



Government of **Western Australia**
Department of **Water and Environmental Regulation**

Ravensthorpe Water Reserve

drinking water source protection review



Ravensthorpe town water supply

Water resource protection series
Report WRP 170
September 2018

Ravensthorpe Water Reserve and Ravensthorpe Bitumen Catchment Area drinking water source protection review

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Report no. 170

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Cover photograph: Aerial photo of Ravensthorpe Bitumen Catchment Area and Ravensthorpe Water Reserve

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The Department of Water and Environmental Regulation was established by the Government of Western Australia on 1 July 2017. It is a result of the amalgamation of the Department of Environmental Regulation, Department of Water and the Office of the Environmental Protection Authority. This publication may contain references to previous government departments and programs. Please email the Department of Water and Environmental Regulation to clarify any specific information.

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

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Summary

This report was prepared by the former Department of Water (DoW). On 1 July 2017, the Government of Western Australia established the Department of Water and Environmental Regulation (DWER) resulting from the amalgamation of DoW, the Department of Environment Regulation, and the Office of the Environmental Protection Authority. As such, this publication may contain references to previous government departments and programs.

Ravensthorpe is a small town located about 540 km south-east of Perth on the South Coast Highway. The town has a resident population of 684 people, which has varied over time with the opening and closing of nearby mines (Shire of Ravensthorpe 2016).

Ravensthorpe's drinking water has been supplied by a combination of groundwater and surface water. Groundwater was sourced from the superficial aquifer immediately south-east of Ravensthorpe. Surface water is collected from the No. 4 dam which is supplied by a bitumen catchment south of Ravensthorpe (Figure A1).

In 2006 the Water Corporation prepared the *Proposed Ravensthorpe Water Reserve drinking water source protection assessment*. The assessment included information about the proposed water reserve for the Ravensthorpe bore field, identified risks to water quality and recommended strategies to manage the risks. The No. 4 dam and the bitumen catchment area were identified in the 2006 assessment but were not proposed to be included in the Ravensthorpe Water Reserve, consistent with DoW's policy at the time.

This drinking water source protection review considers changes that have occurred in Ravensthorpe's drinking water supply scheme since the 2006 assessment. Both of these documents are available on our website or by contacting us (see details on the inside cover of this report).

The main changes since the 2006 assessment are:

- The bore field is no longer used to supply drinking water and is not planned to be recommissioned in the short- to medium-term.
- The bitumen catchment area is now the sole source of drinking water for Ravensthorpe. The bitumen area is being expanded to meet projected water demand to 2025.
- We proposed to proclaim the Ravensthorpe Bitumen Catchment Area to protect it from water quality contamination risks.
- We will assign a Priority 1 area and a reservoir protection zone over the entire bitumen catchment area.
- The Ravensthorpe Water Reserve, proposed in the 2006 assessment, should only be proclaimed if the bore field is planned to be recommissioned in the future.

This review is consistent with:

- the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011)
- State planning policy no. 2.7: *Public drinking water source policy* (WAPC)
- Strategic policy: *Protecting public drinking water source areas in Western Australia* (DoW 2016).

All of these documents aim to provide a reliable, safe good quality drinking water supply to consumers now and in the future.

We prepared this document in consultation with the Water Corporation, the Shire of Ravensthorpe and the Department of Health. Given that the proposed Ravensthorpe Bitumen Catchment Area is located on Crown land vested with the Water Corporation, public consultation was not necessary to undertake this review. Copies of this review will be provided to the Shire of Ravensthorpe and local library for public display.

Table 1, below, shows important information about the proposed Ravensthorpe Water Reserve and Ravensthorpe Bitumen Catchment Area.

Table 1 Key information about the proposed Ravensthorpe Water Reserve and Ravensthorpe Bitumen Catchment Area

	Proposed Ravensthorpe Water Reserve	Ravensthorpe Bitumen Catchment Area
Local government authority	Shire of Ravensthorpe	
Location supplied	Ravensthorpe	
Water service provider	Water Corporation	
Water supply scheme details	Bore field with four bores (11/97, 13/97, 1/05 and 3/05) approximately 4 km south-east of Ravensthorpe. The bore field has not been in use since 2013/14 due to closure of the desalination plant.	No. 4 dam (bitumen catchment area): <ul style="list-style-type: none"> • built in 1968 • 56 250 kL capacity • located on Crown Reserve vested with the Water Corporation, approximately 5 km south of Ravensthorpe Other scheme dams: <ul style="list-style-type: none"> • No. 1 and No. 2 dams have no catchments and are used for storage and/or treatment only

	Proposed Ravensthorpe Water Reserve	Ravensthorpe Bitumen Catchment Area
		<ul style="list-style-type: none"> No. 3 dam is used for non-potable water supply only
Dates of drinking water source protection reports	<p>2006 – <i>Proposed Ravensthorpe Water Reserve drinking water source protection assessment</i></p> <p>2017 – <i>Ravensthorpe Bitumen Catchment Area drinking water source protection review published (this document)</i></p>	
Consultation	2016 – government and water service provider consultation as part of the drinking water source protection review	
Proclamation status	The 2006 proposed Ravensthorpe Water Reserve has not been proclaimed and is no longer used for drinking water supply. It will only need to be proclaimed if the bore field is recommissioned for drinking water supply in the future.	The Ravensthorpe Bitumen Catchment Area will be proclaimed under the <i>Country Areas Water Supply Act 1947</i> after this report is finalised.
Reference documents	<p><i>Australian drinking water guidelines</i> (NHMRC & NRMCC 2011)</p> <p>State planning policy no. 2.7: <i>Public drinking water source policy</i></p> <p><i>Proposed Ravensthorpe Water Reserve drinking water source protection assessment</i> (Water Corporation 2006)</p>	
Contact details	drinkingwater@dwer.wa.gov.au	

1 Review of Ravensthorpe's drinking water source protection assessment

1.1 Update on water supply scheme

1.1.1 Water sources

Ravensthorpe's drinking water has been supplied from a combination of surface water and groundwater sources close to the town site (Figure A1). When the supply of surface water and groundwater have been insufficient to meet demand water has been carted to Ravensthorpe from other sources, typically Hopetoun or Esperance.

No. 4 dam and bitumen catchment area

The primary source of Ravensthorpe's drinking water is No. 4 dam, which collects rainwater from six areas of bitumen (Figure C1), totalling approximately 21 ha (Figure A2). A further two areas of land have been identified for potential expansion of the bitumen catchment to increase inflow to the dam.

Ravensthorpe bore field

Desalinated groundwater has typically provided a minor portion of Ravensthorpe's drinking water supply, but during dry seasonal conditions it has been the main source of water. Since the 2006 assessment, two additional production bores (1/05 and 3/05) have been commissioned, while the two original bores (11/97 and 13/97) have not been used since 2009.

The bore field has not supplied drinking water since the desalination plant closed in 2014. There are no plans to use the bore field or the desalination plant in the short-to medium-term. The Water Corporation intends to reassess the viability of recommissioning the existing bore field and installing a new desalination plant as a long-term option for supply.

1.1.2 Water treatment

Surface water from the No. 4 dam is transferred to a storage dam where it is treated with aluminium sulfate to reduce turbidity. The water is chlorinated for disinfection to ensure microbiological quality for consumers. It is then transferred to a tank for distribution throughout the town. The Water Corporation is upgrading the Ravensthorpe water treatment plant, which is expected to be completed at the end of 2017.

It should be recognised that although treatment and disinfection are essential barriers against contamination, public drinking water source area (PDWSA) management is the first step in protecting water quality and ensuring a safe drinking water supply. This approach is endorsed by the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011) and reflects a preventive risk-based, multiple-barrier approach for providing safe drinking water to consumers. This combination of

catchment protection and water treatment will deliver a more reliable, safer and lower cost drinking water to consumers than either approach could achieve individually.

For more information on why it is so important to protect our catchments, read Appendix E.

1.2 Boundary

1.2.1 Ravensthorpe Water Reserve (bore field)

The *Proposed Ravensthorpe Water Reserve drinking water source protection assessment* (WRC 2006) recommended to proclaim a water reserve over the recharge area of the Ravensthorpe bore field (Figure A1).

