Interpretation of SWAMS 2.0 groundwater modelling results for regional areas of water table decline

October 2005

IPB REPORT No. A4 – 1631
COPY No.:
1 Introduction

Simulation results of the various groundwater pumping scenarios using SWAMS V2.0 groundwater model are presented in this report. Based on results from the three proposed Water Corporation borefield options, it was concluded that the Eastern Split borefield had the least overall impact on surface waterlevels. This borefield was therefore selected as the preferred borefield for the 45 GL South West Yarragadee Water Corporation scheme.

Based on hydrogeological understanding of the southern Perth Basin, the most vulnerable areas for drawdown effects at the watertable resulting from reduced potentiometric heads within the Yarragadee aquifer are identified. The implications of local processes on the actual watertable drawdown compared to those simulated are evaluated, considering the hydrogeology and modelling limitations.

1.1 Locality

The area of the southern Perth Basin is characterised by 3 main topographical units shown on Figure 1.1; Swan Coastal Plain, Blackwood Plateau and Scott Coastal Plain. The coastal plains are typically flat areas gradually sloping to the coast which are subject to winter flooding. Coastal dunes are present adjacent to the coastline, and are extensively developed upon the south-eastern Scott Coastal Plain.

The Blackwood Plateau is an area of dissected elevated terrain situated between the Swan and Scott coastal plains. The greatest elevations are attained in the northern portion of the plateau. An escarpment, known as the Whicher Scarp, marks the northern margin of the plateau, while the southern margin typically slopes gradually into the Scott Coastal Plain. The southern portion of the plateau is cut east-west by the Blackwood River.

1.2 Model limitations

Groundwater models require the simplification of typically complex aquifers and flow systems so that it represents the essential physical hydrogeological features of the system being modelled within the constraints of the model grid and layering. This creates limitations to the model accuracy due to the averaging of aquifer properties over relatively large areas and depths, so that simulated water levels and groundwater flow will also be an average over the parameter zone. Furthermore, the distribution of data is rarely sufficient to fully characterise aquifer units and allow even calibration of the model, creating some degree of uncertainty. Hence, regional scale models provide indicative changes in the water level that need to be assessed for local areas considering parameter uncertainties.

Further model limitations arise from the inability of the groundwater model to incorporate surface hydrology and unsaturated groundwater flow, which need to be indirectly accounted for, typically through recharge and evapotranspiration. Still, the
model will not be able to incorporate the whole of the water cycle, and there will be significant water that is available for recharging groundwater in parts of the system, referred to as rejected recharge, that is not included in the model. These model limitations mean that modelling results can not be taken directly as true representations of the real world, and certain interpretations may be required to properly evaluate the implications of simulated modelling.

With regard to the regional groundwater model SWAMS v.2.0, there are a number of model limitations that are described in the modelling report (Sun, 2005). These limitations include the imperfect understanding and mapping of the regional groundwater aquifer system; and the limitation of MODFLOW (USGS, 2000) in representing the surface flow processes. The lack of surface flow processes is a significant limitation of MODFLOW, leading to potential overestimation of drawdowns when rejected recharge is significant. For the study region, the coastal plains are estimated to have rejected recharge, including surface runoff, in excess of 300 mm/year in an average year. This represents significantly higher volumes of water compared to the projected water table drawdowns of generally below 10-20 mm/year in the coastal plains for the next 30 years. The effect of rejected recharge on reducing the modelled drawdown at the watertable needs analysis and interpretation in order to quantify the real drawdowns due to increased abstraction in the future.

The potentially complex relationship between the water table and surface physical and biological processes need to be considered on a local scale when evaluating the implications from drawdown predicted by the regional groundwater model.
2 Physical attributes influencing potential for watertable drawdown

Several physical features of the terrain and hydrogeology within the southern Perth Basin act to restrict effects at the water table or surface environment resulting from reduced potentiometric heads within the Yarragadee aquifer. Consideration of these attributes allows some of the areas to be confidently excluded from drawdown impacts, and identifies areas of interest with potential for some surface impact.

The main features that exclude some areas from impact, and identify those areas of interest with potential for drawdown impacts are:

- Aquitards and perched groundwater;
- Depth to water table; and
- Vasse Member.

2.1 Aquitards and perched groundwater

Intervening aquitards of the Parmelia Formation, Bunbury Basalt and Mowen Member of the Leederville Formation significantly impede the upward propagation of drawdown. Normally, in areas where any of these aquitards are present the surface watertable is effectively isolated from changes in potentiometric heads within the Yarragadee aquifer. In topographically low areas where the Mowen aquitard is relatively thin and sandy, some hydraulic connection through the unit is possible, such as in the lower portion of St John Brook.

A significant portion of the plateau area contains perched groundwater within the Mowen aquitard or Leederville aquifer, which effectively disconnects the surface water table with the deeper aquifers. In these areas drawdown within the Yarragadee aquifer cannot propagate to the surface watertable.

Figure 2.1 is a regional plan showing areas with aquitards and perched watertables, and the remaining areas susceptible to some drawdown at the water table.

2.2 Depth to water table

Surface ecosystems are not dependent on the water table where the water table is below the root zone. There will be very little dependence where the water table is greater than about 10m depth. The soil profile through most of the region has a high moisture retention capacity that is exploited by shallow rooting vegetation without the need to access the watertable.

The depth to water table (determined by subtracting the water table from the topographical surface elevation) is shallow over most of the coastal plain and upon the Blackwood Plateau. However, upon the plateau the water table depth is highly variable, and most of the areas with a shallow water table correspond to where the Mowen aquitard is present. The most significant area with a deep water table is in the Yarragadee Formation outcrop area in the vicinity of Poison Gully and north of the
eastern Scott Coastal Plain. A large area of deep water table is also present below the coastal dune ridge upon the eastern Scott Coastal Plain.

Figure 2.2 shows where there is a deep (>10m) water table overlying areas that are susceptible to a water table decline resulting from drawdown within the Yarragadee aquifer.

In areas with a shallow water table the soil profile will readily become saturated during winter, at which point the infiltration of additional water cannot occur and will runoff the surface runoff as rejected recharge. There is potential for significant attenuation of any drawdown at the water table in these areas, as a decline of the water table creates a thicker unsaturated zone within the soil profile that can be filled during winter with water from what was previously rejected recharge.

**2.3 Leederville aquifer**

The presence of Vasse Member of the Leederville Formation (within which is the Leederville aquifer) will significantly reduce the transfer of drawdown within the Yarragadee aquifer to the water table due to layering of clay units within the sedimentary unit. The ability of the unit in damping drawdown effects at the water table will depend on the thickness of the unit and presence of poorly permeable clay layers. In most situations surface processes (drainage, evapotranspiration and shallow groundwater seepage) will counteract the drawdown effect that does propagate up through the Leederville aquifer.

Figure 2.3 shows those areas of potential impact where the water table is shallow and where the Vasse Member is present.

**2.4 Potential impact areas**

Figure 2.4 shows the areas of interest where there is potential for drawdown at the water table resulting from reduced potentiometric heads in the Yarragadee aquifer. Blue areas represent outcropping Yarragadee aquifer, or where it subcrops the superficial aquifer, and has the greatest potential for drawdown at the water table, depending on local conditions. The green represents the Leederville aquifer (Vasse Member of Leederville Formation) where there is some, but mostly minor, potential for drawdown to propagate through to the water table. Areas of private land are hashed, and are predominantly cleared for agricultural activities.

A consideration of local conditions is required for each of these areas of interest to evaluate the likely implications at the water table of drawdown within the Yarragadee aquifer. The areas of interest showing potential for some measurable effect at the water table are:

- Swan Coastal Plain east of Busselton; potential is greatest about Bunbury where the Yarragadee Formation subcrops the superficial formations, elsewhere drawdown would need to pass through the Leederville aquifer.
- Blackwood River valley between Jalbarragup and a little upriver of St John Brook, and St John Brook below St Pauls Brook; some potential for drawdown through the Leederville aquifer and thin Mowen aquitard.
• Rosa Brook; potential for propagation of drawdown through the Leederville aquifer.
• Blackwood River valley and tributaries between Adelaide Brook and Chapman Brook (including Reedia wetlands area); potential for drawdown through the Leederville aquifer.
• Blackwood River valley between Layman Brook and Milyeannup Brook, and tributaries (named brooks plus Poison Gully); Yarragadee Formation outcrop.
• Western Scott Coastal Plain; some potential for drawdown to propagate through the Leederville aquifer.
• Eastern Scott Coastal Plain; Yarragadee Formation subcrops the superficial formations.

Local areas that have potential for impacts on the surface environment resulting from reduced potentiometric heads within the Yarragadee aquifer are reviewed in detail in subsequent sections. The effect of local hydrogeological conditions in the attenuation of drawdown at the watertable are considered, and conclusions made of the actual impact that will be observed for each of these areas.
Coastline
Rivers
Geological Units
- Perched Groundwater (Vasse/Yarragadee)
- Quindalup Member
- Mowen Member
- Bunbury Basalt
- Parmelia Formation
- Sue Coal Measures
- Potential Impact Area

Figure 2.1
Figure 2.2

- Coastline
- Rivers
- Depth to Watertable > 10m
- Non-sensitive Areas
- Potential Impact Area
Figure 2.3

Regional impact areas with Leederville Aquifer
3 Predictive Scenarios

Predictive scenarios have been run using a computer groundwater model incorporating likely future growth in groundwater pumping within the region and alternative configurations for the proposed Water Corporation 45 GL borefield to evaluate the spatial distribution and magnitude of drawdown through the southern Perth Basin. The groundwater model, referred to as SWAMS v.2.0 (South West Aquifer Modelling System), has been constructed using the USGS modelling package Modflow 2000, and a detailed description of its construction and calibration is provided in the report, ‘Construction, calibration and application of the South West Yarragadee aquifer model, V2.0.’ (Sun, 2005).

3.1 Modelled scenarios

The SWAMS 2.0 regional groundwater model has been used to simulate water levels and drawdowns for different future scenarios over a 30 year period. The simulated scenarios are:

- Current use – a flat current pumping rate of 64 GL/year at 2004 is extended to 2034 used as a base scenario for drawdown estimation;
- Regional growth – pumping for local use is increased to 159 GL over the next 30 years;
- Water Corporation eastern split – 22.5 GL abstracted from Yarragadee 1 and 3 unit respectively from below the north-eastern Blackwood Plateau;
- Water Corporation eastern – 45 GL abstracted from Yarragadee 3 unit from below the north-eastern Blackwood Plateau;
- Water Corporation western – 45 GL abstracted from Yarragadee 3 unit from the western portion of the Blackwood Plateau (about Rosa Brook);
- Dry climate scenario 1 – recharge linearly reduced every year to 5% reduction at the end of 30 year simulating period;
- Dry climate scenario 2 – recharge linearly reduced every year to 10% reduction at the end of 30 year simulating period.

For each scenario, the drawdown is developed by subtracting water levels of one scenario from another relevant scenario. For example, regional growth drawdown is obtained by subtracting predicted water table of regional growth scenario from that of the current use scenario. This gives a more robust evaluation of drawdown by removing any model aberrations resulting from areas of model instability or poor calibration that would give unrealistic changes in water levels if drawdown were simply calculated by the change in simulated water levels over the 30 year period for a particular scenario simulation. Drawdown resulting from 2004 current use extended over the scenario period is small, and has been evaluated by comparison with average pumping over the calibration period (equivalent to 1997 pumping rate of 47 GL/a).

The relevant annual pumping rates and sites in the past 14 years as well as projected pumping rates and sites for the next 30 years are described in the SWAMS 2.0 model report (Sun, 2005).
3.2 Simulated and interpreted drawdown

Three versions for regional drawdown are presented for each of the simulated drawdown scenarios. They are:

- Simulated (raw) drawdown,
- Masked drawdown,
- Attenuated drawdown.

