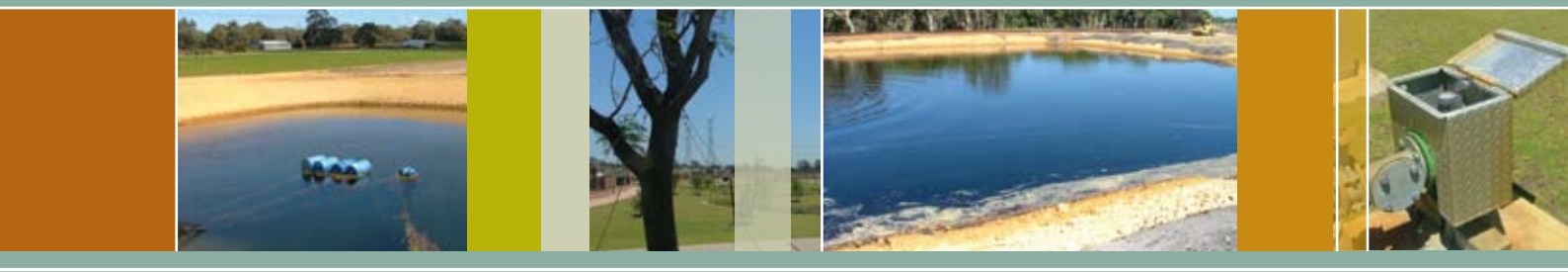
Department of Water
Government of Western Australia

Cockburn Groundwater Area
Water Management Plan

December 2007



Water Resource Allocation and Planning Series
Report no. WRAP 18

Cockburn Groundwater Area

Water Management Plan

Department of Water
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ISSN 1327-8428 (pbk)

ISBN 1834-2620 (pdf)

ISBN 978-1-921468-16-2 (pbk)

ISBN 978-1-921468-17-9 (pdf)

Cover photograph

Local Cockburn Groundwater Area commercial water uses

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Summary

A Cockburn Groundwater Area Management Plan was developed in 1993 by the Water Authority of Western Australia to address the importance of groundwater resources and the future demand for these resources. In recognition of the need to manage the demand for water in the Cockburn Groundwater Area (CGA), the Department of Water reviewed the 1993 plan and produced a new management plan. This new plan will continue to promote sustainable water allocation for current and future users and the protection of groundwater-dependent ecosystems.

Significant wetlands, with national and international protection status, are located in the CGA including the Coastal Plain Lakes; Environmental Protection Policy lakes; Bush Forever sites; conservation, resource enhancement and multiple use reserves and the geomorphic wetlands of the Swan Coastal Plain. All wetlands and phreatophytic vegetation are groundwater dependent, and excessive groundwater abstraction may adversely impact these sensitive environments.

Current water level monitoring data for all aquifers in the CGA are showing signs of decline, demonstrating that private abstraction (in most areas) has exceeded the sustainable level of allocation. Therefore, in recognition that there is only limited potential for further development of groundwater resources in the area, this plan is intended to improve certainty for existing and potential water users in the area by protecting the environment while fostering sound economic and social wellbeing for the people in the region. Care has been taken to ensure that this plan is consistent with the appropriate state legislation, policies and strategies, as well as the broader national and international strategies, frameworks and principles.

The CGA has been subdivided into four sub areas for management of the superficial aquifer to reflect the geological and hydrogeological features of the area. The confined aquifers (the Leederville and Yarragadee aquifers) are regional aquifers and will be managed at the regional level to recognise that impacts from abstraction can be experienced over large areas.

Revised Allocation limits have been set for the aquifers (refer to the Summary table) indicating that licensed abstraction has reached the sustainable level of allocation in the confined aquifers and that there is currently little water available for allocation in two sub areas of the superficial aquifer. The department will not issue any new entitlements when the Allocation limits have been reached.

The department will support individuals who wish to undertake, at their own expense, hydrogeological investigations to demonstrate that additional groundwater can be taken on a sustainable basis from any of the fully allocated aquifers. This will require some groundwater flow modelling and ongoing monitoring to demonstrate that any impacts caused by the groundwater development on social and ecological values, and existing users are acceptable. The department supports water trading as a market-based opportunity for increased development in fully allocated groundwater systems.

This plan guides groundwater licence assessments and allocations within the CGA. The plan recognises the high water use in the CGA is close to sustainable yield. This means careful management is required to ensure that the quality of and accessibility to

groundwater is not compromised. This plan describes an impact management approach to assess new licence applications, which will optimise water use, and protect existing users and their access to water. This signifies that new licences will only be approved if there is no unacceptable impact on existing users. Water licensees will be encouraged to be more efficient users and implement water conservation programs.

The sustainable yield of an aquifer system may be subject to change with the availability of significant new information such as the refinement of estimates of sustainable yields using the Perth Regional Aquifer Modelling System. Monitoring of water levels and water quality trends over time enables adaptive management of the resource, which is used to refine Allocation limits for the aquifer. It is unlikely new water will be available in the CGA.

Summary table water available in CGA (current to April 2007)

Aquifer	Subarea	Allocation Limit (GL/yr)	Licensed entitlements (GL/yr)	Groundwater available for allocation (GL/yr)
Superficial	Kogalup	11.46	8.40	3.05
	Thomsons	8.70	6.85	1.85
	Valley	7.70	6.72	0.98
	Wellard	10.32	6.14	4.18
Leederville	Combined	1.35	1.50	0.00
Yarragadee	Combined	5.15	5.56	0.00

GL = gigalitre

1 Introduction

1.1 Purpose of this plan

The Department of Water has developed the Cockburn Groundwater Area Water Management Plan (the plan) to guide the management of groundwater resources of the Cockburn Groundwater Area (CGA) and support:

- sustainable water allocation and development for current and future users
- protection of ecosystems dependent on groundwater.

The plan provides the policies, principles and strategies that will be used to manage the groundwater resources of the CGA.

1.2 Plan objectives

The objectives of this plan are to:

- ensure that the groundwater resources are allocated reasonably and used sustainably in the long term
- prescribe the policies that will apply in the assessment of licence applications and the issue of groundwater resource entitlements
- prescribe the monitoring requirements for the groundwater resource
- clearly state the policies of the department relative to the CGA.

1.3 Cockburn Groundwater Area

Location

The CGA (Figure 1) is a 157 km^2 area located 30 km south of Perth and covering a coastal strip of 22 km, extending approximately 7 km inland. It is situated within the municipalities of the town of Kwinana, and the cities of Cockburn and Rockingham. Kwinana and Cockburn are the largest population centres in the groundwater area. Smaller localities are Wattleup, Henderson, Coogee, Mandogalup, Beeliar and Hope Valley. The CGA is bounded by the Perth Groundwater Area (GWA) to the north, Jandakot GWA to the east and Rockingham GWA to the south.

Proclamation

The CGA was proclaimed on 29 July 1988 under the provisions of the *Rights in Water and Irrigation Act 1914* (RiWI Act) because of concerns regarding the long-term availability of groundwater. Licensing of groundwater use in the CGA is a statutory requirement under the provisions of the RiWI Act.

History

In 1993, the Water Authority of Western Australia developed the Cockburn Groundwater Area Management Plan to address the importance of groundwater resources in the area and the future demand for these resources. The CGA was subdivided into 12 sub areas based on the geological and hydrogeological knowledge at that time. A review of the

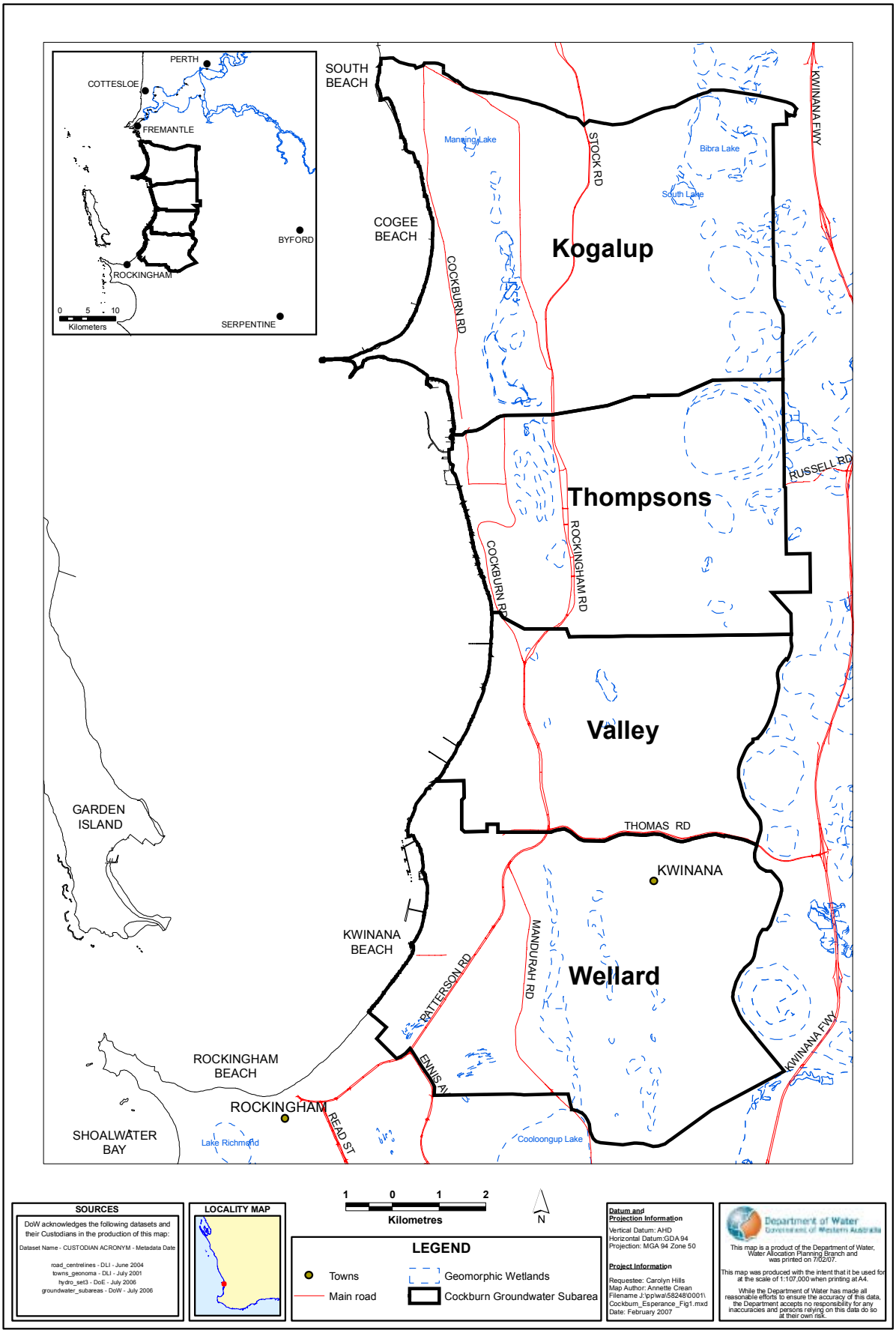


Figure 1 Map of the Cockburn groundwater area showing sub the areas

geology and hydrogeology in 2000, including the sub area boundaries, replaced the original 12 sub areas with four sub areas to reflect the physical features of the area more accurately, in particular to align the boundaries with the groundwater flow lines (see Figure 1). The new sub areas, from north to south, are:

- Kogalup
- Thompsons
- Valley
- Wellard

Information for each of the four sub areas are presented as fact sheets in Appendix A. The physical environment of the CGA is described in Appendix B.

1.4 Groundwater overview

The groundwater resources of the CGA comprise both unconfined and confined aquifers that exist as separate layered aquifer systems. The aquifers are, in order of increasing depth, the superficial aquifer, Rockingham Sand aquifer (where present), Leederville aquifer and the Yarragadee aquifer.

Almost all development, industry and infrastructure within the CGA depend on groundwater for their respective water supply needs. However, there is only limited potential for further development of groundwater resources in the area, as allocation of groundwater supplies in the CGA, particularly from the confined aquifers, has reached the sustainable yield of the aquifers.

Detailed descriptions of the aquifers in the CGA and their recharge characteristics are contained in Appendix C.

1.5 Overview of socio-economic environment

Current population estimates indicate approximately 63 800 residents in Cockburn, 20 200 in Kwinana, and 63 000 in Rockingham.

Land usage in the CGA is subject to the planning schemes and strategies that have been set down by the Western Australian Planning Commission and the respective local municipalities, and includes industrial processing, intensive agriculture and horticulture and recreation or public open space.

Currently, the most dominant land uses in the CGA are horticulture and heavy industry. In the future, the number of industrial subdivisions is likely to increase due to development pressure.

1.6 Water allocation in Western Australia

The Department of Water is the agency responsible for the management of water resources in Western Australia. The department manages the water resources of the state in partnership with other government agencies, interested parties and the community. The primary objective of a water management plan is to ensure the state's water resources are appropriately managed and used to support sustainable development and conservation

of the environment for the long-term benefit of the community. This is achieved through a water allocation licensing process that ensures water is used efficiently and within sustainable limits.

Throughout the state, the department has defined ground and surface water areas and sub areas that are proclaimed under the RiWI Act. It is in these areas that the department issues water licences and allocates water. As part of the water allocation process, the department determines how available water will be shared between consumptive uses. Water management plans identify the water resources and water regimes to be protected, define the water licensing policy and formalise water management objectives for the area covered by the plan.

The area covered by a water management plan ranges in scale from regional to subregional to local. Local area plans may cover individual surface water or groundwater areas or sub areas.

Principles

There are nine water resource management principles adopted in this water management plan that need to be taken into account when considering licensing of groundwater abstraction in the area:

- Water use must be *sustainable*. That is, allocation decisions must not significantly decrease the rights of future generations to benefit from water resources, and they must not lead to unacceptable environmental damage.
- Water use must be *productive*. When water is diverted from the environment, it should be used productively for the benefit of West Australians.
- Water use must be *efficient* to avoid wastage. Those planning to use large quantities of groundwater should demonstrate that water conservation has been considered and will be implemented where possible. All groundwater development must include consideration of, and appropriate investment in, water efficiency measures.
- Water use must be consistent with the regional planning and land use objectives of the region, and generate outputs that contribute to environmentally sustainable development.
- The water allocation process will consider impacts on environmental, social and economic values, before it is allocated to consumptive use.
- The allocation of water should be fair and equitable to allow both short and long-term planning objectives to be met.
- Natural ecological processes and the biodiversity of water-dependent ecosystems are maintained at an acceptable level of risk.
- Where significant impacts are likely, individual licensees are responsible for determining potential groundwater pumping impacts on identified local groundwater-dependent ecosystems and existing users.
- Community education on groundwater matters and involvement in the decision-making process should continue to sustain a strong and effective groundwater management effort.

Several state principles (WRC 2000a) will also be applied when considering licensing of groundwater abstraction in the area.

The precautionary principle

This principle states that where there are threats of serious or irreversible environmental damage, the lack of full scientific knowledge and certainty should not be used as a reason for postponing measures to prevent the environmental damage.

Inter-generational equity

This concept refers to decision-making processes that effectively integrate both short and long-term economic, environmental and social equity considerations.

Integrated management

Integrated management refers to the management of the inter-relationships between surface water, groundwater and land use. In this context, impacts of groundwater abstraction on dependent ecosystems that include surface water regimes and their ecological, social and economic dependencies need to be managed.

Water management should be integrated with relevant policies of other government agencies fostering a holistic management approach.

Adaptive management

Management tools and policies must be able to respond to increasing knowledge of resource dynamics and their interactions with other ecosystems. Management tools must also be able to take into account changing community attitudes and perceptions of sustainability.

Adaptive management relates to management of water resources in a cycle of assessment, planning, implementation, monitoring, review and responding to change, including provision for reallocation to accommodate results of reviews.

1.7 Legislative and Policy Framework

1.7.1 The role of the Department of Water

The department implements water allocation decisions and regulates the use of water through the powers assigned to it under the RiWI Act *(Rights in Water and Irrigation Act 1914),* the Rights in Water and Irrigation Regulations 2000 and the *Water and Rivers Commission Act 1995.*

The department is also responsible for the preparation of water source protection plans and guidelines for the protection of public water supplies. Legislation related to water quality protection includes the *Metropolitan Water Supply Sewerage and Drainage Act 1909* and the *Country Areas Water Supply Act 1947.*

1.7.2 Rights in Water and Irrigation Act 1914

The primary legislation for allocating groundwater in Western Australia is the RiWI Act and the Rights in Water and Irrigation Regulations 2000. The RiWI Act vests the 'right to the use and flow, and to the control, of the water at any time in any watercourse, wetland or underground water source' in the Crown. It requires compulsory licensing of all artesian wells throughout Western Australia.

In addition, supplies from non-artesian wells within specific areas, proclaimed under the RiWI Act as groundwater areas, require licensing. These areas are proclaimed to ensure equitable opportunity for allocation between competing users, including the environment, and to protect existing and future users in areas of major public, agricultural, industrial or mineral developments.

Regulatory controls are designed to:

- encourage the responsible development of groundwater resources and limit abstraction from the aquifer to a level that can be sustained over the long term
- allocate resources for beneficial private and public purposes and to meet the environmental requirements of the area
- enable the resources to be shared in an equitable manner
- protect present and future sources of groundwater for public water supplies and for private use, where appropriate

Groundwater licence administration in the CGA is the responsibility of the department's Kwinana Peel Region and primarily the Kwinana office.

1.7.3 Water Reform

Western Australia signed the National Water Initiative agreement in April 2006. The overall objective of this agreement is to provide a 'nationally compatible, market, regulatory and planning based system of managing water resources in rural and urban settings that optimise economic, social and environmental outcomes'. With the signing of the National Water Initiative there will be some changes in management and supporting legislation for water management. Consultation with water users about these changes has started.

2 Environmental, social and economic considerations

2.1 Sustainable use of water

The long-term management objectives for groundwater resources are to achieve sustainability of the resource and avoid unacceptable impacts caused by pumping on the dependent environmental, social and economic values.

The impact of both current and potential future development must be considered in any management strategy, including the long-term delayed effects of pumping, such as saltwater intrusion or saline upconing, which are not immediately noticeable. They manifest slowly over time, sometimes over many years, and these impacts must be recognised and managed.

Any amount of groundwater abstraction will cause alterations to the existing flow regime that, in turn, will impact to some degree on the other beneficial uses of the resource such as environmental, economic and social uses. The extent of the impact will vary and the acceptability of the impact will depend on the values supported by the resource. Abstraction that causes continuous long-term declines in groundwater levels is not acceptable and could ultimately have effects that cannot be reversed.

The sustainable yield of an aquifer system may be subject to change with the availability of significant new information. Monitoring of water levels and water quality trends over time enables adaptive management of the resource, which is used to refine allocation limits (AL) for the aquifer.

2.2 Environmental considerations

The Department of Water is responsible for managing groundwater resources on a sustainable basis. This means that groundwater abstraction must be managed so that there are minimal impacts to ecosystems relying on groundwater. The process for determining how much water can be sustainably abstracted is guided by *Environmental water provisions Policy for Western Australia, State-wide Policy No. 5* (WRC 2000a) and involves setting of Ecological water requirements (EWRs) and Environmental water provisions (EWPs).

2.2.1 Ecological water requirements and environmental water provisions

The management of groundwater allocation includes determining specific water regimes (EWRs) required to sustain ecosystems dependent on this water. EWRs are determined by identifying environmental values and establishing the level of dependency of the ecosystems on the groundwater. EWRs are then set as criteria and may include absolute water levels in wetlands, rates of groundwater flow to discharge zones, and sufficient throughflow to maintain the saltwater interface.

EWPs are the water regimes provided to the environment as a result of the water allocation decision-making process, taking into account the ecological, social and economic impacts of such decisions. As a consequence, EWPs may be less than EWRs where some ecological impact is accepted as a trade-off to meet water allocation management goals.

The department will aim to meet all EWRs when determining EWPs. If, in the view of the department, the EWR cannot be fully met without significantly compromising the social and economic benefits of the water allocation strategies, the department will ensure that:

- the risks to the ecosystems of not meeting the EWR are identified, together with the social and economic costs of fully meeting the EWR
- allocation scenarios and EWP options are developed in consultation with the community
- the proposed allocation strategy is referred to the Environment Protection Authority for assessment and/or advice under the *Environmental Protection Act 1986.*

2.2.2 Ecological water requirements methodology

As mentioned above, EWRs are determined through the identification of environmental values, the degree of dependency of the groundwater-dependent ecosystems (GDEs) and the subsequent establishment of a water regime. EWRs within the Cockburn Groundwater Area (CGA) were defined by:

- identification of GDE components
- selection of representative ecosystem components for which environmental water regime requirements were set, to ensure appropriate protection
- preliminary identification of the social and environmental values
- determination of basic management objectives based on the social and environmental values
- establishment of water regimes to satisfy the management objectives and define the EWRs.

2.2.3 Groundwater dependent ecosystems

The department has identified one major category of GDE within the CGA - wetlands. There may be other potential GDEs such as cave streams or near-shore marine systems.

Wetlands

Numerous seasonal and intermittent wetlands that rely on water from the superficial aquifer are found throughout the CGA. Wetlands were identified from wetland mapping, classification and evaluation; five have been selected as representative of the wetland types in the CGA (Table 1). The following wetlands were assessed before selecting the representative wetlands for EWR determination:

- Wetlands afforded the conservation category management objective within the department's wetland mapping and evaluation study (Hill et al. 1996) see Appendix D
- Wetlands protected by the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (EPA 1992)
- Wetlands within Bush Forever identified areas

Table 1 Wetlands selected for EWR determination

Wetland	Bibra Lake	Thomsons Lake	Banganup Swamp	Lake Coogee	Long Swamp
Coordinates Easting (m E) Northing (m N)	388838 6447793	389374 6442963	389179 6440793	384698 6443908	386660 6436880
CGA sub area	Kogalup	Thompsons	Thompsons	Kogalup	Valley
Preliminary Management Category	Conservation	Conservation	Conservation	Conservation	Conservation
EPP	Yes	Yes	Yes	Yes	Yes
System 6	M93	M93	M93	M92	No
Type	Lake	Lake	Sumpland	Lake	Sumpland
Suite	S/B.1	S/B.1	S/B.1	S.3	S.4
Vegetation classification	Heteroform	Bacataform	Bacataform	Zoniform	Zoniform
Monitoring well/surface water monitoring station (SWRIS No.)	Q6142520 (Monthly staff gauge reading)	Q6142517 (Monthly staff gauge reading)	Q6142516 (Monthly staff gauge reading)	Q6142514 (Monthly staff gauge reading)	Q6142509 (Monthly staff gauge reading)
Other (Status recognition)	Perth to Bunbury Study	Ramsar Convention, Register of National Estate, Perth to Bunbury Study	Perth to Bunbury Study	Perth to Bunbury Study	Other regional studies

CGA = Cockburn Groundwater Area; EPP =Environmental Protection Policy; SWRIS no. = State Water Resource Information System; System 6 Conservation Reserves for WA - The Darling System, System 6, Department of Conservation and Environment, Western Australia, Report 13

Source: Wetland type - Semeniuk (1987a); consanguineous suite - Semeniuk (1987b); vegetation classification -Semeniuk et al. (1990)

2.2.4 Wetland water level criteria

The Environmental Management Program prepared for the Jandakot Groundwater Scheme (by the Water Authority of Western Australia) during the 1993 Environmental Protection Authority environmental assessment, set water level criteria for several lakes that would

potentially be impacted by groundwater abstraction from the Jandakot Mound. EWR criteria for Thomsons Lake, Bibra Lake and Banganup Lake were developed as part of the program. These criteria have been reviewed as part of Stage 1 of the Section 46 *Review of Environmental Conditions on the Gnangara and Jandakot Mounds*. Current criteria are statutory as per Ministerial Statement 688.

In developing criteria for Lake Coogee and Long Swamp, historical water level records were assessed to determine historical maximum and minimum water levels and normal seasonal fluctuations. For the 20-year rainfall record starting in 1980, operational and action minimum water level criteria were developed. Operational minima (preferred) were determined based upon the average minimum water level reading observed within this time period and action minima (absolute) were derived from the historical minimums recorded. Table 2 details the preferred and absolute wetland water level criteria determined for the five selected wetlands.

Table 2 Wetland water level criteria

Wetland	Minimum Levels[1] (mAHD)	
	Preferred	Absolute
Thomsons Lake	11.3	10.8
Bibra Lake	13.6-14.2	13.6
Banganup Lake		11.5
Lake Coogee		-0.1
Long Swamp		0.1

AHD = Australian height datum

These EWRs have been established using current rather than historical pre-development water regimes. Water levels have been determined by identifying existing values and formulating criteria to help protect these values.

2.2.5 Proposed review of interim environmental criteria

The criteria developed above are the initial step in determining environmental water provisions within the CGA. In other areas, environmental criteria have been amended following the completion of more detailed studies and assessments. These studies include reviews of:

- the areas and monitoring bores to which phreatophytic vegetation and rare flora criteria may apply within the CGA
- phreatophytic and rare flora criteria to address acceptable short (over a season) and long-term (over period of years) rates and the extent of decline in groundwater levels within identified areas of the CGA.

