



Government of **Western Australia**
Department of **Water**

Management triggers and responses for groundwater-dependent ecosystems in the South West groundwater areas

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Department of Water

Water resource allocation planning series

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Summary

This document describes an adaptive management framework for the environmental water provisions for specified groundwater-dependent sites for the *South West groundwater areas allocation plan*. It sets specific groundwater level or discharge triggers (or thresholds) and identifies the appropriate management responses when triggers are reached. This feedback mechanism enhances management of selected high-value groundwater-dependent ecosystems across the plan area and will inform the next phase of allocation planning. This trigger and response document is accompanied by a monitoring program, and both documents complement the *South West groundwater areas allocation plan*.

The allocation plan identifies groundwater that may be potentially available for use and the measures in place to protect groundwater-dependent features in the Bunbury, Busselton–Capel, Blackwood and part of the South West Coastal groundwater areas.

The Department of Water is implementing the monitoring program and the trigger and response framework to ensure that the taking and use of groundwater does not cause unacceptable impacts to identified groundwater-dependent values. The program to monitor the groundwater resource and the environmental condition of representative groundwater-dependent ecosystems within the allocation plan area has been established and is described in *South West groundwater areas monitoring program* (Department of Water 2008). This management framework supports the interpretation of the monitoring data against triggers (or thresholds) and guides an appropriate response.

The management framework applies to selected groundwater-dependent ecosystems (ten wetlands and the lower Blackwood River) in the South West groundwater areas.

The sites have been selected from representative groundwater-dependent ecosystems (GDE) identified as part of the development of the groundwater allocation plan. Resource condition monitoring (vegetation condition, groundwater level and in some cases, groundwater quality monitoring) was done at approximately forty of these sites across the plan area (Figure 1). Work to determine ecological water requirements (EWR) (generally set as a groundwater level criteria) has also been carried out at some of these sites.

Sites used for this management framework are those where sufficient monitoring and EWR data were available to apply a trigger–response framework. The sites and their associated trigger values are listed in tables 1 and 2.

The management responses to be applied to the wetland sites are shown in Figure 2 and Figure 3, and to be applied to the Blackwood River in Figure 4. Specified management actions are taken when:

- an environmental water requirement trigger is reached
- a declining water table trend or sudden abnormal change in water regime is detected
- unacceptable impacts to water quality are detected
- a notable decline in ecological condition is detected
- summer flow at specified gauging stations breaches historical minima (in the case of the Blackwood River).

The specified management responses range from further analysis of the monitoring data to reductions in abstraction if unacceptable impacts are directly linked to local or regional pumping.

Our understanding of the relationships between the GDE and the hydrogeology, and between the local water regime and the site ecology is being improved as we continue our investigations in these areas. Several major studies are either underway or will commence in 2008/2009 with funding through the *Australian Government Water for the Future's – Water Smart Australia program*. These investigations will result in an improved management framework for the next revision of the *South West groundwater allocation plan*.

1 Background

A groundwater allocation plan has been produced for the South West groundwater areas. The plan identifies groundwater that may be potentially available for use and the measures in place to protect groundwater-dependent features in the Bunbury, Busselton–Capel, Blackwood and part of the South West Coastal groundwater areas.

The *South West groundwater areas allocation plan* identifies the groundwater allocation limits for each aquifer and groundwater subarea within the plan boundary (Figure 1). It also identifies the policies and rules that apply to groundwater licensing so as to avoid unacceptable impacts to existing groundwater-dependent ecological, social or economic values in the region.

To ensure the allocation limits and licensing policies are achieving the objectives of the plan, monitoring programs for groundwater levels, groundwater quality, ecological condition (environmental water provisions) and some groundwater-dependent surface water features have been established. The *South West groundwater areas monitoring program 2008* supports the interpretation of the monitoring data against environmental water provision triggers for selected high-value groundwater-dependent ecosystems across the plan area and guides an appropriate response.

While only a limited number of sites have been specified for application of the trigger and response framework, the application will be extended to other groundwater-dependent ecosystems over the next 12 months as more data becomes available, and again over the next 2–4 years prior to the completion of the statutory groundwater allocation plan.

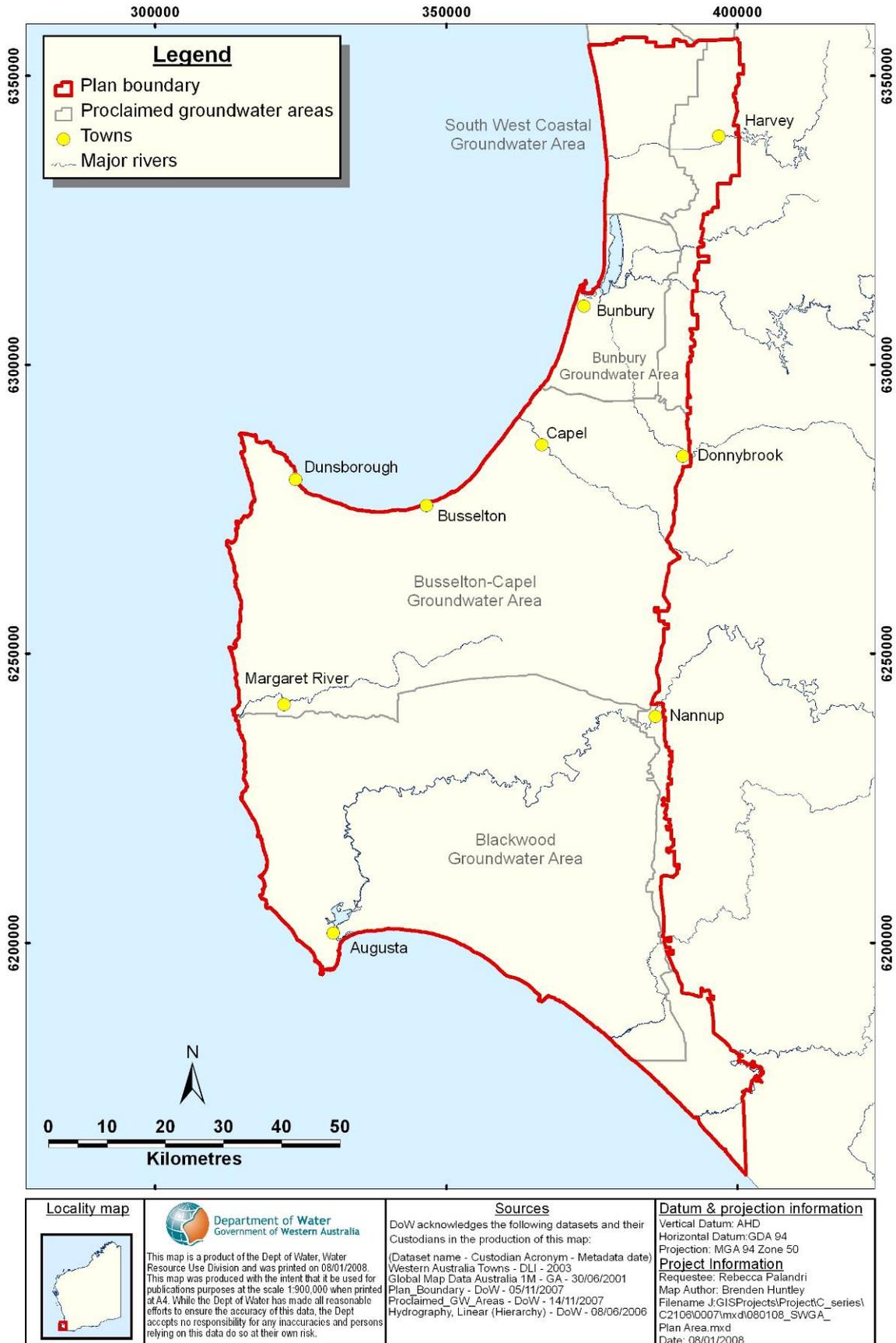


Figure 1 The plan area

2 Trigger-response criteria and management framework

As part of the groundwater allocation planning process, a variety of studies have been conducted over the past five years to:

- identify potential groundwater-dependent ecosystems (GDE)
- ascertain which potential GDE may be at risk of impact due to draw downs caused by current and future groundwater pumping at the local or regional scale
- select a number of high conservation value representative GDE for a local-scale evaluation of risk using the available numerical groundwater models
- determine the ecological water requirements of some of the representative GDE in high and lower risk areas through more detailed, site-specific investigation.

The above work (to December 2006) has been summarised in Hyde (2006), *A summary of investigations into the determination of ecological water requirements for the South West groundwater areas*, Department of Water, Perth.

The work to determine ecological water requirements (EWR) at representative GDE sites involved shallow drilling, establishment of vegetation transects, and ongoing monitoring of water levels, water quality (in some instances) and vegetation condition. This work is being carried out in stages across the plan area. As such, the quantity of available data varies from site to site depending on when investigation and monitoring began.

While triggers and responses have been recommended for a limited number of sites at this point in time, monitoring and evaluation is continuing at other representative GDE sites where shallow bores and vegetation transects have been established (see Department of Water, 2008) and work is continuing to establish new bores and vegetation transects at other GDE sites. Whether or not a trigger and response has been specified, if a decline in ecological health and/or a notable decline in groundwater level occur at any of the monitored GDE, appropriate actions will be taken to investigate the cause and a suitable management response will be developed for that site. This information will be included in the Department of Water's annual reporting associated with the groundwater management plan.

The sites where a management trigger and response framework (figures 2 to 4) will apply for the initial period of this plan are listed in Table 1 and Table 2. Specific triggers and responses will be developed for other GDE reference sites in the following two to three years when sufficient monitoring data is collected at those locations.

Table 1 Trigger–response (wetland) sites, their associated monitoring bore and the ecological water requirement (EWR) trigger level.

Site Name	Groundwater Area	Groundwater Subarea	Monitoring Bore Name	EWR trigger (m AHD)
Kemerton	Bunbury	Kemerton Industrial Park	EW1	7.55
Hay Park	Bunbury	Bunbury West	EW2	2.72
Harewoods Rd	Bunbury	Bunbury West	EW5	5.72
Ludlow Rail Reserve	Busselton–Capel	Busselton–Capel	BN10S	7.50
Ruabon Reserve	Busselton–Capel	Busselton–Capel	EW10	17.16
Ambergate Reserve	Busselton–Capel	Busselton–Capel	BN32S	16.85
Poison Gully	Blackwood	Blackwood Plateau South	Poison Gully – Wetland	30.47
Reedia	Blackwood	Blackwood Plateau South	BP64B	23.99
Black Point Rd	Blackwood	Jasper	Black Point Rd	42.69
Lake Jasper	Blackwood	Jasper	EW8	38.50

Table 2 Trigger–response (surface water) sites and the associated management trigger.

Site name/Location	Groundwater area	Subarea	Management trigger
Blackwood River – Darradup Gauging Station	Blackwood	Blackwood Plateau – South	Flow below historical minimum during months of summer baseflow
Blackwood River - Hut Pool Gauging Station	Blackwood	Blackwood Plateau – South	Flow below historical minimum during months of summer baseflow

Figure 2 and Figure 3 refer to reviews of water quality monitoring data. Currently there is no regular regional groundwater quality monitoring program in operation in the south west. However, some water quality data may be available in the area of interest that has either been collected by the department as part of a specific investigation program or has been collected by licensees as part of their licence conditions. This may enable some assessment of local water quality. Or, if no data is available, there may be a need for water quality samples to be taken and analysed if declines in the water table and/or environmental condition are such that there is concern that the water quality may have been significantly degraded. Currently a Statewide water quality monitoring framework is being prepared by the department and regular water quality monitoring at particular GDE sites may be implemented in the future if warranted.

Table 3 Wetland sites where preliminary EWR criteria have been established and where the (wetland) management trigger–response framework should be applied

Site name	Groundwater area	Groundwater subarea	Monitoring bore name	Monitoring bore location	
				Easting	Northing
Kemerton	Bunbury	Kemerton Industrial Park	EW1	384906	6323330
Hay Park	Bunbury	Bunbury West	EW2	373905	6307073
Harewoods Rd	Bunbury	Bunbury West	EW5	372390	6302405
Ludlow Rail Reserve	Busselton–Capel	Busselton–Capel	BN10S	359579	6280089
Ruabon Reserve	Busselton–Capel	Busselton–Capel	EW10	361191	6276284
Ambergate Reserve	Busselton–Capel	Busselton–Capel	BN32S	344961	6265814
Poison Gully	Blackwood	Blackwood Plateau South	Poison Gully – wetland	366758	6223601
Reedia	Blackwood	Blackwood Plateau South	BP64B	344695	6224241
Black Point Rd	Blackwood	Jasper	Black Point Rd	374002	6202371
Lake Jasper	Blackwood	Jasper	EW8	379690	6190381

Table 4 Groundwater-dependent surface water sites where site-specific management trigger–response frameworks should be applied

Site name	Groundwater Area	Groundwater subarea	Gauging station number	Gauging station location	
				Easting	Northing
Darradup (Blackwood River)	Blackwood	Blackwood Plateau South	609025	372580	6229055
Hut Pool (Blackwood River)	Blackwood	Blackwood Plateau South	609019	342488	6226448

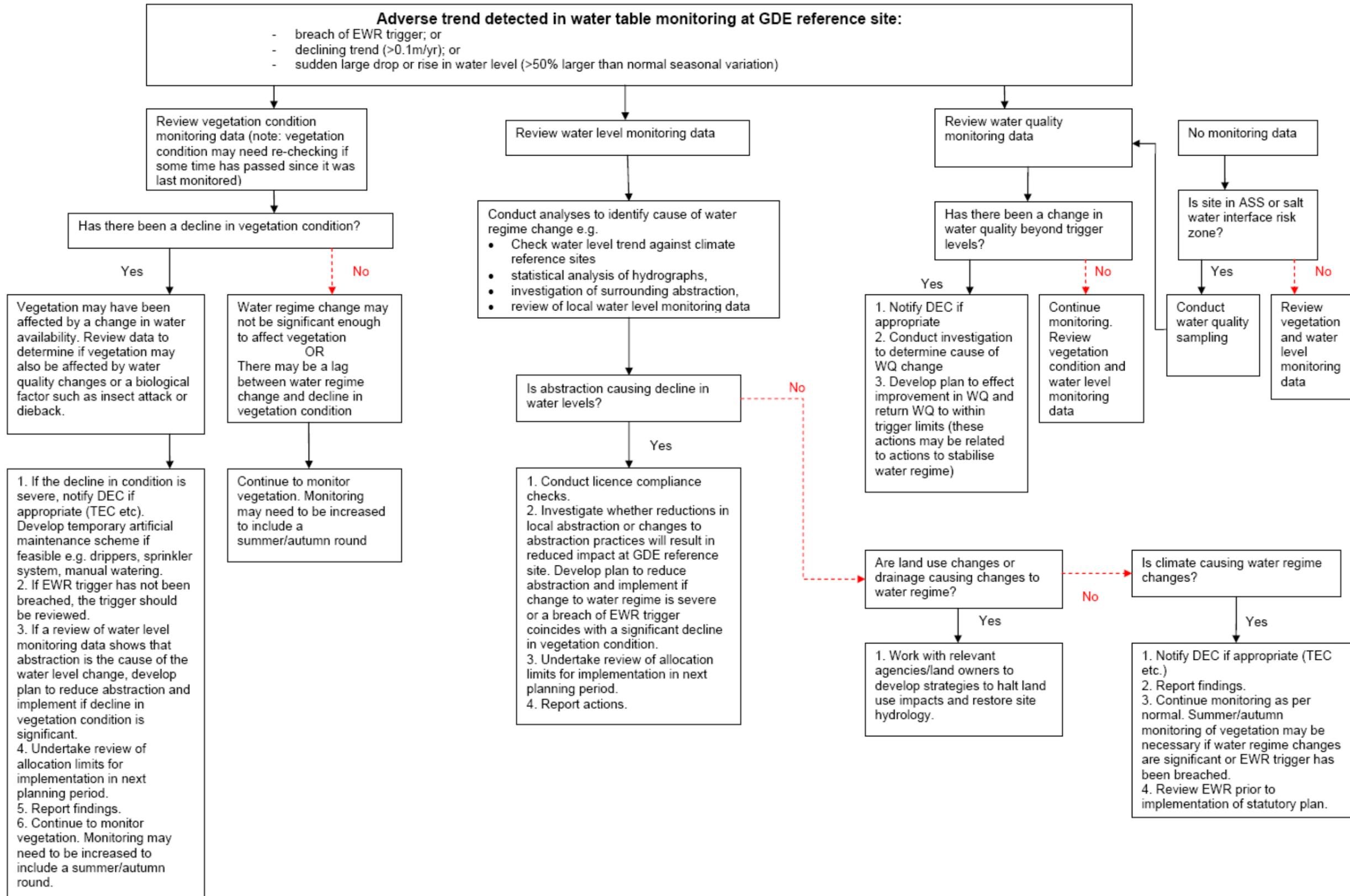


Figure 2 Management trigger and response framework — wetland vegetation

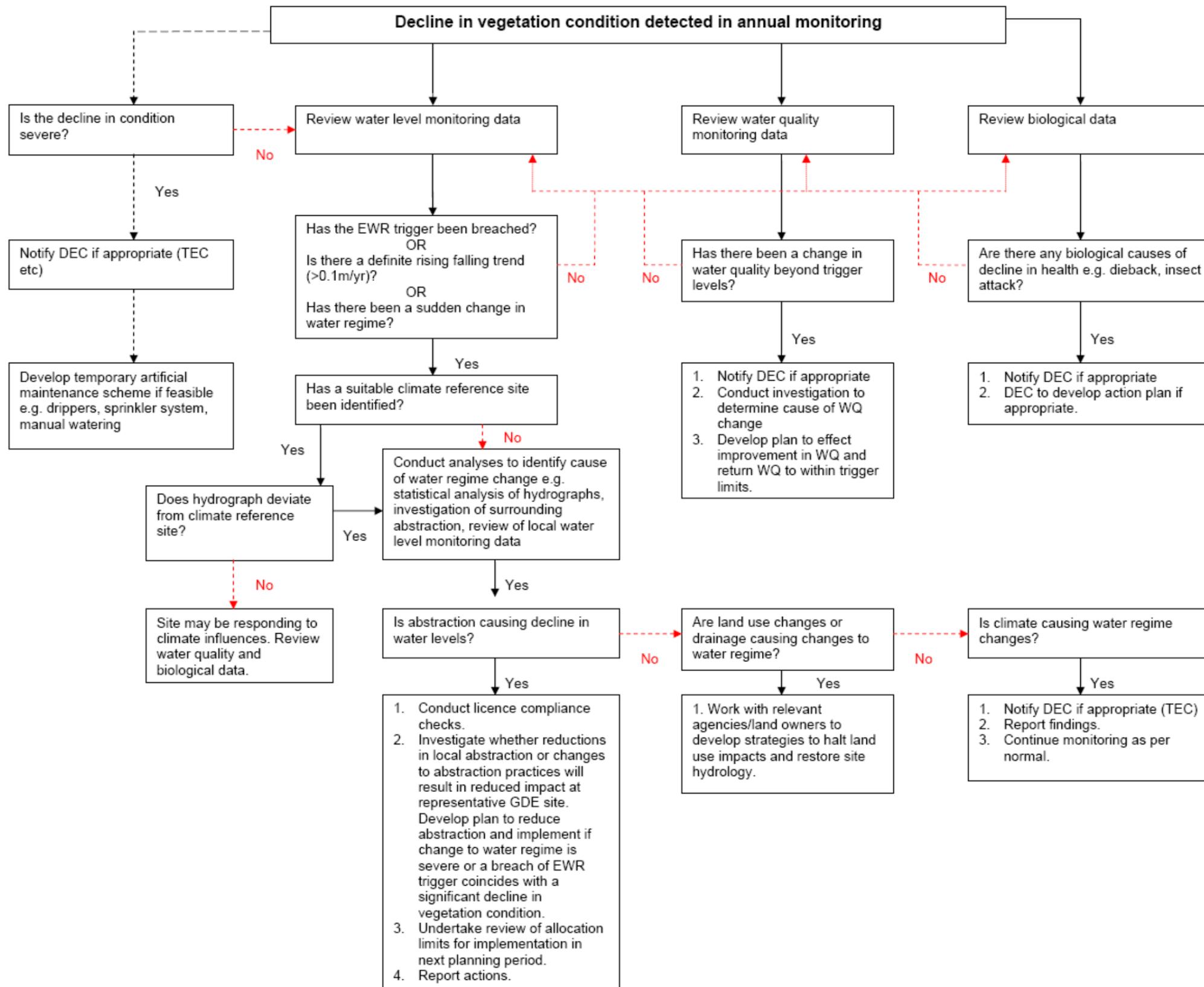


Figure 3 Management trigger and response framework — wetland water regime

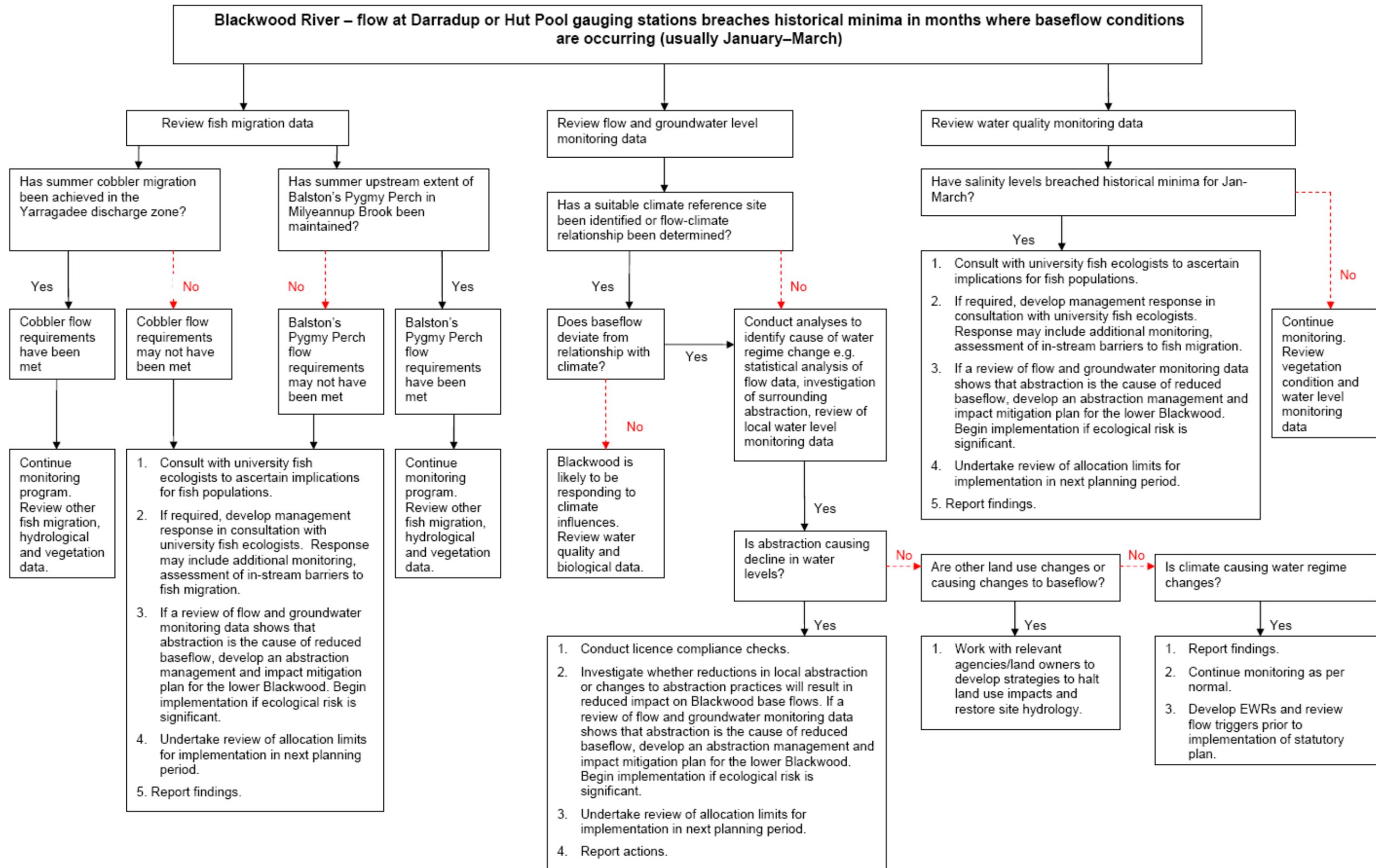


Figure 4 Framework for management of lower Blackwood River baseflow

2.1 Assessing the likelihood of activating EWR triggers in the future

Numerical groundwater modelling was used to give an estimation of the amount of water table draw down that might be anticipated at the selected trigger–response sites. This gave an indication of if and when the preliminary EWR trigger may be exceeded at a site and whether the management framework may need to be applied in the short to medium term.