The simulated drawdown is the drawdown produced from the modelled scenarios, without consideration of model limitations and physical processes that would attenuate drawdown at the watertable. The masked drawdown has two functions; firstly it removes those areas described in Chapter 2 where reduced water levels (heads) due to abstraction within the Yarragadee aquifer are not likely to have an effect on the surface environment, and secondly, shading of agricultural land use areas where there are potentially few areas of ecological value (although those that remain may have increased importance). Finally, an interpreted attenuated version of drawdown is presented that provides an estimate for drawdown when additional recharge that is available from rejected recharge is considered, and other hydrogeological aspects are incorporated (e.g. effect of shales not fully incorporated into the model).

3.2.1 Model predicted drawdown maps

The drawdown resulting from projected regional pumping growth relative to current pumping is shown in Figure 3.1. There is up to 3 m drawdown upon the Swan and Scott coastal plains. On the Swan Coastal Plain the drawdown is most apparent in the areas near Bunbury and Busselton; while upon the Scott Coastal Plain the drawdown is greatest over the western and eastern portions.

Drawdown due to the proposed abstraction within the Yarragadee aquifer from the three Water Corporation borefield scenarios, eastern split, eastern and western, are shown in Figures 3.2 to 3.4. Within layer 7 of the model, the drawdown is up to 8 m, 15 m, and 15 m respectively for each of the three borefield scenarios, which reduces to less than 5 m at the coast. Although these are relatively large drawdowns, they are a confined drawdown at depth, and are not representative of the unconfined drawdown at the water table.

Figures 3.5 to 3.7 show the corresponding drawdown at the water table resulting from the three Water Corporation borefield scenarios. The eastern split scenario causes less drawdown in the Yarragadee outcrop area and eastern Scott Coastal Plain, with very little drawdown in the western part of the basin. However, it results in greater impact locally in the St Johns Brook area. The eastern scenario has reduced local drawdown but greater drawdown in more distant areas as compared to the eastern split scenario. The eastern scenario also causes less flow to the ocean than the other scenarios. The western scenario causes more drawdown in the western part of Blackwood Plateau,
particularly in the western Scott Coastal Plain, and has some simulated impact in the Reedia area.

The combined drawdown from both the regional growth and Water Corp abstraction for the eastern split, eastern and western scenarios in the next 30 years are shown in Figures 3.8 to 3.10.

Figures 3.11 and 3.12 respectively show the drawdown caused by reductions in recharge of 5% and 10% that reduce linearly every year over the 30 year simulating period. These scenarios represent even drier climates than that experienced in the last 30 years and are depictions of the worst case scenarios. It can be seen that reduced recharge results in reduced water levels in almost all areas, as the effect is at the water table, and so the result is immediate. This is different to drawdown resulting from pumping which is mostly indirect in terms of the effect of reduced potentiometric heads having to pass through various hydrogeological units to the water table. The other reason for the relative significant drawdowns is that the reduction to recharge is based on gross recharge rather than the net recharge, and a representation of accumulated impact over 30 years. The corresponding reduction in net recharge would be 8% and 16% respectively at the end of 30 year simulation period.

3.2.2 Masked drawdown
The physical attributes described in Chapter 2 act to remove or limit the modelled drawdowns or its potential impact on the surface environment. These features comprise areas of aquitards, perched groundwater and deep watertable (>10 m), which can be represented as masks and applied to the original modelled drawdown maps to derive potential drawdown maps that are more appropriate for environmental impact analysis. The agricultural land use is presented as shaded areas to indicate land of potentially less ecological value.

Figure 3.13 displays drawdown at the watertable resulting from the Water Corp Eastern Split borefield with the masks applied to the original drawdown map. Areas with potential for drawdown at the watertable are clearly identified, and include the eastern Scott Coastal Plain and adjacent margin of the Blackwood Plateau, localised areas about Poison Gully, and the western portion of the Swan Coastal Plain near Bunbury. Private land is also shown as shaded areas to indicate land uses of potentially less ecological significance. Almost the entire Swan Coastal Plain is under private land tenure, while a significant part of the Scott Coastal Plain is private as well.

3.2.3 Attenuated drawdown
The attenuated drawdown considers hydrogeological properties and processes that have not, or could not be included in the regional groundwater model but would act to moderate the actual effect on water table levels resulting from pumping groundwater. These attributes may not be fully incorporated in the model due to the lack of certain process in modelling (surface hydrology), process simplifications, and scale limitations of modelling (horizontal and vertical). The quantity of reject water is greater in well drained areas (especially agricultural and urban) and locations experiencing seasonally waterlogged conditions, which could off-set a decline in the
watertable in excess of one metre, based on 200 mm drainage. Upon the Blackwood Plateau, drainage is closer to 100 mm, and could off-set around 0.5 m drawdown at the watertable, although it will be greater for the lower flanks of valleys.

Various impact factors between 0.1 and 1 (drawdown is multiplied by factor) of simulated drawdown have been applied to areas over the regional model according to the availability of reject recharge and the degree of simulated drawdown. In determining the appropriate impact factor a comparison is made between the simulated drawdown and the degree of drainage for an area. Where drainage water can off-set considerably more than the simulated drawdown at the watertable, the attenuation is high, and hence the drawdown is multiplied by an impact factor of 0.25. Once the drawdown approaches what can be off-set by drainage the impact factor increases to 0.5, and where drawdown exceeds the drainage off-set, then a factor of 0.75 is used. For instance, most of the coastal plains have a simulated drawdown of less than 0.5 m, which is considerably less than the >1 m that can be off-set by drainage water. Therefore, for these areas a better evaluation of likely drawdown is given by applying an impact factor of 0.25. There is no significant drainage over the Yarragadee outcrop area adjacent to the Blackwood River, so there is no attenuation of the drawdown (impact factor of 1), while an impact factor of 0.1 is used for an area on the Swan Coastal Plain to account for both drainage and the presence of shales in the sub-surface not incorporated in the model.

This attenuated impact approach is essentially a qualitative assessment, but is based on a quantitative approach in classifying areas into high (0.25), medium (0.5) and low (0.75 and 1) levels of attenuation. Figure 3.14 shows the attenuation factors mapped for the whole of the study region. Figure 3.15 and 3.16 represent the attenuated drawdown for the masked eastern split Water Corp borefield and the combined drawdown of Water Corp with regional growth after 30 years, respectively. These represent the best guesses on the real drawdown in the future which are presented as indicative for management and decision making.

Figures 3.17 to 3.18 show the attenuated drawdown maps due to potential climate change of 5 and 10% gross recharge reduction at the end of 30 year simulation period.

### 3.3 Water budgets

Water budgets for the three Water Corp scenarios demonstrates the impact on water flow in the regional aquifer system. Table 3.1 shows the flow to the ocean and drainage on the Blackwood Plateau, Swan and Scott costal plains under the three Water Corp scenarios of eastern split, eastern and western borefields. The Water Corporation eastern scenario results in the lowest flow to the ocean, particularly for the Swan coast; flows to the ocean among the other two borefield scenarios are very similar.

Discharge to model drains reduces by approximately 20% over the simulation period (2004 – 2033), with Regional Growth and Water Corp responsible for 11% and 9% of the reduction respectively. The main reduction will occur over the Blackwood Plateau, with minor reduction upon the Swan and Scott coastal plains. The differences in drainage among the three Water Corp scenarios is minimal, as shown in Table 3.2.
Table 3.1  Discharge to ocean for the calibration and simulated scenarios, 2033.

<table>
<thead>
<tr>
<th>Region</th>
<th>Flow to the ocean (GL/a)</th>
<th>Calibration</th>
<th>Regional Growth</th>
<th>WCEastern Split</th>
<th>WCEastern</th>
<th>WCWestern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackwood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swan coastal</td>
<td></td>
<td>89.4</td>
<td>64.6</td>
<td>53.3</td>
<td>47.1</td>
<td>56.6</td>
</tr>
<tr>
<td>Scott coastal</td>
<td></td>
<td>147.7</td>
<td>134.9</td>
<td>133.4</td>
<td>133</td>
<td>131.3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>237.1</td>
<td>199.5</td>
<td>186.7</td>
<td>180.1</td>
<td>187.9</td>
</tr>
</tbody>
</table>

Table 3.2  Drainages for the calibration and simulated scenarios, 2033

<table>
<thead>
<tr>
<th>Region</th>
<th>Drainage (GL/a)</th>
<th>Calibration</th>
<th>Regional Growth</th>
<th>WCEastern Split</th>
<th>WCEastern</th>
<th>WCWestern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackwood#</td>
<td></td>
<td>91.4</td>
<td>81.2</td>
<td>75.3</td>
<td>77.3</td>
<td>75.8</td>
</tr>
<tr>
<td>Swan Coastal</td>
<td></td>
<td>14.6</td>
<td>12</td>
<td>11.5</td>
<td>11.5</td>
<td>11.6</td>
</tr>
<tr>
<td>Scott Coastal</td>
<td></td>
<td>26.2</td>
<td>23.8</td>
<td>23.4</td>
<td>23.4</td>
<td>23.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>132.2</td>
<td>117</td>
<td>110.2</td>
<td>112.2</td>
<td>110.8</td>
</tr>
</tbody>
</table>

Note: # Dominated by Blackwood River, but includes other significant creeks on plateau.

Recharge to the Yarragadee aquifer for the three Water Corporation scenarios are shown in Table 3.3. Compared to the recharge to the Yarragadee aquifer during the calibration period (1990-2003), when annual abstraction from the aquifers is relatively low, recharge to the Yarragadee aquifer during the scenario run period (2004-2033) is significantly higher. For example, recharge to the Yarragadee aquifer for the eastern split scenario increased 51.5 GL/year during the scenario run period compared to the calibration period (202.6 vs. 151.1 GL/year). The higher recharge rate for the scenarios is a result of the higher long-term recharge used for these scenarios compared to the calibration period, and an effect in response to modeled increased pumping.

Water balances, including recharge to the Yarragadee aquifer, for the regional growth and Water Corporation Eastern Split borefield scenarios, and the model calibration period, are presented in the SWAMS 2.0 modelling report (Sun, 2005).
Table 3.3  Recharge to the Yarragadee aquifer under the simulated scenarios

<table>
<thead>
<tr>
<th>Water Corp scenarios</th>
<th>Total influx to Yarragadee (GL/a)</th>
<th>Influx through outcrop Yarragadee (GL/a)</th>
<th>Influx other than outcrop Yarragadee (GL/a)</th>
<th>Upward flux from Yarragadee (GL/a)</th>
<th>Net influx to Yarragadee (GL/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>164.4</td>
<td>44</td>
<td>120.4</td>
<td>13.3</td>
<td>151.1</td>
</tr>
<tr>
<td>Regional Growth</td>
<td>184.8</td>
<td>47.8</td>
<td>137</td>
<td>10.8</td>
<td>173.9</td>
</tr>
<tr>
<td>WC-Eastern Split</td>
<td>212.6</td>
<td>50.7</td>
<td>161.9</td>
<td>10.0</td>
<td>202.6</td>
</tr>
<tr>
<td>WC-Eastern</td>
<td>207.0</td>
<td>51.3</td>
<td>155.7</td>
<td>9.8</td>
<td>197.2</td>
</tr>
<tr>
<td>WC-Western</td>
<td>209.9</td>
<td>51.4</td>
<td>158.5</td>
<td>8.9</td>
<td>201.0</td>
</tr>
</tbody>
</table>
Figure 3.1

The information contained herein is subject to ongoing review and amendments and should be read in conjunction with the associated report.