[1]Abstraction strategy is revised if operation level is breached or is likely to be breached. A breach or an anticipated breach of the action level may trigger the requirement for artificial maintenance/recharge of selected wetlands.

2.2.6 Groundwater criteria

The management of environmental criteria, as observed by the Department of Water, is precautionary in its nature and involves:

- monitoring intensively[2] on an ongoing basis
- updated forecasts of groundwater decline on a monthly basis
- taking action (such as reducing abstraction) if forecasts indicate that a breach of the maximum criterion is likely.

Therefore, water level breaches of the precautionary maximum criteria for several environmental features, shown in Table 3, are to be reported by the Measurement Section of the department's Kwinana Region Office.

Table 3 Maximum criteria for several environmental features

Environmental feature	Water levels (m)
Rare flora (orchids)	1.0
Phreatophytic vegetation	1.5
Environmentally sensitive areas	1.5

2.3 Socio-economic values

For the purposes of this plan, there have been no studies on social, cultural and economic values. An overview of the socio-economic environment relevant to the CGA has been included in Appendix E.

[2]Wetland vegetation, waterbirds, macroinvertebrates and water quality are monitored annually by the Department of Water in Thomsons Lake, Bibra Lake and Banganup Swamp.

3 Status of the groundwater resources

3.1 Groundwater monitoring

Groundwater monitoring is required to understand the groundwater systems and the effects of factors such as pumping, climate variability and land use change. Groundwater monitoring provides information on the changes that occur in groundwater levels, groundwater quality and groundwater abstraction. Unlike surface water resources assessment, groundwater resources are indirectly determined from the analysis of this data and from an understanding of the hydrogeology and geology of an area. This information is used by the Department of Water to assess how the groundwater resource is responding, and to enable sustainable management.

The Department of Water maintains a monitoring bore network to monitor groundwater levels and quality, with bores drilled in the superficial, Leederville and Yarragadee aquifers. The data from monitoring bores is stored in the department's Water Information Network database. In the Cockburn Groundwater Area (CGA), there are two main series of groundwater monitoring bores: the Artesian Monitoring bores (AM series) and the Thomsons Lake series (T series). The T series are drilled into the superficial and Rockingham Sands (where present) aquifers and the AM series are drilled into the Leederville and Yarragadee aquifers. Details of groundwater monitoring in the CGA are provided in Appendix F.

3.2 Groundwater levels

3.2.1 Monitoring program

The earliest water level measurements in the CGA monitoring bores are from 1974. Water levels in the unconfined aquifers are generally recorded twice a year to approximately coincide with seasonal maximum and minimum water levels.

Groundwater levels (potentiometric head levels) in the AM series (confined aquifers) are recorded monthly, an increase from twice a year before 2000. The frequency was increased to monitor water levels more closely and to provide data for hydrogeological modelling of the Perth Basin.

3.2.2 Superficial aquifer

The locations of monitoring bores in the superficial aquifer (and the other aquifers) are shown in Figure 2. Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 show groundwater levels in representative monitoring bores within the superficial aquifer.

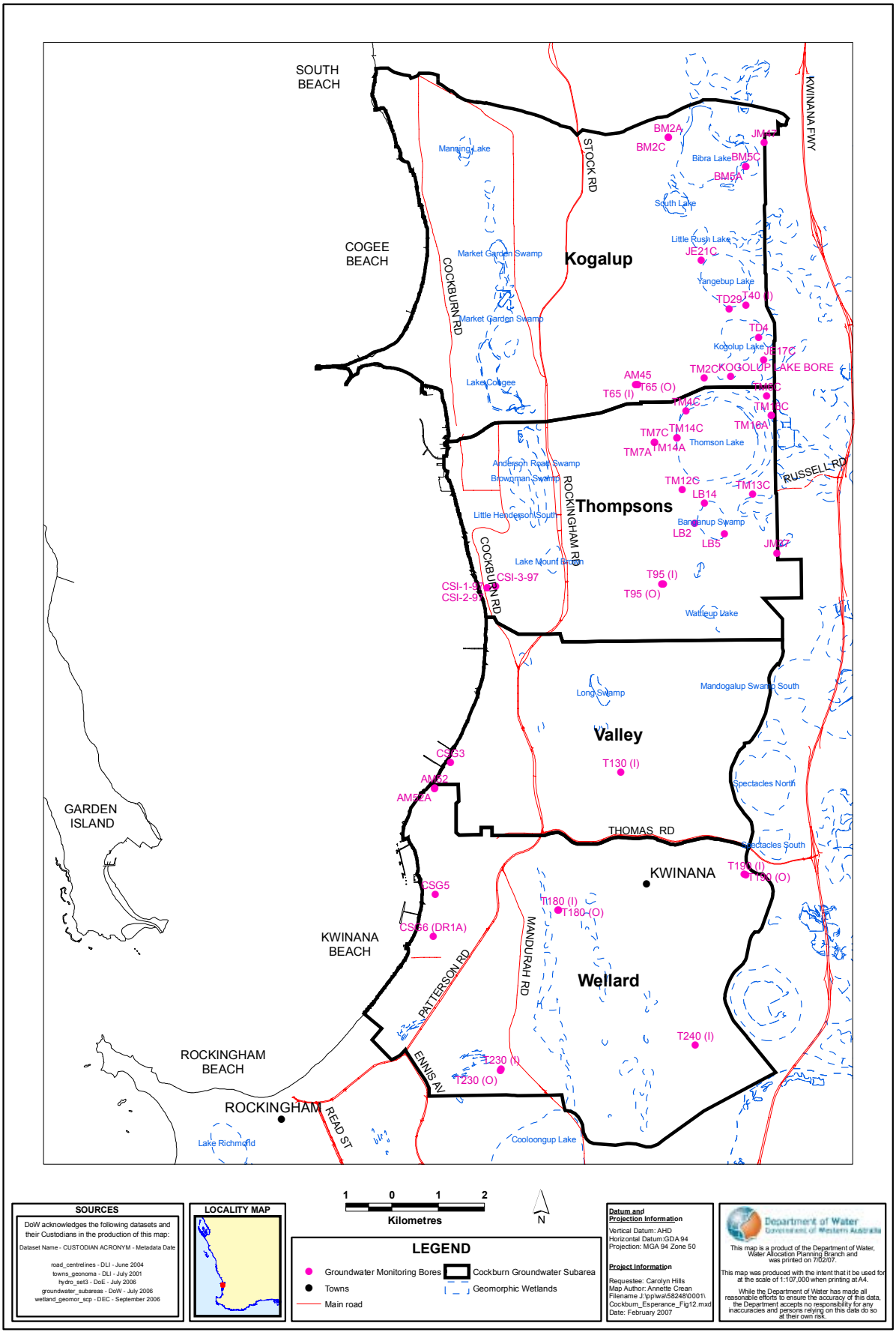
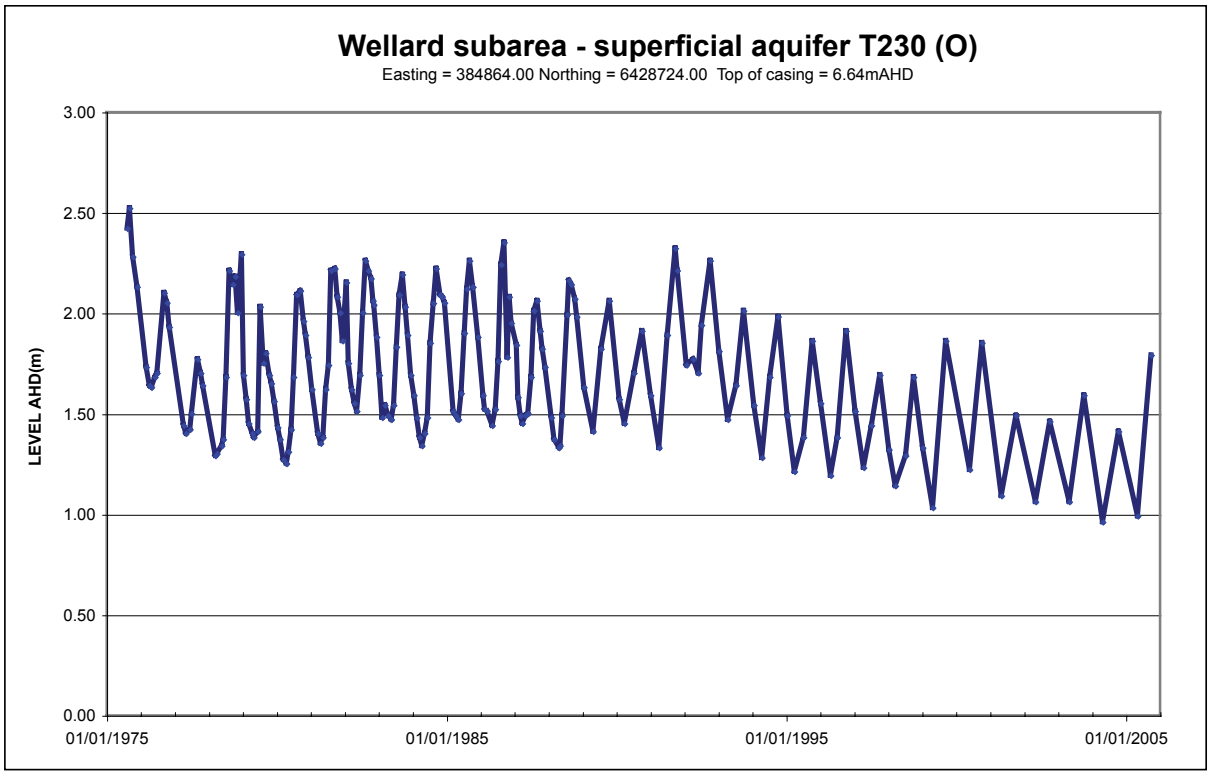


Figure 2 Groundwater monitoring bores

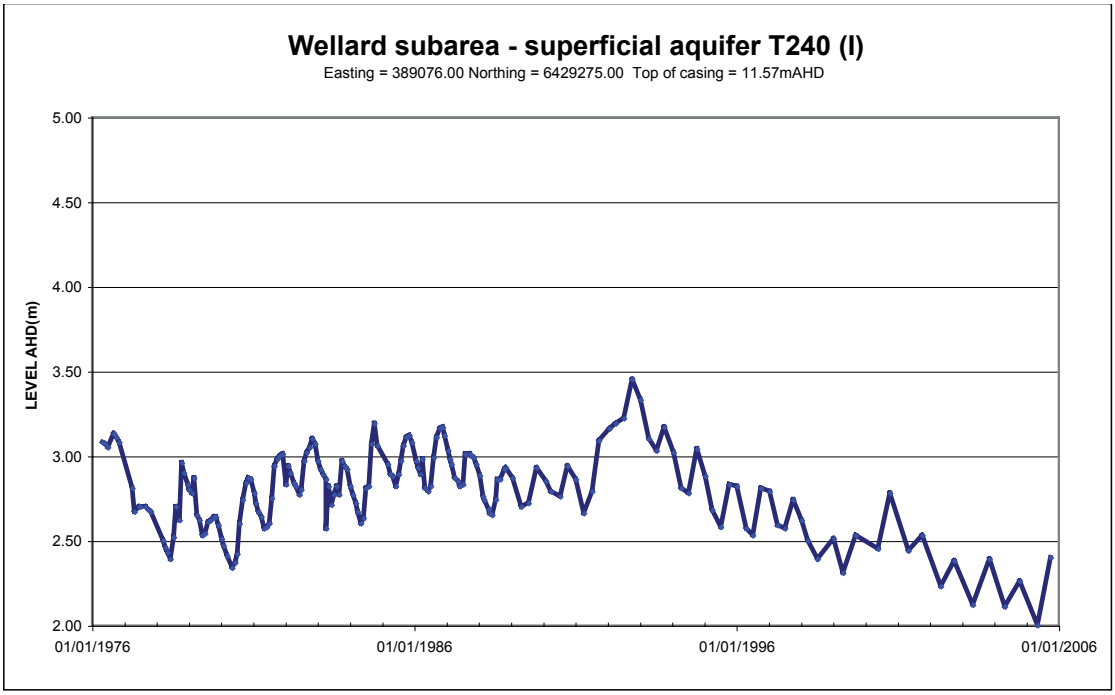
Monitoring bore T230 (Figure 3), located near the southern boundary of the Wellard sub area, shows water level measurements over a 30-year period from 1975 to 2005. Seasonal drawdown and recovery water levels fluctuated within a zone of less than one metre, with a net head decline of less than one metre over the 30-year period. Currently, winter water levels are around 1.5 m AHD (Australian height datum) and steady. The hydrograph also shows the result of a smaller number of annual water level measurements from about 1988 to 1999, with only two measurements per year from 1999 to 2005. Increased abstraction could account for the declining trend from about 1993.

Figure 3 Monitoring bore T230 (0) hydrograph



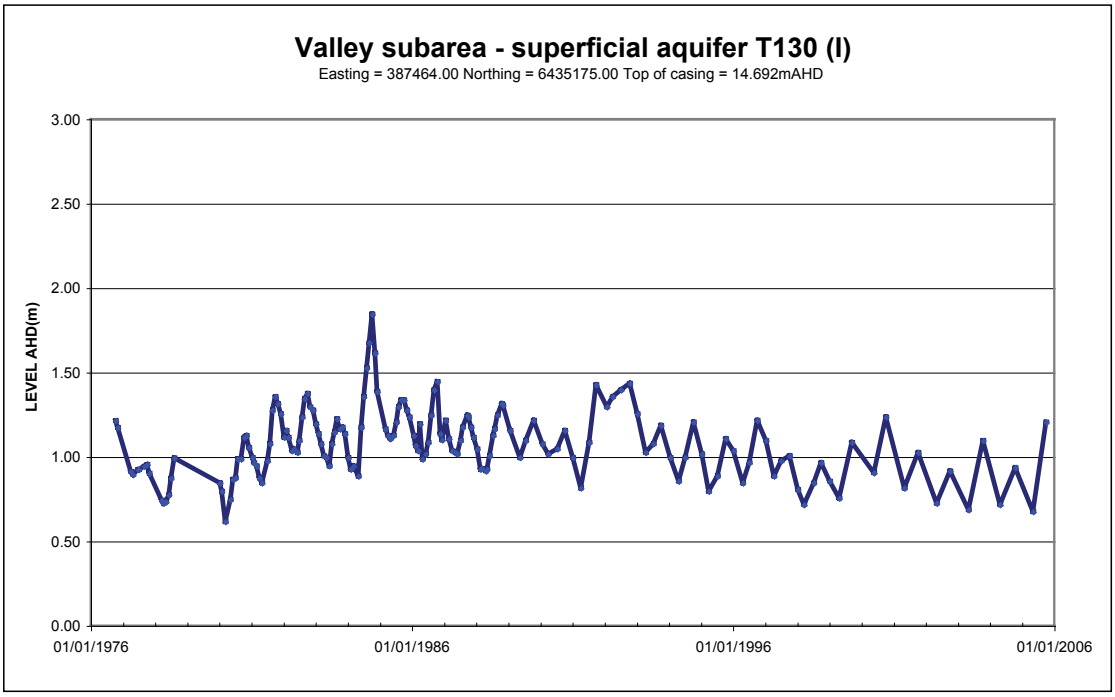
Monitoring bore T240 (1) (Figure 4), near the western boundary of the Wellard sub area shows about a 0.5 m net head decline over the 30 years of monitoring. From 1976 to about 1993, water levels rose to about 3.5 m AHD, but continually declined from then to the present head of about 2.5 m AHD. The reduced frequency of monitoring from 1998 is reflected in the lack of definition of the hydrograph.

Figure 4 Monitoring bore T240 (1) hydrograph



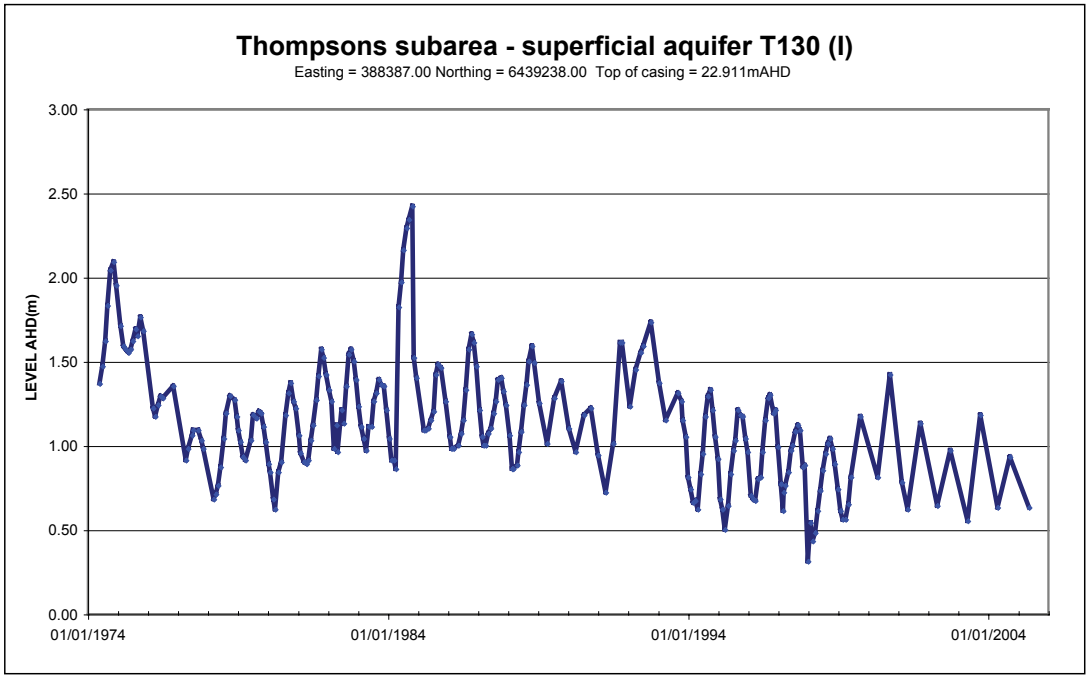
Monitoring bore T130 (1) (Figure 5) is located near the centre of the Valley sub area. The water levels have remained relatively steady over the last 30 years, showing a 0.5 m seasonal fluctuation. Effectively, there has been no net change in water levels at this locality in the superficial aquifer.

Figure 5 Monitoring bore T130(1) hydrograph



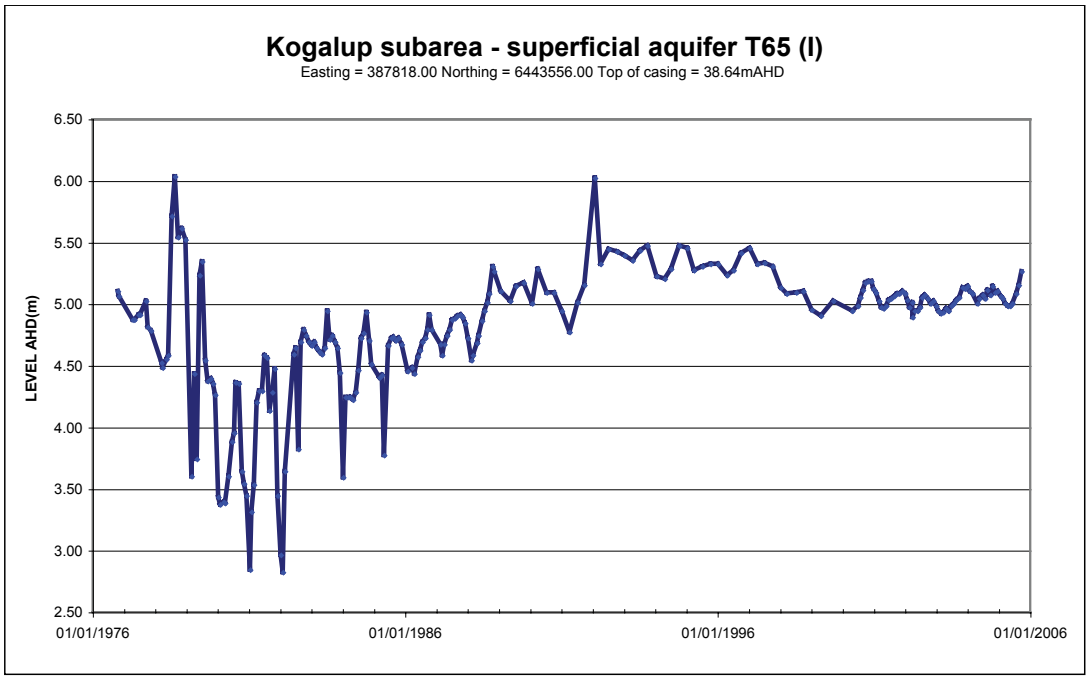
Water levels in monitoring bore T95 (0) (Figure 6) in the Thompsons sub area have fluctuated since 1974, although over this period water level decline is about one metre. The fluctuating pattern appears to be climate related and not affected by abstraction. Water levels show a continuous decline from about 1993.

Figure 6 Monitoring bore T95(0) hydrograph



Monitoring bore T65 (1) (Figure 7) is located near the southern boundary of the Kogalup sub area, north-west of Lake Thompson. The bore shows a fluctuating water level to about 1992 and a steady declining trend of less than 0.5 m since then. Overall, there has been almost no net head loss over the 30 years, although the influence of pumping can be seen on the hydrograph between 1979 and 1985.

Figure 7 Monitoring bore T65(1) hydrograph



Hydrographs of monitoring bores located within the Wellard and Valley sub areas (Figure 3, Figure 4 and Figure 5) suggest declines in water levels may be attributed to the increased abstraction from the Jandakot Mound groundwater scheme, and also from increased rates of draw from the southern Kwinana Beach industrial precinct and production from the northern Serpentine Groundwater Area.

3.2.3 Leederville aquifer

Data for water level monitoring of the Leederville aquifer is restricted to a small number of monitoring bores located mainly east of the CGA (AM52A is located in the north-western corner of the Wellard sub area). Hydrographs of the artesian bores screened in the Leederville aquifer indicate a decline in the potentiometric surface within all monitoring bores.

Groundwater abstraction from the Leederville aquifer in the CGA is currently exceeding recharge, and therefore potentiometric level declines are being observed throughout the groundwater area. Groundwater abstraction from the Leederville and Yarragadee aquifers will inevitably lead to potentiometric head decline, whether or not it exceeds recharge, until a new equilibrium is established. No recharge of the Leederville aquifer occurs within the CGA due to the presence of the Kardinya Shale Member within the Kogalup, Thompsons and Valley sub areas. In the south of the CGA, the superficial aquifer is, however, directly underlain by the Pinjar Member of the Leederville Formation. Potentiometric levels indicate that this area is in fact an area of upward discharge from the Leederville aquifer to the superficial aquifer. Davidson (1995) states, however, that due to the declining hydraulic heads within the aquifer, the area of downward heads is increasing and thus the recharge area is migrating and extending westwards.

During the last 25 years, water levels in monitoring bore AM52A (Figure 8), constructed in the Leederville aquifer and located in the uppermost western corner of the Wellard sub area, have declined by approximately two metres - a continuous decline. The same monitoring bore currently has a seasonal water level fluctuation of about one metre AHD; hence, care must be exercised to mitigate the threat of seawater intrusion dependent on the location of the saltwater interface, which may be some kilometres offshore. Davidson (1995) suggests that due to the abstraction (exceeding recharge by about 1.3 times), for a steady state to once again occur, the potentiometric level will require further declines of up to 10 m.

Monitoring bore AM45 (Figure 9) is located near the southern boundary of the Kogalup sub area. It has a net head decline of about five metres since 1979, although since about 2002, heads are showing a net increase from about -0.5 m to 1 m AHD.

