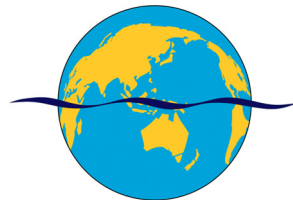


Karalundi Community Drinking Water Source Protection Assessment

January 2010

Department of Housing



Global Groundwater

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Purpose of this assessment^[A1]

A safe drinking water supply is essential to the wellbeing of all communities. Effective community water source protection is fundamental to minimising risks to public health and the cost of supplying water to consumers. The Australian Drinking Water Guidelines, developed by the National Health and Medical Research Council (NHMRC, 2004) provides a framework for management of drinking water quality. The guidelines propose a multiple barrier approach as the most effective method of protecting drinking water. Management of the community drinking water source is considered the first important barrier and involves:

- understanding the community water source, and the hazards and events that can compromise drinking water quality; and
- developing and implementing preventive strategies and operational controls necessary to ensure the safest possible raw water supply (i.e. before treatment).

The Western Australian Government is working towards meeting the NHMRC (2004) framework by producing Drinking Water Source Protection Plans (DWSPP) for all Public Drinking Water Source Areas (PDWSA). The process involves:

Stages in development of a plan		Comment
1	Prepare a Drinking Water Source Protection Assessment (DWSPA) and Short Term Action Plan (STAP)	Prepared following community survey and preliminary information gathering. STAP will recommend mitigation strategies considered straight-forward that are to be implemented prior to DWSPP.
2	Conduct stakeholder consultation	Advice sought from key stakeholders using the assessment as a tool for information and discussion.
3	Prepare a Draft Drinking Water Source Protection Plan	Draft plan developed taking into account input from stakeholders and any additional advice received.
4	Release a Draft Drinking Water Source Protection Plan	Draft plan released for a 6 week public consultation period.
5	Publish approved Drinking Water Source Protection Plan	Final plan published after considering advice received in submissions. Includes recommendations on how to protect water quality.

Where a fully consulted DWSPP does not exist for a community, a Drinking Water Source Protection Assessment (DWSPA) is prepared to readily reflect available information for use in planning assessments and decision making. The Department of Housing, through the Remote Area Essential Services Program (RAESP), has operational responsibility for water quality at the communities covered by the RAESP, which includes Karalundi. The Department of Housing has contracted Parsons Brinckerhoff (PB) to program manage key elements of the RAESP which includes contracts with Regional Service Providers (RSP) who provide planned and unplanned maintenance services at the communities. The RSP for the Karalundi community is Pilbara Meta Maya. Department of Housing has also commissioned PB to prepare community drinking water source assessments referred to as Drinking Water Source Protection Assessments (DWSPA). PB subcontracted the DWSPA for Karalundi to Global Groundwater.

This DWSPA provides information on Karalundi's drinking water source which includes an assessment on the current and future risks to the drinking water source. It is a necessary precursor to developing a plan to protect the community's drinking water source known as a Drinking Water Source Protection Plan (DWSPP).



1. Introduction

The Karalundi Aboriginal community is located approximately 55 km north-northeast of Meekatharra in the Gascoyne/Murchison region of Western Australia. The community lies close to the Yalgar River and about 1 km west of the Great Northern Highway (Figure 1-1).

The community was established as a Seventh-Day Adventist Mission in 1954 and has a population of approximately 150 to 200 people, of which 90 to 100 are students at the school. Most of the students are boarders. Future plans for the community may see the population reach 450 people (Plexus Town Planning, 2007).

Karalundi obtains potable water supplies from two production bores located on the access road between the community and the Great Northern Highway. Average daily abstraction from the bores is 381 m³/day, (PB, 2008), which equates to 0.52 m³/person/day, assuming a population of 200 people.

On 28th August 2009, Global Groundwater conducted a site visit to investigate potential risks and hazards to the water source and the water supply system at Karalundi. This report presents the results of the site visit.



2. Karalundi water supply overview

2.1 Bore construction and location

Original drilling and construction details are not available for the bores and wells at Karalundi and this hampers adequate assessment. Table 2-1 sets out a summary of available production bore and well details. Photographs of each production and irrigation bore and well have been included in Appendix B.

Potable water supplies for the community are currently drawn from two production bores known as bore 1 and bore 2. The bores are located about 180 m and 275 m southeast of the community, respectively, on the access road to the Great Northern Highway and are about 97 m apart (Figure 2-1).

There is an additional unmetered bore, known as, Central Park Bore or bore 3, located near the corner of Ervilla Court and Crystal Brook Road in the southern part of the community which is used for irrigation of the oval (Figure 2-1). Anecdotal accounts are that this bore is capable of producing more water than bores 1 and 2 combined (PB, 2008). Anecdotal advice of community members is also that the bore has previously been used for potable supply.

A stock bore known as bore 4 is located about 1.1 km west of the community. Three wells are located in the north eastern part of the community in the area of crop production. Wells 1 and 2 are used to irrigate crops and well 3 is abandoned. Swimming Pool Well is adjacent to the old swimming pool in the east of the community and is used for irrigation of an orchard.

2.2 Infrastructure and treatment

Water for potable supplies at Karalundi are drawn from bore 1 and bore 2, which are fitted with electric submersible pumps and flow meters. Electric power to the bores is reticulated via overhead powerlines from the community.

The water is pumped from the bores into two ground tanks before being transferred into an elevated tank. Water is then distributed via gravity into the reticulation system.

Groundwater is treated using reverse osmosis and UV before entering the reticulation lines that supply the community with drinking water. Water quality results suggest hand dosing with chlorine may also be undertaken but details of this are unclear and should be followed up.



Table 2-1 Summary of production bore details

Bore name	WGS 84 Coordinates (decimal degrees)		Case Depth (mbgl)	Case Material	Case ID (mm)	Slots (m bgl)		Recommended Rate (m ³ /day)	SWL (m bgl)	Comments
	Latitude	Longitude				From	To			
bore 1	- 26.128968 ^{ab}	118.687650	na	PVC ^a	~150 ^a	na	na	na	na	Production bore
bore 2	- 26.129269 ^{ab}	118.688540	na	PVC ^a	~150 ^a	na	na	na	na	Production bore
Central Park Bore (bore 3)	-26.128200 ^a	118.684050	na	na	na	na	na	na	na	Irrigation bore – oval, spear point in base of well
bore 4	-26.124300 ^a	118.670010	na	PVC ^a	na	na	na	na	na	Stock bore
well 1	-26.126450 ^a	118.684770	na	wood ^a	>1000 ^a	-	-	na	~4.0 ^a	Irrigation well – crop production, square
well 2	-26.126470 ^a	118.685670	na	steel ^a	~1000 ^a	-	-	na	~4.0 ^a	Irrigation well – crop production
Swimming Pool Well	-26.127530 ^a	118.685590	na	wood ^a	>1000 ^a	-	-	na	~4.0 ^a	Irrigation well – orchard, adjacent to old swimming pool, square
well 3	-26.125540 ^a	118.684130	na	concrete ^a	>1000 ^a	-	-	na	~3.0 ^a	Abandoned well, concrete liners

a Data from field visit, August 2009. Co-ordinates have an error of 3 to 5 m.

b Co-ordinates from Ascon (Landinfo) data, error unknown but likely <0.5 m.

na – information not available



2.3 Bore capacities, recommended yields and water consumption

The capacities and recommended yield for bore 1 and bore 2 are not available. A bore at Karalundi was previously reported to have capacity of 1636 m³/day (Brookfield, 1963) but the bore name or number was not provided and this data cannot be correlated to the known bores.

Average daily pumping volumes calculated from bore meter readings between May 2008 and July/August 2009 indicate that bore 1 is the primary contributor to Karalundi's water supply pumping an average of 223 m³/day. However, the pump in this bore shuts down after a short period of operation. The reasons for the problem are not known but may be bore (influx of fines, scaling), aquifer, or pump (incorrectly sized pump) related, or a combination of these. This cannot be confirmed without details of bore construction, bore capacity, pump depth setting and pump capacity. Bore 2 pumps an average of 103 m³/day.

Anecdotal advice of the Essential Services Officer at Karalundi is that Central Park bore (bore 3) is pumped at higher rates than the potable supply bores. Swimming Pool Well and wells 1 and 2 have large pumps and irrigate large areas and so it can be inferred that they are generally pumped at higher rates than the potable supply bores.

The available meter readings suggest water consumption at Karalundi is 326 m³/day, which is reasonably close to the 381 m³/day indicated by PB (2008). The difference might be due to seasonal or population variations. However, regular water audits are not carried out at Karalundi.

2.4 Previous investigations

Brookfield (1963) undertook a regional appraisal of groundwater in the area with a view to determining potential for irrigated horticulture. Elias et al. (1982) presented a summary of water resources for the region as part of explanatory notes for the regional scale geological mapping. However, historical information for the community is limited and original details of bores drilled at the community are incomplete or unavailable.

A search of the Water Corporation database did not find any data for bores drilled at Karalundi. Limited data is available from the Department of Water's WIN database for five shallow wells at Karalundi with depths of 2.4 to 9.1 m. Their supply is given as about 13 m³/day for three of the wells, and 1637 m³/day, for the one bore known as Irrigation Well. Salinity of 1500 mg/L is given for one known as Karalundi Well. The accuracy of this data is not known and it is not of sufficient detail to enable correlation of the data to known bores and wells.

2.5 Environmental setting

2.5.1 Physiography

The physiography of the region is characterised by rugged hills with granitoid rocks forming low outcrops beneath breakaways (Elias et. al, 1982). Karalundi community is situated in the upper part of the Yalgar River catchment and Elias et al. (1982) suggest that saline drainages in the region are remnants of an extensive palaeodrainage network.



The vegetation of the area is broadly described as the “mulga zone” of arid shrublands and woodlands (Australian Natural Resource Atlas).

2.5.2 Climate

Climate data for Karalundi community was obtained from Meekatharra Airport Meteorological Station (Bureau of Meteorology), which is located about 56 km south-southwest of the community. Table 2-2 shows average annual rainfall from 2000 to 2008.

Climate of Karalundi is classified as semi-arid to arid, with hot summers, and cool to mild winters. The mean maximum temperature at Meekatharra is 28.9°C and summer maximum temperatures can be in excess of 40°C. The mean minimum temperature is 15.8°C and winter minimum temperatures can be below freezing.

Rainfall at Meekatharra between 2000 and 2009 is summarised in Table 2-2. Rainfall is generally higher between the months of January and June and is derived from both cyclonic storms from the north and winter rains from the south. The long-term average annual rainfall (1944 to 2008) is 235.5 mm. The total rainfall for 2008 was above average at 302.2 mm.

Figure 2-2 shows the Meekatharra station rainfall records between 1995 and 2009. Between 1995 and 2008 a predominantly wet pattern is evident with ten out of fourteen years exhibiting higher than average rainfall.

The rainfall data has limited relevance to this plan as it stands, as waterlevels for bores are not available to correlate this to aquifer levels and subsequently to resource estimates.

Table 2-2 Rainfall data recorded at Meekatharra Airport Station 7045

Year	Rainfall (mm)												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2000	135.4	55.4	259.0	38.6	0.0	1.2	11.0	19.8	3.8	6.8	22.4	19.8	573.2
2001	33.8	174.2	2.4	18.6	20.2	1.0	7.4	8.2	1.0	18.6	3.0	18.4	306.8
2002	32.4	11.6	41.4	11.4	13.8	18.2	2.0	7.8	6.2	0.0	8.4	33.0	186.2
2003	35.0	4.2	40.6	76.8	9.0	33.2	2.2	14.0	0.6	0.0	24.4	0.0	240.0
2004	39.4	80.4	8.2	57.6	8.4	0.0	59.6	1.0	3.2	2.8	27.0	1.4	289.0
2005	0.0	7.6	7.6	2.8	44.2	13.8	15.4	14.2	2.4	4.4	1.4	11.6	125.4
2006	86.8	85.8	138.0	26.4	1.8	0.8	3.6	0.8	8.4	36.8	7.2	28.6	425.0
2007	23.8	13.8	0.0	24.8	9.2	2.6	21.6	0.8	1.2	1.2	1.2	19.0	119.2
2008	5.4	127.6	57.2	13.8	2.2	10.8	16.8	17.6	0.0	6.2	29.8	14.8	302.2
2009	28.8	11.8	2.6	10.0	2.0	18.6	18.2	4.0					
Average	27.5	35.9	28.6	20.9	23.5	30.8	22.0	11.3	4.6	6.4	11.6	12.2	235.5

Average taken from rainfall data 1944 to 2009, Meekatharra Airport Station 7045, Bureau of Meteorology.

Value = greater than average

2.5.3 Geology

The geology of the region is available from 1:250 000 scale regional geological mapping given by Elias et al. (1982). Karalundi community is located at the northern margin of the Archaean Yilgarn Craton. It is underlain by Early Proterozoic rocks of the Glengarry Sub-basin of the Nabberu Basin and these form the basement rocks of the area. The basement



rocks are predominantly obscured by Cainozoic superficial sediments. Table 2-3 summarises the stratigraphy that may be present at Karalundi, based on the regional geological mapping (Elias et al., 1982).

The superficial sequence consists of alluvial, sand, silt and gravel along with calcrete. Where calcrete occurs it is generally associated with older alluvium often occurring as cement within the alluvial sequence. The thickness of these deposits at Karalundi is not known but it is expected that they would generally be less than 10 m thick based on superficial deposits including calcrete around Wiluna to the southeast (Sanders, 1973).

The superficial sequence obscures the basement rocks at Karalundi but the Findlayson Sandstone outcrops about 1.5 km southwest of the community. It consists of quartz arenite, conglomerate and shale and may be between about 50 and 500 m thick in the region based on the regional mapping of Elias et al. (1982). It is also possible that the community is underlain by an unnamed Glengarry Group unit consisting of quartz wacke, lithic wacke and shale.

Table 2-3 Summary of the Lithostratigraphy of the Glengarry Sub-basin

Age	Unit	Maximum thickness (m)	Lithology
Quaternary	Superficial	-	Sand, silt and gravel
Cainozoic	Superficial	-	Calcrete, laterite and silcrete
Early Proterozoic	Glengarry Group - unassigned	-	Chert, limestone, shale, sandstone, quartz wacke, basalt, quartz arenite and conglomerate.
	Findlayson Sandstone	50 - 500	Quartz arenite, conglomerate and shale

2.5.4 Regional Hydrogeology

Groundwater originates as infiltrated rainfall and accumulated runoff with the latter being the primary source of recharge to aquifers. It occurs in secondary porosity of the basement rocks (for example in weathering zones, fractures or bedding plane partings) and in primary and secondary porosity of the superficial sequence. Once infiltrated, it moves down hydraulic gradient towards the coast or toward inland evaporite lakes.

Groundwater will be freshest at intake areas and increase in salinity down hydraulic gradient. Salinity of less than 1000 mg/L can be encountered close to recharge areas but hypersaline groundwater can occur at terminus of groundwater flow at evaporate lakes.

The most prospective unit in the region for large, sustainable yields of groundwater is calcrete within the superficial sequence, which can have significant secondary porosity of solution channels and cavities that can provide significant storage and high yields. This is in comparison to the basement rock units which overall have lower storage and lower prospectivity of intersecting high yields and are unreliable as aquifers (Elias et al., 1982).



2.5.5 Local hydrogeology

The community is located on the northern margin of a large area of calcrete based on the regional geological mapping (Elias et al., 1982). While actual drilling data from community bores and wells are not available, it is likely that the calcrete forms a shallow unconfined aquifer, with relatively high storage and exploited by the community bores. The calcrete aquifer will be underlain and bounded by aquifers of much lower storage formed by weathered and fractured basement rocks.

Recharge to the calcrete aquifer is predominantly by infiltration of accumulated runoff through the alluvium and calcrete. Groundwater flow direction is not accurately known but it is likely to broadly follow surface water flow and move generally west past the community following the Yalgar River. The watertable is about 4 m below surface.

Groundwater at the community is marginal to brackish with salinity between 1300 and 2000 mg/L, which is generally within the range of salinity expected for the area based on non-synoptic groundwater salinity data provided by Elias et al. (1982). An area with lower groundwater salinity may occur approximately 2 to 3 km northwest of the community based on those data. It is anticipated that lower salinity groundwater may occur for relatively short periods after significant recharge events but that salinity will increase between recharge events.

2.6 Proposed land uses and activities

Proposed activities for Karalundi include a capital works programme planned for 2009 under RAESP which has identified that Karalundi needs an additional water supply bore.

There are also several activities proposed for the community in the Community Layout Plan report (Plexus Town Planning, 2007) including:

- Construction of new residences and facilities within the current community area.
- Relocation of the airstrip west of its current location,
- Ongoing development of the farm facilities, and
- Relocation of sewerage ponds to a site about 400 m northwest of current ponds.

2.7 Future water supply requirements

Water demand in RAESP communities generally ranges from 0.3 m³/day to 1 m³/day per person which is higher than typical urban water consumption, presumably because of significant waste through leaks in internal plumbing, based on anecdotal advice of the RAESP manager. Based on this assumption, the water demand at Karalundi ranges from 60 to 200 m³/day. However, an assessment such as a water audit should be undertaken to determine the community water requirements.

While the future water requirements for the Karalundi community are not clear, it is anticipated the potential land use developments and community population increase will increase the demand for water supplies.

Meter readings indicate the community bores can operate at 326 m³/day and on this basis should be adequate to meet the 200 m³/day currently estimated requirement. However, there appears to be some problem with the operation of bore 1, which shuts down after a short



period of operation and if either bore 1 or bore 2 fail, then no standby capacity is available from other bores.

Bores 1 and 2 require appraisal including testing to determine their condition and capacity and a review should then be undertaken to determine the most appropriate bore pumps.



3. Water quality

A wide range of chemical, physical and microbiological factors can impact on water quality and therefore affect the provision of safe, good quality and aesthetically acceptable drinking water to consumers.

The Department of Housing, through the RAESP, has operational responsibility for water quality at Karatundi. The Water Quality Branch of the Department of Health is responsible for ensuring compliance with standards set by the NHMRC (2004) across the state, including water quality monitoring.

Water quality is regularly monitored at Karatundi for microbiological contamination, health-related and aesthetic (non-health related) characteristics in accordance with the principles of NHMRC (2004) guidelines. Current sampling requires analyses and reports on 37 aesthetic, physical, biological and chemical water quality parameters. The determination and reporting of water quality is a completely 'transparent' process involving:

- regular testing,
- open reporting of results to all involved parties,
- communication to involved parties of corrective actions and timeframes,
- inspection/audit by regulatory body,
- assessment and reporting of performance against compliance criteria; and
- PB reports to the states advisory committee for Purity of Water, which in turn reports to the Department of Health.

3.1 Water quality performance criteria

3.1.1 Microbial testing and response criteria

Non-conformances of microbiological analysis are managed as follows:

- The presence of thermotolerant coliforms (TTC) or Escherichia coli (often referred to as E-coli) warrants immediate attendance and the community is advised to boil their water.
- When Naegleria is detected the community is notified and the RSP is instructed to attend the community as soon as possible for appropriate remedial action.

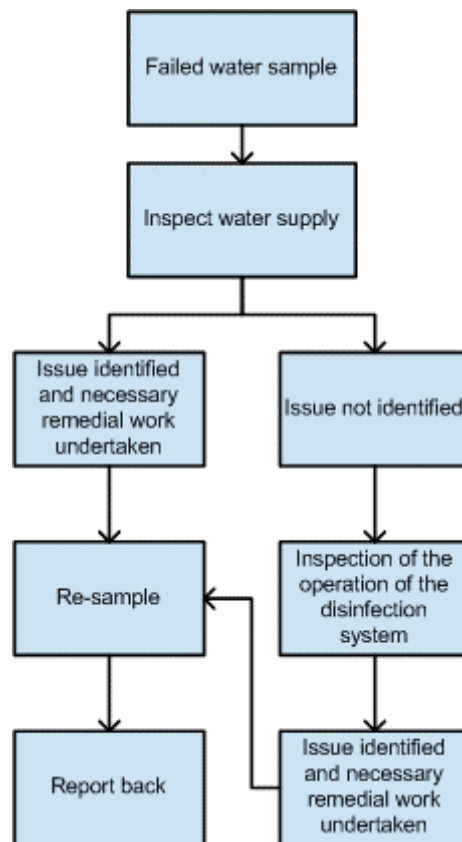
3.1.2 Corrective action for microbiological non-compliance

When non-compliance is recorded, notifications are sent to the community, the Department of Health, the Regional Service Provider (RSP) for the region, the Local Shire, the Regional Population Health Unit and the Department of Employment and Training (Regional Office) if there is a school at a community.

