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

Lower Cane groundwater allocation limit report

Method used to set an allocation limit and licensing rules for the lower Cane alluvial aquifer

Looking after all our water needs

Lower Cane groundwater allocation limit report

Method used to set an allocation limit and licensing rules for the lower Cane alluvial aquifer

Looking after all our water needs

Department of Water

Water resource allocation and planning series

Report no. 51

June 2011

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
National Relay Service 133 677
www.water.wa.gov.au

© Government of Western Australia 2011

June 2011

This work is copyright. You may download, display, print and reproduce this material in unaltered form only (retaining this notice) for your personal, non-commercial use or use within your organisation. Apart from any use as permitted under the *Copyright Act 1968*, all other rights are reserved. Requests and inquiries concerning reproduction and rights should be addressed to the Department of Water.

ISSN 1327-8428 (print)
ISSN 1834-2620 (online)

ISBN 978-1-921789-68-7 (print)
ISBN 978-1-921789-69-4 (online)

Acknowledgements

The Department of Water would like to thank the following for their contribution to this publication: Mike Braimbridge, Darryl Abbott, Fiona Lynn, Michelle Antao, Robyn Loomes, Emily Said, Hazli Koomberi and Chris O'Boy.

For more information about this report, contact:

Allocation Planning section
Department of Water
Telephone 08 6364 7600
Email allocation.planning@water.wa.gov.au

Disclaimer

This document has been published by the Department of Water. Any representation, statement, opinion or advice expressed or implied in this publication is made in good faith and on the basis that the Department of Water and its employees are not liable for any damage or loss whatsoever which may occur as a result of action taken or not taken, as the case may be in respect of any representation, statement, opinion or advice referred to herein. Professional advice should be obtained before applying the information contained in this document to particular circumstances.

This publication is available from our website <www.water.wa.gov.au>.or for those with special needs it can be made available in alternative formats such as audio, large print, or Braille.

Contents

Appendices

Figures

Tables

Summary

Demand for water at Onslow is forecast to rise due to the expansion of the offshore oil and gas industry and the associated increase in the town's population. Additional water supply to meet part of this demand may be sought by water service providers from the lower Cane River alluvial aquifer.

To support any development in the area and provide guidance to proponents, the Department of Water has set an allocation limit and licensing rules for the Lower Cane alluvial aquifer, which are set out in this report.

To determine the lower Cane alluvial aquifer allocation limit, the department has used a risk-based approach (DoW 2010). We use this approach in cases where knowledge about the groundwater resource is limited and where there are few competing demands. This allows us to develop allocation limits and licensing rules quickly and consistently.

This approach has four steps:

1 Identify and define the groundwater resource.

2 Describe aquifer properties, groundwater-dependent values and consumptive uses and assess the risks.

3 Assess whether any risks can be managed through licensing rules.

4 Set allocation limits and licensing rules.

Using the process outlined above, the department has set an allocation limit for the lower Cane alluvial aquifer of 1.0 GL/yr. As at January 2011, there is still water available for licensing.

As there is only limited information about this water resource, the department welcomes new investigations and data which would improve our understanding of the aquifer. If new information shows that more water is available than the estimate that has been used in this report, and that the effects of increased abstraction are manageable, then we may review the allocation limit.

1 Introduction

The Department of Water is responsible for deciding how much of a water resource can be taken for consumptive use and how much needs to remain in the system. Consumptive use includes water for industry, stock watering, domestic use and public water supply. Water left in the system (in situ) is for maintaining the integrity of the water resource, its water-dependent ecosystems and the cultural and social values linked to it. We decide how much water is available for consumptive use through setting allocation limits and licensing rules.

1.1 Scope of this document

This document describes the process we used to set the allocation limit and licensing rules for the lower Cane alluvial aquifer. We are doing this because water demand is increasing due to the expansion of the offshore oil and gas industry and the associated increase in population.

This document sets out:

- the resource boundary of the lower Cane alluvial aquifer
- existing information available on the resource
- an allocation limit for the resource
- licensing rules for the resource.

The allocation limit is set through a process of balancing the risks to the aquifer's integrity and groundwater-dependent environmental, cultural and social values in the area, with the risks of constraining development by not having water available for consumptive use.

1.2 What is an allocation limit?

An allocation limit is the annual volume of water set aside for use from a water resource. Allocation limits are the main tool the department uses to manage abstraction. The allocation limit, and other mechanisms such as monitoring, investigations and compliance, are used to manage the impacts of water abstraction on other water users, the water resource and the environment. As the level of information about a resource increases, the allocation limit may be revised accordingly.

1.3 Process used for setting the lower Cane alluvial aquifer allocation limit

To set the lower Cane alluvial aquifer allocation limit we used a risk-based approach, the details of which can be found in *Groundwater risk-based allocation planning process* (DoW 2010).