As the bore field is not currently being used to supply drinking water and there are no plans to recommission the bore field in the short- to medium-term, the proposed Ravensthorpe Water Reserve will not be proclaimed at this time.

If the Water Corporation decides that the Ravensthorpe bore field will be used in the future, a drinking water source protection report should be prepared by the DWER prior to recommissioning of the bore field to:

- consult the boundary and priority areas of the proposed Ravensthorpe Water Reserve with stakeholders and landowners
- progress proclamation of the water reserve.

If the Water Corporation decides the Ravensthorpe bore field is no longer required in the long-term, a drinking water source protection report should be prepared by DWER to finalise the matter.

In the interim, the 2006 assessment identifies the proposed Ravensthorpe Water Reserve so that its protection can be considered by the Shire of Ravensthorpe when making land use planning decisions.

1.2.2 Ravensthorpe Bitumen Catchment Area (No. 4 dam)

The No. 4 dam and its bitumen catchment were identified in the 2006 assessment but were not proposed to be included in the Ravensthorpe Water Reserve, consistent with DoW policy at the time.

To help protect water quality in the No. 4 dam, this review recommends to proclaim the Ravensthorpe Bitumen Catchment Area (Figure A4) under the *Country Areas Water Supply Act 1947*. This area is larger than the existing bitumen catchment because we want to allow for its expansion.

1.3 Priority areas

The entire Ravensthorpe Bitumen Catchment Area is proposed as priority 1 (P1) because:

- water from this source is the sole drinking water supply available to Ravensthorpe
- current land uses on the Crown land, vested with the Water Corporation, are considered 'acceptable' in P1.

For further detail on priority areas, please refer to our WQPN no. 25: *Land use compatibility tables for public drinking water source areas*.

1.4 Protection zones

A reservoir protection zone (RPZ) is recommended for Ravensthorpe's drinking water source to prevent unauthorised access to the bitumen catchment, where any contamination could be rapidly transported into the No. 4 dam. The RPZ is shown in Figure A4 and covers the No. 4 dam, the existing bitumen catchment area and the potential bitumen catchment expansion areas.

If you require more information about protection zones, please refer to our WQPN no. 25: *Land use compatibility tables for public drinking water source areas*.

The boundary, priority areas and protection zones above have been determined in accordance with current departmental policy.

1.5 Water management

1.5.1 Licence to take water

Water resource use and conservation in Western Australia is administered by DWER in accordance with the *Rights in Water and Irrigation Act 1914*. Under this act, the right to use and control water is vested with the Crown. This means that a licence is required for drilling bores and abstracting groundwater (pumping water from a bore, spring or soak) within proclaimed groundwater areas throughout the state. Some exemptions apply such as abstracting water for domestic purposes only.

The Ravensthorpe bore field is not located within a proclaimed groundwater area under the *Rights in Water and Irrigation Act 1914* and therefore a licence is not required for groundwater abstraction.

A surface water allocation licence is not required for the No. 4 dam as the surface water is collected from a bitumen catchment not stream flows.

1.5.2 Future water needs

Future water demand at Ravensthorpe is difficult to estimate because it is influenced by new mining projects in the area.

The water demand at Ravensthorpe currently exceeds available supply. The bitumen catchment for the No. 4 dam is therefore currently being expanded and is projected to meet water demand through to 2025.

An area of natural catchment to the north and east of the bitumen catchment drains towards the No. 4 dam (Figure A2), but it has been diverted away from the dam due to poor water quality. The Water Corporation is investigating options to remove the diversion and increase inflow to the No. 4 dam following the upgrade of the water treatment system in 2017. The Water Corporation may also seek vesting of the No. 4 dam's natural catchment area as it is unallocated Crown land and adjacent to land vested with the Water Corporation. DWER supports the vesting of this land with the Water Corporation because it will help protect the drinking water source. If vesting occurs, the boundary of the proposed Ravensthorpe Bitumen Catchment Area should be reviewed to include the additional natural catchment.

The Water Corporation also intends to assess the viability of recommissioning the existing bore field to meet long-term water demand.

1.6 Aboriginal native title claims

Native title is the recognition in Australian law that some Aboriginal people continue to hold native title rights to lands and water arising from their traditional laws and customs.

There are two native title claims within the proposed Ravensthorpe Bitumen Catchment Area. These are Wagyl Kaip (WAD6286/1998) and Southern Noongar (WAD6134/1998).

There are no Aboriginal sites of significance within the proposed Ravensthorpe Bitumen Catchment Area.

The State Government of Western Australia and the Noongar native title claimants are negotiating an agreement called an Indigenous Land Use Agreement (ILUA). This agreement will recognise the Noongar people as the traditional owners of land in the South West Settlement Area, which extends from a point south of Dongara on the west coast, approximately east to a point north of Moora and then south-easterly to a point midway between Albany and Esperance (see Figure A5). It will enable some types of land-based customary activities to be undertaken by Noongar people in PDWSAs within the South West Settlement Area. Some of the proposed land-based activities include:

- entry to registered Aboriginal sites in reservoir protection zones
- designated camping sites for Noongar people (outside reservoir protection zones and wellhead protection zones)
- gathering invertebrates and eggs, lighting fires and gathering flora for customary purposes.

The ILUA is available on the Department of Premier and Cabinet website www.dpc.wa.gov.au.

DWER is committed to working with Aboriginal people in its planning and management activities. The department recognises that native title is an important framework for water management.

1.7 Enforcing by-laws, surveying the area and maintenance

The quality of water in PDWSAs within country areas of the state is protected under the *Country Areas Water Supply Act 1947*. Proclamation of PDWSAs allows by-laws to be applied to protect water quality.

DWER considers by-law enforcement, through surveillance of land-use activities in PDWSAs, to be an important mechanism to protect water quality. This review recommends formally delegating catchment management powers to the Water Corporation.

The Water Corporation regularly patrols and surveys the catchment area to identify risks to water quality and enforce the by-laws where required. This also includes:

- erecting and maintaining signs in accordance with *S111 Source protection signage* (Water Corporation 2013)
- maintaining fencing and barriers at the entrance to the No. 4 dam and bitumen catchment area
- ongoing regular surveillance and inspections
- applying penalties for trespass and vandalism under the *Water Agencies (Powers) Act 1984* and *Country Areas Water Supply Act 1947*.

1.8 Other Department of Water and Environmental Regulation work

DoW prepared the *Emergency Farmland Water Response Plan – Shire of Ravensthorpe* (DoW 2006) as part of the Rural Water Plan. This document aims to ensure that the commercial and lifestyle interests of the farming families in the Ravensthorpe dryland areas are safeguarded wherever possible against serious water deficiencies.

1.9 Update on water quality risks

As part of this review, DWER has conducted an assessment of water quality contamination risks to the No. 4 dam and bitumen catchment in accordance with the ADWG. A summary of the risks is contained in Table 2.

Water quality risks to the Ravensthorpe Water Reserve (bore field) have not been included in this report, however they are discussed in the 2006 assessment.

The proposed Ravensthorpe Bitumen Catchment Area covers Crown Reserve vested with the Water Corporation and is surrounded by unallocated Crown land covered by native vegetation (Figures A2 and A3). This means there are fewer risks to water quality from land uses or activities surrounding the bitumen catchment. These risks are discussed below.

Refer to Appendix D for information about typical contamination risks in PDWSAs. Refer to Appendix F to gain a greater understanding about the risk assessment process we use.

1.9.1 Recreation

Recreational off-road driving has previously occurred within the proposed Ravensthorpe Bitumen Catchment Area. Vehicle use in and around the catchment area poses a risk to water quality from hydrocarbons, chemicals, turbidity and pathogens. The Water Corporation has recently upgraded fencing and barriers to deter people from driving vehicles into the No. 4 dam and bitumen catchment.

Fencing and signs has deterred people from swimming in the dam. Swimming in the dam poses a high risk to Ravensthorpe's drinking water quality because pathogens may enter the supply from body-contact with the water.

1.9.2 Native animals and birds

Native animals and birds frequent the dams in Ravensthorpe. Pathogen detections in the raw water at Ravensthorpe are thought to be related to wildlife.

The water treatment system at Ravensthorpe reduces turbidity and disinfects the raw water via chlorination. This has helped ensure that pathogens are not detected in the treated water supplied to consumers. We will discuss this issue with the Water Corporation to investigate further management options.