Figure 8: Monitoring bore AM52A hydrograph (Leederville aquifer)

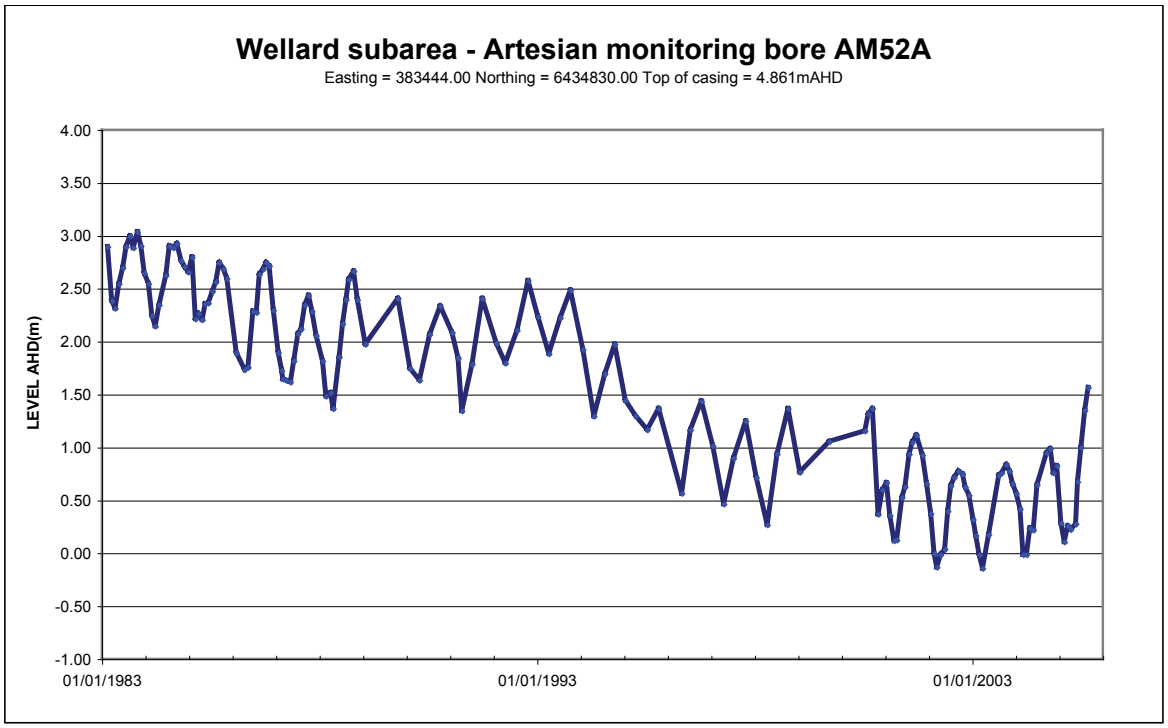
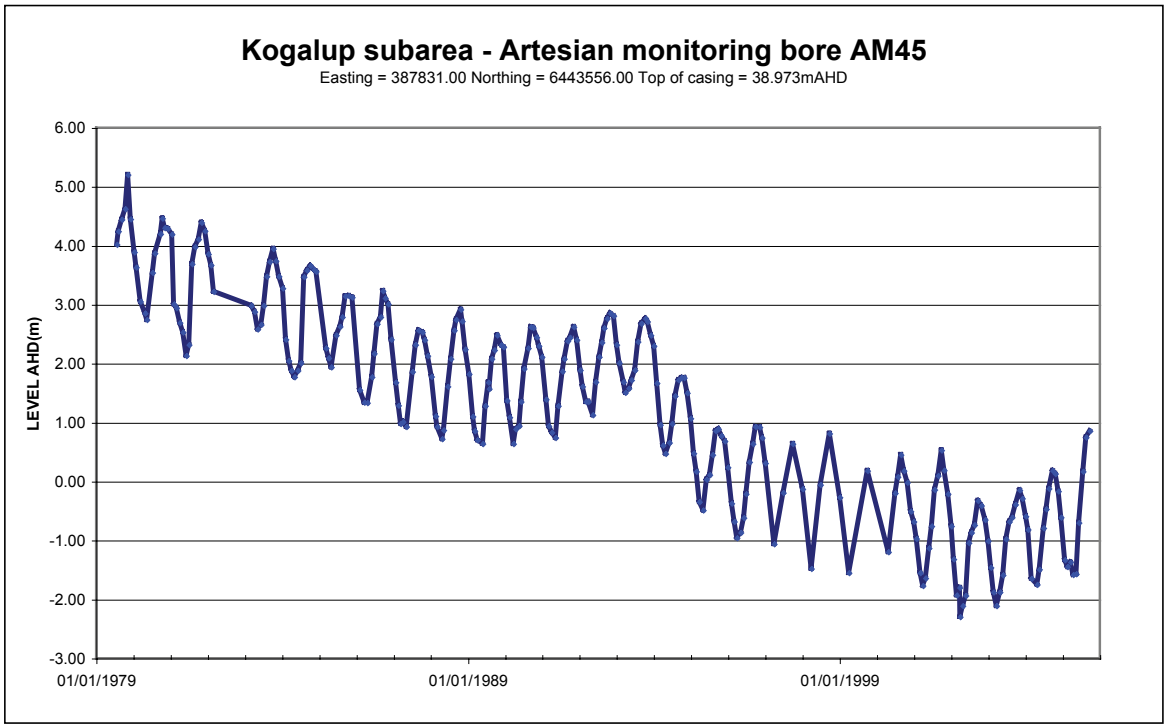


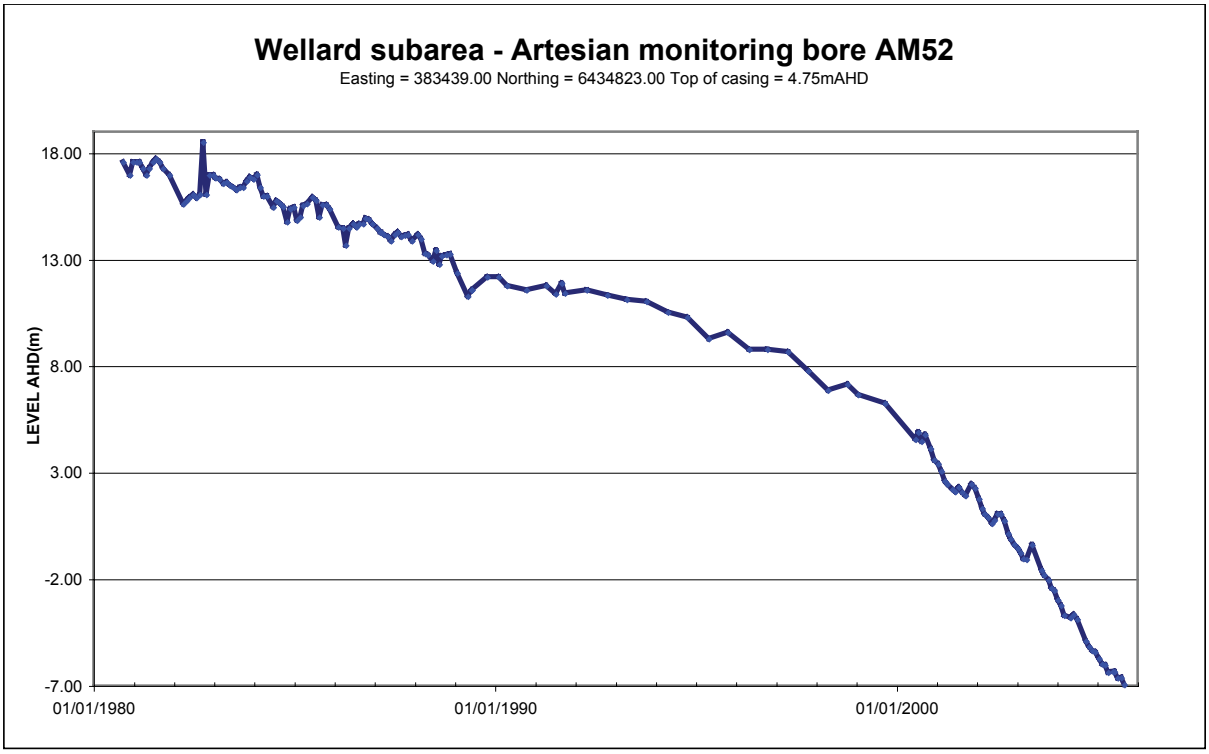
Figure 9: Monitoring bore AM45 hydrograph (Leederville aquifer)



3.2.4 Yarragadee aquifer

Declining potentiometric levels in the Perth Yarragadee aquifer occur in the southern Perth region, including the CGA. Similar to the Leederville aquifer, hydrographs of the artesian wells screened into the Yarragadee aquifer indicate a decline in the potentiometric surface within all monitoring bores.

Figure 10 Monitoring bore AM52 hydrograph (Yarragadee aquifer)



This is due to the annual groundwater abstraction from the Yarragadee aquifer in the Perth region (primarily for public water supply) being over twice the estimated current annual recharge (Davidson 1995). The four monitoring wells screened in the Yarragadee aquifer in the CGA show this annual decline has ranged from 0.5 to 25 m since 1980 (Figure 10). Recharge to the Yarragadee aquifer occurs some 20 km to the east of the groundwater area adjacent to the Darling Scarp. No recharge occurs to the Yarragadee aquifer within the CGA as it is overlain by the confining South Perth Shale.

As the Yarragadee aquifer is deep, saltwater intrusion can occur with the freshwater head above sea level.

3.3 Groundwater quality

Groundwater quality in the CGA could be affected, particularly by saltwater intrusion due to pumping and by disturbance of acid sulphate soils.

3.3.1 Monitoring program

Groundwater salinity from aquifers in the CGA is not monitored regularly. The monitoring program may in the future include increased groundwater salinity monitoring, with frequencies increased consistent with the current coverage.

There is no evidence of groundwater salinity increasing on a regional scale for the aquifers in the CGA. Private monitoring data (submitted through licence conditions) and department data collected and collated from the Cockburn Saltwater Interface bores (CSI-1/97, 2/97 and 3/97) indicate the seawater interface is about 500 m onshore, within the Kwinana Beach industrial area, where abstraction from the superficial aquifer is concentrated. It

is natural that bores pumping freshwater from above a saltwater interface should vary in salinity; this should be monitored carefully and abstraction adjusted accordingly to avoid the freshwater turning salty.

3.3.2 Superficial aquifer

The groundwater salinity in the superficial aquifer ranges from less than 130 mg/L total dissolved salts (TDS) to more than 12 000 mg/L TDS, however, it is mainly less than 1000 mg/L TDS (potable water is about 500 mg/L TDS - refer to Appendix G). At the saline interface, groundwater salinity increases with depth to approximately 36 000 mg/L TDS, which is the salinity of sea water.

3.3.3 Leederville aquifer

The salinity of the groundwater in the upper part of the Leederville aquifer ranges between 500 and 2000 mg/L TDS. In the lower part of the aquifer, the salinity is generally less than 3000 mg/L TDS.

3.3.4 Yarragadee aquifer

In the deep Yarragadee aquifer, groundwater salinity ranges from about 1000 to 2000 mg/L TDS to more than 10 000 mg/L TDS. Fresh groundwater occurs locally, but generally salinity increases in the east with depth.

3.4 Groundwater use

3.4.1 Monitoring program

Accurate monitoring of actual use of groundwater (abstraction) is obtained by the metering of bores, with estimates provided by water use surveys. Large licensees in the CGA are required to monitor groundwater use and levels as part of their licence conditions. In general, large allocations above 500 000 kL/year are metered, although metering is requested on a number of smaller allocations, including all new developments (e.g. public open space).

Water use surveys assess all licence renewals and are undertaken randomly to check compliance. Information gathered from the surveys is stored in the Water Resource Licensing database.

3.4.2 Licensed allocation

At November 2006, the total annual licensed entitlements in the CGA amounted to approximately 36.7 million kilolitres, with 29.6 million kilolitres allocated from the superficial aquifer. Over the last 13 years, the total annual licensed allocation has increased by approximately 14.1 million kilolitres, or 61 per cent.

3.4.3 Unlicensed bore use

Unlicensed groundwater use from domestic bores (which do not require licences) is considered when determining the groundwater availability of an aquifer. This use has been

estimated on a regional basis and has been incorporated in the Perth Regional Aquifer Modelling System (PRAMS) regional groundwater model (Section 3.6).

3.5 Future monitoring

The department consider the groundwater monitoring program be modified to include:

- establishment of monitoring objectives to guide monitoring activities
- regular monitoring of water level and quality (at least quarterly readings in the superficial aquifer)
- monitoring of bores in all aquifers in each sub area
- surveys of domestic bores in each sub area to estimate unlicensed use
- establishment of a database of historical unlicensed and licensed groundwater use

3.6 Groundwater modelling

PRAMS (Yu 2006) has been developed by the Department of Water and Water Corporation, in conjunction with CYMod Systems and CSIRO for sustainable water resources management and to refine estimates of sustainable yields for groundwater areas in the Perth Region.

This modelling system is an interactive and predictive tool for quantitative water resource assessment, evaluating impacts of land and water use options on the environment, and determining sustainable water resource management options (Davidson and Yu 2006).

The department will use the model as a management tool to quantify the groundwater resources, determine the environmental water requirements, assess the effect of private and public groundwater abstraction, and provide information for fair and equitable trading and licensing of groundwater allocations. Application of the PRAMS model in the CGA may result in a change to the allocation limits for the CGA.

4 Groundwater allocation

4.1 Water allocation

The allocation limit (AL) is the maximum volume of groundwater authorised by the Department of Water that is potentially available for abstraction on an annual basis. The AL is set to ensure that the annual groundwater abstraction regime does not have unacceptable impacts on the groundwater resource (quantity and quality), its dependent ecosystems (wetlands, terrestrial vegetation and river base flow, etc.) and its dependent social values.

ALs are determined by considering the sustainable groundwater yield, defined as the 'groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects dependent economic, social, and environmental values' (DEH 2004). The sustainable yield of an aquifer system may be subject to change. Monitoring of water levels and water quality trends over time enables adaptive management of the resource, which can be used to refine the sustainable yield and ALs of the aquifer. Groundwater available for future use is water that is not yet assigned to existing licences, stock and domestic (that is currently not accounted) or reserved for public water supply.

4.2 Groundwater allocation in the superficial aquifer

The superficial aquifer contains groundwater resources that are abstracted for consumption and support environmental features such as wetlands and native vegetation. Concerns associated with retention of such environmental features and intrusion of the saltwater wedge from the ocean limits the quantity of groundwater that may be drawn.

Current ALs are based on 'sustainable supply' figures determined using a simple water balance for each sub area. The sustainable supply was calculated as the total supply minus an allowance for the environment.

Groundwater available in the Cockburn Groundwater Area (CGA) with the current ALs and licensed entitlements is presented in Table 4.

Table 4 Groundwater allocation of the superficial aquifer

Subarea	Allocation limit[a] (kL/yr)	Allocation limit[a] (kL/yr)	Groundwater available for licensed use[c] (kL/yr)	Stock and Domestic (unlicensed)[d]	Resource classification category[e]	Level of utilisation
Kogalup	11 460 000	8 312 714	3 147 286	2 350 000	C3	High
Thompsons	8 700 000	6 854 372	1 845 628	1 520 000	C3	High
Valley	7 700 000	6 722 570	977 430	440 000	C3	High
Wellard	10 320 000	6 145 215	4 174 785	2 130 000	C2	Medium
TOTAL	**38 180 000**	**28 034 871**	**10 146 129**	**6 430 000**		

kL = kilolitre

a DWAID (May 2007)

b Licensed entitlements from the Water Resource Licensing database as at May 2007 (includes private and public supply)

c Groundwater available is equal to the AL minus licensed entitlements

d Refer to Appendix H

e Assessment of superficial yields in the Perth region, (Yu 2006)

4.2.1 Management response

The level of allocation in three sub areas is high (C3 – i.e. 70-100% allocated). As discussed, the Allocation limits were based on 'sustainable supply' figures determined using a sample water balance, which is equivalent to an R1 management response. As most sub areas are C3 level of utilisation, there is a management 'gap'.

On review of the hydrographs in Section 3 it appears that the Allocation limits are close to the actual sustainable limit as monitoring data over the last 30 years indicates no net change in water levels. The sub areas with water available will be managed to ensure that no further declines in water levels are experienced. Increased frequency of monitoring by the department as proposed will ensure that any impacts are identified early. Allocation limits may change with new information.

4.3 Groundwater allocation in the Rockingham aquifer

The Rockingham Sand aquifer exists only in the south-eastern part of the groundwater area and is found at shallow depth owing to the thin nature of the superficial sediments overlying it. The aquifer does reach maximum thicknesses of about 75 m in the south-east of Wellard sub area. Groundwater salinity is highly variable, ranging from about 500 mg/L total dissolved salts (TDS) to more than 3000 mg/L TDS adjacent to the coast.

Groundwater in the aquifer flows over a saltwater interface to the ocean. As stated by Davidson (1995), upconing of the saltwater interface may readily occur as a result of groundwater abstraction from high-yielding wells. No allocation limits have been set and no access will be allowed.

4.4 Groundwater allocation in the Leederville aquifer

The Leederville aquifer extends throughout the CGA.

Recharge to the aquifer occurs through downward leakage from the superficial aquifer where there is direct contact and hydraulic connections between the two aquifers, mainly along the central and eastern margins of the Swan Coastal Plain where downward hydraulic heads prevail. Groundwater in the Leederville aquifer flows from east to west and discharges to the ocean.

Abstraction from the Leederville aquifer is constrained by the limited amount of recharge to the aquifer, high costs of bore development, brackish to saline groundwater in some areas, and a general decline in water levels in the aquifer. The department's Policy on Accessing the Leederville and Yarragadee aquifers in Perth 2006 limits increases in groundwater abstraction from the Leederville aquifer to avoid additional stress on the aquifer water levels.

The deeper confined aquifers (both Leederville and Yarragadee) are not in direct hydraulic connection with the wetlands and other ecological features. Abstraction impacts are transmitted through a confined aquifer by pressure changes over wide areas; whereas, in the unconfined superficial aquifer, drawdowns are expressed as more localised cones of depression. Therefore, each confined aquifer will be managed by groundwater area rather than by the four sub areas.

Previous ALs were based on 'sustainable supply' figures determined on a sub area basis using a simple water balance. An estimate of recharge to the aquifer has been used to calculate the total supply available. Available monitoring data has been incorporated into the Perth Regional Aquifer Modelling System resulting in a new, significantly reduced AL. As per Table 5 this system is now over allocated.

Table 5 Groundwater allocation of the Leederville aquifer

Subarea	Allocation limit[a] (kL/yr)	Allocation limit[a] (kL/yr)	Groundwater available for licensed use[c] (kL/yr)	Resource classification category[d]	Level of utilisation
Combined	5 150 000	5 555 689	0	C4	Over-Allocated

kL = kilolitre

a DWAID (November 2006)

b Licensed entitlements from the Water Resource Licensing database as at 13/11/06 (includes private and public supply)

c Groundwater availability is equal to the allocation limit minus licensed entitlements

d Refer to Appendix H

4.4.1 Management response

The Leederville aquifer is over allocated (C4). Applications for groundwater licences from the Leederville aquifer will be refused in accordance with the departments *Policy on Accessing the Leederville and Yarragadee aquifers in Perth 2005.* The department will also recoup any unused licensed water entitlements in accordance with *State-wide Policy No.11 - Management of Unused Licensed Water Entitlements 2003* (WRC 2003a). The monitoring data being collected in the area will be closely reviewed for further decreases in water level. Continued decline of water levels in the Leederville aquifer may result in the AL being reduced and existing licensed entitlements reduced accordingly.

The department will support individuals investigating, at their own expense, whether additional groundwater can be taken on a sustainable basis from any of the fully allocated aquifers. This will require some groundwater flow modelling and ongoing monitoring to demonstrate that any impacts caused by the groundwater development on social and ecological values, and existing users, are acceptable.

4.5 Groundwater allocation of the Yarragadee aquifer

The Northern Perth Basin Yarragadee aquifer extends throughout the CGA and is found at considerable depth (>400 m below natural surface). Groundwater in the Yarragadee aquifer flows generally from east to west, discharging into the ocean. The base of the Yarragadee aquifer has not been intercepted by drilling, although it is estimated to be about 2000m deep.

Due to the confined nature of the Yarragadee aquifer (presence of overlying South Perth Shale) within the CGA, the impacts of groundwater abstraction may extend many kilometres to the recharge areas (Davidson 1995). Within the CGA, annual groundwater abstraction from the Yarragadee aquifer exceeds the present rate of recharge. Like the Leederville aquifer, abstraction from the Yarragadee aquifer is constrained by the limited amount of recharge to the aquifer, high costs of bore development, brackish to saline groundwater in some areas, and a significant decline in water levels in the aquifer. *The Policy on Accessing the Leederville and Yarragadee aquifers in Perth 2005* (Department of Environment 2003) limits increases in groundwater abstraction from this aquifer to avoid any additional stress on the aquifer water levels.

Previous ALs were based on ‘sustainable supply’ figures determined on a sub area basis using a simple water balance. An estimate of recharge to the aquifer has been used to calculate the total supply available. Available monitoring data has been incorporated into the Perth Regional Aquifer Modelling System, resulting in a new, significantly reduced AL. As per Table 6 this system is now over allocated.

Table 6 Groundwater allocation of the Yarragadee aquifer

Subarea	Allocation limit[a] (kL/yr)	Allocation limit[a] (kL/yr)	Groundwater available for licensed use[c] (kL/yr)	Resource classification category[d]	Level of utilisation
Combined	5 150 000	5 555 689	0	C4	Over-Allocated

kL = kilolitre

a DWAID (November 2006)

b Licensed entitlements from the Water Resource Licensing database as at 13/11/06 (includes private and public supply)

c Groundwater availability is equal to the allocation limit minus licensed entitlements

d Refer to Appendix H

4.5.1 Management response

The Yarragadee aquifer is over allocated (C4). Applications for groundwater licences from the Yarragadee aquifer will be refused in accordance with the *Policy on Accessing the Leederville and Yarragadee aquifers in Perth 2005* (Department of Environment 2003). The department will also recoup any unused licensed water entitlements in accordance with *State-wide Policy No.11 – Management of Unused Licensed Water Entitlements 2003* (WRC 2003a). The monitoring data being collected in the area will be closely reviewed for further decreases in water level. Continued decline of water levels in the Yarragadee aquifer may result in the AL being reduced and existing licensed entitlements reduced accordingly.

The department will support individuals investigating, at their own expense, whether additional groundwater can be taken on a sustainable basis from any of the fully allocated aquifers. This will require some groundwater flow modelling and ongoing monitoring to demonstrate that any impacts caused by the groundwater development on social and ecological values, and existing users, are acceptable.

5 Allocation principles and licensing considerations

Water allocation planning involves deciding how much water can be taken for domestic or commercial purposes while leaving enough water in the environment to meet ecological, recreational and cultural needs. The aim of planning is to identify where water is or is not available for use, and to set rules for how water is to be accessed and used. Planning also identifies ecological objectives and sets out how the environmental impacts of water will be monitored and managed. Planning decisions about how much water can be used are informed by science and by community needs. The water management described in plans is delivered through licences.

The focus for allocation principles and licensing considerations in the Cockburn Groundwater Area (CGA) is on optimisation of water use and the recovery of water. Only limited water is available in superficial aquifers, and the Leederville and Yarragadee aquifers are over allocated.

The area covered by the CGA is proclaimed under the Rights in Water and Irrigation Act 1914 (RiWI Act) and as such, access to groundwater is subject to licensing under Part III of the Act. All state-wide policies endorsed by the department apply in this plan and are available, together with guidelines and notes at the department's website. [3]

The policies for managing either current licensees or applicants requesting access to the groundwater resources in the CGA are outlined below. These policies apply to all aquifers and will remain current until this plan is amended by the department or replaced by another plan. Licensing of groundwater resources in the CGA is administered by the Kwinana Peel Region, Kwinana office.

Each policy has a policy number prefixed with the letters CGA and accompanied by explanatory text, where required. A summary of all policies is provided in Table 7.

[3] http://portal.water.wa.gov.au/portal/page/portal/Policies

Table 7 Summary of allocation policies

Policy Number	Section reference	Policy
CGA-1	5.1	Groundwater licence applications in the CGA will be considered on a first-in-first-served basis, subject to the provision of all required information.
CGA-2	5.1	Groundwater entitlements must not exceed the Allocation Limit for the respective sub area and aquifer.
CGA-3	5.2.2	The department will assess licence applications according to the requirements of the *Rights in Water and Irrigation Act 1914* (RiWI Act) and the Rights in Water and Irrigation Regulations 2000.
CGA-4	5.2.3	The department issues groundwater bore licences if the applications, once assessed, conform to all appropriate departmental policies and RiWI Act requirements.
CGA-5	5.2.3	All new groundwater bore licences will be issued for a two-year period. Following this period, providing the licensee has met licence conditions including satisfactory progress with development, the licence may be renewed for a period up to a maximum of 10 years.
CGA-6	5.2.9	It is the licence holder's responsibility to make an application to extend the term of the existing licence prior to the expiry date.
CGA-7	5.2.9	If a licensee has not abided by all the licence conditions in a fully allocated sub area, the licence is unlikely to be extended without demonstrated extenuating circumstances.
CGA-8	5.2.9	In fully allocated areas, licensees must not allow their licences to expire as the department cannot guarantee that the licence will be renewed if water is not available.
CGA-9	5.2.9	The renewal of an expired licence in a fully-allocated area, may have more stringent conditions places upon it.
CGA-10	5.2.10	An application to increase an existing licensed entitlement will be treated as a new application for additional water.

Policy Number	Section reference	Policy
CGA-11	5.2.12	The allocation of water for different use is to be consistent with the department's *Environmental water provisions Policy for Western Australia* (2000a).
CGA-12	5.3.1	Groundwater management in the CGA will recognise statutory environmental protection criteria for: • Ramsar wetlands • Wetlands of National and International Importance • Declared rare flora *(Wildlife Conservation Act 1950)* • Swan Coastal Plain Lakes (EPP Lakes) • Bushland Reserves.
CGA-13	5.3.2	If significant environmental impacts on groundwater-dependent ecosystems (GDEs) are likely, then the applicant will need to provide an assessment of the water level regime required to maintain the GDE at a low level of risk, including advice on how abstraction will be managed to protect the environmental values.
CGA-14	5.3.2	Individual licensees are responsible for providing information on their potential pumping impacts on identified local GDEs and existing groundwater users. It is up to applicants to demonstrate that their proposed development will be sustainable in the long term.
CGA-15	5.3.4	If deemed necessary by the department, groundwater licence applications may be referred to the Environmental Protection Authority for the assessment of an significant impacts upon Cockburn Sound.
CGA-16	5.3.5	It is the responsibility of the applicant to establish whether the area of application contains acid sulphate soils, and whether the proposed groundwater abstraction, including drainage, will be susceptible to the generation of acidic water and soils.