The risk-based approach has four steps:

1. Identify and define the groundwater resource (including estimation of aquifer recharge).
2. Describe aquifer properties, environmental, cultural and social groundwater-dependent values and assess the risks to those properties and values from abstraction; describe the consumptive uses of water from the aquifer and assess the development risks of not abstracting water for consumptive use.
3. Assess whether any risks identified above can be managed through licensing rules.
4. Set allocation limits (the amount of water available for consumptive use) and licensing rules.

Using the risk-based approach, the allocation limit is based on a proportion of the estimated average annual recharge to (or discharge from) the aquifer. The proportion is determined by considering risks to the resource and dependent in situ and consumptive values, and the ability to manage those risks.

1.4 Need for a Water Licence

The aquifer is within the Pilbara groundwater area, which was proclaimed in 1996 under the *Rights in Water and Irrigation Act 1914*. This means that water users need a licence from the department to legally take groundwater or construct a bore in this area. However, taking water for non-intensive stock watering or for domestic use is exempt from licensing.

2 The lower Cane resource

2.1 Resource boundary

The department has defined the extent of the aquifer (Figure 1) based on the hydrogeology described in Martin (1996). The resource is defined as: Pilbara groundwater area – Lower Cane – alluvial aquifer.

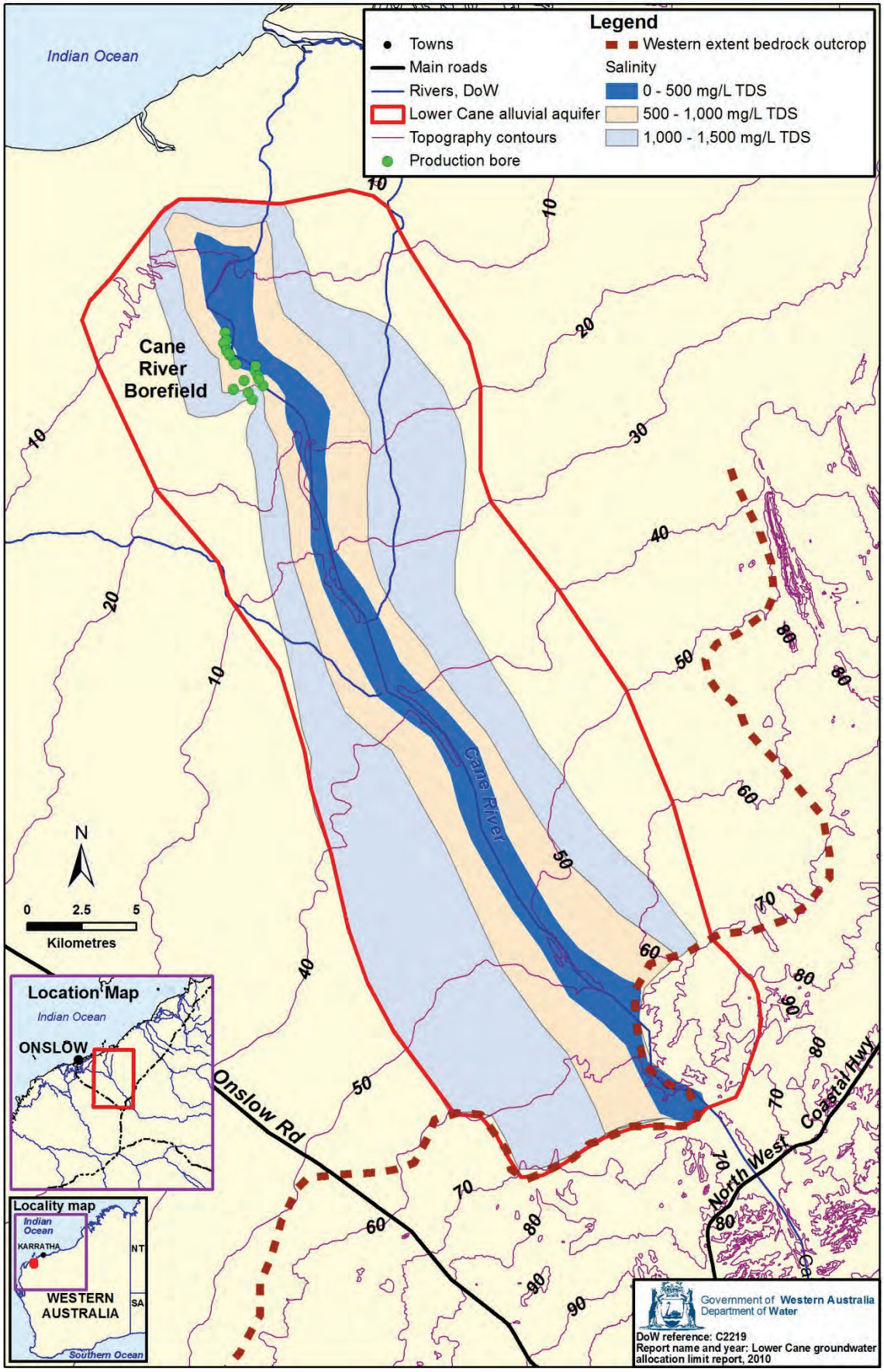

Figure 1 Resource boundary of the lower Cane alluvial aquifer

2.2 Hydrogeology

The lower Cane River alluvial aquifer runs from the North West Coastal Highway almost to the coast, a distance of about 40 km (Figure 1). In the southern end, the upper Cane River area, the alluvial aquifer is underlain by Carnarvon Basin sediments which have limited storage (Haig 2009). This document sets an allocation limit for the alluvial aquifer and does not consider Carnarvon Basin sediments.