The *South West groundwater areas allocation plan* proposes some significant changes to existing allocation limits in the region. Limits have been substantially reduced, particularly for the Yarragadee aquifer, and the Superficial and Leederville aquifers in the Busselton–Capel and Bunbury groundwater areas. The new allocation limits still allow for continuation of current licensed entitlements (and domestic and other uses that are exempt from licensing) plus some growth in Superficial and Leederville abstraction in the future, with a reserve of Yarragadee water for future town water supplies in the region.

The proposed allocation limits for the three major aquifers are 65.68 GL/yr (Superficial), 40.15 GL/yr (Leederville) and 87.50 GL/yr (Yarragadee). In order to understand the possible implications of these new limits on the groundwater resource, numerical modelling was conducted. Current actual and future possible production bore locations were entered into the SWAMS v2 groundwater model and the model was run over a 30-year modelling period applying these allocation limits. Likely further drying of the climate in the future was accounted for by applying reduced recharge rates in the model. At the end of the 30-year modelling period the predicted water table draw downs for any particular location within the study area, including the trigger response sites, could then be analysed.

Due to a change in recharge rates between the model calibration period (prior to the 30-year model run) and the applied scenario run, at many locations the first one to five years of output data before the model stabilised were erratic or unrealistic. Therefore, the first four years of modelled data were removed from the analysis of draw downs at the trigger–response sites.

The amount of draw down in the water table that was predicted to occur between Year 5 and Year 30 of the model run at each trigger–response GDE site was then calculated and compared to the preliminary EWR trigger at the site. If predicted draw downs were less than the EWR trigger value then the site was considered to be at low risk of draw down impacts and unlikely to require implementation of an appropriate management framework. If predicted draw downs were greater than the EWR trigger value, then the possible reasons for this were explored e.g. conservativeness in the model in coastal plain areas, local abstraction impacts, regional abstraction, climate sensitivity etc. and investigative actions recommended.

In some of these cases it is possible that EWR triggers may be exceeded during the life of the plan and the management framework will be applied. However, as the understanding of site water requirements and historical water regimes is limited, the EWR triggers are only preliminary at this stage and exceeding a trigger may not in itself indicate any risk to the site ecology. If an EWR trigger is reached, it will be important to investigate ecological condition indicators and analyse the hydrographic information to help assess the level of risk to the relevant GDE.

The reduced recharge aspect of the model scenario, simulating likely further drying of the climate in the future, increases the total draw downs over the 30-year modelling period for many of the GDE 'trigger–response' sites compared to the model 'base case'. The model base case, with which all model scenarios are compared to calculate the predicted draw downs, used the rainfall of the period 1971–2003 to estimate the recharge variable. Recharge was reduced by a further 5% in the proposed allocation limit scenario and this increased the draw downs at some of the trigger–response sites by up to 0.25 m over the 30-year model period. This indicates that some areas may be particularly sensitive to reductions in rainfall over the medium term and therefore if the climate does dry further as predicted, these areas may need more vigilant monitoring as they are likely to be more susceptible to impacts from additional draw down caused by abstraction.

3 Trigger-response sites for the Bunbury groundwater area

Triggers and responses are recommended for implementation at the following sites in the Bunbury groundwater area.

Kemerton

Site description

The Kemerton site lies in remnant bushland off Devlin Rd in the Shire of Harvey, adjacent to the Kemerton Industrial Park (see Figure 5) in the Kemerton Industrial Park South groundwater subarea. The land is vested in the Department of Environment and Conservation (DEC). The site supports a variety of vegetation complexes including *Eucalyptus gomphocephala*–*Corymbia calophylla*–*Eucalyptus marginata* open forest, Banksia and Jarrah (*E. marginata*) woodlands, paperbark (*Melaleuca*) woodlands and sedgeland. Priority flora has been identified within the industrial park. The vegetation transect established within the site contains a number of exotic species and tree health within the transect ranges from poor to good (Loomes *et al.*, 2007b).

Hydrogeological setting

The Kemerton site sits on the Superficial formation, which is underlain by the Leederville formation. The Leederville formation is underlain by the Cattamarra Coal Measures.

Coring done at the site suggests that it lies on thin Bassendean sands overlying Guildford clays. The clays form a semi-impermeable layer approximately 3 m below ground level which supports the retention of soil moisture in the wetland (Cattlin, 2007). The clay layer does not completely isolate the wetland from the regional groundwater system below it, so it would be expected that significant changes in the groundwater regime are likely to affect the water table within the wetland.

The species present at the site, such as *Banksia littoralis* and *Melaleuca raphiophylla* are groundwater-dependent and therefore would be negatively impacted by significant or ongoing declines in the water table.

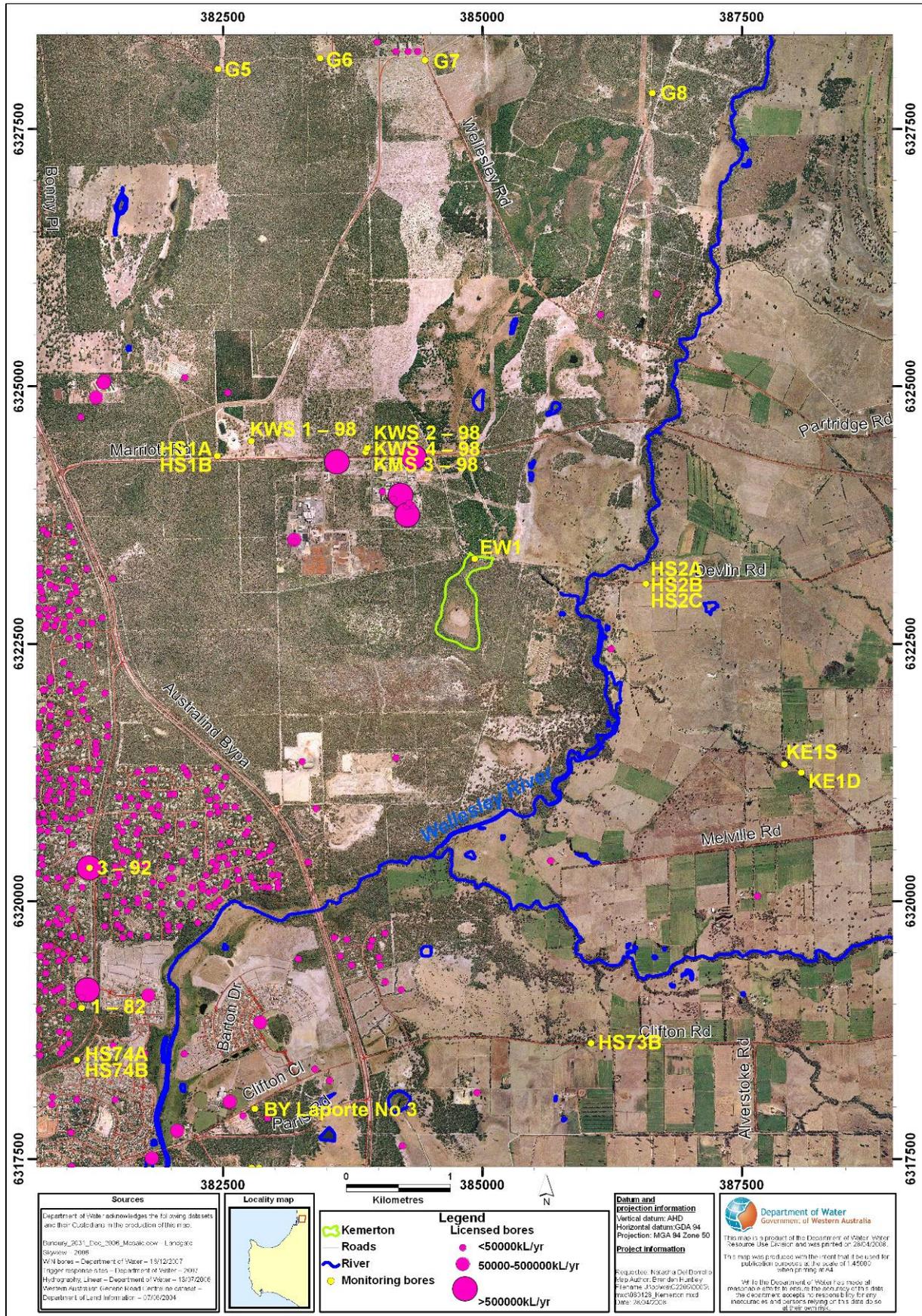


Figure 5 Kemerton GDE site

Surrounding groundwater use

Approximately ten licensed bores with a total allocation of around 2.5 GL/yr are located within 2.5 km of the Kemerton site. These bores draw from the Superficial aquifer (0.12 GL/yr), Leederville aquifer (1.3 GL/yr) and the Cattamarra Coal Measures (around 1 GL/yr). As it is a deep aquifer, abstraction from the Cattamarra Coal Measures is unlikely to cause draw down at the water table.

There is a heavily urbanised area around three kilometres to the west of the Kemerton site where there are over 300 licensed bores with small domestic allocations of around 1000 kL/yr each and three large Leederville aquifer public water supply bores with a total allocation of over 3 GL/yr.

Local water table trends

The nearest long-term monitoring bore to the Kemerton site is the HS2 nested bore around 1.5 km to the east. However, these bores lie on the opposite side of the Wellesley River to the Kemerton site and water levels are substantially deeper. Therefore they are unlikely to be representative of water levels at the Kemerton site.

The nearest monitoring bores with a long-term dataset that may be representative of water levels at the Kemerton site are Superficial monitoring bores G7 and G8. These lie almost 5 km to the north (Figure 5). Water levels in these bores appear relatively stable (Figure 6), with a slight decline of approximately 1 m over almost 30 years of record.

Monitoring bores HS1A and HS1B are located approximately 2.5 km to the north-west of the Kemerton site and they have been monitored intermittently since 1983. These bores also monitor the Superficial aquifer but there is not enough continuous monitoring data to detect any definite trends.

BY Laporte No 3 is a long-term Leederville monitoring bore approximately 5 km to the south-west of the Kemerton site. Abstraction impacts are evident approximately seven years after monitoring commenced and since then water levels have dropped around five metres in 25 years (~0.2 m/yr) (Figure 6). This bore was originally drilled as a Yarragadee production bore in 1962 but casing failures saw it converted into a monitoring bore (Watson, R 2008, pers. comm., 10 March). It is uncertain whether the bore was adequately sealed against Yarragadee pressures and so its integrity as a Leederville aquifer monitoring bore is somewhat questionable. It is recommended that a new Leederville monitoring bore be drilled north of BY Laporte No 3 between the wetland site (and Kemerton Industrial Park area) and the Water Corporation's Old Coast Road Australind production bores (Watson, R 2008, pers. comm., 10 March).

As there was no shallow monitoring bore located close to the Kemerton site, one was installed (EW1) adjacent to the vegetation transect in early 2007 (Figure 5). EW1 is 4.8 m deep and is screened between 1.5 and 4.8 m below ground level in the Bassendean Sand and Guildford Clay of the Superficial formation. The 2007 autumn

minimum water level was recorded at around 2.4 m below ground level and the winter maximum was approximately 0.2 m below ground level.

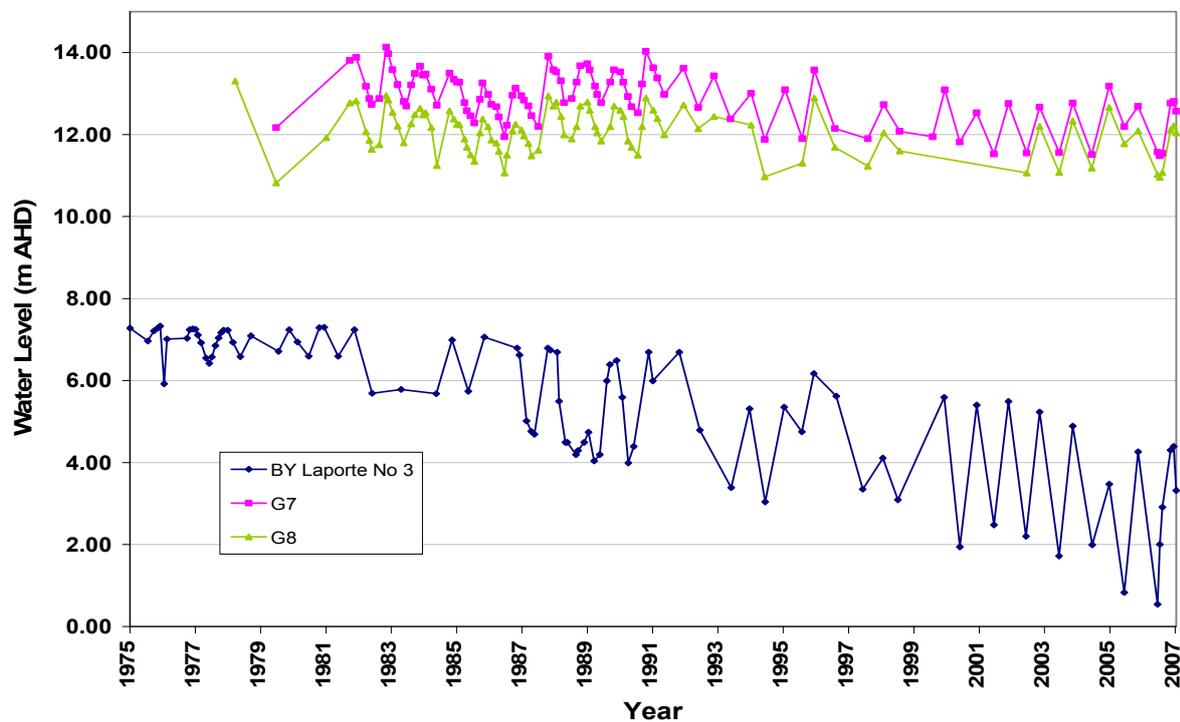


Figure 6 Hydrographs of G7 and G8 Superficial bores, located 5 km to the north of the Kemerton site and BY Laporte No 3 Leederville bore, located 5 km to the south-west

Ecological water requirements

A vegetation transect has been established at the Kemerton site and vegetation condition is being monitored annually. However, no detailed work has yet been done to determine the site-specific ecological water requirements. Hydrogeological and ecological work will occur over the next two years to improve understanding of the susceptibility of the vegetation to groundwater regime change and to develop an improved monitoring framework including updated water requirements and management triggers and responses. In the meantime the generic water requirement criteria established by Froend & Loomes (2004) for maintaining wetland vegetation at a low level of risk has been used as a preliminary EWR trigger. The criteria allow a maximum water level draw down of 0.25 m from the autumn minimum at a rate no greater than 0.1 m/yr.

To establish whether the generic criteria were appropriate for the Kemerton site, the preferred water level range of the species identified in the vegetation transect as being most susceptible to groundwater decline, was compared to the known water regime as measured at the Kemerton piezometer, EW1. *Eucalyptus rudis* and *M. raphiophylla* were the most susceptible species identified and based on their preferred water regime it was determined that the site vegetation could withstand a

further 0.25–0.5 m drop from the measured autumn minimum and still be maintained at the site at a low level of risk. Therefore the generic criterion of 0.25 m maximum draw down is appropriate as a preliminary ecological water requirement for this site. Measured at the on-site piezometer, EW1, this translates to a preliminary EWR trigger of 7.55 m AHD. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined within this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Kemerton site (modelled at EW1) indicate that it would undergo 0.21 m of draw down between Year 5 and Year 30 (Figure 7). These results are within the EWR criteria, indicating the site should be at low risk under the proposed abstraction scenario by the end of the model period. This means there should be no measurable change to ecosystem processes, biodiversity, species abundance or wetland water quality (Froend & Loomes, 2004). Approximately 0.11 m of this draw down can be attributed to the reduced recharge parameters of the model run that approximate the effect of a drying climate. The SWAMS v2 model is said to be conservative model on the Swan coastal plain as it does not account well for 'rejected recharge'.

This is the water that would normally pond on the surface when the Superficial aquifer fills in winter, but if the water table is drawn down by groundwater abstraction this ponded water can then enter the soil profile creating extra recharge. As such it is likely that the SWAMS v2 model may be somewhat over-predicting draw downs and the risk to the ecological values at the Kemerton site may in fact be lower than estimated by the model. A revised local model for the Swan coastal plain is currently under development.

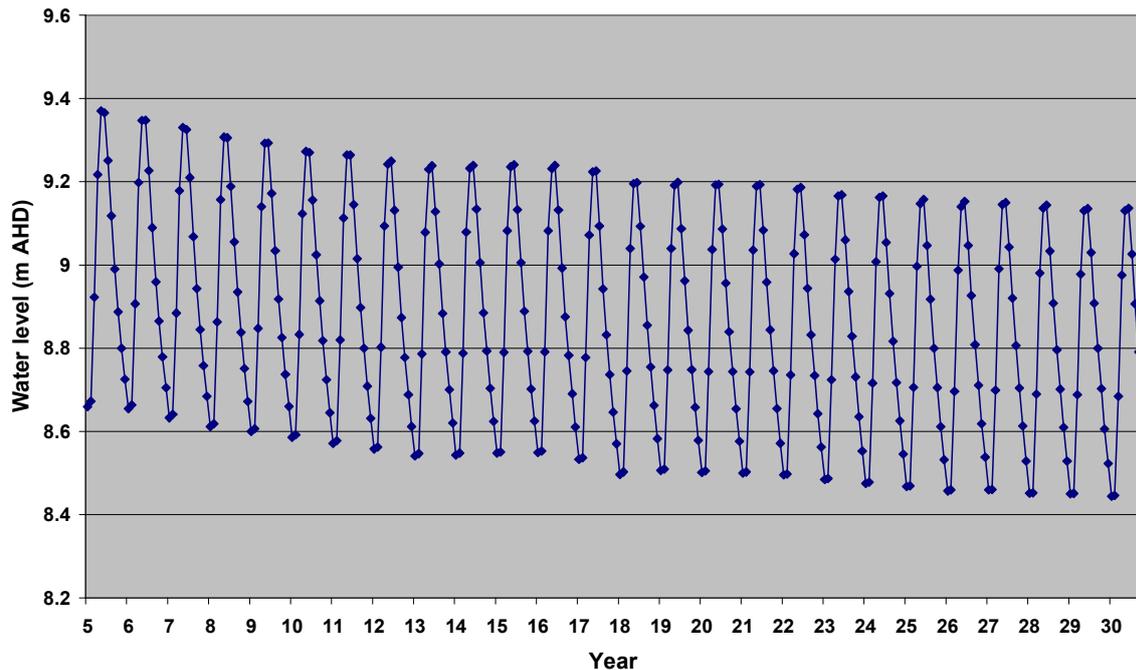


Figure 7 EW1 modelled hydrograph

Discussion and recommendations

The lack of Superficial aquifer monitoring data around the Kemerton site makes it difficult to ascertain whether the water table at the wetland is being affected by abstraction or other impacts. Water levels have declined slightly at G7 and G8, most probably due to the drying climate. Monitoring undertaken by a nearby licensee on Marriott Road indicates that localised draw downs have occurred since the early 1990s due to abstraction impacts on the property and water chemistry data shows generation of acids due to oxidation of potential acid sulphate soils (Watson, R 2008, pers. comm., 10 March).

Ongoing, regular water level monitoring at the Kemerton wetland site will be important in determining whether any of these impacts are affecting the water table at the wetland. Increased monitoring will be implemented through the groundwater allocation plan monitoring program (Department of Water, 2008). Site hydrogeology suggests that the Kemerton site is groundwater dependent and the vegetation it supports would be at risk of impact if there were significant changes to the local water regime.

The site exists close to an industrial area and not far from a high-density urban area. Several significant licences from deeper aquifers exist within approximately 1 km of the site.

Modelling results for the site indicate that draw downs are likely to be within the EWR criteria, and these draw downs may be over-estimated by the SWAMS v2 model on

the Swan coastal plain. However, the modelled water level declines do not stabilise at the end of the modelled period suggesting an ongoing downward trend.

In light of this, the following management approach is recommended:

- the large water users surrounding the Kemerton site should continue to be monitored to ensure their compliance with licence conditions and should be encouraged to adopt water use efficiency measures
- additional hydrogeological investigation should occur at the site to better define the hydrogeological support mechanisms and susceptibility of the site to draw down
- monthly monitoring of the on-site shallow piezometer, EW1, and annual monitoring of the Kemerton vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the 2011 statutory allocation plan
- a new Leederville monitoring bore should be drilled north of BY Laporte No 3 between the wetland site (and Kemerton Industrial Park area) and the Water Corporation's Old Coast Road Australind production bores
- the potential impact of groundwater abstraction on the Kemerton site should be reviewed when the local numerical groundwater model has been developed for the Swan coastal plain
- detailed work should be conducted to help refine ecological water requirements for the Kemerton site prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to this site.

Hay Park

Site description

Hay Park is an important reserve located within the City of Bunbury on the corner of Bussell Hwy and Washington Ave, in the Bunbury West groundwater subarea (Figure 7). It supports wetlands dominated by *Melaleuca raphiophylla*, *M. preissiana* and *Banksia littoralis* and terrestrial vegetation including *Corymbia calophylla* and Banksia woodland (Loomes *et al.*, 2007b). Two threatened ecological communities (TEC) have been recorded at the reserve:

- SCP08 – Herb rich shrublands in clay pans; and
- SCP18 – Shrublands on calcareous silts of the Swan coastal plain.

A priority flora species has been recorded at Hay Park and native fauna such as the Quenda (*Isodon obesulus*) and Western Ringtail Possum (*Pseudocheirus occidentalis*) may also be found there.

Hydrogeological setting

Hay Park sits on the Superficial formation, which in this area, is directly underlain by the unconfined Yarragadee formation, making the reserve susceptible to groundwater declines caused by pumping in the Yarragadee aquifer. Measurements taken at a shallow piezometer installed at the site in autumn 2007 showed that groundwater levels were 2.2 m below the ground surface. The high water table, sandy soils and presence of groundwater-dependent vegetation species suggests that this site is highly groundwater-dependent (Loomes *et al.*, 2007b) and therefore any significant changes in the groundwater regime would be likely to have an impact on the vegetation communities at the site.

Surrounding groundwater use

Around 20 licensed bores can be found within approximately 1.5 km of the reserve (Figure 8). The total licensed allocation within this zone is around 2.1 GL/yr, with almost all of this being abstracted from the Yarragadee aquifer. Six of the bores in this 1.5 km zone have large Yarragadee allocations associated with them, and several of these are located within a few hundred metres of the reserve.