Date: October 2005
Author: J. Vine

Drawdown Extent
- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

Regional Growth
Drawdown (Layer 1 unmasked)
Figure 3.2

Coastline

Rivers

Drawdown Extent

- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

Water Corporation East Split
Borefield Drawdown (Layer 7)
The information contained herein is subject to ongoing review and amendments and should be read in conjunction with the associated report.

Author: J. Vine

Figure 3.5

Water Corporation Eastern Split Borefields Drawdown (Layer 1, unmasked)
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

Figure 3.6

Water Corporation Eastern Borefields Drawdown (Layer 1, unmasked)
Figure 3.7

Water Corporation Western Borefields Drawdown (Layer 1, unmasked)

Coastline
Rivers

Drawdown Extent
- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

Kilometers

10 0 10 20 30 5

1:750,000

DATE: October 2005
COORDINATE SYSTEM: MGA94 - Zone 50
Figure 3.8

Water Corporation Eastern Split Borefields + Regional Growth Drawdown (Layer 1, unmasked)
Figure 3.9

Water Corporation Eastern
Borefields + Regional Growth
Drawdown (Layer 1, unmasked)
Figure 3.10

Water Corporation Western Borefields + Regional Growth Drawdown
(Layer 1, unmasked)
Drawdown resulting from 5% recharge reduction after 30 years (Layer1, unmasked)

COORDINATE SYSTEM: MGA94 - Zone 50

PROJECT No: r302
DATE: October 2005
COORDINATE SYSTEM: MGA94 - Zone 50

Figure 3.11
Figure 3.12

Drawdown Extent

- Coastline
- Rivers

Drawdown resulting from 10% recharge reduction after 30 years
(Layer 1, unmasked)
The information contained herein is subject to ongoing review and amendments and should be read in conjunction with the associated report.

Date: October 2005

Author: J. Vine

Coastline
Rivers

Drawdown Extent
- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

Private Use Land

Water Corporation Eastern
Split Borefields Drawdown
(Layer 1, masked)

Figure 3.13
Figure 3.15

Interpreted, Water Corporation Eastern
Split Borefields Drawdown
(Layer 1, masked)
Figure 3.16

Water Corporation Eastern Split
Borefields + Regional Growth
Drawdown (Layer 1, masked)
Interpreted, Drawdown resulting from 5% recharge reduction after 30 years (Layer 1, masked)

Figure 3.17
Interpreted, Drawdown resulting from 10% recharge reduction after 30 years (Layer 1, masked)

Figure 3.18
4 Swan Coastal Plain local area impacts

The area of interest upon the Swan Coastal Plain is shown on Figure 4.1. The Swan Coastal Plain is situated between Geographe Bay/Indian Ocean and the Blackwood Plateau/Darling Range (Figure 4.2). It is a relatively flat plain about 16 km wide sloping toward the coast that is predominantly cleared for agricultural activities, with urban development at Bunbury and Busselton, and several other smaller towns. The plain behind the coastal dune area is prone to flooding and is extensively drained.

The surface geology comprises Quaternary alluvial and dune sediments termed the superficial formations (Figure 4.3). Beneath the western portion of the coastal plain the Vasse Member of the Leederville formation sub-crops the superficial sediments, while in the Bunbury area the superficial sediments are underlain by the Yarragadee Formation (Figure 4.4). The Bunbury Basalt sub-crops in a small area at Bunbury, and outcrops on the beach south of the port.

The superficial formations contain a relatively thin and poorly permeable aquifer within the Bassendean Sand and Guildford Formation, but becomes more permeable adjacent to the coast within the Tamala Limestone and Safety Bay Sand. The Leederville aquifer within the Vasse Member is a transmissive aquifer in the Australind-Donnybrook area and west of Peppermint Grove, but is relatively thin and impermeable in the Capel area. The Yarragadee aquifer is the principle aquifer in the Bunbury area where it is highly permeable with a thickness in excess of 600 m.

A sea-water interface exists along the coast near Bunbury within the Yarragadee aquifer. Within Dalyellup bore 1/02 (6 km south of Bunbury CBD), situated 700 m from the coast, the sea-water interface is located at 400 m depth. A similar pattern for the sea-water interface probably exists along the coast where the Yarragadee aquifer sub-crops the superficial formations. According to the Ghyben-Herzberg relation, sea water occurs at a depth below sea level approximately 40 times the height of fresh water above sea level. In most real situations, the Ghyben-Herzberg relation underestimates the depth to the saltwater interface due to groundwater flow toward the coast limiting the landward encroachment of the sea-water. For example, at Dalyellup 1/02 the potentiometric head is about 3 m AHD, but the sea-water interface is over double the depth predicted by the relation.

4.1 Susceptible areas

The Bunbury area is most susceptible to drawdown resulting from reduced potentiometric heads within the Yarragadee aquifer. This area has sand and limestone sediments of the superficial formations directly overlying the Yarragadee Formation. The area of Yarragadee Formation sub-crop is shown on Figure 4.4.

Another area of sub-cropping Yarragadee Formation is situated east of Capel, but in this area the aquifer is overlain by less permeable Guildford Formation, and the Yarragadee belongs to units 1 and 2 with significant clay layers.
An ecologically sensitive area is the Tutunup Ironstone vegetation community, situated in a small area about 17 km south of Capel upon the coastal plain at the base of the Whicher Scarp.

4.2 Simulated impact

The simulated drawdown at the watertable, represented by layer 1 of SWAMS 2.0, resulting from the eastern split 45 GL borefield scenario is shown in Figure 4.5. The figure shows drawdown of up to 0.5 m southeast of Bunbury resulting from this Water Corporation borefield scenario. The area adjacent to the Whicher Scarp between the Ludlow River and Vasse Highway has a similar drawdown at the water table, which decreases toward the coast.

Drawdown simulated at Bunbury from 30 years of current pumping is around 0.5 to 1 m at the watertable. The future growth scenario predicts about a 2 m decline in potentiometric heads within the Yarragadee aquifer, with 1 – 2 m drawdown at the water table.

Hydrographs for selected monitoring bore sites (PL2, Bun9, Bun22) are shown below:
4.3 Attenuating processes

The Swan Coastal Plain is predominantly cleared and drained for agricultural activities. Vegetation and ecosystems dependent on groundwater have been largely removed from the privately owned land.

4.3.1 Water table drawdown

In the Bunbury area high potential groundwater recharge rates due to land-use and the drainage of water from the coastal plain will act to counteract the drawdown simulated for the water table. Much of the area is covered by the Bunbury urban area, where runoff from sealed or roofed surfaces directed into compensation basins and soaks enhances groundwater recharge. Groundwater recharge rates in Bunbury will be
in the order of 50% of rainfall, although much of this water is currently discharged via an extensive drainage system. High groundwater recharge rates of around 30% will also occur over land cleared for agricultural purposes.

On average, there is up to about an additional 300 mm of groundwater recharge available that is currently rejected to drainage at Bunbury and the surrounding country where the Yarragadee Formation sub-crops. This recharge would be enough to fully replace groundwater where the water table drawdown is 1 m to 1.5 m. The likely outcome resulting from the Water Corporation borefield and regional development of groundwater resources will be a lower water table minimum during summer, but less than simulated by the regional model which does not include this rejected water. There would be full recovery during winter until all available water currently rejected from groundwater recharge is captured. Local pumping and drainage will cause some variation through the Bunbury area.

The Guildford Formation situated over the Yarragadee Formation east of Capel contains significant clay beds that will restrict the migration of any drawdown from the Yarragadee aquifer to the water table. The Yarragadee Formation units present beneath the superficial formations belong to unit 1 and 2, which are more vertically resistive to groundwater flow.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 4.1. An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Simulated drawdown at 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL2</td>
<td>Regional growth: 0.6 m</td>
<td>50 – 75%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.3 m</td>
<td></td>
</tr>
<tr>
<td>Bun9</td>
<td>Regional growth: 0.8 m</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.5 m</td>
<td></td>
</tr>
<tr>
<td>Bun22</td>
<td>Regional growth: 1.1 m</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.8 m</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3.2 Drawdown about Tutunup

Drawdown simulated west of the Ludlow River is overstated due to vertical permeability used in the model which is significantly higher than appropriate for the local lithology intersected by bores. The area adjacent to the scarp is underlain by superficial formations over the Vasse Member of the Leederville Formation, which in turn overlies unit 1 of the Yarragadee Formation. The superficial sediments variously comprise clay (Bus 29 and 34) and sand (Bus22), while the upper portion of the Vasse Member is dominantly sand. Approximately the lower 14 m of the Vasse Member consists of low permeability clay as intersected by Bus29 and the Tutunup bore (TPB1). The underlying unit 1 Yarragadee Formation comprises sand with extensive clay bedding, and is about 40 m thick at Tutunup. The potentiometric head within unit 1 at Tutunup is around 15 m higher than within the deeper main portion of the
Yarragadee aquifer (unit 3). To maintain this head difference a relatively low vertical permeability through unit 1 is required.

The main units that hydraulically isolate the surface water table from the main portion of the Yarragadee aquifer are clays within the lower Vasse Member and unit 1 Yarragadee Formation. In this area, these are represented by layers 3, 4 and 5 of the regional groundwater model. The parameter values for vertical permeability of these layers in this area are 0.01, 0.01 and 0.005 m/day respectively. These values are at least an order of magnitude higher than would be expected for the clayey strata. The consequence on drawdown of vertical permeability that is an order of magnitude lower than used in the model will be a reduction by up to 90%, or a maximum of about 0.2 m. This discrepancy in parameter values and simulation results has arisen due to the lack of calibration bores within these layers in this part of the model, and failure to reference hydrogeological data during the model calibration process. Parameter values used in the model will need to be rectified during later model refinement.

Another aspect not incorporated into the model is enhanced groundwater recharge, or potential recharge, from runoff from the scarp onto the adjacent coastal plain, which includes the area of greatest simulated drawdown. This process will further attenuate drawdown at the water table resulting from reduced potentiometric heads in the Yarragadee aquifer. It is concluded that the actual drawdown that will be observed at the water table will be <10% of that simulated.

4.3.3 Wonnerup wetlands

The Wonnerup wetlands are situated adjacent to the coast upon permeable sand and limestone sediments. There is good hydraulic connection between the superficial aquifer and the coast, resulting in the water table being close to sea-level and the extension of salt and brackish groundwater extending a significant distance inland. The high salinity groundwater within the superficial aquifer is underlain by low salinity groundwater within the Leederville aquifer.

The area including the Wonnerup wetlands has a simulated drawdown of less than 0.25 m. This is, however, unlikely to occur due to the high permeability of the superficial aquifer in this area and its proximity to the coast, which effectively buffers any drawdown impact. A small increase in groundwater salinity is the most likely impact resulting from the proposed groundwater developments.

4.3.4 Sea-water intrusion

‘Under natural conditions, the flow of fresh water toward the sea limits the landward encroachment of sea water. With the development of groundwater supplies and subsequent lowering of the water table or piezometric surface, the dynamic balance between fresh and sea water is disturbed, permitting the sea water to intrude usable parts of the aquifer. The distance inland that the saltwater interface extends is proportional to the hydraulic conductivity and thickness squared and inversely proportional to the flow of fresh water to the sea. As the flow of fresh water to the sea is reduced, the length of the intruded salt water wedge increases.’ (Domenico & Schwartz, 1990, Physical and chemical hydrogeology)
To summarise the quote from Domenico and Schwartz, a reduction of water levels and groundwater flow adjacent to the coast will allow the inland movement of the sea water, and that the incursion will be proportional to the decrease in groundwater throughflow. Historically, seawater intrusion has occurred in some bores situated close to the coast and screened within the shallow portion of the Yarragadee Formation when those bores have been excessively pumped. Recent re-drilling and geophysical logging of Bunbury Shallow monitoring bore 6, situated less than 200 m from the shoreline, identified a tongue of seawater intrusion at a higher level than observed in the original hole drilled in 1975 (Commander, pers. comm.). These observations confirm that seawater intrusion is occurring, but that there has not been a drastic change over the last 30 years.