Corrective action is then immediately arranged with the relevant RSP. Subsequent to correction action and remedial work, the bore water is re-sampled and an all-clear notification is sent to all parties. The corrective measures undertaken by the RSP is shown below in Figure 3-1.



Figure 3-1 Summary of corrective action for microbiological non-compliance



3.2 Water quality sampling programme

The current sampling regime analyses and reports on 37 aesthetic, physical, biological and chemical water quality parameters. Bore water is tested every month, every 3 months, or every 6 months depending on the analyte. Table 3-1 shows the sampling frequency for each analyte.



Table 3-1 Karalundi water quality sampling programme

Parameter	Sampling frequency		
	Monthly	Quarterly	6 monthly
Microbiological			
Total Coliforms	✓		
Thermotol Coli	✓		
E. Coli	✓		
Nutrients			
Nitrate NO ₃		✓	
Nitrite NO ₂		✓	
Chemical			
pH			✓
TDS			✓
Hardness (CaCO ₃)			✓
Colour			✓
Turbidity			✓
Na			✓
Cl			✓
Sulphate			✓
Fe			✓
Mn			✓
Al			✓
Mg			✓
Ca			✓
K			✓
SiO ₂			✓
As			✓
F			✓
Hg			✓
Ag			✓
B			✓
Ba			✓
Be			✓
Cd			✓
Cu			✓
Mo			✓
Ni			✓
Pb			✓
Se			✓
Sn			✓
Zn			✓
U			✓
Cr			✓



3.3 Water quality results

Microbial water quality data for Karatundi community have been collected since January 2001. Nutrient, physical and chemical data have been collected since December 2001. The sample results are presented in Appendix C and summarised in Table 3-2. The water quality data in Table 3-2 and the following text are compared to the Australian Drinking Water Guidelines (ADWG) set out by the NHMRC (2004). Fact sheets for analytes which exceed the guidelines are given in Appendix D.

Groundwater pumped from the bores is marginal with salinity mostly at 1300 mg/L and one result at 2000 mg/L TDS. The groundwater is also hard with CaCO₃ hardness between 410 and 850 mg/L. Concentrations of nitrate and sulphate can be above health based guidelines and concentrations of sodium and chloride well above aesthetic guideline values. All other tested physical and chemical parameters are within the guideline values.

Since 2001 numerous water samples collected from the bores have exceeded the health NHMRC (2004) guidelines for total coliforms, thermotolerant coliforms and E. Coli. Reasons for the occurrence of coliforms in the samples are not confirmed but likely due to fauna (faeces and remains) contacting water in the aquifer and/or the bores, although other sources cannot be discounted. While the reasons are not clear, the high incidence of biological contaminants is not unexpected in an unconfined calcrete aquifer with a shallow watertable and highlights the vulnerability of such a water source [b10].

Water from the bores is treated by reverse osmosis to reduce the salinity and correspondingly, the reticulated water is fresh, with salinity between 64 and 260 mg/L TDS. All other major and minor ions tested for in the reticulated water are within the guideline values.

Since 2001 one water sample collected from reticulation has slightly exceed the aesthetic NHMRC (2004) guideline for pH. A number of reticulation samples have also exceeded the NHMRC (2004) health guidelines for; total coliforms and thermotolerant coliforms with one confirmed case of E. Coli. Residual chlorine levels are less than recommended under the guidelines in numerous reticulation samples. It is not known if the biological contaminants in the reticulated water are caused by failure of the UV treatment at those times or lack of chlorine dosing or introduction of contaminants post treatment. However, given the nature of the aquifer and the occurrences of biological contaminants in the raw water, the occurrences of biological contaminants in the treated water highlights the need for regular monitoring and maintenance of the water treatment system to ensure adequate operation. The human health effects caused by pathogen waterborne transmission vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis and typhoid fever (NHMRC, 2004).



Table 3-2 Summary of water quality

Sample point	General water quality	Major ions	Minor ions	Trace elements	Microbiological
Reticulation	<ul style="list-style-type: none">pH exceeds the aesthetic guideline for drinking water (6.5-8.5) in one sample since December 2001. pH ranges from 6.4 to 7.9. The average value is 7.3.	<ul style="list-style-type: none">All major ions tested for are within the NHMRC (2004) drinking water guidelines.	<ul style="list-style-type: none">All minor ions tested for are within the NHMRC (2004) drinking water guidelines.	<ul style="list-style-type: none">All trace elements tested for are within the NHMRC (2004) drinking water guidelines.	<ul style="list-style-type: none">Total coliforms exceed the NHMRC (2004) health guideline for drinking water (>0 cfu/100 mL) in 17 samples since January 2001. Concentrations range from 0 cfu/100 mL to 94 cfu/100 mL.Thermotolerant coliforms exceed the NHMRC (2004) health guideline for drinking water (>0 cfu/100 ml) in six samples since January 2001. Concentrations range from 0 cfu/100 mL to 73 cfu/100 mL.E. coli concentrations exceed the NHMRC (2004) health guideline for drinking water (>0 cfu/100 ml) in one sample since January 2001. Concentrations range from 0 cfu/100 mL to 73 cfu/100 mL.Residual chlorine concentrations exceed the NHMRC (2004) health guideline (<0.5 mg/L) in 35 samples since January 2003. Concentrations range from 0 mg/L to 40 mg/L.



Sample point	General water quality	Major ions	Minor ions	Trace elements	Microbiological
Bore samples	<ul style="list-style-type: none"> ▪ TDS exceeds the aesthetic guideline for drinking water (<500 mg/L) in seven samples since February 2008. TDS ranges from 1300 to 2000 mg/L. The average value is 1400 mg/L. ▪ Hardness exceeds the aesthetic guideline for drinking water (<200 mg/L) in seven samples since February 2008. Hardness ranges from 410 to 850 mg/L. The average value is 491 mg/L. 	<ul style="list-style-type: none"> ▪ Nitrate (as NO₃) exceeds the health guideline for drinking water (50 mg/L) in three samples since February 2008. Nitrate ranges from 41 to 62 mg/L. The average value is 51 mg/L. ▪ Sulphate exceeds the health guideline for drinking water (500 mg/L) in one sample and exceeds the aesthetic guideline (<250 mg/L) in five samples since February 2008. Sulphate ranges from 242 to 644 mg/L. The average value is 319 mg/L. ▪ Sodium exceeds the aesthetic guideline for drinking water (180 mg/L) in seven samples since February 2008. Sodium ranges from 257 to 421 mg/L. The average value is 303 mg/L. ▪ Chloride exceeds the aesthetic guideline for drinking water (250 mg/L) in seven samples since February 2008. Chloride ranges from 366 to 523 mg/L. The average value is 401 mg/L. 	<ul style="list-style-type: none"> ▪ All minor ions tested for are within the NHMRC (2004) drinking water guidelines. 	<ul style="list-style-type: none"> ▪ All trace elements tested for are within the NHMRC (2004) drinking water guidelines. 	<ul style="list-style-type: none"> ▪ Total coliforms exceed the NHMRC (2004) health guideline for drinking water (>0 cfu/100 mL) in 33 samples since January 2001. Concentrations range from 0 cfu/100 mL to >1000 cfu/100 mL. ▪ Thermotolerant coliforms exceed the NHMRC (2004) health guideline for drinking water (>0 cfu/100 ml) in 13 samples since January 2001. Concentrations range from 0 cfu/100 mL to >1000 cfu/100 mL. ▪ E. coli concentrations exceed the NHMRC (2004) health guideline for drinking water (>0 cfu/100 ml) in 11 samples since January 2001. Concentrations range from 0 cfu/100 mL to >1000 cfu/100 mL.

Note: Bore water treated by reverse osmosis resulting in reduction of TDS, hardness, nitrate, sulphate, sodium and chloride prior to reticulation to the community.



4. Hazard identification and risk assessment

On 28th August, 2009, Global Groundwater conducted a site visit to investigate potential risks from operational issues and land use hazards on the water source. The CEO or essential service operator (ESO) for Karalundi accompanied Global Groundwater personnel during the site visit and provided access to the areas for inspection. Figure 4-1 shows the major land use hazards and management priorities and Appendix E shows the Department of Planning and Infrastructure Community Layout Plan. The following is an assessment of risks resulting from existing land uses and operational issues based on the assessment procedure set out by PB in Appendix F.

4.1 Risk assessment procedure

The risk assessment framework used in this report is based on the Australian Drinking Water Guidelines (ADWG) (NHMRC, 2004) and the DoW's Water Quality Protection Note (WQPN) – Risk Assessment of Public Drinking Water Source Areas. The methodology used to determine the level of risk and management priority is summarised in Appendix F and described in more detail in the ADWG (NHMRC, 2004). This risk assessment considers current protection strategies, management practices and existing and proposed land uses/activities potentially hazardous to the community water source. A risk level and management priority level is assigned to each hazard by assessing the overall likelihood and consequences of the source being contaminated.

4.2 Risks from operational issues

Risks from operational issues are considered in this assessment to determine the vulnerability of the drinking water for the community. These risks highlight the need to improve the infrastructure to improve the water quality for the community.

4.2.1 Inadequate wellhead protection

Bore 1 is located about 170 m and bore 2 about 250 m from the community and adjacent to the community access road.

The bore sites are up likely groundwater flow gradient of the community. In addition, anecdotal advice is that the irrigation bore and wells within the community are pumped at higher rates than the potable supply bores which would possibly increase the hydraulic gradient from the potable supply bores toward the community. Because of these factors, the aquifer in the vicinity of the potable supply bores is less likely to be impacted by contamination from daily community activities.

The likelihood for contamination of the drinking water source from community activities is considered *unlikely*, the consequence is considered *high*, and the risk is *significant*.



[D11]

4.2.2 Inadequate bore/sump security

Potable water supply bores are adequately fenced and capped. The irrigation bore, wells and an excavated sump within the community are not fenced or adequately capped and are susceptible to vandalism and access by fauna. However these are down anticipated groundwater flow gradient of the production bores.

The likelihood for contamination of the drinking water source by entrance to the aquifer of potential contaminants via these direct pathways at the potable supply bores is considered *unlikely*, the consequence is considered *high*, and the risk is *significant*.

The likelihood for contamination of the drinking water source by entrance to the aquifer of potential contaminants at the irrigation wells (except Swimming Pool Well) and excavated sump is considered *likely*, the consequence is considered *medium*, and the risk is *major*.

The likelihood for contamination of the drinking water source by entrance to the aquifer of potential contaminants at Swimming Pool Well, which is within the WPZ (Wellhead Protection Zone) for bore 1 is considered *likely*, the consequence is considered *high*, and the risk is *high*.

4.3 Risks from existing land uses

Risks from existing land uses may potentially result in degradation or depletion of the water source itself. This risk assessment is based on multiple factors including an assumed groundwater flow direction. Further investigations are recommended to confirm groundwater flow directions.

4.3.1 Roads

The proximity of the access road to the bores and the location of the Great Northern Highway, up hydraulic gradient of the bores present a potential hazard from possible spills of fuels or chemicals being transported. The aquifer is quite vulnerable and if a significant spill occurred along these roads, there is a high chance of aquifer contamination resulting.

The likelihood for contamination of the drinking water source from fuel or chemical spills along the road is considered *rare*, the consequence of such a spill is considered *high*, and the risk is *moderate*.

4.3.2 Workshop

The community workshop is located in the centre of the community and approximately 390 m down the inferred hydraulic gradient of bore 1, which is the closest production bore to the community. Refuelling, repairs and maintenance at the workshop may result in hydrocarbon spillage.



The likelihood of a hydrocarbon spill contaminating groundwater is considered *unlikely*, the consequence is *medium*, and the risk is *moderate*.

4.3.3 Fauna

Pathogen contamination of the water source may occur through fauna contacting the water or animal excreta entering the water source. This may arise through direct pathway (unsecured headworks) or through vertical migration of the contaminant through the vadose zone.

Depth to groundwater in the area is shallow (approximately 4 m bgl) and the aquifer material is likely to have high permeability, therefore the likelihood of drinking water pathogen contamination from fauna entering the water source is considered *likely*, the consequence is *high*, and the risk is *high*.

4.3.4 Sewerage system

Karalundi has a deep sewerage system which includes septic tanks attached to individual buildings with grey water fed to a transfer pump station and then to the waste water treatment ponds, directly west of the livestock yards in the north of the community. The ponds are located about 630 m northwest and down-gradient of bore 1. The performance of the waste water system has not been assessed by water audit. Leaks in the reticulation system, flood events or overflows may result in infiltration of sewage into groundwater.

Based on the assumed groundwater flow direction (west) and distance of the production bores from the waste water treatment ponds the likelihood of leachate from the reticulated sewerage contaminating the drinking water is considered *possible*, the consequence is considered *high*, and the risk is *major*.

4.3.5 Rubbish tip

The current rubbish tip is located approximately 1 km west of the community and about 1.5 km west of bore 1. The confining properties of the tip are unknown, but it is assumed the tip is not lined.

It's highly likely that leachate from an inadequately lined rubbish tip will impact the aquifer. However based on the position of the tip outside the water reserve the likelihood of this impacting the drinking water source is *rare*, the consequence is *medium*, and the level of risk is *low*.

4.3.6 Power station, chemical shed and fuel storage area

The power station and chemical shed are located in the northern part of the community and approximately 390 m northwest and down-gradient of bore 1. The power station consists of three diesel generators and fuel tanks. Various types of chemicals are stored in a shed directly west of the power station.

Considering the location and distance of the production bores from the power station, the likelihood of groundwater contamination from hydrocarbon spillage is considered *possible*, the consequence is considered *medium*, and the risk is *significant*.



4.3.7 Farm sheds

The farm sheds are located in the northern part of the community adjacent to the stock yards and areas of crop production. A fuel pump is located at the sheds. The farm sheds are 570 m down-gradient of bore 1. Spills/leakage/leaching of fuels, chemicals or pesticides in sufficient volumes at the farm sheds has high chance of entering the aquifer.

The likelihood of groundwater contamination from activities at the farm sheds is considered *possible*, the consequence is *medium*, and the risk is *significant*.

4.3.8 Stock yards

Stockyards are located in the northern part of the community and animals including sheep and horses are held there. There is potential for contamination from animal excreta and carcasses.

The bores are at least 540 m up-gradient of the stockyards. The likelihood of groundwater contamination from this area is considered *possible*, the consequence is considered *low* and the risk is *moderate*.

4.3.9 Agricultural areas

Agricultural areas (including irrigated pasture, animal husbandry and orchard) are located in the northern and eastern part of the community. Fertilisers and pesticides are likely be used and would represent a diffuse source of potential contamination.

The likelihood of groundwater contamination from activities in the agricultural areas, excluding the orchard is considered *likely*, the consequence is considered *low*, and the risk is *significant*.

The likelihood of groundwater contamination from activities in the orchard, which is within the WPZ of bore 1, is considered *likely*, the consequence is considered *high*, and the risk is *high*.

4.3.10 Airstrip

The airstrip is located directly west of the community and at least 600 m from the production bores. Refuelling of aircraft or mishandling/improper containment of fuel at the airstrip may result in hydrocarbon spills.

The likelihood of water source contamination resulting from a hydrocarbon spill is considered *rare*, but due to the distance and direction from the production bores, the consequence is considered *low* and the risk is *low*.



Table 4-1 Drinking water quality risk assessment

Activity	Description	Hazard	Level of risk	Management priority
Operational risks				
Inadequate wellhead protection	Production bores up likely groundwater flow gradient of community but within 250 m of the community. Bores may be susceptible to contamination from community activities.	Degradation of water source.	Significant	Medium
Inadequate bore/sump security: potable supply bores	Potable supply bores are adequately fenced.	Degradation of water source.	Significant	Medium
Inadequate bore/sump security: Irrigation wells/sump	Irrigation wells and excavated sump are not adequately fenced.	Degradation of water source.	Major	Medium
Inadequate bore/sump security: Swimming Pool Well	Swimming Pool Well is not adequately fenced and is within the WPZ for bore 1.	Degradation of water source.	High	High
Existing land use risks				
Roads	Potential for contamination from spills along Great Northern Highway.	Degradation of water source.	Moderate	Low
Workshop	The workshop is located in centre of community. Potential for aquifer contamination from spillage of hydrocarbons from maintenance work.	Hydrocarbons contaminating water source.	Moderate	Low
Fauna	Fauna and animal excreta contaminating groundwater near wellhead	Pathogens contaminating water source.	High	High
Sewerage system	Leaks in the reticulated system, flood events or overflows may result in infiltration of sewage into groundwater.	Leachate of wastewater contaminating the water source.	Major	Medium
Rubbish tip	Rubbish tip located 1 km west of the community.	Leaking of contaminants into groundwater	Low	Low
Power station, chemical shed and fuel storage	Power station located in northern part of community. Potential for spillage of hydrocarbons during refuelling.	Hydrocarbons contaminating water source.	Significant	Medium
Farm sheds	Farm sheds with fuel pump in northern part of community.	Hydrocarbons contaminating water source.	Significant	Medium



Karalundi community
Drinking water source protection assessment

Stock yards	Stock yards in north of community. Potential contamination from animal excreta and carcasses.	Pathogens contaminating water source.	Moderate	Low
Agricultural areas: excluding orchard	Located in northern part of community. Likely to be diffuse sources of fertilisers and pesticides.	Leakage of contaminants into groundwater.	Significant	Medium
Agricultural areas: orchard	Located in eastern part of community, in WPZ for bore 1. Likely to be diffuse sources of fertilisers and pesticides.	Leakage of contaminants into groundwater.	High	High
Airstrip	Spillage of hydrocarbons during aircraft refuelling	Hydrocarbons contaminating water source.	Low	Low



5. Proposed water source protection area

The Department of Water's (DoW) current Water Quality Protection Note (WQPN) – Land use compatibility in Public Drinking Water Source Areas (referred to as LUCT) describes a framework for protection of drinking water source areas using three risk-based priority classification areas (Priorities 1, 2 and 3) and two types of protection zones (wellhead protection zones and reservoir protection zones). It also describes the DoW's position on the compatibility of a range of land uses in those protection areas. This same system is used to protect the proposed Karalundi Water Reserve (KWR). For further guidance, refer to the WQPN in Appendix G.

The priority boundaries for the proposed KWR were determined in accordance with the decision flowchart contained within the aforementioned LUCT and Method for Determining Aboriginal Water Reserve Boundaries (Appendix H). It is proposed that the KWR over the community is assigned a Priority 3 (P3) area. Priority 3 classification areas are defined to manage the risk of pollution to the water source from catchment activities that are already in place and/or unavoidable. Protection of P3 areas is mainly achieved through guided or regulated environmental (risk) management for land use activities.

It is proposed that the KWR east of the community to the Great Northern Highway and the area south of the community area be assigned a Priority 1 (P1) area. Priority 1 areas are managed to avoid any risk of contamination to drinking water and, because a majority of land uses create some risk to water quality, most land uses are prohibited.

The proposed KWR is the area identified for the overall protection of the groundwater source in respect to current use and future development of groundwater as a drinking source. The KWR boundary was determined with consideration the following:

- Hydrogeological setting,
- Groundwater flow direction, and
- Potential contaminants of concern.

The proposed KWR boundary extends to 0.5 km up-gradient of the production bores and to 1 km south of the production bores. Figure 5-1 depicts the proposed KWR and the proposed priority classification area.

Within the proposed KWR there are land uses which are considered to pose a risk to the water source. These land uses include the sewerage system, power station and orchard. Relevant stakeholders are encouraged to implement preventive measures prior to development of the DWSPP wherever possible.

The proposed KWR and priority classification area are proposed and should only be used as a guide. When the Karalundi DWSPP is being prepared, the final KWR boundaries and priority classification areas will be determined in consultation with relevant stakeholders.