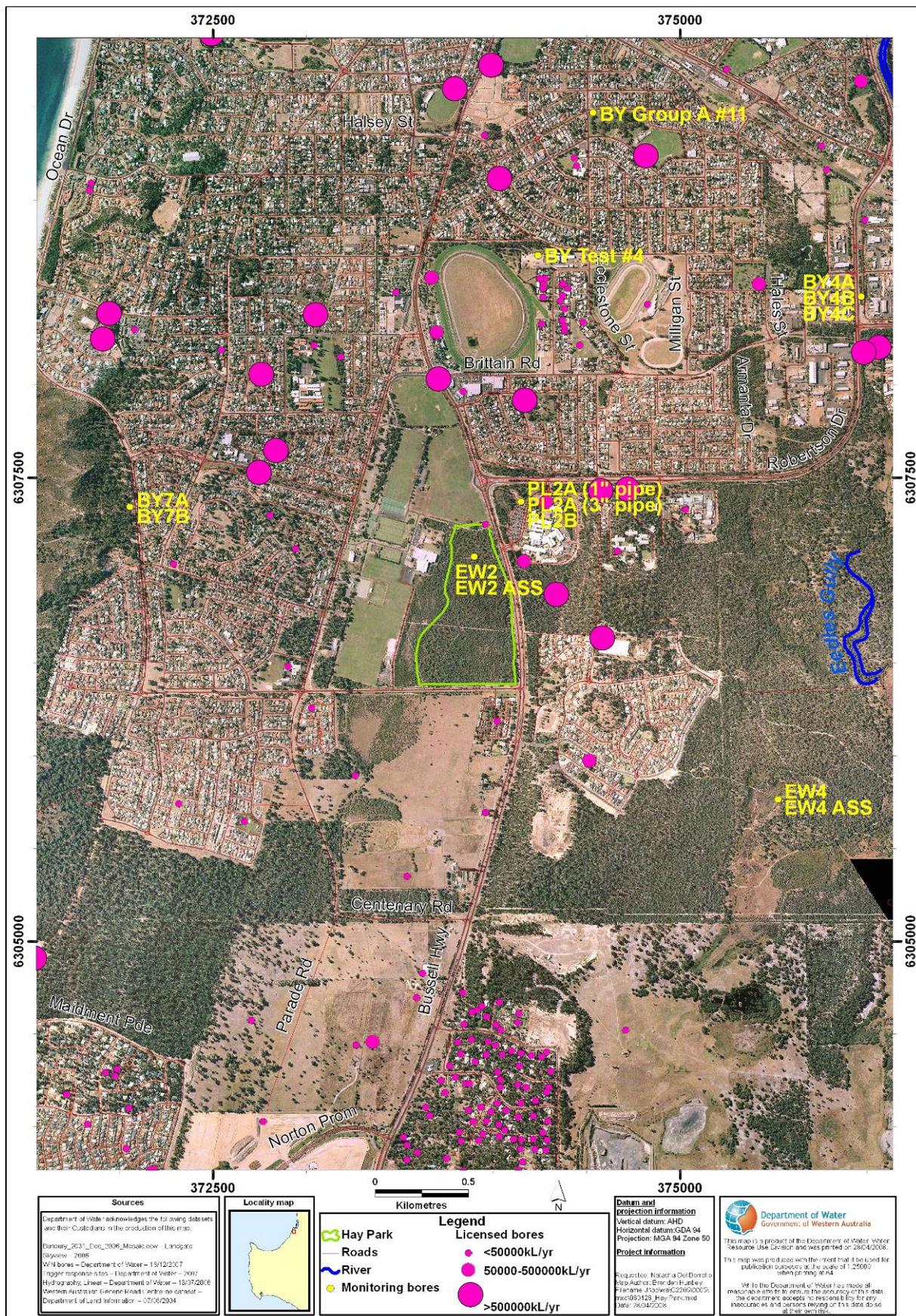


Figure 8 Location of the Hay Park GDE site

Local water table trends

The nearest monitoring bore to the Hay Park with a long term record is PL2, which is 300 m from the reserve and monitors water levels in the Yarragadee aquifer. Monitoring data from PL2B appears to show a slight declining trend of approximately 0.1 m/yr over a 30-year monitoring period.

The nearest shallow monitoring bore to Hay Park with a long term record is BY7B, located approximately 1.7 km to the west of the reserve. This bore has a 30-year monitoring record which shows water levels to be relatively stable (Figure 9). Water levels since 2000 appear to be slightly lower than in previous years. The Yarragadee monitoring bore at the same site, BY7A, also appears to be stable since the early 1980s.

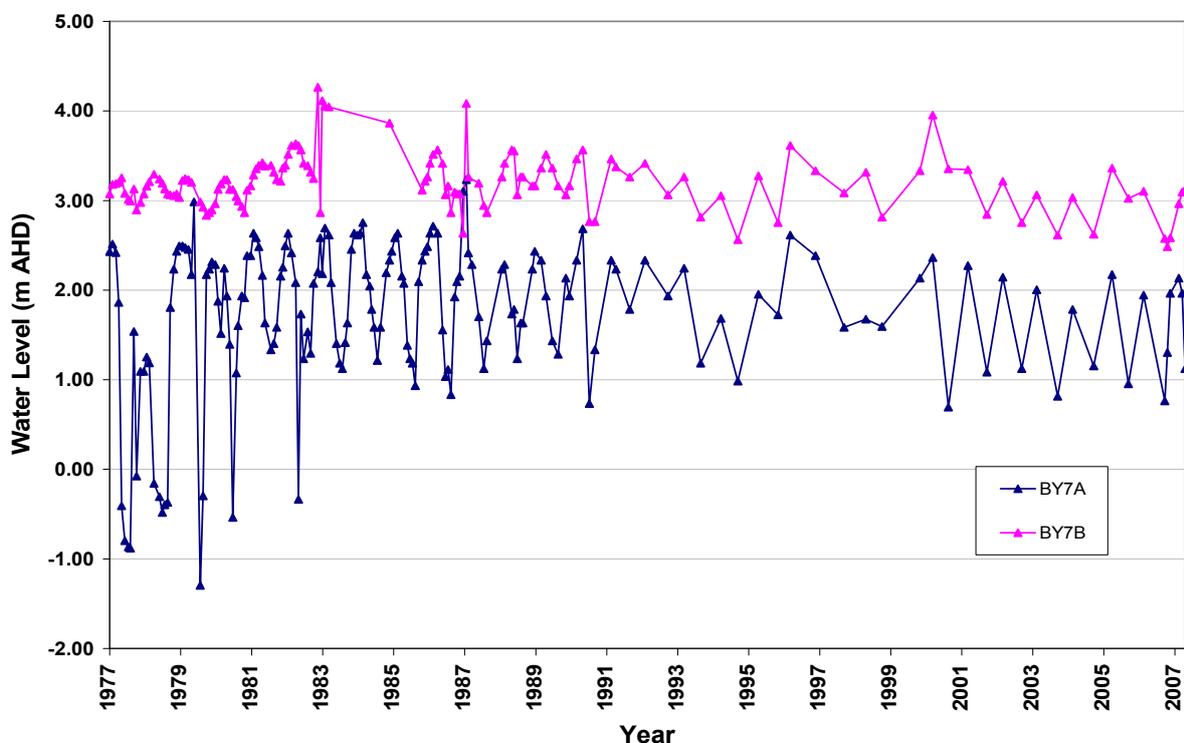


Figure 9 Hydrograph of Superficial monitoring bore BY7B and Yarragadee monitoring bore BY7A

As there was no shallow monitoring bore located close to the site, one was installed (EW2) adjacent to the vegetation transect in early 2007 (Figure 8). EW2 is 9 m deep and is screened between 3.5 and 9.0 m below ground level in the Superficial formation (Bassendean sands). The 2007 autumn minimum water level was recorded at around 2.7 m below ground level and the winter maximum was approximately 1.1 m below ground level.

Ecological water requirements

A vegetation transect has been established at the Hay Park site and vegetation condition is being monitored annually. The preferred water level range of the species identified in the vegetation transect as being most susceptible to groundwater decline was compared to the known water regime as measured at the Hay Park piezometer (EW2). *Banksia littoralis* was the most susceptible species identified and based on its preferred water regime it was determined that this species could withstand a further 0.5 m drop from the measured autumn minimum (at a rate of 0.1 m/yr or less) and still be maintained at a low level of risk. Therefore the preliminary ecological water requirement for this site is a maximum draw down of 2.72 m AHD measured at monitoring bore EW2 at a rate of no more than 0.1 m/yr. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined within this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Hay Park site (at the on-site piezometer) indicate that Hay Park would undergo 0.31 m of draw down over a 25-year period (Year 5 to Year 30) (Figure 10). Approximately 0.06 m of this draw down may be attributed to the reduced recharge aspect of the scenario. These results are just outside of the preliminary EWR criteria, indicating the site may be maintained at a moderate level of risk under the proposed abstraction scenario for the model period. This means there could be a small change to ecosystem processes, biodiversity, species abundance and water quality (Froend & Loomes, 2004).

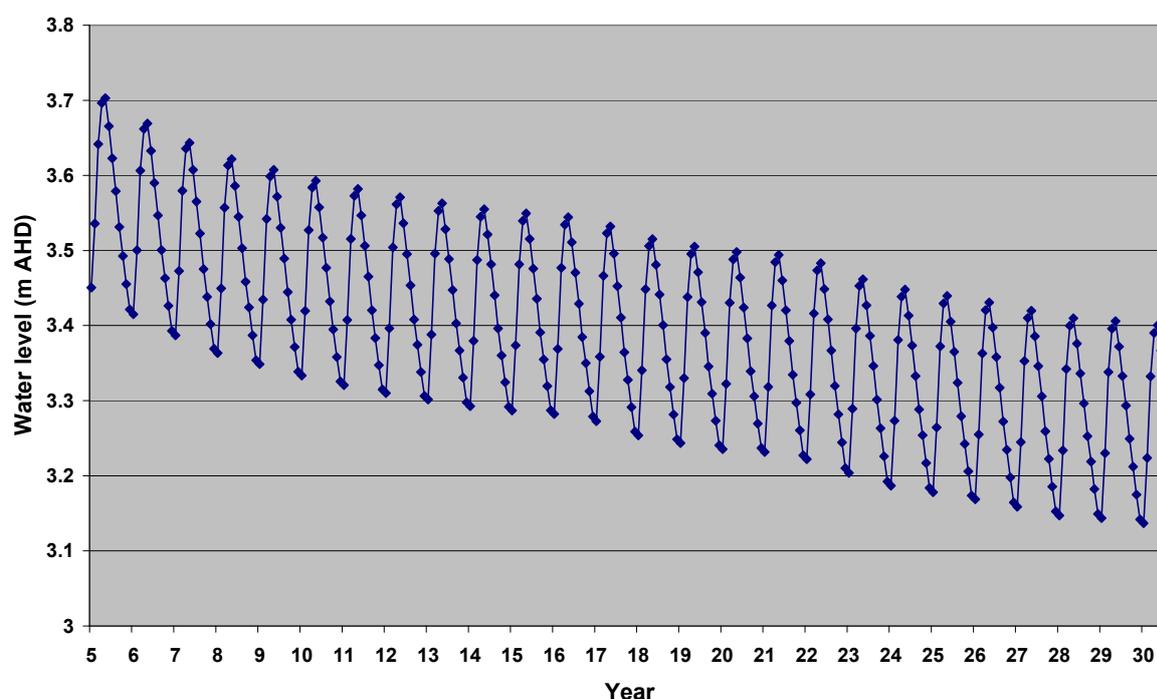


Figure 10 EW2 modelled hydrograph

Discussion and recommendations

There are limited monitoring data for the Hay Park site. The available long-term water level monitoring data does not currently appear to show evidence of abstraction impacts. However, site hydrogeology and vegetation type suggests that Hay Park would be at high risk of impact if there were significant changes to the local water regime. The site exists within an urban setting and several large licensed allocations are being abstracted close to the reserve. Modelling results for the site indicate that draw downs are likely to be just outside of the EWR criteria. However, the modelled water level declines do not stabilise at the end of the modelled period, suggesting an ongoing downward trend.

In light of this, the following management approach is recommended:

- the large water users surrounding Hay Park should continue to be monitored to ensure their compliance with licence conditions and should be encouraged to adopt water use efficiency measures
- monthly monitoring of the on-site shallow piezometer, EW2, and annual monitoring of the Hay Park vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- the potential impact of groundwater abstraction on the Hay Park site should be reviewed when the local numerical groundwater model has been developed for the Swan coastal plain
- detailed work should be conducted to refine ecological water requirements for the Hay Park site prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to this site.

Harewoods Rd

Site description

This site is located on the corner of Bussell Highway and Harewoods Rd in Dalyellup, Shire of Capel, (Figure 11) in Bunbury West groundwater subarea. The coast lies less than 2.5 km away to the west and Minninup Swamp (Muddy Lakes) lies approximately 4 km to the south-west of the site. The land around the Harewoods Rd site is being increasingly urbanised, with established lots to the east across Bussell Highway and new subdivisions to the west and north. The site supports wetlands dominated by *Melaleuca preissiana*/*B. littoralis* and Jarrah/Marri/Banksia woodland (Loomes *et al.*, 2007b).

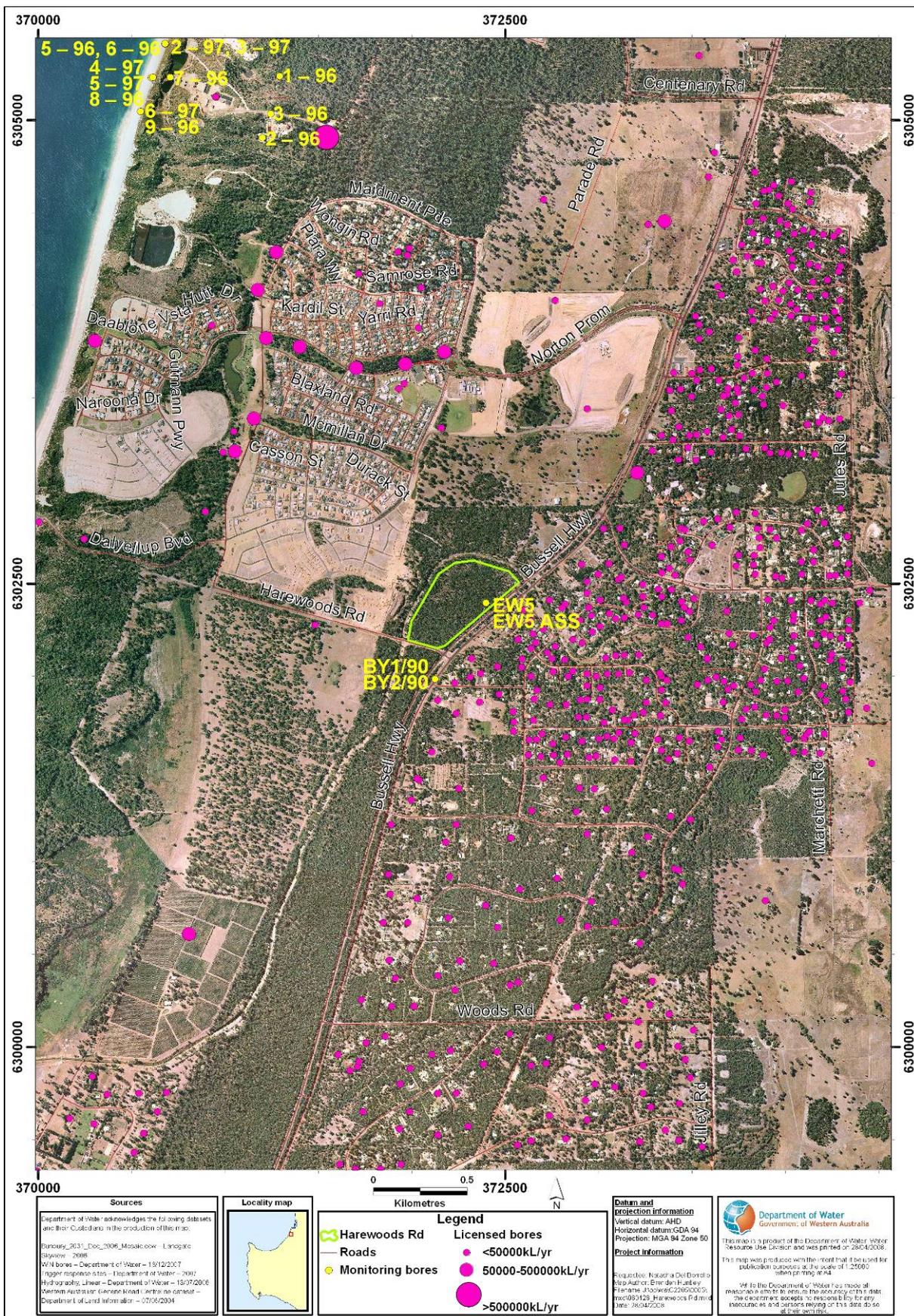


Figure 11 Location of the Harewoods Rd GDE site

Hydrogeological setting

The Harewoods Rd site sits on Bassendean sands in the Superficial formation overlying the Yarragadee aquifer. There is a downward piezometric head from the Superficial aquifer towards the Yarragadee aquifer, indicating the Bassendean sands may be recharging the Yarragadee aquifer in this area. Therefore a reduction in pressure head in the Yarragadee caused by groundwater abstraction or reduced rainfall may induce more recharge from the Superficial aquifer (Cattlin, 2007). This would cause water levels to fall at the Harewoods Rd site, which if significant enough, would result in impacts to the wetland values. The presence of known groundwater-dependent species of vegetation at the site (all in moderate to good condition) indicated a high reliance on the presence of a shallow water table (Loomes *et al.*, 2007b).

Surrounding groundwater use

There are around 300 licensed bores within a 2 km radius of the Harewoods Rd site. The vast majority of these are small domestic Superficial or Yarragadee aquifer licences with allocations of <1500 kL/yr. The largest allocation within the 2 km radius is 165 000 kL/yr and the total allocation is less than 1 GL/yr. Most of the licensed bores are located to the east of the site.

Local water table trends

The nearest long-term monitoring bores, BY1/90 and BY2/90 are located approximately 200 m south of the Harewoods Rd site and water levels have been measured biannually since 1990. BY1/90 monitors the Yarragadee aquifer and BY2/90 is screened around 8–14 m below ground level in the Superficial aquifer (Figure 12). BY1/90 and BY2/90 show an overall declining trend of 2 m and 1 m respectively since 1990. It appears that the Superficial aquifer is not clearly reflecting the declines evident in the last few years in the Yarragadee aquifer at this location. However, measurement of water levels has been only biannual up until 2007 when the frequency was increased to six times per year.

As there was no shallow monitoring bore located close to the site, one was installed (EW5) adjacent to the vegetation transect in early 2007 (Figure 11). EW5 is nine metres deep and is screened between 1.5 and 7.0 m below ground level in the Bassendean Sand of the Superficial formation. The 2007 autumn minimum water level was recorded at around 6.7 m below ground level and the winter maximum was approximately 5.5 m below ground level.

Ecological water requirements

A vegetation transect has been established at the Harewoods Rd site and vegetation condition is being monitored annually. However, no detailed work has yet been done to determine the site-specific ecological water requirements. This work will occur during the next two years. In the meantime it is proposed to use the generic criteria

established by Froend & Loomes (2004) for maintaining wetland vegetation at a low level of risk. The criteria allow a maximum water level draw down of 0.25 m from the autumn minimum at a rate no greater than 0.1 m/yr.

To establish whether the generic criteria were appropriate for the Harewoods Rd site, the preferred water level range of the species identified in the vegetation transects as being most susceptible to groundwater decline was compared to the known water regime as measured at the Harewoods Rd piezometer, EW5. *Melaleuca preissiana* and *Lepidosperma longitudinale* were the most susceptible species identified. The data available on their preferred water regime indicated that these species could withstand a further 0.25 m draw down and still be maintained at a low level of risk.

Therefore the generic criterion of 0.25 m was considered appropriate as a preliminary EWR for this site. Measured at the on-site piezometer, EW5 (and taken from the autumn 2007 minimum), this translates to a preliminary EWR of 5.72 m AHD. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined within this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Harewoods Rd site (modelled at EW5) indicate that it would undergo 0.43 m of draw down over a 25-year period (Figure 13). These results indicate the site may be at 'moderate' risk under the proposed abstraction scenario by the end of the model period. This could mean a small change to ecosystem processes, biodiversity, species abundance and water quality (Froend & Loomes, 2004). Approximately 0.08 m of this draw down can be attributed to the reduced recharge parameters of the model run that approximate the effect of a drying climate.

For reasons previously described it is likely that the SWAMS v2 model may be somewhat over-predicting draw downs on the Swan coastal plain and the risk to the ecological values at the Harewoods Rd site may in fact be lower than estimated by the model. A revised local model for the Swan coastal plain is currently under development.



Figure 12 Hydrograph of Superficial monitoring bore BY2/90 and Yarragadee monitoring bore BY1/90, approximately 200 m to the south of the Harewoods Rd site

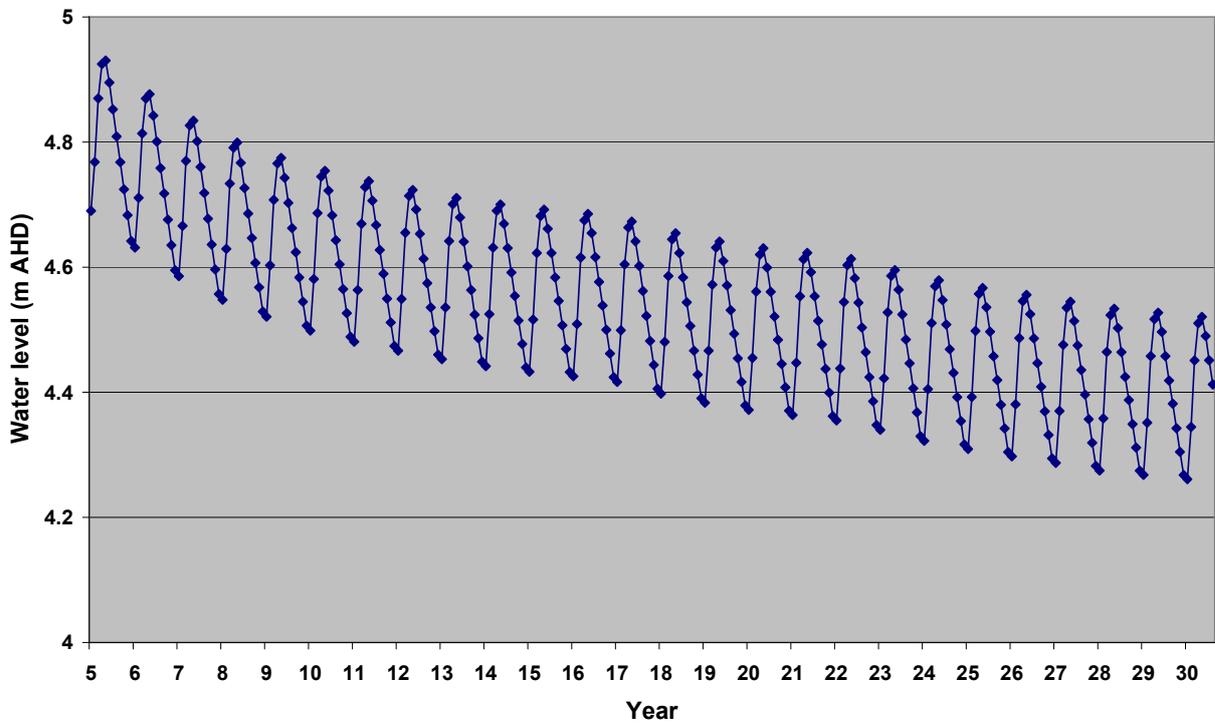


Figure 13 EW5 modelled hydrograph

Discussion and recommendations

The available long-term water level monitoring data at BY1/90 and BY2/90 do not show evidence of abstraction impacts in the Yarragadee aquifer that are also affecting water levels in the Superficial aquifer. However, site hydrogeology suggests there is potential for this to occur and Cattlin (2007) proposes that another monitoring bore be installed between the shallow and deep bores to help monitor the interactions between the aquifers. The vegetation type suggests that Harewoods Rd would be at high risk of impact if there were significant changes to the local water regime. The site exists in an area that is being increasingly urbanised and so may be at risk of cumulative impacts from many small allocations from the shallow aquifer and changes to drainage in the area.

Modelling results for the site indicate that draw downs are likely to be outside of the EWR criteria and ecology may be at moderate risk from draw down impacts if the climate becomes drier as is predicted. The SWAMS model may be over-estimating draw downs on the Swan coastal plain but due to the hydrogeology in the Harewoods Rd area of Superficial overlying the Yarragadee formation, a precautionary approach should be adopted for this site. The following management actions are recommended:

- Estimates of the amount of groundwater that is abstracted for domestic use in the area (both licensed and unlicensed) needs to be verified through water surveys and checks should be carried out to indicate what the level of risk of this abstraction is to the Harewoods Rd site. Residents should be alerted to the need to obey watering restrictions and further restrictions should be applied if necessary (if studies indicate local bore use is affecting the water table at the Harewoods Rd site)
- monthly monitoring of the on-site shallow piezometer, EW5, and annual monitoring of the Harewoods Rd vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- an 'intermediate' depth monitoring bore should be installed at the site to enable better monitoring of the interactions between the Yarragadee and Superficial aquifers as per the recommendations in Cattlin (2007)
- the potential impact of groundwater abstraction on the Harewoods Rd site should be reviewed when the local numerical groundwater model has been developed for the Swan coastal plain
- detailed work should be conducted to refine EWR for the Harewoods Rd site prior to the statutory allocation plan in 2011.
- the management framework as set out in figures 2 and 3 should be applied to this site.

4 Trigger-response sites for the Busselton-Capel groundwater area

Ludlow Rail Reserve

Site description

The Ludlow Rail Reserve site is located off the Ludlow-Hithergreen Rd to the north of the Bussell Highway, Shire of Busselton, (Figure 14) in the Busselton-Capel groundwater subarea. The site is in Crown Reserve land just outside of the Tuart Forest National Park and Ludlow State Forest boundaries. The surrounding land use is generally farmland, mainly pasture with some horticulture to the north-west and mining to the north-east.

Hydrogeological setting

The bore construction details for monitoring bore BN10 suggests that the Ludlow site sits on top of approximately 10 m of the Superficial formation, which is underlain by the Leederville formation. A coffee rock layer lies 3–9 m below the ground surface at the Ludlow site, significantly retarding the vertical movement of groundwater and potentially isolating the site from any changes in the groundwater regime below it.

