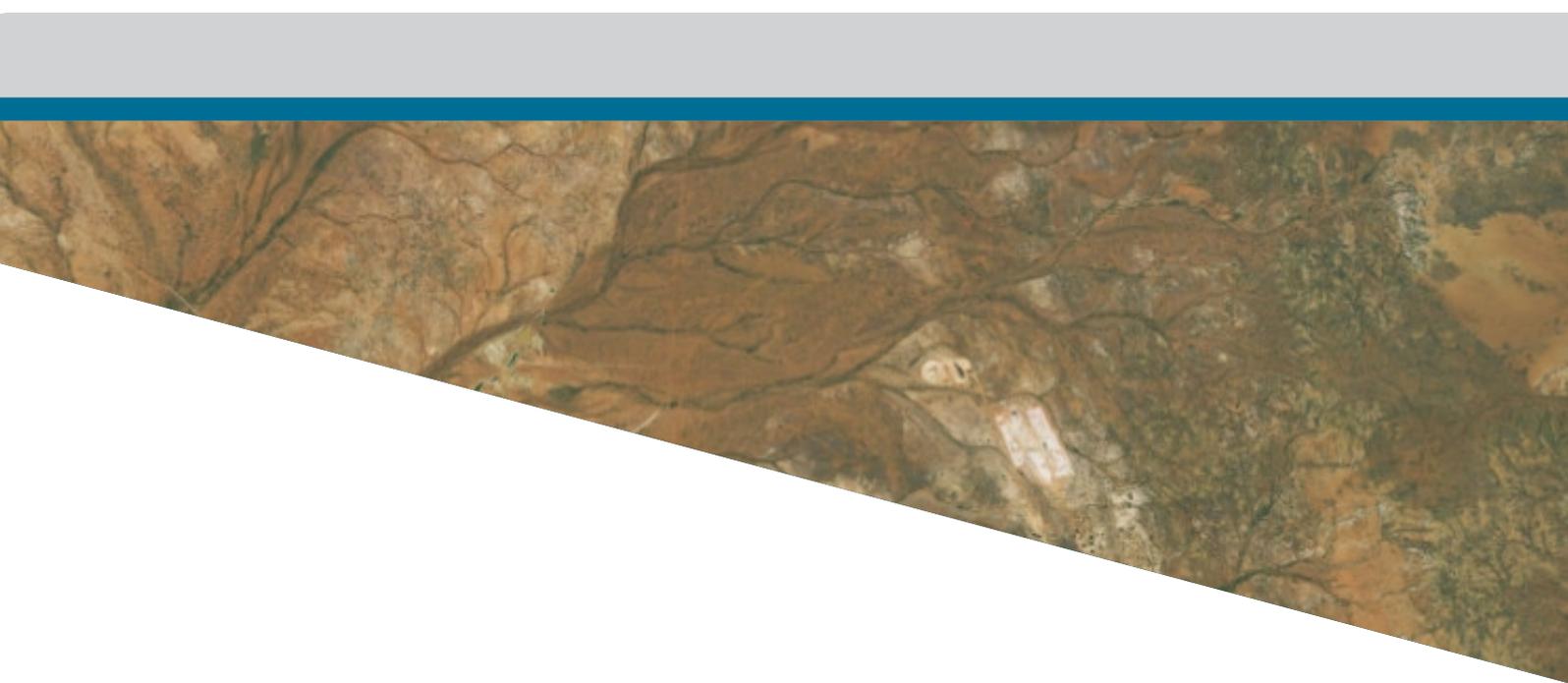




Government of **Western Australia**
Department of **Water and Environmental Regulation**

Laverton Water Reserve and Catchment Area

drinking water source protection review



Laverton town water supply

Water resource protection series
Report WRP194
August 2021

Laverton Water Reserve and Catchment Area drinking water source protection review

Laverton town water supply

Department of Water and Environmental Regulation

Water resource protection series

Report no. 194

August 2021

Department of Water and Environmental Regulation
Prime House, 8 Davidson Terrace
Joondalup Western Australia 6027
Locked Bag 10 Joondalup DC WA 6919

Phone: 08 6364 7000

Fax: 08 6364 7001

National Relay Service 13 36 77

dwer.wa.gov.au

© Government of Western Australia

August 2021

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

ISSN 1835-3924 (online)

Acknowledgements

The following people contributed to this publication: Vivien Claughton, Gerard Paul and Stephen Watson (Department of Water and Environmental Regulation), Mark Ayson (Water Corporation).

For more information about this report, contact the Water Source Protection Planning team on +61 8 6364 7600 or drinkingwater@dwer.wa.gov.au.

Cover photograph: Aerial photo of Laverton Water Reserve and Catchment Area

Disclaimer

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

This publication is available 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

Contents

Summary	v
1 Review of Laverton Water Reserve and Catchment Area drinking water source protection plan.....	1
1.1 Water supply scheme	1
1.2 Water licensing and planning	1
1.3 Boundary	2
1.4 Priority areas and protection zones.....	2
1.5 Land use planning	3
Regional planning.....	3
Local planning	3
1.6 Aboriginal sites of significance	3
1.7 Native title claims.....	4
1.8 Enforcing by-laws, surveying the area and maintenance	4
1.9 Related water source management work.....	4
Water for growth	4
1.10 Update on water quality risks	5
Pastoral lease.....	5
Mining and exploration.....	5
Recreation	7
Native and wild fauna	8
Roads and tracks.....	9
Other groundwater bores.....	9
1.11 Water quality information.....	14
2 Implementing Laverton’s drinking water source protection plan	15
2.1 Status of previous recommendations	15
2.2 Consolidated recommendations.....	17
Appendices.....	19
Appendix A — Figures.....	19
Appendix B — Water quality data	23
Aesthetic characteristics	24
Health-related characteristics	25
Microbiological contaminants.....	26
Appendix C — Photographs.....	27
Appendix D — Typical contamination risks in surface water and groundwater sources	32
Microbiological risks.....	32
Physical risks	33
Chemical risks	34
Appendices.....	35
Appendix E — Assessing and managing risks in public drinking water source areas	35
Introduction.....	35
Public drinking water source areas	35
Australian drinking water guidelines	36
‘Catchment to consumer’ and multiple barriers (element three of the ADWG)	36
Preventive risk-based approach explained	38
Possible consequences	40
WA’s drinking water source protection framework.....	40

Shortened forms44
Glossary47
References51
Further reading53

Tables

Table 1 Key information about the Laverton Water Reserve and Catchment Area vii
Table 2 Summary of potential water quality risks, land use compatibility and best management practices 11
Table 3 Implementation status for Laverton Water Reserve and Catchment Area 15

Summary

This drinking water source protection review considers changes that have occurred in and around the Laverton Water Reserve and Catchment Area since the *Laverton Water Reserve and Catchment Area drinking water source protection plan* (Department of Water 2007) was released. The plan still contains relevant information, so it is important that the 2007 plan and this review are read in conjunction. Both are available on our website or by contacting us.

Laverton is a small mining town in the Goldfields region, about 1,000 km east-north-east of Perth, in the Shire of Laverton (see Figure A1). The Water Corporation supplies drinking water to approximately 340 people from five production bores contained within secure compounds (see Figure C1).

The bores draw water from an unconfined aquifer which is vulnerable to contamination from surface-based land uses and activities. This vulnerability, combined with the fact that this is the sole supply of drinking water for Laverton, means that land uses and activities and their approval and management need particularly careful attention. There are currently no other drinking water sources available in the region and if sources were discovered, it is likely they would be limited and expensive to develop. Therefore, it is important to avoid risks to drinking water quality and public health wherever possible, and to protect the Laverton Water Reserve and Catchment Area to ensure the ongoing supply of safe, affordable, reliable, good quality drinking water for Laverton.