6. Conclusions and Recommendations

A management priority level has been assigned to each potentially hazardous operational issue and land use activity. The management priority level was determined by assessing the likelihood and consequences of the water source being contaminated. The management priorities highlight the need for a drinking water source protection plan.

High management priority has been assigned to the following hazardous operational issues and land use activity:

- Inadequate bore/sump security: Swimming Pool Well,
- Fauna, and
- Agricultural areas: orchard.

Medium management priority has been assigned to the following hazardous operational issues and land use activities:

- Inadequate wellhead protection,
- Inadequate bore security: potable supply bores, irrigation wells and excavated sump,
- Sewage system,
- Power station, chemical shed and fuel storage,
- Farm sheds, and
- Agricultural areas.

Low management priority has been assigned to the following hazardous land use activities:

- Roads,
- Workshop,
- Rubbish tip,
- Stock yards, and
- Airstrip.

Based on the risks identified in this document, it is recommended that a community Drinking Water Source Protection Plan (DWSP) be developed. The DWSP should include the drinking water source protection area and priority classifications. Prior to the development of the DWSP, a short term action plan detailing mitigation strategies considered relatively straight-forward will be developed and sent to RAESP. The following mitigation strategies will be included in the short term action plan:

- Central Park Bore (bore 3) should not be utilised for potable supply.
- A water audit should be conducted and actual community water requirements determined along with an assessment of condition of the waste water system.
- Bores 1 and 2 should be test pumped to determine bore capacity.
- Bore 1 shuts down after a short period of pumping and may require de-scaling, and/or re-development or may require a smaller sized bore pump.



- Subject to the results of bore assessments and water audit an additional potable supply bore may be required.
- A basic model should be generated using either parameters determined from test pumping and/or as may be available from more comprehensive appraisal of similar aquifers to determine potential area of influence of pumping from the bores to more adequately determine vulnerability of the existing production bore sites to contamination originating at the community.
- An estimate of water resources should be determined for the aquifer to put the pump volumes into perspective.

It is essential that existing management strategies be continued and protection measures identified in the forthcoming DWSP be implemented to ensure the ongoing availability of good quality drinking water at Karalundi.



7. References and further reading

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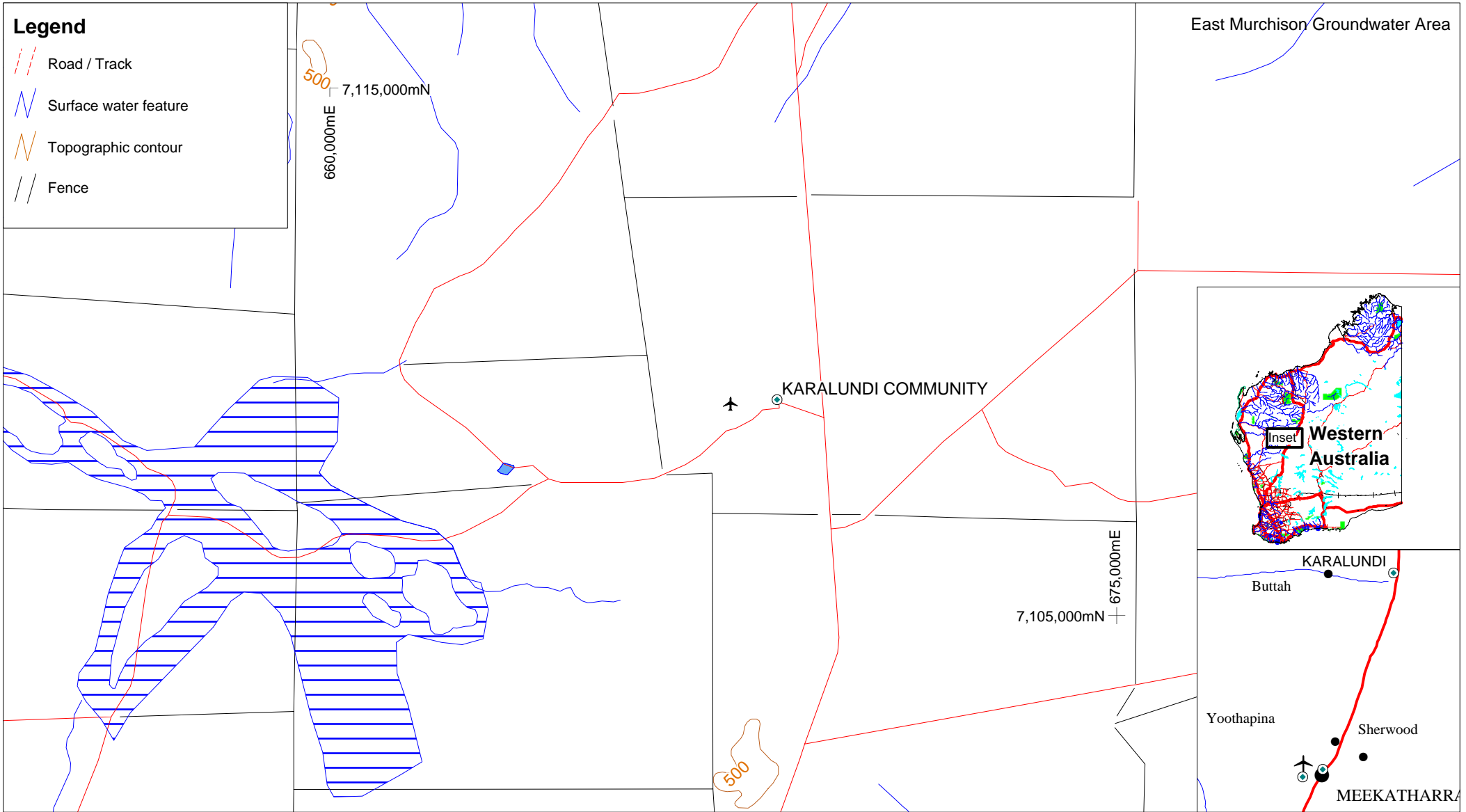
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 Topographic data
 GPS data recorded
 Aug 2009

Draft
 Date 7 September 2009
 Drawn By L. Hopgood
 Approved R. Nixon

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Scale: 1:100,000 at A4
 Coord system MGA50 GDA94

Department of Housing
Drinking Water Source Protection Assessment
Karalundi site location plan
Figure 1-1




Legend

- Road / Track
- Surface water feature
- Production bore (operational)
- Irrigation bore/well (operational)
- Irrigation well (disused)
- Stock bore


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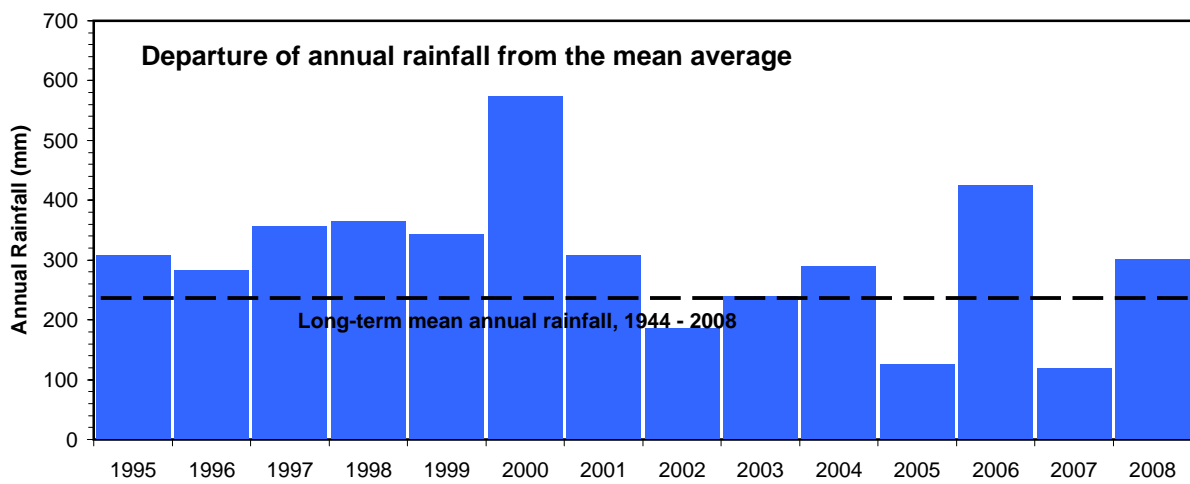
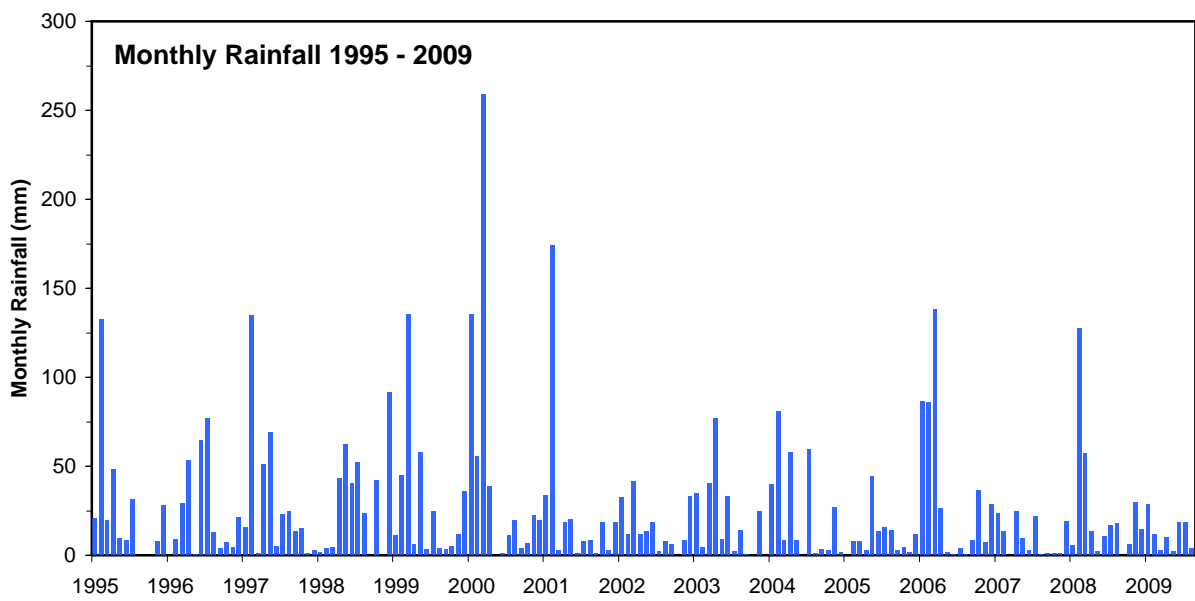
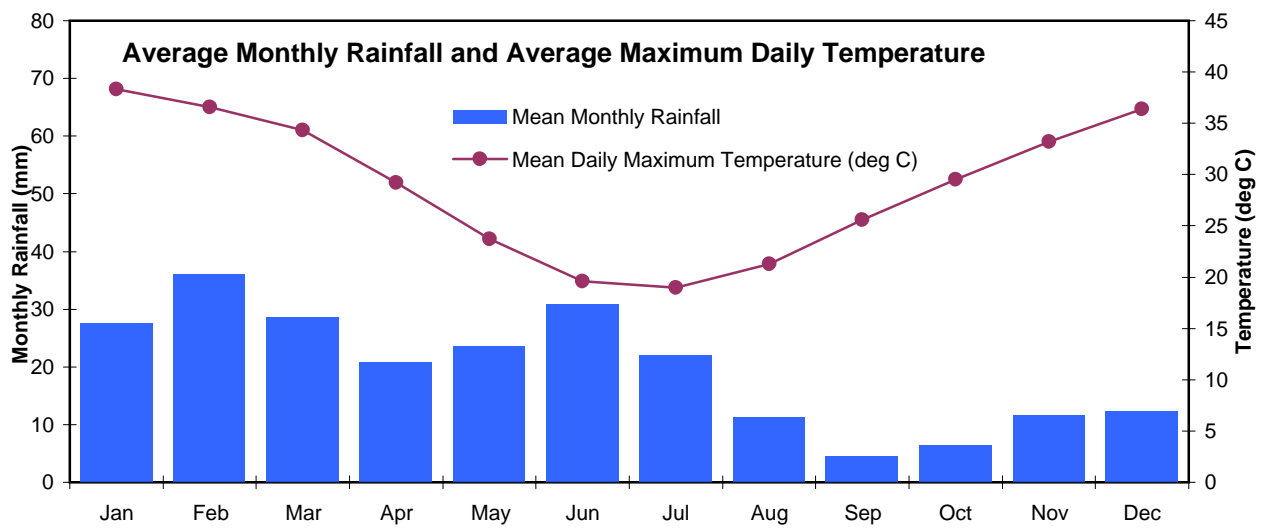

Global Groundwater


0.1 0 0.1 0.2

 Kilometres
 Scale: 1:10,000 at A4
 Coord system MGA50 GDA94

Google Earth data
 GPS data recorded
 Aug 2009

Draft
 Date 10 September 2009
 Drawn By L. Hopgood
 Approved R. Nixon

Department of Housing
Drinking Water Source Protection Assessment
Karalundi bore location plan
Figure 2-1



Rev: Draft Date: 10/9/09 Drawn: L.H Approv: R.N		Summary of climatic conditions near Karalundi Karalundi Community Drinking Water Source Protection Assessment		 Global Groundwater
		Client: Department of Housing	Job No.: 291g Figure 2-2	



Management Priority

- High
- Medium
- Low

See Table 4-1 for details

Legend


- Road / Track
- ~ Surface water feature
- Production bore (operational)
- Irrigation bore/well (operational)
- Irrigation well (disused)
- Stock bore
- ➔ Assumed groundwater flow


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 GPS data recorded
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Draft
 Date 5 October 2009
 Drawn By L. Hopgood
 Approved R. Nixon

0.2 0 0.2 0.4

 Kilometres
 Scale: 1:12,500 at A4
 Coord system MGA50 GDA94

Department of Housing

Drinking Water Source Protection Assessment
Karalundi land use hazards management priority

Figure 4-1



Legend

- Road / Track
- Surface water feature
- Production bore (operational)
- Irrigation bore/well (operational)
- Irrigation well (disused)
- Stock bore

Land use hazards

- 1. Workshop
- 2. Waste water treatment ponds
- 3. Rubbish tip
- 4. Power station, chemical shed
- 5. Farm sheds
- 6. Stock yards
- 7. Agricultural areas
- 8. Orchard
- 9. Excavated sump
- 10. Airstrip
- Priority 1 area
- Priority 3 area
- Proposed Karalundi water reserve
- Proposed wellhead protection zone

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0.2 0 0.2 0.4
Kilometres
Scale: 1:17,500 at A4
Coord system MGA50 GDA94

Google Earth data
GPS data recorded
Aug 2009

Draft
Date 5 October 2009
Drawn By L. Hopgood
Approved R. Nixon

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Drinking Water Source Protection Assessment
Proposed Karalundi water reserve
Figure 5-1



Appendix A

Glossary of terms, units and
acronyms



Glossary of terms, units and acronyms

ADWG	The Australian Drinking Water Guidelines, outlining acceptable criteria for the quality of drinking water in Australia.
Aesthetic guideline	A water-quality criteria in the ADWG associated with acceptability of water to the consumer e.g. appearance, taste and odour (NHMRC & NRMMC, 2004).
ANZECC	Australian and New Zealand Environment Conservation Council.
Aquifer	A geological formation or group of formations able to receive, store and transmit significant quantities of water.
AST	Above ground Storage Tanks
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
KWR	Karatundi Water Reserve: An area proclaimed under the <i>Country Areas Water Supply Act 1947</i> or the <i>Metropolitan Water Supply Sewerage and Drainage Act 1909</i> for the purposes of protecting a drinking water supply.
Borefield	A group of bores to monitor or withdraw groundwater.
DWSPA	Drinking Water Source Protection Assessment
DWSPP	Drinking Water Source Protection Plan
cfu	Colony forming units. A measure of pathogen contamination in water.
GL	Gigalitre (1,000,000,000 litres) or one million kilolitres.
Health guideline	A water-quality criteria in the ADWG associated with human health that, based on present knowledge, does not result in any significant risk to the consumer over a lifetime of consumption (NHMRC & NRMMC 2004).
Hydrocarbons	A class of compounds containing only hydrogen and carbon, such as methane, ethylene, acetylene and benzene. Fossil fuels such as oil, petroleum and natural gas all contain hydrocarbons.
Leaching/ leachate	The process by which materials such as organic matter and mineral salts are washed out of a layer of soil or dumped material by being dissolved or suspended in percolating rainwater. The material washed out is known as leachate. Leachate can pollute groundwater and waterways.
mAHD	Metres Australian Height Datum is the height of land in metres above mean sea level. For example, this is +0.026 m at Fremantle.
NHMRC	National Health and Medical Research Council.
NRMMC	Natural Resource Management Ministerial Council.



NTU	Nephelometric turbidity units are a measure of turbidity in water.
Nutrients	Minerals dissolved in water, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) which provide nutrition (food) for plant growth. Total nutrient levels include the inorganic forms of an element plus any bound in organic molecules.
Pathogen	A disease producing organism that can cause sickness and sometimes death through the consumption of water, including bacteria (such as <i>Escherichia coli</i>), protozoa (such as <i>cryptosporidium</i> and <i>giardia</i>) and viruses).
Public Drinking Water Source Area (PDWSA)	Includes all underground water pollution control areas, catchment areas and water reserves constituted under the <i>Metropolitan Water Supply Sewerage and Drainage Act 1909</i> and the <i>Country Areas Water Supply Act 1947</i> .
Recharge	Water infiltrating to replenish an aquifer.
Reservoir Protection Zone (RPZ)	A buffer measured from the high-water mark of a drinking water reservoir, and inclusive of the reservoir (usually two km). This is referred to as a 'Prohibited Zone' under the <i>Metropolitan Water Supply, Sewerage and Drainage Act By-laws 1981</i> .
RSP	Regional Service Provider
TDS	Total Dissolved Solids: a measurement of ions in solution, such as salts in water.
Treatment	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes, including drinking and discharge to the environment.
Turbidity	The cloudiness or haziness of water caused by the presence of fine suspended matter.
Unconfined aquifer	An aquifer in which the upper surface of water is lower than the top of the aquifer itself. The upper surface of the groundwater within the aquifer is called the watertable.
Wastewater	Water that has been used for some purpose and would normally be treated and discarded. Wastewater usually contains significant quantities of pollutant.
Water quality	The physical, chemical and biological measures of water.
WHPZ	Wellhead Protection Zones: zones with a 300 m radius around a production bore.
WQPN	Water Quality Protection Note
Watertable	The upper saturated level of the unconfined groundwater.