Future pumping scenarios show groundwater discharge to the ocean from the Bunbury area decreases to 78% of original groundwater flow as a result of regional pumping compared to no-pumping. This reduces further to 60% of flow resulting from the combination of regional usage and the Water Corporation 45GL Eastern Split borefield option. When applied to Dalyellup, the reduction in groundwater flow in the long-term would cause the sea-water interface at 400 m depth to migrate inland by about 150 m in response to the simulated regional growth, while in would rise about 90 m at the Dalyellup 1/02 site. The Water Corporation borefield would cause ingress of sea-water on top of that caused by regional pumping of about 130 m, and a rise of the interface by about 70 m. This implies that production bores within about 1 km of the shoreline may be susceptible to saltwater intrusion. However, aquifer heterogeneity (especially vertical), bore screened intervals, the pumping rate, and location of bores all influence the magnitude of saltwater intrusion, the depth levels at which it migrates (e.g. salt water moving in over freshwater), and the rate of movement.

Additional groundwater recharge captured as a result of pumping will help to maintain groundwater throughflow and reduce the inland movement of the sea-water interface, possibly by around 20%.

The proximity of some bores to the coast at Bunbury will cause an uneven distribution of the sea-water wedge. There will be a greater landward movement of sea-water where large quantities of water are drawn close to the coast. The appropriate distance for bores from the coast to avoid causing significant inland movement of the sea-water wedge will depend on the amount of water pumped from the bore, the screened depth, and aquifer properties. This will be a local planning issue for groundwater development at Bunbury to maximise the resource while limiting the degree of seawater intrusion, and can only be achieved through on-going monitoring of the saltwater interface and production. Modelling of saltwater movement within the aquifer should be possible through appropriate monitoring (MODFLOW is not capable of saltwater interface modelling).

4.4 Conclusions

The actual drawdown for the Bunbury area is likely to be less than 1 m at 30 years for the Regional growth scenario, and increasing to a little over 1 m with addition of the eastern split Water Corporation 45 GL borefield. The drawdown will be mostly
observed as a deeper summer minimum waterlevel, while the winter maximum level will rise to near normal levels. The effects of local pumping may result in some areas of greater drawdown.

Drawdown in the Tutunup area is likely to be considerably less than simulated. It is unlikely that drawdown would exceed 0.2 m from the Water Corporation borefield, and may be less than 0.25 m with regional growth, except where effected by local pumping. Water levels within the Wonnerup wetlands will not be affected by pumping from the Yarragadee or Leederville aquifers.

The sea-water interface will move inland by up to 280 m over an extended period of time (uncertain) in response to local and regional pumping growth, and the Water Corporation borefield.
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.
Geological Units

- Safety Bay Sand
- Alluvium, Estuarine Mud
- Tamala Limestone
- Bassendean Sand
- Guildford Formation
- Yoganup Formation
- Quindalup Member
- Mowen Member
- Vasse Member
- Bunbury Basalt
- Yarragadee Unit 1
- Boreholes
The information contained herein is subject to ongoing review and amendments and should be read in conjunction with the associated report.

Geological Units
- Quindalup Member
- Mowen Member
- Vasse Member
- Bunbury Basalt
- Yarragadee Unit 1

Boreholes

Eastern Swan Coastal Plain - Sub-crop Geology of the Superficial Formations

Figure 4.4
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

Drawdown Extent

- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

- Simulated Hydrograph Sites
- /\ Private Land Use

Eastern Swan Coastal Plain - Simulated Water Corporation Eastern Split Borefields Drawdown (layer1, v2.0)

Figure 4.5
5 Potential impact on water balance and water quality of the Blackwood River

Modeled drainage within the Blackwood River catchment incorporates both groundwater baseflow, evaporation from the river surface, and a portion of evapotranspiration, with simulated reductions to drainage also coming from each of these components. Within the Yarragadee outcrop area the component of evaporation and evapotranspiration is small due to the large groundwater baseflow contribution through this area and the large depth to groundwater beyond the valley limiting potential evapotranspiration. However, in areas upon the Leederville Formation the component of evapotranspiration may be large due to the much greater river length represented and the smaller flux of groundwater contributing to baseflow.

Due to the difficulty in separating the potential evapotranspiration and drainage on the Blackwood Plateau, potential drainage reduction is best estimated by the ratio of simulated drain reduction in MODFLOW modelling; which serves as an indication of the potential reduction that may be observed in baseflow within the Blackwood River and tributaries during summer period. Modeling indicates an average of 20% reduction of baseflow over the driest summer month upon the Blackwood Plateau, with a greater reduction from the Yarragadee outcrop area of about 30%. River flow reduction during other seasons other than summer is minimal for the Blackwood River.

There is a 20% reduction in baseflow resulting from combined regional growth and Water Corporation pumping. For the driest month this represents flow decreasing by 0.4 GL per month at Hutt Pool based on March 2004 data, or 0.48 GL for the month of February averaged over the period of 1984 – 1998. This extrapolates to 4.8 GL and 5.8 GL annual flow reduction for the two observed data sets. These reductions are insignificant compared to winter and spring river flow in the Blackwood River which comprises the bulk of annual flow averaged at 577 GL/year. The estimated annual flow reductions for the Blackwood River at Hutt Pool would be 11% and 13% respectively, using the two methods stated above and based on the baseflow estimation of URS (2004b). Out of these reductions, Water Corp abstraction explains 5 and 6 % respectively for the baseflow reduction in the Blackwood River.

As a result of 0.4 GL/month flow reduction in the driest month of the year (Feb), salinity may increase by 20% during that month if no upland inflow from Nannup and above contributes to the streams. For the driest two months (Jan-Feb), salinity may increase by 14%. For the driest three months and over, salinity reduction in the Blackwood River becomes minimal as increased stream flow from agricultural areas in the upper catchment brings high salinity water and overwhelms the whole fresh water system. Figure 4.1 shows the observed monthly baseflow and salinity for the Blackwood River at Hutt Pool. It can be seen that salinity in the summer months are fairly variable with some reaching stability at early summer, while others keep falling with occasional rising in the summer period. This means that salinity in the Blackwood River would be highly variable in summer. A reduction in baseflow discharge may cause a delay on the arrival of the lower salinity, or a change of the lowest level of salinity reached in a year when there is no upstream flow involved. If
there is upstream storm inflow into the lower Blackwood River, it will generally dominate the salinity of the river water making the baseflow salinity analysis much less relevant.

![Graph showing river flow and salinity data with dates and corresponding salinity readings.](image)

**Figure 5.6** Observed river flow and salinity of the Blackwood River at Hutt Pool

In summary, the baseflow reduction as well as water quality change in the Blackwood River due to Water Corp future abstraction is likely to be less than 10%.
6 Blackwood Plateau local area impacts

Local drawdown impact areas identified on the Blackwood Plateau are associated with outcrop areas of the Yarragadee Formation or Vasse Member of the Leederville Formation, and are within the Blackwood River valley and tributaries. The local areas are: St John Brook below St Pauls Brook, Rosa Brook, Reedia wetlands (including Spearwood Brook area), and Blackwood River valley between Layman Brook and Milyeannup Brook.

6.1 St John Brook

The St John area of interest is shown in Figure 6.1. The lower portion of St John Brook is situated upon the eastern Blackwood Plateau north of the Blackwood River into which it discharges (Figure 6.2). This part of the catchment retains native vegetation cover (mostly Jarrah forest) within state forest and nature reserves. The brook falls in elevation from 70 m AHD at St Paul Brook to 51 m at the Blackwood River, a distance of 13 km. The Brook is deeply incised into the surrounding landscape, and contains a number of pools within 10 km of the Blackwood River. There is a small perennial flow continuing through summer (about 0.02 GL/month) that is maintained by groundwater discharge from the Mowen Member of the Leederville Formation. The up-stream limit of baseflow is situated about 700 m south of St Paul Brook.

The surface geology (Figure 6.3) shows the Quindalup Member of the Leederville Formation covering most of the catchment area, with the valley incised into the underlying Mowen Member. These units are both part of the Mowen Aquitard. The Vasse Member, containing the Leederville aquifer, in not exposed in the valley, but is present below the Mowen Member. In this area the unit 1 of the upper Yarragadee Formation underlies the Vasse Member.

The water table elevation within the Quindalup and Mowen Members is controlled largely by the surface topography, with the depth to water typically 5 to 10 m. The depth to water is deeper at the top of the valley slope for the brook, such as at BP28 where the water table is about 40 m depth, although there may be some perching upon overlying clay layers at this site. Groundwater flow within the Quindalup and Mowen members is limited. Extensive flow systems occur within the underlying Leederville aquifer, in which groundwater flow is toward the Blackwood River and the lower reaches of St John Brook. At the top of the Yarragadee aquifer (unit 1) groundwater levels and flow is similar to the overlying Leederville aquifer with which there is reasonable hydraulic connection. Extensive clay layers within the Yarragadee unit 1 restrict the hydraulic connection with increasing depth, so that there is little or no effect of St John Brook on heads and flow within the middle of the aquifer unit.

An upward potentiometric head gradient exists between the upper Yarragadee unit 1/Leederville aquifer and the water table within the lower St John Brook. There is also a downward gradient from the top of the Yarragadee unit 1 aquifer and deeper sections of the aquifer. Artesian heads exist between the top of the Yarragadee unit 1 aquifer and the brook at Barrabup Pool, where the head is about 4 m above the brook.
surface. The artesian head is interpreted to decrease both upstream and downstream of this point. Downstream at Mowen Road the potentiometric head is similar to the brook level, while upstream at St Paul Brook there is a downward hydraulic gradient. Pools within St John Brook are maintained by seepage discharge from the Mowen Member and upward leakage from the Leederville aquifer.

### 6.1.1 Susceptible areas

The area susceptible to drawdown impacts at the water table resulting from a drawdown within the Yarragadee aquifer are confined to the brook and fringing bank area between St Paul Brook and the Blackwood River. The Quindalup and Mowen members are relatively thin below the brook, so that there is some hydraulic connection between the top of the Yarragadee unit 1 aquifer and the water table.

### 6.1.2 Simulated impact

Simulations of the eastern split Water Corporation 45 GL borefield show a 30 year drawdown of 0.5 to about 4 m for layer 1 along St John Brook (Figure 6.4), with drawdown generally increasing to St Paul Brook. The predicted drawdown resulting from the eastern borefield option is up to 2 m, while the western borefield has the least simulated impact of around 0.5 m for layer 1 along St John Brook, increasing up to about 1 m in some adjacent areas.

Hydrographs for selected monitoring bore sites (SJB1, SJB2) are shown below:

![Hydrograph](image_url)

SJB1 (E377340, N6247280); source of flow;
6.1.3 Attenuating processes

Extensive clay beds within Yarragadee unit 1 provides significant hydraulic resistance to the propagation of reduced potentiometric heads from the Yarragadee unit 3 aquifer to the Leederville aquifer and water table. URS (2004a) concluded in their study of St John Brook that abstraction of groundwater from the Yarragadee unit 3 aquifer would not affect groundwater levels in the Leederville aquifer or baseflow in the brook. The eastern split borefield scenario draws half of the production from unit 1 of the Yarragadee Formation, and so does not have the same intervening shale units that isolate the producing aquifer zone from the surface. Consequently, a significantly
greater local drawdown is observed, including the St John Brook area, resulting from the eastern split borefield than the other borefield options.