Policy Number	Section reference	Policy
CGA-17	5.4	In certain circumstances, proponents of a proposal may be required to submit to the department a hydrogeological report assessing the possible local and regional impacts of the proposed abstraction on the hydrology, environment and other groundwater users in support of a groundwater well licence application. The report is to be prepared by a competent groundwater professional and is to be completed at the applicant's expense.
CGA-18	5.5.1	All licences to construct and alter bores will contain a condition that a certified driller must construct the bore(s).
CGA-19	5.5.1	Bore logs are to be submitted by the proponent to the department for every new or altered bore.
CGA-20	5.5.2	Bores screened within the confined aquifers, below the bottom of the superficial aquifer, must be pressure-cement grouted.
CGA-21	5.5.2	The casing of collapsed or abandoned bores must be sealed, at the owner's expense, in accordance with 'Minimum Construction Requirements for Water Bores in Australia'.
CGA-22	5.5.3	All new groundwater licences may be required to prepare a monitoring program, undertake regular monitoring and submit the results to the department.
CGA-23	5.5.4	The department may reduce unused portions of licensed entitlements in accordance with Policy No. 11, where it cannot be established that extenuating circumstances have resulted in part of the entitlement not being used.
CGA-24	5.5.5	All new groundwater licences may be subject to a condition requiring installation and maintenance of a department approved flow meter to monitor abstraction.

Policy Number	Section reference	Policy
CGA-25	5.5.6	The department may require the development and implementation of an operating strategy where: • the taking of water may impact on the environment • the volume of water to be taken is significant • the water resource being accessed requires stringent management • water is abstracted from several sources or from a number of bores and requires careful management • in the opinion of the department it is necessary in order to fulfil the requirements of the RiWI Act.
CGA-26	5.5.6	A detailed development plan and timetable stipulating the proposed activity, the area of development and the timeframe for each stage of development must accompany all new or amended licence applications.
CGA-27	5.5.8	Groundwater should be used efficiently and in accordance with best management practices and irrigation methods.
CGA-28	5.5.9	Where appropriate and practicable, other sources of water including drainage, stormwater and wastewater should be used in preference to groundwater and surface water sources.
CGA-28	5.5.10	The regular self-auditing of water usage by licensees is encouraged with the aim of minimising wastage and increasing the efficiency of water usage.
CGA-30	5.6.1	Under the RiWI Exemption and Repeal (Section 26C) Order 2001, groundwater abstraction is exempt from licensing from the superficial aquifer for the following purposes only: • fire fighting • watering cattle or other stock, other than those being raised under intensive conditions • watering an area of lawn or garden that does not exceed 0.2 hectare • other ordinary domestic uses.

5.1 Basis for groundwater allocation

In Western Australia, water has been allocated on the basis of the 'first in - first served' approach. Under this approach, licence applications are assessed in the order in which they are received and entitlements are issued up to the allocation limit (AL) for a particular sub area and aquifer.

Department policy is to license water use up to the AL only where there is an immediate need and efficient water use can be demonstrated. The department will support individuals investigating, at their own expense, whether additional groundwater can be taken on a sustainable basis from any of the fully allocated aquifers. This will require some groundwater flow modelling and ongoing monitoring to demonstrate that any impacts caused by the groundwater development on social and ecological values, and existing users, are acceptable.

CGA-1	*Groundwater licence applications in the CGA will be considered on a first in-first-served basis, subject to the provision of all required information.*
CGA-2	*Groundwater entitlements must not exceed the Allocation Limit for the respective sub area and aquifer.*

5.2 Protocols for groundwater allocation

5.2.1 Application for a groundwater well licence

The process of assessing a groundwater licence application starts when an application is submitted to the Department of Water on the prescribed form, in accordance with schedule 1 clause 4 of the RiWI Act.

An application is required under the following circumstances:

- the bore is defined as artesian under s. 26A of the RiWI Act
- the property upon which a non-artesian bore is to be situated lies within a groundwater area proclaimed under s. 26B of the RiWI Act.

Under these circumstances, an applicant must gain approval in the form of a Licence to Construct or Alter a Well (26D licence) to commence constructing, enlarging, deepening, altering or drawing groundwater from any bore. Stock and domestic use from a non-artesian bore is exempt from a Licence to Take Groundwater (5C licence) (refer to s. 5.6). A person in breach of these requirements, or found to be in contravention of a licence condition, may be liable to a fine.

5.2.2 Licence approval process

The legislative requirements for assessing applications are indicated in the RiWI Act and RiWI regulations. Applications for licences will be accepted by the department and either granted or refused at the discretion of the department in accordance with clause 7(1). In exercising that discretion, the department is to have regard to all matters that it considers relevant in accordance with clause 7(2).

In an urgent situation where a new or replacement bore or alteration to a bore is required to minimise loss of production, the department will consider 26D licence applications in priority. The applicant would need to make the department aware that the construction work is critical. This applies to 26D licence applications only. Applications to amend 5C licences would need to be treated on an 'as received' basis for equity reasons.

CGA-3 The department will assess licence applications according to the requirements of the Rights in Water and Irrigation Act 1914 and the Rights in Water and Irrigation Regulations 2000.

5.2.3 Issue of groundwater licences

Licences are issued when the department's assessment process has been satisfied. A licence entitlement is not an implied guarantee that the quantity (and quality) of water will always be available.

The department may issue a groundwater exploration licence for a period up to 12 months. Licences for exploration purposes (issued under s. 26D of the Act) allow applicants to construct bore(s), investigate whether there is sufficient water available to meet the requirements of their development plan and determine any likely impacts caused by pumping. This is particularly important where licensees are contemplating purchasing an entitlement on the trading market in a fully allocated area. The department gives no guarantee that a licence to take water (under s. 5C of the Act) will be issued at the completion of the investigation.

The Kwinana Peel Region can approve and issue a groundwater bore licence directly if the assessment has considered all matters required in schedule 1 clause 7(2), adequate water is available and the assessment indicates that the taking of water is consistent with departmental policies and does not adversely affect the environment or other users.

CGA-4 The department issues groundwater bore licences if the applications, once assessed, conform to all appropriate departmental policies and RiWI Act requirements.

CGA-5 All new groundwater well licences will be issued for an initial two-year period. Following this period, providing the licensee has met licence conditions, including satisfactory progress with development, the licence may be renewed for a period up to a maximum of 10 years.

5.2.4 Refusal of groundwater well licences

The department may make a decision to refuse an application for a licence after undertaking an assessment in accordance with the requirements of schedule 1 clause 7(2), if the taking of water is inconsistent with policies or plans applying in the area or it may cause significant adverse impacts to the aquifer, environment or existing users.

Applications must be refused if the department considers that an applicant would not be willing or able to comply with terms, conditions and restrictions included in a licence. An application must also be refused if the department is not satisfied that the applicant has the

resources, including financial, to carry out the activity, or if a person has been convicted of an offence under the RiWI Act.

5.2.5 Appeals relating to groundwater well licences

Applicants aggrieved by a decision of the department relating to a refusal of a licence or transfer of entitlement, or the period for which a licence is granted, or any condition or restriction in a licence, may apply to the State Administrative Tribunal for a review of the decision (s. 26GG of the RiWI Act).

5.2.6 Compliance and monitoring of resources and licences

Given the high level of allocation, compliance and monitoring are very important for management. Site inspections and water use surveys may be undertaken periodically to assess compliance of in situ development with licensed activities. Unused entitlements should be managed in accordance with the department's State-wide Policy No. 11 - Management of unused licensed water entitlements (WRC 2003a).

Action will be taken to address overuse and non-compliance with the terms of the licence on a case-by-case basis depending on the circumstances of the non-compliance.

5.2.7 Re-allocation of entitlements

Where existing entitlements remain unused for a significant period of time or the applicant proposes to reduce their allocation, then the water may be recouped as per the department's *State-wide Policy No 11 - Management of unused licensed water entitlements* (WRC 2003a). Recouped water may become available for reallocation to consumptive use or to the environment.

5.2.8 Water Resources Management Committees

The department may establish local Water Resources Management Committee (WRMC) in accordance with division 3C s. 26GK of the RiWI Act, to assist the department in water resource planning and management. There is currently no WRMC related to water management of the Cockburn Groundwater Area. The department will consider whether a WRMC is required to assist with management in the CGA.

5.2.9 Renewal of existing licences

Groundwater licences to take water are valuable documents that should be kept in a safe place and not allowed to expire. The department will endeavour to notify licence holders in advance of expiry; however, it is the licence holder's responsibility to make an application to extend the term of the existing licence before the expiry date.

Generally, when a licence to take water is due to expire, and the licensee has abided by all the licence conditions, the licence will be extended for a further period. However, if an application for a licence to take water expires and the licensee has not abided by all the licence conditions, there is no guarantee that the term of the licence will be extended automatically and the licensee will need to show why the term of the licence in its entirety should be extended or may need to apply for a new licence. If a licensee has not abided by

all the licence conditions in a fully allocated sub area, the licence is unlikely to be extended without demonstrated extenuating circumstances.

CGA-6 It is the licence holder's responsibility to make an application to extend the term of the existing licence before the expiry date.

CGA-7 If a licensee has not abided by all the licence conditions in a fully allocated sub area, the licence is unlikely to be extended without demonstrated extenuating circumstances.

CGA –8 In fully allocated areas, licensees must not allow their licences to expire as the department cannot guarantee that the licence will be renewed if the water is not available.

CGA-9 The renewal of an expired licence in a fully allocated area, may have more stringent conditions placed upon it.

5.2.10 Applications for increasing an existing entitlement

Existing licensees may require additional groundwater to expand operations that will require an amendment to their licence. The proposed increased abstraction will require assessment to ensure that the taking of water is consistent with departmental policies and does not adversely affect the environment.

CGA-10 An application to increase an existing licensed entitlement will be treated as a new application for additional water.

5.2.11 Transferring (trading) water entitlements

New water users are able to access water in a fully allocated system through a transfer (trading) of licensed entitlements. An application for a transfer (trade) will be assessed by the department in accordance with the requirements of the RiWI Act and relevant policies, and potential impacts to dependent ecosystems and existing users. A transfer (trade) of a licensed entitlement can occur only with the approval of the department.

The ability to transfer (trade) water entitlements detailed in *State-wide Policy No. 6 - Transferable (Tradeable) Water Entitlements in WA, 2001* (WRC 2000b). This enables a licence holder to transfer (trade) all or part of their licensed entitlement to take water to another licensed water user. Transferring (trading) licensed entitlements is a market-based instrument that can be used to:

- reallocate scarce water resources to uses with higher economic benefit
- achieve more efficient use of water resources
- allow the water industry to respond to changing conditions
- assist regional development.

5.2.12 Priority use of groundwater

Within the CGA there are several environmentally significant wetlands identified within the Environmental Protection Authority System 6 Report, the Swan Coastal Plain Lakes Environmental Protection Policy (EPA 1992), and the publication entitled *Wetlands of the Swan Coastal Plain* (Hill et al. 1996). Wetlands and phreatophytic vegetation are groundwater-dependent ecosystems, and without sustainable groundwater allocation and management, excessive groundwater abstraction may impact adversely on these sensitive environments.

Priority beneficial use of a groundwater resource identifies present or future use that should receive priority over other potential uses. The priority beneficial use will determine the criteria for management and regulation of groundwater allocation. Allocation limits are applied in proclaimed management areas to restrict abstraction to sustainable levels and policies have been formulated for the protection of wetlands from excessive groundwater abstraction.

Regulatory controls enable:

- abstraction from aquifers and management areas to be maintained at a sustainable level for the long term
- allocation of available groundwater resources for beneficial public and private uses while protecting environmentally sensitive areas
- sharing of groundwater resources in an equitable manner and identifying and

CGA-11 The allocation of water for different use is to be consistent with the department's Environmental water provisions Policy for Western Australia (2000a).

5.3 Environmental protection

5.3.1 Wetlands

Significant wetlands and groundwater-dependent ecosystems are located in the CGA. They exist as surface expressions of the watertable and, therefore, are susceptible to adverse impacts if excessive abstraction occurs in their vicinity. Legislation has been enacted ensuring the protection and conservation of these wetlands and conservation areas.

CGA-12 Groundwater management in the CGA will recognise statutory environmental protection criteria for:

- *Ramsar Wetlands*
- *Wetlands of National and International Importance*
- *Declared rare flora (Wildlife Conservation Act 1950)*
- *Swan Coastal Plain Lakes (EPP Lakes)*
- *Bushland Reserves.*

5.3.2 Groundwater dependent ecosystems

If an applicant's abstraction regime is likely to have significant impacts on local groundwater-dependent ecosystems (GDEs) or other values, then the department may require site-specific work to be done on the value concerned, such as:

- more accurate mapping and identification of the GDE
- a values and condition assessment of the GDE
- determination of ecological water requirements for the GDE
- setting of water level criteria at representative GDEs and associated monitoring bores
- monthly monitoring of water levels, including baseline levels
- annual monitoring of biological condition
- reporting to the department on water level trends, trends in biological condition, the relation between the two, and compliance with water level criteria
- triggers and associated management actions, including switching off production bores if criteria were likely to be breached.

CGA-13 *If significant impacts are likely, then the applicant will need to provide an assessment of the water level regime required to maintain GDEs at a low level of risk, including advice on how abstraction will be managed to protect the environmental values.*

CGA-14 *Individual licensees are responsible for providing information on their potential pumping impacts on identified local GDEs and existing groundwater users. It is up to applicants to demonstrate that their proposed development will be sustainable in the long term.*

5.3.3 Salt water interface

A potential limitation for groundwater abstraction in the CGA is the maintenance of the saltwater interface and prevention of saltwater upconing. Regular monitoring and management of wells should be encouraged to prevent upconing and saline intrusion, which would result in deterioration of the freshwater aquifer.

5.3.4 Cockburn Sound

Groundwater discharge has been shown to influence coastal flushing by establishing a density gradient driving onshore-offshore circulation (WAWA 1993). Of importance to the Cockburn Sound is the near-shore strip, adjacent to the coast, from which groundwater discharge may impact on the summer mixing and circulation patterns.

Groundwater discharge is, in fact, a major contributor to the total nutrient loading to Cockburn Sound. Changes to groundwater discharge may impact on nutrient levels within Cockburn Sound and the sensitive marine ecosystem.

CGA-15 *If deemed necessary by the department, groundwater licence applications may be referred to the Environmental Protection Authority for the assessment of any significant impacts upon Cockburn Sound.*

5.3.5 Acid Sulphate Soils

Acid sulphate soils are naturally occurring soils that contain iron sulphides, predominantly as pyrite. These soils are benign when undisturbed, but the exposure of the pyrite to air by the drainage, dewatering (water level declines by pumping groundwater) or excavation of soil, can generate substantial amounts of sulphuric acid. Discharge of acidic water into waterways and wetlands can cause fish kills and loss of aquatic biodiversity. Infiltration of acidic water may contaminate groundwater with acid, metals and other contaminants which are toxic to humans and other biota. Lowering of pH in soil, water or water bodies can change community composition of dependent biota whereby acid-tolerant species are favoured, and those that are intolerant disappear from that environment. In effect, the impact will lead to the deterioration of the quality of the groundwater.

CGA-16 *It is the responsibility of the applicant to establish whether the area of application contains acid sulphate soils, and whether the proposed groundwater abstraction, including drainage, will be susceptible to the generation of acidic water and soils.*

It is in the interest of the applicant that such understanding is established, as the generation of acid may have a significant impact on property and the activities of the applicant.

5.4 Hydrogeological assessment

Applicants seeking large quantities of groundwater from the superficial aquifer adjacent to wetlands or the coastal fringe, or the Leederville or Yarragadee aquifers, are required to carry out an investigation to demonstrate that the water can be taken on a sustainable basis. This is particularly applicable to proponents accessing new entitlements through the water trading market. In these cases, an exploratory groundwater licence is issued allowing the applicant to investigate the groundwater resources and to determine how the requirement will be achieved.

At the conclusion of the investigation, a hydrogeological report must be submitted to the department for assessment.

CGA-17 *In certain circumstances, proponents of a proposal may be required to submit to the department a hydrogeological report assessing the possible local and regional impacts of the proposed abstraction on the hydrology, environment and other groundwater users in support of a groundwater well licence application. The report is to be prepared by a competent groundwater professional and is to be completed at the applicant's expense.*

5.5 Licensing considerations

5.5.1 Bore construction and groundwater licensing

When a new application is received for a new bore, the licences may be issued in two parts:

- a 26D licence for the construction of the bore
- a 5C licence, only after a 'Form L - Particulars of Completed Borehole' has been received from the proponent and the aquifer has been identified.

CGA-18 All licences to construct and alter bores will contain a condition that a certified driller must construct the bore(s).

Licensees are required to submit information to the department regarding bore construction on the prescribed form within one month of bore completion (RiWI Act, s. 26E).

CGA-19 Bore logs are to be submitted by the proponent to the department for every new or altered bore.

5.5.2 Cement grouting

Bores screened within the confined aquifers must be pressure-cement grouted. When drilling a bore beneath the superficial aquifer, a risk exists that groundwater will flow within the annulus between the borehole casing and the aquifer, resulting in the intermixing of varying quality groundwater. The cement grouting of wells screened below the superficial aquifer mitigates such mixing, and acts to provide borehole stability and prevent casing corrosion.

Bores constructed into the Leederville and Yarragadee aquifers may require cement grouting, which must be performed by an individual possessing a Class 2 or 3 Water Well Driller's Certificate issued by the Australian Drilling Industry Association (ADIA 1996). It is preferable to seal the bore with cement poured down the bore casing.

CGA-20 Bores screened within the confined aquifers, below the bottom of the superficial aquifer, must be pressure-cement grouted.

Collapsed and abandoned wells require sealing to prevent potential future aquifer contamination. It is preferable to seal the bore with cement poured down the casing. Local soil materials may not seal the bore satisfactorily due to upward potentiometric pressure in some areas of the CGA.

National guidelines on *Minimum Construction Requirements for Water Bores in Australia, edition 2*[4], provides guidance regarding cement grouting and abandonment of bores.

CGA-21 The casing of collapsed or abandoned wells must be sealed, at the owner's expense, in accordance with 'Minimum Construction Requirements for Water Bores in Australia'.

[4]www.nrm.qld.gov.au/water/management/bores/aust_standards.html

5.5.3 Monitoring program

The department may require a licensee to establish groundwater monitoring bores to monitor the local impact of the abstraction on the groundwater levels in sensitive environments or where usage is large. It is in the interest of the licensee to monitor the groundwater levels, as any reduction or reducing trend in the levels could limit the availability of water. Licensees should implement measures to prevent significant reduction in groundwater levels.

The department may require a licensee to monitor the quality of the groundwater to ensure it is not compromised by adverse saltwater impacts.

CGA-22 *All new groundwater licences may be required to prepare a monitoring program, undertake regular monitoring and submit the results to the department.*

5.5.4 Water use surveys

Officers of the department will conduct water use surveys to determine if the licensee is using their allocation in accordance with their licence conditions. If a licensee is not using all of the authorised allocation, the licensee will be asked to explain why the allocation should not be reduced at the time of licence renewal to better reflect current use and near future requirements.

The department may reduce unused portions of licensed allocations where it cannot be established that extenuating circumstances have resulted in part of the entitlement not being used, in accordance with *State-wide Policy No. 11 - Management of Unused Licensed Water Entitlements* (WRC 2003a). The reduction of unused allocations will be strictly adhered to, to ensure unused allocations do not hinder sustainable development of the groundwater.

CGA-23 *The department may reduce unused portions of licensed entitlements in accordance with Policy No. 11, where it cannot be established that extenuating circumstances have resulted in part of the entitlement not being used.*

Where it is determined that a licensee is using water in excess of that approved, the department will take appropriate action to limit any additional risk to the groundwater resource and its dependent values and other groundwater users.

5.5.5 Metering

Depending on the volume of water to be taken and any other relevant factors and policies, meters may need to be installed to enable groundwater use to be measured accurately.

CGA-24 All new groundwater licences may be subject to a condition requiring installation and maintenance of department-approved flow meters to each bore to monitor abstraction.

It is the responsibility of licensees to ensure that the water pumped is of meterable quality to prevent damage to the meters. The department may at any time require a meter to be tested by the licensee.

Licensees will be required to read their meters monthly, record the volume of groundwater pumped from each bore at the close of each month, and submit the following information to the department one month after the end of the water year (by 31 July each year).

The department will use this information, together with the water level and quality information, to assist in managing the regional impact of groundwater abstraction on the water resources of the CGA. The information collected will be used to provide further calibration of the Perth Regional Aquifer Modelling System.

5.5.6 Development plans and operating strategies

The department will require applicants requesting large volumes of water, or where the impacts of taking water are significant, to prepare and implement operating strategies at their own cost. Where required, licensees should prepare an operating strategy to the satisfaction of the department in accordance with State-wide Policy No. 10 - Use of Operating Strategies in the Water Licensing Process (2003b) and comply with its requirements including monitoring.

Operating strategies indicate the licensee's responsibilities in managing the impacts of taking and using the water and specify:

- the licensee's land use, water abstraction regime, and the methods and infrastructure used to abstract, treat or distribute water
- monitoring and reporting requirements
- methods used to manage impacts on the environment and other water users
- contingency plans, describing how the licensee will alter their operations to cope with any directions to temporarily reduce water consumption
- water efficiency measures used.

Licences will include a condition requiring licensees to comply with department pre-approved operating strategies. Monitoring requirements are not necessarily restricted to the development area, and the department may also request off-site monitoring of impacts. This information is used to ensure protection of neighbouring groundwater users, minimise environmental degradation and maintain the long-term sustainability of the aquifer system.

CGA-25 The department may require the development and implementation of an operating strategy where:

- *the taking of water may impact on the environment*
- *the volume of water to be taken is significant*
- *the water resource being accessed requires stringent management*
- *water is abstracted from several sources or from a number of bores and requires careful management*
- *in the opinion of the department it is necessary in order to fulfil the requirements of the RiWI Act*

Should the total allocation requested be available, the department may approve entitlements for staged development of the project. The entitlement may be increased gradually to satisfy water needs in accordance with the agreed development timetable. If the proposed development does not take place or is delayed, the licensee should justify why the entitlement should be renewed for the following years or stages. If less water is required for the development than originally anticipated, or there is adverse impact on other users or the environment, the entitlement may be reduced.

CGA-26 A detailed development plan and timetable stipulating the proposed activity, the area of development and the timeframe for each stage of development may be required for all new or amended licence applications.

5.5.7 Bylaws

The department may develop by-laws in accordance with s. 26N(2) of the RiWI Act. There are no by-laws relating to water management in the CGA.

5.5.8 Water efficiency and conservation

Groundwater is an essential requirement and a valuable resource for many developments. Licensees must use groundwater efficiently and ensure that all practical water conservation methods are being considered and, where practical, used. Projects planning to use large volumes of groundwater may be required to demonstrate that water conservation methods have been considered and will be implemented where possible.

CGA-27 Groundwater should be used efficiently and in accordance with best management and irrigation methods.

5.5.9 Wastewater reuse

The use of water by industry often results in considerable quantities of wastewater. Opportunities should be sought to reuse wastewater either within the industry or by transferring it to other users. These resources should be used where appropriate in place of disposal.

CGA-28 *Where appropriate and practicable, other sources of water including drainage, stormwater and wastewater should be used in preference to groundwater and surface water sources.*

5.5.10 Water auditing

The regular monitoring and assessment of water usage by industry and individuals is essential in increasing the efficiency of resources available for use. This is particularly important for enterprises consuming large volumes of groundwater within their operations.

CGA-29 *The regular self-auditing of water usage by licensees is encouraged with the aim of minimising wastage and increasing the efficiency of water usage.*

5.6 Stock and domestic use

Domestic and stock water demand is acknowledged as a priority need for all landholders in areas where no reticulated water supply exists.

Domestic and stock bores are currently exempt from licensing requirements from the superficial aquifer only, under the Rights in Water and Irrigation Exemption and Repeal (section 26C) Order 2001.

5.6.1 Rights in Water and Irrigation Exemption and Repeal (Section 26C) Order 2001

Made by the Lieutenant-Governor and deputy of the Governor in Executive Council under s. 26C of the Act.

Citation

This order may be cited as the Rights in Water and Irrigation Exemption and Repeal (section 26C) Order 2001.

Application

This Order applies to all parts of the state that are proclaimed areas for the purposes of s. 26B of the Act, other than:

- the Albany Groundwater Area
- that part of the Gascoyne Groundwater Area in the North-West Cape north of south latitude 22.5 degrees.