Appendix B

Photographs



Photograph 1: Bore 1 – potable supply bore



Photograph 2: Bore 2 – potable supply bore



Photograph 3: Central Park Bore (bore 3) – irrigation bore



Photograph 4: Bore 4 – stock bore



Photograph 5: Well 1



Photograph 6: Well 2



Photograph 7: Well 3



Photograph 8: Swimming Pool Well



Appendix C

Nutrient and Chemical Data

Karatundi Water Quality Results

Site ID	Aesthetic value	Health value	Bore 1	Bore 1	Bore 1	Bore 2	Bore 2	Bore 2	Bore 3	Retic	Retic	Retic	Retic	*	*	*	*	*	*	*	
Date			10-Feb-09	12-Aug-08	12-Feb-08	10-Feb-09	12-Aug-08	12-Feb-08	12-Feb-08	10-Feb-09	12-Aug-08	12-Feb-08	08-Aug-07	12-Dec-06	12-Dec-06	12-Sep-05	17-Jan-04	14-Jul-03	20-Jan-03	20-Jan-03	10-Dec-01
pH	6.5-8.5		8	7.4	7.6	7.8	7.7	7.5	7.2	7.7	6.8	7.4	6.9	-	-	6.4	7.4	7.9	-	7.4	7.8
TDS	500 mg/L		1300	1300	1300	1300	1300	1300	2000	120	100	79	120	-	-	64	260	160	-	100	80
Hardness	200 mg/L		440	410	430	470	420	420	850	16	5	8	10	-	-	<5	20	20	-	15	15
Colour	15 HU		1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	-	-	<5	<5	<5	-	<5	5
Turb	5 NTU		<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-	-	<1	1	<1	-	<1	<1
Na	180 mg/L		282	257	265	331	287	280	421	40.4	28.5	32.5	34.1	-	-	13	57	32	-	32	29
Chloride	250 mg/L		377	369	366	398	392	386	523	48	32	31	39	-	-	15	65	38	-	41	34
SO4	250 mg/L	500 mg/L	254	242	274	285	256	277	644	13.4	5.8	6.4	9.1	-	-	1	26	7	-	12	10
Fe	0.3 mg/L		<0.005	0.009	0.031	<0.005	0.043	0.016	0.018	<0.005	<0.005	<0.005	<0.005	-	-	<0.05	<0.05	<0.05	-	<0.05	<0.05
Mn	0.1 mg/L	0.5 mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	<0.001	<0.001	<0.001	<0.001	-	-	<0.05	<0.05	<0.05	-	<0.05	<0.05
Al	0.2 mg/L		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.025	<0.005	<0.005	<0.005	<0.005	-	-	<0.1	<0.1	<0.1	-	<0.1	<0.1
Nitrate NO3		50 mg/L	41	44	47	62	44	60	60	18	8	14	12	-	-	0.4	19	14	-	14	8.2
Nitrite NO2		3 mg/L	<0.1	<0.1	<0.1	<0.001	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-
Mg			66.5	63.8	65.7	71.6	64.3	63.4	121	2.4	0.9	1.3	1.4	-	-	<0.5	-	-	-	-	-
Ca			64.7	60.8	63.4	70.7	63.2	63.3	142	2.3	0.6	1.2	1.5	-	-	-	-	-	-	-	-
K			34.5	32.9	32.4	38.1	33.6	33	49.7	4.1	3.2	3.4	3.7	-	-	-	-	-	-	-	-
SiO2			78	74	76	72	72	76	82	12	8.7	9.1	8.1	-	-	-	-	-	-	-	-
As	0.007 mg/L		0.001	0.001	0.001	0.001	0.001	0.001	0.002	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-
F	1.5 mg/L		1.0	1.2	1.1	1.1	1.2	0.99	1.2	0.08	0.21	0.12	0.17	-	-	-	-	-	-	-	-
Hg	0.001 mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	-	-	-	-	-	-	-
Ag	0.1 mg/L		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-	-	-	-	-	-	-
B	4 mg/L		1.7	1.4	1.5	1.6	1.5	1.4	2.2	1.3	1.1	1.3	1.4	-	-	-	-	-	-	-	-
Ba	0.7 mg/L		0.027	0.025	0.026	0.026	0.026	0.026	0.031	<0.002	<0.002	<0.002	<0.002	-	-	-	-	-	-	-	-
Be			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-
Cd	0.002 mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	-	-	-	-	-	-	-
Cu	1 mg/L	2 mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	0.013	0.028	0.043	<0.005	-	-	-	-	-	-	-	-
Mo	0.05 mg/L		0.003	0.002	0.003	0.003	0.002	0.003	0.004	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-
Ni	0.02 mg/L		<0.001	0.002	0.001	<0.001	0.004	0.002	0.011	<0.001	<0.001	0.001	<0.001	-	-	-	-	-	-	-	-
Pb	0.01 mg/L		0.0001	0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0003	0.0005	0.0004	0.0006	0.0005	-	-	-	-	-	-	-	-
Se	0.01 mg/L		0.004	0.003	0.003	0.003	0.003	0.003	0.004	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-
Sn			<0.0001	<0.0001	<0.02	<0.0001	<0.0001	<0.02	<0.02	<0.0001	<0.0001	<0.02	<0.02	-	-	-	-	-	-	-	-
Zn	3 mg/L		0.014	0.037	0.035	0.030	0.013	0.019	0.033	0.041	0.052	0.025	0.016	-	-	-	-	-	-	-	-
U		0.02 mg/L	0.0032	0.0025	0.0031	0.0034	0.0025	0.003	0.0083	0.0002	<0.0001	0.001	0.0001	-	-	-	-	-	-	-	-
Cr		0.05 mg/L	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.01	<0.005	<0.005	<0.02	-	-	-	-	-	-	-	-

- Not analysed

* Sample not labelled

Value Exceedence of aesthetic NH&MRC (2004)

Value Exceedence of health NH&MRC (2004)

Karalundi Microbiological Results

Sample site	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Bore	Borehead	ground tank
Date Sampled	16-May-06	11-Apr-06	14-Mar-06	15-Mar-04	08-Sep-03	14-Jul-03	12-May-03	10-Mar-03	10-Feb-03	09-Dec-02	11-Nov-02	09-Sep-02	12-Aug-02	15-Jul-02	12-Jun-02	15-Apr-02	12-Nov-01	10-Sep-01	13-Aug-01	14-Feb-01	14-Oct-02	
Total Coliforms	11	>100	76	0	0	0	3	0	1	0	0	0	0	0	74	>100	0	9	1	>100	100	
Thermotolerant Coliforms	0	>70	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
E Coli	0	>60	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
CI Residual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample site	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Community	Community	Community
Date Sampled	18-Aug-09	18-Aug-09	21-Jul-09	21-Jul-09	16-Jun-09	16-Jun-09	19-May-09	19-May-09	21-Apr-09	21-Apr-09	10-Feb-09	10-Feb-09	13-Jan-09	13-Jan-09	09-Dec-08	09-Dec-08	11-Nov-08	11-Nov-08	14-Oct-08	14-Oct-08	09-Sep-08	
Total Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermotolerant Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E Coli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CI Residual	0.09	0.08	0.07	0.05	0.06	0.06	0.08	0.08	0.06	0.08	0.06	0.06	0.07	0.06	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05

Sample site	Community	Community	Community	Karalundi	Karalundi	Community	Community	Community	Community	Community	Community	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Community	Community	Karalundi	Community
Date Sampled	09-Sep-08	12-Aug-08	12-Aug-08	15-Jul-08	15-Jul-08	10-Jun-08	10-Jun-08	13-May-08	26-Mar-08	26-Mar-08	26-Mar-08	12-Feb-08	12-Feb-08	14-Jan-08	14-Jan-08	05-Dec-07	05-Dec-07	13-Nov-07	13-Nov-07	09-Oct-07	09-Oct-07
Total Coliforms	0	0	0	0	0	0	0	0	24	5	94	0	1	0	0	0	0	0	0	0	0
Thermotolerant Coliforms	0	0	0	0	0	0	0	0	18	0	73	0	0	0	0	0	0	0	0	0	0
E Coli	0	0	0	0	0	0	0	0	18	0	73	0	0	0	0	0	0	0	0	0	0
CI Residual	0.06	0.03	0.04	0.45	0.04	0.07	0.05	0.37	-	-	-	-	-	-	-	0	-	-	-	-	-

Sample site	Community	Community	Community	Community	Community	Karalundi	Karalundi	Karalundi	Community	Karalundi	Karalundi	Community	Community	Community	Community	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi	Karalundi
Date Sampled	11-Sep-07	11-Sep-07	14-Aug-07	14-Aug-07	10-Jul-07	10-Jul-07	12-Jun-07	12-Jun-07	30-May-07	15-May-07	15-May-07	10-Apr-07	10-Apr-07	02-Apr-07	02-Apr-07	12-Feb-07	12-Feb-07	08-Jan-07	08-Jan-07	08-Jan-07	12-Dec-06
Total Coliforms	0	0	0	0	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0
Thermotolerant Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E Coli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CI Residual	-	-	-	-	-	-	-	-	-	40	40	-	-	-	-	-	-	-	-	-	-

Sample site	Community	Community	Karalundi	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community	Community
Date Sampled	14-Nov-06	14-Nov-06	10-Oct-06	10-Oct-06	12-Sep-06	12-Sep-06	15-Aug-06	15-Aug-06	11-Apr-06	11-Apr-06	14-Mar-06	14-Mar-06	13-Feb-06	13-Feb-06	13-Feb-06	12-Jul-06	12-Jul-06	13-Jun-06	13-Jun-06	16-May-06	16-May-06	
Total Coliforms	10	8	1	0	1	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	
Thermotolerant Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
E Coli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
CI Residual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	

Sample site	Community	Community	Community	Community	Community	Community	Retic 2	Pt 1	Pt 1	Pt 1	Pt 1	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic
Date Sampled	13-Dec-05	13-Dec-05	10-Oct-05	10-Oct-05	15-Aug-05	15-Aug-05	13-May-08	12-Jun-01	16-May-01	11-Apr-01	13-Mar-01	20-Mar-07	12-Sep-05	13-Jun-05	16-May-05	11-Apr-05	14-Mar-05	14-Feb-05	10-Jan-05	13-Dec-04	08-Nov-04
Total Coliforms	0	6	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermotolerant Coliforms	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
E Coli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CI Residual	-	-	-	-	-	-	0.33	-	-	-	-	-	-	-	40	40	-	-	-	-	-

- Not analysed
 * Sample not labelled
Value Exceedence of health NH&MRC (2004)

Karatundi Microbiological Results

Sample site	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic	Pt 1 Retic
Date Sampled	11-Oct-04	13-Sep-04	16-Aug-04	14-Jun-04	17-May-04	19-Apr-04	19-Feb-04	19-Jan-04	08-Dec-03	10-Nov-03	13-Oct-03	11-Aug-03	09-Jun-03	14-Apr-03	20-Jan-03	11-Mar-02	18-Feb-02	30-Jan-02	14-Jan-02	10-Dec-01	10-Jul-01
Total Coliforms	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	16	33	0	55	0	0
Thermotolerant Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0
E Coli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-
Cl Residual	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	4	-	-	-	-	-	-

Sample site	Pt 1 Retic	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore
Date Sampled	16-Jan-01	13-Jun-05	16-May-05	11-Apr-05	14-Mar-05	14-Feb-05	10-Jan-05	13-Dec-04	08-Nov-04	11-Oct-04	13-Sep-04	16-Aug-04	14-Jun-04	17-May-04	19-Apr-04	19-Feb-04	19-Jan-04	08-Dec-03	10-Nov-03	13-Oct-03	11-Aug-03
Total Coliforms	0	0	0	21	2	13	0	0	1	0	0	3	0	6	0	-	0	0	0	0	2
Thermotolerant Coliforms	0	0	0	1	1	8	3	0	0	0	0	0	0	0	0	-	0	0	0	0	0
E Coli	-	0	0	-	1	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cl Residual	-	180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample site	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 2 Bore	Pt 3 Retic	Retic	Retic	Retic	Retic	Retic
Date Sampled	09-Jun-03	14-Apr-03	20-Jan-03	13-May-02	11-Mar-02	18-Feb-02	30-Jan-02	14-Jan-02	10-Dec-01	10-Jul-01	12-Jun-01	16-May-01	10-Apr-01	13-Mar-01	16-Jan-01	20-Mar-07	12-Sep-05	15-Mar-04	08-Sep-03	14-Jul-03	12-May-03
Total Coliforms	1	0	2	>100	82	0	4	330	0	1	2	4	>1000	>1000	>100	0	0	0	0	0	0
Thermotolerant Coliforms	0	0	0	72	33	0	0	0	0	0	0	0	0	>1000	0	0	0	0	0	0	0
E Coli	0	0	0	72	13	-	-	-	-	-	-	-	-	>1000	-	0	0	0	0	0	0
Cl Residual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-

Sample site	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic	Retic
Date Sampled	10-Mar-03	10-Feb-03	09-Dec-02	11-Nov-02	09-Sep-02	12-Aug-02	15-Jul-02	12-Jun-02	15-Apr-02	12-Nov-01	15-Oct-01	10-Sep-01	13-Aug-01	13-May-02	10-Mar-09	15-Apr-08	31-Mar-08	17-Mar-08	10-Mar-09	31-Mar-08	15-Apr-08
Total Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	52	0	1	0
Thermotolerant Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	14	0	0	0
E Coli	0	0	-	0	0	0	0	0	-	-	-	-	-	4	0	0	0	0	0	0	0
Cl Residual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	0.04	-	40	0.09	-	0.04

Sample site	Retic 3	Swimming Pool Out	ground tank 2	Shed	*
Date Sampled	17-Mar-08	14-Oct-08	14-Oct-02	15-Oct-01	14-Feb-01
Total Coliforms	28	48	0	7	0
Thermotolerant Coliforms	1	-	0	0	0
E Coli	0	-	0	-	-
Cl Residual	40	-	-	-	-

- Not analysed
 * Sample not labelled
 Value Exceedence of health NH&MRC (2004)



Appendix D

WHO and ADWG factsheets

Chlorine

GUIDELINE

Based on health considerations, the guideline value for chlorine in drinking water is 5 mg/L.

GENERAL DESCRIPTION

Chlorine dissociates in water to form hypochlorous acid and hypochlorite ion. Chlorine and hypochlorites are toxic to microorganisms and are used extensively as disinfectants for drinking water supplies. Chlorine is also used to disinfect sewage and waste water, swimming pool water, in-plant supplies, and industrial cooling water.

Chlorine has an odour threshold in drinking water of about 0.6 mg/L, but some people are particularly sensitive and can detect amounts as low as 0.2 mg/L. Water authorities may need to exceed the odour threshold value of 0.6 mg/L in order to maintain an effective disinfectant residual.

In the food industry, chlorine and hypochlorites are used for general sanitation and for odour control. Large amounts of chlorine are used in the production of industrial and domestic disinfectants and bleaches, and it is used in the synthesis of a large range of chemical compounds.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

When used as a disinfectant, the free chlorine residual in major Australian reticulated supplies ranges from 0.1 mg/L to 4 mg/L, with typical concentrations of about 0.2 mg/L.

REMOVAL FROM DRINKING WATER

Chlorine can be removed from drinking water by aeration, by exposure to sunlight, or by the addition of reducing agents such as sodium bisulfite.

MEASUREMENT

The concentration of chlorine in drinking water can be determined by the DPD ferrous titrimetric method (APHA Method 4500-Cl Part F 1992). The limit of determination is 0.1 mg/L.

HEALTH CONSIDERATIONS

Chlorine, or hypochlorites, are strong oxidising agents that readily react with organic molecules to produce a wide variety of chlorinated compounds. This reactivity makes it difficult to separate the effects of chlorine from those of its metabolites. In animal studies using a naturally occurring nonradioactive chlorine isotope, chlorine was rapidly absorbed by the gastrointestinal tract, and highest concentrations of the isotope were found in blood plasma.

It is assumed that the toxicities of aqueous solutions containing chlorine, hypochlorous acid or hypochlorite are similar since they are in dynamic equilibrium. Chlorine concentrations therefore refer to free available chlorine.

Very few toxic effects have been associated with drinking water containing high chlorine concentrations. In one report, 150 people drank water with 50 mg/L during a period of mains disinfection, with no adverse effects. Several instances have been reported where military personnel drank water with chlorine concentrations up to 32 mg/L for several months with no ill effects.

NOTE: Important general information is contained in PART II, Chapter 6

Mouth irritation and momentary constriction of the throat were observed when the chlorine concentration exceeded 90 mg/L. Most people would refuse to drink water with a chlorine concentration over 25 mg/L.

A number of studies have suggested an association between water chlorination byproducts and various cancers. This association has been most consistent in relation to cancers of the bladder and rectum, but there are insufficient data to determine concentrations at which chlorination byproducts might cause increased risk to human health (see Section 6.3.2 for a discussion of disinfection byproducts, and Section V - Fact Sheets on specific disinfection byproducts).

Long-term animal toxicity studies have shown no specific effects from the ingestion of chlorine. Chlorine, hypochlorous acid and hypochlorite did not act as carcinogens or tumour initiators.

Assessment of the mutagenicity of chlorine is complicated by the reactivity of chlorine. Hypochlorite was found to be mutagenic in tests with one strain of bacteria but not with another. Chromosome aberrations were reported in tests with mammalian cells.

The International Agency for Research on Cancer has concluded that hypochlorites are not classifiable as to their carcinogenicity in humans (Group 3, no human data and inadequate evidence in animals) (IARC 1991).

DERIVATION OF GUIDELINE

The guideline value for chlorine in drinking water was determined as follows:

$$5 \text{ mg/L} = \frac{15 \text{ mg/kg body weight per day} \times 70 \text{ kg}}{2 \text{ L/day} \times 100}$$

where:

- 15 mg/kg body weight per day is the no effect level from a 2-year drinking water study using rodents (NTP 1992)
- 70 kg is the average weight of an adult
- 2 L/day is the average amount of water consumed by an adult
- 100 is the safety factor in using the results of an animal study as a basis for human exposure (10 for interspecies variations and 10 for intraspecies variations).

It is assumed that all chlorine intake is from drinking water.

REFERENCES

APHA Method 4500-Cl Part F (1992). Chlorine (residual): DPD Ferrous Titrimetric method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

IARC (International Agency for Research on Cancer) (1991). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: chlorinated drinking water, chlorination byproducts, some other halogenated compounds, cobalt and cobalt compounds. World Health Organization, International Agency for Research on Cancer, 52.

NTP (National Toxicology Program) (1992). Toxicology and carcinogenesis studies of chlorinated water and chloraminated water in F344/N and B6C3F1 mice (drinking water studies). National Toxicology Program, Technical Report No. 392, Publication No. 92-2847. United States Department of Health and Human Services, National Institute of Health.

NOTE: Important general information is contained in PART II, Chapter 6

***Escherichia coli* and thermotolerant coliforms**

(revised 2002)

GUIDELINE

***Escherichia coli* (or thermotolerant coliforms) should not be detected in a minimum 100 mL sample of drinking water. If detected, immediate action should be taken (see summary table of microbiological guidelines).**

GENERAL DESCRIPTION

Coliforms are gram-negative, nonsporing rod-shaped bacteria capable of aerobic and facultative anaerobic growth in the presence of bile salts or other surface active agents with similar growth-inhibiting properties. They are found in large numbers in the faeces of humans and other warm-blooded animals.

Thermotolerant coliforms are more specific indicators of faecal contamination than total coliforms. Either thermotolerant coliforms as a group, or *Escherichia coli*, can be used to indicate the presence of contamination. Tests for thermotolerant coliforms can be simpler but *E. coli* is a better indicator because some environmental coliforms are thermotolerant (*Klebsiella*, *Citrobacter* and *Enterobacter*). *E. coli* is the most common thermotolerant coliform present in faeces and is regarded as the most specific indicator of recent faecal contamination.

Thermotolerant coliforms, including *E. coli*, can ferment lactose (or mannitol) at $44.5 \pm 0.2^\circ\text{C}$ with the production of acid within 24 hours. Thermotolerant coliforms that produce indole from tryptophan at $44.5 \pm 0.2^\circ\text{C}$ are regarded as being *E. coli*. *E. coli* also give a positive result in the methyl-red test and a negative Voges-Proskauer test and cannot use citrate as the sole source of carbon. Also, most *E. coli* produce the enzyme β -glucuronidase.

AUSTRALIAN SIGNIFICANCE

E. coli (or thermotolerant coliforms) are used as specific indicators of faecal contamination and hence the safety of water for drinking. However, some waters can support survival or regrowth of environmental thermotolerant coliforms. Where this is suspected, *E. coli*, should be used.

TREATMENT OF DRINKING WATER

Treatment by chlorination or other acceptable forms of disinfection inactivates *E. coli*, (or thermotolerant coliforms) in water, provided the turbidity is low.

METHOD OF IDENTIFICATION AND DETECTION

E. coli, (or thermotolerant coliforms) numbers can be determined using membrane filtration (MF) for concentration of the organisms from water, followed by growth in enrichment/selective media or multiple tube dilution (most probable number – MPN) procedures (AS 4276.6 and 4276.7 1995). Specific secondary tests are used with both MF and MPN procedures to confirm the identification of thermotolerant coliforms.

Alternatively, the presence of *E. coli*, can be detected by testing for the production of the enzyme β -glucuronidase (APHA method 9223 1998). Test methods include the enzyme substrates such as 4-methylumbelliferyl- β -D-glucuronide (MUG) which is hydrolysed by β -glucuronidase to produce the fluorogenic metabolite 4-methylumbelliferyl. Both enumeration and presence/absence tests are available.

As the detection of any *E. coli*, in 100 mL of drinking water requires further action, either form of test is acceptable.