The main changes since the 2007 plan are:

- The reduced boundary was gazetted on 23 May 2008 under the *Country Water Supply Act 1947*.
- Production bore 3/99 collapsed and was decommissioned (see Figure C2). It has been replaced with production bore 2/16. This review proposes an updated reservoir and wellhead protection zone to protect the new bore.
- Mineral exploration should not occur within the protection zones of the Laverton Water Reserve and Catchment Area. This recommendation comes as a result of a notifiable event of public health significance resulting from mining exploration in Laverton's protection zones. Avoiding this risk in the future will provide higher protection for this water reserve and catchment area.
- The water treatment has been altered to remove pH stabilisation and Calgon dosing. The current treatment includes aeration, sand and Anthracite filtration and chlorination (see section 1.1 and Figure C3).

This review implements the *Australian drinking water guidelines* (ADWG), which are published by the National Health and Medical Research Council (NHMRC & NRMCC 2011, August 2018 update). The Minister for Health, Hon Roger Cook MLA (Minister for Health) endorsed the August 2018 update of the ADWG as the basis for setting policy for drinking water quality, safety and risk management in Western Australia (WA). It is also consistent with State planning policy 2.7: *Public drinking water source policy* (Western Australian Planning Commission 2003) and Strategic policy:

Protecting public drinking water source areas in Western Australia (Department of Water 2016a), which outline how PDWSAs are managed in WA.

The Department of Water and Environmental Regulation (the department) prepared this document in consultation with the following key stakeholders:

- Shire of Laverton
- Water Corporation
- mining lease holders
- Department of Mines, Industry Regulation and Safety
- Laverton Downs Station
- Nurra Kurramunoo Aboriginal Corporation.

Information about the Laverton Water Reserve and Catchment Area is in Table 1.

Table 1 Key information about the Laverton Water Reserve and Catchment Area

Laverton Water Reserve and Catchment Area				
Local government	Shire of Laverton			
Location supplied	Laverton town			
Population supplied	340 people			
Water service provider	Water Corporation			
Aquifer type	Unconfined, making it vulnerable to contamination from surface-based land uses and activities			
Size	~330 km ²			
Licence to take water	300,000 kL per year, issued under the <i>Rights in Water and Irrigation Act 1914</i>			
Number of bores	Five, comprising one in Beasley Creek bore field and four in Wedge Pit bore field			
Bore details	Bore name	Date drilled	Depth (m)	Coordinates (MGA, zone 51)
	1/90	2 July 1990	70.4	E 434 119, N 6 839 985
	2/99	11 May 1999	84.5	E 440 877, N 6 843 993
	2/03	28 May 2003	91.0	E 440 676, N 6 843 927
	3/03	1 June 2003	64.3	E 440 866, N 6 844 058
	2/16	May 2016	85.0	E 440 687, N 6 844 012
	3/99*	1999	79.0	E 440 750, N 6 843 790
	* Bore 3/99 collapsed then was decommissioned and replaced by production bore 2/16			
Native title	Nyalpa Pirniku WC2019/002 (WAD91/2019) native title area Nurra Kurramunoo Aboriginal Corporation			

Laverton Water Reserve and Catchment Area	
Dates of drinking water source protection reports	<p>2004 – <i>Laverton Water Reserve drinking water source protection assessment</i> (Water Corporation)</p> <p>2007 – <i>Laverton Water Reserve and Catchment Area drinking water source protection plan</i> (Department of Water)</p> <p>2021 – <i>Laverton Water Reserve and Catchment Area drinking water source protection review</i> (this document)</p>
Consultation	<p>2007 – public consultation as part of the water source protection plan</p> <p>2020 – consultation with key stakeholders</p>
Gazettal history	<p>The Laverton Water Reserve was first constituted on 31 December 1970 under the <i>Country Areas Water Supply Act 1947</i></p> <p>The water reserve was amended on 13 June 1975 under the <i>Country Areas Water Supply Act 1947</i></p> <p>The boundary was again amended to reduce its size on 23 May 2008 under the <i>Country Areas Water Supply Act 1947</i>, and the name was updated to the Laverton Water Reserve and Catchment Area, to reflect the surface water catchment</p>
Reference documents	<p><i>Australian drinking water guidelines</i> (NHMRC & NRMCC 2011)</p> <p>State planning policy 2.7: <i>Public drinking water source policy</i> (Western Australian Planning Commission 2003)</p> <p><i>WAter resources inventory 2014, Water availability, quality and trends</i> (Department of Water 2014a)</p>

1 Review of Laverton Water Reserve and Catchment Area drinking water source protection plan

1.1 Water supply scheme

The Water Corporation supplies drinking water to Laverton from a sole supply, sourced from two bore fields (see Figure A2). The Beasley Creek bore field contains one production bore (1/90, see Figure C3) and the Wedge Pit bore field contains four production bores (2/99 (see Figure C4), 2/03, 3/03 and 2/16 (see Figure C5)). The bores draw water from the local unconfined aquifer, meaning that it is vulnerable to contamination from surface-based land uses.

Groundwater from this source undergoes oxidation, coagulation, filtration and disinfection in the form of aeration, sand and anthracite filtration and then chlorination. Oxidation and coagulation are designed to remove arsenic by precipitation with ferric salt, which is then removed by filtration. Chlorination disinfects the water, to ensure microbiological quality for consumers. The treated water is then pumped into a storage tank and distributed via gravity to the town scheme.

Public drinking water source area (PDWSA) management is the first step in protecting water quality and ensuring a safe drinking water supply. Although treatment and disinfection are essential barriers against contamination, catchment protection is the most important, as advocated by the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011, August 2018 update). The ADWG is based on preventing risks and managing multiple barriers for providing safe drinking water to consumers. The combination of catchment protection and water treatment delivers a more reliable, safer and lower cost drinking water to consumers than either approach could achieve individually.

For more information about how the department protects PDWSAs, read Appendix E.

1.2 Water licensing and planning

The department recently renewed the Water Corporation's groundwater allocation licence for this source under the *Rights in Water and Irrigation Act 1914*. Licence no. 106845 allows the Water Corporation to draw 300,000 kL of water from the unconfined Goldfields, Lake Carey, combined – fractured rock west aquifer for public water supply. This licence expires in 2026.

The existing bores are reaching their production limits to supply Laverton's current water demand. This is partly due to the use of water from the Beasley Creek production bore 1/90 (see Figure C3) being limited by high levels of naturally occurring nitrate. The nitrate levels are managed under exemptions from compliance with the ADWG by the Department of Health.

Production bore 2/16 has been drilled and equipped to replace the collapsed bore 3/99 (see Figure C1). However due to its low yield, it is likely to be used only as a backup. As this bore has not yet been extensively operated its long-term reliability is unknown.

Future water source planning to investigate additional sources for drinking water will be undertaken by the Water Corporation. This planning will occur in consultation with the water supply planning and water source protection planning sections of the department.

The availability of other good quality drinking water resources in the Laverton area, however, may be limited. The *WAter resources inventory 2014, Water availability, quality and trends* (Department of Water 2014a), describes the hydrogeology in the Laverton area as fractured rock for both shallow and middle groundwater level resources. The region covers a large area and large volumes of groundwater of various qualities are stored in several types of aquifer systems, including confined paleochannels; unconfined alluvial, calcrete aquifers; and fractured rock. The hydrogeological information for this remote area is incomplete. However due to low recharge of groundwater resources, they are generally saline and non-renewable across the Goldfields region.

Even if there are other water sources in the area, the Laverton Water Reserve and Catchment Area is the only current developed supply of safe, good quality drinking water. As such it is very important that this source is protected from potential contamination risks.

1.3 Boundary

The Laverton Water Reserve was first constituted on 31 December 1970 and then amended on 13 June 1975 under the *Country Areas Water Supply Act 1947*.

