydrogeology Report 1995/39.
Prangley, C.J., 1996b. *East Wilga Basin Drilling Proposal*. Western Australia, Water and Rivers Commission, Hydrogeology Report 14.

Prangley, C.J., 1996c. *East Wilga Basin Bore Completion Report, Sites BW11 and BW12.* Western Australia, Water and Rivers Commission, Hydrogeology Report 27.

Rutherford, J.L., 2000. *Hydrogeology of the Collie 1:250 000 sheet*: Western Australia, Water and Rivers Commission, Hydrogeological Map Series Explanatory Notes, Report HM7.

Queensland Department of Natural Resources, 2004. *SILO Data Drill for Wilga Basin*.
Varma, S., 2002. *Hydrogeology and Groundwater Resources of the Collie Basin*. Western Australia, Water and Rivers Commission, Hydrogeological Record Series, Report HG 5, 80p.

Waterhouse, J.D., 1994. *Boyup and Wilga Basins Drilling Proposal*. Western Australia, Geological Survey, Hydrogeology Report 1994/7.

Western Aluminium NL, 1960. *Gravity Surveys of Wilga area*: Western Aluminium N.L. (unpublished).

Western Collieries Ltd, 1990. *Partial relinquishment report for exploration licence 70/142 for period ending 12 September 1990*, Report No. 143 (unpublished).

Wilde, S.A., and Walker, I.W., 1982. *Collie, W.A.* Western Australia, Geological Survey, Explanatory Notes, SI/50-06.

Wilson, R.C., 1922. *The Wilga Coalfield*. Western Australia, Geological Survey, Annual Report, 1922, 30-37.

Yesertener, C., 1996. *Boyup Basin Drilling Project*, Western Australia, Water and Rivers Commission, Hydrogeology Report 54.

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