NOTE: Important general information is contained in PART II, Chapter 5

HEALTH CONSIDERATIONS

Thermotolerant coliforms are normal inhabitants of the intestine, are always present in high numbers in human and animal faeces, and are generally regarded as specific indicators of faecal contamination. However, environmental thermotolerant coliforms, which can occur in some waters, are of lesser significance. *E. coli*, is the most specific indicator for faecal contamination. While most thermotolerant coliforms are nonpathogenic there are some pathogenic subtypes of *E. coli*, that can cause enteric illness including enteropathogenic, enteroinvasive, enterotoxigenic and enterohaemorrhagic strains (Bopp 1999).

Enteropathogenic *E. coli*, have been associated with outbreaks of infantile gastroenteritis but experiments in adult volunteers have shown that they also cause disease in adults. The pathogenic mechanisms employed by these organisms are not fully understood.

Enteroinvasive *E. coli*, (EIEC) produce dysentery by a mechanism similar to *Shigella* spp. These organisms invade the colonic mucosa and cause bloody diarrhoea. This property seems to be restricted to a few O sero-groups.

Epidemiological evidence suggests that enterotoxigenic *E. coli* (ETEC) are responsible for most episodes of *E. coli* diarrhoea, particularly in developing countries. ETEC strains can cause a cholera-like syndrome in infants, children and adults, producing a heat-labile enterotoxin (LT) related to cholera enterotoxin and/or a heat-stable enterotoxin (ST). The action of LT is the same as the cholera toxin. The ability of ETEC to cause disease depends not only on the production of enterotoxin but also upon the ability of these organisms to colonise the small intestine. Various colonising factors or adhesins have been described.

Enterohaemorrhagic *E. coli* (EHEC), including serogroups such as O111 and O157 are relatively rare strains that produce large quantities of shiga-like (or vero) toxins that can cause illness ranging from mild diarrhoea to haemorrhagic colitis. The latter is characterised by blood-stained diarrhoea accompanied by abdominal pain. In addition, EHEC strains can cause haemolytic uraemic syndrome (HUS), which is characterised by acute renal failure and haemolytic anaemia. The infectious dose may be very low.

Standard *E. coli* identification methods cannot be used to detect EHEC strains. *E. coli* 0157:H7 does not grow above 41°C on selective media and it does not produce β-glucuronidase. However, specific testing is not recommended unless presence is suspected.

DERIVATION OF GUIDELINE

E. coli (or thermotolerant coliforms) should not be present in a minimum 100 mL sample of drinking water. The presence of these organisms is indicative of faecal contamination and suggests a potentially serious fault in the integrity of the water supply system.

The effect on the community of noncompliance with the guideline will depend on the *E. coli* strain involved, whether faecal pathogens are also present, the number of organisms and the presence of susceptible individuals.

REFERENCES

APHA Method 9223 (1998). Standard methods for the examination of water and wastewater, 20th edition. American Public Health Association, Washington.

AS 4276.6 (1995). Thermotolerant coliforms and *Escherichia coli* – Estimation of most probable number (MPN). Australian Standards, Standards Association of Australia, Sydney, NSW.

AS 4276.7 (1995). Thermotolerant coliforms and *Escherichia coli* – Membrane filtration method. Australian Standards, Standards Association of Australia, Sydney, NSW.

Bopp CA, Brenner FW, Wells JG and Strockbine NA (1999). *Escherichia*, *Shigella* and *Salmonella*. In: Murray PR, Baron EJ, Pfaller MA, Tenover FC and Tenover RH (eds), *Manual of Clinical Microbiology*, 7th edition. ASM Press, Washington DC, pp 459–474.

NOTE: Important general information is contained in PART II, Chapter 5

Hardness (as Calcium carbonate)

GUIDELINE

To minimise undesirable build-up of scale in hot water systems, total hardness (as calcium carbonate) in drinking water should not exceed 200 mg/L.

GENERAL DESCRIPTION

Hard water requires more soap than soft water to obtain a lather. It can also cause scale to form on hot water pipes and fittings. Hardness is caused primarily by the presence of calcium and magnesium ions, although other cations such as strontium, iron, manganese and barium can also contribute.

Total hardness is the sum of the concentrations of calcium and magnesium ions expressed as a calcium carbonate equivalent. Hardness may also be classified as carbonate (temporary) or noncarbonate (permanent) hardness. Carbonate hardness is the total alkalinity expressed as calcium carbonate, where alkalinity is the sum of the carbonate, bicarbonate and hydroxide content. Noncarbonate hardness is the difference between the total and carbonate hardness.

Degrees of hardness can be described as follows:

<60 mg/L CaCO ₃	soft but possibly corrosive
60-200 mg/L CaCO ₃	good quality
200-500 mg/L CaCO ₃	increasing scaling problems
>500 mg/L CaCO ₃	severe scaling

Public acceptance of hardness can vary considerably among communities and is generally related to the hardness that the consumer has come to expect, which in turn is due to the source of the water.

Soft water may lead to greater corrosion of pipes, although this will depend on other factors such as pH, alkalinity and dissolved oxygen concentration. Total hardness above 200 mg/L may lead to excessive scaling of pipes and fittings, and cause blockage of safety relief valves in hot water systems.

High total hardness may be a problem for supplies reliant on groundwater. Surface waters can generally be expected to have acceptable values.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

Total hardness in major Australian reticulated supplies ranges between about 5 mg/L and about 380 mg/L.

MEASUREMENT

Hardness can be determined by titration of calcium and magnesium with EDTA (APHA Method 2340C 1992).

TREATMENT OF DRINKING WATER

Carbonate (temporary) hardness can be readily reduced by treatment, for example using lime softening; however, this is rarely practised for Australian drinking water. Sodium hexametaphosphate has been used to reduce scale build-up, but does not affect hardness.

NOTE: Important general information is contained in PART II, Chapter 6

HEALTH CONSIDERATIONS

Some epidemiological studies have found that hard water may have a beneficial effect on health, particularly on some types of cardiovascular disease (NAS 1977), but the data are inadequate to conclude that the association is causal.

There is some indication that soft water, with a hardness of less than about 75 mg/L, may adversely affect mineral balance.

DERIVATION OF GUIDELINE

The guideline value is based on two considerations:

- difficulty in obtaining a lather with soap
- water with a total hardness (as calcium carbonate) above 200 mg/L can cause a rapid build-up of undesirable deposits, or scale, in hot water pipes and fittings. Removal of these deposits can be costly.

GUIDELINES IN OTHER COUNTRIES

The 1984 WHO Guideline value for total hardness is 500 mg/L. The 1993 WHO Guidelines do not provide a specific value for hardness.

The Canadian Guidelines rate over 500 mg/L as unacceptable, over 200 mg/L as poor, and 80-100 mg/L as acceptable.

The EEC standards do not include a maximum concentration for hardness, but consider a minimum concentration of at least 60 mg/L to be desirable.

REFERENCES

APHA Method 2340C (1992). Hardness: EDTA titrimetric method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

NAS (1977). Drinking water and health. National Academy of Sciences, Washington DC.

Nitrate and nitrite

GUIDELINE

Nitrate: Based on health considerations, the guideline value of 50 mg-NO₃/L (as nitrate) has been set to protect bottle-fed infants under 3 months of age. Up to 100 mg-NO₃/L can be safely consumed by adults and children over 3 months of age.

Where a water supply has between 50 and 100 mg-NO₃/L nitrate, active measures are required to ensure that those caring for infants are aware of the need to use alternative water sources in making up bottle feeds for babies under 3 months of age.

Nitrite: Based on health considerations, the concentration of nitrite in drinking water should not exceed 3 mg-NO₂/L (as nitrite).

GENERAL DESCRIPTION

Nitrate and nitrite ions are naturally occurring oxides of nitrogen that make up part of the nitrogen cycle.

Nitrate is formed from the oxidation of organic wastes such as manure, by the action of nitrogen-fixing bacteria in soils, or from lightning strikes through air. Nitrates are also manufactured for use in explosives and inorganic fertilisers.

Intensification of farming practices and sewage effluent disposal to streams have led to increasing amounts of nitrate in some waters, particularly groundwater.

The nitrite ion is relatively unstable and can be formed by the reduction of nitrate in poorly oxygenated waters. It is rapidly oxidised to nitrate and is seldom present in well oxygenated or chlorinated supplies. Chemical and biological processes can result in further reduction to various compounds, including ammonia, or oxidation back to nitrate.

Food, particularly vegetables and cured meat, is the major source of nitrate intake for humans.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

In major Australian reticulated supplies nitrate concentrations range up to 18 mg-NO₃/L, with typical concentrations usually less than 0.15 mg-NO₃/L. Nitrite is generally not present in significant concentrations, although operational difficulties in chloramination can lead to nitrite formation due to the action of nitrifying bacteria.

Very high nitrate concentrations (200-300 mg-NO₃/L) have been recorded in some groundwater supplies in rural areas.

TREATMENT OF DRINKING WATER

Conventional water treatment is not effective for nitrate removal. Nitrate reduction facilities are expensive to operate and involve the use of anion exchange resins.

MEASUREMENT

The nitrate concentration in drinking water can be determined by a colorimetric procedure following reduction of nitrate to nitrite using a cadmium column (APHA Method 4500-NO₃ Part E 1992). The limit of determination is 0.01 mg/L. Nitrite can be determined separately using the same procedure but without the reduction column (APHA Method 4500-NO₂ Part B 1992). Alternatively, nitrate and nitrite can be determined using ion chromatography (APHA Method 4110 Part B 1992).

HEALTH CONSIDERATIONS

The toxicity of nitrate to humans is thought to be solely due to its reduction to nitrite. The major biological effect of nitrite in humans is its involvement in the oxidation of normal haemoglobin to methaemoglobin, which is unable to transport oxygen to the tissues. This condition is called methaemoglobinaemia. Young infants are more susceptible to methaemoglobin formation than older children and adults. Other susceptible groups include pregnant women and people with a deficiency of glucose-6-phosphate dehydrogenase or methaemoglobin reductase.

In animals, laboratory experiments suggest that neither nitrite nor nitrate acts directly as a carcinogen. There is concern that nitrite may react with foods rich with secondary amines to form N-nitroso compounds in the stomach: many of these compounds are known to be carcinogenic in animals. Some epidemiological evidence suggests a relationship between nitrate and gastric cancer in humans, but this has not been confirmed in more definitive analytical studies.

Nitrate is not mutagenic in tests with bacteria and mammalian cells *in vitro*. Chromosome aberrations have been observed in the bone marrow of rats but may be due to the formation of N-nitroso compounds. Nitrite is mutagenic in both *in vivo* and *in vitro* experiments using mammalian cells.

DERIVATION OF GUIDELINE

The guideline value of 50 mg-NO₃/L for nitrate is set to protect young infants, the most sensitive group (USEPA 1990). Up to 100 mg-NO₃/L can be used by adults and children over 3 months of age without significant health effects. The guideline level for nitrite of 3 mg-NO₂/L is based on a relative potency for nitrite and nitrate with respect to methaemoglobin formation.

If the value of 50 mg-NO₃/L is exceeded, the local health authority should be informed so that parents can be advised to use rainwater or bottled water in making up feeds for babies under 3 months of age in order to prevent methaemoglobinaemia.

REFERENCES

APHA Method 4110 Part B (1992). Determination of ions by ion chromatography: ion chromatography with chemical suppression of eluant conductivity. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

APHA Method 4500-NO₃ Part E (1992). Nitrogen (nitrate): Cadmium reduction method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

APHA Method 4500-NO₂ Part B (1992). Nitrogen (nitrite): Colorimetric method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

USEPA (1990). Drinking water criteria document on Nitrate/Nitrite. Report TR-1242-608 from ICAIR Life Systems Inc., Cleveland, Ohio. Prepared for Criteria and Standards Division Office of Drinking Water, United States Environmental Protection Agency, Washington DC.

NOTE: Important general information is contained in PART II, Chapter 6

GUIDELINE

Based on the need to reduce corrosion and encrustation in pipes and fittings, the pH of drinking water should be between 6.5 and 8.5.

New concrete tanks and cement-mortar lined pipes can significantly increase pH and a value up to 9.2 may be tolerated, provided monitoring indicates no deterioration in microbiological quality.

GENERAL DESCRIPTION

pH is a measure of the hydrogen ion concentration of water. It is measured on a logarithmic scale from 0 to 14. A pH of 7 is neutral, greater than 7 is alkaline, and less than 7 is acidic.

One of the major objectives in controlling pH is to minimise corrosion and encrustation in pipes and fittings. Corrosion can be reduced by the formation of a protective layer of calcium carbonate on the inside of the pipe or fitting, and the formation of this layer is affected by pH, temperature, the availability of calcium (hardness) and carbon dioxide. If the water is too alkaline (above pH 8.5), the rapid deposition and build-up of calcium carbonate that can result may eventually block the pipe.

When pH is below 6.5 or above 11, the water may corrode plumbing fittings and pipes. This, however, will depend on other factors such as the material used, the concentration and type of ions in solution, the availability of oxygen, and the water temperature. Under some conditions, particularly in the presence of strong oxidising agents such as chlorine, water with a pH between 6.5 and 7 can be quite corrosive.

Chlorine disinfection efficiency is impaired above pH 8.0, although the optimum pH for monochloramine disinfectant formation is between 8.0 and 8.4. In chloraminated supplies chlorine can react with ammonia to form odorous nitrogen trichloride below pH 7.

Chlorination of water supplies can decrease the pH, while it can be significantly raised by lime leached from new concrete tanks or from pipes lined with asbestos cement or cement mortar. Values of pH above 9.5 can cause a bitter taste in drinking water, and can irritate skin if the water is used for ablutions.

MEASUREMENT

pH can be determined potentiometrically using a standard glass electrode and reference (APHA Method 4500-H⁺ 1992).

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

In major Australian reticulated supplies pH ranges between 6 and 10.8.

CONTROL IN DRINKING WATER SUPPLIES

The pH of water can be adjusted by the addition of acid or alkali. Usually lime, soda ash, sodium hydroxide, or a combination of lime and carbon dioxide are used (AWWA 1990).

HEALTH CONSIDERATIONS

A direct relationship between pH and human health is difficult to determine, as pH is closely associated with other aspects of water quality. Consumption of food and beverages with quite low or high pH is common and does not result in adverse health effects. Some carbonated soft drinks, for instance, have a pH of 2.5, orange fruit juice has a pH of about 3.8, and the pH of milk is 6.7.

In humans, extreme values of pH result in irritation of the eyes, skin and mucous membranes. Eye irritation and exacerbation of skin disorders have been associated with pH values above 11. Gastrointestinal irritation may occur in sensitive individuals at pH values above 10. Below pH 4, redness and irritation of the eyes have been reported, with the severity increasing with decreasing pH. Below pH 2.5, damage to the epithelium is irreversible and extensive.

pH may have an indirect effect on bacteriological quality through its effects on disinfection processes. It can affect the solubility of heavy metals, particularly lead and copper from pipes, and the formation of trihalomethanes (see Section 6.3.2) (USEPA 1989).

In studies using animals, solutions of differing pH have been injected into the abdominal skin of mice, resulting in irritation at pH 10 after 6 hours. In rabbits, eye irritation was reported at pH 10 but not at pH 4.5.

Chromosome aberrations and gene mutations have been reported in cultured mammalian and invertebrate cells using different acids between pH 4 and 6.5.

The effect of pH on health will depend on the buffering capacity of the water used. This is related to the nature and amount of dissolved inorganic and organic material. Water with a low buffering capacity can change pH rapidly, but water with a high buffering capacity is resistant to pH change. Extreme values of pH in association with highly buffered water are of greater concern than when the water has a low buffering capacity.

DERIVATION OF GUIDELINE

The guideline value is based on minimising corrosion and encrustation of plumbing fittings and pipes. Water with a pH between 6.5 and 8.5 should deposit a protective coating of calcium carbonate and prevent corrosion. High pH can cause scaling and encrustation problems, while lower pH can result in corrosion.

New concrete tanks and cement-mortar lined pipes can significantly increase pH and a value up to 9.2 may be tolerated, provided microbiological monitoring indicates no deterioration in bacteriological quality.

Insufficient data are available to set a health-based guideline value for pH.

GUIDELINES IN OTHER COUNTRIES

The Canadian Guidelines, United States Regulations, European Economic Community Standards, and 1984 WHO Guidelines all recommend a pH range of 6.5 to 8.5. The 1993 WHO Guidelines do not provide a specific range of pH values.

NOTE: Important general information is contained in PART II, Chapter 6

REFERENCES

APHA Method 4500-H⁺ (1992). pH value: B. Electrometric method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

AWWA (1990). *Water Quality and Treatment: A handbook of community water supplies*. American Water Works Association, 4th edition, McGraw-Hill Inc.

USEPA (1989). Health effects of drinking water treatment technologies. United States Environmental Protection Agency, Lewis Publ. Inc.

Sodium

GUIDELINE

Based on aesthetic considerations (taste), the concentration of sodium in drinking water should not exceed 180 mg/L.

No health-based guideline value is proposed for sodium. Medical practitioners treating people with severe hypertension or congestive heart failure should be aware if the sodium concentration in the patient's drinking water exceeds 20 mg/L.

GENERAL DESCRIPTION

The sodium ion is widespread in water due to the high solubility of sodium salts and the abundance of mineral deposits. Near coastal areas, windborne sea spray can make an important contribution either by fallout onto land surfaces where it can drain to drinking water sources, or from washout by rain. Apart from saline intrusion and natural contamination, water treatment chemicals, domestic water softeners and sewage effluent can contribute to the sodium content of drinking water.

Sodium salts are used in the paper, glass, soap, pharmaceutical and general chemical industries, and for a variety of other purposes. Sodium is also used in the food industry and for culinary purposes. Considerable amounts are excreted by humans and it is a common constituent of domestic sewage.

Sodium, as sodium salts such as sodium chloride or sodium sulfate, has a taste threshold of about 135 mg/L. The taste becomes appreciable when the sodium concentration exceeds 180 mg/L.

In most countries the majority of water supplies contain less than 20 mg/L but concentrations of up to 250 mg/L have been reported.

Food is the major contributor to sodium intake. In Australia the average dietary sodium intake has been estimated at about 4 g/day. Low-sodium diets may restrict this to less than 2 g/day.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

In major Australian reticulated supplies, sodium concentrations vary from 3 mg/L to 300 mg/L, with a typical value of 50 mg/L. Concentrations can vary markedly with local conditions.

TREATMENT OF DRINKING WATER

Sodium salts cannot be easily removed from drinking water; however, any steps to reduce sodium concentrations are encouraged (such as the use of alternative salts in domestic water softeners). Processes such as reverse osmosis or distillation can be employed but are costly to operate.

MEASUREMENT

The sodium concentration in drinking water can be determined by flame atomic absorption spectroscopy, inductively coupled emission spectroscopy or flame emission spectroscopy (APHA Method 3500-Na Parts B, C or D 1992). The limits of determination are less than 0.1 mg/L.

HEALTH CONSIDERATIONS

Whether water is consumed directly or with food or beverages, virtually all of the sodium in it will be absorbed. Sodium is present in all body tissues and fluids and its concentration is maintained by the kidney; increases in the sodium concentration in plasma give rise to the sensation of thirst.

Sodium is essential to human life but there is no agreement on the minimum daily amount needed to maintain health. It has been estimated that a total daily intake of less than 200 mg/person is required to meet the needs of growing infants and children.

Excessive sodium intake, usually via diet, can severely aggravate chronic congestive heart failure.

While it is clear that reduced sodium intake can reduce the blood pressure of some individuals with hypertension, it is equally clear that this type of therapy is not effective in all cases. Health authorities are of the opinion, however, that reduced sodium intake is beneficial.

DERIVATION OF GUIDELINE

The guideline value for sodium in drinking water is based on the taste threshold for sodium in water of 180 mg/L.

While there is evidence linking excess sodium intake with cardiovascular disease, it must be recognised that sodium intake via the water supply makes only a modest contribution to total intake. Nevertheless, water authorities are strongly encouraged to keep sodium concentrations as low as possible.

People with severe hypertension or congestive heart failure may need to restrict their overall dietary intake of sodium further if the concentration in drinking water exceeds 20 mg/L. Medical practitioners treating people with these conditions should be aware of the sodium concentration in the patient's drinking water.