Surrounding groundwater use

There are 17 licensed allocations within approximately 3 km of the Ludlow site, totalling around 5.6 GL/yr. Seven of these have large water allocations associated with them. Most of the water (almost 4.5 GL/yr) is taken from the Yarragadee aquifer in one location, a mine site just over 2 km to the north-east. Of the remaining allocations within the 3 km radius, approximately 0.39 GL/yr is abstracted from the Leederville aquifer and 0.24 GL/yr from the Superficial aquifer. One large Superficial licence of 0.18 GL/yr exists around 2 km to the north-east of the Ludlow site, and one large Leederville licence of around 0.3 GL/yr, has been allocated 2.7 km to the north-west of the site. Two other licences of around 0.25 GL/yr each are pending assessment.

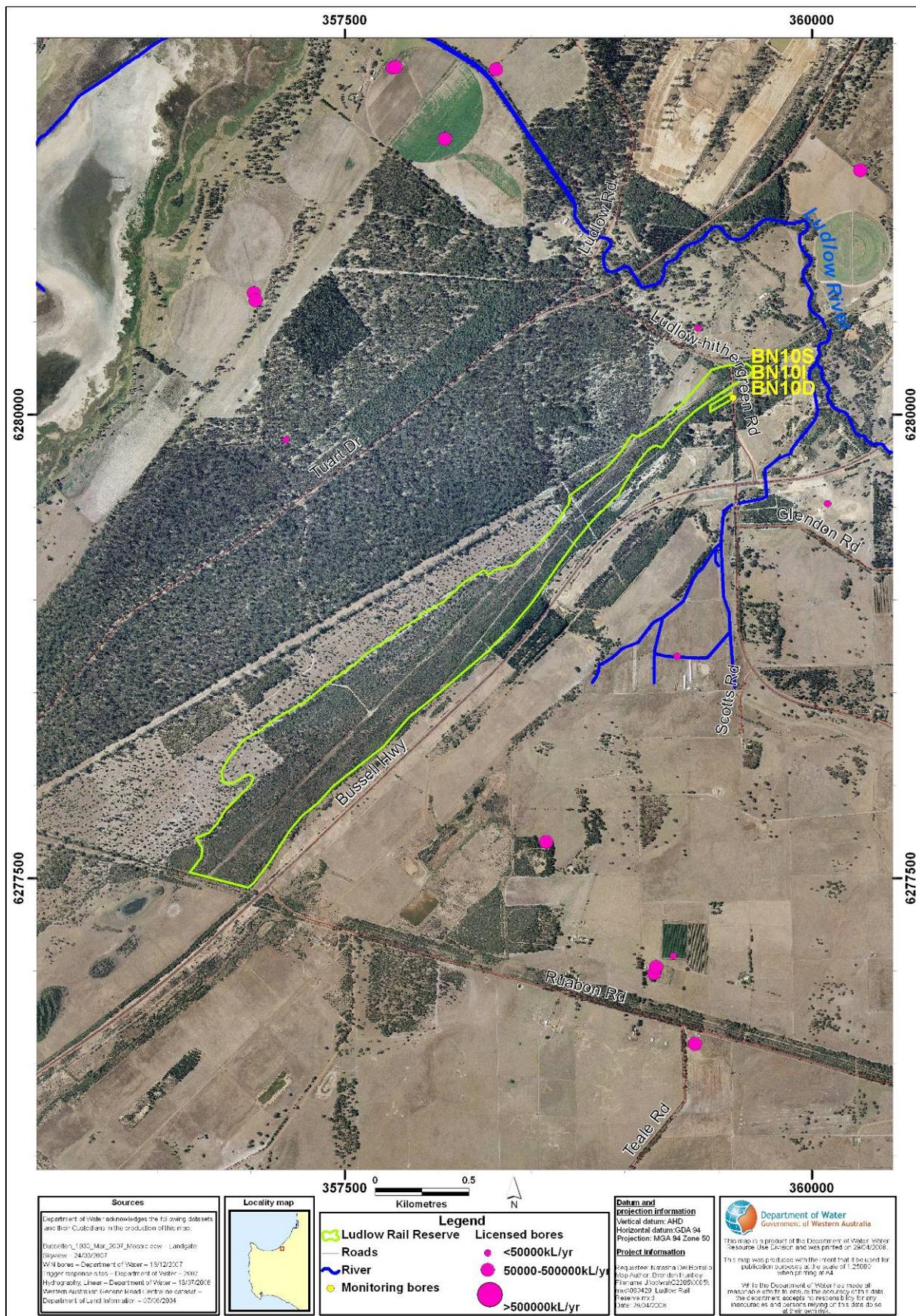


Figure 14 Location of the Ludlow Rail Reserve GDE site

Local water table trends

The nearest long-term groundwater monitoring site is located adjacent to the Ludlow site on the Ludlow-Hithergreen Rd. The monitoring bore is a nested bore, BN10, at which water levels have been monitored in the Superficial and lower Leederville aquifer since 1987. A third monitoring bore was installed in 2000 and this monitors water levels in the upper Leederville aquifer.

The lower Leederville monitoring bore, BN10D, indicates ongoing declines totalling approximately 2 m, with the most significant drop in minimum levels occurring between 2006 and 2007. The upper Leederville bore, BN10I, appears to show a declining trend from 2000 when it was installed, then a recovery following good rainfall in 2005 and then a return to a declining trend. The Superficial bore, BN10S, shows a slight but steady downwards trend since monitoring began in 1987, with overall declines of around one metre (Figure 15).

The seasonal amplitude appears to be inconsistent from year to year but this may be because the biennial monitoring was not frequent enough to pick up the peaks and troughs in the water table. Monthly monitoring has now been implemented. The autumn water level at BN10S in 2007 was approximately 5.7 m below the top of the bore casing.

The next closest long-term monitoring bore to the Ludlow site is BN11, located 3.6 km to the east. The monitoring period is the same as for BN10. BN11 shows water levels in the lower Leederville as steady, until large fluctuations in 1999 and then a declining trend from 2000. The upper Leederville shows a decline of around 2 m since monitoring began in 2000 and the Superficial monitoring bore indicates inter-annual levels have been steady with large seasonal fluctuations of around 3 m.

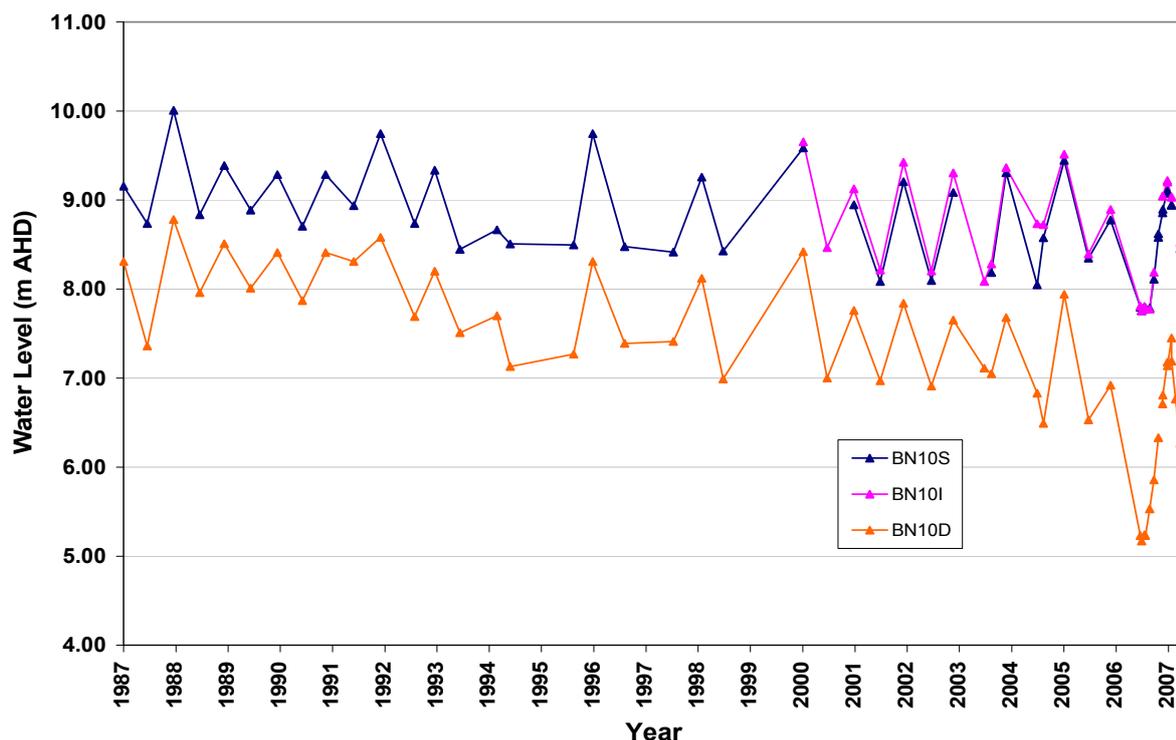


Figure 15 Hydrograph of Superficial monitoring bore BN10S, upper Leederville monitoring bore BN10I and lower Leederville monitoring bore BN10D, adjacent to the Ludlow Rail Reserve site.

Ecological water requirements

While a vegetation transect has been established and is being monitored there is no site-specific work completed to determine the EWR. However, this work will occur over the next two years. It is proposed to use the generic criteria established by Froend & Loomes (2004) for maintaining wetland vegetation at a low level of risk in the interim. The criteria allow a maximum water level draw down of 0.25 m from the autumn minimum at a rate no greater than 0.1 m/yr.

A check of the preferred water level range of the species identified in the vegetation transect as being most susceptible to groundwater decline was compared to the known water regime as measured at the Ludlow shallow bore, BN10S. *Eucalyptus rudis* and *B. littoralis* were the most susceptible species identified and it was determined that their preferred water regime was comparable to the generic criteria of 0.25 m maximum draw down (i.e. they could tolerate this draw down and still remain at a low level of risk). This is considered appropriate as a preliminary EWR for this site. Measured at the on-site piezometer, BN10S (and taken from the autumn 2007 minimum), this translates to a preliminary EWR of 7.5 m AHD. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined within this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Ludlow site (modelled at BN10S) indicate that it would undergo 0.05 m of draw down over a 25-year period (Figure 16). These results indicate the site will be at low risk under the proposed abstraction scenario throughout the model period. This means there should be no measurable change to ecosystem processes, biodiversity, species abundance and water quality (Froend & Loomes, 2004).

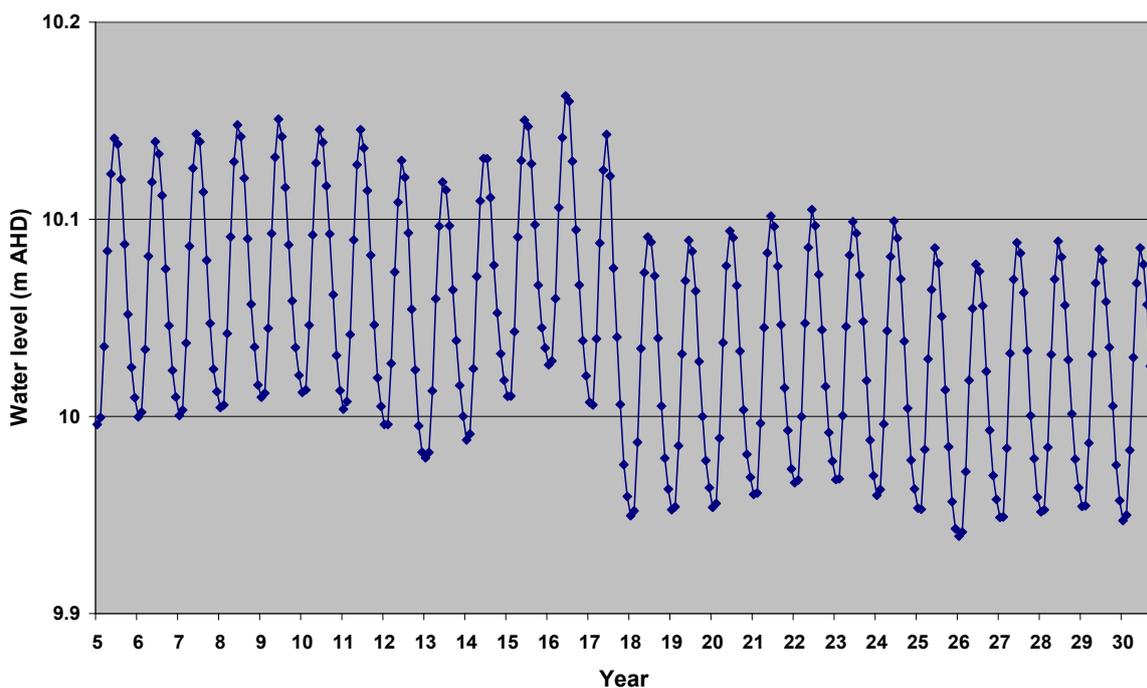


Figure 16 BN10S modelled hydrograph

Discussion and recommendations

The Superficial aquifer monitoring data around the Ludlow site currently does not appear to show strong evidence of abstraction impacts at the water table, though the Leederville monitoring bores do show ongoing declining trends for most or all of the monitoring period. Site hydrogeology suggests that the Ludlow site may be somewhat protected from impacts of abstraction from deeper aquifers due to the existence of thick Leederville formation below the Superficial sands. In addition, coffee rock occurs at depths of between 3 and 9 m, suggesting the potential for a perched water table at the Ludlow site (Loomes *et al.*, 2007b). The vegetation at the Ludlow site is moderately groundwater-dependent, though some highly dependent tree species such as *B. littoralis* exist there (Loomes *et al.*, 2007b).

There is a significant amount of groundwater abstraction occurring within a few kilometres of the Ludlow site. The fact that most of these are Leederville or

Yarragadee licences and water levels in BN10S do not appear to be affected by the draw, may also support the theory that some perching of groundwater is occurring.

Modelling results suggest that water levels will only fall slightly at the Ludlow site under the proposed abstraction scenario and that most of this decline is related to the reduced recharge aspect of the scenario, which simulates a drying climate. Thus the model also appears to uphold the theory that groundwater abstraction is unlikely to have a significant impact at the site. However, ongoing monitoring of the site is still necessary to confirm this, and the issuing of large licences in the Superficial aquifer in close proximity to the area should be avoided.

The following management approach is recommended:

- the large water users surrounding the Ludlow site, particularly those tapping into the Superficial and upper Leederville aquifers should continue to be monitored to ensure their compliance with licence conditions. Licensees should be encouraged to adopt water use efficiency measures
- monthly monitoring of the on-site shallow piezometer, BN10S, and annual monitoring of the Ludlow vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- the potential impact of groundwater abstraction on the Ludlow site should be reviewed again when:
 - a statistical analysis of groundwater hydrograph trends in the South West region, which is currently under way, has been completed by consultants to the Department in early 2008
 - the local numerical groundwater model has been developed for the Swan coastal plain
- detailed work should be conducted to help refine ecological water requirements for the Ludlow site prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to this site.

Ruabon Nature Reserve

Site description

Ruabon Nature Reserve is located at the junction of Ruabon Rd, Tutunup Rd and Ludlow-Hithergreen Rd, Busselton Shire (Figure 17), in the Busselton-Capel groundwater subarea. The reserve is managed by the Department of Environment and Conservation (DEC) and forms part of one of the two existing vegetation corridors in the area. It is the largest remaining piece of southern Marri and Banksia woodland and wetland in this part of the Swan coastal plain (Keighery *et al.*, 1996 in Loomes *et al.*, 2007b). Eight Declared Rare Flora (DRF) species, nine priority flora,

regionally significant floristic communities and a TEC (SCP07 – Herb rich saline shrublands in clay pans) have been identified in the reserve (Loomes *et al.*, 2007b). The vegetation at the site is in moderate to good condition with little weed invasion. Ruabon Reserve is surrounded by farmland.

Hydrogeological setting

Cattlin (2007) describes the Ruabon site as occurring on the boundary between the Bassendean sand and Guildford clays. The top 6 m of the profile is composed mostly of Bassendean sands with the Guildford clay dominant below this point. Interpreted from surrounding bores, the Leederville formation occurs about 12 m below ground surface and is at least 60 m thick in this area. Below the Leederville formation lies the Yarragadee formation. The interaction between the Leederville and Superficial aquifers at the site is not well understood and it is in question as to whether the site is supported in part by upward pressure from the Leederville aquifer or whether it relies almost wholly on rainfall.

Surrounding groundwater use

There are approximately 20 licensed groundwater allocations within 5 km of the Ruabon site. The total licensed volume is just under 0.7 GL/yr. A large allocation of 0.7 GL/yr from the Superficial aquifer is pending assessment. Most of the remaining licences are Leederville aquifer licences and all but one are allocated less than 0.05 GL/yr. Two Yarragadee licences exist near the reserve; both are to the west or north-west of the site and have allocations of around 0.15 GL/yr each.

Local water table trends

The nearest long-term groundwater monitoring site to Ruabon Reserve is 2.5 km to the south-east. This nested bore, BN21, monitors water levels in the Superficial and Leederville aquifers. Superficial bore BN21S shows water levels have been relatively stable since monitoring began in 1987, with seasonal fluctuations of around one metre (Figure 18). Superficial bore BN21I also shows a stable trend since monitoring began in 2000. The lower Leederville monitoring bore BN21D shows a relatively stable trend between 1987 and 2000 and then a decline of around 2.5 m since 2002.

The next closest monitoring bores to the Ruabon site are BN10 and BN11, which are located between 3.5 and 4 km to the north and north-east. The trends in these bores are described in the previous section on the Ludlow Rail Reserve site.

A shallow piezometer, EW10 was installed at the Ruabon site in April 2007 and is being monitored monthly. The seasonal fluctuation in this bore appears to be around two metres and the water table is shallow (generally <3 m below ground surface).

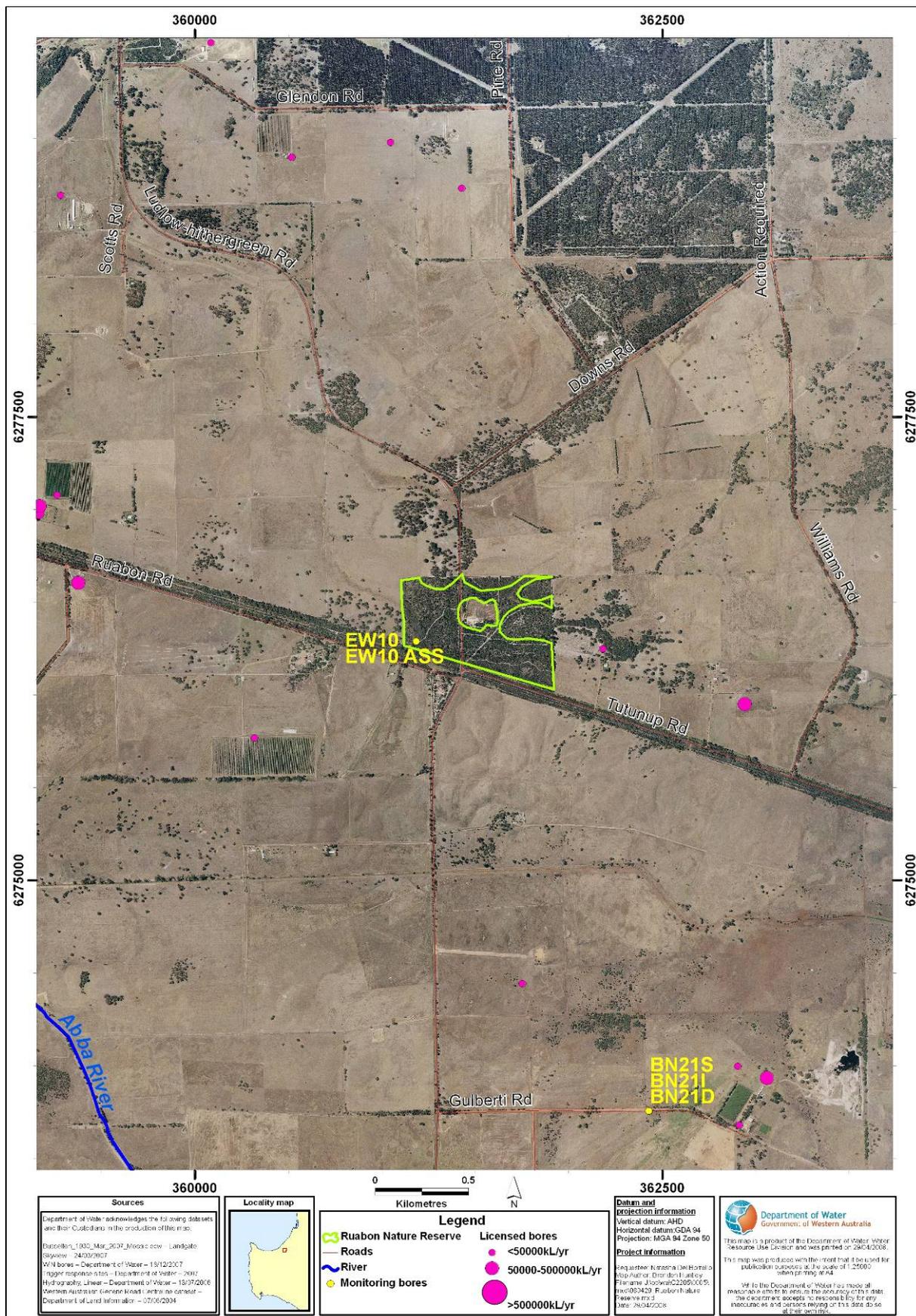


Figure 17 Location of the Ruabon GDE site

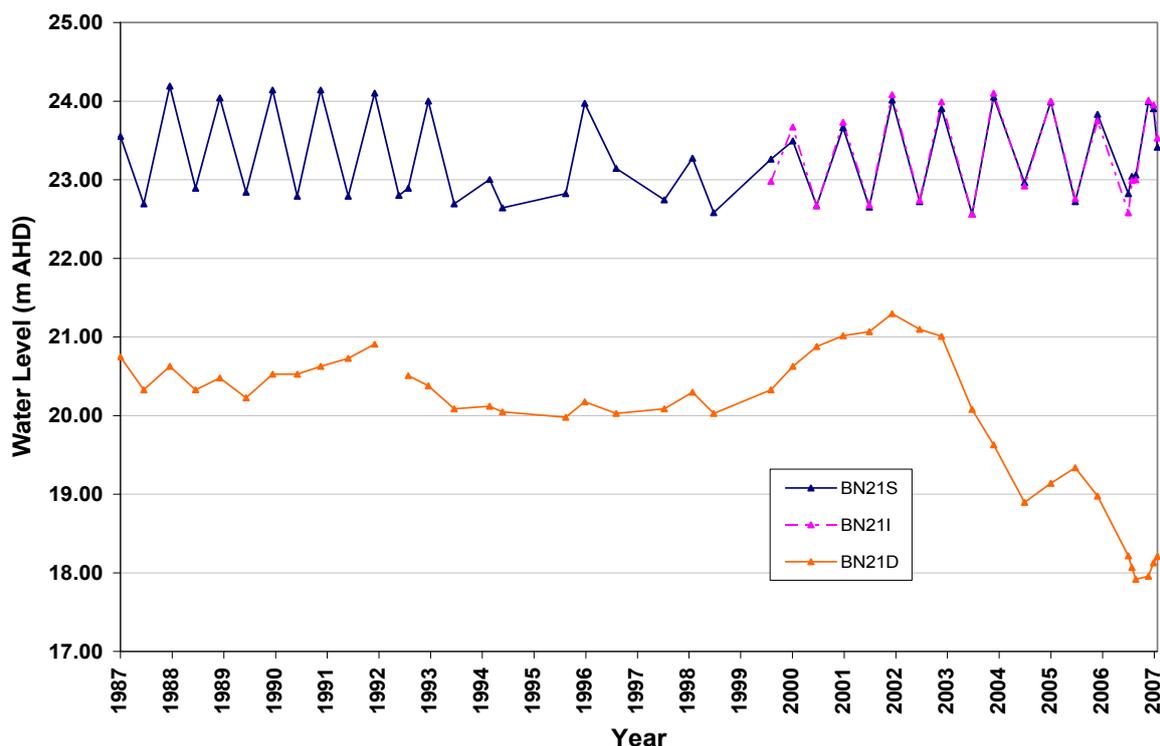


Figure 18 Hydrograph of Superficial monitoring bores BN21S and BN21I and lower Leederville monitoring bore BN21D, 2.5 km to the south-east of the Ruabon site

Ecological water requirements

A vegetation transect has been established at the Ruabon site and is being monitored, but no site-specific work has been done to determine the site's EWR. Until detailed EWR have been developed, it is proposed to use the generic criteria established by Froend & Loomes (2004) for maintaining wetland vegetation at a low level of risk. The criteria allow a maximum water level draw down of 0.25 m from the autumn minimum.