As a result of the 2007 plan, it was amended again on the 23 May 2008 to:

- reduce the boundary to reflect the topological and hydrogeological catchment area for the production bores, surface water catchment and the related Wedge Pit waterbody (see figures C4 to C6)
- re-name it from the Laverton Water Reserve to the Laverton Water Reserve and Catchment Area.

This report is not proposing any further changes to the boundary.

1.4 Priority areas and protection zones

The entire Laverton Water Reserve and Catchment Area was assigned a priority 1 (P1) area (see Figure A2) as part of the 2007 drinking water source protection plan. This report does not propose any changes to the priority area.

The 2007 plan also assigned a 500 m wellhead protection zone (WHPZ) around each of the five production bores, and a reduced reservoir protection zone (RPZ) buffer

area around Wedge Pit. This RPZ reflects the total area created by the WHPZs around each of the four Wedge Pit production bores.

Since the 2007 plan, production bore 3/99 collapsed and was replaced with production bore 2/16. The associated WHPZ and RPZ will be updated to reflect this change (see Figure A2).

The boundary, priority areas and protection zones are consistent with the department's Strategic policy: *Protecting public drinking water source areas in Western Australia* (Department of Water 2016a).

1.5 Land use planning

Regional planning

The Laverton Water Reserve and Catchment Area is within the Goldfields-Esperance regional planning area. The *Goldfields-Esperance Regional Planning and Infrastructure Framework* (Department of Planning; Western Australian Planning Commission 2015) identifies infrastructure projects to facilitate economic and population growth in the region. It includes plans for the Laverton town health centre to be upgraded.

Local planning

The Laverton Water Reserve and Catchment Area is zoned as pastoral and mining under the Shire of Laverton's local planning scheme (*Local planning scheme no. 2*, Department of Planning, Lands and Heritage 2003, amended 2019).

The scheme does not yet include a special control area for the Laverton Water Reserve and Catchment Area or its protection. It is important that the shire include this in its next scheme update and consult the department for advice at that time (see section 2.2, recommendation no.1).

1.6 Aboriginal sites of significance

Aboriginal sites of significance are important places with special cultural connections to Aboriginal people. They are important because they link Aboriginal cultural tradition to place, land and people over time. These sites are integral to the lives of Aboriginal people, and are found in urban, rural and remote areas. They are most common near rivers, lakes, swamps, hills and the coast. The *Aboriginal Heritage Act 1972* and the *Heritage Act 2018* protects all Aboriginal places and objects that are culturally important to Aboriginal people. It is against the law to disturb a site or to remove artefacts.

There are five recorded Aboriginal sites of significance within the Laverton Water Reserve and Catchment Area. These are; Tjiri 1 (Place ID 3123), Wiltya Site 1 (Place ID 17063), Laverton 1 (Place ID 3100), Piriya (Place ID 3122), Beasley – Whisper 01 (Place ID 15629).

There are also seven Aboriginal sites of significance within the Laverton Water Reserve and Catchment Area that are awaiting registration or that are stored data, including Great Central Road Hills (GC06) (Place ID 20681), Lancefield well (Place ID 1566), Crawford Soak (GC07) (Place ID 20680), Admiral Hill Wiltjas (Place ID 21890), Bun-garl (Place ID 16082), Admiral Hill Scatter (Place ID 21891) and Upper Beasley Creek (Place ID 2835).

Not all Aboriginal sites of significance and heritage have been recorded and are on the register of Aboriginal sites, so it's important that traditional custodians are always consulted in regards to their country. The Nurra Kurramunoo Aboriginal Corporation is the local Aboriginal corporation in the Laverton area.

1.7 Native title claims

Native title is the recognition in Australian law that some Aboriginal people continue to hold native title rights and interests in lands and waters.

The Laverton Water Reserve and Catchment Area lies within the Nyalpa Pirniku WC2019/002 (WAD91/2019).

The department 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.

1.8 Enforcing by-laws, surveying the area and maintenance

This department recommends that the Water Corporation continue by-law enforcement in the Laverton Water Reserve and Catchment Area under the existing delegation arrangement (see section 2.2, recommendations no. 3 and no. 4). This also includes:

- erecting and maintaining signs in accordance with *S111 Source protection signage* (Water Corporation 2013)
- maintaining security and fencing surrounding the bores, water treatment compound and Wedge pit (see figures C1, C4 and C6)
- ongoing regular surveillance and inspections of operational areas and bores.

1.9 Related water source management work

The department has published other reports that relate to the Goldfields region. They are not directly linked to this report but provide context and background for water-related issues in the Laverton Water Reserve and Catchment Area.

Water for growth

Water for growth, An overview of current and future water management plans in Western Australia (Department of Water 2014b) describes a brief summary of water availability and town supplies across WA, including Laverton.

The 2014 *Water resources inventory* (Department of Water 2014a), expanded upon this with more detail, including for Laverton (see section 1.2).

1.10 Update on water quality risks

As part of this review, the department has conducted an updated assessment of water quality contamination risks to the Laverton Water Reserve and Catchment Area, in accordance with the ADWG. Table 2 shows the risks that are new or changed since the 2007 plan, and also includes risks that are still considered high. Please refer to the 2007 plan for the contamination risks that occur within the Laverton Water Reserve and Catchment Area.

Refer to Appendix D for information about typical contamination risks in PDWSAs.

Refer to Appendix E to gain a greater understanding about the risk assessment process the department uses in PDWSAs.

Pastoral lease

The majority of Laverton Water Reserve and Catchment Area is covered by a pastoral lease held by Laverton Downs Station, which is used for cattle grazing.

Cattle faeces can pose a risk of nutrient and pathogen contamination to drinking water sources. The dry climate of the area reduces this risk as the rainfall only supports sparse vegetation which can only sustain low stocking rates. This reduces the number of stock in the area, however the stock can enter Wedge Pit to access the water, which exacerbates the risk. This has been assigned a high management priority.

To minimise this, a stock watering point has been installed downstream of Wedge Pit (see Figure C7). Evidence shows that it has a high usage rate by cattle and therefore is achieving its aim.

The gate and fence surrounding Wedge Pit is too low to prevent animals from accessing it (see Figure C6). This should be improved to further reduce the risk of contamination (see section 2.2, recommendation no.5).

Cattle grazing should be undertaken with best management practices consistent with Water quality protection note 35: *Pastoral activities within rangelands*.

Mining and exploration

There are 17 different mining companies and individuals that have mining tenements that are entirely or partially within the Laverton Water Reserve and Catchment Area. These tenements include exploration licences, mining leases, prospecting licences, licences to treat tailings and miscellaneous licences.

Historically, significant mining and exploration occurred within the Laverton Water Reserve and Catchment Area. The number of mine pits is indicative of this; see Figure C8 which shows a rehabilitated mine pit. This increases contamination risks to

the aquifer because pits and drill holes that have not been appropriately decommissioned provide pathways for contaminants to enter the aquifer.

Exploration and mining activities pose a risk of pathogen contamination from increased human access, and chemical and hydrocarbon risks from vehicles, machinery and processing. The pathogen risks of mining and exploration has been assigned a high management priority while the chemical and hydrocarbon risks have been assigned a medium management priority. Turbidity risks from the disturbance of the land from exploration and mining activities has been assigned a low management priority.

Exploratory drilling poses a risk to vulnerable aquifers as drill holes can provide a direct pathway for contaminants such as pathogens, chemicals and hydrocarbons at the surface to reach the aquifer. Therefore, all exploration drill holes should be drilled and decommissioned consistent with the *Minimum construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2012) (see section 2.2, recommendation no. 11). This requirement for water bores is applied to mining drill holes to better protect the aquifer.