Exemptions from sections 5C and 26B(3) to (6)

Sections 5C and 26B(3) to (6) of the Act do not apply in relation to a non-artesian well if:

- the only water that can be taken from the well is from the watertable aquifer
- water taken from the well is used only in accordance with clause 4.

Use of water

1. Water taken from a well referred to in clause 3 may be used for:
   - fire fighting
   - watering cattle or other stock, other than those being raised under intensive conditions as defined in s. 21(4) of the Act;
   - watering an area of lawn or garden that does not exceed 0.2 hectare, subject to subclauses (2) and (3)
   - other ordinary domestic uses.
2. A lawn or garden is not to be watered by use of a sprinkler at any time during the hours of 9 am to 6 pm.
3. Subclause (2) does not apply in respect of a lawn for a period of 28 days from when the lawn was planted.

Sections 5C and 26B(3) to (6) of the Act do not apply in relation to a non-artesian well if:

- the only water that can be taken from the well is from the water table aquifer
- water taken from the well is used only in accordance with clause 4.

CGA-30 Under the RiWI Exemption and Repeal (section 26C) Order 2001, groundwater abstraction is exempt from licensing from the superficial aquifer for the following purposes only:

- *fire fighting*
- *watering cattle or other stock, other than those being raised under intensive conditions*
- *watering an area of lawn or garden that does not exceed 0.2 hectare*
- *other ordinary domestic uses.*

5.7 Dewatering

Dewatering is the removal of groundwater to facilitate excavation for the purposes of carrying out works, construction or other similar activity. In the Kwinana Peel Region, many of the areas where dewatering activities are occurring contain potential and actual acid sulphate soils. Works are generally of relatively short duration (averaging less than one year); however, they can have large impacts as pump rates are generally high.

Larger projects, where dewatering is expected to continue for a significant length of time, may require hydrogeological investigation. For smaller projects that require licensing (as some projects due to the size will be exempt from licensing as per s. 5.7.1 of the RiWI Act), a Dewatering Management Plan may be required in support of the application for a groundwater licence.

Dewatering Management Plans should include a detailed project description; proposed start date and duration of project; the need for, extent and details of dewatering required, including the proposed methodology for abstraction; and likely rate and volume of dewatering. Depending on the volumes and duration of dewatering, monitoring and contingencies may be required.

5.7.1 Dewatering exemption

The Rights in Water and Irrigation Dewatering Exemption (Section 26C) Order 2005 applies to all parts of the state that are proclaimed areas for the purposes of s. 26B of the Act.

Sections 5C and 26B(3) to (6) of the Act do not apply in relation to a non-artesian well if:

a. the only water that is able to be taken from the well is from the water table aquifer

b. the water is taken from the well at a pump rate of less than five litres per second over a period of less than seven days

c. the water taken from the well is taken for the purposes of dewatering.

6 Implementation and review

The Department of Water has the statutory responsibility of administrating and enforcing this plan. The provisions in this plan for the allocation and taking of groundwater from the Cockburn Groundwater Area (CGA) will continue to have effect for seven years under the existing terms and conditions in this plan, until this plan is reviewed or replaced by another plan.

6.1 Implementation of this plan

An implementation program will set out recommendations and actions by which the provisions of this plan will be achieved and the status of implementation will be reviewed by the department each year. If implementation of the plan raises issues of concern that need to be addressed urgently, an amendment of this plan may occur at any time if the department is satisfied that the plan's objectives are either:

- no longer appropriate
- not being met.

6.2 Annual reporting

Monitoring and regular reporting will allow for identification and management of new issues through the review of this plan.

For the purposes of groundwater management planning and annual reporting, the water accounting year in the Kwinana Peel Region commences on 1 July and ceases 30 June. All management decisions and monitoring practices undertaken by the department will be based on this accounting period.

The monitoring report will be used to provide information on the status of the groundwater resources in terms of quantity and quality, as observed to the end of the water accounting year, and identify any emerging issues relevant to the access and use of the groundwater resources in the CGA.

The report will provide details on:

- the current level of licensed entitlements against the Allocation limits set in this plan
- an estimate of annual groundwater abstraction against the licensed entitlements
- the effectiveness of the management strategies in meeting the purpose and objectives of this plan
- the results of the monitoring program.

6.3 Review of this plan

This plan will be formally reviewed, or replaced within seven years. The department, with advice from the community, will take into account any relevant report or information gathered from the monitoring program and consider if changes need to be made to the plan.

The purpose of the review is to ascertain whether the plan's provisions remain adequate and appropriate for the sustainable management of the groundwater resources in the CGA.

The review may recommend the continuation of this plan, or the development of a new plan.

Corrections for clerical mistakes, errors, inaccuracies or omissions, or the replacement of any outdated factual information may be made at any time and will be publicly declared.

Appendices

Appendix A — Fact sheets for the sub areas in the Cockburn groundwater area

A1.1 Kogalup

Subarea Description	
Area	5065 hectares
Local Government	City of Rockingham

Hydrogeology	
Superficial aquifer	• Average saturated thickness of the sediments is approximately 30 m. • Aquifer consists mainly of sandy sediments and limestone formations. • The watertable is shallow (around 3012 m below ground level). • Recharge is mainly through infiltration of rainfall, however local upward leakage from the Leederville aquifer does occur. • Discharges into wetlands, the ocean and into the Leederville aquifer through downward leakage. • Saltwater interface occurs along the coast where salinity increases with depth to approximately 36 000 mg/L TDS and extends about 500 metres inland at the base of the aquifer. Groundwater salinity varies between 130 mg/L TDS to more than 12 000 mg/L TDS; however it is mainly less than 1000 mg/L TDS.

Hydrogeology	
Leederville aquifer	• Aquifer is confined by the Kardinya Shale and Henley Sandstone members of the Osborne Formation. • Top of the aquifer (the Pinjar Member) may be encountered at a depth of about 100-150 m below ground level, with a thickness of about 200-250 m. • Recharge occurs through downward leakage from the superficial aquifer along the central and eastern margins of the Swan Coastal Plain (outside the CGA). • Discharge occurs offshore. • Groundwater salinity in the upper Leederville is fresh (500–2000 mg/L TDS) and the lower Leederville is generally less than 3000 mg/L TDS.
Yarragadee aquifer	• Confined aquifer beneath the South Perth Shale at depths of about 450–550 m below ground surface, with depth increasing in an easterly direction. • Recharge occurs along the eastern edge of the Swan Coastal Plain (outside the CGA) and from downward leakage from the Leederville aquifer where the South Perth Shale is absent. • Discharge occurs offshore. • Groundwater salinity is 1000-2000 mg/L TDS.

CGA = Cockburn Groundwater Area; TDS = total dissolved salts

Groundwater Allocation			
Aquifer	**Superficial**	**Leederville (kL/yr)**	**Yarragadee kL/yr)**
Allocation Limit[1]	11 460 000	1 350 000	5 150 000
Licensed entitlements[a]	8 312 714	1,500 000	5 555 689
Public water supply reserve commitments[a]	0	0	0
Groundwater available[b]	3 147 286	0	0
Resource classification[c]	C3	C4	C4
Level of use	High	Over-allocated	Over-allocated
Allocation Limit[1]	High	Over-allocated	Over-allocated

a Figures are from DWAID (May 2007)

b Groundwater Availability (i.e. Allocation Limit - (Licensed entitlements + public water supply reserve commitments), may be rounding discrepancies

c Refer to Appendix H

Groundwater Use	
Superficial aquifer	Used primarily for irrigated agriculture and horticulture, recreation and domestic supply.
Leederville aquifer	Mainly used for industrial requirements (shell-sand slurrying).
Yarragadee aquifer	Essentially used for industrial purposes (stockpile watering and slurry conveyance).

Specific Groundwater Licensing Policies
• Groundwater down gradient of the former Australian Paper Manufacturers site may be saline. Licensees contemplating drawing water downstream of this contaminant are advised that the consumption and/or use of these waters may only be suitable following suitable pre-treatment.
• The now decommissioned Jandakot Wool Scourers is similarly a site of groundwater contamination. Licensees contemplating drawing water downstream of this contaminant source are advised that the consumption and/or use of these waters may only be suitable following suitable pre-treatment.
• Water level declines in the Leederville and Yarragadee aquifers are most likely caused by groundwater abstraction outside the Cockburn Groundwater Area (CGA) and any additional abstraction within the CGA may exacerbate reductions in water levels. Groundwater licence applications from the Leederville and Yarragadee aquifers will be refused.

A1.2 Thompsons

Subarea Description	
Area	3397 hectares
Local Government	City of Cockburn

Hydrogeology	
Superficial aquifer	• Average saturated thickness of the sediments is approximately 30 m. • Aquifer consists mainly of the Tamala limestone (leached sand and calcarenite). • The watertable is shallow (around 3–12 m below ground level). • Recharge is mainly through infiltration of rainfall. • Discharges into wetlands, the ocean and into the Leederville aquifer through downward leakage. • Saltwater interface occurs along the coast where salinity increases with depth to approximately 36 000 mg/L TDS and extends about 500 metres inland at the base of the aquifer. Groundwater salinity varies between 130 mg/L TDS to more than 12 000 mg/L TDS; however, it is mainly less than 1000 mg/L TDS.
Leederville aquifer	• Aquifer is confined by the Kardinya Shale and Henley Sandstone members of the Osborne Formation. • Top of the aquifer (the Pinjar Member) may be encountered at a depth of about 100 m below ground level, with a thickness of about 200–250 m. • Recharge occurs through downward leakage from the superficial aquifer along the central and eastern margins of the Swan Coastal Plain (outside the CGA). • Discharge occurs offshore. • Groundwater salinity is the upper Leederville is fresh (500–2000 mg/L TDS) and the lower Leederville is generally less than 3000 mg/L TDS.

Hydrogeology	
Yarragadee aquifer	• C Confined aquifer beneath the South Perth Shale at depths of about 500 m below ground surface, with depth increasing in an easterly direction. • Recharge occurs along the eastern edge of the Swan Coastal Plain (outside the CGA) and from downward leakage from the Leederville aquifer where the South Perth Shale is absent. • Discharge occurs offshore. • Groundwater salinity is 1000–2000 mg/L TDS.

CGA = Cockburn Groundwater Area; TDS = total dissolved salts

Groundwater Allocation			
Aquifer	**Superficial**	**Leederville (kL/yr)**	**Yarragadee kL/yr)**
Allocation Limit[a]	8 700 000	1 350 000	5 150 000
Licensed entitlements[a]	6 854 372	1 500 000	5 555 689
Public water supply reserve commitments[a]	0	0	0
Groundwater available[b]	1 845 628	0	0
Resource classification[c]	C3	C4	C4
Level of use	High	Over-allocated	Over-allocated

a Figures are from DWAID (May 2007)

b Groundwater Availability (i.e. Allocation Limit - (Licensed entitlements + public water supply reserve commitments), may be rounding discrepancies

c Refer to Appendix H

Groundwater Use	
Superficial aquifer	Used primarily for irrigated agriculture and horticulture, and for industrial purposes (power generation).
Leederville aquifer	No abstraction occurs from this aquifer within the Thompsons sub area boundary.
Yarragadee aquifer	No abstraction occurs from this aquifer within the Thompsons sub area boundary.

Specific Groundwater Licensing Policies
• Applications for renewals of groundwater well licences must provide sufficient detail to indicate that previous allocations granted are commensurate with future requirements and that past allocations have been used efficiently.
• Water level declines in the Leederville and Yarragadee aquifers are most likely caused by groundwater abstraction outside the Cockburn Groundwater Area (CGA) and any additional abstraction within the CGA may exacerbate reductions in water levels. Groundwater licence applications from the Leederville and Yarragadee aquifers will be refused.

A1.3 Valley

Subarea Description	
Area	2723 hectares
Local Government	City of Kwinana

Hydrogeology	
Superficial aquifer	• Average saturated thickness of the sediments is approximately 30m. • Aquifer consists mainly of Safety Bay Sand and Tamala limestone (leached sand and calcarenite). • The watertable typically exceeds 6 m below ground level. • Recharge is mainly through infiltration of rainfall. • Discharges into wetlands, the ocean and into the Leederville aquifer through downward leakage. • Saltwater interface occurs along the coast where salinity increases with depth to approximately 36 000 mg/L TDS and extends about 500 metres inland at the base of the aquifer. Groundwater salinity varies between 130 mg/L TDS to more than 12 000 mg/L TDS; however, it is mainly less than 1000 mg/L TDS.
Leederville aquifer	• Aquifer is confined by the Kardinya Shale and Henley Sandstone members of the Osborne Formation. • Over the south-western third of the sub area (where the Osborne Formation is absent), groundwater is discharged upwards to the overlying superficial aquifer due to the positive head difference between the watertable and the potentiometric surface of the Pinjar Member of the Leederville Formation. • Top of the aquifer (the Pinjar Member) may be encountered at a depth of about 50 m below ground level, with a thickness of about 200 m. • Recharge occurs through downward leakage from the superficial along central and eastern margins of the Swan Coastal Plain (outside the CGA). • Discharge occurs offshore. • Groundwater salinity is the upper Leederville is fresh (500–2000 mg/L TDS) and the lower Leederville is generally less than 3000 mg/L TDS.

Hydrogeology	
Yarragadee aquifer	• Confined aquifer beneath the South Perth Shale at depths of about 500 m below ground surface, with depth increasing in an easterly direction. • Recharge occurs along the eastern edge of the Swan Coastal Plain (outside the CGA) and from downward leakage from the Leederville aquifer where the South Perth Shale is absent. • Discharge occurs offshore. • Groundwater salinity is 1000–2000 mg/L TDS.

CGA = Cockburn Groundwater Area; TDS = total dissolved salts

Groundwater Allocation			
Aquifer	**Superficial**	**Leederville (kL/yr)**	**Yarragadee kL/yr)**
Allocation Limit[a]	7 700 000	1 350 000	5 150 000
Licensed entitlements[a]	6 722 570	1 500 000	5 555 689
Public water supply reserve commitments[a]	0	0	0
Groundwater available[b]	977 430	0	0
Resource classification[c]	C3	C4	C4
Level of use	High	Over-allocated	Over-allocated

a Figures are from DWAID (May 2007)

b Groundwater Availability (i.e. Allocation Limit - (Licensed entitlements + public water supply reserve commitments), may be rounding discrepancies

c Refer to Appendix H

Groundwater Use	
Superficial aquifer	Used primarily for irrigated agriculture and horticulture, recreational purposes and for industrial supply (bauxite and oil refining).
Leederville aquifer	No abstraction occurs from this aquifer within the Valley sub area boundary.
Yarragadee aquifer	No abstraction occurs from this aquifer within the Valley sub area boundary.

Specific Groundwater Licensing Policies
• Applications for renewals of groundwater well licences must provide sufficient detail to indicate that previous allocations granted are commensurate with future requirements and that past allocations have been used efficiently.
• Water level declines in the Leederville and Yarragadee aquifers are most likely caused by groundwater abstraction outside the Cockburn Groundwater Area (CGA) and any additional abstraction within the CGA may exacerbate reductions in water levels. Groundwater licence applications from the Leederville and Yarragadee aquifers will be refused.

A1.4 Wellard

Subarea Description	
Area	4562 hectares
Local Government	City of Kwinana

Hydrogeology	
Superficial aquifer	• Average saturated thickness of the sediments is approximately 20 m. • Aquifer consists mainly of Safety Bay Sand, Tamala limestone (leached sand and calcarenite) and Bassendean Sands. • The watertable exceeds 6 m (below ground level) in the eastern half of the sub area and is shallow in the western half (less than 6 m below ground level). • Recharge is mainly through infiltration of rainfall. • Discharges into wetlands, the ocean and into the Leederville aquifer through downward leakage. • Saltwater interface occurs along the coast, with groundwater salinity generally between 500 and 1000 mg/L TDS. Saltwater interface occurs along the coast, with groundwater salinity generally between 500 and 1000 mg/L TDS.
Leederville aquifer	• Aquifer is confined by the Kardinya Shale and Henley Sandstone members if the Osborne Formation. • Over the sub area (where the Osborne Formation is absent), groundwater is discharged upwards to the overlying superficial aquifer due to the positive head difference between the watertable and the potentiometric surface of the Pinjar Member of the Leederville Formation. • Top of the aquifer (the Pinjar Member) may be encountered at a depth of about 25–50 m below ground level, with a thickness of about 200 m. • Recharge occurs through downward leakage from the superficial along central and eastern margins of the Swan Coastal Plain (outside the CGA). • Discharge occurs offshore. • Groundwater salinity is the upper Leederville is fresh (500–2000 mg/L TDS) and the lower Leederville is generally less than 3000 mg/L TDS.

Hydrogeology	
Yarragadee aquifer	• Confined aquifer beneath the South Perth Shale at depths of about 450 m below ground surface, with depth increasing in an easterly direction. • Recharge occurs along the eastern edge of the Swan Coastal Plain (outside the CGA) and from downward leakage from the Leederville aquifer where the South Perth Shale is absent. • Discharge occurs offshore. • Groundwater salinity is 1000–2000 mg/L TDS.

CGA = Cockburn Groundwater Area; TDS = total dissolved salts

Groundwater Allocation			
Aquifer	**Superficial**	**Leederville (kL/yr)**	**Yarragadee kL/yr)**
Allocation Limit[a]	10 320 000	1 350 000	5 150 000
Licensed entitlements[a]	6 145 215	1 500 000	5 555 689
Public water supply reserve commitments[a]	0	0	0
Groundwater available[b]	4 174 785	0	0
Resource classification[c]	C2	C4	C4
Level of use	Medium	Over-allocated	Over-allocated

a Figures are from DWAID (May 2006)

b Groundwater Availability (i.e. Allocation Limit - (Licensed entitlements + public water supply reserve commitments), may be rounding discrepancies

c Refer to Appendix H

Groundwater Use	
Superficial aquifer	Used primarily for industrial supply and recreational purposes.
Leederville aquifer	Used primarily for industrial supply from this aquifer within the Wellard sub area boundary
Yarragadee aquifer	Used primarily for industrial supply from this aquifer within the Wellard sub area boundary.

Specific Groundwater Licensing Policies
• Proposed abstraction from the superficial aquifer adjacent to the coastal fringe should be assessed so as to determine the impacts of the proposed abstraction on the groundwater interface. Should the assessment show the impacts to be largely self-mitigating, approval should be granted; however, the implementation of a monitoring program to adequately monitor groundwater salinity and the movement of the interface is required.
• Water level declines in the Leederville and Yarragadee aquifers are most likely caused by groundwater abstraction outside the Cockburn Groundwater Area (CGA) and any additional abstraction within the CGA may exacerbate reduction in water levels. Groundwater licence applications from the Leederville and Yarragadee aquifers will be refused.

Appendix B — Physical environment

B1.1 Climate

The Cockburn Groundwater Area (CGA) has a Mediterranean climate, experiencing mild, wet winters and hot, dry summers. The average annual rainfall within the CGA is approximately 870 mm. Approximately 90 per cent of the annual rainfall is received during the period from April to October. Rainfall normally exceeds evaporation during the five months from May to August. The average annual evaporation is 1800 mm.

Climate variability/change

Climate change is a problem where cause and effect is separated over very long time scales. Climate change may pose a future risk to water supply, but predicting the degree of impact is made difficult by the long response times and large uncertainties. It is wise for both water managers and water users not to ignore it but to be aware that it may impact on the availability of water in the future.

The Allocation limits for the sub areas in the CGA were calculated on the basis of the last 28 years of average annual rainfall. The long-term trend towards a drier climate may impact on the rainfall patterns which will affect the recharge characteristics and ultimately reduce the availability of water. This in turn could result in a reduction of the Allocation limits, which may require a corresponding reduction in water entitlements and water use.

B1.2 Geomorphology

The slope and relief of the land and nature of the soils are basic considerations in planning. They determine, to a large extent, how the land may be used and the ease or difficulty associated with various activities. Regional geology has a major influence on the pattern of landform-soil units and provides the basis for primary classification.

The geomorphology (landform-soil relationships) of the entire Perth region is covered in considerable detail by several authors (McArthur and Bettenay 1960; Playford et al. 1976; Seddon 1972). Figure 11 illustrates the geomorphology of the CGA.

The geomorphological province identified in the groundwater area is the Swan Coastal Plain consists of eolian and fluviatile sediments.

B1.2.1 Swan Coastal Plain

The CGA covers a coastal trip of some 22 km in a north-south direction and extends approximately 7 km inland. The deposits in the plain generally show a progressive decrease in elevation and age from east to west and occur in bands that are generally parallel to the present coastline.

There are two geomorphological units in this part of the Swan Coastal Plain:

- the Coastal Belt
- the Bassendean Dunes.

Coastal Belt

The Coastal Belt contains the Quindalup and Spearwood Dune systems. The Quindalup Dunes consist of windblown lime and quartz beach sand, forming both dunes and ridges generally oriented parallel to the coastline.

The Spearwood Dunes consist of yellow to white (slightly calcareous) quartz sand that has been leached from the underlying limestone. The contact between the sand and unleached limestone is irregular, with rounded pinnacles of limestone extending upwards into the sand. The dunes form a gently undulating landscape that has been consolidated by rainwater solution to form hills of relatively low relief. The Spearwood Dunes occur quite extensively in the eastern part of the CGA.

Bassendean Dunes

The Bassendean Dunes lie between the Coastal Belt and the Pinjarra Plain in a zone up to 11 km wide. The dunes form a gently undulating landscape of eolian sand. Swampy areas and small lakes commonly occupy the interdunal depressions.

The Bassendean Dunes are generally oriented parallel to the present coastline and probably accumulated as shoreline deposits and coastal dunes in the Early to Middle Pleistocene during interglacial periods of high sea level. These deposits originally consisted largely of lime sand with smaller proportions of quartz sand, but the carbonate has been almost entirely leached out in most areas.

The present shape of the dunes has been largely inherited from that of the original coastal dunes, but the relief has been significantly diminished as a result of leaching and differential wind erosion.

South of the Swan River, the coastal plain has an average elevation of about 25 m AHD, with an east-west variation in elevation, with the coastal Spearwood and Bassendean Dune systems being irregular in elevation and often higher that the adjacent Quindalup Dune system.

B1.3 Geology

B1.3.1 Regional setting

The CGA is located in the Perth Basin, a deep linear trough of sedimentary rocks extending north-south for about 1000 km in the south-west of Western Australia beneath the coastal area, continental shelf and continental slope. The basin covers an area of 45 000 km2 onshore and 55 000 km2 offshore.

The Perth Basin is essentially a half-graben (down-faulted block) bounded to the east by the north–south trending Darling Fault, about 1000 km long, which separates the basin from the Archaean crystalline rocks of the Yilgarn Craton.

The total thickness of Phanerozoic sedimentary rocks in the Perth Basin could reach a maximum of 15 000 m. Exposure of rock outcrop is poor throughout the Perth Basin with much of the geological information based on interpretation of exploratory drilling and

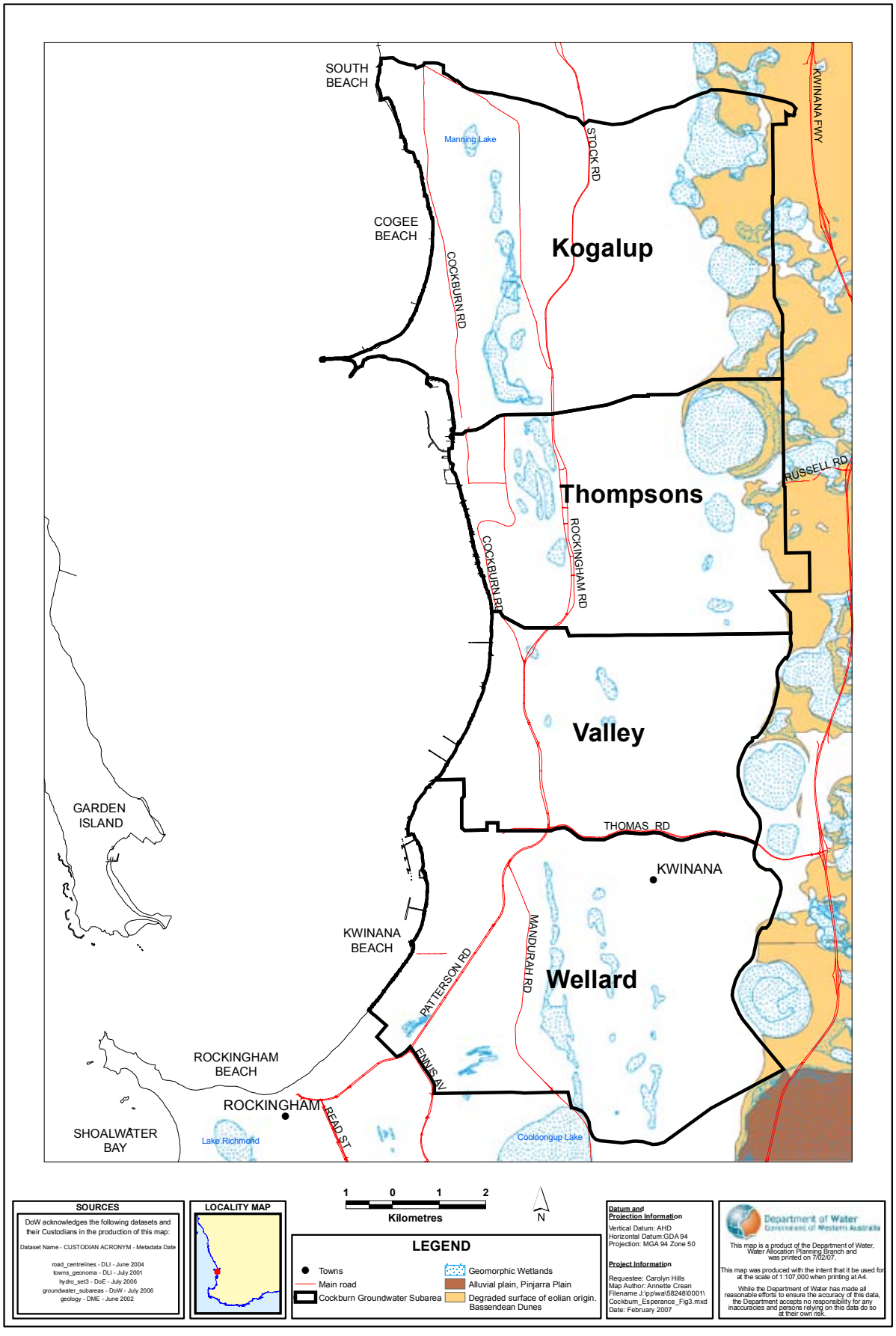


Figure 11: Generalised geomorphology of the Cockburn groundwater area

geophysical data. There is an extensive Quaternary cover (sand, silt, clay and limestone) over the basin that masks much of the underlying geology.