A check of the preferred water level range of the species identified in the vegetation transect as being most susceptible to groundwater decline was compared to the known water regime as measured at the Ruabon shallow bore, EW10. *Melaleuca raphiophylla* was the most susceptible species identified and it was determined that its preferred water regime was comparable to the generic criteria of 0.25 m maximum draw down. This is therefore appropriate as a preliminary EWR for this site. Measured at the on-site piezometer, EW10 (and taken from the autumn 2007 minimum), this translates to a preliminary EWR of 17.16 m AHD. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined within this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Ruabon site (modelled at EW10) indicate that it would undergo 0.01 m of draw down over a 25-year period. These results indicate the site will be at low risk under the proposed abstraction scenario throughout the model period. This means there should be no measurable change to ecosystem processes, biodiversity, species abundance and water quality (Froend & Loomes, 2004).

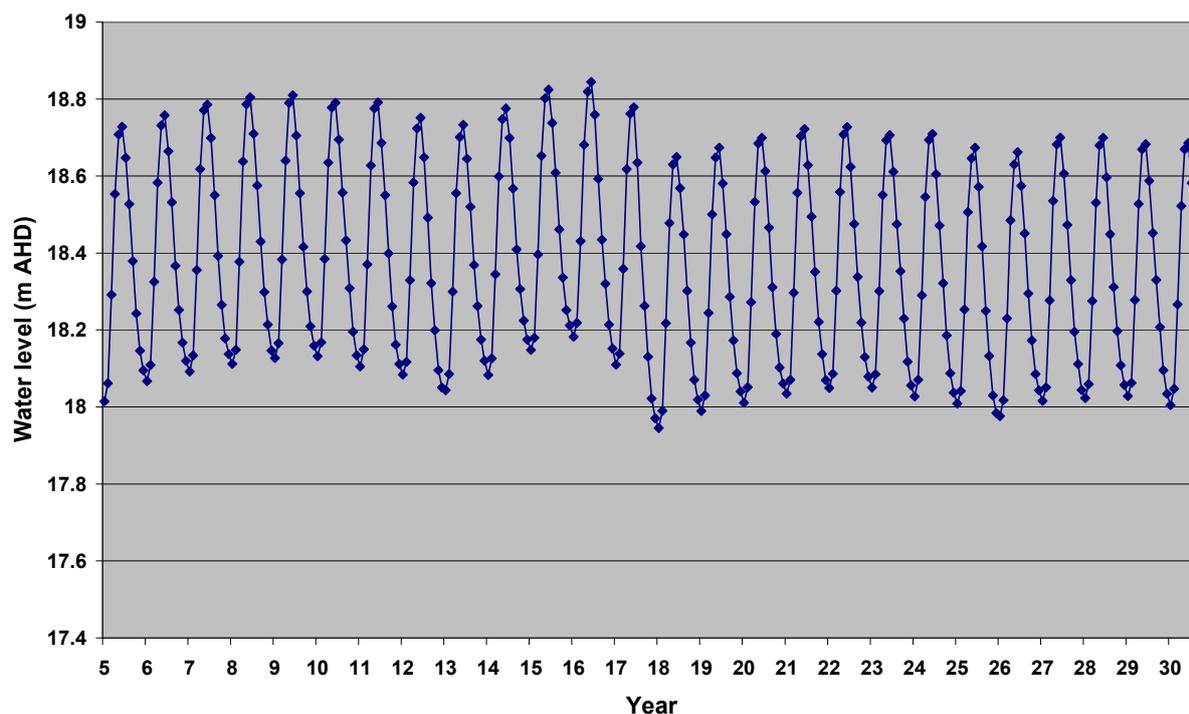


Figure 19 EW10 modelled hydrograph

Discussion and recommendations

The Superficial aquifer monitoring data around the Ruabon site currently does not appear to show any evidence of abstraction impacts at the water table, though the Leederville monitoring bores show declining trends for some or all of the monitoring period. Site hydrogeology suggests that the Ruabon site may be somewhat protected from impacts of abstraction from deeper aquifers due to the existence of clayey Guildford sediments and thick Leederville formation below the Superficial sands.

The occurrence of the Guildford clays, 6 m below ground level, provides some protection from abstraction impacts in the confined aquifers. However, there is a possibility that upward pressure in the Leederville aquifer could provide some hydrological support to the Ruabon site and therefore declining water levels in the Leederville may eventually have an impact on the water table. Additional monitoring bores into the Leederville aquifer will be needed at the site to confirm or refute this (Cattlin, 2007). The vegetation at the Ruabon site is highly groundwater-dependent (Loomes *et al.*, 2007b).

There is relatively little groundwater abstraction occurring within 5 km of the Ruabon site. Most of these licences are small Leederville licences that do not appear to be affecting the shallow water table at BN21S. The largest allocation is a Superficial licence of 0.7 GL/yr, 4 km to the east, which would be large enough to affect water levels at the reserve. However, it is likely that this bore, although licensed as a Superficial bore, is in fact a Leederville aquifer bore, as allocations of this size would be difficult to extract from a single point in the Superficial aquifer. A bore of this size and distance would probably still affect the Leederville aquifer under the Ruabon site, but impacts may not be transmitted through to the Superficial (as suggested by the water level monitoring data).

Modelling results suggest that water levels will only fall slightly at the Ruabon site under the proposed abstraction scenario and two-thirds of this decline is related to the reduced recharge aspect of the scenario, which simulates a drying climate. Thus the model also appears to support the theory that groundwater abstraction is unlikely to have a significant impact at the site. However, additional monitoring bores and ongoing monitoring of the site is still necessary to confirm this and the issuing of large licences in the Superficial or upper Leederville aquifers in close proximity to the area should be avoided.

The following management approach is recommended:

- the large licensee to the east of the Ruabon site should continue to be monitored to ensure compliance with licence conditions. The implementation of water use efficiency measures should be encouraged
- monthly monitoring of the on-site shallow piezometer, EW10, and annual monitoring of the Ruabon vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- additional monitoring bores should be constructed into the Leederville formation at the site, as recommended by Cattlin (2007)
- the potential impact of groundwater abstraction on the Ruabon site should be reviewed when the local numerical groundwater model has been developed for the Swan coastal plain
- detailed work should be conducted to help refine ecological water requirements for the Ruabon site prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to this site.

Ambergate Reserve

Site description

Ambergate Reserve is located along Queen Elizabeth Avenue approximately 10 km south of Busselton town centre (Figure 20) in the Busselton-Capel groundwater subarea. The site supports three species of DRF, five priority species, endangered fauna and two TEC – SCP1b (*Corymbia calophylla* woodlands on heavy soils of the southern Swan coastal plain) and SCP02 (Southern wet shrublands, Swan coastal plain). The site contains walking trails, an information bay and car park, which are all managed by the Busselton Naturalist Club (Loomes *et al.*, 2007b).

Hydrogeological setting

The Ambergate Reserve is underlain by a thin layer of sandy Superficial sediments and around 100 m of Leederville formation. The composition of the Superficial is most likely Bassendean sand underlain by Guildford clays to 9 m.

Surrounding groundwater use

There are approximately 25 licensed groundwater allocations within 4 km of the Ambergate Reserve site. The total licensed allocation within this zone is approximately 1.15 GL/yr. Most of these allocations are small (<0.05 GL/yr) Leederville aquifer licences.

Within these licences there are a few larger allocations; one licence of 0.36 GL/yr less than 2.5 km to the west of the Ambergate site and one licence of around 0.2 GL/yr 3 km to the south-east (both in the Leederville aquifer) and two licences totalling 0.25 GL/yr 3 km to the south of the site in the Yarragadee aquifer.

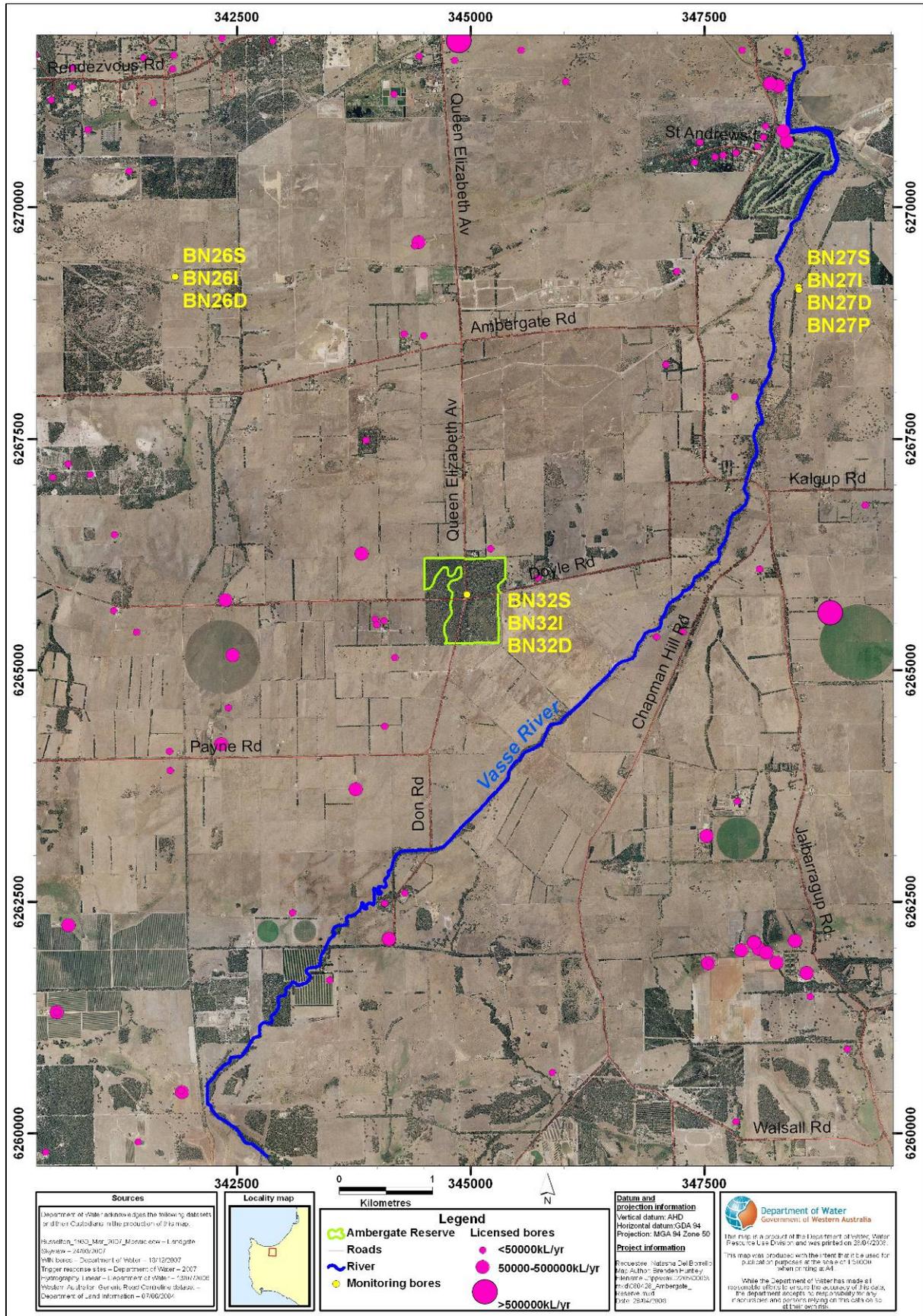


Figure 20 Location of Ambergate GDE site

Local water table trends

The nearest long-term groundwater monitoring site to Ruabon Reserve is BN32, a nested bore located in the reserve that monitors the Superficial and upper and lower parts of the Leederville aquifer. The lower Leederville has been monitored by BN32D since 1984 and water levels have declined by <math><0.05\text{ m/yr}</math>. The upper Leederville has been monitored by BN32I since 2000 and water levels appear steady, though the monitoring record is very short.

The Superficial aquifer has been monitored since 1987 by BN32S and shows water levels were steady until approximately 2002 but beyond that the annual minima has been falling, while maxima is steady (Figure 21). The autumn minimum water level in 2007 was approximately 8.2 m below the top of the bore casing (TOC) and the post-winter peak level was around 3.7 m below TOC. More frequent monitoring is now picking up the large seasonal fluctuations in water level at the site.

BN36S and BN36D are located approximately 6 km to the south of Ambergate Reserve and monitor the Superficial and lower Leederville aquifers respectively. BN36S show levels to be steady from 1987 when monitoring began followed by a decline of approximately one metre after 2002. BN36D shows ongoing declines since monitoring began in 1984, totalling approximately 1.5 m.

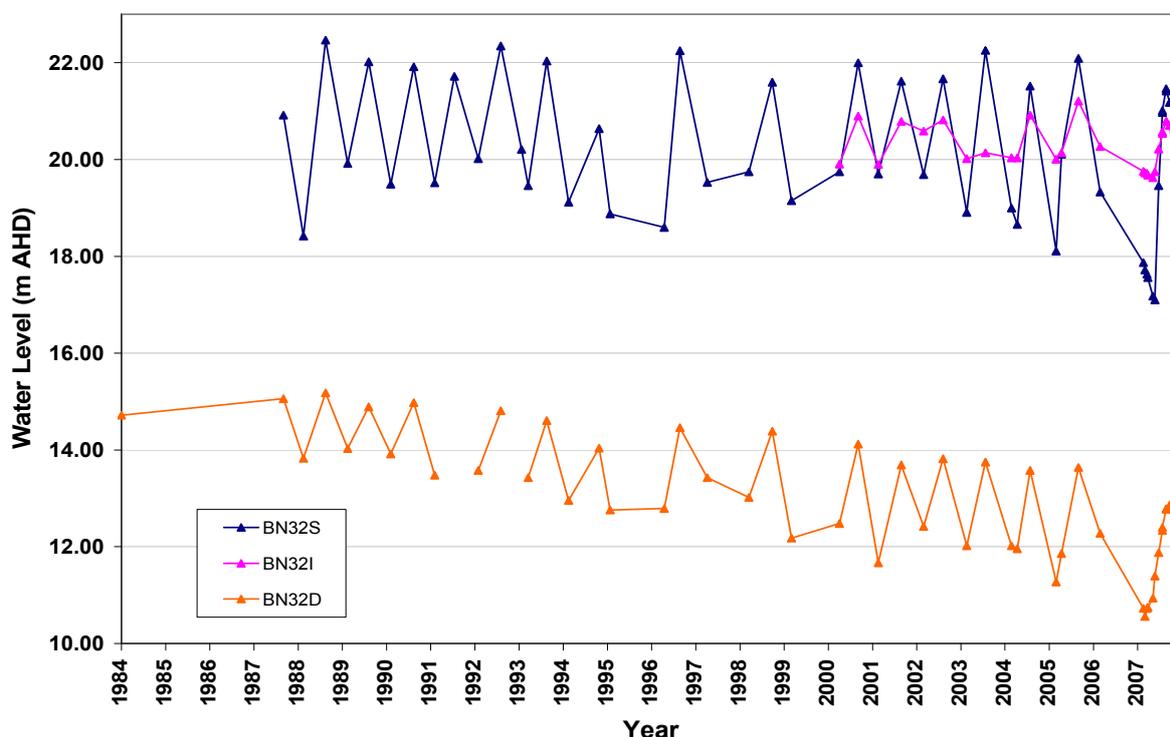


Figure 21 Hydrograph of Superficial monitoring bore BN32S, upper Leederville monitoring bore BN32I and lower Leederville monitoring bore BN32D, located within the Ruabon Reserve GDE site

Ecological water requirements

A vegetation transect has been established at Ambergate Reserve and is being monitored, but no site-specific work has been completed to determine the EWR. Until detailed EWR have been developed, the generic criteria established by Froend & Loomes (2004) for maintaining wetland vegetation at a low level of risk will be used. The criteria allow a maximum water level draw down of 0.25 m from the autumn minimum.

A check of the preferred water level range of the species identified in the vegetation transect as being most susceptible to groundwater decline, was compared to the known water regime as measured at the Ambergate shallow bore, BN32S. *Melaleuca raphiophylla* was the most susceptible species identified and its preferred water regime was comparable to the generic criteria of 0.25 m maximum draw down. Therefore the generic criteria are appropriate as a preliminary EWR for this site. Measured at the on-site piezometer, BN32S (and taken from the autumn 2007 minimum), this translates to a preliminary EWR of 16.85 mAHD. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined in this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Ambergate site (modelled at BN32S) indicate that it would undergo no draw down over a 25-year period (Figure 22). These results indicate the site will be at a low level of risk under the proposed abstraction scenario throughout the model period. This means there should be no measurable change to ecosystem processes, biodiversity, species abundance and water quality (Froend & Loomes, 2004).

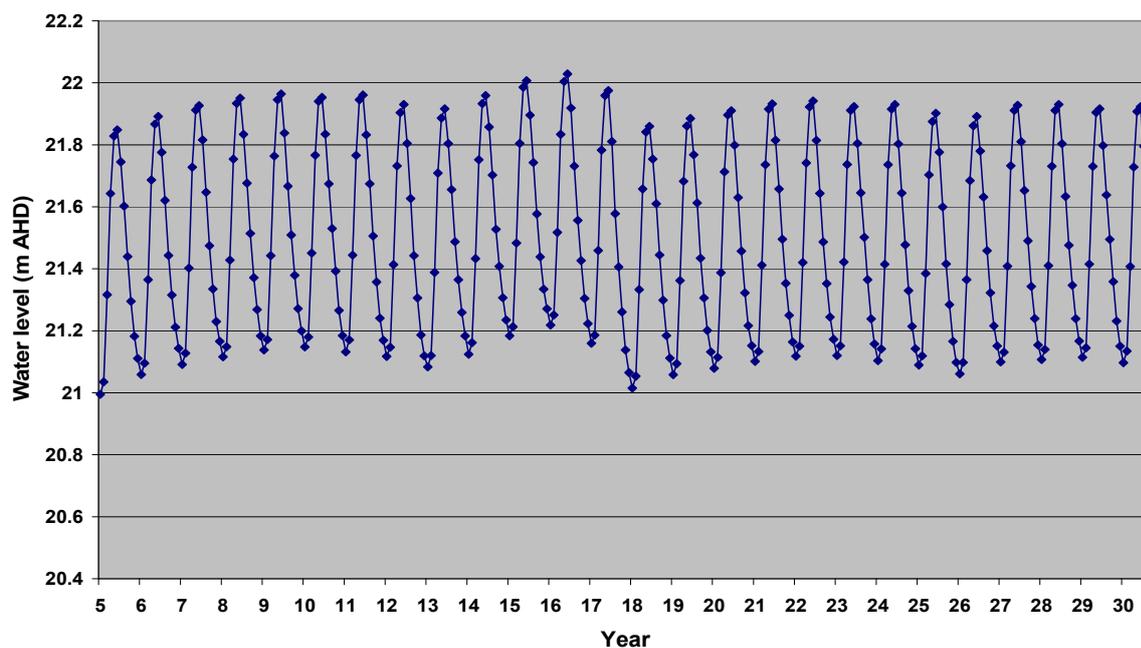


Figure 22 Modelled hydrograph at BN32S

Discussion and recommendations

The Superficial aquifer monitoring data around the Ambergate site does not currently appear to show strong evidence of abstraction impacts at the water table, though the deep Leederville monitoring bore shows a declining trend for the entire monitoring period. Drilling logs at the Ambergate site suggest the site lies on approximately 18 m of Superficial formation (primarily sands), under which 6 m of tight Leederville clay exists. If this clay layer is homogenous below the Ambergate site, the groundwater-dependent ecological values may be somewhat protected from impacts of abstraction from deeper aquifers. However, if the layer is not homogenous there would only be limited buffering of draw down effects from confined aquifer abstraction.

Detailed coring would be needed to confirm the nature of the Leederville formation at the site (Cattlin, T 2008, pers. comm., 4 February). Upward heads in the Leederville aquifer may be providing some hydrological support of the Ambergate site and, if this is the case, declining water levels in the Leederville may eventually have an impact at the water table. The vegetation at the Ambergate site is highly groundwater-dependent (Loomes *et al.*, 2007b).

There is not a large amount of groundwater abstraction occurring within 4 km of the Ambergate site. Most of these licences are small Leederville licences which do not appear to be affecting the shallow water table at BN32S.

Modelling results suggest that water levels will not decline at the Ambergate site under the proposed abstraction scenario. However, ongoing monitoring of the site is still necessary to confirm this and the issuing of large licences in the Superficial or Leederville aquifer in close proximity to the area should be avoided.

The following management approach is recommended:

- the large licensees near the Ambergate site should continue to be monitored to ensure compliance with licence conditions. The implementation of water use efficiency measures by these users should be encouraged
- monthly monitoring of the on-site shallow piezometer, BN32S, and annual monitoring of the Ambergate vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- the potential impact of groundwater abstraction on the Ambergate site should be reviewed when the local numerical groundwater model has been developed for the Swan coastal plain
- detailed work should be conducted to help refine ecological water requirements for the Ambergate site prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to this site.

5 Trigger-response sites for the Blackwood groundwater area

Poison Gully

Site description

Poison Gully is a northern-flowing tributary of the lower Blackwood River in the Yarragadee discharge zone located in the Blackwood Plateau South groundwater subarea. The vegetation within the system varies greatly with the soil conditions and ranges from sedgeland to low Melaleuca woodlands (Mattiske, 2005b). Surveys by Mattiske Consulting (2005a) found one rare flora species and six priority species within the valley system.

Poison Gully is also an important habitat for native freshwater fish and crayfish (Beatty *et al.*, 2006). The Poison Gully vegetation transect was established in State Forest adjacent to Blackwood Rd, west of the Brockman Highway (Figure 23). The vegetation within the transect included open woodland of *Eucalyptus marginata*, *Banksia grandis*, *Xylomelum occidentale* and *Allocasuarina fraseriana* with *B. littoralis* over *Taxandria parviceps* (Froend & Loomes, 2006).

Hydrogeological setting

Poison Gully is located on an area of Yarragadee formation sub-crop and is maintained directly from groundwater from that formation (URS, 2004b). Therefore, significant changes in water levels or pressure heads within the Yarragadee formation, which may be induced by abstraction of large amounts of water from the aquifer, would likely have an effect on water levels in the riparian zone and the volume of groundwater discharge into Poison Gully. Mattiske Consulting (2005a) found that a significant number of the species in their established transects in Poison Gully were likely to be highly dependent on regional groundwater levels. Therefore, significant regional abstraction of groundwater from the Yarragadee aquifer has the potential to have an adverse impact on the ecological values within Poison Gully.

Surrounding groundwater use

There are approximately 15 licensed allocations within 10 km of the Poison Gully site, the closest abstraction points being 2.5 km away, adjacent to the Blackwood River. All of these 15 draw points are small domestic allocations which together total less than 30,000 kL/yr. All wells are licensed to take water either from the Yarragadee or Leederville aquifer.