Proposed mining activities require approvals from the Department of Mines, Industry Regulation and Safety, which includes a program of works for exploration and a mining proposal for mining activity. If these activities are proposed within the Laverton Water Reserve and Catchment Area, the Department of Mines, Industry Regulation and Safety needs to refer these documents to the Department of Water and Environmental Regulation for assessment, consistent with the administrative agreement between the two agencies. The *Administrative agreement between the Department of Mines and Petroleum and Department of Water for mineral exploration and mining operations in water resource areas of Western Australia* (2016) describes that, under the *Mining Act 1978*, the Minister for Mines and Petroleum must get advice from the Department of Water and Environmental Regulation before providing consent to undertake a mining activity. This ensures that, if supported, drinking water source protection can be considered in licensing conditions for the mining activity. Alternatively, the mining activity may be opposed if it is deemed too high a risk by the Department of Water and Environmental Regulation.

The department recommends that these proposals are also referred to the water service provider (in Laverton's case this is the Water Corporation), irrespective of land tenure. As the licensed water service provider for Laverton, Water Corporation is an important stakeholder for activities that occur in the water reserve and catchment area.

Exploration and mining activities should be guided by best practice guidance including the Water quality protection guidelines 1–11: *Mining and mineral processing* and other relevant water quality protection notes published by the department. In addition, the *Guidelines for the protection of surface and groundwater resources during exploration drilling* (Department of Mineral and Petroleum Resources 2002) should also be followed for exploration activities.

Under the Department of Water and Environmental Regulation, Water quality protection note 25: *Land use compatibility tables in Public Drinking Water Source Areas*, exploration and mining is compatible with conditions in P1 areas, unless they are deemed to be a high level risk. There are some activities associated with mining such as mineral processing of materials that are incompatible in P1 areas due to the chemical contamination risks they pose.

Notifiable event

In 2019, a notifiable event of public health significance occurred in the Laverton Water Reserve and Catchment Area. The resulting investigation identified numerous mining exploration drilling sites within the protection zones of the Wedge Pit bore field, presenting an unacceptable contamination risk to the drinking water source. These are the outcomes of the investigation:

- The exploration holes need to be quickly and appropriately decommissioned to protect this vulnerable, sole, harnessed source of public drinking water.
- The department recommends no further exploration and mining activities within the reservoir and wellhead protection zones of the Laverton Water Reserve and Catchment Area.
- For existing exploration and mining approvals within the reservoir and wellhead protection zones, higher development and decommissioning standards are required. These practices are outlined in the *Minimum construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2012). Discussion with the department is required for development and decommissioning timing and requirements.

These measures will ensure the ongoing supply of safe, reliable good quality drinking water for Laverton. The department will reflect these measures in updated guidance documents which will be available on our website or by contacting us. An update to the administrative agreement between Department of Mines, Industry Regulation and Safety and this department is planned to ensure consistency.

Recreation

The department's Operational policy 13: *Recreation within public drinking water source areas on Crown land* (Department of Water and Environmental Regulation 2019) outlines how to manage recreation activities and facilities in PDWSAs on all Crown land. This policy applies to the Laverton Water Reserve and Catchment Area.

The intent of the policy is to protect drinking water quality and public health by managing recreation. It aims to deliver a consistent, equitable and integrated approach to recreation management in PDWSAs on Crown land and increase awareness of public health, water quality protection and recreation matters.

The policy applies to the protection zones (reservoir and wellhead protection zones) and outer catchment of a PDWSA and defines where and what types of recreation can occur. Within reservoir protection zones, the policy prohibits public access,

consistent with legislation and other department policies (except on public roads). The Laverton Water Reserve and Catchment Area has a defined reservoir protection zone surrounding Wedge Pit, to which this policy applies.

The policy supports approved recreation events and facilities that existed prior to September 2012, however where possible these should be relocated outside the PDWSA. Please read the policy for more information.

There are no approved recreation facilities in the Laverton Water Reserve and Catchment Area. However, some unauthorised recreation occurs including camping, hunting, off-road vehicle use and swimming in Wedge Pit (see Figure C5). The main water quality risks related to illegal recreation include spills of hydrocarbons and other chemicals from vehicles, and pathogen contamination from human access.

Surface water in Wedge Pit recharges the surrounding fractured rock aquifer providing a direct contamination pathway for pathogens from swimmers and the production bores are located within metres of the edge of Wedge Pit.

The pathogen risk of recreation has been assigned a high management priority.

These activities are difficult to control because of the existing minor roads and tracks and easy off-road access (see Figure C9) and the Water Corporation has a limited ability to regularly monitor the area. However, recreation levels are relatively low here due to the isolated nature and small population of the area.

To reduce the risk, this review recommends that signs are maintained and improved at entry points, on main roads and along the boundary of the Laverton Water Reserve and Catchment Area. This will educate the public that they are within the PDWSA and describe activities that are not supported (see section 2.2, recommendation no.3). Signs should include an emergency contact telephone number, in accordance with the Water Corporation's *S111 Source protection signage*, and also indicate that penalties may apply. Future legislation proposes an infringement notice process that will allow fines to be issued.

The gate and fence surrounding Wedge Pit are too low to prevent people from accessing it (see Figure C6). This should be improved to further reduce the risk of contamination (see section 2.2, recommendations no.5).

Native and wild fauna

Wedge Pit is an attractive source of fresh water for native and wild animals in an otherwise water-limited area. Animals regularly accessing the pit include camels, goats and kangaroos, as indicated by dead animals and tracks in and surrounding the pit. This poses a water quality risk of pathogens and nutrients from faeces and carcasses. Surface water runoff along the slope into Wedge Pit contributes to this pathogen load.

However, the dry climate of the area reduces this risk somewhat, as the rainfall only supports sparse vegetation which restricts the potential numbers of native and wild fauna. The pathogen risk of native and wild fauna has been assigned a high management priority.

To reduce this risk, a stock watering point (see Figure C7) has been installed downstream of the pit. Wild fauna such as camels and goats use it, but native animals (such as kangaroos) may find it difficult to use due to its design, and instead may prefer to jump the low fence to access water in Wedge Pit.

The gate and fence surrounding Wedge Pit is too low to prevent animals from accessing it (see Figure C6). This should be improved to further reduce the risk of contamination (see section 2.2, recommendation no.5).

Roads and tracks

There are numerous minor unsealed roads and tracks within the Laverton Water Reserve and Catchment Area. These pose a contamination risk by providing access to the production bores and thereby introducing pathogens from people. Vehicles pose a hydrocarbon contamination risk from leaks, spills or accidents.

There are three main roads within the Laverton Water Reserve and Catchment Area, the Laverton-Leonora road, Great central road and the Lancefield Diversion road. These roads are used by tankers to transport large quantities of fuel. If there is a road accident involving large amounts of fuel this would pose a significant hydrocarbon contamination risk to the water source. Road incidents involving fuel tankers should be prepared for consistent with State Hazard Plan – HAZMAT (see section 2.2, recommendation no.10).

Risks from tracks and roads has been identified as a medium management priority.

To reduce these risks, minor unsealed roads and tracks that are not required should be managed to reduce access. The closing of these roads and tracks is difficult because surrounding landscape provides easy off-road access, so it would be best to use signage to manage access.

The installation of signage along main roads including emergency contact details will help reduce this risk. This risk can be further reduced by ensuring any hydrocarbon spills are immediately reported and remediated consistent with WQPN 10: *Contaminant spills – emergency response plan (ERP)* (see section 2.2, recommendation no.3).

Other groundwater bores

Bores drilled near a public drinking water supply bore (such as for stock water or mining purposes) can cause contamination of the drinking water source. For example, a poorly constructed bore may introduce contaminants from surface leakage down the outside of the bore casing into an otherwise uncontaminated aquifer.