REFERENCES

APHA Method 3500-Na Part B (1992). Sodium: Atomic Absorption Spectrometric method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

APHA Method 3500-Na Part C (1992). Sodium: Inductively Coupled Plasma method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

APHA Method 3500-Na Part D (1992). Sodium: Flame emission photometric method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

NOTE: Important general information is contained in PART II, Chapter 6

Sulfate

GUIDELINE

Based on aesthetic considerations (taste), the concentration of sulfate in drinking water should not exceed 250 mg/L. Purgative effects may occur if the concentration exceeds 500 mg/L.

GENERAL DESCRIPTION

Sulfate occurs naturally in a number of minerals, and is used commercially in the manufacture of numerous products including chemicals, dyes, glass, paper, soaps, textiles, fungicides and insecticides. Sulfate, including sulfuric acid, is also used in mining, pulping, and the metal and plating industries. Barium sulfate is used as a lubricant in drilling rigs for groundwater supply.

In the water industry, aluminium sulfate (alum) is used as a flocculant in water treatment, and copper sulfate is used for the control of blue-green algae (cyanobacteria) in water storages.

The highest concentrations reported in drinking water overseas are from groundwater supplies where the presence of sulfate is due to natural leaching from rocks. Concentrations have been reported up to 2200 mg/L. In source waters, concentrations are typically less than 100 mg/L.

The taste threshold for sulfate is in the range 250–500 mg/L.

Under anoxic conditions, the reduction of sulfate to sulfide by sulfate-reducing bacteria can result in unpleasant taste and odour due to the release of hydrogen sulfide, and can increase corrosion in pipes.

Food is probably the major source of intake of sulfate. In areas where the concentration of sulfate in water is high, drinking water may constitute the principal source of intake.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

In major Australian reticulated supplies, sulfate concentrations range from 1 mg/L to 240 mg/L, with a typical concentration of 20 mg/L. Sulfate concentrations can vary markedly in different parts of the country.

TREATMENT OF DRINKING WATER

Most sulfate salts are very soluble and cannot be removed from drinking water by conventional water treatment processes. Desalination methods such as reverse osmosis or distillation are required for sulfate removal.

MEASUREMENT

The sulfate concentration of drinking water can be determined by the methylthymol blue method (APHA 4500-SO₄²⁻ Part F 1992) or using ion chromatography (APHA Method 4500-SO₄²⁻ Part B 1992). Limits of determination are 0.1 mg/L and 1 mg/L respectively.

HEALTH CONSIDERATIONS

Sulfate is rapidly absorbed by the gastrointestinal tract but a number of factors, such as the accompanying cation, can influence the rate of absorption. Low doses are probably absorbed more effectively than high doses. Sulfate is found in all body tissue but is highest in the metabolically active areas of bone and tooth formation, and may be important in regulating bone development.

Sulfate is one of the least toxic anions. Ingestion of high doses can result in catharsis (loosening of the bowels) with dehydration as a possible side effect.

No harmful effects have been reported in studies with animals.

Sulfate can interfere with disinfection efficiency by scavenging residual chlorine. It can also increase corrosion of mild steel pipes.

DERIVATION OF GUIDELINE

The guideline value is based on the taste threshold of sulfate in drinking water of 250 mg/L.

REFERENCES

APHA Method 4500-SO₄²⁻ Part F (1992). Sulphate: Methylthymol blue method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

APHA Method 4500-SO₄²⁻ Part B (1989). Sulphate: Ion Chromatographic method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

Total dissolved solids

GUIDELINE

Based on taste, total dissolved solids in drinking water should not exceed 500 mg/L. The equivalent figure in electrical conductivity units (EC units) can be roughly determined by doubling this value.

GENERAL DESCRIPTION

Total dissolved solids (TDS) consist of inorganic salts and small amounts of organic matter that are dissolved in water. Clay particles, colloidal iron and manganese oxides, and silica fine enough to pass through a 0.45 micrometer filter membrane can also contribute to total dissolved solids.

Total dissolved solids comprise sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate, carbonate, silica, organic matter, fluoride, iron, manganese, nitrate (and nitrite) and phosphate.

The palatability of drinking water has been rated according to TDS concentrations as follows (Bruvold and Daniels 1990):

mg/L	quality
<80	excellent
80-500	good
500-800	fair
800-1000	poor
>1000	unacceptable

Water with extremely low TDS may taste flat and insipid.

High TDS values may be associated with excessive scaling in pipes, fittings and household appliances. Excessive corrosion may also occur with high TDS values.

The electrical conductivity of water, measured in EC units, increases with the concentration of dissolved solids. Electrical conductivity can be used as a measure of TDS, but the factor used to convert EC into TDS will depend on the type of dissolved solids present in the water.

TYPICAL VALUES IN AUSTRALIAN DRINKING WATER

In major Australian reticulated supplies TDS values range from about 45 mg/L to 750 mg/L.

MEASUREMENT

Three methods can be used to determine total dissolved solids. The most accurate entails a complete analysis of the sample and summation of the concentration of all the anions and cations. The most common and least expensive method is to convert electrical conductivity measurements to TDS values by multiplication with a factor that varies with the type of water (APHA Method 2510A 1992). Gravimetric measurements (i.e. by evaporation and weighing) can also be used (APHA Method 2540C 1992).

TREATMENT OF DRINKING WATER

It is difficult to remove dissolved solids from drinking water. Suitable technologies include reverse osmosis, ion exchange, and distillation, but all of these require considerable energy input and can be expensive to operate. Lime softening may also be effective where high TDS is mainly due to hardness.

NOTE: Important general information is contained in PART II, Chapter 6

HEALTH CONSIDERATIONS

No health effects have been associated specifically with high TDS concentrations. The health effects of individual components of TDS are discussed separately in the discussions on inorganic chemicals (Section 6.3.1 and relevant Fact Sheets).

DERIVATION OF GUIDELINE

Based on taste, water with a total dissolved solids content of less than 500 mg/L is regarded as good quality water (Bruvold *et al* 1990), although water with a total dissolved solids content of up to 1000 mg/L is acceptable to many communities.

In Australian surface water, the major ions contributing to total dissolved solids are sodium and chloride. Individual guideline values for these ions are consistent with a guideline value for total dissolved solids of 500 mg/L (see Fact Sheets on Chloride and Sodium); a higher TDS value may result in these other guideline values being exceeded.

GUIDELINES IN OTHER COUNTRIES

The 1984 WHO guideline value for total dissolved solids is 1000 mg/L. The 1993 WHO Guidelines indicate that concentrations above 1000 mg/L may give rise to consumer complaints.

The European Economic Community Standards have a guideline for total dry residue of 1500 mg/L but also state that electrical conductivity of less than 400 EC units is desirable.

Both the Canadian Guidelines and the United States EPA Regulations set a level of 500 mg/L.

REFERENCES

APHA Method 2510A (1992). Conductivity: Laboratory method. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

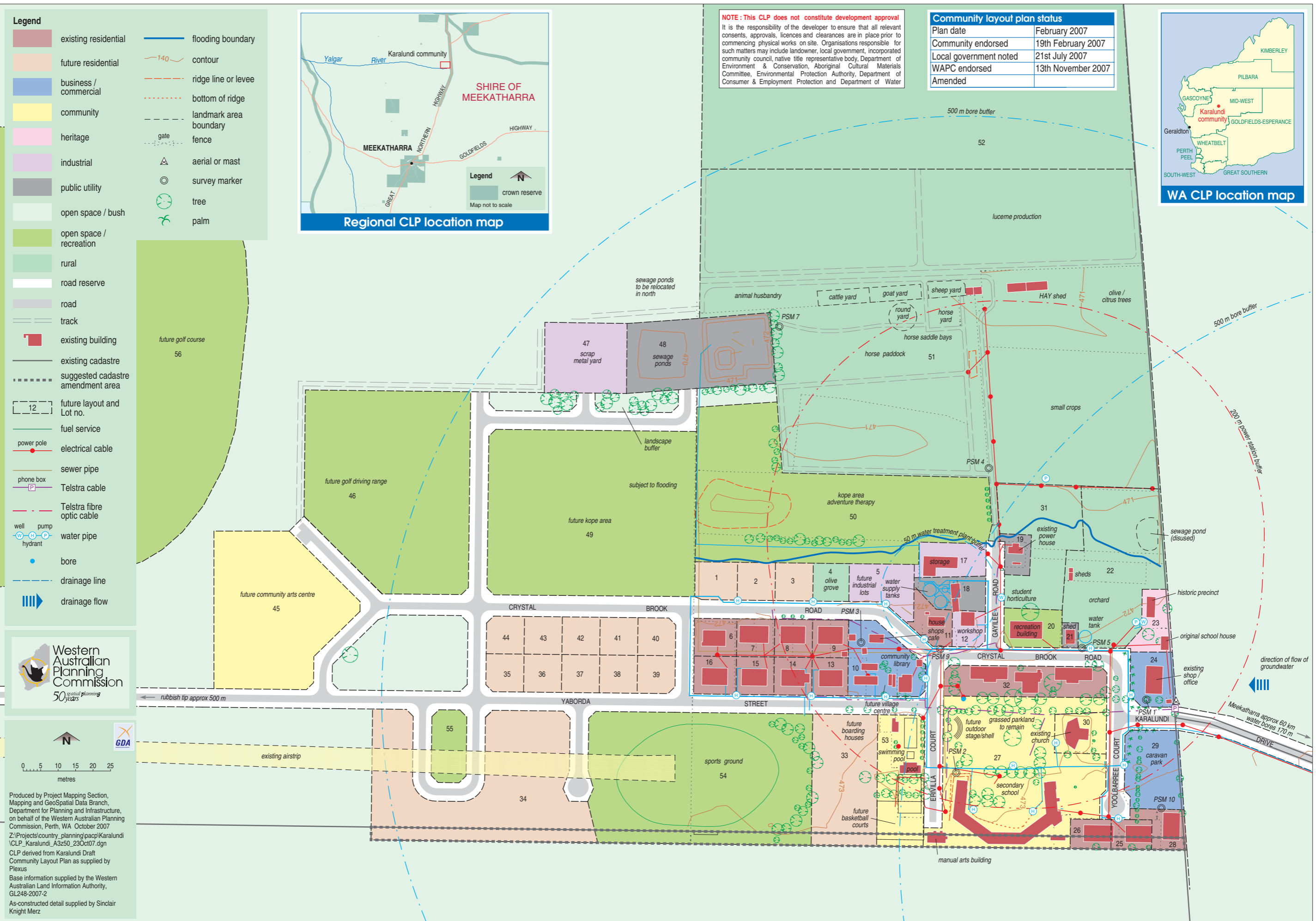
APHA Method 2540C (1992). Total Dissolved Solids Dried at 180°C. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington.

Bruvold WH and Daniels JI (1990). Standards for mineral content in drinking water. *Journal of the American Water Works Association*, 82, February, 59–65.

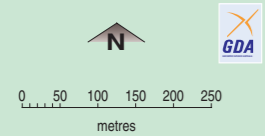


Appendix E

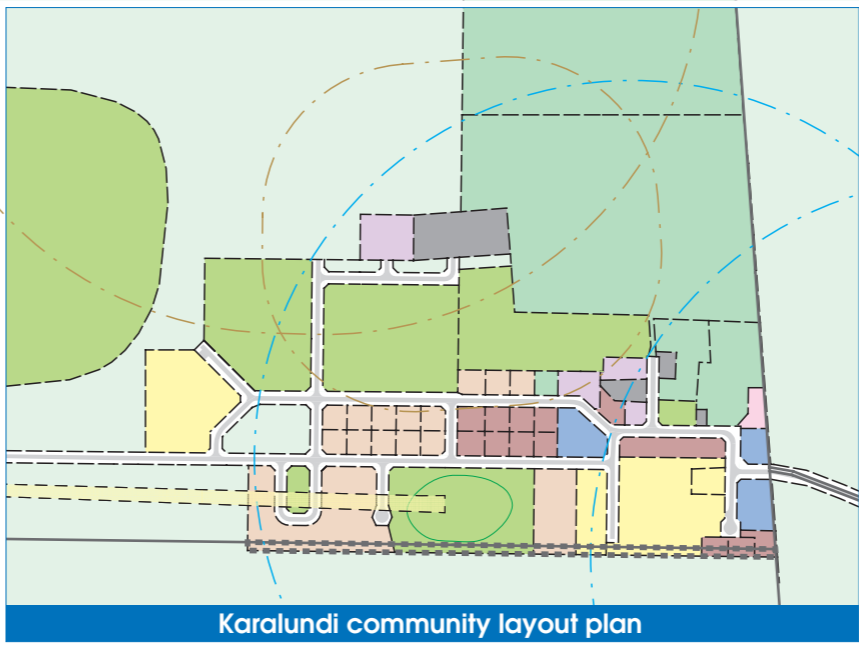
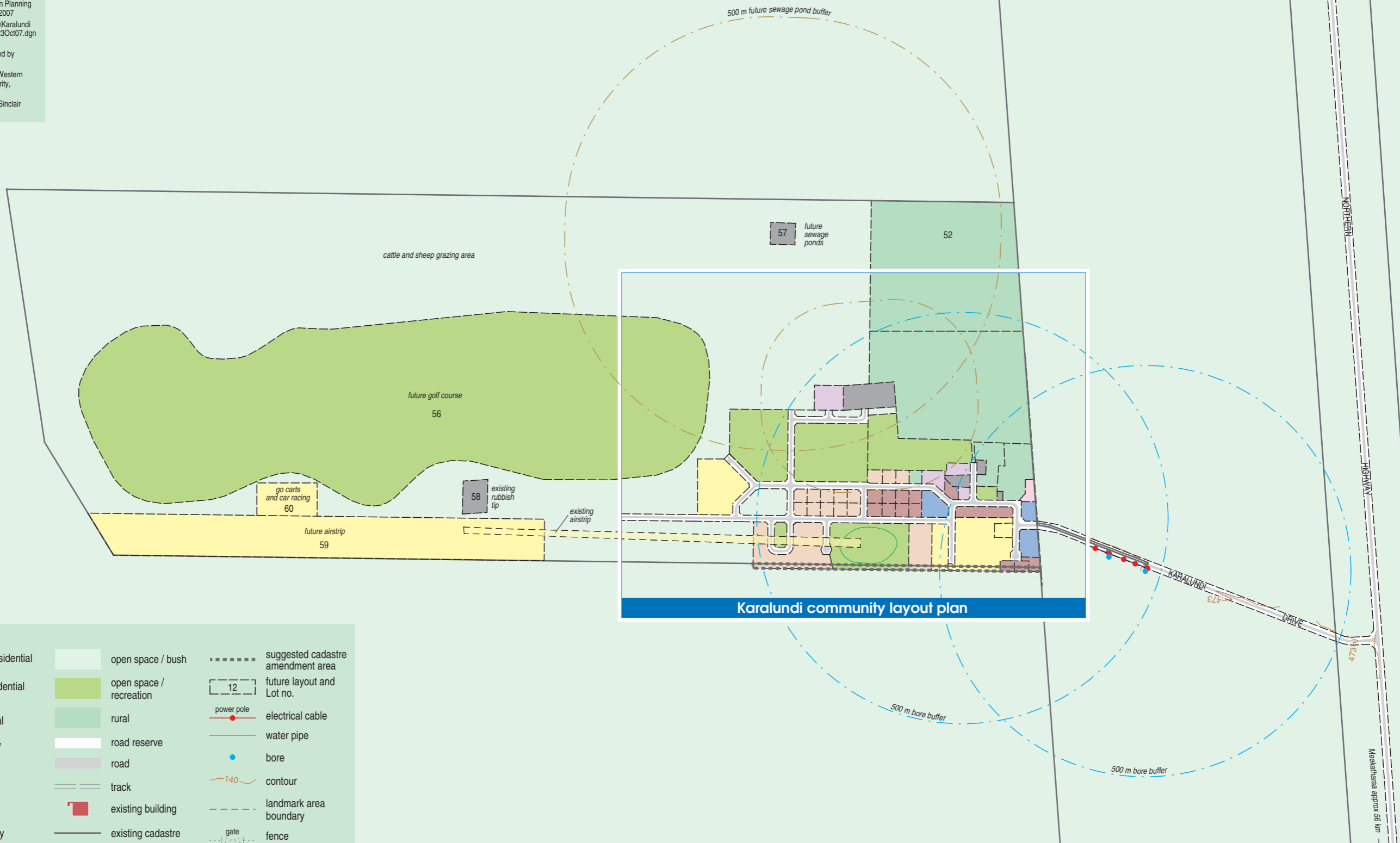
Department of Planning and
Infrastructure – Community Layout
Plan



NOTE: This CLP does not constitute development approval
It is the responsibility of the developer to ensure that all relevant consents, approvals, licences and clearances are in place prior to commencing physical works on site. Organisations responsible for such matters may include landowner, local government, incorporated community council, native title representative body, Department of Environment & Conservation, Aboriginal Cultural Materials Committee, Environmental Protection Authority, Department of Consumer & Employment Protection and Department of Water



Produced by Project Mapping Section, Mapping and GeoSpatial Data Branch, Department for Planning and Infrastructure, on behalf of the Western Australian Planning Commission, Perth, WA October 2007
Z:\Projects\country_planning\pacp\Karalundi\CLP_Karalundi_context_A3z50_23Oct07.dgn
CLP derived from Karalundi Draft Community Layout Plan as supplied by Plexus
Base information supplied by the Western Australian Land Information Authority, GL248-2007-2
As-constructed detail supplied by Sinclair Knight Merz



Legend			
	existing residential		suggested cadastre amendment area
	future residential		future layout and Lot no.
	business / commercial		electrical cable
	community		water pipe
	heritage		bore
	industrial		contour
	public utility		landmark area boundary
	open space / bush		fence
	open space / recreation		
	rural		
	road reserve		
	road		
	track		
	existing building		
	existing cadastre		



Appendix F

Risk assessment methodology

Level of risk scale

Likelihood	Level of consequence			
	Extreme	High	Medium	Low
Almost certain	Severe	Severe	High	Major
Likely	Severe	High	Major	Significant
Possible	High	Major	Significant	Moderate
Unlikely	Major	Significant	Moderate	Low
Rare	Significant	Moderate	Low	Low

Management priority scale

Management Priority	Level of Risk
High	Severe or High
Medium	Major or Significant
Low	Moderate or Low

Definition of residual likelihood

Likelihood	Definition
Almost certain	May occur at least several times per year
Likely	May arise about once per year
Possible	May arise approximately once every 2 to 5 years
Unlikely	May arise at least once in the operational history of the site
Rare	Has not occurred in the operational history of the site

Definition of consequence

Consequence	Environmental	Community
Extreme	Adverse change in existing beneficial use of water source. Immediate remediation required. Long-term effect on the environment (greater than 5 year to remediate or implement management strategy)	Immediate and/or long term human health risk created. Community notified and unable to drink water until remediation has taken place
High	Adverse change in existing beneficial use of water source. Immediate remediation required. Medium to short term effect on the environment (0-5 years to remediate or implement management strategy)	Immediate and/or long term human health risk created. Community notified and unable to drink water until remediation has taken place
Medium	Adverse change in potential beneficial use of water source. Long-term effect on the environment (greater than 5 year to remediate or implement management strategy)	Community concerns exist, no known immediate human health risks
Low	Adverse change in potential beneficial use of water source. Medium to short term effect on the environment (0-5 years to remediate or implement management strategy)	Community concerns do not exist, no known immediate human health risks
Negligible	Negligible effect on the environment	Community awareness does not exist, no known immediate human health risks



Appendix G

Water Quality Protection Notes

Water Quality Protection Note

Land use compatibility in Public Drinking Water Source Areas

Purpose

The Department of Environment (DoE) is responsible for managing and protecting the State's water resources. This note provides advice on the acceptability of land uses and activities within specific catchments that are the water source for schemes supplying cities and towns. These catchments are termed Public Drinking Water Source Areas (PDWSAs) and they require comprehensive water resource quality and land planning protection measures to ensure the ongoing availability of a 'safe, good quality drinking water' supply to protect the health of consumers for now and into the future. This note supports the DoEs Public Drinking Water Resource Policy (July 2004).