1.9.3 Weed control

Bitumen catchments are often susceptible to spray drift from herbicides, via application to the surrounding land or from weed control within the catchment itself. The bitumen surface increases the mobility of pesticide residues by reducing opportunities for adhesion to soil or organic matter and providing rapid transport from the catchment to the reservoir. Metsulfuron-methyl has been detected in the No. 4 dam, but the concentrations are below the *Australian drinking water guidelines* (NHMRC & NRMCC 2011) health guideline values.

The Water Corporation follows best management practices when applying herbicides in water catchments and undertakes water quality monitoring. Herbicides are only sprayed under suitable weather conditions to minimise the risk of spray drift or heavy rains washing herbicides into the No. 4 dam. The Department of Health's *Use of herbicides in water catchment areas* (2007) will apply to the Ravensthorpe Bitumen Catchment Area once it is proclaimed.

Table 2 Summary of potential water quality risks, land use compatibility and best management practices

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
Unauthorised recreational vehicle use in and around the bitumen catchment	Turbidity Hydrocarbons and chemicals	Medium	Surveillance, signs and fencing to deter unauthorised access	Operational policy no. 13: <i>Recreation in PDWSAs on Crown land</i>
Unauthorised recreational access, including swimming in the reservoir	Pathogens	High	Surveillance, signs and fencing to deter unauthorised access Swimming is illegal and penalties apply	Operational policy no. 13: <i>Recreation in PDWSAs on Crown land</i>
Native birds and animals	Pathogens	High	Water treatment to reduce turbidity and disinfect the water.	n/a
Weed control	Chemicals from herbicides	Medium	Best management practices for herbicide use, alternatives to chemical weed control and water quality monitoring	<i>Use of herbicides in water catchment areas, Circular no: PSC 88</i>

1.10 Water quality information

The Water Corporation has provided updated water quality information for Ravensthorpe. This is shown in Appendix B.

Some detections of iron, manganese and turbidity in the raw water have exceeded the ADWG's aesthetic water quality levels, however, these water quality parameters are typically below the guideline values. Turbidity from sediments is reduced by a sediment trap between the No. 4 dam and the bitumen catchment area (Figure C2)

¹ Water quality protection notes (WQPNs) are available www.dwer.wa.gov.au or see Further reading.

and detention time in the No. 4 dam and subsequent storage dams prior to treatment and distribution to consumers.

Pathogens are frequently detected in the No. 4 dam at Ravensthorpe. These detections are attributed to wildlife and birds using the dam and are not indicative of faecal contamination from cattle, domestic animals or human origins.

The water treatment process at Ravensthorpe has helped ensure that the water supplied to consumers meets the ADWG's aesthetic and health guidelines.

2 Consultation

2.1 Stakeholder consultation process

Stakeholders have been consulted on the proposed Ravensthorpe Bitumen Catchment Area and the recommendations of this review. A full copy of the draft review was made available to key stakeholders.

As the proposed Ravensthorpe Bitumen Catchment Area is located on Crown land vested with the Water Corporation public consultation was not necessary. However, final copies of this review will be made available at the Shire of Ravensthorpe and local library, and it will be published on DWER's website.

2.2 Issues raised in consultation

The following table provides a summary of the issues raised during consultation of the *Ravensthorpe Water Reserve and Ravensthorpe Bitumen Catchment Area drinking water source protection review*. Individual stakeholders have not been identified in order to protect their privacy. Issues that are very specific or are not related to this review have not been listed, but have been explained or resolved directly with the affected stakeholder(s).

Table 3 Key issues raised during consultation for Ravensthorpe Bitumen Catchment Area

Issue raised	Response
How did you determine the boundary of the proposed Ravensthorpe Bitumen Catchment Area?	The boundary of the proposed Ravensthorpe Bitumen Catchment Area covers the existing bitumen catchment area and allows for future expansion to meet water demand to 2025.
Concerns that pathogens and turbidity have been detected in raw water samples.	The Water Corporation undertakes water quality monitoring and treatment to ensure the drinking water supplied to Ravensthorpe meets the requirements of the 2004 <i>Australian drinking water guidelines</i> (ADWG; NHMRC & NRMMC 2004). We will discuss this issue with the Water Corporation to investigate further management options.
Potential water quality risks during construction of bitumen expansion need to be considered.	The Water Corporation applies best management practices to the construction of bitumen catchments, including turbidity management and monitoring for any potential contaminants from the construction activities or materials.

3 Recommendations

Based on the findings of this review the following recommendations will now be applied to the Ravensthorpe Bitumen Catchment Area. These recommendations do not apply to the proposed Ravensthorpe Water Reserve (bore field) because the bore field is not being used.

The bracketed stakeholders are those expected to have a responsibility for, or an interest in, the implementation of that recommendation.

1. Proclaim the Ravensthorpe Bitumen Catchment Area under the *Country Areas Water Supply Act 1947*. (DWER)
2. Incorporate the findings of this review and the location of the Ravensthorpe Bitumen Catchment Area (including its priority areas and protection zones) in the Ravensthorpe local planning scheme in accordance with the WAPC's State planning policy no. 2.7: *Public drinking water source policy*. (Shire of Ravensthorpe)
3. Refer development proposals within the Ravensthorpe Bitumen Catchment Area that are inconsistent with DWER's WQPN no.25: *Land use compatibility tables for public drinking water source areas* or recommendations in this review to DWER's regional office for advice. (Department of Planning Lands and Heritage, Shire of Ravensthorpe, proponents of proposals)
4. Ensure incidents covered by Westplan–HAZMAT in the Ravensthorpe Bitumen Catchment Area are addressed by ensuring that:
 - the Ravensthorpe LEMC is aware of the location and purpose of the Ravensthorpe Bitumen Catchment Area
 - the locality plan for the Ravensthorpe Bitumen Catchment Area is provided to the Department of Fire and Emergency Services headquarters for the HAZMAT emergency advisory team
 - the Water Corporation acts in an advisory role during incidents in the Ravensthorpe Bitumen Catchment Area
 - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Ravensthorpe Bitumen Catchment Area and information to help them recognise the potential impacts of spills on drinking water quality. (Water Corporation)
5. Maintain signs along the boundary of the Ravensthorpe Bitumen Catchment Area including an emergency contact telephone number, in accordance with the Water Corporation's *S111 Source protection signage (2013)*. (Water Corporation)
6. Water Corporation should continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. (Water Corporation)
7. Review the boundary of the Ravensthorpe Bitumen Catchment Area to include the additional natural catchment if the Water Corporation reconnect it to the No. 4

dam and the land is vested with the Water Corporation. (DWER, Water Corporation)

8. Prepare a drinking water source protection report when long-term planning for the Ravensthorpe bore field is completed, to either proclaim the proposed Ravensthorpe Water Reserve or recognise that the water reserve will no longer be required. (DWER)
9. Update this review within seven years. (DWER)