The effects of any drawdown within the brook will be significantly counteracted by stream-flow and shallow groundwater seepage during winter. In summer, the eastern split borefield may cause an attenuated decline of the water table, resulting in a fall in pool levels and a reduction in summer stream. At Barrabup Pool, the artesian head that exists is greater than the simulated drawdown within the Leederville aquifer of less than 3 m, so that there should be no effect upon the pool. Some drawdown may be observed beneath the flanking slopes of the valley, although the watertable is typically deep in these areas.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 6.1. An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

Table 6.1 St John Brook scenario hydrographs and attenuated impacts.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Drawdown @ 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
</table>
| SJB1            | Regional growth: 0.35 m  
Eastern Slit Water Corp: 4.1 m | 25%                        |
| BP63            | Regional growth: 0.3 m  
Eastern Slit Water Corp: 2.0 m | 25%                        |
| SJB2            | Regional growth: 0.1 m  
Eastern Slit Water Corp: 0.6 m | 25%                        |

6.1.4 Conclusions

The effects of regional pumping and the Water Corporation eastern and western borefield options should have no discernable impact on water levels at St John Brook or stream flow. The eastern split borefield option may cause some reduction in summer pool levels north of Barrabup Pool, although there should be no effect at Barrabup Pool. Summer baseflow may decrease, with the section between Barrabup Pool and St Paul Brook experiencing the greatest impact and potentially ceasing to flow through the upper section.

Summer minimum watertable levels are likely to be deeper by around 1 to 2 metres up-stream of Barrabup Pool, especially beneath the valley flanks, in response to the eastern split Water Corporation borefield. There should be no discernable effect at the watertable down-stream of Barrabup Pool, although some drawdown at the watertable may occur away from the valley floor. Winter stream-flow and seepage of water down the valley flanks should allow the full recovery of watertable levels.
Figure 6.1

The information contained herein is subject to ongoing review and amendments and should be read in conjunction with the associated report.

Date: October 2005

1:50,000

Kilometers
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

St John Brook - Simulated Water Corporation Eastern Split Borefields Drawdown (layer1, v2.0)

Figure 6.4

AUTHOR: J. Vine

PROJECT No: r302 DATE: October 2005
COORDINATE SYSTEM: MGA94 - Zone 50
6.2 *Rosa Brook*

The Rosa Brook area of interest is shown in Figure 6.5. Rosa Brook is situated near the centre of the Blackwood Plateau, north of the Blackwood River into which it discharges, and comprises two main sub-catchments (Figure 6.6). The entire catchment retains native vegetation. The Brook does not have perennial flow, typically flowing from early winter through to late spring. The brook bed rises from about 16 m AHD elevation at the Blackwood River, to about 31 m AHD at the convergence of the two branches, and reaches over 140 m AHD at the head of the catchment.

Surface geology for the Rosa Brook catchment is shown in Figure 6.7. Most of the catchment surface consists of the Mowen Member of the Leederville Formation, which comprises mostly of clay and silt. The lower slope of the valley cuts down into the Vasse Member of the formation, which contains the Leederville aquifer. The interpretive geology indicates a small area of exposed Yarragadee Formation approximately midway up the eastern branch of the brook, but this has not been confirmed in the field.

An upward potentiometric head gradient and artesian heads exist between the Yarragadee aquifer and the surface along the Blackwood River, and extending approximately 1.7 km up Rosa Brook (Figure 6.8). An artesian head of 9 m is interpreted to occur at the Blackwood River where Rosa Brook enters, and decreases up the brook.

### 6.2.1 Susceptible areas

Areas potentially susceptible to drawdown at the water table are the lower brook area where it cuts into the Leederville aquifer, and the adjacent lower slope of the valley. Up-slope of these areas the water table is considerably deeper or is perched upon clayey strata.

### 6.2.2 Simulated impact

Simulated drawdown at the water table (layer 1) is shown on Figure 6.9 after 30 years of pumping from the eastern split 45 GL borefield. Drawdown is least adjacent to the Blackwood River, and increases up-stream, but is mostly less than 0.25 m.

The simulated drawdown for the eastern borefield is similar to the eastern split. Under the western borefield option there is a simulated drawdown of 0.1 to 0.25 m at the termination of Rosa Brook with Blackwood River, increasing to 0.5 to 1 m near the convergence of the two main branches. The greatest drawdown is predicted upstream of the convergence, reaching up to 5 m on the western branch. A 2 – 3 m decline is simulated at the BP35/SWY1/03 site.

Hydrographs for selected monitoring bore sites (Rosa 1, Rosa 2, Rosa 3) are shown below:
Rosa 1 (E354870, N6229530); end of Rosa Brook adjacent to the Blackwood River

Rosa 2 (E356080, N6232710); where main branches of Rosa Brook meet
6.2.3 Attenuating processes

Generalisation in the model means that the full water balance is not simulated. In the Rosa Brook area shallow winter seepage and summer evapotranspiration from vegetation is not included. Both will counter-act drawdown at the water table, reducing the total decline, although the magnitude of this reduction would be site specific and cannot be accurately assessed.

Winter watertable levels are unlikely to be effected by pumping by the Water Corporation eastern split (and eastern) borefield and regional growth due to the recharging that will occur from winter stream-flow and shallow groundwater seepage. Some additional decline of summer minimum watertable levels may occur. This would be least in the lower reaches of Rosa Brook, which is ecologically the most sensitive area due to the shallow watertable. There should be no effect within about 1 km of the Blackwood River where artesian heads with the underlying Yarragadee aquifer would be maintained, while up-stream to about the fork of the two main branches, the seasonal minimum water level could be up to 0.2 m deeper. The summer minimum watertable may be up to 1 m deeper further up-stream below each of the two main branches of Rosa Brook.

Much of the valley has a significant depth to water, but it is not possible to produce an accurate distribution of water table depth due to its variability. Within BP35C the depth to water is about 7 m, and in most areas the watertable depth would increase further up the valley slope.

The upper portion of the Rosa Brook catchment contains perched groundwater within the Leederville aquifer or Mowen aquitard (see Figure 2.1). Perched groundwater may be present at BP45, where there appears to be an unsaturated section at 19 – 22 m. There should be no hydraulic connection between the Yarragadee aquifer and the surface water table in these areas of perched groundwater. In response to drawdown,
there is potential for the expansion of these unsaturated zones through the Leederville aquifer, thereby increasing the area of surface watertable isolated from any further effects within the Yarragadee aquifer.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 6.2. An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

Table 6.2 Rosa Brook scenario hydrographs and attenuated impacts.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Drawdown @ 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSA1 Blackwood River</td>
<td>No observable drawdown (&lt;0.1)</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.2</td>
<td></td>
</tr>
<tr>
<td>BP35</td>
<td>Regional growth: 0.36 m</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.49 m</td>
<td></td>
</tr>
<tr>
<td>ROSA2</td>
<td>Regional growth: 0.14 m</td>
<td>25%</td>
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<tr>
<td></td>
<td>Eastern Split Water Corp: 0.15 m</td>
<td></td>
</tr>
<tr>
<td>ROSA3 western branch</td>
<td>Regional growth: 0.36 m</td>
<td>50 – 75%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.42 m</td>
<td></td>
</tr>
</tbody>
</table>

6.2.4 Conclusions

Under the regional growth, eastern and eastern split Water Corporation borefield options it is unlikely that any significant effects at the water table would be observed. A summer minimum watertable up to 0.2 m deeper may occur upstream of around 1 km from the Blackwood River, increasing to around 1 m below the eastern and western branches of the brook. Perched watertable conditions are likely within 5 km upstream of the main brook fork, above which there should be no effect observed at the watertable resulting from the borefields. Under the western borefield option significantly greater drawdown would occur.

The lower flanking slope of the lower brook may experience some drawdown at the water table, even though the brook area does not. The maximum drawdown here is likely to be around 0.5 m. Further up the valley slope the water table depth will become deeper and may be beyond the rooting depth.
Figure 6.5

Rosa Brook

Geological Units
- Vasse Member
- Non-sensitive Areas
- Potential Impact Area

Coastline
Rivers
Areas of Interest

AUTHOR: J.Vine

DATE: October 2005

COORDINATE SYSTEM: MGA94 - Zone 50

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.
Elevation

- 0 - 10
- 10 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 180
- 180 - 200
- 200 - 220
- 220 - 240

- Boreholes

Figure 6.6

Rosa - Topography
Figure 6.8

Rosa -
Area of Artesian Heads
Yarragadee Aquifer

Elevation Artesian Head

- 0 - 10
- 10 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 180
- 180 - 200
- 200 - 220
- 220 - 240

0 - 3
3 - 5
5 - 7
7 - 10
10 - 13
13 - 15
15 - 17
17 - 20
20 - 25
25 - 30

Kilometers
1:60,000

COORDINATE SYSTEM: MGA94 - Zone 50

AUTHOR: J. Vine

DATE: October 2005

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.
Drawdown Extent

- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

*Simulated Hydrograph Sites*

**Rosa - Simulated Water Corporation Eastern Split Borefields Drawdown (layer1, v2.0)**

**Figure 6.9**

**AUTHOR:** J. Vine

**DATE:** October 2005

**COORDINATE SYSTEM:** MGA94 - Zone 50
6.3 Reedia

The Reedia area of interest is shown in Figure 6.10. Wetlands and perennial stream flow occur upon the south-western Blackwood Plateau in the vicinity of the Blackwood River, approximately between Adelaide Brook and Chapman Brook (Figure 6.11). The area is under native vegetation. The most significant area of wetlands, referred to as the Reedia wetlands after a rare plant type found there, are situated both sides of the Blackwood River between Hutt Pool and Adelaide Brook.

The local surface geology (Figure 6.12) comprises the Vasse Member of the Leederville Formation, within which is the Leederville aquifer, overlying the Lesueur Sandstone which also forms a thick aquifer. The Mowen Member of the Leederville Formation is an aquitard present upon higher ground north of the wetland areas, although as an aquitard it is likely to be leaky in part due to some sandy.

Stream flow is maintained by groundwater discharge from the Leederville aquifer into which the streams are incised, while the moist conditions within the wetlands are maintained to a large extent by the artesian potentiometric heads between the Lesueur Sandstone/Leederville aquifers and the surface water table. Areas with artesian heads with the Lesueur Sandstone are shown on Figure 6.13, which closely correspond with the observed extent of perennial baseflow. The magnitude of the Lesueur Sandstone artesian head above ground surface is up to 20 m, as determined from the interpretive regional potentiometric heads.

Faults are known to be present through the Lesueur Sandstone. The Cockleshell Gully Formation, which has extensive shale layers, may be faulted between the Lesueur Sandstone and Yarragadee Formation, creating additional barriers to flow. A significant horizontal impedance to flow is required to maintain a potentiometric head within the Lesueur Sandstone about 8 m higher than that observed in the adjacent Yarragadee Formation. Basic modelling indicates that a fault conductance of less than 0.0001 m/day is required to maintain the observed head difference between the aquifers in the vicinity of monitoring bores BP67 and SC7.

6.3.1 Susceptible areas

The Lesueur Sandstone aquifer and Leederville aquifer are hydraulically connected. Any regional drawdown propagating through the Lesueur Sandstone will cause additional downward leakage of groundwater from the Leederville aquifer and result in a reduction in potentiometric heads in that aquifer. This may result in a lowered water table, but will not be significant in elevated areas between the valleys and over the Mowen Member, or where artesian heads are maintained within the valleys. The most sensitive areas to a drawdown of potentiometric heads in the Lesueur Sandstone will be areas where there is currently a shallow water table or small artesian head, which will include the lower valley flanks and upper sections of valleys where the Vasse Member is exposed.

Adelaide Brook is the eastern-most significant tributary, and so has the greatest potential for impact from drawdown within the Yarragadee aquifer.
6.3.2 Simulated impact

The predicted drawdown after 30 years of pumping are shown in Figure 6.14 for the eastern split Water Corporation 45 GL borefield.