The lower Cane River alluvial aquifer consists of about 25 m of Quaternary alluvium underlain by Trealla Limestone. The saturated thickness of the alluvial aquifer ranges from 7 m in the north to 18 m in the south with an average of 10 m. Bore yields can be variable but are generally higher yielding where the sediments alternate between hard and soft layers of sandy alluvium, and in contact zones between the alluvium and Trealla limestone.

The aquifer is recharged directly through periodic streamflow from the Cane River, which since 1987 has had a long-term mean annual flow of 88 GL. This is the main source of recharge to the aquifer. Rainfall recharge occurs to a lesser extent through direct infiltration. The underlying Trealla Limestone aquifer is recharged by leakage from the overlying alluvial sediments.

Studies have not determined any recharge or storage estimates for the Cane River alluvium or underlying limestone aquifer (Haig 2009). The department has estimated groundwater outflow of 4.0 GL/yr along the 80 km length of alluvial aquifer on both sides of the Cane River with a thickness of 10 m, hydraulic conductivity of 10 m/d, and hydraulic gradient of 0.0005.

This equates to an estimated ‘available yield’ of 0.1 GL/yr/km length of the river (Tomlinson 1994). Assuming an available yield of 0.1 GL/yr/km across the 40 km length of the aquifer, gives a total available yield of 4.0 GL/yr with a TDS of less than 500 mg/L. Bores would need to be spaced along the 40 km length of the Cane River. This required bore spacing combined with variable thickness of the alluvium is likely to be a significant limiting factor on the supply capacity of the resource.

The characteristics of the lower Cane alluvial aquifer are shown in Table 1.

Table 1 Characteristics of interest of the Lower Cane alluvium

Characteristic	Value or description
Water quality	Less than 500 mg/L
Maximum aquifer thickness	18 m
Annual available yield	0.1 GL/yr/km
Groundwater outflow estimate	4.0 GL/yr

3 Assessment

3.1 Assessment panel

The assessment panel included the following Department of Water staff:

- District Manager, Pilbara region
- Regional Hydrogeologist, Pilbara region
- Project Hydrogeologist, Groundwater Assessment
- Project Environmental Scientist, Environmental Water Planning
- Project Water Planning officer, Allocation Planning.

3.2 Aquifer properties

To maintain the aquifer's ability to yield water for consumptive use in the long term, it is essential to maintain the quantity and quality of its water, that is, the integrity of the aquifer.

An important consideration for managing the long-term integrity of the aquifer is maintaining the position of the saltwater interface. The aquifer's salinity increases towards the coast due to seawater intrusion into the aquifer. Adequate freshwater throughflow towards the coast is needed so the position of the saltwater interface is maintained.

Salinity also increases away from the river, which is the main source of freshwater recharge (from river flows) to the aquifer. To prevent saline intrusion towards the river, the freshwater volume needs to be maintained to stop salt water moving in from the aquifer's flanks.

3.3 Groundwater-dependent ecosystems

The department conducted a desktop review and a short duration field survey to investigate any groundwater-dependent ecosystems (GDEs) that may be associated with the lower Cane alluvial aquifer. Where possible, the review made use of regional ecological assessments to consider the significance of ecosystems in a regional context. Site-specific survey information was also included in the review where it was available.

The review:

- identified and described the possible types of groundwater-dependent ecosystems
- mapped the likely distribution of groundwater-dependent ecosystems
- considered the conservation significance of groundwater-dependent ecosystems

- considered the sensitivity of groundwater-dependent ecosystems to water regime change, identifying the most sensitive components.

As part of the Pilbara region biological survey (2002–9), several sites were surveyed for stygofauna. Preliminary results show the richness of Ostracods is relatively high in the lower Cane River aquifer (Reeves et al. 2007). It is likely that other taxa are also abundant.

The Cane River (Peedamulla) Wetland is a seasonally inundated delta near the mouth of the Cane River (Astron 2003). It is predominantly fed from flows from an upstream branch of the main river channel. The wetland supports a unique vegetation community of seasonally inundated coolibah (*E. victrix*) over a mixed sedgeland of Cyperaceae species. The combination of Eucalypts over sedges is unusual in the Pilbara (Kendrick and Stanley 2002).