B1.3.2 Structure

The structure of the Perth Basin is dominated by faulting with the overall structure of the basin having been described as that of an intensely faulted half-graben (Playford et al. 1976). The basin is defined to the east by the Darling Fault and limited to the west (for the most part) by the continental slope.

In the CGA, as with much of the basin, there is a network of faults in the earliest Cretaceous and older rocks. However, much of this complex fault pattern is not seen at the surface owing to the extensive cover of late Cretaceous and Quaternary deposits. The positions of most faults have been determined by seismic surveys and deeper exploratory holes.

The CGA is within the Dandaragan Trough, which is the largest and deepest section of the Perth Basin. The trough, which becomes shallower towards the south, is bounded by the Darling Fault in the east and by the Harvey Ridge in the south.

The present form of the Dandaragan Trough was established at the end of the Neocomian Stage. However, during the intra-Neocomian break up of the Indian and Australian plates and the onset of sea floor spreading, widespread uplift and erosion occurred.

In the CGA, the Yarragadee Formation is unconformably overlain by the Gage Formation, the South Perth Shale and the Leederville Formation. The Leederville Formation, deposited after the Neocomian break up, is unfaulted and has been gently folded.

B1.3.3 Stratigraphy

Stratigraphic cross sections traversing the Perth Basin in an east–west direction have been determined by the Geological Survey of Western Australia at numerous locations between the Darling Scarp and the Indian Ocean.

The full stratigraphic sequence is summarised in Table 8. Surface geology is shown in Figure 12, subsurface geology in Figure 13, and geological cross sections from the borehole lines are provided in Figure 14 and Figure 15.

The formations relevant to this groundwater area (i.e. those with major aquifer potential or development) are described briefly below.

A1.3.4 Superficial formations

The ‘superficial formations’ is the collective name used to describe surface or near-surface sediments on the Swan Coastal Plain that, despite varying lithologies, form a single, predominantly unconfined aquifer system (Allen 1976). The sediments consist of a laterally and vertically variable sequence of sand, limestone, silt and clay (Figure 14). They are of Cainozoic age (principally Quaternary) and unconformably overlie sediments of Mesozoic age. The superficial formations in the CGA range in thickness from 20 m to 110 m, and rest on a gentle westerly sloping erosional surface.

The Osborne Formation lies unconformably below the superficial formations throughout most of the groundwater area. In the south-east, the superficial formations unconformably

Table 8 Sedimentary stratigraphic sequence of Cockburn groundwater area

Era	Geological period	Age (10^6 yr)		Stratigraphy	Max. thickness (m)	Lithology	Ground-water aquifer
CAINOZOIC	Quaternary-Late Tertiary			Safety Bay Sand	24	Sand and shelly fragments	Superficial aquifer
				Becher Sand	20	Sand, silt, clay and shell fragments	
				Tamala Limestone	110	Sand, limestone, minor clay	
				Bassendean Sand	80	Sand and minor silt and clay	
		2		Rockingham Sand	70	Sand, silt and minor clay	Rocking-ham aquifer
MESOZOIC	Cretaceous	80	Cooly-ena Group	Osborne Formation	180	Sandstone, siltstone and shale	
		114		Kardinya Shale Member	140	Shale, siltstone, minor sandstone	Confining bed
				Henley Sandstone Member	100	Sandstone and minor siltstone	Leederville aquifer
		118		Leederville Formation	600	Sandstone, siltstone and shale	
				Pinjar Member	150	Sandstone, siltstone and shale	
				Wanneroo Member	450	Sandstone, siltstone and shale	
				Mariginiup Member	250	Sandstone, siltstone and shale	
				South Perth Shale	300	Shale, siltstone, minor sandstone	Confining bed
				Gage Formation	350	Sandstone, siltstone and shale	Yarraga-dee aquifer
	Jurassic	146		Yarragadee Formation	>2,000	Sandstone, siltstone and shale	Yarraga-dee aquifer
				Cattamarra Coal Measures	>500	Sandstone, siltstone and shale	
				Unconformity			

overlie the Rockingham Sand. However, in the south-west, the superficial formations unconformably overlie the Leederville Formation.

B1.3.5 Rockingham Sand

The Rockingham Sand (Passmore 1967) consists of medium to coarse-grained subangular quartz sand that is slightly silty and felspathic, of shallow marine origin and with a maximum thickness of about 70 m in the CGA. The Rockingham Sand occupies an eroded channel incised into the Leederville Formation (Pinjar and Wanneroo Members) and is unconformably overlain by the superficial formations.

B1.3.6 Osborne Formation

The Osborne Formation (McWhae et al. 1958) consists of interbedded sandstone, siltstone and shale. The Osborne Formation occurs over the northern two-thirds of the groundwater area. It is unconformably overlain by the superficial formations and unconformably underlain by the Leederville Formation. In the CGA, the Osborne Formation consists of a weakly consolidated sandstone section (Henley Sandstone Member) overlain by a siltstone-shale sequence (Kardinya Shale Member). The thickness of the formation ranges from 20 m in the south to 120 m in the north.

B1.3.7 Leederville Formation

The Leederville Formation (Cockbain and Playford 1973) consists of interbedded sandstone, siltstone and shale that were laid down during the Early Cretaceous in both marine and non-marine depositional environments. The Leederville Formation is about 200-250 m in thickness throughout the extent of the CGA.

The Leederville Formation has three distinct and mappable units, which are, in order of deposition, the Mariginiup Member, the Wanneroo Member and the Pinjar Member.

In the southern part of the groundwater area, the Leederville Formation is unconformably overlain mainly by the superficial formations and the Rockingham Sand. In the central and northern areas it is overlain by the Kardinya Shale and Henley Sandstone members, respectively. The formation is conformably underlain by the South Perth Shale.

B1.3.8 South Perth Shale

The South Perth Shale (Playford et al. 1976) is predominantly of shallow marine origin and consists mainly of thinly interbedded siltstone and shale with minor thin, sandy beds and locally, thin calcareous beds.

The South Perth Shale conformably overlies the Gage Formation. The South Perth Shale is overlain with conformable and transitional contact by the Leederville Formation. It forms an aquiclude between the Leederville and Yarragadee Formations.

B1.3.9 Gage Formation

The Gage Formation (Davidson 1995), which was formerly referred to as the Gage Sandstone Member of the South Perth Shale, consists of interbedded sandstones, siltstones and shales. The sandstone beds are of variable thickness, ranging from

3 m to 30 m. They consist of fine to coarse-grained sand; similar to that of the Yarragadee Formation, from which they probably originated by erosion.

The Gage Formation unconformably overlies the Yarragadee Formation and is overlain with conformable and abrupt contact by the South Perth Shale.

B1.3.10 Yarragadee Formation

The Yarragadee Formation (Playford et al. 1976) consists of laterally discontinuous interbedded sandstones, siltstones and shales that were laid down during the Middle to Late Jurassic in a non-marine depositional environment. The Yarragadee is unconformably overlain by the Gage Formation.

B1.3.11 Cattamarra Coal Measures

The Cattamarra Coal Measures, a former member of the Cockleshell Gully Formation, has been given formation status in the Perth Region (Mory and Lasky 1996). The Cattamarra Coal Measures consists of interbedded sandstone, siltstone, shale and coal. The Cattamarra Coal Measures is conformably overlain by the Yarragadee Formation.

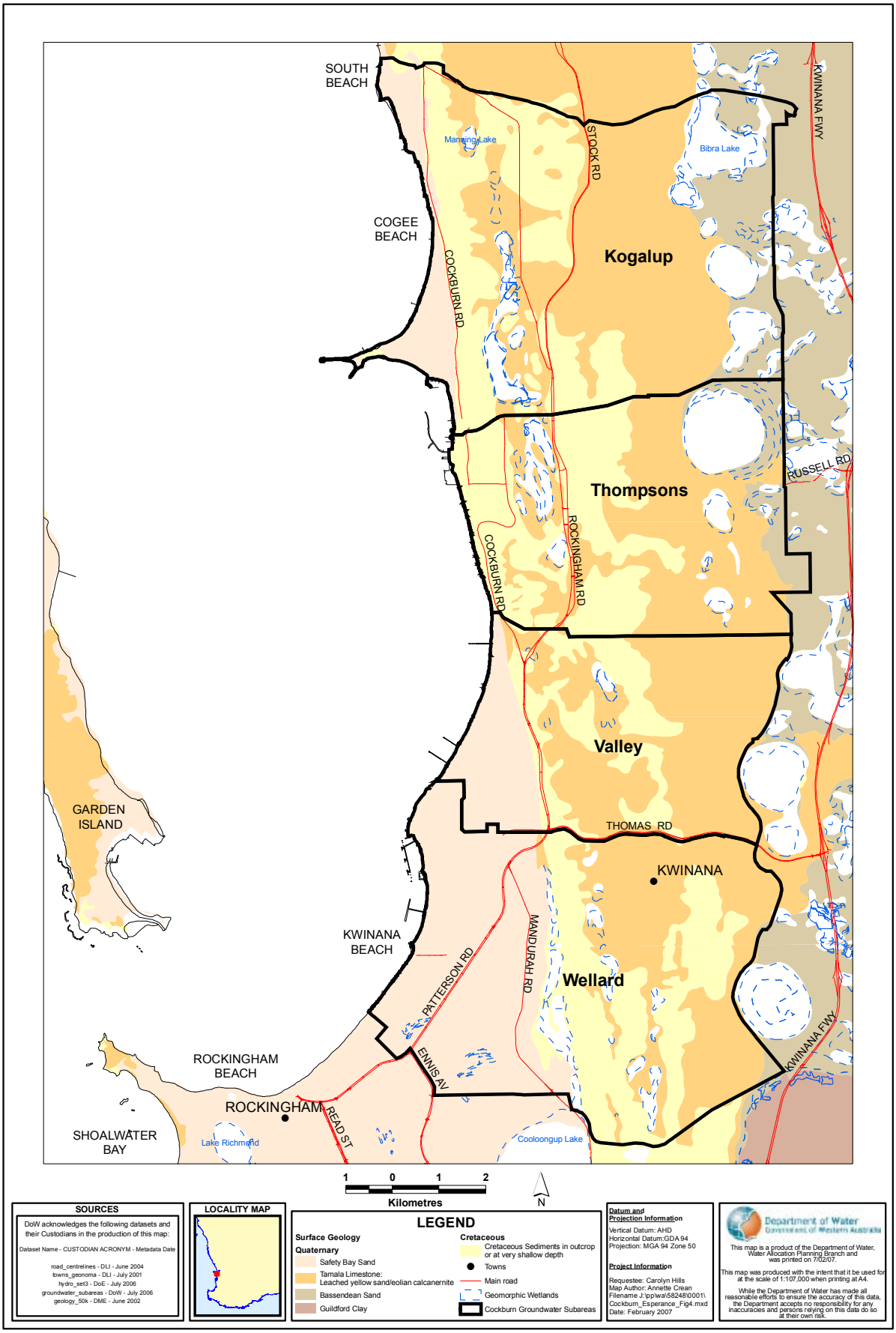


Figure 12: Surface geology of the Cockburn groundwater area

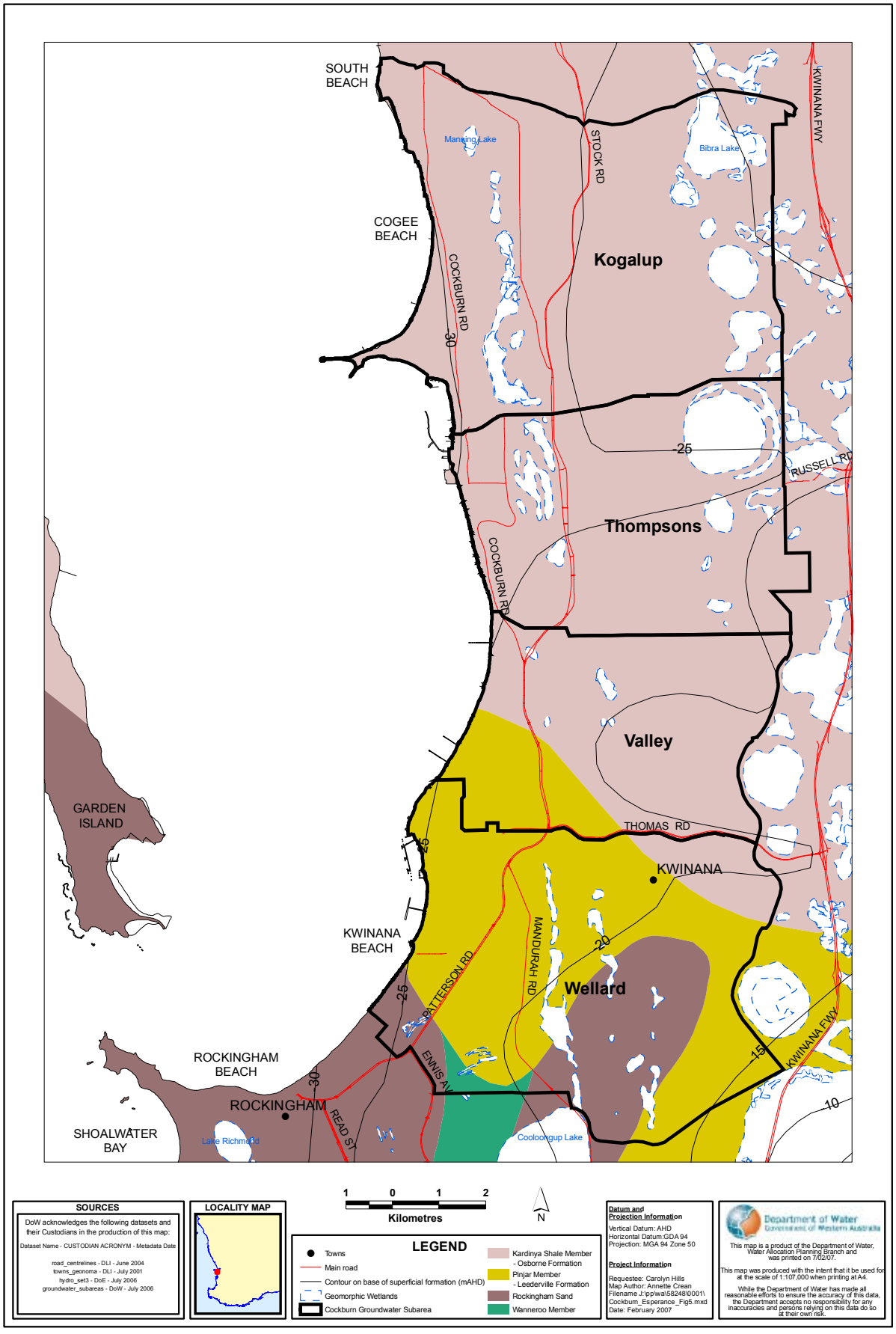


Figure 13: Sub-surface geology of the Cockburn groundwater area

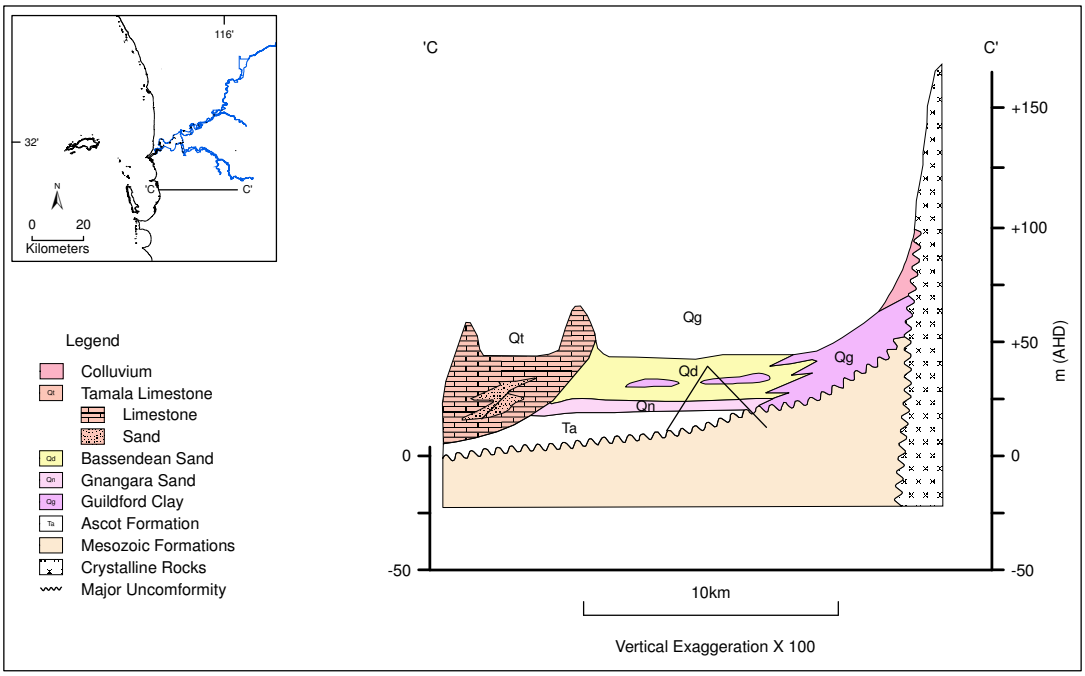


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Figure 14: Geological cross section of the stratigraphy of the superficial formations

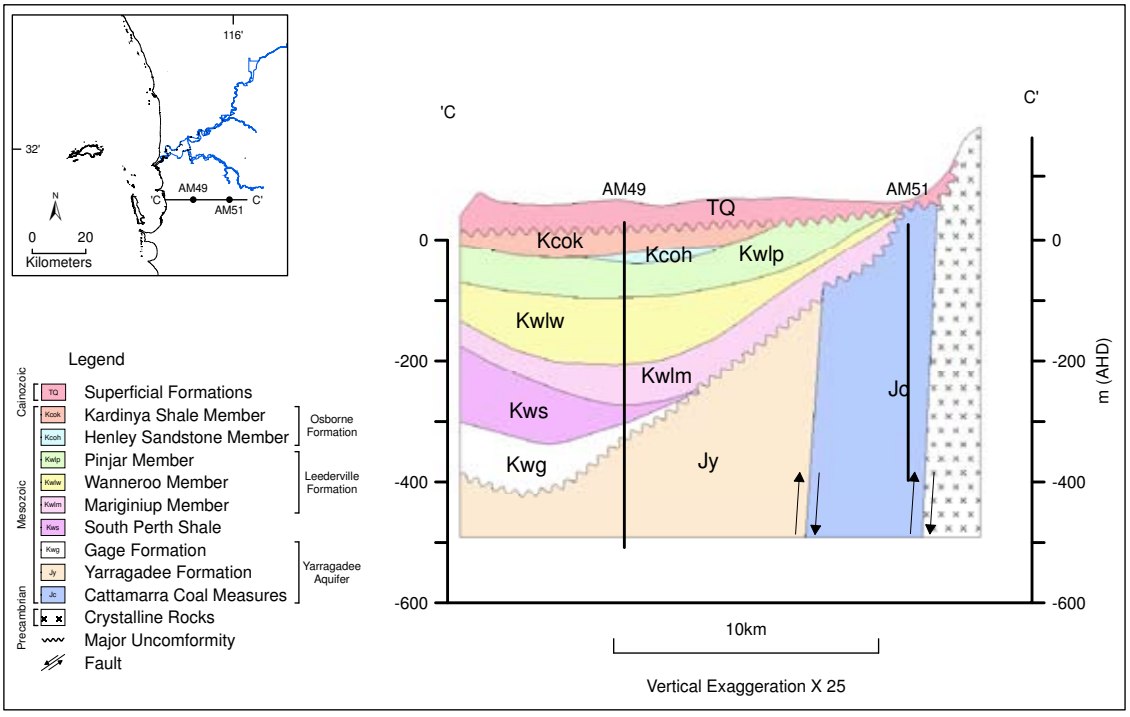

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Figure 15 Geological cross section of the stratigraphy of the Cainozoic and Mesozoic formations

Appendix C — Hydrogeology

C1.1 Groundwater occurrence

Groundwater occurs in the superficial formations beneath the Swan Coastal Plain and the underlying geological formations of the Perth Basin. Groundwater within the shallow sediments originates from direct rainfall recharge on the coastal plain, and groundwater in the deeper, confined aquifers flows from the recharge areas to the north and east adjacent to the Darling Scarp.

The geological formations have been assigned to three distinct aquifers. The aquifer names represent the dominant stratigraphic unit within each geological unit grouping. Table 8 summarises the stratigraphic nomenclature and sequencing, and the aquifer delineation.

The major aquifers of the Cockburn Groundwater Area (CGA) are:

- *Superficial aquifer:* a major unconfined aquifer consisting of the Quaternary-Tertiary Tamala Sand, Tamala Limestone, Safety Bay Sand and Bassendean Sands.
- *Leederville aquifer:* a major confined aquifer comprising the Cretaceous Osborne Formation (Henley Sandstone Member) and Leederville Formation (Pinjar Member, Wanneroo Member and Mariginiup Member).
- *Yarragadee aquifer:* a major confined aquifer comprising the Cretaceous Gage Formation and the Jurassic Yarragadee Formation.

C1.2 Superficial aquifer

The superficial formations form an unconfined aquifer system that is bounded to the east by the Darling Scarp and to the west by the ocean. The superficial aquifer consists predominantly of sand, silt, clay and limestone. It is a multilayered aquifer that is inhomogeneous and anisotropic. Generally, the seasonal range in the water table elevation is about one to two metres.

The highly transmissive Tamala Limestone comprises most of the western half of the CGA, with the high transmissivities due to the presence of karst features (solution channels) located more commonly near the water table (Nield 1999). In certain areas of the coastal fringe, the superficial formations consist of the moderately permeable Safety Bay Sand, which acts to reduce the overall transmissivity of the superficial aquifer, and provides a partial barrier to coastal discharge from the more transmissive Tamala Limestone.

At the base of the Safety Bay Sand there is a silty layer that impedes vertical exchange with the underlying Tamala Limestone. However, Nield (1999) states that the continuity of the Safety Bay Sand and its basal silty layer is uncertain, as both are known to be absent in some locations near the south-west corner of the CGA.

A saltwater intrusion wedge rests on the base of the Tamala Limestone, extending up to 600 m inland (at Alcoa's Kwinana refinery) (Nield 1999). Where the Safety Bay Sand is present, a smaller saltwater intrusion wedge rests on its basal silty layer.

The eastern part of the CGA is occupied by the moderately permeable Bassendean Sand. A north-south trending zone of lower permeability separates the moderately permeable Bassendean Sand and the extremely permeable Tamala Limestone.

Recharge to the aquifer system is by direct infiltration of rainfall with lesser amounts from runoff. Recharge rates vary across the coastal plain as a result of the variation in lithology, depth to water table and topographic gradient.

Inflow to the superficial aquifer may also occur locally by upward leakage from the Leederville aquifer. This occurs where there are increasing hydraulic heads with depth and where there are no confining beds between the underlying aquifer and the superficial aquifer.

Groundwater discharges from the superficial aquifer into the coastal lakes and to the large number of drains and wetlands. Groundwater outflow to the coast is another form of discharge.

Significant quantities of groundwater are lost by evapotranspiration from the wetlands and areas where the water table is shallow. Discharge to the deeper aquifers by downward leakage occurs locally through the south-eastern areas in zones where downward hydraulic gradients exist and confining beds are absent.