Appendices

Appendix A – Figures

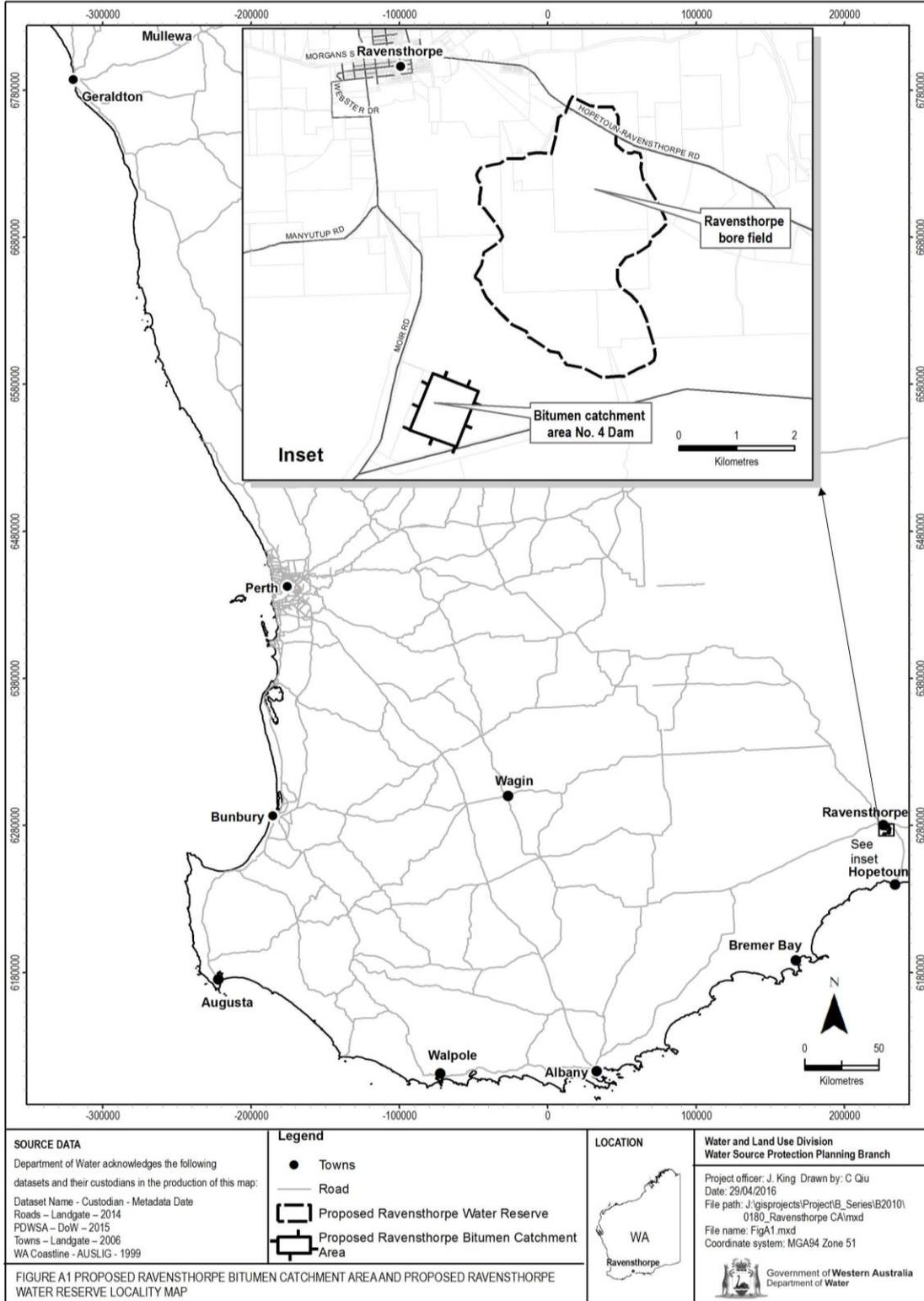


Figure A1 Proposed Ravensthorpe Bitumen Catchment Area and proposed Ravensthorpe Water Reserve locality map

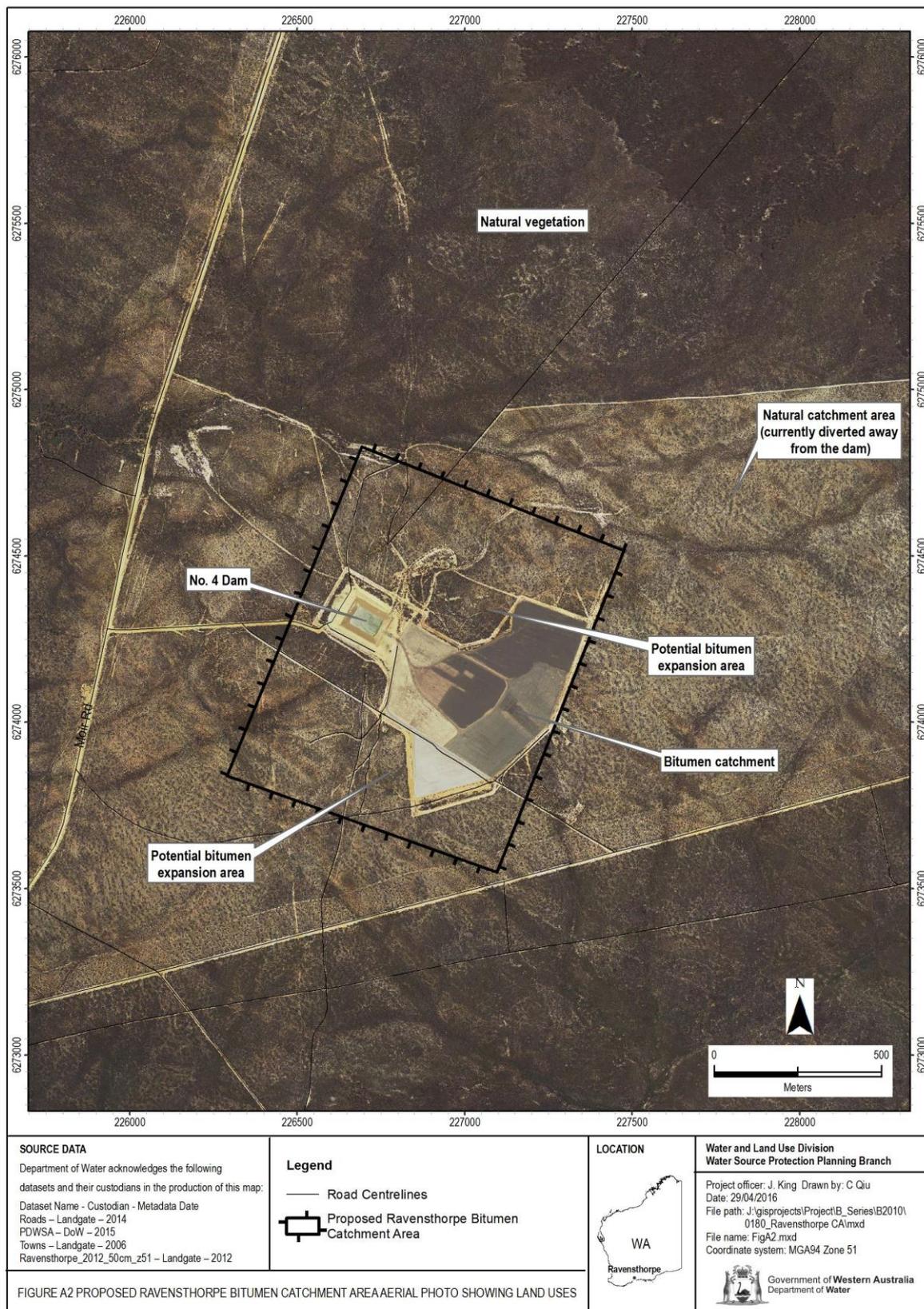


Figure A2 Proposed Ravensthorpe Bitumen Catchment Area aerial photo showing land uses