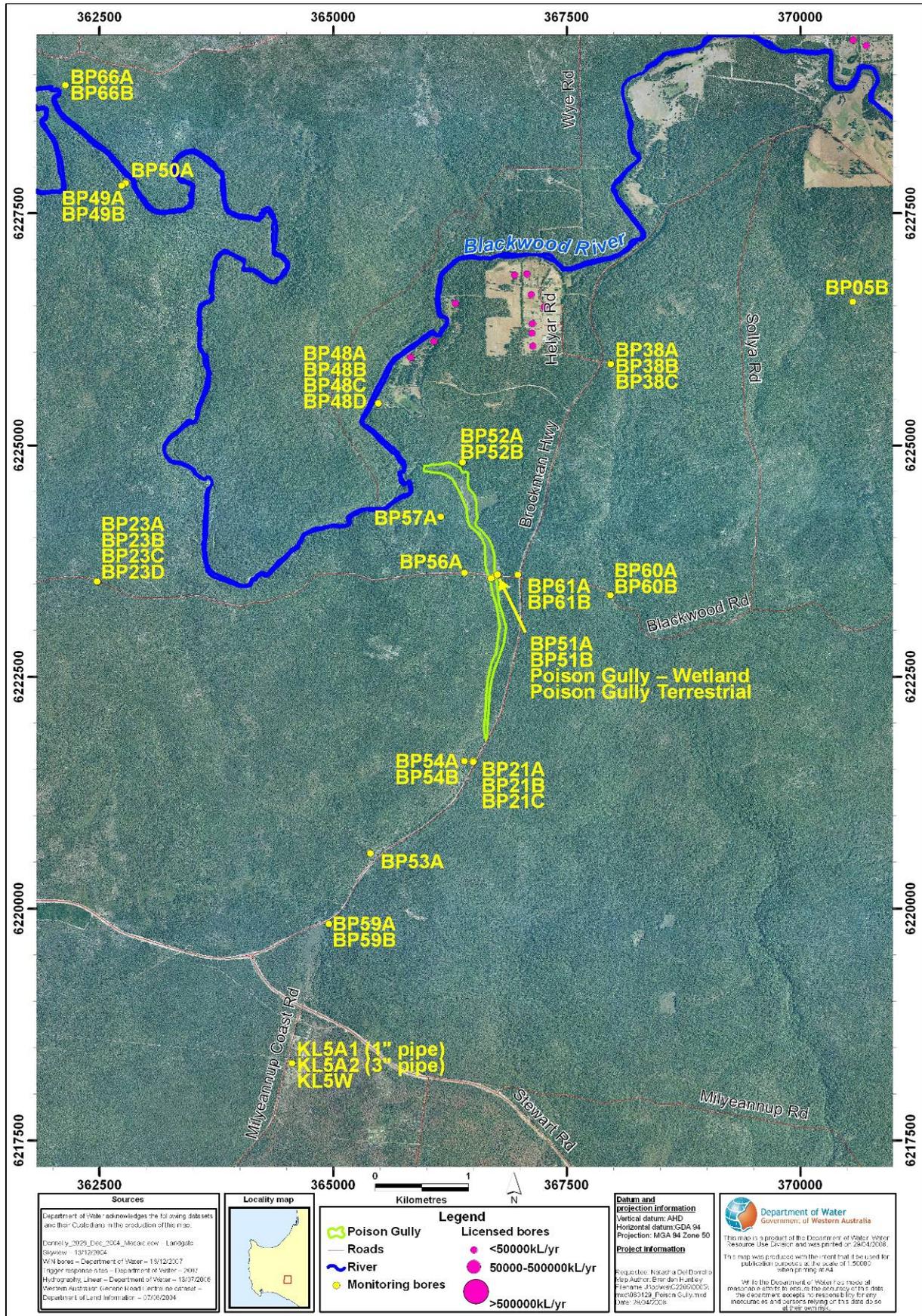


Figure 23 Location of Poison Gully GDE site

Local water table trends

There are no long-term shallow monitoring bores within the vicinity of Poison Gully. Several nested piezometers (BP51, BP56 and BP61) have been installed by the Water Corporation within 500 m of the vegetation transect but monitoring records for these only began three to four years ago. Several other monitoring bores have also been installed by the Water Corporation in the Poison Gully area (predominantly into various parts of the Yarragadee aquifer) and all bores show similar downward trends over the past three to four years since monitoring began. Shallower bores seem to show a response to the recent rainfall conditions, with a high peak in 2005 when winter rainfall was good, and a low peak in 2006 when rainfall was poor. A shallow monitoring bore near the vegetation transect, BP51C, shows a similar trend, though overall seasonal fluctuation is less than one metre and the variation in annual minima has been only around 0.1 m (Figure 24).

The nearest long-term monitoring bore to Poison Gully is KL5 which has measured water levels at different depths within the Yarragadee aquifer since 1989. KL5 is located around 5.5 km south of the Poison Gully transect and the bore data show that there has been a decline in the deepest bore of around one metre over that time period, while the two shallower bores (at around 400 m and 30 m depth) show increasing levels to 2001 followed by sharp declines of two to three metres since that time.

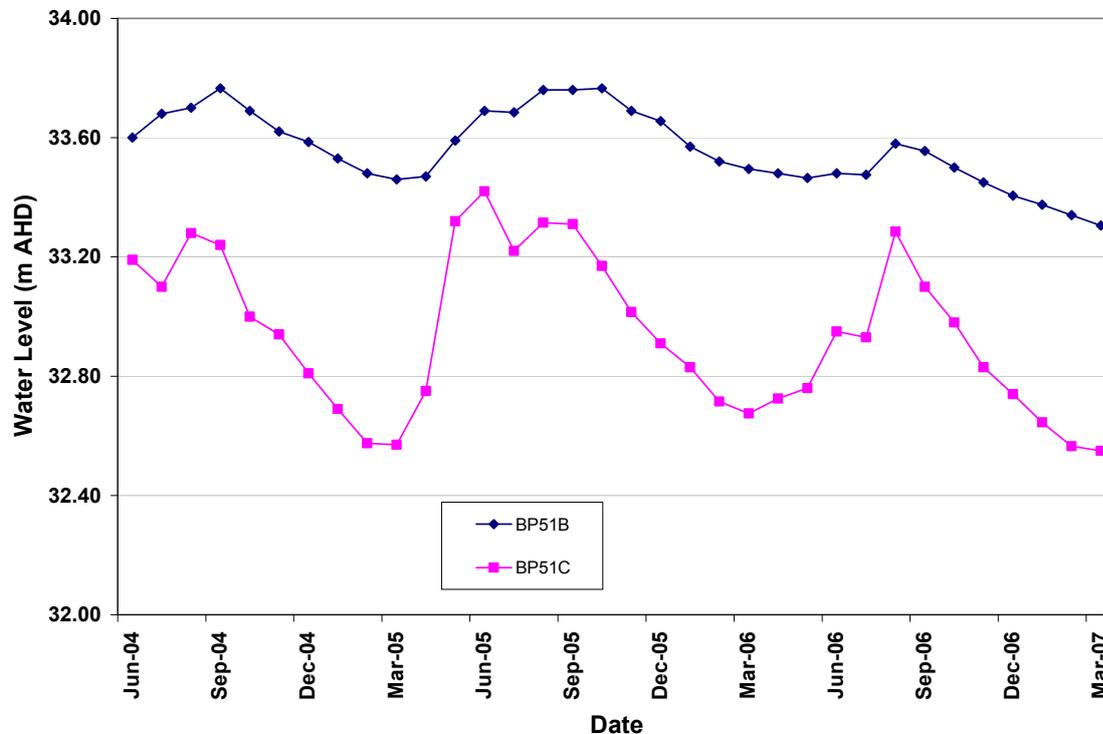


Figure 24 Hydrograph of Superficial monitoring bore BP51C and Yarragadee monitoring bore BP51B, located approximately 50 m from the Poison Gully GDE site

Ecological water requirements

Froend & Loomes (2006) recommended EWR criteria for the Poison Gully site based on maintaining the most vulnerable of the dominant wetland species recorded at the vegetation transect (*Pultenaea reticulata*). Due to the lack of knowledge of the water requirements of many other species at the site the maximum draw down criterion was then further reduced as a precaution to 0.75 m below ground level. Measured at a temporary shallow piezometer near the transect (site no. 60910125) this criterion translates to 30.47 m AHD. It is recommended that minimum water levels should persist no more than two consecutive years below this level and site-specific water requirements should be determined within this period.

A suitable shallow monitoring bore should be installed at the Poison Gully transect to replace the temporary piezometer.

Modelling results

Discounting the first four years of data to allow for stabilisation of the model, the model outputs for the Poison Gully site indicate that it would undergo 0.84 m of draw down to Year 30 under the proposed allocation scenario (Figure 25). These results indicate that vegetation at the site would be under a 'high' to 'severe' level of risk. It appears that a significant part of this draw down (over 0.3 m) is due to the reduced recharge input into the model under the 'climate change' scenario. The high risk factor implies that there is the potential for large changes to occur to the ecosystem processes, to the vegetation, to the dependent fauna and to water quality (Froend & Loomes, 2004).

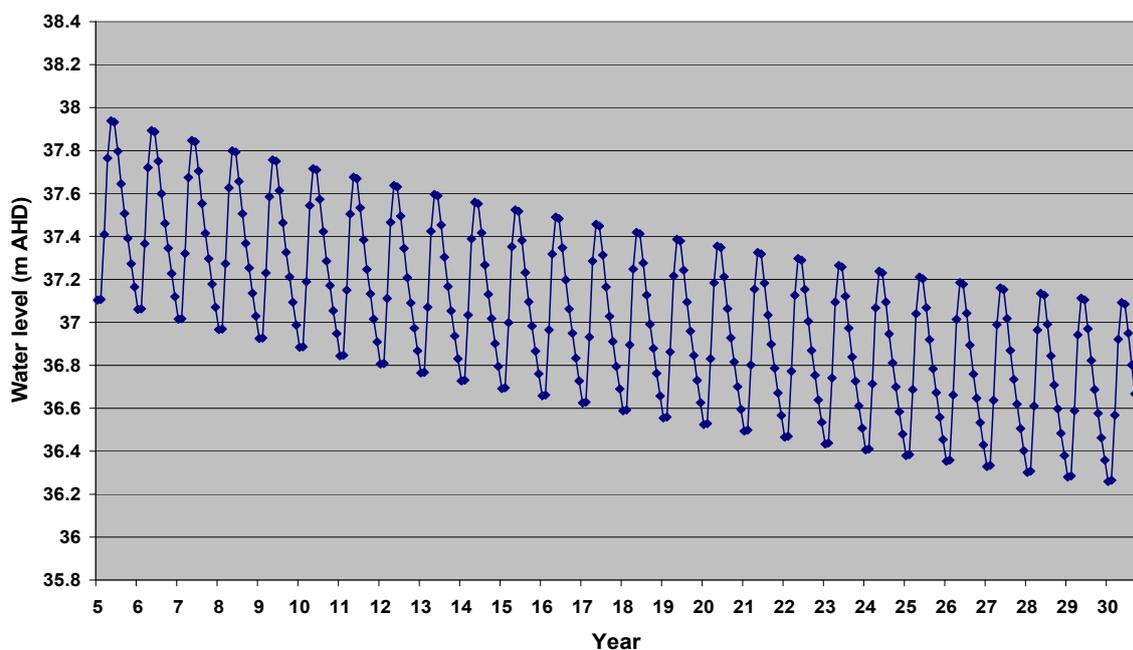


Figure 25 Modelled hydrograph of water levels at the 'Poison Gully-wetland' temporary piezometer

Discussion and recommendations

Licensed abstraction around the Poison Gully site is currently insignificant and is likely to remain so due to its location in State forest. However, there is the potential for large allocations from the Yarragadee aquifer further a field to cause draw down impacts in the local area and to adversely affect the ecological values of the wetland and tributary environments. Poison Gully has high ecological value due to the diversity of landscapes within it. Its high diversity of both flora and fauna is due to the relatively undisturbed nature of the area, the variety of soil conditions and the presence of permanent, fresh water. Its likely sensitivity to changes in the regional hydrology (due to both a drying climate and regional groundwater abstraction) will require careful monitoring and assessment.

The following management approach is recommended:

- monthly monitoring at both the temporary shallow piezometer (site no. 60910125) and the nearby shallow piezometer, BP51C, and annual monitoring of the Poison Gully wetland and terrestrial vegetation transects in spring should continue until such time as the monitoring program is reviewed again prior to the development of the statutory allocation plan
- continuous flow monitoring near the confluence of Poison Gully with the Blackwood River should continue for the life of the current plan
- the annual 'snapshot' of summer base flow discharge measurements at defined points along Poison Gully should continue at least until the 2010 summer and then be reviewed
- the current Murdoch and Edith Cowan University fish, freshwater crayfish and macroinvertebrate monitoring program for the lower Blackwood River (including Poison Gully) should continue, with annual reviews, until the program ends in 2010. The recommendations coming out of this program for ongoing monitoring of aquatic fauna should then be implemented
- the surface and groundwater relationships at Poison Gully should be further investigated (an initial review of flow, groundwater and rainfall data has been initiated and will be completed before mid-2008)
- detailed work should be conducted to refine ecological water requirements for the Poison Gully site prior to the statutory allocation plan in 2011
- the temporary piezometer (site no. 60910125) should be replaced as part of the current review of the monitoring infrastructure
- the ASS potential of the organic soils of the Poison Gully area should be investigated (currently occurring and investigations will be complete by mid-2008)
- the management framework as set out in figures 2 and 3 should be applied to this site.

Reedia South

Site description

Reedia swamps occur north and south of the lower Blackwood River in the vicinity of Spearwood and Adelaide creeks in the Blackwood Plateau South groundwater subarea. The site where the wetland triggers and management actions should be applied is located 1.5 km south of the Blackwood River, a few hundred metres from the intersection of Blackwood Rd and Few Rd (Figure 26). Reedia South is partly within the Blackwood River National Park and partly within State Forest. The Reedia swamp communities are listed as a proposed TEC by the Department of Environment and Conservation and are habitat for the threatened orange-bellied and white-bellied frogs (*Geocrinia vitellina* and *G. alba*). The Reedia site supports sedgeland of *Reedia spathacea*, *Meeboldina* species and *Leptocarpus tenax*, open heathlands and Eucalyptus forest.

Hydrogeological setting

The Reedia South site is located on the Vasse Shelf. The site is underlain by the Leederville formation, which is underlain by the Lesueur Sandstone. The Busselton Fault lies to the east of the Reedia site, and the Bunbury Trough lies beyond the Fault. The Yarragadee formation underlies the Leederville formation in the Bunbury Trough area (URS, 2004a).

The connection between the Yarragadee formation and the Reedia wetlands has been the subject of some debate. The risk to the Reedia area from regional draw downs in the Yarragadee is generally thought to be fairly low, despite SWAMS modelling results suggesting that the site may be at risk of significant draw downs under the proposed abstraction scenario. The area is likely to be more at risk from groundwater abstraction from the Lesueur Sandstone aquifer occurring in the western Scott coastal plain agricultural zones.

Mattiske Consulting (2005a) described many of the species occurring within the Reedia wetlands as highly groundwater dependent and noted that impacts to the vegetation would be expected should there be a change in local hydrological conditions at the site.

Surrounding groundwater use

There are no licensed groundwater bores within 4 km of the Reedia South site and only around ten licensed allocations within 10 km of the site. Most of these are small licences in the Leederville aquifer, though also included are two larger allocations totalling less than 1 GL/yr and a large allocation from the Lesueur Sandstone aquifer of 1.65 GL/yr. The larger allocations are all located between 6.5 and 10 km of the site.

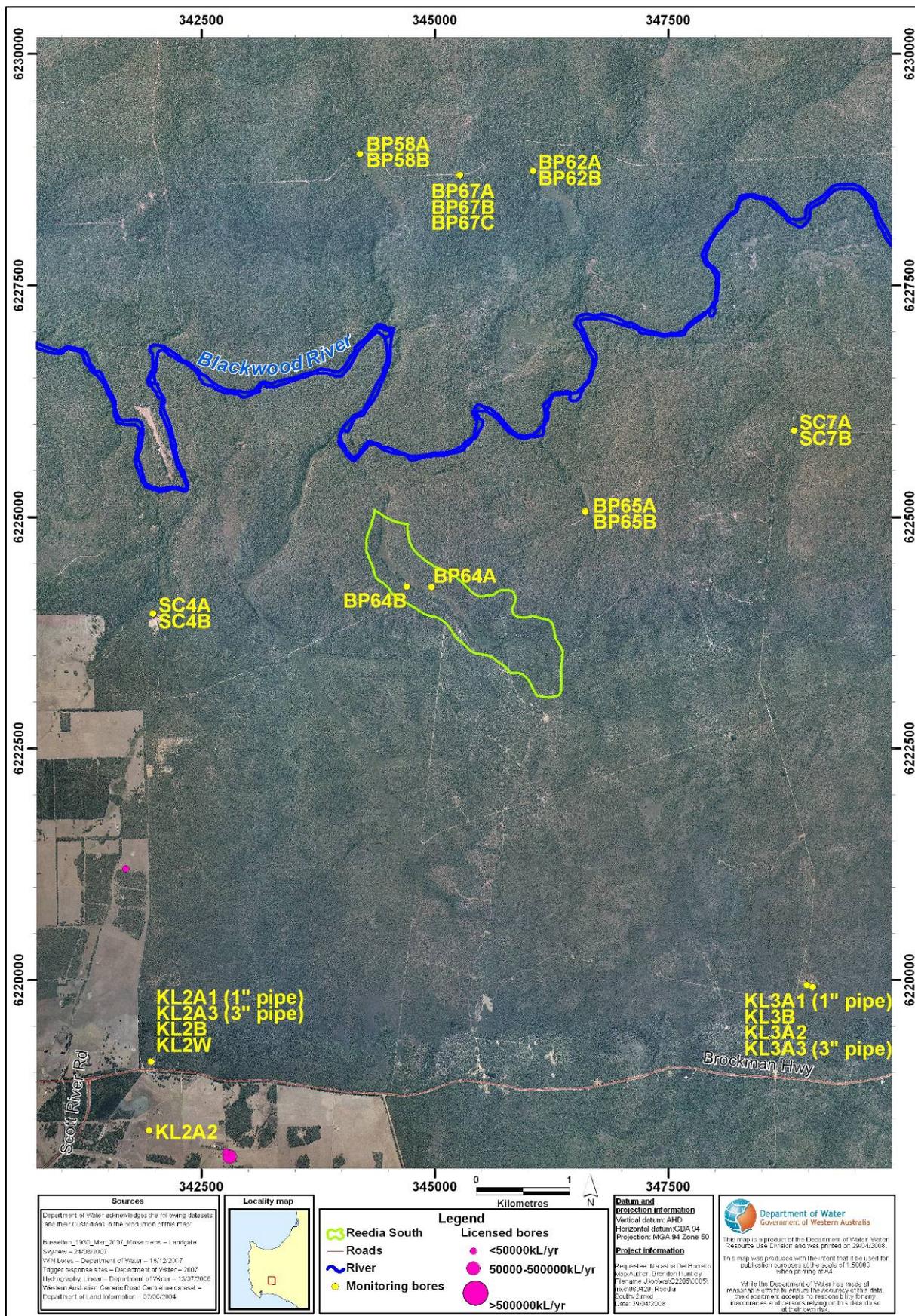


Figure 26 Location of Reedia South GDE site

Local water table trends

There are no long-term shallow monitoring bores within 5 km of the Reedia South site. The nearest long-term monitoring bores, SC4A and SC4B, are located within 3 km of the site and measure water levels in the Leederville and Lesueur Sandstone aquifers. Monitoring has been undertaken since 1992 and water levels in both bores have been declining gradually since 2000.

A shallow piezometer, BP64B, was installed at the site by the Water Corporation in mid-2004 and water levels appear stable over that time period, with seasonal fluctuations of approximately one metre (Figure 27). The autumn minimum water level in 2007 was approximately 1.5 m below the top of the bore casing.

A Leederville aquifer monitoring bore (BP64A) was also established by the Water Corporation approximately 250 m from BP64B. This bore is 25 m deep and water levels mirror those recorded in BP64B.

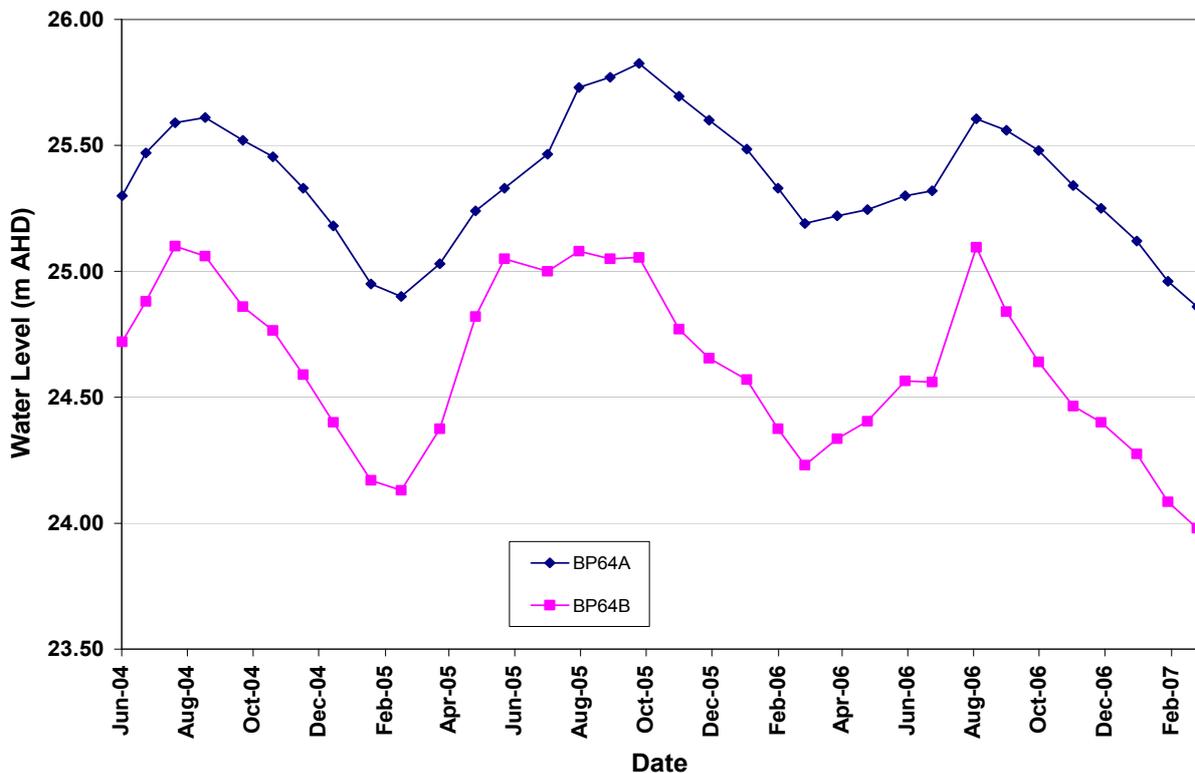


Figure 27 Hydrograph of shallow Leederville monitoring bore BP64B and deeper Leederville monitoring bore BP64A, located at the Reedia South site

Ecological water requirements

While vegetation transects have been established and monitored by the Water Corporation, no site-specific work has been completed at the Reedia South site to determine the EWR. However, this work will occur over the next two years. In the meantime the generic criteria established by Froend & Loomes (2004) for maintaining wetland vegetation at a low level of risk will be used. The criteria allow a maximum water level draw down of 0.25 m from the autumn minimum at a rate no greater than 0.1 m/yr. Taking autumn of 2007 as the baseline year, the minimum ecological water requirement criterion for the Reedia site, measured at BP64B, would be 23.73 m AHD.

The generic rate criterion of 0.1 m/yr immediately becomes problematic as over the three year period of monitoring this has already been exceeded, showing the need for site-specific EWR work. This work is scheduled to begin by mid-2008. It is recommended that minimum water levels should persist no more than two consecutive years below the EWR trigger level of 23.73 m AHD and site-specific water requirements should be determined within this period.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the model outputs for the Reedia South site indicate that it would undergo 0.55 m of draw down between Year 5 and Year 30 under the proposed allocation scenario (Figure 28). These results indicate that vegetation at the site would be under a 'high' level of risk. This implies that there is the potential for moderate changes to occur to the ecosystem processes, to the vegetation, to the dependent fauna and to water quality (Froend & Loomes, 2004).

As has been previously mentioned, there is a lack of confidence in the conceptual hydrogeology in this area and the SWAMSV2 model is not well calibrated here. As such the modelled draw downs are unreliable and there is a definite need for a better understanding of the hydrogeological processes in this area.