Analysis of long-term satellite imagery (1999–2007) (Department of Water 2009) showed eight pools approximately 8 km upstream of the existing borefield in the vicinity of the Northwest Highway crossing. The majority of these pools were classified as intermittent, occurring only in wetter years, while only one (Jabaddar Pool) was semi-permanent. No permanent pools were identified (Appendix B).

Morgan et al. (2003) undertook fish surveys in Northern Western Australia rivers. They sampled one site within the Cane River study area, Jabaddar Pool. Two native, freshwater, fish species, *Nematalosa erebi* (bony bream) and *Leioptherapon unicolour* (spangled perch), were identified. Both are common and widespread species (Pusey et al. 2004; Beesley 2006).

A field survey by department staff in August 2009, verified earlier descriptions of the riparian vegetation fringing the Cane River by Van Vreeswyk et al. (2004) (see Figure 2). The vegetation communities are predominantly *Melaleuca argentea* or *Eucalyptus camaldulensis* woodland, over a tall shrub layer with occasional sedges (e.g. *Cyperus vaginatus)* and perennial grasses (Appendix A). The survey also noted that the vegetation was generally intact and in excellent condition.

Both *E. camaldulensis* and *M. argentea* are regarded as phreatophytic (groundwater dependent) (O'Grady et al. 2002). *Melaleuca argentea* is adapted to areas of shallow groundwater (2 to 3 m below ground level). *Eucalyptus camaldulensis* is also commonly associated with shallow depths to groundwater (2 to 5 m below ground level), but has been recorded where groundwater is up to 21 m below ground level (Landman 2001).