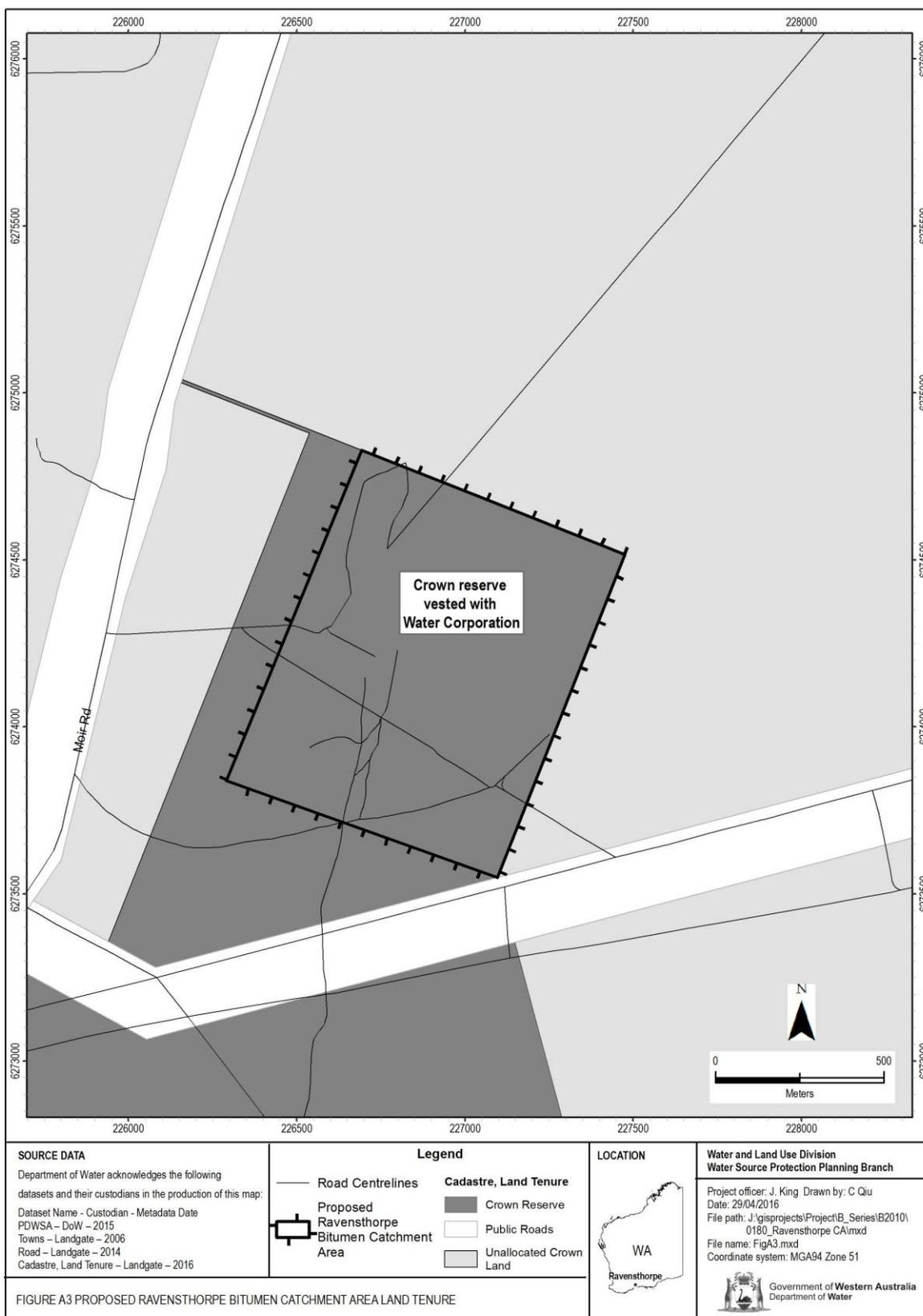


Figure A3 Proposed Ravensthorpe Bitumen Catchment Area land tenure

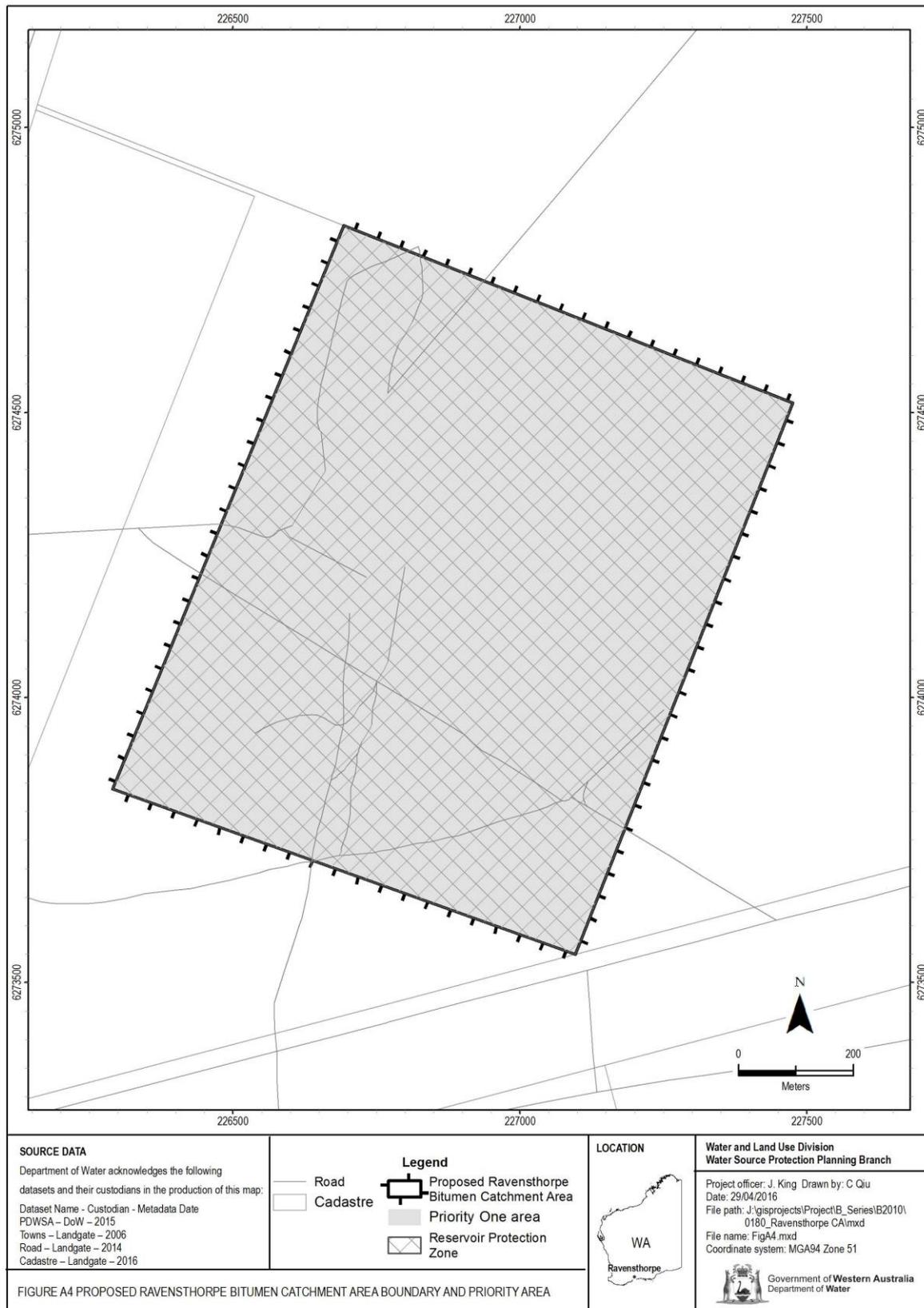


Figure A4 Proposed Ravensthorpe Bitumen Catchment Area boundary and priority area

Appendix B – Water quality data

The information provided in this appendix has been supplied by the Water Corporation.

The Water Corporation has monitored the raw (source) water quality from Ravensthorpe dam in accordance with the requirements of the 2004 *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2004) and interpretations agreed to with the Department of Health. This data shows the quality of water in the public drinking water source area (PDWSA). The raw water is monitored regularly for:

- aesthetic characteristics (non-health-related)
- health-related characteristics including:
 - health-related chemicals
 - microbiological contaminants.

The following data represents the quality of raw water from Ravensthorpe. In the absence of specific guidelines for raw water quality, the results have been compared with the ADWG values set for drinking water, which defines the quality requirements at the customer's tap. Any water quality parameters that have been detected are reported; those that on occasion have exceeded the ADWG are in bold and italics to give an indication of potential raw water quality issues associated with this source. The values are taken from ongoing monitoring for the period December 2010 to November 2015.

It is important to appreciate that the raw water data presented does not represent the quality of drinking water distributed to the public. Barriers such as storage and water treatment exist downstream of the raw water to ensure it meets the requirements of the ADWG.

For more information on the quality of drinking water supplied to Ravensthorpe refer to the most recent Water Corporation drinking water quality annual report at www.watercorporation.com.au.

Aesthetic characteristics

The aesthetic quality analyses for raw water from Ravensthorpe are summarised in the following table.