The note also forms an integral part of the Western Australian Planning Commission's *Statement of Planning Policy No. 2.7- Public Drinking Water Source Policy* 2003 (relevant to approximately 140 existing PDWSAs in Western Australia) prepared by the Department for Planning and Infrastructure under Section 5AA of the *Town Planning and Development Act 1928*. It is also intended to support the proposed Statement of Planning Policy for *Water Resources* designed to guide planning decisions in future PDWSAs. This note should be used by Local Government when developing local planning strategies, structure plans and town planning schemes. It should also be used in the assessment of subdivision and other development applications. The note will also assist the development of formal guidelines on land use activities in PDWSA prepared in liaison with key stakeholders such as the Water Corporation, Department of Health, Department of Conservation and Land Management, Department of Agriculture, Department of Industry and Resources, Department for Planning and Infrastructure and local government.

A review of this note may occur within 12 months (depending on feedback) to reflect DoE's policy position (which is influenced by public consultation undertaken for PDWSAs), advances in technology or land use activity standards, and Government decisions made concerning drinking water quality protection. This note may not consider all the circumstances that exist for planning strategies, plans and schemes across the State. Accordingly, changes to this note will only be considered if they apply broadly across the State. Other means of addressing localised special circumstances may be employed and the DoE will assist in achieving this outcome provided those changes do not place the PDWSA at a higher contamination risk.

Scope

This note provides the DoE's position on a range of land uses assessed against the Department's water quality protection strategy and management objectives within PDWSAs. Where a specific land use has not been covered in the accompanying tables, it should be referred to the Department's Water Source Protection Branch for assessment and a written response concerning its acceptability or any necessary water resource protection measures.

Public Drinking Water Source Area in Western Australia is the collective description for:

- Underground Water Pollution Control Areas,
- Water Reserves, and
- Catchment Areas,

declared under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* or the *Country Areas Water Supply Act 1947*.

This note is intended to complement the statutory role and policy of State and local government authorities, but it does not override Government policy or the need for proponents to fulfil their legal responsibilities for land use planning, and environmental, health, building or other necessary approvals.

PDWSA protection framework

The protection of PDWSAs relies on statutory measures available in water resource management and land use planning legislation. The DoE policy for the protection of PDWSAs includes three risk management based priority classification areas and two types of protection zones. The priority classification areas and protection zones are determined via specific Drinking Water Source Protection Plans (DWSPP) that are prepared in consultation with State government agencies, landowners, local government, and key industry and community stakeholders. Where a fully consulted DWSPP does not exist for a PDWSA, the DoE initially prepares Drinking Water Source Protection Assessment (DWSPA) documents to reflect readily available information for use in land use planning assessments and decision making.

Priority classification areas

Priority 1 (P1) classification areas are managed to ensure that there is **no degradation** of the drinking water source by preventing the development of potentially harmful activities in these areas. The guiding principle is **risk avoidance**. This is the most stringent priority classification for drinking water sources. P1 areas normally encompass land owned or managed by State agencies, but may include private land that is strategically significant to the protection of the drinking water source (e.g. land immediately adjacent to a reservoir). Most land uses create some risk to water quality and are therefore defined as “**Incompatible**” in P1 areas.

Priority 2 (P2) classification areas are managed to ensure that there is **no increased risk** of water source contamination/ pollution. For P2 areas, the guiding principle is **risk minimisation**. These areas include established low-risk land development (e.g. low intensity rural activity). Some development is allowed within P2 areas for land uses that are defined as either “**Compatible with conditions**” or “**Acceptable**”.

Priority 3 (P3) classification areas are defined to **manage the risk of pollution** to the water source from catchment activities. Protection of P3 areas is mainly achieved through guided or regulated environmental (risk) management for land use activities. P3 areas are declared over land where water supply sources co-exist with other land uses such as residential, commercial and light industrial development. Land uses considered to have significant pollution potential are nonetheless opposed or constrained.

Wellhead and reservoir protection zones

In addition to the three Priority Classification Areas, specific protection zones are defined to protect drinking water sources from contamination in the immediate vicinity of water extraction facilities. Within these zones by-laws may prohibit, restrict or approve defined land uses and activities to prevent water source contamination or pollution. Special conditions, such as restrictions on storage and use of chemicals, may apply within these zones. The legislation is currently being reviewed to simplify and enhance the protection of public drinking water sources.

Wellhead protection zones (WHPZ) are used to protect underground sources of drinking water. They are circular (unless information is available to determine a different shape), with a radius of 500 metres in P1 areas, and 300 metres in P2 and P3 areas. WHPZ do not extend outside PDWSA boundaries. Reservoir protection zones (or ‘**prohibited zones**’ as they are called in the by-laws) consist of a statutory 2 kilometre wide buffer area around the top water level of storage reservoirs in the Perth water supply area, and include the reservoir water-body. The reservoir protection zones (RPZ) apply over Crown land and prohibit public access to prevent contamination (physical, chemical and biological) of the source water. RPZ do not extend outside PDWSA boundaries. The DoE is currently considering a provision for RPZ buffer areas of less than 2 kilometres, and creation of consistent by-laws for country and Perth PDWSAs.

Special protection measures apply in WHPZ and RPZ (prohibited zones) as described in the By-laws under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* and the *Country Areas Water Supply Act 1947*.

The determination of priority classification areas or protection zones over land in a PDWSA is based on:

- the strategic importance of the land or water source,
- the local planning scheme zoning,
- form of land tenure, and
- existing approved land uses/activities.

The land use tables in this protection note directly apply to the three types of priority classification areas identified in DWSP or agreed in specific *Land Use and Water Management Strategy* documents. Currently there are 45 DWSPs available to guide land use planning decisions in PDWSAs, and (nearly 100) others are in development. In the absence of a DWSP, the DoE recommends that planning decisions within any gazetted or proposed PDWSA are guided by DWSPA documents (where they exist) and the **'potential'** priority classification area or protection zone status of a proposal identified using **Diagram 1: Assessment of potential priority classification areas and protection zones** (overleaf).

Compatibility of land uses within PDWSAs

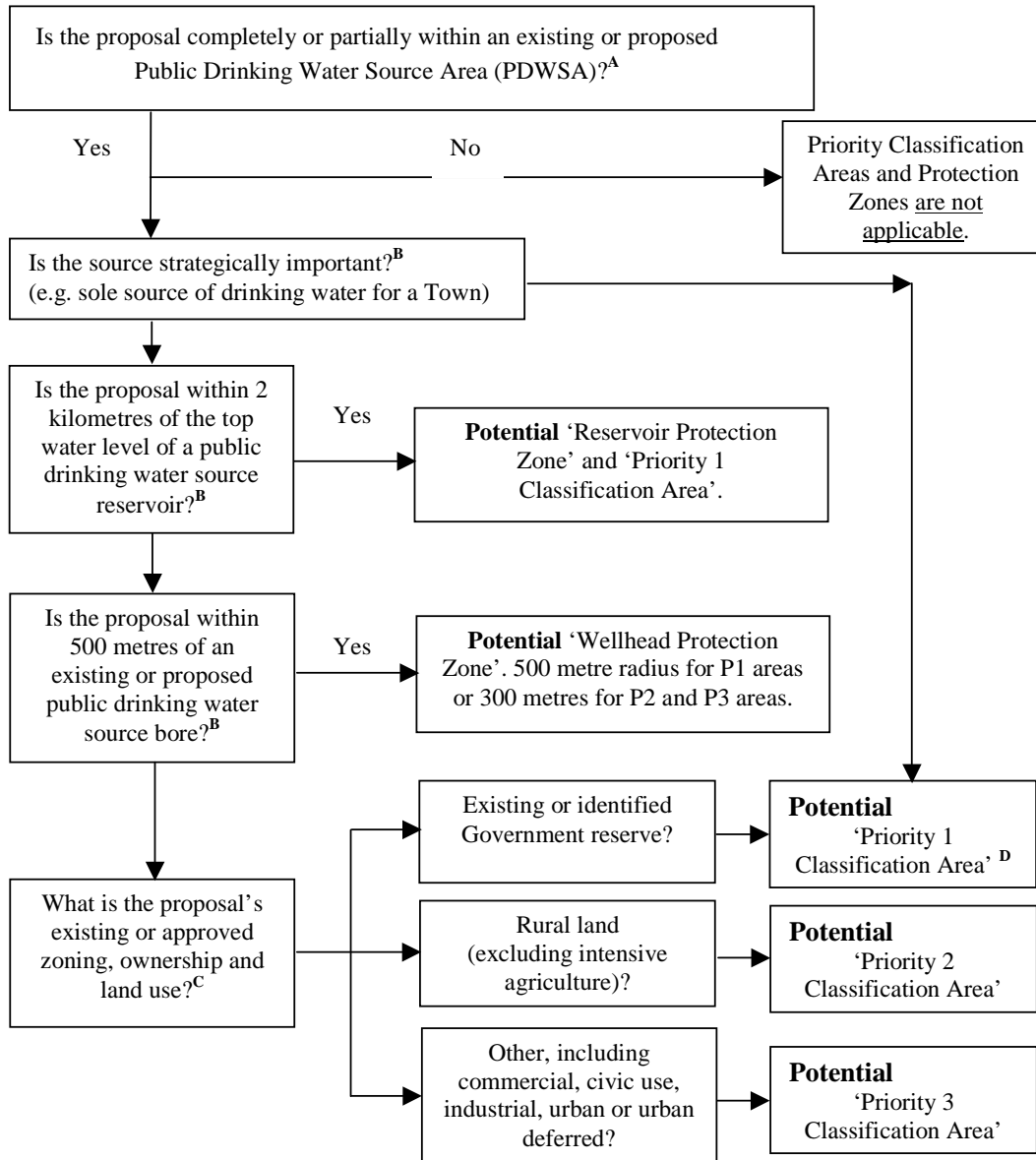
The tables in this note have been prepared for use by local governments, State planners and other agencies as a basis for regulating land use within PDWSAs. The note complements the Western Australian Planning Commission's *Statement of Planning Policy Number 2.7 (June 2003) Public Drinking Water Sources*. These tables define land uses in terms of their compatibility with the sustainable use of the drinking water source. They promote a priority for protection of the environmental value: 'drinking water' within a PDWSA over other values that may exist. The three definitions used are **'Incompatible'**, **'Compatible with conditions'** and **'Acceptable'**. In previous versions of this note the definitions were 'Incompatible', 'Conditional' and 'Compatible'.

The DoE recognises that there may be special circumstances which may occasionally result in an **'Incompatible'** land use receiving approval. Where planning decisions result in this outcome it is important for project proponents to have demonstrated an overriding community benefit and that the land use will not increase the risk of contamination to the PDWSA. The DoE expects to have significant, early involvement in planning decisions of this nature to maximise the protection of the drinking water resource. It should be noted that where a water source is the sole supply for a community, or has a particularly high strategic value for the supply of drinking water, then it would be difficult to understand how that source might be put at any risk of contamination.

Detailed information on water quality protection issues and recommended best management practices for **'Compatible with conditions'** land uses are being developed in approved environmental policy, codes of practice, management guidelines and water quality protection notes. These documents, along with the most recent version of this note, can be found on the DoE Internet site <http://www.environment.wa.gov.au>. Information on land use and development regulation within PDWSAs can also be obtained from DoE's regional offices.

The DoE's Water Source Protection Branch, presently located in East Perth, is custodian of this water quality protection note and will provide detailed advice on its application and coordinate any suggested amendments.

Diagram 1: Assessment of potential priority classification areas and protection zones



Legend

- A. The location of PDWSAs can be found in DoE's Drinking Water Source Protection Assessments and Plans or through your regional DoE office, Local Government office, Water Corporation or from the Department for Planning and Infrastructure.
- B. Strategically significant sources and potential contamination from land uses close to drinking water reservoirs or abstraction bores are considered first, due to these involving the highest risk of contamination reaching consumers.
- C. Current zoning or land use information is available from your Local Government office.
- D. Government land is protected to achieve the highest level of safety for drinking water in all parts of a catchment through a Priority 1 classification, wherever this is reasonable and practicable.

Existing approved land uses

Many land uses covered in this note may have been legally established prior to establishment/ gazettal of the PDWSA or modern protection measures being required. The DoE policy is that existing approved land uses/ activities can continue at their presently approved level, provided they operate lawfully. Where necessary, negotiations may be arranged with land owners to acquire property rights in P1 source protection areas. Where practical, this agency will also negotiate with the operators of existing 'Incompatible', or 'Compatible with conditions' activities to implement environmental management practices that minimise risks to water sources.

Proposed land uses

After reading this protection note, please view the DoE Internet site and/ or contact your nearest DoE Regional Office for advice on the location of PDWSAs, priority classification areas, and reservoir or wellhead protection zones. You may discuss with DoE staff any proposed land use activities that may affect water resources. The early identification of water resource protection issues in development stages of land use planning proposals is recommended in both the June 2003 *Statement of Planning Policy for Public Drinking Water Sources* and proposed *Water Resources Policy* by the Western Australian Planning Commission.

Definition of terms used in the following tables

'Acceptable' (equivalent to 'compatible' in previous version of this note)- means the land use is accepted by DoE as not likely to harm the drinking water source, and is consistent with the management objectives of that priority classification. The adoption of best practice environmental management methods for new proposals to protect water quality is expected. Existing land users are also encouraged to adopt best practice environmental management methods to help protect water quality. These land uses generally do not need referral to the DoE.

'Compatible with conditions' (equivalent to 'conditional' in previous version of this note) - means the land use is likely to be accepted by DoE as not likely to harm the drinking water source, (and is consistent with the management objectives of the priority classification) provided best environmental management practices are used. This may result in the application of 'specific conditions' (via the planning or environmental approval processes) that must be complied with to ensure the water quality objective of the priority area is maintained.

Land uses described as 'Compatible with conditions' need ONLY to be referred to DoE for assessment and a written response if the activity does not follow recommendations endorsed by DoE such as those made in policy, environmental management guidelines, protection notes; Ministerial Conditions, Works Approvals, Licenses or agreements (e.g. a 'Memorandum of Understanding' developed between any Local Government and DoE).

'Incompatible'- means the land use is UNACCEPTABLE to DoE as it does not meet the management objectives of the priority classification area. DoE will normally oppose approval of these land uses through the planning decision making process and under legislation administered by DoE. If planning decisions are made to approve these land uses (e.g. as a consequence of a planning appeals process), then DoE should be advised of that decision and have been directly involved in providing advice to the planning decision makers on water quality protection issues. It should be noted that contentious proposals may be referred to the EPA for Environmental Impact Assessment under the *Environmental Protection Act 1986*.

'Extensive'- means limited additional inputs beyond those supplied by nature are required to support the land use, e.g. for agriculture- animal feed supplements only during seasonal dry periods, or during the final preparation of stock for the market.

'Intensive'- means regular additional inputs are required to support the desired land use, e.g. for agriculture-irrigation, fertilisers, pesticides, or non-forage animal feeding dominantes.

Interpretation of land use recommendations for planning schemes and development approvals

When using the following land use compatibility tables to guide planning schemes and development approval decisions, the following relationships should be used:

- a) Where the table identifies a land use as ‘**Acceptable**’, this use is permitted by DoE within that priority classification area. It may be identified as a ‘**P**’ (permitted) use in a scheme, providing the use complies with the relevant development standards and requirements of the planning scheme.
- b) Where the table identifies a use as ‘**Compatible with conditions**’, this use should be a discretionary use within the priority classification area and should be identified as either a ‘**D**’ or ‘**A**’ (after special notice) use in the scheme. Proposals for ‘**Compatible with conditions**’ uses should **ONLY** be referred to DoE for assessment and response if they do not meet existing agency policy, guidelines or protection note measures, unless prior agreement has been made between a specific local government and DoE on alternative measures.
- c) Relevant environmental management guidelines, codes of practice, water quality protection notes or agreements should be used in the first instance to define DoE's position on any land-use and limit the need to refer proposals to the DoE. Where these do not exist, site specific advice may be provided by the DoE.
- d) Where the table identifies a use as ‘**Incompatible**’, that use should not be permitted within that priority source protection area, and should be identified as an ‘**X**’ (unacceptable use) in the scheme.

Where the table does not include a proposed land use that could affect water quality, that use should be considered to be ‘**Incompatible**’ until the proponent can demonstrate that it meets the drinking water quality protection objective of the designated priority classification area. Specific advice on the proposed land use should be obtained from the DoE’s Water Source Protection Branch.

If the land use planning approval process supports a proposal that is inconsistent with this water quality protection note, then DoE Water Source Protection Branch should be advised of this situation and the reasons for that decision. This advice will trigger DoE’s assessment of the significance/ consequence of that decision to the drinking water source and the outcome will be considered in future strategies for water quality protection, and in the periodic review and update of this note. A means to ensure the DoE’s effective early involvement with such cases is currently being developed.

Tables defining compatibility of various land uses within PDWSA

It is important to note that this table provides the DoE’s recommended compatibility of land uses for the current zoning of land. It must not be used to support rezoning of land to provide for more intensive land uses. For example, although P3 areas provide for high density urban development when the land is already zoned Urban or Urban deferred, this Table must not be read to justify a zoning change within P3 areas to allow for high density urbanisation of rural zoned land.

Model Scheme Text (MST) land uses are shown in **bold** in the first column. Definitions covered in the MST (see note 23) can also be found in the *Town Planning Amendment Regulations 1999*.