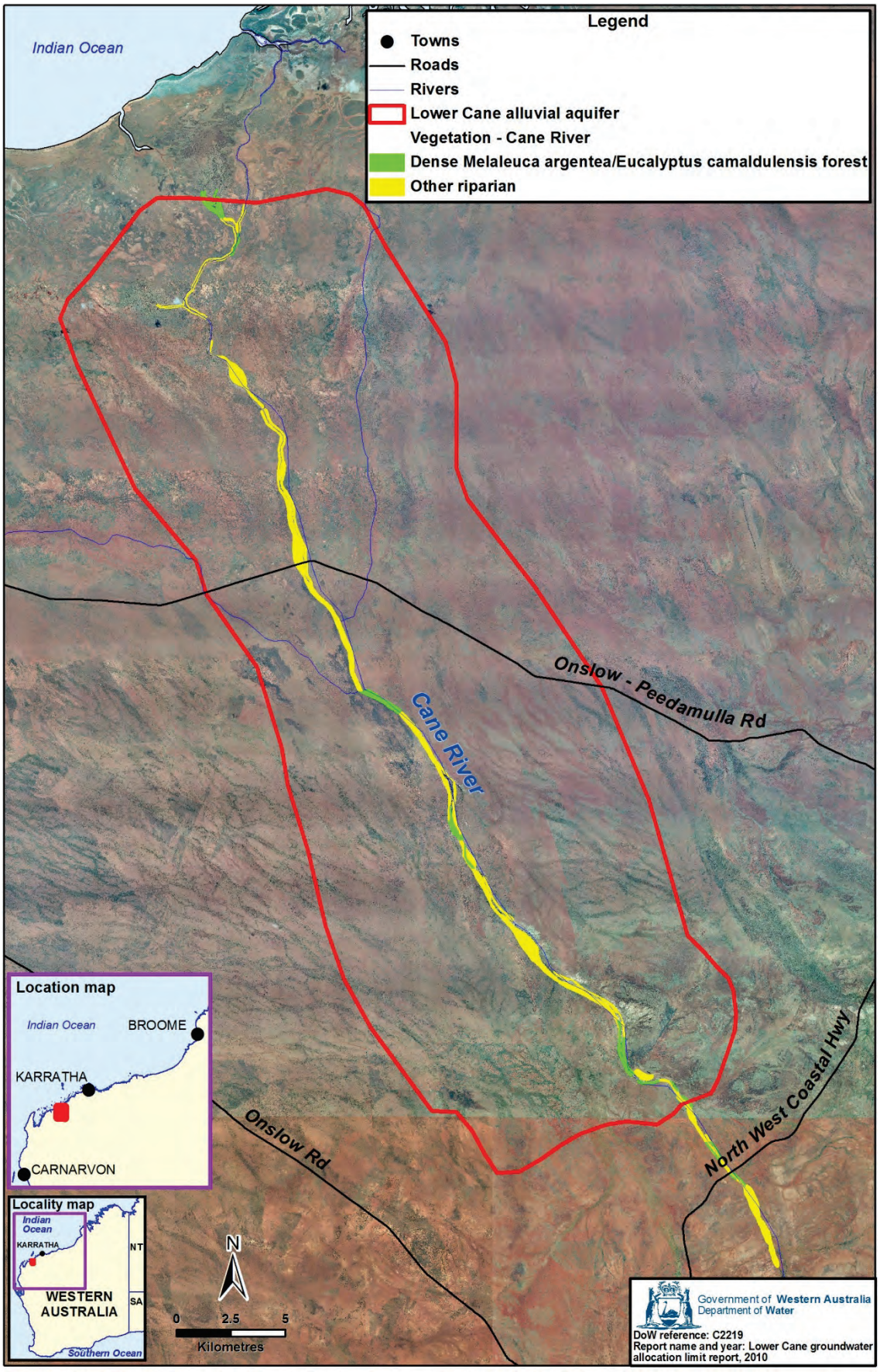

Figure 2 Vegetation assessment sites within the study area

3.4 Cultural and social values

The lower Cane River area, or the Peedemulla area, has a native title claim that is not registered yet, but is formerly of the Noala people. There are registered native title claims surrounding the Peedamulla/lower Cane River area including Kuruma Marthudunera (WC99/12), Yaburara Mardudhunera (WC96/89) and Thalanyji (WC99/45). The department has consulted with the Pilbara Native Title Service as they are the recognised representatives for the native title claimants for the area.

Local knowledge of the area holds that the Lower Cane River is highly significant due to the proximity of the Ceremonial Law Ground. Survey work in 1974 noted that that Aboriginal people travelled from Yandeyarra, Roebourne and Port Hedland to attend ceremonies at Cane River. The number of Aboriginal people attending has been estimated from historical material to be in the hundreds. The songs performed at initiation ceremonies relate to the travels and exploits of ancestral beings along dreaming tracks, which are generally rivers.

Permanent pools are often associated with the dreamtime serpent, Warlu, for which Aboriginal elders have certain custodial responsibilities. Wooden implements important to the rituals used in these ceremonies are generally obtained from the surrounding vegetation. Therefore the pools, waterways and the vegetation which accesses water are important features associated with the ceremonial ground. We have considered this in developing the licensing rules (see Section 4.2).

The area is very significant to Aboriginal people and a number of heritage sites are present. It was recommended that ongoing consultation with traditional owners occur as allocation decisions are made. The department recognises that direct consultation with traditional owners has been limited in preparation of this report and supports this recommendation.

3.5 Consumptive use

The only licensed water use from the aquifer is the Cane River borefield, which is operated by the Water Corporation to supply water to Onslow. The current licensed allocation is 0.35 GL/yr. There is also water use for stock in the area, from bores that draw on shallow groundwater.

The department has estimated stock and domestic water use to be 7500 kL/yr, as shown in Table 2.

Table 2 Estimated stock and domestic water use, which is exempt from licensing

Usage	Estimated water use kL/yr	Estimated number of water users	Total water use kL/yr
Stock bores	500	15	7500

The Water Corporation is currently investigating whether there is capacity to expand their current borefield and increase the level of abstraction to meet increasing demand. The results of this investigation are not yet available.

Future demand is expected to increase as the oil and gas industry expands, but given the limited capacity of the aquifer it is expected that a new source of 1 to 3 GL/yr will need to be identified and assessed.

4 Allocation limit decision and licensing rules

4.1 Assessment of risks

To determine the annual volume of water to be allocated for abstraction, the Department of Water assigned ratings (high, medium or low) to in situ risk and development risk. We then used a risk matrix (Section 4.3.2) to convert the risks into a proportion of average annual recharge.

The department's risk assessment has two components:

- in situ risk: the risks to aquifer properties and to environmental, social and cultural values that may arise from groundwater abstraction
- development risk: the risks to productive use that may arise if water is not abstracted.

Table 3 shows what we considered in assigning risk ratings.

4.1.1 Initial risk assessment

For the lower Cane alluvial aquifer we assigned a high risk to in situ values from abstraction, as well as a medium risk to development from restricting abstraction. For the overall in situ and development risks we took the highest risk rating (Table 3).

Table 3 Determining the risk of abstraction on in situ values and the risk of limiting water available for consumptive use

Values		Likelihood and/or sensitivity	Consequences	Risk rating	Overall Risk
In situ risk	Aquifer properties	What are the risks to the aquifer from abstraction?	Concern of saline intrusion to the aquifer from increasing pump rates of bore fields.	Medium	**High** (highest risk rating)
		What is the overall level of risks to the aquifer of abstraction?	The overall risk to the aquifer and in situ values are considered as being moderate.	Medium	
	Groundwater-dependent ecosystems	Are some GDE or components of GDE more sensitive to changes in hydrogeological regime than others?	GDEs are sensitive to drops in water level from groundwater abstraction.	High	
		How significant are the GDE?	Subregional significance of permanent pools and high condition of riparian vegetation communities.	High	