The groundwater salinity of the superficial aquifer is variable and ranges from less than 130 mg/L total dissolved solids (TDS) to more than 12 000 mg/L TDS; however, it is mainly less than 1000 mg/L TDS. A saline interface is present at the coast where groundwater salinity increases with depth to approximately 36 000 mg/L TDS and extends about 500 m inland at the base of the aquifer.

Acidity varies within the various lithological units of the superficial formations. Within the Bassendean Sand, groundwater at the water table is acidic, with a pH range of 4.0 to 6.5. At the base of the Bassendean Sands, groundwater has a pH range of 6.5 to 7.5. The Tamala Limestone, however, has groundwater of pH range 7.0 to 8.0.

Dissolved iron concentrations of groundwater within the superficial aquifer range from less than 1 mg/L to in excess of 15 mg/L, with decreased concentrations near the base of the aquifer (Davidson 1995). Nitrate concentrations may reach 20 mg/L in urbanised areas and areas of intensive horticulture as a result of fertiliser leaching. Phosphorous concentrations of the superficial aquifer typically do not exceed 0.2 mg/L, with the principal source being the application of fertiliser.

C1.3 Rockingham Sand aquifer

The Rockingham Sand is a localised semi-unconfined aquifer that exists only in the Rockingham area, confined by the discontinuous clay lenses at the base of the superficial aquifer. The two aquifers are in hydraulic connection where the clay lenses are absent. The aquifer has a maximum thickness of 110 m, however, the basal 70 m contains ocean water beneath overlying freshwater.

The Rockingham Sand aquifer is recharged by downward leakage from the superficial aquifer and by upward leakage from the Leederville aquifer.Groundwater in the aquifer flows

over a saltwater interface to the ocean. Upconing of the saltwater interface may readily occur as a result of groundwater abstraction from high yielding wells. Groundwater salinity is highly variable and may range from about 500 mg/L to more than 3000 mg/L TDS.

Groundwater flow is westerly within the Rockingham aquifer over the saltwater interface. Groundwater discharge occurs adjacent to the coast and also offshore from the superficial aquifer. Groundwater salinity ranges from 300 mg/L TDS to greater than 3000 mg/L TDS within the mixing zone between the fresh groundwater in the upper aquifer zone and the underlying brackish to saline groundwater.

C1.4 Leederville aquifer

The Leederville aquifer is a major confined groundwater source in the Perth Region. The Leederville aquifer is a multilayered groundwater flow system consisting of discontinuous interbedded sandstones, siltstones and shales. The aquifer has a maximum thickness of about 250 m in the CGA.

The natural seasonal variation in potentiometric head within the aquifer is 0.5–1 m (Davidson 1995). In areas of high groundwater abstraction, the seasonal variations may be more than 10 m. The horizontal hydraulic conductivity of sandstone beds in the Leederville aquifer may locally reach 10 m/day, and that of the siltstone and shale are about 1 x 10-6 m/day.

The Leederville aquifer is recharged by downward leakage from the superficial aquifer. This occurs in areas where there is direct contact and hydraulic connection between the two aquifers. Recharge due to direct infiltration from the overlying superficial formations occurs mainly along the central and eastern margins of the Swan Coastal Plain where downward hydraulic heads prevail.

Pumping has reduced the hydraulic heads within the aquifer, increasing the area over which recharge is occurring. By further increasing the groundwater abstraction from the Leederville aquifer, the hydraulic gradient between the superficial and Leederville aquifers will increase, thereby inducing additional groundwater recharge to the Leederville aquifer. The Leederville aquifer is also recharged by upward discharge from the underlying Yarragadee aquifer in areas where the confining South Perth Shale is absent and hydraulic heads increase with depth.

In the CGA, the confining beds of the Kardinya Shale Member of the Osborne Formation mainly separate the flow systems of the Leederville and superficial aquifers.

The average rate of groundwater flow within the Leederville aquifer, south of the Swan River, is about 1 m/year.

There may be some upward discharge to the superficial aquifer in zones where the potentiometric heads increase with depth and the two aquifers are hydraulically connected, due to the absence of the Kardinya Shale Member.

The salinity of the groundwater in the upper part of the Leederville aquifer ranges between 500 and 2000 mg/L TDS. In the lower part of the aquifer, the salinity is generally less than 3000 mg/L. Groundwater of the Leederville aquifer is generally of sodium chloride type;

however, that of the Mariginiup Member is a blend of calcium, bicarbonate and sodium chloride type.

Dissolved iron concentrations range from less than 1 mg/L to in excess of 15 mg/L. Treatment is required for groundwater obtained from artesian groundwater production bores due to iron concentrations exceeding the national drinking water guidelines.

C1.5 Yarragadee aquifer

The Yarragadee aquifer is a major confined aquifer covering the entire expanse of the Perth Region. The aquifer is multilayered, consisting of interbedded sandstones, siltstones and shales. Within the CGA, the aquifer comprises the Gage Formation, Yarragadee Formation and the Cattamarra Coal Measures, and is more than 2000 m thick. The Yarragadee aquifer is confined by both the South Perth Shale and clay beds of the Leederville Formation.

Recharge to the Yarragadee aquifer occurs from the superficial aquifer where it overlies the Cattamarra Coal Measures, adjacent to the Darling Scarp in the south-east. Recharge also occurs due to downward leakage from the Leederville aquifer where the confining South Perth Shale is absent and where downward hydraulic heads occur.

Potentiometric surface delineation indicates that the regional groundwater flow in the Yarragadee aquifer is south-westward. The rate of groundwater flow in the southern area is very slow due to the very flat potentiometric surface. Average rates of groundwater flow are approximately 0.9 m/year.

The seasonal variations in potentiometric head are less than 1 m and are generally the result of variations in head in the overlying aquifers; however, in areas of abstraction, seasonal variations may approach 7 m. The horizontal hydraulic conductivity of the aquifer has been determined from pump tests, and may range between 1 x 10-6 m/day and 6 m/day, dependent upon the lithological variance in sandstones, siltstones and shales. Regional groundwater throughflow estimates suggest an average hydraulic conductivity of 0.7 m/day.

The majority of groundwater throughflow within the Yarragadee aquifer discharges offshore; however, groundwater also discharges into the overlying Leederville aquifer where the confining South Perth Shale is absent and upward hydraulic heads exist.

Groundwater salinity in the Yarragadee aquifer ranges from 1000 to 2000 mg/L TDS in the CGA. Groundwater at depth in the Cattamarra Coal Measures exceeds 10 000 mg/L TDS.

Appendix D — Environmental considerations

D1.1 The environment

The health of the many diverse wetlands and flora and fauna found within reserves of the Cockburn Groundwater Area (CGA) are dependant on groundwater. Most wetlands within the area are hydraulically connected to the watertable and are sensitive to variations in watertable elevations. Groundwater abstraction can result in the lowering of the watertable and therefore requires regulation and control to prevent drying out of wetlands and any subsequent endangerment of local flora and fauna.

Most of the native flora that existed before settlement in the CGA has been cleared for horticultural activities and industrial ventures. However, there remain areas of very important and strategic remnant vegetation, particularly within Bush Forever Reserves (previously termed System 6 Reserves), and the surrounding wetland areas.

The CGA also plays host to significant quantities of phreatophytic (water-loving) vegetation dependent upon shallow groundwater.

The department's approach in determining how water will be provided to protect ecological values when allocating the right to use water in the CGA is described in Environmental water provisions Policy for Western Australia. State-wide Policy No. 5 (WRC 2000a).

D1.2 Statutory environmental protection

D1.2.1 Swan Coastal Plain Lakes Environmental Protection Policy 1992 (Lakes EPP)

This plan prohibits unauthorised filling, mining, drainage into or out of, and effluent discharge into, specific wetlands. A proposed development is unlikely to receive environmental approval if the development involves such prohibited activities. A breach of the plan's provisions may result in prosecution under Part V of the Environmental Protection Act 1986. Wetlands identified under this plan are afforded the highest level of protection under the Act.

The requirements of wetland conservation can extend beyond reserve or wetland boundaries. Land activities within a catchment can adversely impact on wetlands by changing water levels and water quality. This does not mean that development should not occur or that public acquisition of private land is necessarily required. Development should proceed in a manner that protects the wetland reserves' environmental value, and is best controlled through the planning process.

D1.2.2Environmental Protection Authority Conservation Reserve System 1993 (System 6, Red Book) (recently renamed Bush Forever Reserves)

Wetlands of the Swan Coastal Plain are protected from degradation by the Conservation Reserve System recommended by the Environmental Protection Authority in their 'System 6 (Red Book)'. All areas (Bush Forever Reserves) recommended in the Red Book have potential significance for conservation.

Wetlands on the Swan Coastal Plain are generally surface expressions of the shallow unconfined groundwater. The condition of wetlands, remnant phreatophytic vegetation and

associated fauna is dependent upon groundwater. The maintenance of natural wetland water regimes is important due to their extreme sensitivity to watertable fluctuations. Groundwater abstraction may result in a localised reduction in the watertable, and such changes in the wetland water regime may affect both flora and fauna.

D1.3 Non-statutory protection policies

D1.3.1 Water and Rivers Commission wetland mapping, classification and evaluation

The department has produced a series entitled 'Wetlands of the Swan Coastal Plain'. This series was produced to assist in effective wetland management and incorporates wetland-boundary description and delineation, and detailed information concerning groundwater hydrology and groundwater-dependent flora and fauna. Management objectives defined within the documentation are aimed at wetland restoration, conservation and sustainable use.

To protect wetlands of high conservation value not included in Lakes Environmental Planning Policy, the department has mapped, evaluated and classified all wetlands on the Swan Coastal Plain (Hill et al. 1996, Appendix 2). This report evaluated wetlands as either (1) Conservation, (2) Resource Enhancement, or (3) Multiple Use Category wetlands.

Further protection of wetlands is being investigated by the Department of Environment and Conservation (formerly the Department of Conservation and Land Management [CALM]) in the form of buffer zones.

Wetlands and reserves currently identified within the CGA are listed in Table 9 and shown in Figure 16, Figure 17 and Figure 18.

Table 9 Bush Forever Reserves within the Cockburn groundwater area

Identity no.	Conservation reserve
M90	Quarantine Station and Explosives Magazine Reserve, Woodman Point, situated some 7 km south of Fremantle. The reserve comprises: • the Quarantine Station at Woodman Point (Location 1845) and lots 16, 17 and part lot 15, all owned by the state government • Reserve C24305 for Explosives Magazine vested in the Minister for Mines • Reserve A24306, for Recreation and Purposes Incidental Thereto, vested in the City of Cockburn.
M91	Reserve A24309, Coogee, located about 12 km south of Fremantle. The Reserve comprises: • Reserve A24309, designated for recreation and camping and vested in the City of Cockburn.
M92	Cockburn Wetlands – Western Chain, situated between 5 and 12 km south of Fremantle. The reserve comprises: • Reserve C26870, for recreation • part of Location 83, lot 9 (Loc. 3), lot 61 (Loc. 81), lot 10 (Loc. 84), parts of lots 11 and 65 (Loc. 109), part of lot 2 (Loc. 102), lots 1, 21, 27, 37, 50, 78 and part of lots 35 and 36 (Loc. 280), lot 38 (Loc. 150), and part of Loc. 133 (Manning Lake) • Reserve C22227 for drainage • part of lots 1–4, 7–9, 14–19, 23, 50 and 505 (Loc. 2), lot 23 (Loc. 951, lots 1 and 3 and part of lot 4 (Loc. P18), part of lots 1, 2, 9, 11 Rockingham Road, 2 and 12 Mayor Road (Loc. 300), part of lot 503 (Loc. P10), part of lots 1 Rockingham Road, 3, 21–27, 1 Hamilton Road, 33–36 and 52–54, all of Loc. 264, part of lots 17, 18, 21–23 (Loc. 150), privately owned freehold land (Market Garden Swamps and adjacent lands) • Reserve C30861, for recreation, vested in the City of Cockburn and part of lots 26 and 27 (Loc. 404) privately owned freehold land (Lake Coogee) • Cockburn Sound Locations 1841, 2074 and part of Cockburn Sound Locations 1843 and 2197, land held in the name of the Crown; and part of Locations P13–P17, privately owned freehold land (Mt. Brown, Mt. Brown Lake and Brownman Swamp).

Identity no.	Conservation reserve
M93	Cockburn Wetlands-Eastern Chain, Situated adjacent to South Western Highway, 12 km south of Pinjarra. Consists of: • Reserves A6208, for recreation, under the Cockburn City Council; Reserve C27488; part of Reserve C31986; lots 38, 39, 54–59 and part of lot 37 (Loc. 235), part of lots 1, 4, 7, 52, 53 (Loc. 10), lots 1 and 2 (loc. 405), part of Locations 21, 35, 50, 65, 179, 387, 393, 438, 485, 552 and 772 (North Lake and Bibra Lake) • lots 2 and 6 (Loc. 541), part of lots 9, 10, 20 (Loc. 21), and part of Locations 21 and 542 (South Lake and Little Rush Lake) • lot 1 and part of lots 2, 5 and 7 (Loc. 406), and part of Loc. 298 (Yangebup Lake) • part of Reserve C31829, lots 1–4, 6–9, 12–15 (Loc. 391), lots 1, 7 and 8 (Loc. 677), Locations 756, 759, 763 and 766, and 769–771, and part of Locations 433 and 751–755 (Kogolup Lake) • Reserves A15556; C29241; C31882, part of lot 1 (Loc. 464) and Location 2017 (Thompson Lake and Banganup Lake) • lots 63–65, 86 and part of lots 57 and 59 (Loc. 15), and part of lots 1, 2, 3, 612 and 615 (Loc. 16) (Wattleup Lake).
M104	Reserves C31102 and C33581, Leda, located 8 km east of Rockingham, comprising: • Reserves C31102 (cemetery site) and C33581 (parks and recreation); vacant Crown land; and Kwinana lot S33.

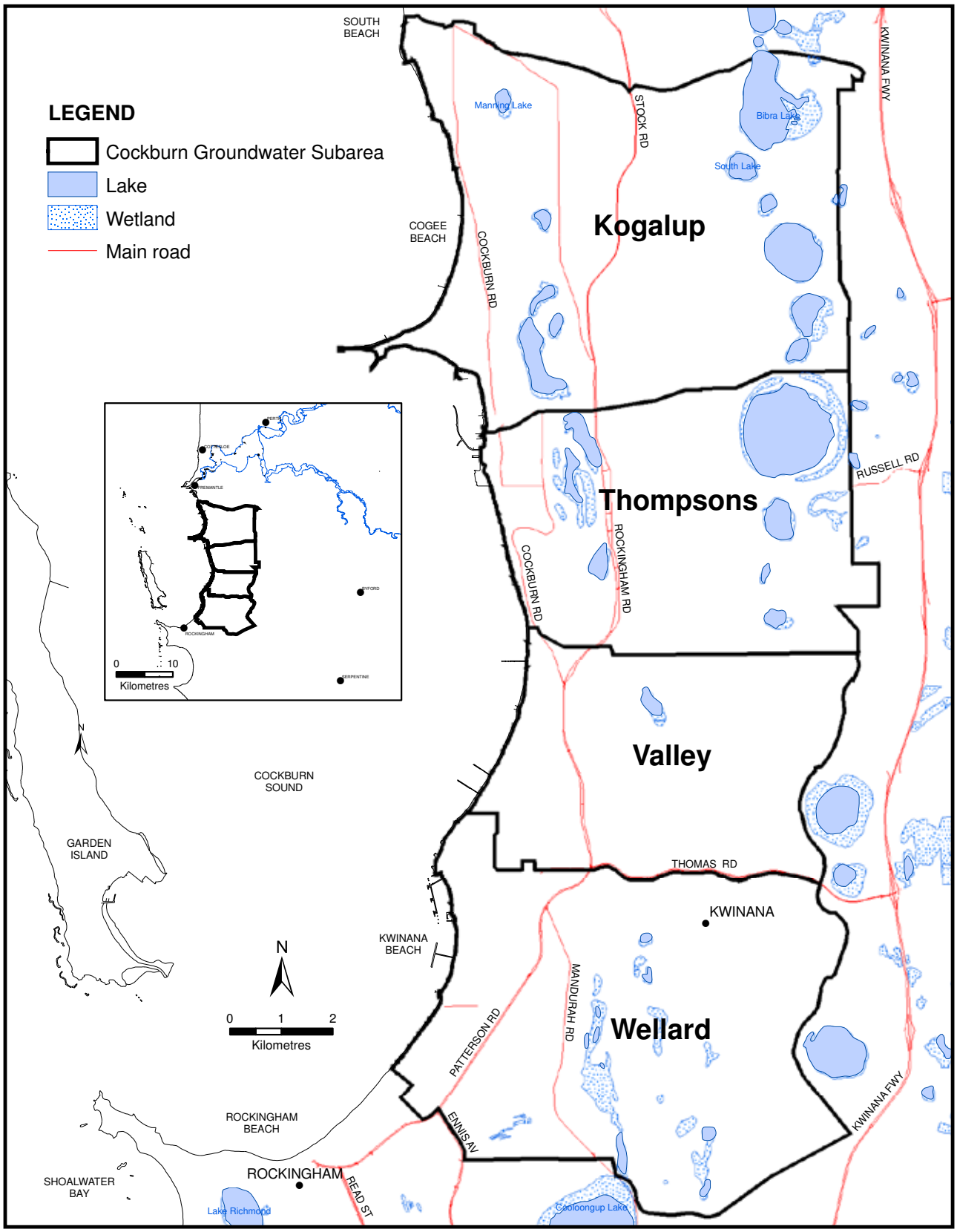

Figure 16: Environmental protection policy lakes and wetlands

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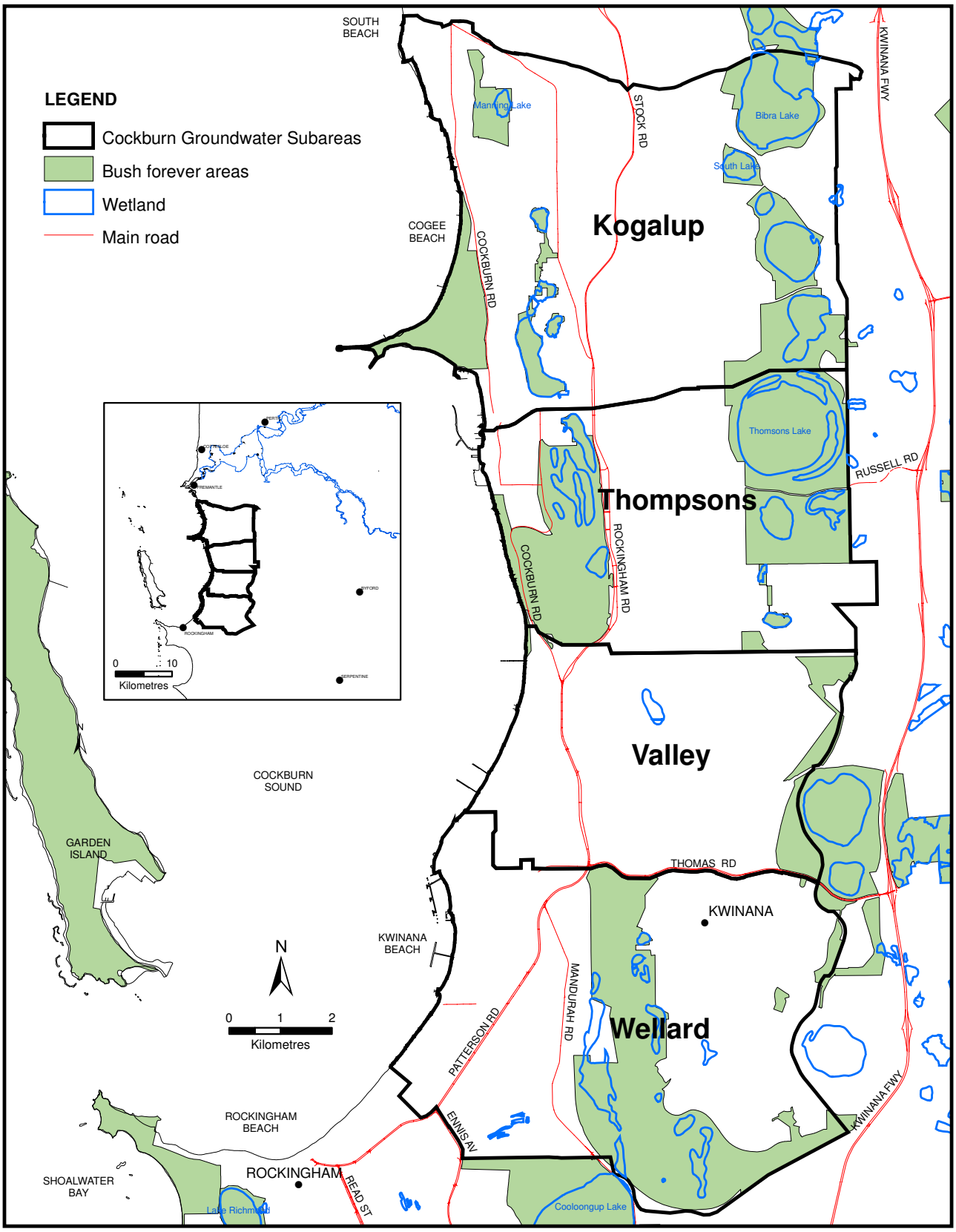

Figure 17: Bush Forever areas in the Cockburn groundwater area

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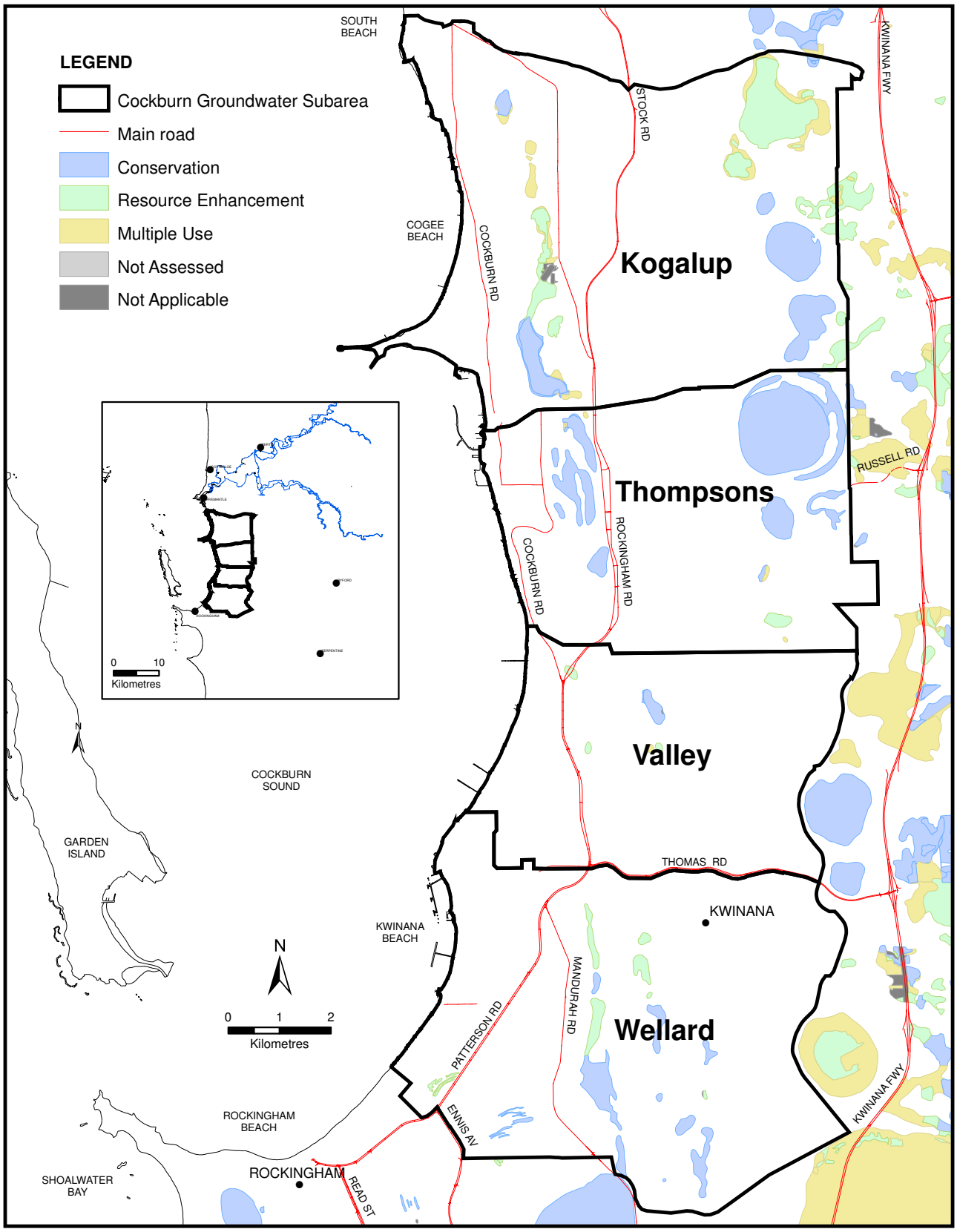

Figure 18: Conservation reserves, resource enhancement reserves and multiple use reserves

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Appendix E — Socio-economic environment

E1.1 History

The genesis of the Cockburn area dates back to the very early settlement of the Western Australian colony. A government grant was issued to Thomas Peel in 1830 encompassing an area of some 100 000 hectares, with Cockburn Sound and the Cockburn River as its northern and southern borders respectively. Land allocations were initially granted for crop cultivation, cattle grazing and horse rearing, and these early efforts established the rural precedent that continues to endure, although to a lesser extent, within the Cockburn Groundwater Area (CGA).