Aesthetic detections for Ravensthorpe

Parameter	Units	ADWG aesthetic guideline value*	Ravensthorpe No. 4 Dam	
			Range	Median
Ammonia as nitrogen	mg/L	0.41	<0.005–0.9	0.006
Chloride	mg/L	250	15–34	23.5
Colour (true)	TCU	15	5–14	8
Copper	mg/L	1	0.006	-
Hardness as CaCO ₃	mg/L	200	10-56	17
Iron unfiltered	mg/L	0.3	0.07– 1.2	0.24
Manganese unfiltered	mg/L	0.1	<0.002– 0.22	0.003
Silicon as SiO ₂	mg/L	80	1.3–2.9	2.35
Sodium	mg/L	180	12–25	17.5
Sulfate	mg/L	250	0.5–13	4.75
Total filterable solids by summation	mg/L	600	63–164	85
Turbidity	NTU	5	1.2- 15	4.4
pH measured in laboratory	no units	6.5–8.5	6.82- 9.14	7.42

* An aesthetic guideline value is the concentration or measure of a water quality characteristic that is associated with good quality water

Health-related chemicals

Raw water from Ravensthorpe is analysed for chemicals that are harmful to human health, including inorganics, heavy metals, industrial hydrocarbons and pesticides. Health-related parameters that have been detected in the source are summarised in the following table.

Health-related detections for Ravensthorpe

Parameter	Units	ADWG health guideline value*	Ravensthorpe No. 4 Dam	
			Range	Median
Barium	mg/L	2	0.017	–
Boron	mg/L	4	0.03	–
Copper	mg/L	2	0.006	
Manganese unfiltered	mg/L	0.5	<0.002–0.22	0.003
Metsulfuron-methyl	µg/L	30	<0.9–22	<0.9
Nitrite as nitrogen	mg/L	0.91	<0.002–0.012	<0.002
Nitrite plus nitrogen as N	mg/L	11.29 [†]	<0.002–0.3	<0.05

* A health guideline value is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & NRMCC 2011).

† A guideline value of 11.29 mg/L (as nitrogen) has been set to protect bottle-fed infants less than three months of age. Up to 22.58 mg/L (as nitrogen) can be safely consumed by adults and children over three months of age.

Microbiological contaminants

Microbiological testing of raw water samples from Ravensthorpe is currently conducted on a weekly basis. *Escherichia coli* counts are used as an indicator of the degree of recent faecal contamination of the raw water from warm-blooded animals.

A detection of *E. coli* in raw water may indicate contamination of faecal material.

During the reviewed period, positive *E. coli* counts were recorded in 79 per cent of samples from No. 4 dam. Of these, 24 per cent of samples had *E. coli* counts greater than 20 MPN/100mL.

Appendix C – Photographs



Figure C1 Bitumen catchment area for the No. 4 dam



Figure C2 Sediment trap between the No. 4 dam and the bitumen catchment area

Appendix D – Typical contamination risks in surface water sources

Land development and land or water-based activities within a catchment area can directly affect the quality of drinking water and its treatment. Contaminants can reach drinking water sources through runoff over the ground and infiltration through soil. A wide range of microbiological, chemical and physical contamination risks can impact on water quality and therefore affect the provision of safe, good quality drinking water to consumers.

Some contaminants in drinking water can affect human health resulting in illness, hospitalisation or even death. Other impurities can affect the water's aesthetic qualities, including its appearance, taste, smell and 'feel' but are not necessarily hazardous to human health. For example, cloudy water with a distinctive odour or strong taste may not be harmful to health, but clear, pleasant-tasting water may contain harmful, undetectable microorganisms (NHMRC & NRMCC 2011). Contaminants can also interfere with water treatment processes, and damage water supply infrastructure (such as iron corroding pipes).

The *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011) outline criteria for acceptable drinking water quality to protect human health, manage aesthetics and maintain water supply infrastructure.

Some commonly seen contamination risks relevant to surface water drinking water sources are described below.

Microbiological risks

Pathogens are types of microorganisms that are capable of causing illness and include bacteria, protozoa and viruses. When people consume drinking water that is contaminated with pathogens, the consequences vary considerably, ranging from mild illness (such as stomach upset or diarrhoea) to hospitalisation and in some cases even death. For example, seven people died and about 2500 became ill in Walkerton, Canada, during 2000, because the town's water supply was contaminated by a pathogenic strain of *E. coli* and *Campylobacter* (NHMRC & NRMCC 2011).

The types of pathogens that are likely to cause harm to people are commonly found in the faeces of humans and domestic animals (such as dogs and cattle). These pathogens can enter drinking water supplies from faecal contamination in the catchment area, either directly or indirectly.

Directly: When people or domestic animals come into contact with a body of water, pathogens may enter that water source. This occurs through the direct transfer of faecal material into the water such as while fishing, marroning or swimming.

Indirectly: Pathogens can wash over or infiltrate into the soil, and find their way into water supplies, such as from septic tanks or animal manure deposited in paddocks.

A number of pathogens are commonly known to contaminate water supplies worldwide. These include bacteria (for example *Salmonella*, *Escherichia coli* and

cholera), protozoa (such as *Cryptosporidium* and *Giardia*) and viruses. Monitoring for the presence of *E. coli* in water supplies provides an indication of the level of recent faecal contamination.

Pathogen contamination of a drinking water source is influenced by many factors including the existence of pathogen carriers (humans and domestic animals), the transfer to and movement of the pathogen in the water source and its ability to survive in the water.

The percentage of humans in the world that carry pathogens varies. For example, it is estimated that between 0.6 to 4.3 per cent of people are infected with *Cryptosporidium* worldwide, and 7.4 per cent with *Giardia* (Geldreich 1996).

The ability of pathogens to survive in surface water differs between species. *Salmonella* may be viable for two to three months, *Giardia* may still infect after a month in the natural environment (Geldreich 1996) and *Cryptosporidium* oocysts (cells containing reproductive spores) may survive weeks to months in fresh water (NHMRC & NRMCC 2011).

Unlike chemicals, which dissipate and dilute when they enter a water source, pathogens can multiply under the right conditions, increasing the likelihood of contamination. Therefore it is important to understand both the groundwater and surface water systems to be able to protect the drinking water source from pathogens.

Given the wide variety of pathogens, their behaviour in the environment and the potential consequences of consuming contaminated water, the most effective way to protect public health and reduce water treatment costs is to avoid the introduction of pathogens into a water source.

Physical risks

Turbidity is the result of soil or organic particles becoming suspended in water (cloudiness). Erosion from activities such as off-road driving and clearing of vegetation can cause turbidity in surface water sources. Increased turbidity can result in cloudy or muddy-looking water, which is not aesthetically appealing to consumers. Turbidity can also reduce the effectiveness of treatment processes (such as disinfection). This is because pathogens and chemicals can attach onto soil particles and become more difficult to remove during disinfection and treatment processes. High levels of turbidity in a water body can also affect the environment. Suspended particles smother riparian vegetation and reduce the ability of light to penetrate the water column. This affects plant growth which in turn can affect water quality.

Other physical properties of water can affect water supply infrastructure, or the aesthetics of the drinking water. For example, pH can contribute to the corrosion and encrustation of pipes; iron and dissolved organic matter can affect the colour and smell of water; and salinity levels can affect its taste. Although not necessarily harmful to human health, water with properties like this will be less appealing to customers.

Chemical risks

Chemicals can occur in drinking water as a result of natural leaching from mineral deposits or from different land uses (NHMRC & NRMMC 2011). A number of these chemicals (organic and inorganic) are potentially toxic to humans.

Pesticides include agricultural chemicals used to control:

- weeds (herbicides)
- pests (insecticides, rodenticides)
- worms (nematicides)
- mites (miticides).

Contamination of a drinking water source by pesticides (and other chemicals) may occur as a result of accidental spills, incorrect use or leakage from storage areas. In these cases, the relevant authorities should be notified promptly and the spill cleaned up to prevent contamination of the drinking water source.

Hydrocarbons such as fuels and oils are potentially toxic to humans. Harmful chemical by-products may be formed when hydrocarbons are combined with chlorine during the water treatment process. Hydrocarbons can occur in water supplies as a result of spills and leaks from vehicles and machinery.

Drinking water sources can also be contaminated by nutrients such as nitrogen and phosphorus. Nutrients can be introduced into a catchment via the application of fertiliser, from septic systems, and from animal faecal matter deposited in the catchment that washes over soil and down waterways and into the water supply. Nitrate and nitrite are two forms of nitrogen that can be toxic to humans at high levels, with infants younger than three months being most susceptible (NHMRC & NRMMC 2011).

Other chemicals and heavy metals can be associated with land uses such as industry and landfill. These may enter groundwater and could be harmful to human health if consumed.