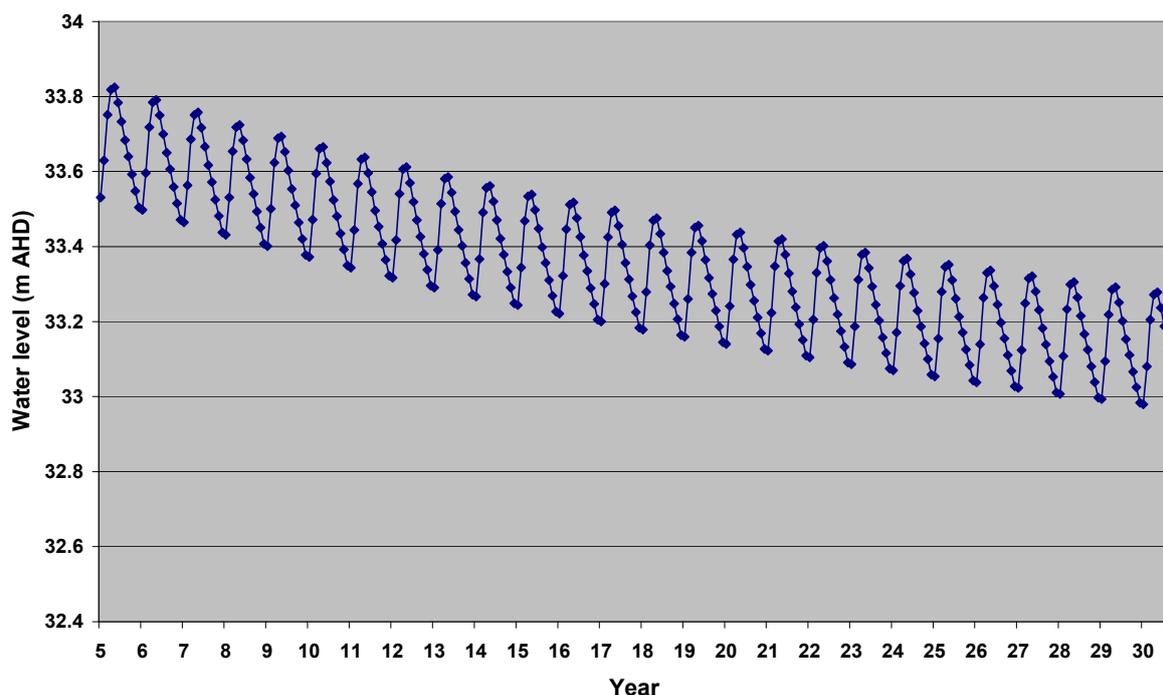


Figure 28 Modelled hydrograph at BP64B

Discussion and recommendations

The uncertainty about the regional hydrogeological processes that affect the Reedia wetlands together with the high ecological value and high level of groundwater-dependence of the site suggests that careful ongoing monitoring and further investigation is necessary to determine the best groundwater allocation management approach for this area.

The following management approach is recommended:

- the few large water users within 10 km of Reedia South should continue to be monitored to ensure their compliance with licence conditions and should be encouraged to adopt water use efficiency measures
- monthly monitoring of the on-site shallow piezometer, BP64B, and annual monitoring of the Reedia vegetation transect in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- detailed work should be conducted to refine ecological water requirements for the Reedia South site prior to the statutory allocation plan in 2011
- there should be continued liaison with the Department of Environment and Conservation regarding appropriate management of the Reedia wetlands
- the management framework as set out in figures 2 and 3 should be applied to this site.

Black Point Rd

Site description

The Black Point Road site is located in State Forest on the Scott coastal plain on the northern side of Black Point Rd in between Jack Track and Fouracres Road (Figure 29) in Jasper groundwater subarea. The site is a palusplain that has been burnt in recent years, resulting in a relatively sparse understorey (Froend & Loomes, 2006). The dominant vegetation species at the site are *Pericalymma ellipticum*, *Agonis juniperiana* and sedges at lower elevations, moving to denser shrubs and *M. preissiana* woodland and *E. marginata* in the upland areas. The vegetation is in good to moderate condition and the site is virtually free of exotic species (Loomes *et al.*, 2007a).

Hydrogeological setting

As there is a lack of site specific data for the Black Point Road site, bores SC18 and SC19 must be used to interpret the hydrogeology. Information from these sites indicate that the Superficial sands are approximately 15 m thick and are underlain by interbedded sands and clays of the Leederville formation to approximately 20 m. The Yarragadee formation lies under the Leederville formation and typically consists of interbedded sands and silts that are generally unconsolidated to a depth of around 30 m (Cattlin, T 2008, pers. comm., 4 February).

Surrounding groundwater use

There are several licensed allocations within 10 km of the Black Point Road site. A total of 6.6 GL/yr is currently licensed from the Yarragadee aquifer, 4.0 GL/yr of this to a single mining licence approximately 5 km to the south of the Black Point Road site. However, only a percentage of the 4.0 GL/yr entitlements are currently being taken, mainly for rehabilitation purposes (Palandri, R 2008, pers. comm., 29 February). A further 1.39 GL/yr is proposed to be taken, mostly from the Yarragadee aquifer, pending licence assessment.

Whilst the closest licensed abstraction point is two kilometres from the Black Point Road site and the number of abstraction points within 10 km is very small, the allocation volumes are very large. This suggests careful monitoring of the groundwater-dependent ecosystem is required to ensure that draw downs in the Yarragadee aquifer are not translated through the Leederville aquifer to cause draw downs at the site or at surrounding GDE.

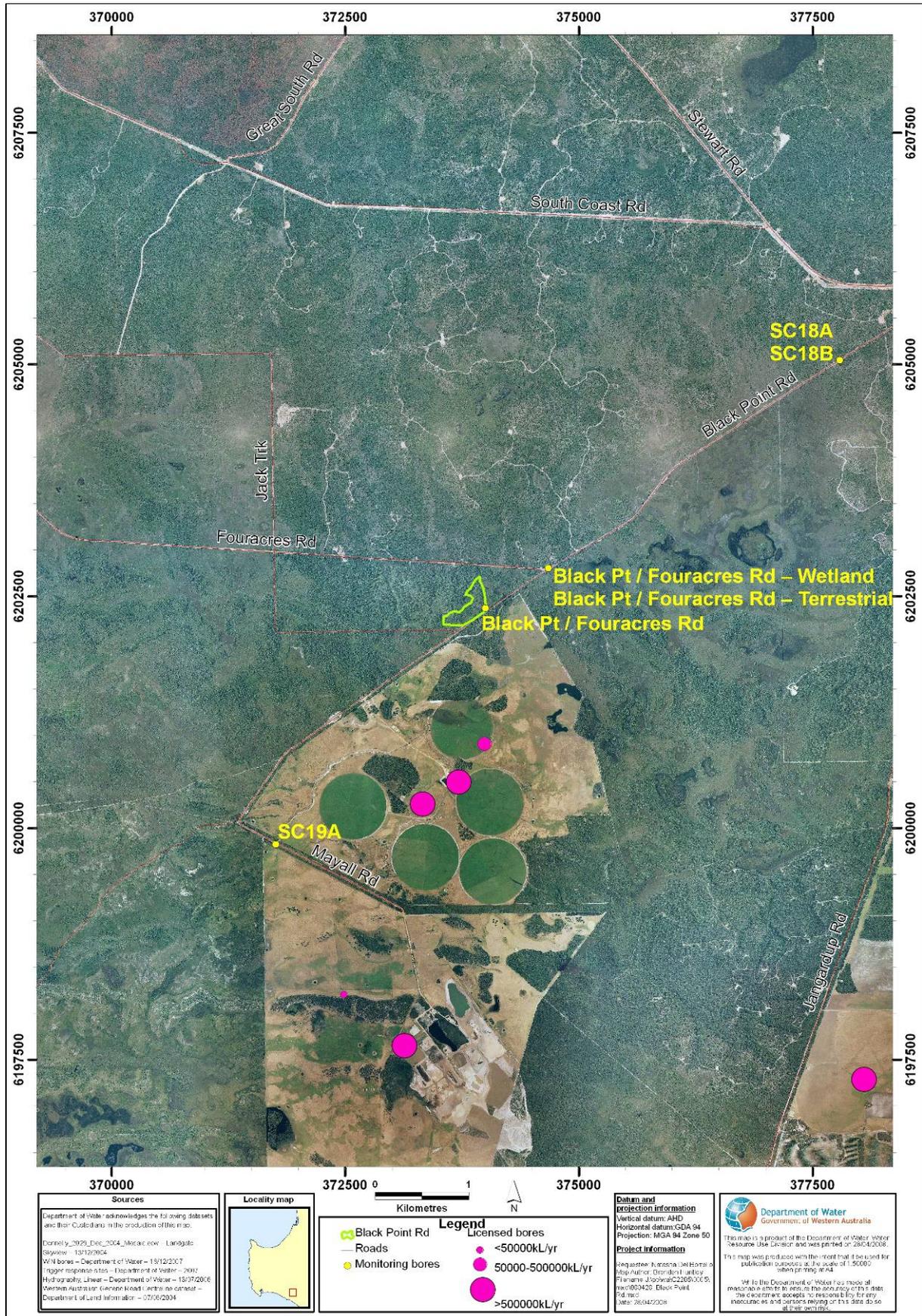


Figure 29 Location of Black Point Rd GDE site

Local water table trends

There are no long-term water table monitoring bores close to the Black Point Road site. A shallow piezometer was installed at the site in May 2006 and monitoring has been conducted monthly or bi-monthly since that time. This piezometer shows approximately a 1.5 m seasonal fluctuation in water levels at the GDE. The nearest long-term water level monitoring bore, SC19A, lies 3.5 km to the south-west of the Black Point Road site and monitors the Yarragadee aquifer at a depth of around 100 m. SC19A has been monitored biannually since 1992 and shows water levels to be relatively stable, with a very gradual decline of around 0.25 m since 2000.

Monitoring bores SC18A and SC18B also monitor the Yarragadee aquifer and are located 4.7 km to the north-east of the Black Point Road site. SC18A monitors the Yarragadee at a similar depth to SC19A and records show that water levels rose between 1992 and 2000 and have since declined around 1.2 m. SC18B is screened in the Yarragadee at a depth of around 20 m and its records show a rise of around 3 m between 1992 and 1998 and a fall of around 3.5 m since that time.

Two new monitoring bores were drilled in April 2006 at a site approximately 700 m to the north-east of the Black Point Road site, one into the Leederville and one into the Yarragadee aquifer. This site (Black Point–Fouracres Rd (Figure 29)) also has a temporary shallow piezometer and two vegetation transects have been established here. Because of the amount of monitoring infrastructure it is recommended that trigger–response criteria be transferred to this site in time for the revised allocation plan in 2011.

Ecological water requirements

Froend & Loomes (2006) recommended an EWR criterion for the Black Point Road site based on maintaining the most vulnerable of the dominant wetland species recorded at the vegetation transect (*Banksia littoralis*). Froend & Loomes (2006) recommended that minimum groundwater levels should persist no longer than two years below the criterion of 42.95 m AHD, measured at a temporary shallow piezometer near the transect (site no. 60914933). In autumn 2007 the piezometer measured 43.43 m AHD, almost 0.5 m above the EWR level.

The piezometer at the Black Point Road transect is only a temporary structure and should be replaced with a permanent monitoring bore as soon as practicable.

As previously mentioned, the Black Point–Fouracres Rd site to the north-east of the Black Point Road site has better groundwater monitoring infrastructure and it is therefore recommended that site-specific EWR work be carried out here rather than at Black Point Road over the next two years.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the model outputs for the Black Point Road site indicate that it would undergo 1.16 m of draw down between Year 5 and Year 30 under the proposed allocation scenario (Figure 30). These results indicate that vegetation at the site would be under a 'severe' level of risk. This implies that there is the potential for large changes to occur to the ecosystem processes, to the vegetation, to the dependent fauna and to water quality (Froend & Loomes, 2004). Approximately 0.25 m of that change is due to the reduced recharge factor of the model, applied to represent the likelihood of a further decline in rainfall in the future.

The SWAMS v2 model is considered to be a conservative model on the coastal plains and therefore the modelled draw downs are likely to be greater than would be anticipated in reality. A local model has been produced for the eastern Scott coastal plain but it needs further modifications before it may be used to predict draw down impacts.

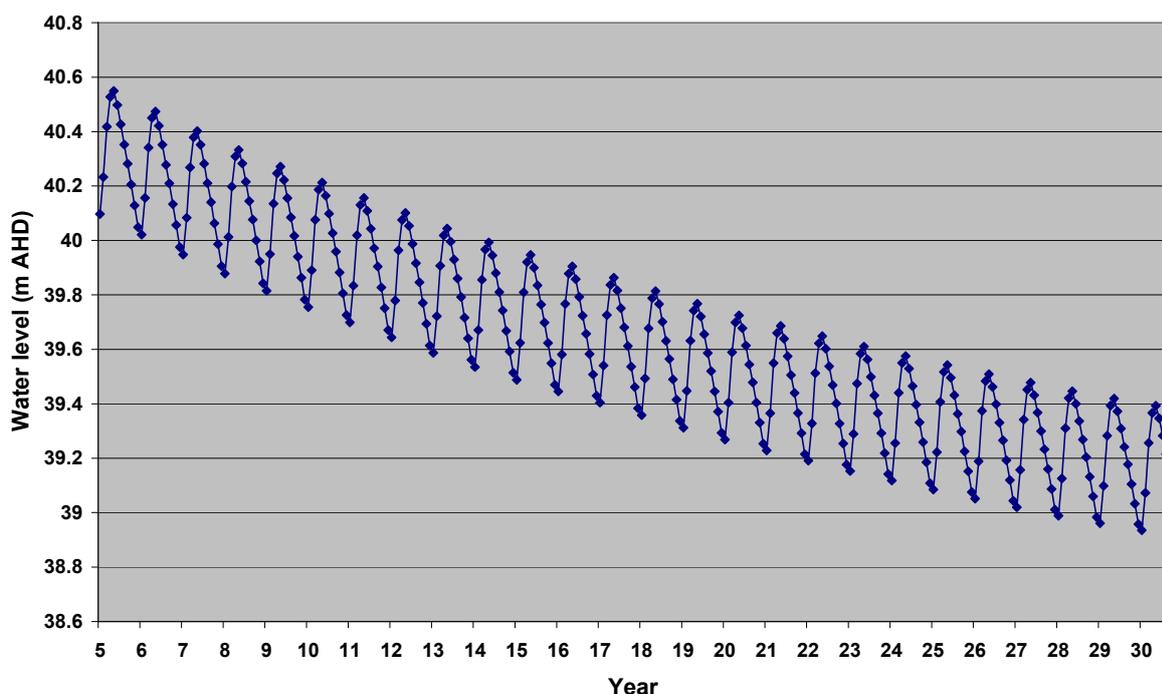


Figure 30 Modelled hydrograph at 'Black Point Rd' temporary piezometer

Discussion and recommendations

SWAMsv2 modelling suggests that the Black Point Road site is at significant risk of groundwater draw down, predominantly due to abstraction effects. The model is likely to be over-predicting draw downs on the coastal plains, as previously discussed, so a revised local model is needed in this area. However, despite the lack of an adequate model, the large amount of groundwater abstraction in the vicinity of the site and the lack of a significant Leederville formation to act as a confining layer indicates that the

site will be at risk of draw down impacts and should be carefully monitored to ensure unacceptable impacts to the ecological values do not occur.

There is a paucity of Superficial groundwater monitoring data within the vicinity of the Black Point Road site, so it is unclear whether the site may have already experienced groundwater declines due to the large volumes being abstracted from the Yarragadee aquifer nearby. Due to the impacts of a recent fire, it is also difficult to ascertain whether the vegetation community has suffered any decline in health in response to water table draw down. There is a need to replace the existing temporary piezometer at the site with a permanent monitoring bore and water levels should continue to be measured at least six times per year to ensure the peaks and troughs of the water regime are adequately captured.

The following management approach is recommended for the Black Point Road site:

- the large water users within 10 km of the Black Point Road site should continue to be monitored to ensure their compliance with licence conditions and should be encouraged to adopt water use efficiency measures
- monthly monitoring of the temporary on-site piezometer, 'Black Point Road' (site 60914933), and annual monitoring of the site vegetation transect in spring should continue until such time as the monitoring program is reviewed again prior to the development of the statutory allocation plan. Regular monitoring of the temporary piezometers and vegetation transects at the Black Point–Fouracres Rd site should also continue with the view that the trigger–response criteria is to be transferred from Black Point Road to this site
- the temporary piezometers installed at both the Black Point Road and Black Point–Fouracres Rd sites should be replaced with permanent shallow monitoring bores
- the relationship between the shallow water table and the underlying aquifers at the Black Point Road and Black Point–Fouracres Rd sites should be further investigated to understand the likelihood of impacts from Yarragadee aquifer abstraction
- the eastern Scott coastal plain local model should be revised or redeveloped so that the area may be adequately modelled
- detailed work should be conducted to define ecological water requirements for the Black Point–Fouracres Rd site prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to this site.

Lake Jasper East

Site description

Lake Jasper is part of the Lake Jasper wetland system on the eastern Scott coastal plain; a large area of permanent and seasonal wetlands that drain into the lower Donnelly and upper Scott rivers. Lake Jasper is located in the D'Entrecasteaux National Park. It has around 440 ha of open water and is up to 10 m deep, making it possibly the largest and deepest natural permanent freshwater lake in the state. The lake is recognised as a wetland of National Significance (ANCA, 1993) and is a registered Aboriginal Heritage site. It has extremely high habitat value, supporting significant populations of native birds, frogs, fish and invertebrates, as well as unique stands of vegetation (Pen, 1997).

The department has established wetland transects at two sites at Lake Jasper, one of which, the Lake Jasper East site, is located on the south-eastern edge of the lake, near a public boat ramp and close to an existing surface water monitoring gauge and new monitoring bore EW8 (Figure 31). The Lake Jasper East site is located in the Jasper groundwater subarea. The second site, Lake Jasper South, is located near monitoring bores SC21A and SC21B. The following information and management triggers and responses apply to the Lake Jasper East site.

Hydrogeological setting

Various hydrogeological investigations have been conducted around Lake Jasper; most recently the department and CSIRO have conducted separate investigative drilling projects. The Lake Jasper hydrogeology has been revealed as very complex. It is thought that approximately ten metres of Superficial sands are underlain by Yarragadee formation (typically interbedded sands and silts) but there are also indications that the Leederville formation may be present. The area requires more investigative drilling to better define the hydrogeological interactions that support the groundwater-dependent ecological values (Cattlin, T 2008, pers. comm., 4 February).

Surrounding groundwater use

There are several licensed allocations within 12 km of the Lake Jasper East site. These are all located to the north-east of Lake Jasper and are the same licences detailed for the Black Point Road site. The closest licensed abstraction point is seven kilometres from the Lake Jasper East site. There are only four abstraction points and a further three licences pending assessment within 12 km. However, the allocation volumes are very large and the ecological, social and cultural values of Lake Jasper are very high. Existing licensees should continue to be monitored to ensure that they are meeting licence conditions and new proposals should be carefully scrutinised to verify that draw downs will not have an unacceptable impact on lake values. Ongoing monitoring of the lake levels and groundwater levels around Lake Jasper is required to ensure any declining water level changes in the Yarragadee aquifer are not translated through the confining layer causing impacts to the lake.

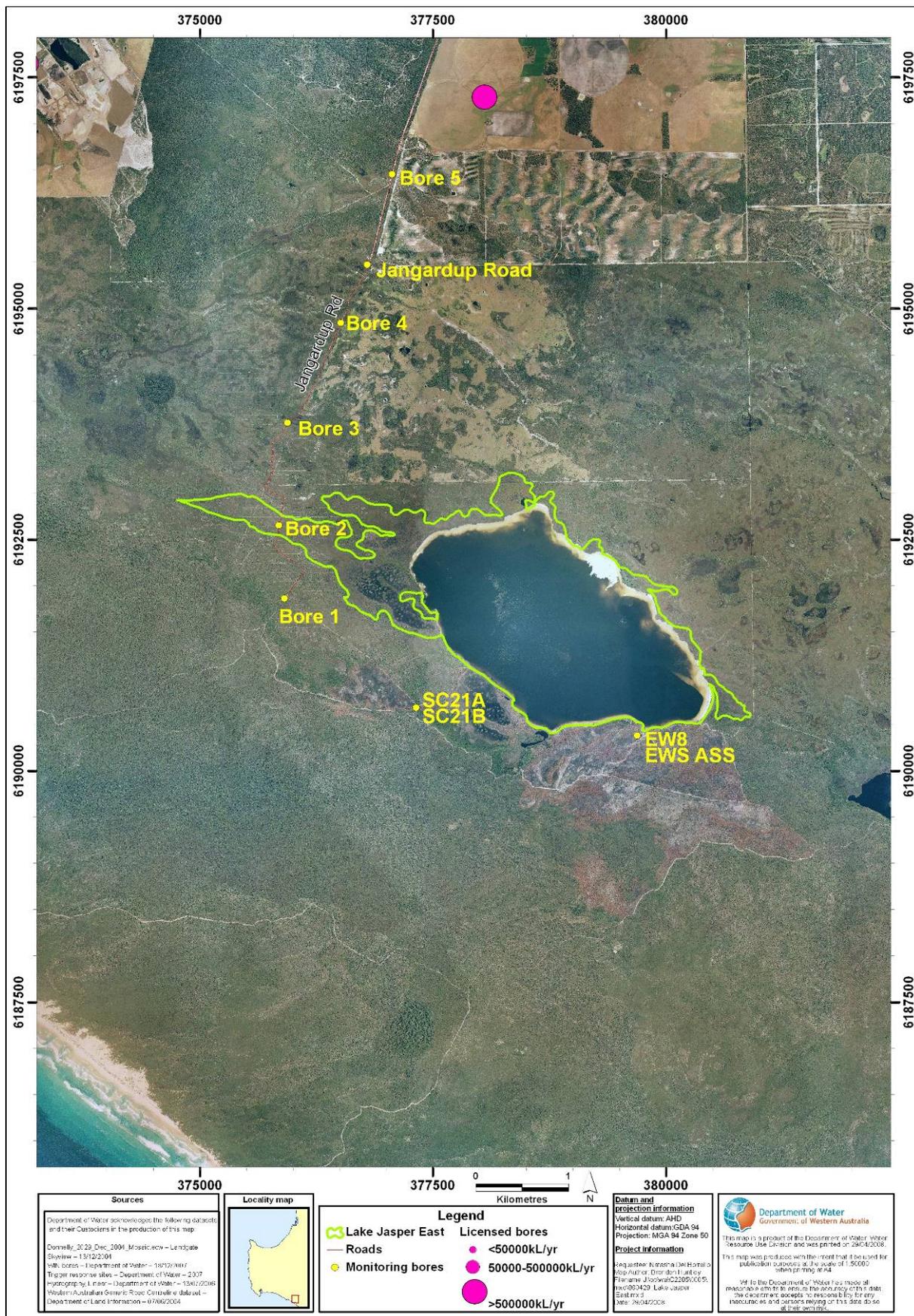


Figure 31 Location of Lake Jasper GDE site

Local water table trends

The closest long-term water table monitoring bore to the Lake Jasper East site is SC21B, which is located approximately 2.4 km to the west (Figure 32). Water levels have been measured at the bore since 1992, though sampling was very infrequent until 2007 when the measurement rate was increase to six times per year. As a result, it is difficult to ascertain what the water level trends have been, but overall they appear to have been stable, with seasonal fluctuations of up to 1.5 m. Water levels at SC21A and SC21B are now measured manually six times per year and are also continuously logged.

A similar pair of monitoring bores site is located 4 km to the east of Lake Jasper East. Both the Superficial and Yarragadee aquifers have been monitored irregularly at this location since 1992. Water levels in the Superficial monitoring bore, SC22B, appear to have been stable throughout the period, though there are significant gaps in the data. Seasonal fluctuations are up to 1.5 m. The Yarragadee monitoring bore, SC22A, measures water levels at a depth of around 50 m below ground level. Water levels in these bores are now measured monthly.

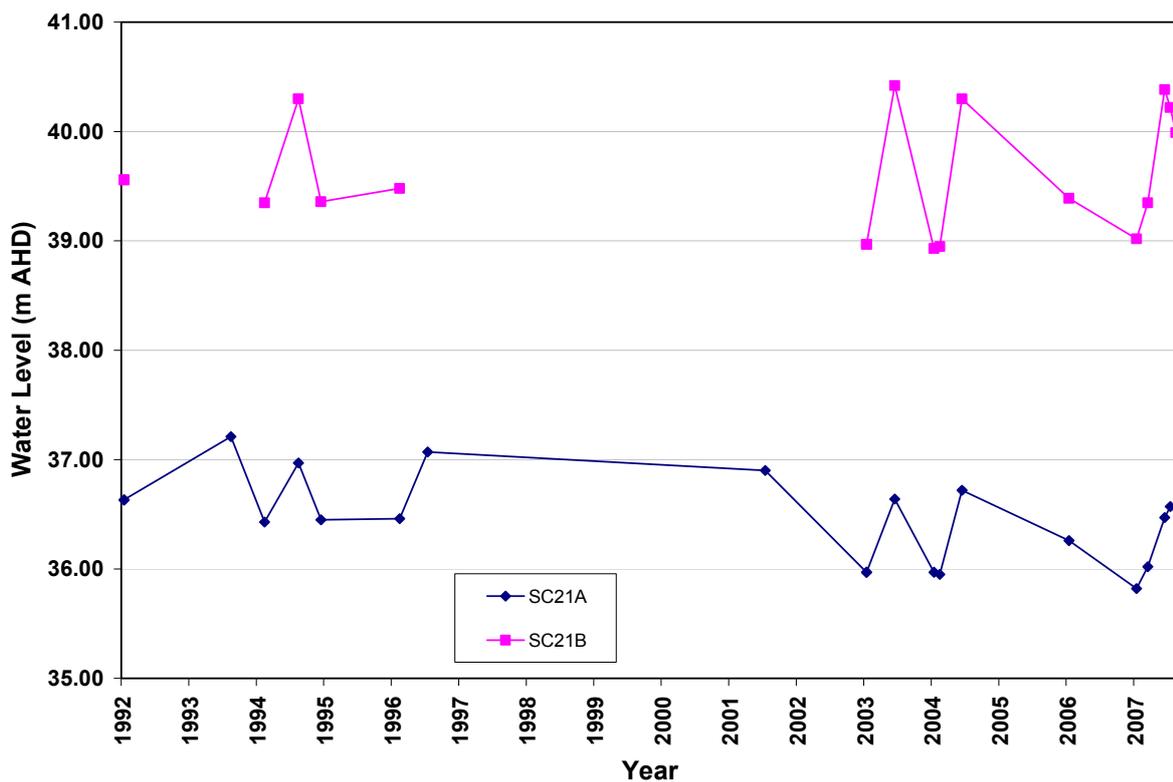


Figure 32 Hydrograph of Superficial monitoring bore SC21B and Yarragadee monitoring bore SC21A, located 2.4 km west of the Lake Jasper East site

As there was no shallow monitoring bore located close to the site, one was installed (EW8) adjacent to the vegetation transect in early 2007 (Figure 31). EW8 is 9 m deep and is screened between 1.5 and 3 m below ground level in the Bassendean Sand of

the Superficial formation. The 2007 autumn minimum water level was recorded at around 5.3 m below ground level and the winter maximum was approximately 4.2 m below ground level.