There is no appreciable drawdown associated with either regional growth or the eastern or eastern split Water Corporation borefield options. The simulated drawdown from the western Water Corporation borefield is up to 0.5 m in areas of Leederville outcrop, but decreases to less than 0.25 m in the valleys.

Hydrographs for selected monitoring bore sites (Reedia 1, Reedia 2, Reedia 3, Reedia 4) are shown below:

![REEDIA1](image)

Reedia 1 (E342050, N6225220); Schroeder;

![REEDIA2](image)

Reedia 2 (E342500, N6226740); Hut Pool;
6.3.3 Attenuating processes

Any drawdown at the water table will be partially counteracted by additional infiltration of runoff/streamflow during winter.

Where artesian heads are maintained, there should be little or no drawdown at the water table. A drawdown of 1 m within the Lesueur Sandstone is simulated in the eastern split borefield scenario, which is small compared to the existing artesian heads. Consequently, the artesian areas will be essentially unaffected.
Any drawdown propagating toward the Reedia area from the Yarragadee Formation in the east will be progressively impeded by faults as it expands westward. The complexity of faulting has not been fully incorporated into the model, and is likely to impede drawdown expansion into the area more than simulated.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 6.3. An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

Table 6.3 Reedia scenario hydrographs and attenuated impacts.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Drawdown @ 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>REEDIA1 Schroeder on Blackwood River</td>
<td>There will be no observable impact for any scenario.</td>
<td>-</td>
</tr>
<tr>
<td>REEDIA2 Hut Pool on Blackwood River</td>
<td>There will be no observable impact for any scenario.</td>
<td>-</td>
</tr>
<tr>
<td>BP58</td>
<td>There will be no observable impact for any scenario.</td>
<td>-</td>
</tr>
<tr>
<td>REEDIA3 Lower Spearwood</td>
<td>Regional growth: 0.1 m eastern split Water Corp: 0.05</td>
<td>25 – 50%</td>
</tr>
<tr>
<td>REEDIA4 Lower Adelaide Brook</td>
<td>Regional growth: 0.15 m eastern split Water Corp: 0.05</td>
<td>25 – 50%</td>
</tr>
<tr>
<td>BP64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.3.4 Conclusions

The Reedia wetlands area will be unaffected by the proposed eastern split Water Corporation borefield. Adelaide Brook would be the most likely area affected by drawdown within the Yarragadee aquifer.

Under the western Water Corporation borefield scenario the summer water table minimum may be around 0.2 m deeper within the Adelaide Brook north of approximately Denny Road. The magnitude of drawdown decreases to the south toward the Blackwood River. South of Denny Road the drawdown may occur upon the flanks of the valley, again decreasing downslope toward the valley floor. It is unlikely that any drawdown in summer water levels will be observed along the brook within 1 km of the Blackwood River. The water table level should fully recover during winter.
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

Drawdown Extent

- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- 5 - 10

- Simulated Hydrograph Sites
- /\ Private Land Use

Reedia - Simulated Water Corporation Eastern Split Borefields Drawdown (layer1, v2.0)

Figure 6.14
6.4 Yarragadee outcrop area (Poison Gully, Milyeannup Brook, Layman Brook)

The Poison Gully area is shown in Figure 6.15, and is situated upon the south-eastern Blackwood Plateau within the Blackwood River valley, and extends from about Layman Brook to Milyeannup Brook (Figure 6.16). The main area of interest is the lower section of Poison Gully which discharges into the Blackwood River. The gully is within a significant valley that is believed to have been an ancient course of the Blackwood River, but is now partially filled with predominantly sand sediments. The area is covered with native vegetation.

The Yarragadee Formation (unit 2) outcrops through the area, with the Vasse and Mowen Members of the Leederville Formation present over the adjoining areas (Figure 6.17). The river banks and lower flood plain of the Blackwood River contain alluvial sand, silt and clay sediments deposited by the river. Alluvial sediments are also associated with the Poison Gully paleovalley, and may be a more extensive cover than shown in Figure 6.17. The Poison Gully alluvium comprises mainly fine-grained sand with silty and clayey layers.

The water table occurs within the Yarragadee Formation, with levels declining toward the Blackwood River into which groundwater discharges. Artesian heads exist along the Blackwood River, increasing from about 5 m at Milyeannup Brook to 7 m at Poison Gully-Layman Brook. The Blackwood River gains approximately 10 GL of flow a year where it crosses the Yarragadee Formation outcrop, while Poison Gully and Milyeannup Brook have significant perennial flow in excess of 20 L/s where they discharge into the Blackwood River (combined annual groundwater discharge of about 1.3 GL). Poison Gully starts flowing (perennial) 3500 m upstream from the Blackwood River, while Milyeannup commences 2500 m from the river. Layman Brook experiences annual flow through winter and early spring, but becomes dry over the summer period. Artesian heads exist between the deeper portion of the Yarragadee aquifer and the surface along the Blackwood River, and up Poison Gully and Milyeannup Brook (Figure 6.18).

The extent of perennial flow within Poison Gully and Milyeannup Brook is related to artesian heads with the underlying Yarragadee aquifer. Consequently, the perennial flow is sensitive to changes in water levels within the aquifer. Within Poison Gully air photography suggests that in the past the extent of perennial flow may have extended several hundred metres further up the gully than currently observed. Artesian heads commence down valley of BP54, where the potentiometric head within the deeper section of the Yarragadee aquifer is approximately equal with ground surface of the gully. The artesian head increases to approximately 2.5 m at BP51, is about 3 m adjacent to BP52 and BP57, 500 m from the Blackwood River, and increases to 7 m at the termination of the gully with the river. The majority of stream flow is gained in the lower-most portion of the gully.

Within Milyeannup Brook artesian heads less than 1 m occur for most of the brook with perennial flow. It is only over the lower 500 m of the brook that larger artesian heads occur, which reach over 5 m at the Blackwood River.
6.4.1 Susceptible areas
The surface environment that may be susceptible to a drawdown within the Yarragadee aquifer are the upper sections of Poison Gully and Milyeannup Brook where there is a shallow water table or stream flow maintained by groundwater discharge. Figure 6.19 shows the depth of water table for the area of Yarragadee outcrop in the Layman Brook – Milyeannup Brook area, indicating that only a small portion of the area has a shallow water table susceptible to drawdown.

The rate of groundwater discharge into the Blackwood River is also likely to reduce.

6.4.2 Simulated impact
Drawdown within the deeper Yarragadee (Layer 7) of about 2.5 m metres is simulated resulting from the eastern split Water Corporation 45 GL borefield. For the western and eastern borefield scenarios the drawdown is 3 to 4 m.

Drawdown at the water table is shown on Figure 6.20 for the eastern split borefield option.

Groundwater discharge to the Blackwood River under the scenario of regional growth with the eastern split borefield reduces by 3 GL/yr after 30 years; regional growth causes 1.3 GL/yr of the reduction and Water Corp causes 1.7 GL/yr. This represents a reduction of 31% of the average 9.7 GL/yr simulated over the calibration period of 1990-2004. At Hut Pool this reduction would be 10% of summer baseflow during the driest month, of which 6% is attributable to the Water Corporation borefield.

Hydrographs for selected monitoring bore sites (PG 1, BP21, BP38) are shown below:

![BP51L1](image)

PG 1 (E365900, N6224700); (Poison Gully/Blackwood River)
6.4.3 Attenuating processes

The large depth of water table for the majority of the Yarragadee outcrop area means that any lowering of the water table will not have an impact upon the surface environment for these areas of deep water table.

Blackwood River
Artesian heads will be maintained along the Blackwood River, although it will be reduced to approximately half of the existing head. The main effect would be a reduction in the rate of upward movement of groundwater. The reduction will be approximately proportional to the reduction in the upward head.
A water table drawdown will be observed up the valley flanks away from the river. This drawdown will mostly occur in areas of deep water table, although the river floodplain terrace has a relatively shallow water table and is within the affected area. The effect upon the floodplain will be significantly attenuated by the river alluvium that limits effects at the water table from the underlying Yarragadee aquifer. The water table and soil moisture within the floodplain alluvium is maintained largely from river-bank storage from the annual winter river flood and runoff/seepage from the valley flanks which infiltrates into the alluvium.

Poison Gully/Milyeannup Brook
A drawdown of up to 3 m is simulated within Poison Gully and Milyeannup Brook, and is similar for all Water Corporation borefield options. This drawdown represents the decline of the water table over the general area, but does not fully translate to drawdown within the valleys where upward potentiometric head gradients currently exist (area of perennial streamflow).

The water table within Poison Gully below the spring source is lower than the adjacent area outside the valley. A transect of monitoring bores across the gully along Blackwood Road (BP56, 51 & 61) shows that the water table declines into the valley. It falls by 0.4 m (April 2005) over 350 m between BP56 and BP51 on the western side of the valley, and 0.22 m between BP61 and BP51 over 220 m on the eastern side of the valley. The water table is interpreted to be about 2 m higher than the gully about 1 km distance from BP51. There is no appreciable difference in the water table across the valley south of the spring source.

The consequence of this water table pattern is that the drawdown will be greatest away from the valley, decreasing to a minimum within the gully. A shallow water table will be maintained within the gully until the drawdown at the water table exceeds the difference between levels below the gully and those outside, which could be up to 2 m. Some drawdown within the gully may still occur. Above the spring source the drawdown within the gully will be similar to that outside.

The spring source for both Milyeannup Brook and Poison Gully will retreat as a result of head drawdown due to future abstraction. Where artesian heads are maintained, groundwater discharge and baseflow will continue, and the water table remain supported. Two-dimensional modelling of Poison Gully predicts a drawdown of about 0.6 m would result from a drawdown of 5 m in the underlying Yarragadee aquifer (URS, 2004a), and cause the spring source of Poison Gully to migrate downstream by about 190 m. Flow emanating from the remainder of the gully will decrease by about 31%, and may become negligible during summer for the section beyond about Blackwood Road. Perennial flow for Milyeannup Brook is likely to retreat to within 500 m of the Blackwood River.

Other factors will also help to attenuate the effects of reduced potentiometric heads in the Yarragadee aquifer. Within Poison Gully there is a concentration of groundwater recharge that cannot be simulated in the regional groundwater model, but must be averaged over a much larger area. This higher local recharge would reduce the magnitude of any drawdown at the water table, although the effect would depend upon the local vertical permeability. Where the vertical permeability is very high, then
the high local recharge may have limited effect or would be effective only during winter.

Alluvial, fine grained sand, silt and clayey sand up to 15 m infill the palaeovalley upon which Poison Gully is formed. These sediments will assist in maintaining a water table if there is a drop in the water table, but mostly the vertical permeability is too high to create much perching. The fine grained lithology has a high moisture retaining capacity, and has potential to maintain wetland type vegetation, similar to the Canebreak Sedgeland described by URS (2004a) where the water table is at 10 m depth.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 6.4. An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

Table 6.4 Blackwood scenario hydrographs and attenuated impacts.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Drawdown @ 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG1 Poison Gully at Blackwood River</td>
<td>Regional growth: 0.9 m Eastern Split Water Corp: 1.3 m</td>
<td>75%</td>
</tr>
<tr>
<td>BP51</td>
<td>Regional growth: 1.2 m Eastern Split Water Corp: 1.85 m</td>
<td>75%</td>
</tr>
<tr>
<td>BP38</td>
<td>Regional growth: 0.9 m Eastern Split Water Corp: 1.4 m</td>
<td>75%</td>
</tr>
</tbody>
</table>

6.4.4 Conclusions

Within Poison Gully and Milyeannup Brook the spring fed base-flow will retreat toward the Blackwood River in response to pumping by the Water Corporation borefield and regional pumping growth. The distance of the retreat for Poison Gully is likely to be several hundred metres, with some impact possible to Blackwood Road. Along Milyeannup Brook baseflow retreat is uncertain, but may be to within 500 m of the Blackwood River. Along Poison Gully the area south of Blackwood Road is most at risk of some drawdown at the watertable, while for Milyeannup Brook it is the section above the Brockman Highway. The sections of the streams within about 500 m of the Blackwood River should not be affected, except for a reduction in the rate of groundwater discharge and stream-flow. The effect caused by the Water Corporation and regional pumping will be approximately equal.