It is therefore important to ensure that any bores are appropriately located and constructed to prevent contamination of the public drinking water source. This will be assessed through the department's water licensing process where applicable under the *Rights in Water and Irrigation Act 1914*. All bores should be constructed in accordance with *Minimum construction requirements for water bores in Australia*

(National Uniform Drillers Licensing Committee 2012). It is important that GIS coordinates for all bores are recorded correctly, to ensure proper assessment of the risk to drinking water bores.

There are only three other groundwater licences (172290, 160685 and 160209) in addition to the licences held by the Shire of Laverton (160208), Main Roads (204218 and 204219) and the Water Corporation (106845) within the Laverton Water Reserve and Catchment Area.

There are two old bore fields (Skull Creek and Telegraph Shaft) in the Laverton Water Reserve and Catchment Area. The Skull Creek bore was handed to Crescent Gold Ltd in 2006 with the condition that they decommission it and dispose of the assets in an appropriate manner once it is no longer used. The Telegraph Shaft bore field has not been decommissioned. However, the production bore infrastructure is still in place, effectively sealing the bores. They are also within a fenced and locked compound (see Figure C10). These bore fields should be appropriately decommissioned when possible (see section 2.2, recommendation no. 6).

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
Exploration and mining	Chemicals from mineral processing	Medium	There are currently no operating mines in the proposed PDWSA although there are active mining leases.	Mining activities (excluding chemical tailings dams and mineral processing with chemicals) are acceptable with conditions in P1 areas.
	Hydrocarbons from vehicles and machinery	Medium	Past activities include open-cut mining and exploration. Exploration drill holes can provide a direct route for drill fluids, animals and their waste to contaminate groundwater with pathogens and need to be appropriately decommissioned.	Exploration and mining is not recommended within the reservoir and wellhead protection zones.
	Pathogens from human access	High		<i>Guidelines for the protection of surface and groundwater resources during exploration drilling</i> (Department of Mineral and Petroleum Resources 2002) <i>Water quality protection guidelines 1–11: Mining and mineral processing</i> <i>Minimum construction requirements for water bores in Australia</i> (National Uniform Drillers Licensing Committee 2012) Specific mining tenement and exploration conditions are placed on leases and licences for the protection of water quality.

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
Roads and tracks	Hydrocarbons from vehicles	Medium	<p>There are three main roads, including one within a WHPZ, which are used to transport large quantities of fuel.</p> <p>There is low level use of minor tracks and roads.</p>	<p>Signs should be installed along main roads to ensure spills are immediately reported and remediated (section 2.2, recommendations no.3 and no.10).</p> <p>Unsealed roads and tracks should be managed to control access.</p> <p><i>WQPN 44: Roads near sensitive water resources.</i></p> <p><i>WQPN 10: Contaminant spills – emergency response plan (ERP).</i></p>
Swimming in Wedge Pit	Pathogens from body contact	High	Recreation levels are relatively low due to the isolated nature and small population of the area.	<p><i>Operational policy 13: Recreation in public drinking water source areas on Crown land.</i></p> <p>Upgrade the gate, fencing and signs surrounding Wedge Pit to discourage public access (section 2.2, recommendations no.5 and no.3).</p>

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
Stock grazing, native and wild fauna	Pathogens and nutrients from animal faeces and carcasses	High	Stock, native and wild animals are accessing Wedge Pit via a slope and getting past existing fencing, despite a stock watering point being installed downstream. Surface water runoff into Wedge Pit contributes to the pathogen load.	Maintain the stock watering point down stream of Wedge Pit. Upgrade the gate and fencing surrounding Wedge Pit to prevent animal access (section 2.2, recommendation no. 5). <i>WQPN 35: Pastoral activities within rangelands.</i>

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

1.11 Water quality information

The Water Corporation has provided updated water quality information for the Laverton Water Reserve and Catchment Area. This is shown in Appendix B.

It is important to appreciate that this raw-water data 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, (except for nitrates), and provision of safe drinking water to consumers.

Existing treatment does not reduce high nitrate levels. The Water Corporation has an exemption for Laverton from the Department of Health for meeting the required nitrate health guideline. Exemptions are only granted for drinking water supplies where nitrate concentrations are between 50 and 100 mg/L, there are no alternative drinking water resources, and where acceptable arrangements can be made by the water service provider to inform the customers about the nitrate levels. A guideline value of 50 mg/L (as nitrate) has been set to protect bottle-fed infants under three months of age. Up to 100 mg/L (as nitrate) can be safely consumed by adults and children over three months of age (NHMRC & NRMCC 2011, August 2018 update).

The water treatment plant includes a nitrate analyser which is used to monitor for nitrate concentration in the treated water. Even though the Water Corporation has an exemption, it manages nitrates to meet the infant guidelines levels by blending water from production bores with low and high nitrate levels.

The town health centre and the Water Corporation should, however, continue to inform residents (in particular expecting and new mothers, visitors and businesses in Laverton) about the high nitrates in the drinking water and alternative measures should be offered for bottle-fed infants and other vulnerable consumers, as recommended by the Department of Health (see section 2.2, recommendation no. 8).

High levels of arsenic are naturally occurring, which is treated before supply to consumers. There has also been high levels of turbidity and total filterable solids by summation.

2 Implementing Laverton's drinking water source protection plan

2.1 Status of previous recommendations

Table 3 outlines recommendations from the 2007 plan and their current status.

Table 3 Implementation status for Laverton Water Reserve and Catchment Area

No.	Recommendation from the 2007 plan	Current status
1	Implement recommended protection strategies detailed in the plan.	This continues to occur as part of the normal implementation process for drinking water source protection plans, implemented by a range of stakeholders and agencies.
2	Gazettal of the updated boundary.	The updated boundary was gazetted on 23 May 2008 under the <i>Country Areas Water Supply Act 1947</i> .
3	Prepare an implementation strategy for the plan.	Implementation strategies are no longer prepared via drinking water source protection reports.
4	Decommission the Skull Creek and Telegraph Shaft bore fields.	This has been continued as a recommendation of this review (section 2.2, recommendations no. 6 and no.7).
5	Incorporation into local land planning schemes and strategies.	The water reserve and catchment area are not yet incorporated in the Shire of Laverton's local planning scheme. This is important to achieve, so this review recommends to carry forward this action (section 2.2, recommendation no. 1).
6	Referral of development proposals that are likely to impact on water quality or are inconsistent with WQPN 25: <i>Land use compatibility tables for public drinking water source areas</i> State planning policy 2.7: <i>Public drinking water source policy</i> .	Development proposals within all PDWSA are referred to the department's Swan Avon Region office. This has been continued as a recommendation of this review (section 2.2, recommendation no. 2), with the addition of Water Corporation as the licensed service provider.

No.	Recommendation from the 2007 plan	Current status
7	Emergency response protocols should follow the Westplan-HAZMAT and the local emergency management committee guidance.	Emergency response protocols follow State Hazard Plan–HAZMAT and the local emergency management committee. This has been continued as a recommendation of this review (section 2.2, recommendation no. 10).
8	Surveillance program: <ul style="list-style-type: none"> • implement a surveillance program to identify incompatible land uses or potential threats • delegate surveillance and enforcement to the Water Corporation. 	Responsibility and powers for enforcement within all PDWSAs have now been legally delegated to the Water Corporation. The Water Corporation undertake surveillance near the production bores and water treatment compound of the Laverton Water Reserve and Catchment Area. This has been continued as a recommendation of this review (section 2.2, recommendation no. 4).
9	Erection of signs: <ul style="list-style-type: none"> • signs should be erected and maintained along the boundary of the Laverton Water Reserve and Catchment Area • signs should include an emergency contact number. 	There are signs with an emergency contact number on main entry roads and on fencing surrounding the production bores. Signs should be added to the new production bore compound and around Wedge Pit, indicating that penalties may apply to illegal activities. This has been continued as a recommendation of this review (section 2.2, recommendation no. 3).
10	Wedge Pit should be fully or partially fenced to restrict access to the decline.	Wedge Pit is gated and surrounded with a low wire fence (see Figure C6). This review recommends that this fencing be upgraded to reduce access to the water (section 2.2, recommendation no. 5).
11	Elevated microbiological counts in Wedge Pit should be investigated and the source of contamination removed.	The latest raw water quality monitoring data for this source has not registered any continued elevated <i>E.coli</i> counts.