Values		Likelihood and/or sensitivity	Consequences	Risk rating	Overall Risk
	Cultural and social	Are some values or components of values more sensitive to changes in the hydrogeological regime than others?	These cultural sites are associated with GDEs and mitigation strategies used to protect these sites will also protect the cultural values.	High	
		How significant are the identified values?	There are no regionally significant sites known that are water dependent	High	
		Is there a risk of impacts on existing water users (consumptive) from increased abstraction?	Consideration should be given however, to unlicensed stock and domestic use within the area when considering mitigation strategies to protect other users	Low	
Development risk	Future use	How reliant is the community on abstraction from the resource?	The resource is the sole source for public water supply to Onslow. It is closer than other resources, requiring less infrastructure, but yield is low.	Medium	**Medium** (highest risk rating)
		How easily can future water needs be met by access to alternative supplies?	Additional sources (e.g. desalinisation) are likely to be required for large scale development regardless of provision of groundwater.	Medium	

4.2 Licensing rules and resource management

The department assessed the capacity to manage the in situ risks identified in the initial risk assessment stage (Section 4.1.1).

To manage the risks to in situ values, the department has developed the licensing rules in Table 4.

The rules have been developed to achieve the following objectives:

- maintain the aquifer's integrity
- maintain the aquifer's water quality
- maintain in situ values
- minimise impacts on existing users
- manage the aquifer as a sustainable productive resource.

Table 4 Licensing and management rules for the Lower Cane alluvial aquifer

Topic	Rule
Permanent, groundwater-dependent pools	1. No impacts from abstraction on permanent river bodies and groundwater-dependent vegetation including those defined in Figure 2 and listed in Appendix B.
Other water users	2. Additional abstraction must not have an impact on existing water users.
Water quality	3. Proponents holding licence entitlements of 100 000 kL or more must monitor salinity as per the monitoring program outlined in their licence conditions and/or operating strategy. 4. Abstraction must not adversely affect the current range of the saltwater interface. 5. Allocation requests above 0.1 GL/km will not be permitted without adequate hydrogeological investigation.

4.3 Allocation limit and water availability

4.3.1 Final risk assessment

The department assessed whether the level of risk determined in the initial risk assessment step (Section 4.1.1) could be reduced if we applied the licensing rules developed in Section 4.2. Given the risk to in situ values, which are considered to be of high value, and the uncertainty around estimates of hydrogeology of the aquifer, we did not reduce the in situ risk rating.

4.3.2 Using a risk matrix to determine yield

Using a risk matrix (Table 5), the final overall ratings of the in situ and development risks were used to select the appropriate yield as a proportion of average groundwater outflow. As Table 5 shows, a medium in situ risk and a medium development risk (from Table 3) resulted in a 25% proportion of groundwater outflow being selected.

Table 5 Risk matrix for determining the proportion of yield for allocation

	Proportion of yield %		
	Low development risk	**Medium development risk**	**High development risk**
High in situ risk	5	**25**	50
Medium in situ risk	25	50	60
Low in situ risk	50	60	70

4.3.3 Allocation limit and water availability

Using the estimated annual groundwater outflow of 4.0 GL/yr (Table 1) and the selected yield proportion of 25%, the department has set the lower Cane alluvium's allocation limit at 1.0 GL/yr. As at January 2010, there is still water available for licensing.

Table 6 Allocation limit and components for the Lower Cane alluvial aquifer

Allocation limit kL/yr	**Licensable component kL/yr**		**Un-licensable component kL/yr**
	General licensing	**Public water supply**	**Unlicensed use**
1 000 000	92 500	900 000	7 500

4.4 Monitoring and reporting

Licensees are required to complete monitoring to demonstrate their compliance with licensing rules in relation to groundwater levels, salinity and river pools. Monitoring procedures must be developed as part of the operating strategy attached to the licence conditions. Licensees' monitoring requirements are related to the volume of their licensed allocation. Licensees must report their monitoring data to the department annually. The department will review and evaluate the monitoring reports and data to see whether licence conditions are being met and risks are being managed effectively.

The Water Corporation carries out twice-yearly monitoring of groundwater levels in 15 bores as part of their requirements under the Onslow water resource management operating strategy. The Department of Water will review our groundwater monitoring program for the resource as part of the allocation planning activities in the Pilbara region scheduled for completion in 2012.

We will also continue maintenance and monitoring of the river gauging station 707005 situated at the North West Coastal Highway bridge. This station provides continuous stage height (water level) data for the Cane River which is needed to detect possible changes in aquifer recharge.

Monitoring data improves our knowledge of the resource, so that we can revise licensing rules and improve our estimate of the resource's sustainable yield.

4.5 Review of allocation limits

More detailed information could improve estimates of throughflow or recharge and other aspects of the resource. The department welcomes new hydrogeological investigations and data to improve our understanding of the aquifer. Monitoring data collected by licensed water users is also valuable to improve our knowledge of the resource.

If new information shows that more water can be taken without compromising the resource, then we may review the allocation limit and/or consider new proposals for water abstraction from the resource.

Appendices

Appendix A – Results of Cane River vegetation survey

The Department of Water completed a field survey in August 2009 to verify the composition of riparian vegetation fringing the Cane River. The survey noted that the vegetation was generally intact and in excellent condition. A description and photograph of each site is provided below. Table A 1 lists the family and species of vegetation found.