Away from the Blackwood River, and Poison Gully and Milyeannup Brook where baseflow is maintained, some drawdown is likely to be observed beneath the adjacent valley slope, increasing in magnitude away from the valley. These areas, however, also correspond to where the depth of watertable is large.

Along the Blackwood River there should be no discernable effect from the groundwater pumping apart from reduced discharge which will decrease
approximately 30% over the 30 years. As a portion of river flow is derived up-river of the outcrop area, the total summer baseflow through the area should not be reduced more than about 20%.
Poison Gully - Topography
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

AUTHOR: J. Vine

DATE: October 2005

COORDINATE SYSTEM: MGA94 - Zone 50

Kilometers

1 0.5 0 1 2 3

Poison Gully - Surface Geology

Poison Gully Geology
- Poison Gully Alluvium
- Blackwood River Alluvium
- Quindalup Member
- Moven Member
- Vasse Member
- Bunbury Basalt
- Parmelia Sand
- Parmelia Shale
- Yarragadee Unit 1
- Yarragadee Unit 2
- Boreholes

Figure 6.17

PROJECT No: r302
DATE: October 2005
COORDINATE SYSTEM: MGA94 - Zone 50
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

Elevation Artesian Head

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10

Boreholes (>200m depth)

Poison Gully - Artesian Heads

Figure 6.18
Poison Gully - Depth to Watertable

Depth to Watertable

- 0 - 1
- 1.001 - 3
- 3.001 - 5
- 5.001 - 7
- 7.001 - 10
- 10.001 - 15
- 15.001 - 20
- 20.001 - 30
- 30.001 - 50
- 50.001 - 100

Boreholes
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

Poison Gully - Simulated Water Corporation Eastern Split Borefields Drawdown (layer1, v2.0)

Figure 6.20
7 Scott Coastal Plain local area impacts

Local drawdown impact areas identified upon the Scott Coastal Plain are associated with the superficial formations where they overlie the Yarragadee Formation in the eastern part of the plain, and over the Vasse Member of the Leederville Formation in the west. Outcrop of the Yarragadee Formation on the south-eastern margin of the Blackwood Plateau, adjacent to the eastern Scott Coastal Plain is also part of the eastern Scott area of interest. The main risk arising from drawdown at the watertable would be the effect that this would have on wetlands present across the plain, especially the eastern portion, and includes Lake Jasper and Lake Quitjup.

7.1 Scott Coastal Plain – western

The western portion of the Scott Coastal Plain is of interest (Figure 7.1) where the Vasse Member of the Leederville Formation sub-crops the superficial formations. The Scott Coastal Plain is situated between the Blackwood Plateau and Southern Ocean, and upon its western portion is up to 15 km wide, comprising of a relatively flat plain sloping toward the coast with a series of dunes adjacent to the coast (Figure 7.2). The plain experiences extensive inundation during winter, which is drained by the Scott River and tributary streams and constructed drains.

The plain is covered with Quaternary age superficial sediments up to about 20 m thick. The sediments comprise several formations as shown on Figure 7.3. Adjacent to the coast is the Tamala Limestone with overlying dune sand of the Safety Bay Sand, while inland surface sand overlies the Guildford Formation. The Guildford Formation comprises dominantly sand on the Scott Coastal Plain, with some silt, clay and peat present. Coffee Rock is extensively developed within some areas of the Guildford Formation.

Groundwater flow is toward the coast in each of the aquifers (superficial aquifer, Leederville aquifer, Yarragadee aquifer). Upward potentiometric head gradients exist between the Yarragadee aquifer and overlying aquifers within the drainage area of the Scott River. Locally, artesian flows occur from the Yarragadee aquifer and Leederville aquifer.

7.1.1 Susceptible areas

There may be some susceptibility for drawdown at the water table resulting from reduced potentiometric heads in the Yarragadee aquifer where the Leederville aquifer is exposed at the surface upon the south-western margin of the Blackwood Plateau, and where the Leederville aquifer is overlain by the superficial formations.

7.1.2 Simulated impact

There is no discernable drawdown simulated at the watertable (layer 1) by SWAMS v.2.0 upon the western Scott Coastal Plain for the eastern and eastern split
Water Corporation borefield scenarios. There is a small drawdown of up to 0.25 m on the south-western margin of the Blackwood Plateau (Figure 7.4).

For the western borefield option the simulated drawdown is mostly less than 0.25 m, but does reach up to 0.5 m west of Dennis Road, and 1 to 2 m on the south-western margin of the Blackwood Plateau. A small area of high drawdown is shown above the coastal plain near Milyeannup Coast Road.

Hydrographs for selected monitoring bore sites (WSc 1, WSc 2, SC10) are shown below:

![WESTSCT1](image1)

WSc 1 (E349200, N6215020); Paget Road

![WESTSCT2](image2)

WSc 2 (E344850, N6208930); Governor Broome Road;
7.1.3 Attenuating processes

The hydraulic connection between the Yarragadee aquifer and the water table is considerably less than upon the eastern Scott Coastal Plain, due to extensive clay layers present within the intervening Leederville Formation. An exception to this is the northern part of the plain in the area of Scott River Road, about Beenup, where the Leederville Formation is relatively thin and lacks the extensive clay layers overlying the Lesueur aquifer.

A significant portion of the western Scott Coastal Plain receives little groundwater recharge or has net discharge as a result of the upward potentiometric head gradients. In addition, extensive clearing and drainage of the western Scott Coastal Plain means that there is considerable water rejected as groundwater recharge. The combination of these processes will buffer drawdown at the water table, which has not been incorporated in the SWAMS v.2.0 regional model. There is possibly in the order of 200 to 300 mm per year of additional recharge available, which is equivalent to replenishing up to 1.5 m of drawdown. A deeper summer minimum water table level is likely in some areas, although the effect from the Water Corporation 45GL scheme (both options) may not be measurable. Winter maximum water table levels would recover to normal levels.

Much of the area upon the coastal plain north of the Scott River with the highest simulated drawdown (west of Dennis Rd) corresponds to ironstone (also known as coffee rock or bog iron ore) occurrence. The coffee rock is extensively developed upon this part of the coastal plain and provides an effective confining unit. Artesian flows have been observed from farm bores penetrating the coffee rock in the vicinity of the Scott River. It is therefore unlikely that any drawdown at the water table will be observed in the area of extensive coffee rock. A small group of wetlands (semi-permanent?) that may be vulnerable are situated upon location 4263 (2.5 km NW of
Dennis Rd & Governor Broom Rd intersection) in an area surrounded by coffee rock, and may represent a hole through the unit where groundwater discharge is occurring.

The south-western margin of the Blackwood Plateau has a simulated drawdown at the water table. Evapotranspiration and stream-flow into the area has not been incorporated into the model, and both will act to minimise the actual drawdown at the water table experienced resulting from pumping from the Yarragadee aquifer. A shallow clay lithology would act to further restrict drawdown at the water table and assist in perching groundwater above these effects. However, the local lithology is not known and so is not included in model parameters.

The small area of high drawdown near Milyeannup Coast Road represents an interpreted hole through the Bunbury Basalt and Parmelia Shale that allows drawdown within the Yarragadee aquifer to propagate to the surface units. Similar issues apply at this location as with the south-western margin of the plateau where local processes will result in significantly less drawdown to that predicted by the model.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 7.1. An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

Table 7.1 Western Scott Coastal Plain scenario hydrographs and attenuated impacts.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Drawdown @ 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSc1 South-western margin of plateau</td>
<td>Regional growth: 0.9 m Eastern Split Water Cor: 0.2 m</td>
<td>25 – 50%</td>
</tr>
<tr>
<td>WSc2 Governor – Broome Rd</td>
<td>Regional growth: 0.4 m Eastern Split Water Cor: 0.06 m</td>
<td>0 – 50%</td>
</tr>
<tr>
<td>SC10</td>
<td>Regional growth: 0.65 m Eastern Water Cor: 0.06 m</td>
<td>75%</td>
</tr>
</tbody>
</table>

7.1.4 Conclusions

There should be no drawdown at the water table from the eastern or eastern split borefield options, while some effect is possible resulting from regional growth and the western Water Corporation borefield option. Any drawdown upon the coastal plain will be dominated by local pumping, and be highly variable across the plain depending on the distribution of coffee rock. Where drawdown effects from the regional growth scenario do propagate to the surface the magnitude of water table decline is likely to be up to 0.5 m. The most sensitive area to pumping may be a small group of wetlands upon Location 4263.

The southern flank of the Blackwood Plateau may also experience a water table drawdown of around 0.5 m, of which about 0.1 m would be due to the Water Corporation pumping. There may be considerable variation in the distribution of the drawdown depending on abundance and extent of clay in the sub-surface.
Western Scott Coastal Plain - Areas of Interest

Figure 7.1
Western Scott Coastal Plain - Location

Figure 7.2
Western Scott Coastal Plain - Surface Geology

Figure 7.3
Western Scott Coastal Plain - Simulated Water Corporation Eastern Split Borefields Drawdown (layer1, v2.0)

Figure 7.4
7.2 Scott Coastal Plain - eastern

The area of interest upon the eastern Scott Coastal Plain is shown on Figure 7.5. The eastern Scott Coastal Plain, situated between the Blackwood Plateau and Southern Ocean, comprises a relatively flat plain sloping toward the coast, with a large coastal dune ridge present adjacent to the coastline (Figure 7.6). Extensive wetlands exist upon the coastal plain, especially behind the coastal ridge, including Lake Jasper and Lake Quitjup. The northern portion of the plain has been extensively cleared of native vegetation for agricultural activities, while the southern portion is mostly covered by the D'Entrecasteaux National Park.

The coastal plain has a cover of superficial sediments typically 20 to 30 m thick, but which is up to about 200 m thick beneath the coastal ridge. The superficial formations comprise several units consisting of mainly sand with variable amounts of silt and clay, with limestone adjacent to the coast (Figure 7.7). The Yarragadee Formation subcrops the superficial formations approximately between Black Point and Lake Jasper (Figure 7.7). Elsewhere, the superficial formations overly the Vasse Member of the Leederville Formation.

7.2.1 Susceptible areas

Areas with the greatest potential to experience a fall in the water table resulting from a drawdown in the underlying potentiometric head in the Yarragadee aquifer are upon the coastal plain where the superficial formations directly overlie the Yarragadee Formation, and upon the adjacent margin of the Blackwood Plateau with outcropping Yarragadee Formation.

7.2.2 Simulated drawdown

The simulated drawdown for the water table (layer 1) in the regional groundwater model SWAMS v2.0 is shown on Figure 7.9 for the eastern split Water Corporation 45 GL borefield. The largest drawdown at the water table is just north of the coastal plain in the area of Yarragadee Formation outcrop, where a simulated decline of about 1 m is predicted. Upon the coastal plain the simulated drawdown for the water table (layer 1) decreases to the south to around 0.1 m adjacent to the coast. Drawdown at Lake Jasper is less than 0.2 m.

The simulated drawdown in the deeper Yarragadee aquifer (layer 7) is a little greater than at the water table. Beneath the eastern Scott Coastal Plain it is simulated to be about 1 m in the north, decreasing to about 0.2 m at the south coast. Beneath Lake Jasper the drawdown is approximately 0.4 m in layer 7.