No.	Recommendation from the 2007 plan	Current status
12	Doveridge Investments Pty Ltd to prepare and implement an environmental management plan for their mineral processing and old tailings dam, including monitoring provisions for chemicals used on site.	No environmental management plan that meets this criteria has been prepared or implemented. This has been continued as a recommendation of this review (section 2.2, recommendation no. 9).
13	Review of the plan and recommendations.	Undertaken through the preparation of this review document.

2.2 Consolidated recommendations

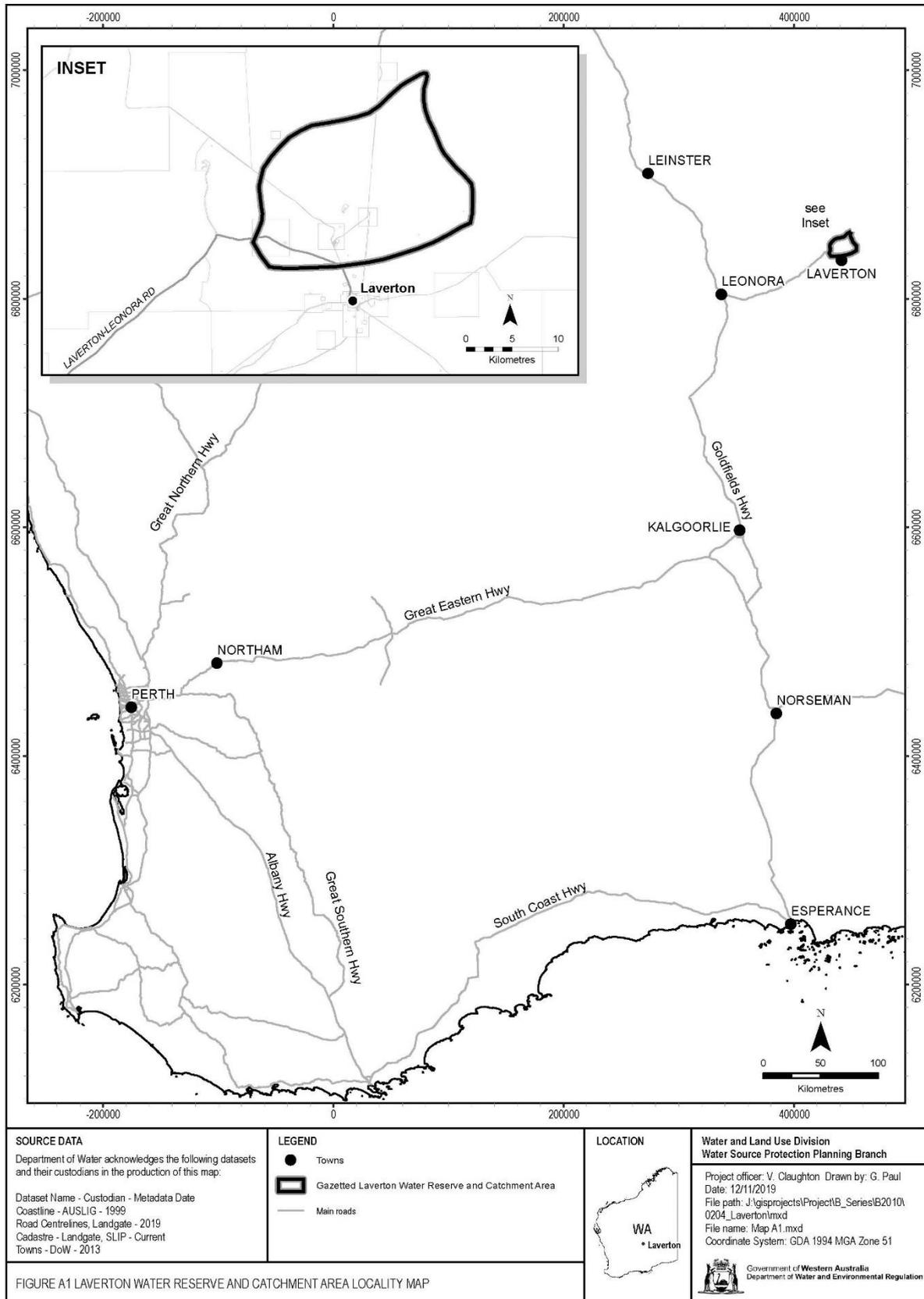
Based on the findings of this review, the following recommendations will now be applied to the Laverton Water Reserve and Catchment Area. The stakeholders listed in brackets are responsible for, or expected to have an interest in, implementing that recommendation.

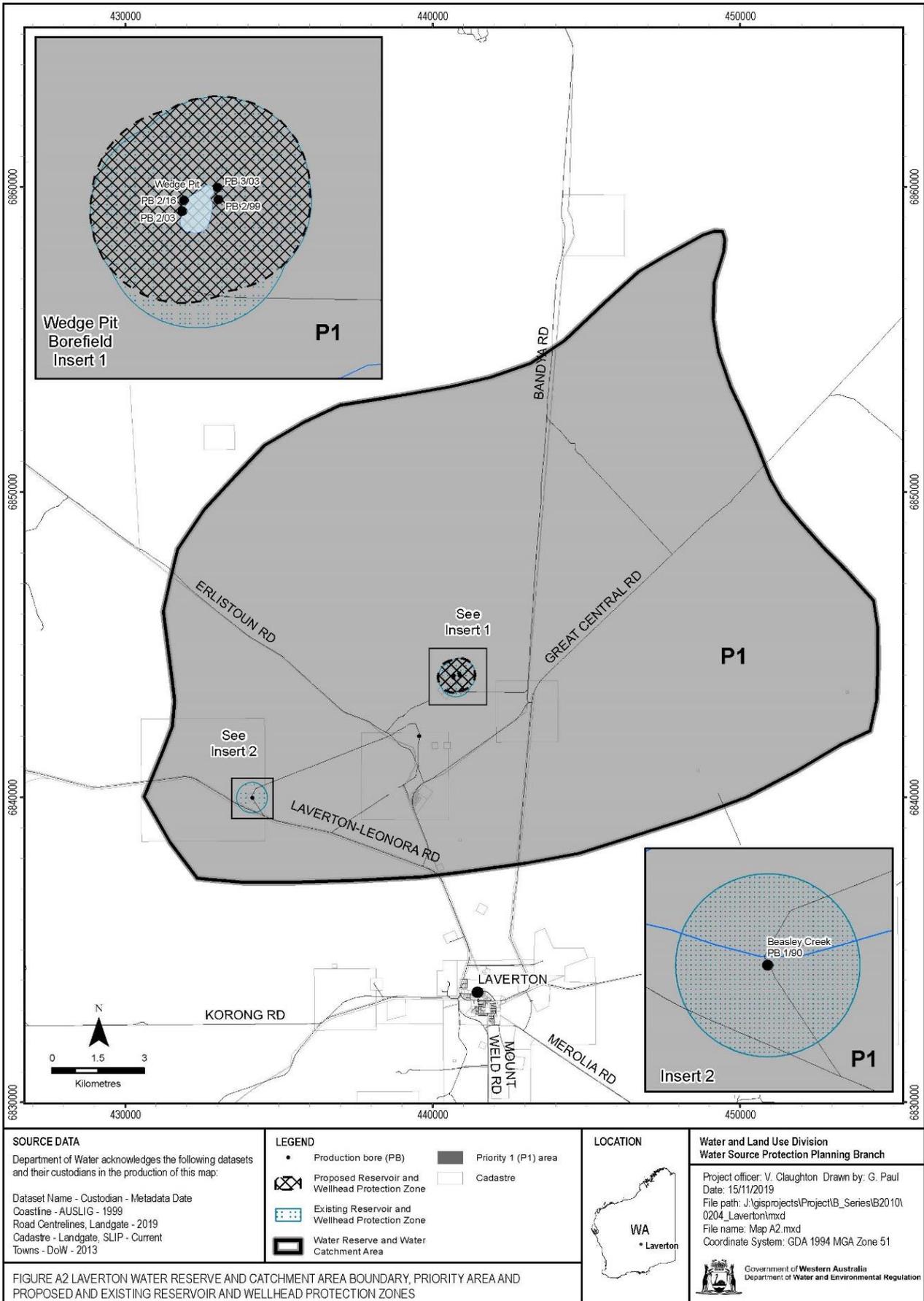
1. Incorporate the findings of this review and the location of the Laverton Water Reserve and Catchment Area (including its priority area and protection zones), as per Figure A3 in the Shire of Laverton's local planning scheme in accordance with the Western Australian Planning Commission's State planning policy 2.7: *Public drinking water source policy*. (Shire of Laverton)
2. Refer development proposals within the Laverton Water Reserve and Catchment Area that are inconsistent with the department's WQPN 25: *Land use compatibility tables for public drinking water source areas* or recommendations in this review to the department's regional office for advice, and to the Water Corporation as the licensed water service provider. (Department of Planning, Lands and Heritage, Shire of Laverton, proponents of proposals)
3. Maintain signs along the boundary and access roads to the Laverton Water Reserve and Catchment Area. Install new signs along main roads and on the new production bore compound. Improve signage surrounding Wedge Pit. All signs should include an emergency contact telephone number in accordance with the Water Corporation's *S111 Source protection signage* (2013). (Water Corporation)
4. Continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. (Water Corporation)
5. The fencing around Wedge Pit should be upgraded to reduce animal and human access. (Water Corporation)