Appendix E – How do we protect public drinking water source areas?

The *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011) outline how we should protect drinking water in Australia. The ADWG recommends a ‘catchment to consumer’ framework that uses a preventive risk-based and multiple-barrier approach. A similar approach is recommended by the World Health Organization.

The catchment to consumer framework applies across the entire drinking water supply system – from the water source to the taps in your home. It ensures a holistic assessment of water quality risks and solutions to ensure the delivery of a reliable and safe drinking water to supply your home.

A preventive risk-based approach means that we look at all the different risks to water quality. We determine what risks can reasonably be avoided and what risks need to be minimised or managed to protect public health. This approach means that the inherent risks to water quality are as low as possible. A multiple-barrier approach means that we use different barriers against contamination at different stages of a drinking water supply system.

The first and most important barrier is protecting the public drinking water source area (PDWSA) (the area from which water is captured to supply drinking water). If we get this barrier right, it has a flow-on effect that can result in a lower cost, safer drinking water supply. Other barriers against contamination include:

- storage of water to help reduce contaminant levels
- disinfecting the water (for example chlorination to inactivate pathogens)
- maintenance of pipes
- testing of water quality.

Another community benefit from PDWSA protection is that it complements the state’s conservation initiatives.

Research and experience shows that a combination of catchment protection and water treatment is safer than relying on either barrier on its own. That’s why this drinking water source protection review is important. We should not forget that ultimately it’s about protecting your health by protecting water quality now and for the future.

In Western Australia, DWER protects PDWSAs by implementing the ADWG, writing reports, policies and guidelines, and providing input into land use planning.

This drinking water protection report achieves elements 2 and 3 of the 12 elements in the ADWG recommended for protecting drinking water. It shows the PDWSA’s location, its characteristics, existing and potential water quality contamination risks, and makes recommendations to deal with those risks.

The *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* provide us with important tools to protect water quality in proclaimed PDWSAs. These Acts allow us to assess and manage the water quality contamination risks from different land uses and activities. The department works cooperatively with other agencies and the community to implement this legislation and develop drinking water source protection reports. For example, the Western Australian Planning Commission (WAPC) has developed a number of state planning policies to help guide development in public drinking water source areas.

An important step in maximising the protection of water quality in PDWSAs is to define their boundaries, priority areas and protection zones to help guide land use planning and to identify where legislation applies. There are three different priority areas:

- The objective of priority 1 (P1) areas is risk avoidance – ensuring there is no degradation of the water quality (for example over Crown land).
- The objective of priority 2 (P2) areas is risk minimisation – maintaining or improving water quality (for example over rural-zoned land).
- The objective of priority 3 (P3) areas is risk management – maintaining the water quality for as long as possible (for example, urban- or commercial-zoned land).

Protection zones surround drinking water abstraction bores and surface water reservoirs so that the most vulnerable areas are protected from contamination.

DWER's Water quality protection note (WQPN) no. 25: *Land use compatibility in PDWSAs* outlines appropriate development and activities within each of the priority areas (P1, P2 and P3).

With 129 proclaimed PDWSAs across Western Australia, the department prioritises the update of drinking water source protection reports (such as this document). Our aim is to update each report every seven years. In some locations, more frequent updates may be required to address changing water quality risks and land uses. These updates allow us to make changes to the PDWSA boundary, priority areas and protection zones if required. They also allow solutions to new water quality risks to be considered.

There are three different types of drinking water source protection reports – each providing for different needs. The following table shows the differences between the types of reports.

There is also a fourth type of report – Land use and water management strategy – that performs the same functions as a drinking water source protection report. However, these strategies are prepared by the WAPC (with input from DWER) and are strategic documents that integrate land use planning with water management. There are currently land use and water management strategies for Gnangara, Jandakot and Middle Helena.

If you would like more information about the ADWG and how we protect drinking water in Western Australia, visit www.dwer.wa.gov.au or contact the Water source protection planning team on +61 8 6364 7600 or drinkingwater@dwer.wa.gov.au .

Drinking water source protection reports produced by the DWER

Drinking water source protection report	Scope and outcome	Consultation	Time to prepare	Implementation table	Proclamation
Drinking water source protection assessment (DWSPA)	Desktop assessment of readily available information.	Preliminary	Up to 3 months	No	Proclamation to protect water quality and guide land use planning can occur as a result of any type of drinking water source protection report.
Drinking water source protection plan (DWSPP)	Full investigation of risks to water quality building on information in the DWSPA.	Public	6–12 months	Prepared from recommendations in the DWSPA and/or information from public consultation.	
Drinking water source protection review (DWSPR)	Review changes in land and water factors and implementation of previous recommendations. Sometimes prepared to consider specific issues in a PDWSA.	Key stakeholders	3–6 months	Prepared from recommendations in the DWSPA or DWSPP.	

Appendix F – Understanding risks to drinking water quality

The existing integrated land use planning and public drinking water source area (PDWSA) protection program is based on the findings of three parliamentary committee reports in 1994, 2000 and 2010 (see *Further reading*). Since 1995, this integrated program has resulted in the development of four Western Australian Planning Commission state planning policies (SPPs), recognising the importance of PDWSAs for the protection of water quality and public health:

- SPP no. 2.2: *Gnangara groundwater protection*
- SPP no. 2.3: *Jandakot groundwater protection*
- SPP no. 2.7: *Public drinking water source policy*
- SPP no. 2.9: *Water resources*.

This integrated program relies upon a preventive risk-based assessment process in each PDWSA through the development of drinking water source protection reports. It is important to understand how risks are assessed to appreciate the impact of development within PDWSAs.

Risk-based assessments normally focus on the acceptability of risks after mitigation (residual risks). For drinking water sources, a preventive risk-based assessment that considers both the maximum and residual risks is required. This means that in some cases, the maximum risks from land uses will still be considered unacceptable, even after mitigation has reduced the risk. This is a more conservative approach needed to protect the health of consumers.

Water quality risks are evaluated by considering the type and scale of a potential contamination event (consequence), together with the probability/frequency of that event occurring (likelihood). An understanding of this relationship will prevent the common misunderstanding that probability equals risk (see risk matrix below).

Risk matrix: Level of risk (from the Australian drinking water guidelines 2011)

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Moderate	High	Very high	Very high	Very high
Likely	Moderate	High	High	Very high	Very high
Possible	Low	Moderate	High	Very high	Very high
Unlikely	Low	Low	Moderate	High	Very high
Rare	Low	Low	Moderate	High	High

For example, just because a drinking water contamination incident has not occurred for many years (low likelihood) does not mean that the risk is low - we also need to consider the consequence of that contamination when determining risk. Furthermore, no previous detection of contamination is not proof that the risk is acceptable.

Shortened forms

List of shortened forms

ADWG	<i>Australian drinking water guidelines</i>
ANZECC	Australian and New Zealand Environment Conservation Council
DoW	Department of Water
DWER	Department of Water and Environmental Regulation
HAZMAT	hazardous materials
ILUA	Indigenous Land Use Agreement
LEMC	local emergency management committee
MPN	most probable number
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NTU	nephelometric turbidity units
P1, P2, P3	priority 1, priority 2, priority 3
PSC 88	Public sector circular number 88
PDWSA	public drinking water source area
RPZ	reservoir protection zone
TCU	true colour units
WAPC	Western Australian Planning Commission
Westplan- HAZMAT	Western Australian plan for hazardous materials
WHPZ	wellhead protection zone
WQPN	water quality protection note
WRC	Water and Rivers Commission

Units of measurement

ha	hectare
m	metres
mg/L	milligram per litre
km	kilometre

Volumes of water

One millilitre	0.001 litre	1 millilitre	(mL)
One litre	1 litre	1 litre	(L)
One thousand litres	1000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 megalitre	(ML)
One thousand million litres	1 000 000 000 litres	1 gigalitre	(GL)

Glossary

Abstraction	The pumping of groundwater from an aquifer, or the removal of water from a waterway or water body.
Aesthetic guideline value	The concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer, for example appearance, taste and odour (NHMRC & NRMCC 2011).
Allocation	The volume of water that a licensee is permitted to abstract, usually specified in kilolitres per annum (kL/a).
Aquifer	A geological formation or group of formations able to receive, store and transmit significant quantities of water.
Australian drinking water guidelines	The <i>National water quality management strategy: Australian drinking water guidelines 6, 2011</i> (NHMRC & NRMCC 2011) (ADWG) outlines acceptable criteria for the quality of drinking water in Australia (see <i>References</i>).
Bore	A narrow, lined hole drilled into the ground to monitor or draw groundwater (also called a well).
Bore field	A group of bores to monitor or withdraw groundwater (also see <i>wellfield</i>).
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
Colony forming units	A measure of pathogen contamination in water.
Contamination	A substance present at concentrations exceeding background levels that presents – or has the potential to present – a risk of harm to human health, the environment, water resources or any environmental value.
Drinking water source protection report	A report on water quality hazards and risk levels within a public drinking water source area; includes recommendations to avoid, minimise, or manage those risks for the protection of the water supply in the provision of safe drinking water supply.
Gigalitre	A gigalitre is equivalent to 1 000 000 000 litres or one million kilolitres.