Hydrographs for selected monitoring bore sites (SC8, SC16, SC19, ESc 1, ESc 2, SC21, Lake Jasper) are shown below:
SC19 (E 371755, N 6199819)

ESc 1 (E370845, N6195200); Northern Lake Quitjup
ESc 2 (E378040, N6193000); Northern margin of Lake Jasper:

SC21 (E 377319, N 6190681); Southern margin of Lake Jasper
7.2.3 Attenuating processes

**Depth to water table**
There is a large depth to water table beneath the coastal dune ridge. In this area there will be no dependence of vegetation on the water table, so that any drawdown at the water table will have no surface impact. A large depth to the water table also occurs on the northern margin of the Yarragadee outcrop. At BP14 the water table is measured at about 44 m depth. The water table depth shallows toward the coastal plain.

**Perched groundwater**
The Vasse Member of the Leederville Formation overlies the Yarragadee Formation north of the outcrop area. In this area there is perched groundwater within Leederville aquifer, as observed at BP33 and BP20. Therefore, the simulated drawdown at the water table in this area will not occur as the water table is hydraulically disconnected from the underlying Yarragadee aquifer.

**Reject water**
There is significant rejected water upon the coastal plain behind the coastal ridge and the adjoining area of Yarragadee outcrop. This water is available for groundwater recharge, but cannot infiltrate as the aquifer becomes full during winter. The excess water drains from the area, much of it ponding behind the coastal ridge, or discharging via drains into the Scott River and Donnelly River. The areas of inundation dissipate through summer through evaporation and evapotranspiration, and seepage discharge into the superficial aquifer, with some water permeating down to the Yarragadee aquifer.

By lowering the water table upon the coastal plain additional storage is made available for winter recharge, allowing greater groundwater recharge to occur before water is rejected. Practically, this will result in a deeper water table minimum at the
end of summer, but the water table will recover through winter to levels close to previous maxima. The simulated drawdown will approximately represent the increased depth of the summer minimum water table. This effect is seen in monitoring bore SC16A, which has shown a deeper summer minimum (by about 0.7 m) since 2003 probably in response to pumping from irrigation bores about 3 km distance, but with winter water levels returning to peak levels observed over the longer term.

To counteract simulated drawdown, there would be a need to induce approximately an additional 80mm of recharge (adopting an effective porosity of 20%), which would be reasonable for the quantity of available reject water. Inducing a greater portion of rainfall as groundwater recharge will result in reduced drainage discharge from the area. There may also be some reduction in the area of inundation, although this will be partially buffered by an associated reduction in evaporation and evapotranspiration. The maximum area inundated in winter is likely to be within the range observed historically, but would be less than is typical under current pumping conditions for equivalent rainfall.

Lithology
The hydraulic connection between the Yarragadee aquifer and water table is reduced in areas where silt and clay beds occur within the superficial sediments. Even where silt/clay sediments are present they may not be sufficiently impermeable to effectively confine and isolate the Yarragadee aquifer from the water table (there would be little recharge here otherwise), but will reduce the magnitude of water table drawdown and should allow sufficient retardation during winter for more typical maximum water levels. This situation occurs about Lake Jasper. Paired monitoring bores JS021 (superficial) and JS023 (Yarragadee) situated about 2km NW of Lake Jasper (reported by Rockwater) show water levels within the superficial aquifer unresponsive to changes within the underlying Yarragadee aquifer.

In local areas with coffee rock the water table is typically isolated from deeper groundwater. In areas where the water table is supported above coffee rock or peat deposits, there is unlikely to be any drawdown impact at the water table. The distribution of coffee rock and peat is, however, poorly defined, but they are known to occur extensively, but discontinuously, across the plain.

Where the superficial aquifer is underlain by the Leederville Formation (Vasse Member), the confining units within the formation will retard the migration of drawdown from the underlying Yarragadee aquifer to the water table. For the drawdown simulated within the Yarragadee aquifer beneath the eastern Scott Coastal Plain, there should be no identifiable drawdown at the water table due to the low magnitude of the drawdown and the buffering effects of recharge, evaporation and evapotranspiration.

Land-use
The majority of the northern portion of the eastern Scott Coastal Plain is freehold property that is predominantly cleared for agricultural activities. Ecosystems which were potentially sensitive to a fall in the water table have been mostly removed.

A summary of drawdown at hydrograph sites after 30 year scenarios for regional growth and the eastern split Water Corporation borefield are presented in Table 7.2.
An estimate is made of the probable portion of simulated drawdown that will eventuate after attenuating processes.

Table 7.2 Eastern Scott Coastal Plain scenario hydrographs and attenuated impacts.

<table>
<thead>
<tr>
<th>Hydrograph site</th>
<th>Drawdown @ 30 years</th>
<th>Probable portion of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC8</td>
<td>Regional growth: 1.2 m</td>
<td>50 – 75%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.8 m</td>
<td></td>
</tr>
<tr>
<td>SC16</td>
<td>Regional growth: 0.9 m</td>
<td>25 – 50%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.26 m</td>
<td></td>
</tr>
<tr>
<td>SC19</td>
<td>Regional growth: 0.7 m</td>
<td>25 – 50%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.5 m</td>
<td></td>
</tr>
<tr>
<td>ESc1 North of Lake Quitup</td>
<td>Regional growth: 0.45 m</td>
<td>25 – 50%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.25 m</td>
<td></td>
</tr>
<tr>
<td>ESc2 North of Lake Jasper</td>
<td>Regional growth: 0.22 m</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.16 m</td>
<td></td>
</tr>
<tr>
<td>SC21</td>
<td>Regional growth: 0.28 m</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.22 m</td>
<td></td>
</tr>
<tr>
<td>LJ1</td>
<td>Regional growth: 0.16 m</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Eastern Split Water Corp: 0.15 m</td>
<td></td>
</tr>
</tbody>
</table>

7.2.4 Conclusions

Similar drawdown results from the three Water Corporation borefield options, with the drawdown a little greater for the eastern borefield. The greatest drawdown is upon the southern margin of the Blackwood Plateau where the Yarragadee Formation outcrops. In this area the water table is likely to decline by about 0.7 m, with up to another 1.2 m drawdown resulting from regional pumping growth. The combined effect could be close to 2 m drawdown.

The magnitude of drawdown decreases toward the south. Upon the coastal plain the likely impact is for the summer water table minimum to be deeper by about 0.2 m due to Water Corporation pumping and by about 0.7 m as a result of regional pumping. The water table will recover during winter to current maximum levels, or close to those levels. Areas with extensive peat or coffee rock will perch groundwater and not be prone to a water table decline due to pumping from the Yarragadee aquifer.

About Lake Jasper, the combined regional and Water Corporation pumping is likely to cause summer water table levels to decline by up to 0.2 m, with almost full recovery during winter. There will be no impact on water levels along the Donnelly River.
THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

D'Entrecasteaux National Park

SM27

SC8

Kilometers

Quitjup

Eastern Scott Coastal Plain - Location

Figure 7.6

SM24

BP31

BP14

BP18

BP20

BP33

SC16

D'Entrecasteaux National Park

Lake Agnes

SC17

SC19

SC19

SC20

SC22

Boreholes

D'Entrecasteaux National Park

AUTHOR: J. Vee

PROJECT No: R302
DATE: October 2005
COORDINATE SYSTEM: MGA94 - Zone 50

2 1 0 2 4 6

1:150,000

Kilometers
8 Summary

SWAMS v2.0 has been used to simulate drawdown at the watertable resulting from regional growth and three possible 45GL/a Water Corporation borefields over 30 year scenarios. Local area implications from the simulated drawdown must be considered with regards to model limitations and physical attributes, which generally result in reduced drawdown to that simulated. Limitations of the regional groundwater model include averaging due to scale, and the inability to include surface hydrology that constitutes water rejected from groundwater recharge. Physical attributes are aquitards and areas of perched groundwater not adequately represented in the model that restrict the effects at the water table, and areas of deep watertable where any drawdown has no surface implications. Consideration of these attributes allows the identification of those areas where the potential for surface impacts resulting from pumping from the Yarragadee aquifer are greatest, and some qualification of what those impacts will be relative to those simulated.

The areas with potential for some measurable effect at the water table are: eastern Swan Coastal Plain about Bunbury, St John Brook and adjacent Blackwood River valley, Rosa Brook, Blackwood River and tributaries between Adelaide and Chapman Brooks (including Reedia area), Blackwood River valley and tributaries within the Yarragadee outcrop area between Milyeannup Brook and Layman Brook (including Poison Gully), Western Scott Coastal Plain, and Eastern Scott Coastal Plain.

Within the Bunbury area drawdown resulting from Regional growth and the eastern split Water Corporation borefield is likely to be a little over 1 m after 30 years, compared to about 2 m simulated. No significant drawdown is anticipated further west in the Tutunup area and Wonnerup wetlands. Reduced groundwater throughflow to the ocean will result in some inland movement of the saltwater interface, estimated to be around 280 m in response to combined regional growth and Water Corporation pumping, but this will vary in response to local pumping.

Baseflow of the Blackwood River and tributaries sustained by groundwater is simulated to decrease by 20%, with around 30% decrease from the Yarragadee Formation where it is cut by the river. This represents about 0.48 GL/month reduction of flow at Hut Pool, and about 0.25 GL/month reduced discharge from the Yarragadee Formation. Approximately half of the reduced baseflow is attributable to the Water Corporation borefield. The effect of reduced groundwater discharge into the river is negligible compared to normal river flow, except during late summer when river flow is often sustained entirely by baseflow. A reduction in baseflow will slow the flushing of salt from river pools during summer, resulting in river salinity about 14% greater than currently observed.

Upon the Blackwood Plateau, most scenarios have no discernable impact at St Jon Brook, Rosa Brook and the Reedia wetlands area. Under the eastern split Water Corporation borefield scenario where water is drawn from unit 1 of the Yarragadee Formation, some reduction in baseflow during summer may occur, with lowering of pool levels up-stream of Barrabup Pool, although Barrabup Pool should not be effected. At Rosa Brook significant drawdown of several metres only occurs upstream from the convergence of the two main sub-catchments with the western Water
Corporation scenario. All scenarios have a similar impact in the Poison Gully/Milyeannup Brook area, where the spring fed base-flow for these streams will retreat toward the Blackwood River in response to pumping by the Water Corporation and regional growth. The section of the streams within about 500 m of the Blackwood River, and the Blackwood River itself, should not be effected, except for a reduction in stream flow. Some drawdown at the watertable will occur away from these areas, but corresponds to areas of deep watertable, except adjacent to the valleys.

The western Scott Coastal Plain should not be effected by either to the eastern Water Corporation borefield scenarios. Drawdown resulting from regional pumping growth is likely to be up to 0.5 m in some areas, while the western Water Corporation borefield may cause an additional 0.25 m decline, increasing to over 1 m on the south-western margin of the plateau. Upon the eastern part of the Scott Coastal Plain each of the Water Corporation borefields cause a similar, with the eastern borefield having a marginally greater impact. Drawdown is greatest upon the southern margin of the Blackwood Plateau where the watertable is likely to decline by about 0.7 m, with another 1.2 m drawdown resulting from regional (mostly local) pumping growth. The magnitude of drawdown decreases south, so that upon the coastal plain it is about 0.2 m from the Water Corporation and 0.7 m from regional pumping. Full recovery of the watertable is likely over winter with the capture of additional recharge water. A combined drawdown of up to 0.2 m in the Lake Jasper area may occur.
9 References

URS, 2004a, Hydrogeological assessment of groundwater dependent ecosystems of the Blackwood River area.

URS, 2004b, Establishment of interim ecological water requirements for the Blackwood groundwater area, WA – Stage 2.

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