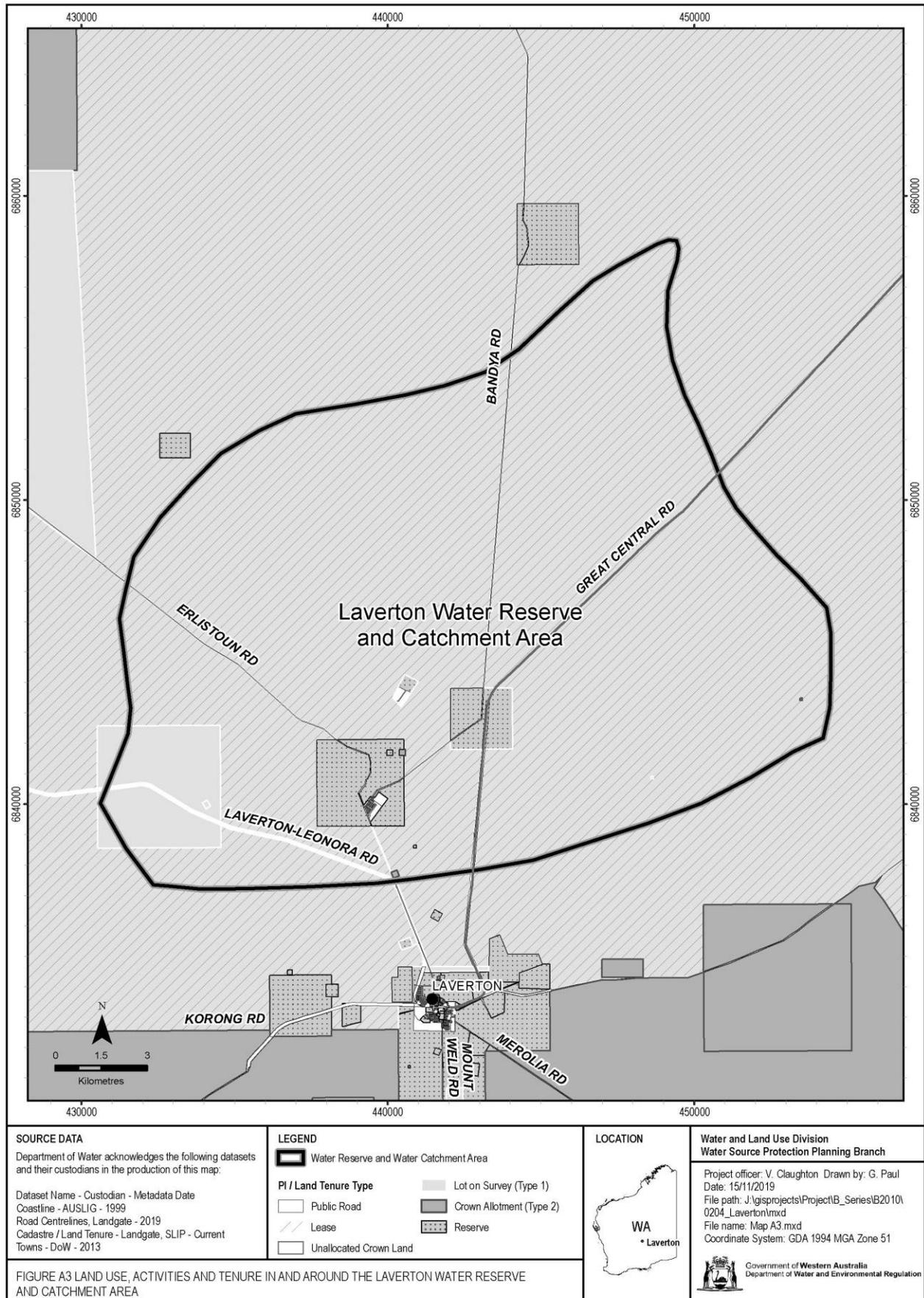
6. Decommission the Skull Creek bore field once it is confirmed that it is no longer required. (Mining company)
7. Decommission the Telegraph Shaft bore field once it is confirmed that it is no longer required. (Water Corporation)
8. Continue to advise residents, visitors and businesses of high nitrate levels in drinking water for infants under three months old and other vulnerable consumers, consistent with Department of Health recommendations. (Shire of Laverton, Water Corporation, Laverton health centre, Department of Health)
9. Doveridge Investments Pty Ltd to prepare and implement an environmental management plan, to the reporting requirements of Department of Mines, Industry Regulation and Safety, for their mineral processing and old tailings dam, including monitoring provisions for chemicals used on site. A copy of this plan should be sent to this department for review and comment. (Doveridge Investments Pty Ltd, Department of Mines, Industry Regulation and Safety, Department of Water and Environmental Regulation)
10. Ensure incidents covered by State Hazard Plan – HAZMAT in the Laverton Water Reserve and Catchment Area are addressed by ensuring that:
 - the Shire of Laverton local emergency management committee is aware of the location and purpose of the Laverton Water Reserve and Catchment Area
 - the locality plan for the Laverton Water Reserve and 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 Laverton Water Reserve and Catchment Area
 - personal dealing with State Hazard Plan incidents in the area have ready access to a locality map of the Laverton Water Reserve and Catchment Area and information to help them recognise the potential impacts of spills on drinking water quality.(Water Corporation)
11. All drill holes should be appropriately drilled and decommissioned in accordance with the relevant standards outlined in section 1.10 Update on water quality risks, Mining and Exploration. (Department of Mines, Industry Regulation and Safety, proponents of proposals)
12. This report will be reviewed in seven years or in response to changes in water quality contamination risks. (Department of Water and Environmental Regulation)