Current population estimates for the major population centres are 63 800 residents for Cockburn, 20 200 for Kwinana and 63 000 for Rockingham.

E1.2 Land use

Land use in the CGA is subject to the planning schemes and strategies that have been set down by the Western Australian Planning Commission (WAPC) and the cities of Cockburn, Rockingham and the town of Kwinana. These have been established in response to increasing development pressure and the need to zone land appropriately for the different land uses within an area.

The WAPC completed a detailed land use study (WAPC 1999) that encompasses the CGA. Cockburn and Rockingham each have town planning schemes in place that set down the basis for land zoning and development.

Examples of the different land uses within the CGA include industrial processing, intensive agriculture (horticulture) and recreation or public open space irrigation.Groundwater allocations and usage vary dependent upon the designated land use.

Currently, the most dominant land uses are horticulture and heavy industry. In the future, the number of industrial subdivisions is likely to increase due to development pressure derived from the expansion and dispersion of the irrigation precinct.

E1.3 Industry

Agriculture and rural development continues to be a vibrant and profitable industry in the area. Some 30 per cent of the land in the CGA is zoned rural, and 25 per cent is designated for industrial use. The traditional rural pursuits remain; however, the area plays host to the state's largest industrial area – Kwinana.

The main agricultural activities in the CGA include market gardening and horticulture. Crops and market gardens are established in the central northern belt of the groundwater area, and are concentrated in the localities of Coogee, Wattleup, Mandogalup and Hope Valley.

The region also accommodates emerging ship building enterprises; chemical supply manufacturing; cement and lime manufacturing; tanneries; bauxite and oil refineries; nitrogen and fertiliser production; power stations and structural engineering operations. Significant processing operations are situated along the coastal belt with the alumina and oil refineries of Alcoa of Australia and BP Oil.

E1.4 Social values

Social values have not been studied in detail in the CGA.

E1.5 Aboriginal cultural values

Aboriginal cultural values in the CGA have not been studied in detail.

E1.6 Economic values

Economic values have not been studied in detail.

E1.7 Beneficial groundwater use

'Beneficial use' of a groundwater resource is the identified present or future community use that should receive priority over other potential uses. The priority beneficial uses will determine the protection criteria for both water quality and quantity.

Private abstraction must not affect neighbouring users detrimentally with respect to water levels or water quality. This general policy applies to all users. Excessive abstraction that exceeds throughflow and recharge may cause decreasing water levels. Rising groundwater salinity may also result.

In many instances, the individual user will be the first to be affected by salinity rises or decreasing yields, particularly in the case of upconing saline water. In cases where large private abstractions or combined abstractions induce horizontal movement of saline water (e.g. the migration of the saltwater interface near the coast), neighbouring users may be influenced first. Neighbouring users must be protected from the effects of over abstraction.

Groundwater must also be allocated to the environment; a portion of groundwater throughflow is required to maintain general groundwater quality and regional water levels (e.g. in and around wetlands). This includes preventing any inland movement of the saltwater interface and maintaining adequate water for groundwater-dependent vegetation and water bodies.

Groundwater abstraction is generally constrained or restricted within and adjacent to conservation reserves and wetlands. Groundwater allocation for abstraction within and adjacent to conservation areas that are recommended for the conservation of flora, fauna, wetlands or recreational potential are restricted to mitigate the adverse impacts; unless, however, the proposal has been referred to the Environmental Protection Authority and necessary assessments have been initiated and subsequent approval granted.

E1.8 Existing groundwater use

The use of general groundwater within the CGA has been grouped into seven categories, as shown in Table 10. While exact amounts of groundwater abstraction constantly change, some general trends concerning groundwater consumption within the CGA are evident:

- The three largest groundwater uses are industrial supply (63.4 per cent), plant production (22.2 per cent) and recreation (9.7 per cent).

- The largest individual groundwater abstraction (2.9 million kL/year) from the Yarragadee aquifer within the Wellard sub area is for industrial purposes and equates to 8.6 per cent of the total groundwater usage.
- Groundwater allocation within the respective sub areas (Table 11) is relatively evenly distributed.
- Groundwater abstraction from the superficial, Leederville and Yarragadee aquifers is 26.76 million kL/year, 1.04 million kL/year and 5.79 million kL/year respectively.
- The three smallest groundwater uses are miscellaneous (0.6%), domestic supply (0.9%) and animal production (0.4%).

When comparing activities as listed in Table 10, it is apparent that:

- pasture/lucerne/turf - besides concentrated use in Thompsons sub area, the remaining irrigation is evenly distributed over most of the other sub areas
- irrigated agriculture/plant production - 55 per cent of all irrigation exists in Thompsons sub area
- domestic supply - domestic supply is concentrated in Kogalup and Thompsons sub areas, where reticulated water supply is not available
- recreation - nearly 50 per cent of irrigation exists in Kogalup sub area, largely utilised by Cockburn for public open space irrigation.

Table 10 Existing groundwater usage (ML/yr)

Groundwater use	Subarea				Total
	Kogalup	Thompsons	Valley	Wellard	(%)
Pasture/ lucerne/ turf	00	870	30	10	2.8
Irrigated agriculture/ plant production[a]	1 840	4 070	1 530	10	22.2
Recreationb	1 730	60	390	1,060	9.7
Animal productionc	20	120	10	-	0.4
Industrial supply[d]	4 890	2 470	4 780	9 180	63.4
Domestic supply[e]	110	160	20	10	0.9
Miscellaneous	10	-	180	20	0.6
(x 10^6 kL/year)	**8 610**	**7 750**	**6 940**	**10 290**	**100**

kL = kilolitre; ML = megalitre

a Includes gardens, orchards, flower production, etc.

b Includes golf courses, public open space, water skiing facilities, etc.

c Includes piggeries, stock, poultry, marron farming, etc.

d Includes ore processing, refinery water, contaminant recovery, wastewater treatment plant requirements, etc.

e Includes domestic garden usage, drinking water requirements, etc.

The total Allocation Limit for all aquifers within the CGA is approximately 45 000 ML/year. The allocation limit comprises about 84 per cent from the superficial aquifer (38 000 ML/year), 3 per cent from the Leederville aquifer (1350 ML/year) and 13 per cent from the Yarragadee aquifer (5150 ML/year).

Table 11 illustrates the number of licences issued from each aquifer within the individual sub areas. Approximately 79 per cent of licences currently issued draw from the superficial aquifer. Figures indicate that all groundwater abstraction from the Leederville and Yarragadee aquifers occur within Kogalup and Wellard sub areas.

Table 11 Summary of current groundwater allocation within the Cockburn groundwater area (ML/yr)

Subarea	Aquifer			Total	% of Total
	Superficial	Leederville	Yarragadee		
Kogolup	4 690	1 030	2 890	8 610	25.62
Thompsons	7 750	-	-	7 750	23.08
Valley	6 940	-	-	6 940	20.66
Wellard	7 380	10	2 900	10 290	30.64
TOTAL	**26 760**	**1 040**	**5 790**	**33 590**	**100**

ML = megalitre

As groundwater is required to facilitate conservation and protection of environmental concerns (e.g. wetlands), the environment may be viewed as a competitor for the groundwater resources. In the future, the demand for environmental allocation of groundwater may increase as public awareness of the significance and importance of environmental sensitivity increases. However, it is envisaged that the environmental water requirements and environmental allocations evaluated within the allocation plan will closely reflect the actual quantities necessary to provide the required and appropriate protection and conservation of environmental features within the CGA.
The increase in public awareness may be attributed to the expected expansion of land use practices (i.e. agriculture, refining, light industry, etc.) which have the potential to alter the natural environment significantly. Environmental issues do, however, already have high priority in the Cockburn Sound catchment due to the nitrate leaching/discharge problems that have been experienced in the coastal embayment in recent years.

Groundwater Usage information

About 80 per cent of all pumping in the CGA is from the superficial aquifer across all four sub areas. Minor abstraction occurs from the Leederville and Yarragadee aquifers in sub areas Kogalup and Wellard only.

Annual groundwater abstraction data for all users is not currently available, although this information is available from some high users. However, some general trends concerning groundwater consumption within the CGA are evident and described in Section 3.

Appendix F — Groundwater monitoring

The monitoring network of the Cockburn Groundwater Area (CGA) consists of wells, drilled to various depths, which were originally designed to monitor the local and regional aquifer systems and provide geological and hydrogeological information. Figure 2 illustrates the department's superficial aquifer monitoring network of the CGA.

The wells being monitored can be grouped into a number of programs (as originally drilled) and are detailed below.

F1.1 Monitoring wells

F1.1.1 Artesian monitoring wells (AM Series)

The AM series of wells formed part of the exploratory drilling program during the assessment of the groundwater resources of the confined aquifers in the Perth region. Several artesian monitoring wells are located within and adjacent to the CGA and are screened at various depths in the Leederville and Yarragadee aquifers. Within and adjacent to the CGA, two wells were drilled and screened into the Leederville aquifer and the Yarragadee aquifer respectively.

F1.1.2 Lake Thomson investigation (T Series)

The Lake Thomson investigation series comprised the drilling of 133 bores screened against various intervals within the superficial aquifer. The regional investigation started at Lake Thomson in the north, and extended about 60 km south to Nambeelup.

F1.1.3 Thomsons Lake limnology study series (TM series)

These wells were drilled to examine the interaction of the unconfined aquifer with Lake Thomson. The investigation also supplied geological information of the immediate area. These series of wells extend as far south as the northern half of Thompsons sub area.

F1.1.4 Bibra Lake monitoring

The drilling of Bibra Lake was proposed in 1967 to determine the hydrogeological environment of the lake. The drilling of 21 shallow bores was completed in 1983. These bores were drilled and screened over various depths (0 m BNS (below natural surface) to 45 m BNS) to monitor shallow watertable movements and superficial aquifer fluctuations within and adjacent to Bibra Lake.

F1.1.5 Cockburn Sound study

Four fully slotted monitoring bores were completed in 1976 to facilitate the sampling and assessment of groundwater discharging into Cockburn Sound.

F1.1.6 Jandakot aquifer evaluation

The water authority drilled 20 wells in 1980 in an attempt to investigate the hydrogeology and superficial aquifer potential at discrete stratigraphic levels. Wells with numbers suffixed with the letter 'A' were commissioned to monitor the potentiometric level at the base of the superficial aquifer, and those suffixed with the letter 'C' are shallow wells, monitoring shallow watertable fluctuations.

F1.1.7 Jandakot monitoring

Preliminary investigations in the determination of the Jandakot aquifer began in 1980 with the commissioning of the Jandakot evaluation series. Forty-four monitoring bores were drilled into the superficial aquifer to monitor the impacts of abstraction from the Jandakot public water supply wellfield.

F1.1.8 Kwinana wastewater treatment plant

Ten monitoring wells were completed in 1984 to enable the monitoring of groundwaters both upstream and downstream of the Kwinana Wastewater Treatment Plant secondary treated effluent disposal basins. The bores serve as a vehicle to monitor the hydraulic mounding and water quality impacts of the surface infiltration.

F1.1.9 Banganup Lake

Fourteen shallow bores were drilled and screened between 0 m BNS and 6 m BNS to monitor shallow watertable movements adjacent to Banganup Lake.

F1.1.10 Lakes and wetlands group

These bores (often staff gauges) were drilled to depths just below the watertable to assess the impacts of groundwater abstraction on phreatophytic vegetation, wetland water levels and groundwater quality.

F1.1.11 Cockburn saltwater interface series

Three groundwater monitoring bores were drilled in 1997 to delineate the saltwater interface and monitor its movement. These bores facilitate the determination of the location of the saltwater interface within the coastal strip of the northern parts of the CGA that are subject to saline groundwater intrusion.

F1.1.12 Private wells

Groundwater licensees with water allocations exceeding 500 000kL/year are required to provide the department with monitoring data from their bore(s) and make regular aquifer assessments. These private bores are monitored by the licensee to ascertain and determine water level fluctuations and water quality changes that may occur in response to groundwater draws.

Large licensees such as Alcoa of Australia and British Petroleum provide vast quantities of data that aid the department in their assessment of coastal abstraction, where the movements of the coastal saltwater interface due to groundwater abstraction and tidal fluctuations are monitored.

F1.2 Current monitoring program

The current groundwater monitoring program is detailed in Table 12. Data from the monitoring wells are stored in a computer database named the State Water Resource Information System (SWRIS).

Table 12 Current groundwater monitoring program

Monitoring series	Aquifer	Water level	Salinity
AM Series	Leederville	Monthly/	-
	Yarragadee	Monthly Biannually**	-
Lake Thomson investigation (T Series)	Superficial	Biannually	-
Thomsons Lake limnology study series (TM series)	Superficial	Monthly	-
Bibra Lake monitoring	Superficial	Quarterly/Monthly#	-
Cockburn Sound study	Superficial	Biannually	-
Jandakot aquifer evaluation	Superficial	Monthly	-
Jandakot monitoring	Superficial	Monthly	-
Kwinana wastewater treatment plant	Superficial	Monthly	-
Banganup Lake	Superficial	Monthly	-
Lakes and etlands group	Superficial	Monthly Bimonthly+/ Biannually^	-
Cockburn saltwater interface series	Superficial	Biannually	Biannually

+ Bimonthly = Lake Coogee; Long Swamp

^ Biannually = Lake Mt Brown

Monthly = BM5A and BM5C

** Biannually =AM54

F1.3 Recommended changes to monitoring program

Salinity data is currently solely sourced within the groundwater area from the Cockburn Saltwater Interface Series. Current coverage and frequency of water level monitoring is considered adequate and appropriate; however, it is recommended that groundwater salinity monitoring be increased.

Table 13 Proposed groundwater monitoring program

Monitoring series	Aquifer	Water level	Salinity
AM Series	Leederville	Monthly/	-
	Yarragadee	Monthly/Biannually**	-
Lake Thomson investigation (T Series)	Superficial	Biannually	Biannually
Thomsons Lake limnology study series (TM series)	Superficial	Monthly	-
Bibra Lake monitoring	Superficial	Quarterly/Monthly##	-
Cockburn Sound study	Superficial	Biannually	Biannually
Jandakot aquifer evaluation	Superficial	Monthly	-
Jandakot monitoring	Superficial	Monthly	-
Kwinana wastewater treatment plant	Superficial	Monthly	-
Banganup Lake	Superficial	Monthly	-
Lakes and etlands group	Superficial	Monthly/Bimonthly+/ Biannually^	-
Cockburn saltwater interface series	Superficial	Biannually	Biannually

+ Bimonthly = Lake Coogee; Long Swamp
^ Biannually = Lake Mt Brown
# Monthly = BM5A and BM5C
** Biannually =AM54

It is proposed that salinity monitoring occur on a biannual basis for bores within the Cockburn Sound study series and the Lake Thomson investigation series as detailed in Table 13 above.

F.1.3.1 Groundwater quality monitoring

Groundwater salinity is not regularly monitored from aquifers in the CGA. Salinity data is currently solely sourced within the groundwater area from the Cockburn saltwater interface series. Current coverage and frequency of water level monitoring is considered adequate and appropriate; however, it is recommended that groundwater salinity monitoring be increased.

Appendix G — Salinity classification

Table 14 Salinity classifications

Salinity (mg/L TDS)	Salinity status	Category
<500	Fresh	Drinking and irrigation
500–1000	Marginal	Irrigation
1000–2000	Brackish	Irrigation with caution
2000–5000	Moderately saline	Primary drainage
5000–10,000	Saline	Secondary drainage and saline groundwater
10,000–35,000	Highly saline	Very saline groundwater
>35,000	Brine	Seawater

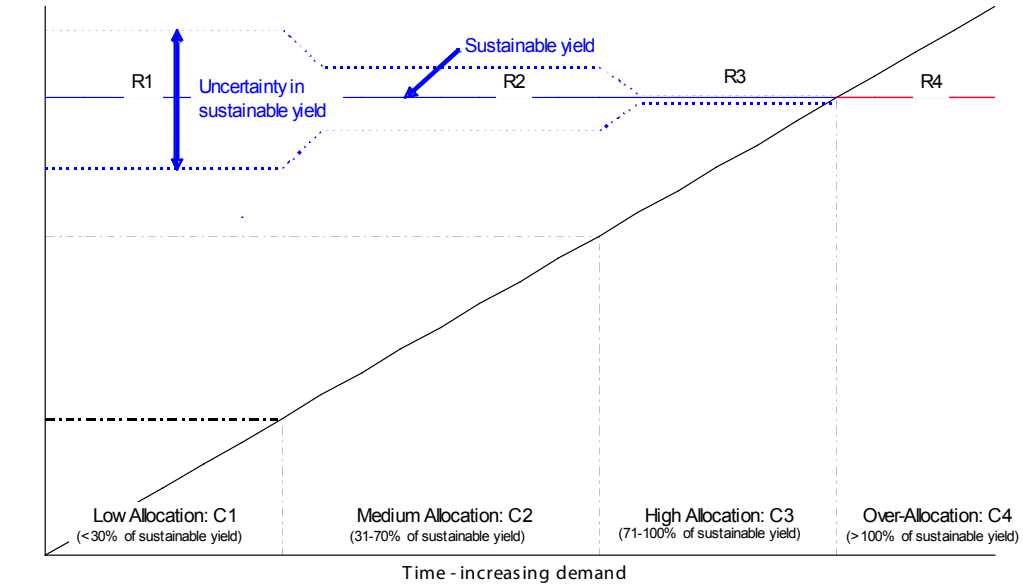
Appendix H — Resource classification

Resource classification is based on the total water used (licensed and unlicensed use) in an area as a percentage of the sustainable yield, and was formalised as part of the National Land and Water Resources Audit: Water Availability and Use Theme (WRC 2000d).

The level of understanding required about the sustainable yield from a resource is related to the use. For example, where the water use is low, only a preliminary estimate of the sustainable yield is required. As the allocated volume increases, the uncertainty in the sustainable yield needs to be reduced through more detailed investigations. The required management response category corresponds to the level of use or allocation (Table 15).

Table 15 Resource categories according to level of use

Classification Category	Utilisation as percentage of Sustainable Yield (%)	Level of Use	Required Response Category
C1	0 – 30	Low	R1
C2	31 – 70	Medium	R2
C3	71 – 100	High	R3
C4	>100	Over-allocated	R4



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.
AHD	The datum used for the determination of elevations in Australia. The determination used a national network of bench marks and tide gauges, and set mean sea level as zero elevation.
Allocation Limit (AL)	The amount of water set aside for annual licensed use. In the department's current water licensing system, the AL is a volumetric licensing limit. As such, the AL does not always account for basic stock and domestic water rights that do not require a licence. However, the meaning of the term will become broader as the department's water accounting systems are developed. Note: Setting an AL involves making a decision. The AL is ordinarily equal to or less than the sustainable yield. If the sustainable yield is highly uncertain, the AL is usually set to be conservative. A triple bottom assessment may, under some circumstances, result in a decision to set an AL greater than the ecologically sustainable yield.
Aquifer	A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water. Usually described by whether they consist of sedimentary deposits (sand and gravel) or fractured rock. Aquifer types include unconfined, c, and a.
Artesian aquifer	A confined aquifer in which the hydraulic pressure will cause water to rise in a bore or spring above the land surface. If the pressure is insufficient to cause the well to flow at the surface, it is called a sub-artesian aquifer.
Artesian well	A well, including all associated works from which water flows, or has flowed, naturally to the surface.
BNS	Below Natural Surface
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.
Domestic allocation	The volume of water required for household purposes and the irrigation of a small domestic gardens

Domestic use	The use of a water resource that is not for commercial purposes.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of those systems.
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.
Ecological water requirements	The water regime needed to maintain ecological values of water-dependent ecosystems at a low level of risk.
Equity	Treating those in the same circumstances in the same manner, through a system of principles, policies and processes that supplement the common and statutory law framework.
Evaporation	The vaporisation of water from a free water surface above or below ground level, normally measured in millimetres.
Evapo-transpiration	The loss of water to the atmosphere by evaporation and by transpiration through living organisms.
Groundwater	Any underground water, including water that percolates from the ground surface into a well or other works.
Groundwater area	An area of land that overlies a particular water resource, or resources, that has been proclaimed under the Rights in Water and Irrigation Act 1914, for the purposes of controlling, through licensing, the construction of water wells and the taking and use of the water resource(s).
Groundwater-dependent ecosystems	An ecosystem that is partially or fully dependent on groundwater for its sustained existence.
Hectare (ha)	10 000 square metres or 2.47 acres.
Kilolitre (kL)	1000 litres or 220 gallons.
Leakage	The flow of water from one aquifer to another.
Policy	Refers to a guideline that is not directly supported by any legislation but has been adopted by the department as its guideline.

Potentiometric level	An imaginary surface representing the total head of groundwater and defined by the level (surface) to which water will rise in a well.
Precautionary principle	Taking a cautious approach to development and environmental management decisions when information is uncertain, unreliable or inadequate.
Recharge	The downward movement of water, usually expressed as a percentage of rainfall depending on the stratigraphy, that contributes to the groundwater resources of an aquifer system.
Salinity	The measure of total soluble salt (i.e. mineral constituents in water). Water resources are classified on the basis of salinity in terms of total dissolved salts (TDS) or total soluble salts (TSS). Measurements are usually milligrams per litre (mg/L) or parts per thousand (ppt).
Sub area	A subdivision within a surface or groundwater area, defined for the purpose of managing the allocation of groundwater resources.
Surface water	An open body of water such as a stream, lake or reservoir.
Sustainability	Meeting the needs of current and future generations through integration of environmental protection, social advancement and economic prosperity.
Sustainable yield	The volume of water abstracted from a source that can be sustained on a long-term basis without exceeding the rate of replenishment.
Throughflow	The flow of water within an aquifer.
Transferable (tradable) water entitlement	The ability to transfer or trade a water entitlement, or a part thereof, to another person within a common water resource.
Unconfined aquifer	An 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 conservation	The management of water use to achieve and maintain an appropriate level of water use efficiency.

Water efficiency	The minimisation of water use through adoption of best management practices.
Water entitlement	The quantity of water that a person is entitled to take on an annual basis in accordance with the RiWI Act or a licence.
Water regime	A description of the variation of flow rate in surface water or water level in groundwater over time; it may also include a description of water quality.
Watertable	The groundwater surface of an unconfined aquifer at which pressure is equal to atmospheric pressure.
Well	An opening in the ground made or used to obtain access to underground water. This includes soaks, wells, bores and excavations.
Wetland	A permanent or seasonal lake, swamp or permanently waterlogged soils or inundated land.

Acronyms and abbreviations

AHD	Australian height datum
AL	Allocation Limit
AM series	Artesian Monitoring bores
BNS	Below natural surface
CGA	Cockburn Groundwater Area
EWP	Environmental Water Provision
EWR	Environmental Water Requirement
GDE	groundwater-dependent ecosystem
GWA	groundwater area
PRAMS	Perth Regional Aquifer Modelling System
RiWI Act	Rights in Water and Irrigation Act 1914
T series	Thomsons Lake series
TDS	total dissolved salts

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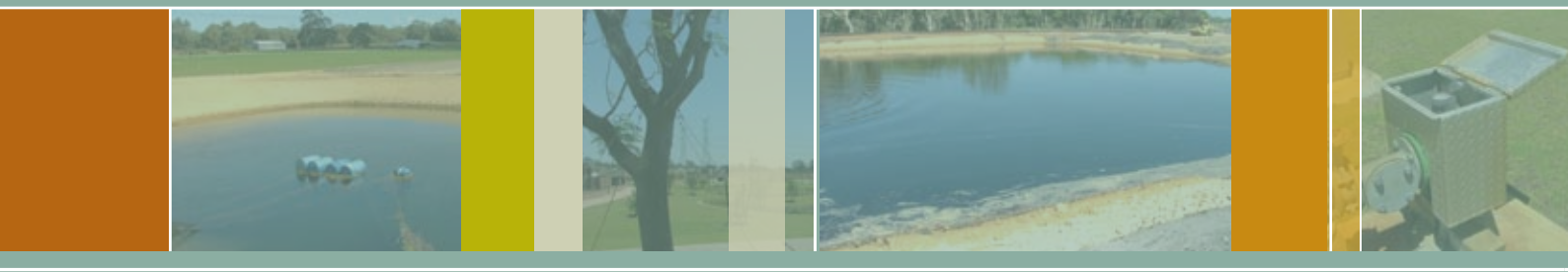

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