Ecological water requirements

Froend & Loomes (2006) recommended an EWR criterion for the Lake Jasper East site based on maintaining the most vulnerable of the dominant wetland species recorded at the vegetation transect (*Banksia littoralis*) at a low level of risk. Froend & Loomes (2006) recommended that groundwater levels should persist no longer than two years below the criterion of 38.5 m AHD, measured at monitoring bore EW8, located near the transect. In autumn 2007 the piezometer measured 38.6 m AHD, 0.1 m above the EWR level.

Modelling results

Discounting the first four years of modelled data to allow for stabilisation of the model, the outputs for the Lake Jasper East site indicate that it would undergo 0.08 m of draw down between Year 5 and Year 30 under the proposed allocation scenario (Figure 33). These results indicate that vegetation at the site would be under a low level of risk. This implies that there should be no measurable change to the ecosystem processes, to the vegetation, to the dependent fauna and to water quality (Froend & Loomes, 2004).

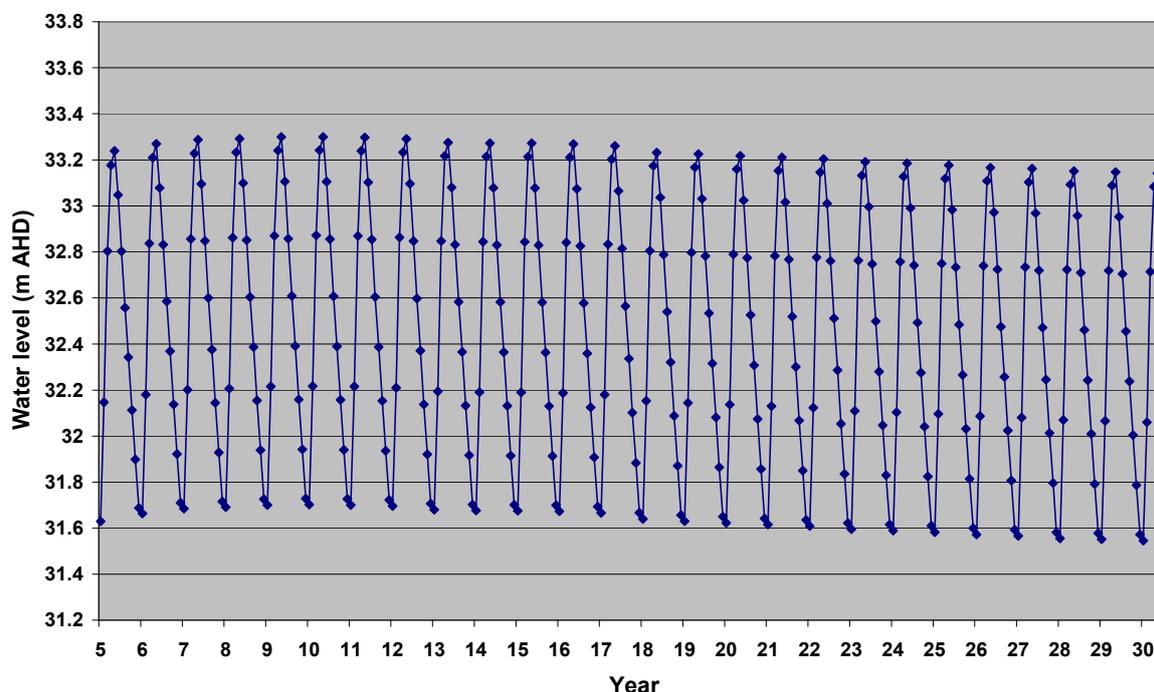


Figure 33 Modelled hydrograph at EW8

Discussion and recommendations

SWAMSV2 modelling suggests that the Lake Jasper East site is at low risk of groundwater draw down. However, the significant abstraction volumes in the vicinity of Lake Jasper, the potential for future high volume use on the Scott coastal plain, and the very high ecological, social and cultural value of the site require that further investigation of the hydrogeology and regular, ongoing monitoring occurs to ensure protection of these assets.

Due to the large area of the lake, EWR criteria should be established at several locations under the current methodology of calculating the required groundwater levels based on the vegetation within a transect. The department has established criteria at, and currently monitors, two vegetation transects in the southern part of the lake, but due to inaccessibility of the northern areas of Lake Jasper, no vegetation transects or monitoring bores have been set up in this area. Intensive ecological and hydrogeological work at selected sites, such as Lake Jasper, will be undertaken using state and federal funding (through the *Australian Government Water for the Future's – Water Smart Australia program*) over the next three years to help determine more representative EWR for the lake.

Currently, the following management approach is recommended for the Lake Jasper East site:

- the large water users on the eastern Scott coastal plain in the vicinity of Lake Jasper should continue to be monitored to ensure their compliance with licence conditions and should be encouraged to adopt water use efficiency measures
- monthly monitoring of bores EW8 and SC21B, and annual monitoring of the vegetation transects near these bores in spring should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan
- the relationship between the shallow water table and the underlying aquifers at the site should be further investigated to better understand the likelihood of impacts from Yarragadee aquifer abstraction
- the eastern Scott coastal plain local model should be revised or redeveloped so that the area may be adequately modelled
- detailed work should be conducted to refine ecological water requirements for Lake Jasper prior to the statutory allocation plan in 2011
- the management framework as set out in figures 2 and 3 should be applied to the Lake Jasper East site (at bore EW8).

Lower Blackwood River

Site description

The lower Blackwood River flows through the township of Nannup, across the Blackwood Plateau and out to the Southern Ocean through the Hardy Inlet at Augusta (Figure 34). Downstream of Warner Glen Bridge, which is located approximately 25 km from Hardy Inlet, the Blackwood River drains mostly agricultural land until it reaches the bushland and National Park areas surrounding the estuary. Most of the channels and creek lines between the estuary and Warner Glen Bridge are in poor to moderate condition. Upstream of Warner Glen Bridge the river and many of its tributaries are mostly contained in state forest or conservation reserves and the channel condition is relatively natural. Towards Nannup, the Blackwood River main channel passes through a narrow stretch of farmland and is fairly degraded, but most of its tributaries are contained within state forest and remain in good condition (Pen, 1997).

While the lower Blackwood River area has largely escaped clearing, the main channel still suffers the effects of the extensive clearing in the upper catchment; the most obvious problem being the changes in hydrology such as increased salinity and reductions in water quality. These impacts have altered the fauna that utilise the main channel, with many salt-intolerant native fish species now remaining downstream of Darradup and retreating into the fresh tributaries during the winter months when salinity is highest. Groundwater discharge into the main channel and permanent tributaries helps to reduce salinity levels enough over the summer months to allow some of these species to venture into the main channel again before the start of winter rains. During the winter months, surface water flows dominate the Blackwood River and groundwater discharge is insignificant by comparison (see Figure 35 and Figure 36).

Hydrogeological setting

The lower Blackwood River receives groundwater discharge from both the Leederville and Yarragadee aquifers downstream of Nannup. While the discharge volumes from each aquifer are believed to be similar, the Yarragadee aquifer discharges into the river in only a small area between Milyeannup Brook and Layman Brook (Figure 34), while the Leederville aquifer discharges over a larger area, both upstream of Milyeannup Brook and downstream of Layman Brook. Both aquifers also discharge into some of the tributaries of the Blackwood. The Yarragadee aquifer supports two permanent tributaries, Poison Gully and Milyeannup Brook, which are recognised as having very high habitat value for native fish (Milyeannup Brook) and freshwater crayfish (Poison Gully), and significant vegetation values (Poison Gully) (Beatty *et al.* (2006) and Matiske Consulting (2005a, 2005b)). The Leederville aquifer supports several tributaries of the lower Blackwood including St John Brook, and Spearwood and Adelaide Creeks, which are recognised as key habitat areas for rare frog species.

Surrounding groundwater use

Apart from some larger allocations in the western Scott coastal plain area, there is only relatively minor groundwater use along the lower Blackwood River. Concerns relating to groundwater use and its impacts on groundwater discharge into the river have mainly centred on the potential for significant allocations from the Yarragadee aquifer on a regional scale, to reduce summer flows in Milyeannup Brook and Poison Gully and the adjacent section of the Blackwood River main channel. The Yarragadee is a regionally confined aquifer, but as it outcrops or sub-crops in a small area in this part of the lower Blackwood River, any reductions in pressure heads within the aquifer caused by abstraction will affect this area to a greater extent.

Abstraction from the Leederville aquifer also has the potential to affect groundwater base flows in those waterways that receive discharge from that aquifer. Due to the nature of the aquifer, however, Leederville-dependent waterways are not as likely to be affected by abstraction located some distance from the river channel, unless the abstraction volume is very large. Leederville licences on the Swan coastal plain, for example, are unlikely to affect the Blackwood River.

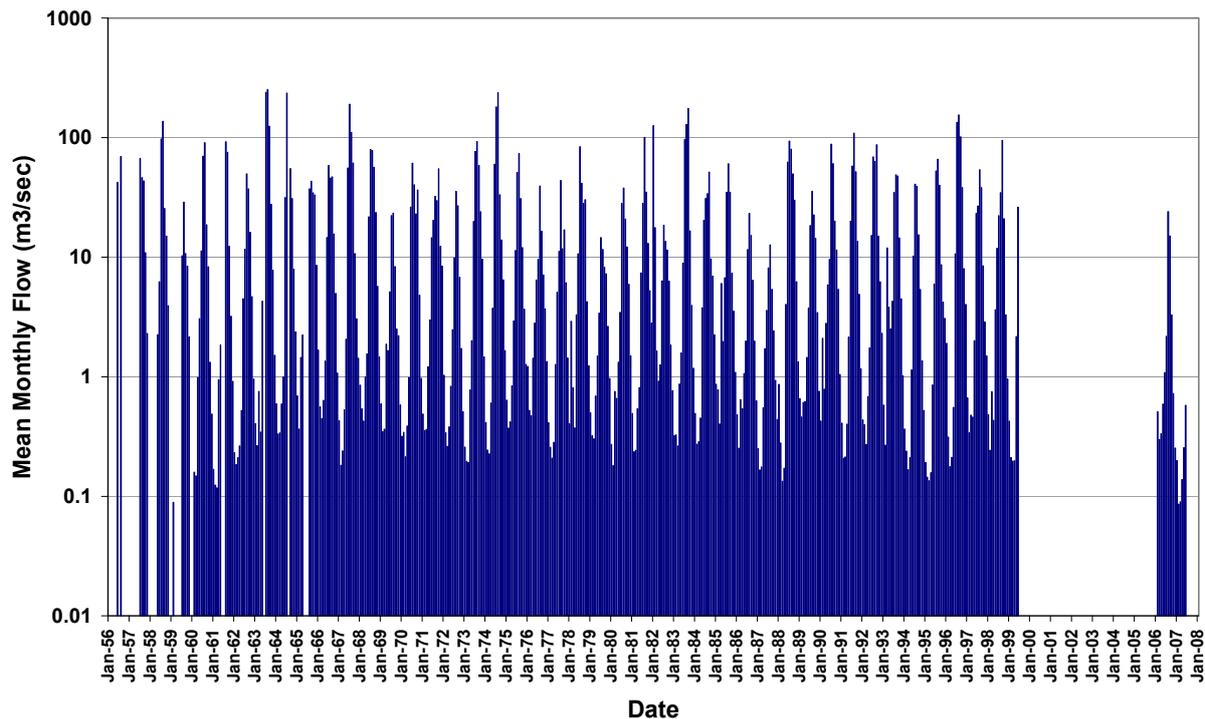


Figure 35 Mean monthly flows recorded at Darradup gauging station

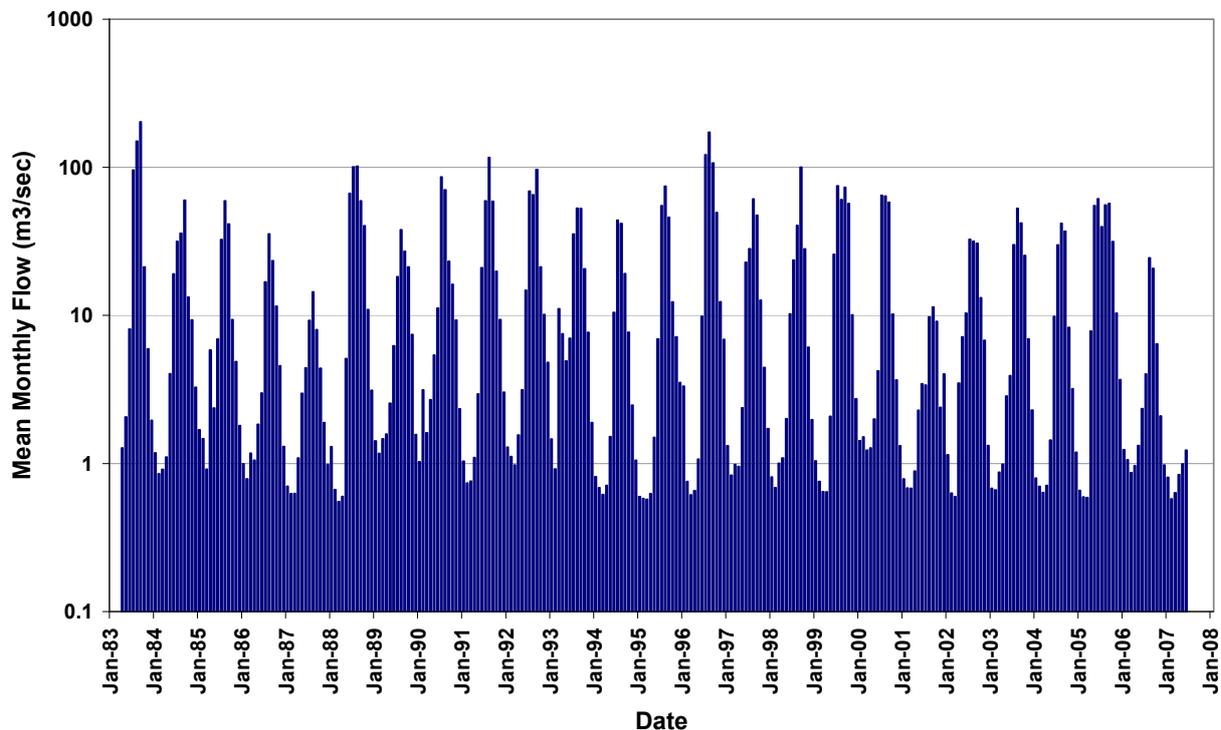


Figure 36 Mean monthly flows recorded at Hut Pool gauging station

Ecological water requirements

Ecological water requirements are yet to be determined for the lower Blackwood River. Ecological investigations of the fish, and crayfish of the lower Blackwood River have been ongoing since 2005 and it is anticipated that by mid-2008 there may be sufficient data to establish some summer flow criteria within the Yarragadee discharge zone to support fish populations.

Murdoch University are also carrying out salinity tolerance testing on native fish, which will enable establishment of some water quality criteria for the Blackwood River main channel to help ensure any reductions in groundwater discharge do not exceed their salinity tolerance levels. Edith Cowan University (ECU) is in partnership with Murdoch University (funded by the Department of Water for up to three years) to work toward development of ecological water requirements for the lower Blackwood River. ECU is focusing on understanding the water requirements of the freshwater crayfish and invertebrates in the main channel and selected tributaries, while Murdoch University is focusing on the native fish components of the system.

As the ecological work is still ongoing, the department has used basic hydrological information to establish some flow triggers for the Blackwood River in the interim period until the studies are completed. A statistical analysis of the large amount of flow, groundwater level and rainfall data is being conducted with the aim of developing a relationship between climate, groundwater levels and Blackwood River summer flows. This relationship, if it is found to exist in the available data, may then be used to differentiate between those changes in summer base flow due to reductions in groundwater discharge caused by abstraction and those changes to discharge caused by reduced rainfall. Flow criteria may then be established that trigger management actions before abstraction has an unacceptable impact on groundwater discharge volumes. This statistical analysis is due for completion in April 2008.

As an interim measure prior to the completion of these studies, it is proposed to use the Blackwood River summer historical minimum flow as a basic trigger for further investigation, should abnormal reductions in summer base flow occur in early 2008. This should be applied at Darradup and Hut Pool gauging stations, as these have long term flow monitoring data, in months of base flow conditions i.e. when zero flow is recorded at Nannup gauging station.

Table 5 Trigger–response (surface water) sites and the associated management trigger.

Site name/Location	Groundwater area	Subarea	Management trigger
Blackwood River – Darradup Gauging Station	Blackwood	Blackwood Plateau – South	Flow below historical minimum during months of summer base flow
Blackwood River - Hut Pool Gauging Station			Flow below historical minimum during months of summer base flow

Discussion and recommendations

SWAMSV2 modelling indicates that the amount of groundwater discharge into the Blackwood River downstream of Nannup would be likely to reduce at high levels of Yarragadee aquifer abstraction. SWAMSV2 simulations of a drying climate also indicate that base flow would reduce under lower rainfall conditions. The base flow of two Yarragadee-dependent permanent tributaries, Poison Gully and Milyeannup Brook, is also likely to be similarly affected by both groundwater abstraction and reductions in rainfall.

While the Water Corporation's proposal to take large volumes of Yarragadee water from the area has been abandoned, regional use of the Yarragadee aquifer on the Scott and Swan coastal plains still has the potential to affect these ecosystems. The large distances between the Blackwood River and the coastal plains will mean establishing a link between decreases in summer base flow in the river and tributaries, and regional groundwater use, will be more difficult than if the groundwater use was close to the river. Therefore it will be important to determine if relationships existing between river base flow, rainfall and groundwater levels as changes in that relationship are likely to indicate that influences other than climate may be affecting the river. These investigations have begun and will inform a revision of the management framework in the next round of planning.

The lower Blackwood River and its tributaries contain significant ecological values that will be affected if base flow volumes drop significantly or if water levels in the riparian zone are drawn down too far. Determining the water requirements of these values in the areas most susceptible to draw down impacts (the Yarragadee aquifer discharge zone of the Blackwood River main channel and tributaries Poison Gully and Milyeannup Brook) is important in setting improved management triggers in the next round of planning. State and federal funding through the *Australian Government Water for the Future's – Water Smart Australia program*, is supporting detailed ecological work by ECU and Murdoch University that will be critical in informing a revised management framework.

Currently, the following management approach is recommended for the Lower Blackwood River:

- continuous gauging of flows at the Darradup and Hut Pool gauging stations and monitoring of temperature and conductivity at these points should continue until such time as the monitoring program is reviewed again prior to the development of the statutory allocation plan
- the adequacy of the rainfall gauging, stream gauging and groundwater level monitoring network should be reviewed as part of the investigation into defining the relationships between climate, river base flow and groundwater levels in the lower Blackwood River area
- the annual 'snapshot' of summer base flow in the lower Blackwood River and permanent tributaries should continue until such time as the monitoring program is reviewed prior to the development of the statutory allocation plan

- a flow model for the Lower Blackwood River (Yarragadee aquifer discharge zone) and Milyeannup Brook should be developed, incorporating the ecological information emerging from the ECU and Murdoch University studies. These models should be used to develop ecological flow criteria for these two systems prior to the development of the 2011 statutory allocation plan
- the adequacy of the SWAMSV2 and Blackwood Valley numerical models in predicting changes in groundwater discharge to the Blackwood River and tributaries should be reviewed and it should be determined how information from the groundwater models will be incorporated into the proposed surface water models
- the management framework as set out in Figure 4 should be applied to the Lower Blackwood

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Aquifer	A geological formation or group of formations that is able to receive, store and transmit significant quantities of groundwater.
Base flow	The component of stream flow supplied by groundwater discharge
Biodiversity	The variety of organisms, including species themselves, genetic diversity and the assemblages they form (communities and ecosystems). Sometimes includes the variety of ecological processes within those communities and ecosystems. Biodiversity has two key aspects: its intrinsic value at the genetic, individual species, and species assemblage levels; and its functional value at the ecosystem level. Two different species assemblages may have different intrinsic values but may still have the same functional value in terms of the part they play in maintaining ecosystem processes.
Bore	A narrow, normally vertical hole drilled in soil or rock to monitor or withdraw groundwater from an aquifer.
Confined aquifer	An aquifer lying between confining layers of low permeability strata (such as clay, coal or rock) so that the water in the aquifer cannot easily flow vertically.
Discharge	The water that moves from the groundwater to the ground surface or above, such as a spring. This includes water that seeps onto the ground surface, evaporation from unsaturated soil, and water extracted from groundwater by plants (evapotranspiration) or engineering works (groundwater pumping).
Draw down	The lowering of a watertable resulting from the removal of water from an aquifer or reduction in hydraulic pressure
Ecological water requirements	The water regime needed to maintain ecological values of water-dependent ecosystems at a low level of risk.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, e.g. lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Entitlement	The annual quantity of licensed groundwater abstraction in kilolitres/year (kL/yr).
Environmental water provisions	The water regimes that are provided as a result of the water allocation decision-making process taking into account ecological, social, cultural and economic impacts. They may meet in part or in full the ecological water requirements
Evaporation	Loss of water from the water surface or from the soil surface by vaporisation due to solar radiation.
Evapotranspiration	The combined loss of water by evaporation and transpiration. It includes water evaporated from the soil surface and water transpired by plants.
Groundwater	Water which occupies the pores and crevices of rock or soil beneath the land surface

Groundwater area	Are the boundaries that are proclaimed under the <i>Rights in Water and Irrigation Act 1914</i> and used for water allocation planning and management.
Groundwater subarea	Areas defined by the Department of Water within a groundwater area, used for water allocation planning and management
Groundwater-dependent ecosystem	An ecosystem that is dependent on groundwater for its existence and health.
Hydrogeology	The hydrological and geological science concerned with the occurrence, distribution, quality and movement of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality
Hydrograph	A graph showing the height of a water surface above an established datum plane for level, flow, velocity, or other property of water with respect to time.
Licence	A formal permit which entitles the licence holder to 'take' water from a watercourse, wetland or underground source
m AHD	Australian Height Datum – height in metres above Mean Sea Level + 0.026m at Fremantle.
Non-artesian well	A well, including all associated works, from which water does not flow, or has not flowed, naturally to the surface but has to be raised, or has been raised, by pumping or other artificial means
Recharge	Water that infiltrates into the soil to replenish an aquifer
Salinity	The measure of total soluble salt or mineral constituents in water. Water resources are classified based on salinity in terms of total dissolved salts (TDS) or total soluble salts (TSS). Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt).
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Through flow	The flow of water within an aquifer.
Unconfined aquifer	Is the aquifer nearest the surface, having no overlying confining layer. The upper surface of the groundwater within the aquifer is called the watertable. An aquifer containing water with no upper non-porous material to limit its volume or to exert pressure.
Water-dependent ecosystems	Those parts of the environment, the species composition and natural ecological processes, of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers.
Water table	The saturated level of the unconfined groundwater. Wetlands in low-lying areas are often seasonal or permanent surface expressions of the watertable.
Wetland	Wetlands are areas that are permanently, seasonally or intermittently waterlogged or inundated with water that may be fresh, saline, flowing or static, including areas of marine water of which the depth at low tide does not exceed 6 m.

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