Site 1: Cane River–Peedamulla Rd crossing

Open woodland of *Eucalyptus camaldulensis* and *E. victrix* in channel with *Corymbia flavescens* on floodplain, over *Melaleuca glomerata* and *Acacia miniritchie* mid storey over *Triodia wiseana* and *Cenchrus ciliaris*.

Site 2: In vicinity of bore 1/71

Open woodland of *E. victrix* and *M. argentea* over *C. ciliaris*

Site 3: On floodplain in vicinity of bore 1/69

E. victrix and E. camaldulensis open woodland over *C. ciliaris*

Site 4: Junction of Cane River and tributary in the borefield.

E. camaldulensis over *C. ciliaris* in river channel, with *E. victrix* over *Acacia miniritchie* mid storey and *T. wiseana* on floodplain.

Site 5: Floodplain in vicinity of bore 28/88

Open *E. victrix* woodland over *C. ciliaris*

Site 6: 500 m downstream of Cane River–Northwest Highway crossing in vicinity of Jabaddar Pool

Dense *M. argentea* / *E. camaldulensis* woodland along channel, with mixed Acacia scrubland over *T. wiseana* on floodplain.

Table A 1 List of species from Cane River vegetation survey (August 2009)

Family	Species
Amaranthaceae	*Ptilotus pterocaulon*
Cyperaceae	*Cyperus vaginatus*
Malvaceae	*Sida hacketiana*
Mimosaceae	*Acacia glaucocaesia*
	Acacia sp
	Vachellia farnesiana
Myrtaceae	*Corymbia flavescens*
	Eucalyptus camaldulensis
	Eucalyptus victrix
	Melaleuca glomerata
Poaceae	*Cenchrus ciliaris**
	*Cynodon dactylon**
	Triodia wiseana
Solanaceae	*Solanum sp.*

** Denotes exotic species*

Appendix B – River pools in the lower Cane River groundwater resource area

The following list is based on pool mapping conducted by the Department of Water across the Pilbara (DoW 2009). This list may not be definitive and the licensing rules specified in Section 4.2 of this report should also be applied to any pools in the allocation area not on this list.

Table B 1 Details of location and permanency of pools in the lower Cane River alluvial aquifer

Name	Permanency*	Latitude	Longitude
Unknown	Intermittent	-22.009	115.583
Unknown	Intermittent	-22.020	115.591
Unknown	Intermittent	-21.996	115.576
Unknown	Intermittent	-21.992	115.573
Cattle Pool	Intermittent	-21.988	115.569
Jabbadar Pool	Semi-permanent	-21.975	115.547
Unknown	Intermittent	-21.969	115.545
Unknown	Intermittent	-21.981	115.558

** Details of permanency assessment and mapping methodology are provided in Department of Water (2009).*

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.
Allocation limit	Annual volume of water set aside for use from a water resource.
Aquifer	A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water.
Bore	A narrow, normally vertical hole drilled in soil or rock to monitor or withdraw groundwater from an aquifer.
Bore field	A group of bores to monitor or withdraw groundwater.
Consumptive use	The use of water for private benefit consumptive purposes including irrigation, industry, urban and stock and domestic use.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, e.g. lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environment	Living things, their physical, biological and social surroundings, and interactions between all of these.
Groundwater	Water which occupies the pores and crevices of rock or soil beneath the land surface.
Groundwater area	Boundaries proclaimed under the *Rights in Water and Irrigation Act 1914* (WA) and used for water allocation planning and management.
Groundwater-dependent ecosystem	An ecosystem that is dependent on groundwater for its existence and health.
Groundwater pumping	Extraction of water from saturated soil (groundwater) using an electric, wind powered or compressed air pump and bore hole.

Groundwater recharge	The rate at which infiltration water reaches the watertable.
Hydrogeology	The hydrological and geological science concerned with the occurrence, distribution, quality and movement of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Licence	A formal permit which entitles the licence holder to 'take' water from a watercourse, wetland or underground source.
Recharge	Water that infiltrates into the soil to replenish an aquifer.
Salinity	The measure of total soluble salt or mineral constituents in water. Water resources are classified based on salinity in terms of total dissolved salts (TDS) or total soluble salts (TSS). Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt).
Social value	A particular in situ quality, attribute or use that is important for public benefit, welfare, state or health (physical and spiritual).
Stock and domestic water use	Water that is used for ordinary domestic purposes associated with a dwelling, such as: water for cattle or stock other than those being raised under intensive conditions, or water for up to 0.2 ha (if groundwater) or 2 ha(if surface water) of garden from which no produce is sold. This take is generally considered a basic right.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Watercourse	A watercourse includes the bed and banks of anything referred to in paragraph (a), (b) or (c): a) any river, creek, stream or brook in which water flows b) any collection of water (including a reservoir) into, through or out of which anything coming within paragraph (a) flows c) any place where water flows that is prescribed by local by-laws to be a watercourse.
Water-dependent ecosystems	Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers.