Model Scheme Text & interpreted type of land use	P1 areas	P2 areas	P3 areas
Agriculture– extensive			
- pastoral leases	Compatible with conditions	Acceptable	Acceptable
- floriculture (non irrigated), stock grazing (excluding pastoral leases) and broad hectare cropping,	Incompatible	Compatible with conditions (see notes 11, 12)	Acceptable
Agriculture- intensive			
- aquaculture (fish, plants and crustaceans)	Incompatible	Compatible with conditions	Compatible with conditions
- orchards; production nurseries– potted plants; viticulture– wine and table grapes	Incompatible	Compatible with conditions	Acceptable
- floriculture; market gardens (see note 24); turf farms	Incompatible	Incompatible	Compatible with conditions
- hydroponic plant growing	Incompatible	Compatible with conditions	Compatible with conditions
- plant nurseries / garden centres	Incompatible	Compatible with conditions (see note 2)	Acceptable
Agro-forestry	Incompatible	Compatible with conditions	Acceptable
Amusement parlour	Incompatible	Incompatible	Acceptable (see note 1)
Animal establishment			
- animal saleyards and stockyards (see note 13)	Incompatible	Compatible with conditions (see note 2)	Compatible with conditions (see note 2)
- apiaries	Compatible with conditions	Acceptable	Acceptable
- catteries	Incompatible	Acceptable	Acceptable
- dairy sheds	Incompatible	Compatible with conditions (see notes 2, 3, 12)	Compatible with conditions (see note 3)
- dog kennels	Incompatible	Compatible with conditions	Compatible with conditions
- equestrian centres (see note 17)	Incompatible	Incompatible	Acceptable
- feedlots, intensive outdoor livestock holding	Incompatible	Incompatible	Compatible with conditions
- stables (see note 18)	Incompatible	Compatible with conditions	Acceptable
Animal husbandry- intensive			
- piggeries	Incompatible	Incompatible	Incompatible
- poultry farming - housed	Incompatible	Compatible with conditions	Compatible with conditions
Bed and breakfast (accommodating a maximum of 6 guests)	Compatible with conditions (see notes 6, 16)	Acceptable (see note 23)	Acceptable
- farm stay accommodation, rural chalets)	Compatible with conditions (see notes 6, 16)	Compatible with conditions (see note 4)	Acceptable
Betting agency	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)
Caravan park	Incompatible	Incompatible	Compatible with conditions (see note 1)
Caretakers dwelling	Compatible with conditions (see note 2)	Compatible with conditions	Acceptable
Car park	Incompatible	Compatible with conditions (see note 2)	Acceptable

Model Scheme Text & interpreted type of land use	P1 areas	P2 areas	P3 areas
Cemeteries	Incompatible	Incompatible	Compatible with conditions
Child care premises	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)
Cinema/ theatre	Incompatible	Incompatible	Acceptable (see note 1)
Civic use	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)
Club premises			
- sporting or recreation clubs	Incompatible	Compatible with conditions	Acceptable (see note 1)
- health centres	Incompatible	Incompatible	Acceptable (see note 1)
Community purpose			
- community halls	Incompatible	Compatible with conditions (see note 2)	Acceptable
- irrigated golf courses or recreational parks	Incompatible	Incompatible	Compatible with conditions (see note 11)
- motor-sports (permanent racing facilities)	Incompatible	Incompatible	Compatible with conditions
- public swimming pools/ aquatic centres	Incompatible	Incompatible	Compatible with conditions
- rifle ranges	Incompatible	Compatible with conditions	Acceptable
Consulting rooms	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)
Convenience store	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)
Corrective institution	Incompatible	Incompatible	Compatible with conditions (see note 1)
Educational establishment			
- community education centres, scientific research institution	Compatible with conditions (see note 2)	Compatible with conditions (see note 2)	Acceptable (see note 1)
- primary / secondary schools, tertiary education facilities	Incompatible	Incompatible	Acceptable (see note 1)
Exhibition centre	Incompatible	Incompatible	Acceptable (see note 1)
Family day care	Incompatible	Acceptable (see note 19)	Acceptable (see note 1)
Fast food outlet	Incompatible	Incompatible	Acceptable (see note 1)
Forestry (native forest/ silviculture/ tree farming)	Compatible with conditions (see note 11)	Compatible with conditions (see note 11)	Acceptable
Fuel depot (storage/ transfer)	Incompatible	Incompatible	Compatible with conditions
Funeral parlour	Incompatible	Incompatible	Acceptable (see note 1)
Home business	Incompatible	Acceptable (see note 20)	Acceptable (see note 1)
Home occupation	Compatible with conditions (see note 15)	Acceptable (see note 21)	Acceptable (see note 1)

Model Scheme Text & interpreted type of land use	P1 areas	P2 areas	P3 areas
Home office	Compatible with conditions (see note 15)	Acceptable	Acceptable
Home store	Incompatible	Compatible with conditions	Acceptable (see note 1)
Hospital	Incompatible	Incompatible	Compatible with conditions (see note 1)
Hotel (includes hotels, hostels, resorts)	Incompatible	Incompatible	Acceptable (see note 1)
Industry			
- abattoirs	Incompatible	Incompatible	Incompatible
- cottage	Compatible with conditions	Compatible with conditions	Acceptable
- drinking water treatment plant	Compatible with conditions	Compatible with conditions	Compatible with conditions
- extractive, includes construction/ mining camps (see note 10)	Compatible with conditions	Compatible with conditions	Compatible with conditions
- food processing, dairy product factories, breweries	Incompatible	Incompatible	Compatible with conditions (see note 1)
- general (chemical manufacture/ formulation, dry cleaners, dye works, laboratories, photo-processors)	Incompatible	Incompatible	Compatible with conditions (see note 1)
- general (metal production/ finishing, pesticide operator depots, heavy or energy industry, petroleum refineries)	Incompatible	Incompatible	Incompatible
- general (concrete batching, cement products, fertiliser manufacture/ bulk storage, wrecking)	Incompatible	Incompatible	Compatible with conditions
- general (mineral processing)	Incompatible	Incompatible	Compatible with conditions (see note 9)
- light industry	Incompatible	Incompatible	Compatible with conditions (see note 1)
- milk transfer depots	Incompatible	Incompatible	Compatible with conditions
- mining (includes mineral and energy exploration, oil or gas extraction / decontamination for transport)	Compatible with conditions (see note 9)	Compatible with conditions (see note 9)	Compatible with conditions (see note 9)
- mining (tailings dams)	Incompatible	Incompatible	Compatible with conditions (see note 9)
- mining (includes construction/ mining camps), (see note 10)	Compatible with conditions	Compatible with conditions	Compatible with conditions
- rural (animal product rendering works, tanneries, wool scours)	Incompatible	Incompatible	Incompatible
- rural (farm supply centres, manure stockpiling/ processing facilities)	Incompatible	Compatible with conditions (see note 2)	Compatible with conditions
- rural (forestry products processing– chip mills, pulp/ paper, timber preservation, wood/ fibre works, composting/ soil blending - commercial)	Incompatible	Incompatible	Compatible with conditions
- service industry	Incompatible	Incompatible	Compatible with conditions
Landfill (solid waste disposal)			
- class I (refer also to 'Storage - used tyres' advice)	Incompatible	Incompatible	Compatible with conditions
- class II or III	Incompatible	Incompatible	Incompatible
- class IV or V	Incompatible	Incompatible	Incompatible
Lunch bar	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)

Model Scheme Text & interpreted type of land use	P1 areas	P2 areas	P3 areas
Major transport infrastructure (roads, railways)	Incompatible	Compatible with conditions (see note 14)	Acceptable
Marina (includes boat moorings and servicing)	Incompatible	Incompatible	Compatible with conditions
Marine filling station (boat fuelling)	Incompatible	Incompatible	Compatible with conditions
Market (food; general produce; second-hand goods)	Incompatible	Incompatible	Acceptable (see note 1)
Medical centre	Incompatible	Incompatible	Acceptable (see note 1)
Motel	Incompatible	Incompatible	Acceptable (see note 1)
Motor vehicle, boat or caravan sales (sales yards)	Incompatible	Incompatible	Acceptable (see note 1)
Motor vehicle repair	Incompatible	Incompatible	Compatible with conditions
Motor vehicle wash	Incompatible	Incompatible	Compatible with conditions
National and regional parks and nature reserves	Acceptable	Acceptable	Acceptable
Night club	Incompatible	Incompatible	Acceptable (see note 1)
Office	Incompatible	Compatible with conditions	Acceptable (see note 1)
Park home park	Incompatible	Incompatible	Compatible with conditions (see note 1)
Place of worship	Incompatible	Incompatible	Acceptable (see note 1)
Plantation	Compatible with conditions (see note 11)	Compatible with conditions (see note 11)	Acceptable
Reception centre	Incompatible	Incompatible	Acceptable (see note 1)
Recreation – private (within non-designated recreation areas on Crown land)	Incompatible	Incompatible	Acceptable
Residential building			
- house	Compatible with conditions (see note 16)	Acceptable (see note 4)	Acceptable (see note 1)
- group dwellings (aged and dependent persons)	Incompatible	Incompatible	Acceptable (see note 1)
Restaurant	Incompatible	Incompatible	Acceptable (see note 1)
Restricted premises (adult interests)	Incompatible	Incompatible	Acceptable (see note 1)
Rural pursuit	See Agriculture, Animal establishment or husbandry		
Service station (includes aircraft, automotive repairs, boats, mechanical plant, service stations at transport and municipal works depots)	Incompatible	Incompatible	Compatible with conditions (refer to note 1)
Shop	Incompatible	Compatible with conditions (see note 2)	Acceptable (see note 1)
Showroom	Incompatible	Incompatible	Acceptable (see note 1)
Storage			
- used tyres (see note 22)	Incompatible	Incompatible	Incompatible

Model Scheme Text & interpreted type of land use	P1 areas	P2 areas	P3 areas
- chemical storage in under ground tanks	Incompatible	Incompatible	Compatible with conditions
- chemical storage in above ground tanks	Incompatible	Compatible with conditions	Compatible with conditions
Tavern	Incompatible	Incompatible	Acceptable (see note 1)
Telecommunications infrastructure	Compatible with conditions	Compatible with conditions	Compatible with conditions
Toilet blocks and change rooms	Compatible with conditions (see note 2)	Compatible with conditions	Acceptable
Trade display	Incompatible	Incompatible	Acceptable (see note 1)
Veterinary centre	Incompatible	Compatible with conditions (see note 2)	Compatible with conditions (see note 1)
Warehouse	Incompatible	Compatible with conditions (see note 2)	Compatible with conditions (see note 1)
Waste transfer station (includes recycling depots)	Incompatible	Incompatible	Compatible with conditions
Wastewater infrastructure			
- sewerage – gravity sewers	Incompatible	Incompatible	Acceptable
- sewerage – pressure mains	Incompatible	Compatible with conditions	Acceptable
- sewer pump stations	Incompatible	Compatible with conditions	Compatible with conditions
- treatment plants, wastewater disposal to land	Incompatible	Incompatible	Compatible with conditions
- wastewater injection into the ground (see note 25)	Incompatible	Incompatible	Incompatible
Water treatment plants (drinking)	See Industry		
Winery (includes wine tasting facilities)	Incompatible	Compatible with conditions (see notes 3 & 5)	Compatible with conditions (see note 3)

Table recommending compatibility of land subdivision within PDWSA:Note - This table reflects the recommended size of a subdivision based on the existing zoning and the priority classification area status of land. It should be noted that Town Planning Scheme provisions for specific zones and reserves will take precedent over the following recommended lot sizes.

Form of subdivision (specific to current zoning)	P1 areas	P2 areas	P3 areas
Rural subdivision			
- to a lot size of 4 hectares or greater	Incompatible	Acceptable	Acceptable
- to a lot size less than 4 hectares	Incompatible	Incompatible	Incompatible
Special rural subdivision			
- to a lot size of 2 hectares or greater	Incompatible	Compatible with conditions (see notes 7 & 8)	Compatible with conditions (see note 8)
- to a lot size between 1 and 2 hectares	Incompatible	Incompatible	Compatible with conditions (see notes 7 & 8)
- to a lot size less than 1 hectare	Incompatible	Incompatible	Compatible with conditions (see note 7)
Urban subdivision	Incompatible	Incompatible	Acceptable (see note 1)
Industrial subdivision	Incompatible	Incompatible	Acceptable (see note 1)

Explanatory notes related to land uses described the tables:

The following notes provide interpretive information based on the scale or type of development described in the preceding tables. They do not list all the conditions that could apply to any activity or development.

1. Must be connected to deep sewerage, except where exemptions apply under State Government Sewerage Policy. The Policy recognises that sewer connection may be impractical in some areas. Under these circumstances maximum wastewater loadings (based on people/ hectare) apply linked to the management Priority of the site.
2. The land use is normally incompatible, but may be conditionally approved where this facility is consistent with approved State and local government planning strategies or schemes.
3. The land use must incorporate best environmental management practices compatible with the management strategy for the designated priority area defined in the relevant source protection plan.
4. In Priority 2 areas: conditions may apply to density of dwellings (i.e. hectares per dwelling).
5. Size of the grape crush shall not exceed 500 tonnes per year.
6. May be approved if occupancy is of equivalent size to a single dwelling household (i.e. less than 10 people– defined by capacity of a septic tank based on-site wastewater treatment system).
7. An average, rather than minimum, lot size may be accepted if the proponent can demonstrate that the water quality objectives of the source protection area are met, and caveats/memorials are placed on titles of specified blocks stating that further subdivision shall not occur.
8. Lots should only be created where land capability assessment shows that effective on-site soakage of treated wastewater can be achieved. Conditions apply to siting of wastewater disposal systems in areas with poor land drainage and/ or a shallow depth to groundwater, animals are held or fertiliser is applied. Alternative wastewater treatment systems, where approved by the Department of Health, may be accepted with ongoing maintenance requirements.
9. Conditions are likely to be placed via a Department of Industry and Resources mineral tenement lease, and / or as a result of Minister for the Environment’s approval after an Environmental Impact Assessment.
10. Conditions apply to the storage of fuels and chemicals, the depth of excavation related to the water table and rehabilitation criteria. Underground fuel or chemical storage tanks are prohibited via DoE by-laws in Priority 1 and 2 areas within Underground Water Pollution Control Areas.
11. Conditions apply to regulate fertiliser and pesticide application.
12. Can be approved if animal stocking levels (animals per hectare, guided by the Department of Agriculture’s stocking rate guidelines) are consistent with the priority source protection area objectives.
13. This does not include stockyards occasionally used on farms or pastoral leases for animal husbandry.
14. Conditions may be imposed to cover design, construction of infrastructure and the types of goods.
15. May only be approved if *Home Occupation* relates to an existing residence.
16. Limited to one residential building per property.
17. Includes land or buildings dominantly used for the showing, competition or training of horses, and riding schools.
18. Includes any land, building or structure used for equine (e.g. horses, asses, mules and donkeys) housing, keeping and feeding and associated activities.
19. In accordance with *Community Services (Child Care) Regulations 1988: A child care service provided to a child in a private dwelling in a family of or domestic environment. No more than 5 children of pre-school age and no more than 7 children under 12 years old, including the children of the licensee or permit holder.*

20. No more than 2 employees, and the home business occupies an area up to 50 square metres. Compatible if only an office/ administrative business (i.e. overnight parking of only one commercial vehicle, no refuelling or repair/ maintenance of business vehicles, and no activities involving on-site use storage or disposal of chemicals or process wastewater).
21. Employees shall be members of the household, and the home business occupies an area of up to 20 square metres. No provision for refuelling, repair or maintenance of commercial/ business vehicles or on-site use or storage of chemicals.
22. Used tyre use, storage and disposal are subject to *Used Tyre Regulations 1996*, administered by the this agency.
23. As defined in the *Model Scheme Text (1997)* or the *Residential Design Codes of Western Australia (2002)* prepared by the Western Australian Planning Commission, and covering local government planning schemes.
24. Applies to the commercial production of horticultural crops e.g. vegetables, flowers and fruit crops grown in contact with the ground. Does not apply to cereal or oil seed crops, perennials e.g. orchards, vineyards, nuts; or any crop grown separate from contact with soils in the natural environment e.g. hydroponics.
25. The use of recycled (reclaimed) water to address the diminishing level of scheme water supply in Western Australia is currently being investigated by Government. The social, environmental, health and economic issues related to this option are significant and need to be further progressed before its applicability in PDWSA is reconsidered.

More information or feedback

More information about recommended best management practices is available in Environmental Management Guidelines and Water Quality Protection Notes for some of the listed land uses. These are available on DoE's Internet site <http://drinkingwater.environment.wa.gov.au> or by contacting DoE regional offices.

We welcome your comments on this note. The note will be updated from time to time as feedback is received or land-use activity standards change. If you wish to discuss this note, please contact DoE Water Source Protection Branch at the Hyatt Centre in East Perth. Phone: (08) 9278 0300 (business hours); Fax: (08) 9278 0585; or E-mail: use {feedback} section at DoE Internet address <http://www.environment.wa.gov.au> citing the topic and version.



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Appendix H

Aboriginal Reserves methodology
Community Water determination

Method for Determining Aboriginal Water Reserve Boundaries

May 2009

Department of Housing



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Method for Determining Aboriginal Water Reserve Boundaries

For the purpose of this assessment the following were considered in determining groundwater protection boundaries in the communities under investigation:

- Anticipated hydrogeological setting (i.e. geology type),
- Published hydraulic properties of anticipated hydrostratigraphic units,
- Estimated groundwater flow direction; and
- Potential contaminant sources with researched half life times.

The above factors were used to estimate groundwater flow velocities and flow directions (i.e. distance that groundwater would travel in one day under the given circumstances). As well as the potential effects of degradation and attenuation of dissolved contaminants along the flow paths.

1. Hydrogeological setting

The hydrogeological setting, including underlying lithologies, were assessed from the information obtained from the geological maps published by the Department of Minerals and Energy, Government of Western Australia and the Geological Survey of Australia. Additional data, where available, was obtained from consulting hydrogeological reports and the Department of Water's WIN database.

2. Hydraulic properties of hydrostratigraphic units

Factors taken into consideration included:

- hydraulic conductivity (K),
- effective porosity (α),
- hydraulic gradient (dh/dl); and
- Darcy velocity and linear velocity.

Due to the absence of detailed information for the hydrostratigraphic units in the communities or study area, typical published values for the hydrostratigraphic units were used in determining the water reserves. The typical values used are listed in Tables 1 and 2 below.

Table 1: Typical hydraulic conductivity values

Matrix	Typical Lithology	Low K (m/d)	High K (m/d)
Clean Gravel	Vesicular and scoriaceous basalt and cavernous limestone and dolomite	10 ³	10 ⁴
Clean sand & gravel		10 ¹	10 ³
Fine Sand	Clean sandstone and fractured igneous and metamorphic rocks	10 ⁻²	10 ¹
Silt, clay, mixture of sand silt and clay	Laminated sandstone, shale and mudstone	10 ⁻⁴	10 ⁻²
	Massive igneous and metamorphic rocks		
Massive Clay		10 ⁻⁵	10 ⁻⁴

* Reference: *Hydrogeology and Groundwater Modeling, Second Edition (Kresic, 2008)*

Table 2: Typical porosity values

Matrix	Porosity range (%)	Average effective porosity (%)
Clean Gravel	25 - 50	38
Clean sand & gravel	20 - 35	28
Fine Sand	35 - 50	43
Silt, clay, mixture of sand silt and clay	35 - 50	38
Massive Clay	33 - 60	47

* Reference: *Hydrogeology and Groundwater Modeling, Second Edition (Kresic, 2008)*

The hydraulic conductivity, effective porosity and hydraulic gradient values were then used to determine the Darcy velocity for the flow of groundwater in each of the hydrostratigraphic units.

$$\text{Darcy Velocity (DV)} = K \times \left(\frac{dh}{dl} \right)$$

The Darcy velocity was then used to determine the average linear velocity which expresses the likely distance groundwater would travel under homogeneous and isotropic conditions (i.e. ideal conditions).

$$\text{Average linear velocity} = K \times \left(\frac{dh/dl}{\eta} \right)$$

3. Contaminant sources

Contaminant sources are classed as any constituents that could negatively impact the quality of drinking water sources within the community or study area. Contaminants are also human introduced and not a result of natural geological or hydrogeological characteristics of the aquifer underlying the community.

Typical contaminants (of concern) identified in the communities include microbial constituents (E-coli, Coliforms etc), major ions (NO₃ etc), petroleum hydrocarbons (C₆ – C₄₀, BTEX etc) and metals (e.g. Lead). These contaminants are mainly associated with waste disposal facilities, sewerage treatment works and fuel storage areas for electricity generators.

For the purpose of deriving the water reserve boundaries, the contaminant that is likely to remain in the groundwater system the longest i.e. have the slowest attenuation and degradation rate was used. For most of the communities the contaminant used in the assessment was BTEX (component in gasoline used in the electricity generators).

Based on research done in a sandy soil (low silt content) environment the half life of BTEX (under natural conditions) was determined to be between 0.6 years (ethanol) and 1.2 years (xylene). For the purpose of determining groundwater recharge protection zones the half life of xylene (1.2 years) was used.

4. Determination of water reserve boundaries

Due to the incomplete nature of hydrogeological databases for the communities or study area the above published data sets and assumptions were used in the determination of the water reserve boundaries.

Based on this, average values for the different input parameters will be used to determine the distance between the groundwater drinking source and the water reserve boundary. Where sufficient data is available this will be used in determining the distance to the water reserve boundary.

The formulae used for determining the distance to the water reserve boundary are outlined below:

- Hydraulic Conductivity (K) – Detailed aquifer testing data required, otherwise use average of published data,
- Hydraulic Gradient (dh/dl) – Groundwater elevations is required. Where not available an arbitrary value based on in field observations will be used; and
- Effective porosity (α) – Use average of published data where accurate data is not available.

The data above are then used in the calculation of the Darcy velocity, linear velocity and distance of boundary from source by applying the following formulas:

$$\text{Darcy velocity (DV)} = K \times \left(\frac{dh}{dl} \right) - (\text{m/d})$$

$$\text{Average linear Velocity (LV)} = K \times \left(\frac{dh/dl}{\eta} \right) - (\text{m/d})$$

$$\text{Travel Distance of groundwater in one year (TD)} = LV \times 365 - (\text{m/yr})$$

$$\text{Distance required from drinking source} = TD \times t_{1/2} (\text{contaminant}) - (\text{m or km})$$

The distance to the water reserve boundary will only be applied to the up-gradient side of the drinking source, while the standard well head protection zone guidelines (prescribed by the Department of Water) will be applied to the down gradient side of the drinking water source.

It must however be stated that although the above is based on sound hydrogeological theories these boundaries are not fixed as there are many unknowns if the exact extent of the aquifer, fracture network, and recharge patterns are not known. These boundaries can be better defined once detailed hydrogeological investigations are conducted in these communities with the specific aim of characterising and determining the extent of the aquifers underlying the communities / study area.