Health guideline value	The concentration or measure of a water quality characteristic that, based on current knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & NRMCC 2011).
Hectare	A measurement of area, equivalent to 10 000 square metres.
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.
mg/L	A measurement of something (such as salinity) in a solution, i.e. 0.001 grams per litre.
Microbe	A microorganism, usually one of vegetable nature, a germ. Also known as a bacterium, especially one causing illness.
Most probable number	A measure of microbiological contamination.
Nephelometric turbidity units	A measure of turbidity in water.
Nutrients	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.
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.
Pesticides	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
pH	A logarithmic scale for expressing the acidity or alkalinity of a solution. A pH below 7 indicates an acidic solution and above 7 indicates an alkaline solution.
Public drinking water source area	The area from which water is captured to supply drinking water. It 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> or the <i>Country Areas Water Supply Act 1947</i> .

Priority 1, 2 and 3	Three different priority areas are assigned within PDWSAs to guide land use decisions. The objective of priority 1 (P1) areas is <i>risk avoidance</i> , priority 1 (P2) areas is <i>risk minimisation</i> and priority 3 (P3) areas is <i>risk management</i> .
Public sector circular number 88	A state government circular produced by the Department of Health providing guidance on appropriate herbicide use within water catchment areas.
Recharge	The action of water infiltrating through the soil/ground to replenish an aquifer.
Recharge area	An area through which water from a groundwater catchment percolates to replenish (recharge) an aquifer. An unconfined aquifer is recharged by rainfall throughout its distribution. Confined aquifers are recharged in specific areas where water leaks from overlying aquifers, or where the aquifer rises to meet the surface.
Runoff	Water that flows over the surface from a catchment area, including streams.
Scheme supply	Water diverted from a source or sources by a water authority or private company and supplied via a distribution network to customers for urban and industrial use or for irrigation.
Superficial aquifer	Shallow (near to the surface) aquifers which are easily recharged and can be readily accessed by bores.
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 where the upper boundary is the watertable and therefore is in contact with the atmosphere through the pore spaces in the unsaturated zone. Typically (but not always) it is the shallowest aquifer at a given location.
Water quality	Collective term for the physical, aesthetic, chemical and biological properties of water.
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.
Wellhead	The top of a well (or bore) used to draw groundwater.

**Westplan-
HAZMAT**

State emergency management plan for hazardous materials emergencies.

References

- Department of Health 2007, *Use of herbicides in water catchment areas*, Circular no: PSC 88, February 2007, Government of Western Australia, Perth, available www.health.wa.gov.au.
- Department of Water 2006, *Emergency Farmland Water Response Plan – Shire of Ravensthorpe* Emergency farmland water response series plan No. RWP – EF 4, available www.dwer.wa.gov.au.
- 2012, *Operational policy 13: Recreation within public drinking water source areas on Crown land*, available www.dwer.wa.gov.au.
- 2016, *Strategic policy: Protecting public drinking water source areas in Western Australia*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Water quality protection notes (WQPNs)*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2016, *WQPN 25: Land use compatibility tables for public drinking water source areas*.
- Geldreich, EE 1996, 'Pathogenic agents in freshwater resources', *Hydrological Processes*, vol. 10, pp. 315–333.
- Government of Western Australia 1909, *Metropolitan Water Supply, Sewerage, and Drainage Act*, reprinted under the *Reprints Act 1984* as at 27 April 2008, State Law Publisher, Perth, available www.slp.wa.gov.au.
- 1914, *Rights in Water and Irrigation Act*, Reprinted under the *Reprints Act 1984* as at 1 February 2008, State Law Publisher, Perth, available www.slp.wa.gov.au.
- 1947, *Country Areas Water Supply Act*, reprinted under the *Reprints Act 1984* as at 4 May 2012, State Law Publisher, Perth, available www.slp.wa.gov.au.
- 1984, *Water Agencies (Powers) Act*, reprinted under the *Reprints Act 1984* as at 17 January 2014, State Law Publisher, Perth, available www.slp.wa.gov.au
- National Health and Medical Research Council (NHMRC) & Natural Resource Management Ministerial Council (NRMMC) 2011, *National water quality management strategy: Australian drinking water guidelines*, Australian Government, Canberra, available <https://www.nhmrc.gov.au/guidelines/publications/eh52>.
- Shire of Ravensthorpe 2016, <http://www.ravensthorpe.wa.gov.au/shire-profile.aspx>, accessed 28/04/2016.
- State Emergency Management Committee 2009, *State emergency management policy no. 2.4: District emergency management arrangements*, as amended 12 April 2010, Government of Western Australia, Perth, available www.oem.wa.gov.au.

Water Corporation 2006, *Proposed Ravensthorpe Water Reserve drinking water source protection assessment*, Leederville, available www.dwer.wa.gov.au.

—2013, *S111 Source protection signage*, unpublished corporate standard, Water Corporation, Leederville.

Western Australian Planning Commission 2003, State planning policy no. 2.7: *Public drinking water source policy*, Government Gazette Western Australia, 10 June 2003, pp. 2077–82, Government of Western Australia, Perth, available www.planning.wa.gov.au.

Further reading

- Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) & Australian and New Zealand Environment and Conservation Council (ANZECC) 2000, *Rural land uses and water quality – A community resource document*, ARMCANZ & ANZECC, Canberra, available www.environment.gov.au.
- Board M (MLA Member for Jandakot and Chairman of the Select Committee) 1994, *The Select Committee on Metropolitan Development and Groundwater Supplies – Report*, Legislative Assembly, Perth, Western Australia.
- Department of Water 2011, *Living and working in public drinking water source areas*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2014, *Water resources inventory 2014 – Water availability, quality and trends*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- *Water quality protection notes (WQPNs)*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2009, WQPN no. 36: *Protecting public drinking water source areas*.
- Hrudey, SE & Hrudey, EJ 2004, *Safe drinking water – Lessons from recent outbreaks in affluent nations*, IWA Publishing, London.
- National Health and Medical Research Council (NHMRC) & Natural Resource Management Ministerial Council (NRMMC) 2004, *Water made clear – A consumer guide to accompany the Australian drinking water guidelines*, Australian Government, Canberra, available http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh33.pdf.
- Robertson, JB & Edbery, SC 1997, Natural protection of spring and well drinking water against surface microbial contamination. I. Hydrogeological parameters, *Critical Reviews in Microbiology*, vol. 23(2), pp. 143 – 178.
- Sharp Hon C (MLC and Chairman of the Standing Committee) 2000, *Report of the Standing Committee on Ecologically Sustainable Development in relation to the quality of Perth's water supply*, Legislative Council, Perth, Western Australia, available www.parliament.wa.gov.au.
- Standing Committee on Public Administration, 2010, *Report 11: Recreation activities within public drinking water source areas*, Legislative Council, Perth, available www.parliament.wa.gov.au.
- Western Australian Planning Commission 2006, State planning policy no. 2.9: *Water resources*, Government Gazette Western Australia, 19 December 2006, pp. 5707-22 Government of Western Australia, Perth, available www.planning.wa.gov.au.

World Health Organization 2004, *Guidelines for drinking-water quality – Volume 1 – Recommendations*, 3rd edn, World Health Organization, Geneva,
<http://www.who.int/en>.

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