Water entitlement	The quantity of water that a person is entitled to take annually in accordance with the *Rights in Water and Irrigation Act 1914* (WA) or a licence.
Wetland	Wetlands are areas that are permanently, seasonally or intermittently waterlogged or inundated with water that may be fresh, saline, flowing or static.
Yield	The volume of water that may be drawn from a well or water supply system.

Volumes of water

One litre	1 litre	1 litre	(L)
One thousand litres	1000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 megalitre	(ML)
One thousand million litres	1 000 000 000 litres	1 gigalitre	(GL)

Map disclaimer – Figures 1 and 2

Datum and projection information

Vertical datum: Australian Height Datum (AHD)

Horizontal datum: Geocentric Datum of Australia 94

Projection: MGA 94 Zone 50

Spheroid: Australian National Spheroid

Project information

Client: Emily Said

Map Author: Dianne Abbott

Filepath: J:\gisprojects\Project\C_series\C2219\0026_Cane_River_Maps\mxd\

Filename: 101025_Cane_boundary_Interim.mxd, 101025_vegetation_CaneRiver.mxd

Compilation date: 03 November, 2010

Disclaimer

These maps are a product of the Department of Water, Water Resource Use Division and were printed as shown.

These maps were produced with the intent that they be used for information purposes at the scale as shown when printing.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Sources

The Department of Water acknowledges the following datasets and their custodians in the production of this map:

Hydrography, Linear (Hierarchy) – DoW – 05/11/2007

Road Centrelines – DoW – Current

Towns –DLI – Current

Topography – Landgate – 23/03/2009

Bores – Water Corporation – Unknown

DWAID Aquifer – DoW – Current

Aerial Photography – Landgate Skyview – 2001-2005

WA Coastline, WRC (Poly) – DoW – 20/07/2006

Australian Coastline - DoW – 08 September, 2002

References and further reading

Astron 2003, *As assessment of erosion at the Cane River wetland*, Prepared for Central Agricultural and Pastoral Aboriginal Corporation, Karratha.

Beesley, L 2006, *Environmental stability: Its role in structuring fish communities and life history strategies in the Fortescue River, Western Australia*, School Of Animal Biology, University of Western Australia, Perth.

Department of Water (DoW) 2009, *Pilbara pool mapping*, Corporate GIS layer, Department of Water, Perth.

—— 2011, *Groundwater risk-based allocation planning process*, Water Allocation Planning Branch, Department of Water, Perth.

Goater, S & Horgan, J 2006, *Stygofauna investigations at the proposed Bulgarene water supply borefield – stygofauna pilot study*.

Haig, T 2009, *The Pilbara coast water study*, Hydrogeological record series, report no. HG34, Department of Water, Perth, p. 183.

Kendrick, P and Stanley, F 2002, 'Pilbara 4 (PIL 4 – Roebourne synopsis)', in *A biodiversity audit of Western Australia's 53 biogeographical subregions in 2002*, Department of Conservation and Land Management, Perth.

Landman 2001, *The ecology and physiology of acacias and eucalypts in the Pilbara region of Western Australia*, University of Western Australia, Perth.

Martin 1996, *Onslow – Cane River borefield, geophysical investigation*, Hydrogeology report no. 33, Water and Rivers Commission, Perth.

Morgan, D, Gill, H, Allen, M & Maddern, M 2003, *Distribution and biology of fish in inland waters of the Pilbara (Indian Ocean) drainage division*, Project no. 003026, Centre for Fish and Fisheries Research, Murdoch University, Perth.

O'Grady, AO, Eamus, D, Cook, P, Lamontagne, S, Kelly, G & Hutley, L 2002, *Tree water use and sources of transpired water in riparian vegetation along the Daly River, Northern Territory*, Department of Environment and Heritage, Canberra.

Pusey, B, Kennard, M & Arthington, A 2004, *Freshwater fishes of north-eastern Australia*, Nathan, CSIRO Publishing, Queensland.

Reeves, JM, De Decker, P & Halse, SA 2007, 'Groundwater Ostracods from the arid Pilbara region of northwestern Australia: distribution and water chemistry', *Hydrobiology,* 585**,** pp. 99–118.

Tomlinson, 1994, *Onslow groundwater scheme review*, Report no. WG179, Water Resources Directorate, Groundwater and Environment Branch, Water Authority, Perth.

Van Vreeswyk, AME, Payne, AL, Leighton, KA & Henning, P 2004, *An inventory and condition survey of the Pilbara region*, *Western Australia*, Technical bulletin no. 92, Department of Agriculture, Perth.

Department of **Water**
168 St Georges Terrace, Perth, Western Australia
PO Box K822 Perth Western Australia 6842
Phone: 08 6364 7600
Fax: 08 6364 7601
www.water.wa.gov.au