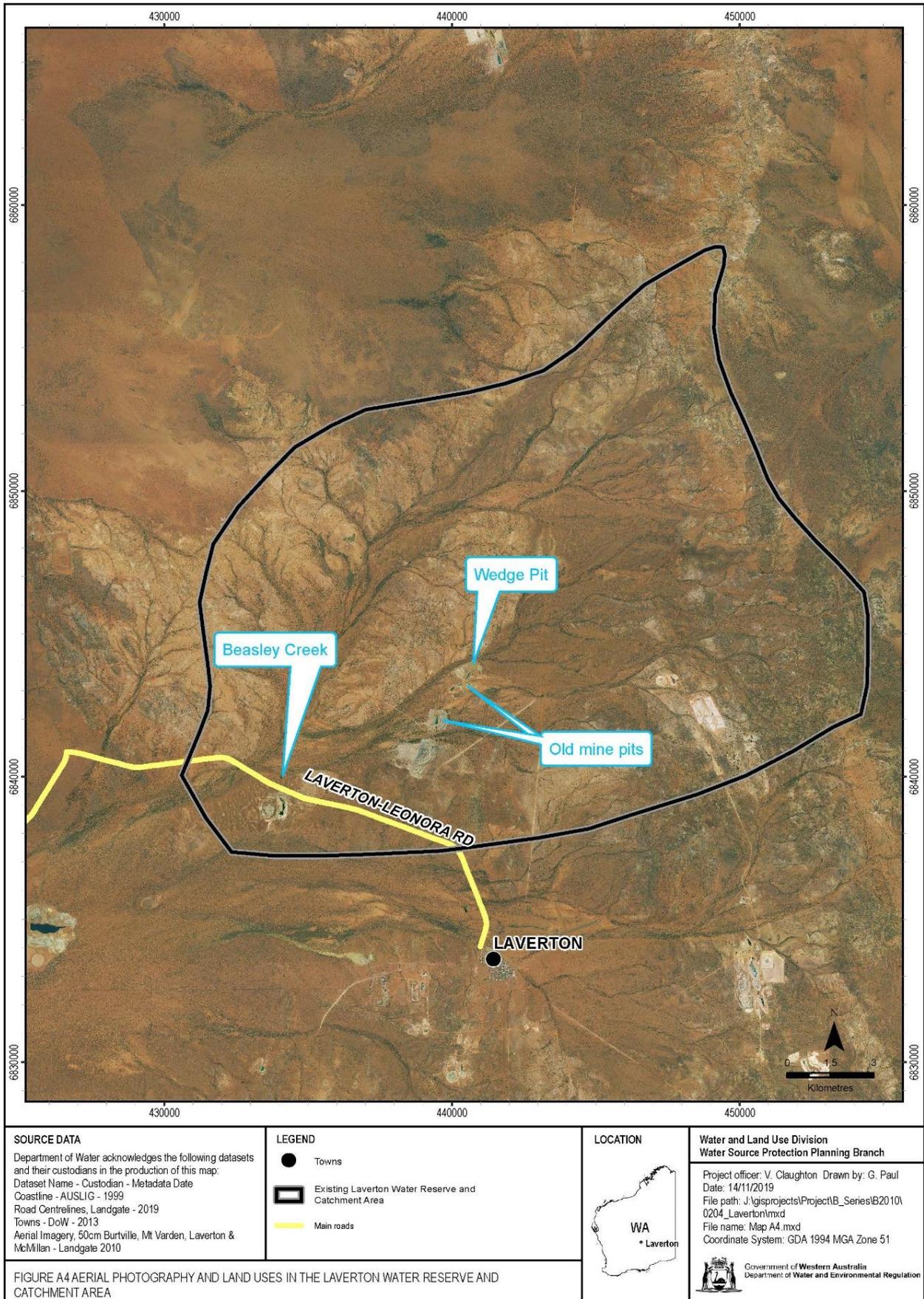
Appendices

Appendix A – Figures









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 Laverton in accordance with the requirements of the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011, August 2018 update) and interpretations agreed to with the Department of Health. This data shows the quality of raw water in the public drinking water source area (PDWSA). The raw water is monitored regularly for:

- aesthetic characteristics (non-health-related)
- health-related characteristics (chemical, radiological and microbiological hazards).

The following data represents the quality of raw water from Laverton. 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 consumer's tap. Any water quality parameters that have been detected are reported; those that on occasion have exceeded the ADWG guideline values 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 February 2014 to July 2019.

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 that drinking water supplied to consumers meets the requirements of the ADWG.

For more information on the quality of drinking water supplied to the name Laverton 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 Laverton are summarised in the following table.

Table B1 Aesthetic detections for Laverton [bold and italics for exceeded values]

Parameter	Units	ADWG aesthetic guideline value ¹	Laverton bores – composite raw		
			Number of samples	Range	Mean
Ammonia as nitrogen	mg/L	0.41	21	<0.005–0.006	<0.005
Chloride	mg/L	250	25	3–140	116
Colour (true)	TCU	15	25	<1–12	4
Hardness as CaCO ₃	mg/L	200	25	37–130	104
Iron unfiltered	mg/L	0.3	25	0.004–0.26	0.05
pH measured in laboratory	no units	6.5–8.5	25	7.52–8.07	7.78
Silicon as SiO ₂	mg/L	80	25	6–45	39
Sodium	mg/L	180	25	81–140	114
Sulfate	mg/L	250	25	29–72	58
Total filterable solids by summation	mg/L	600	25	298– 637	539
Turbidity	NTU	5	25	<0.1– 5.3	0.5

¹ An aesthetic guideline value is the concentration or measure of a water quality characteristic that is associated with good quality water.

Health-related characteristics

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

Table B2 Health-related detections for Laverton [bold and italics for exceeded values]

Parameter	Units	ADWG health guideline value ¹	Laverton bores – composite raw		
			Number of samples	Range	Mean
Arsenic	mg/L	0.01	22	0.006– 0.04	0.024
Barium	mg/L	2	14	0.0022–0.007	0.005
Boron	mg/L	4	14	0.45–1.1	0.84
Fluoride	mg/L	1.5	23	<0.1–1.2	1.0
Iodide	mg/L	0.5	1	0.06	0.06
Manganese unfiltered	mg/L	0.5	25	<0.002–0.035	0.008
Molybdenum	mg/L	0.05	14	0.005–0.012	0.01
Nitrate	mg/L	50 ²	46	6.2– 62.0	30.8
Uranium	mg/L	0.017	14	<0.001–0.001	<0.001

¹ 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 & NRMMC 2011, August 2018 update).

² A guideline value of 50 mg/L (as nitrate) has been set to protect bottle-fed infants under three months of age. Up to 100 mg/L (as nitrate) can be safely consumed by adults and children over three months of age (NHMRC & NRMMC 2011, August 2018 update).

Microbiological contaminants

Microbiological testing of raw-water samples from Laverton is currently conducted on a monthly 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, 69 samples were taken for *E. coli*. Positive *E. coli* counts were recorded in 1.4 per cent of samples. Of these, none had *E. coli* counts greater than 20 MPN/100mL.

During the reviewed period, three samples were taken for thermophilic *Naegleria* with no positive detections received.

Appendix C – Photographs

Photographs by V. Cloughton, Department of Water and Environmental Regulation



Figure C1 *New production bore 2/16 in a secure fenced compound*



Figure C2 *Decommissioned production bore 3/99*



Figure C3 Beasley Creek production bore 1/90 and the water treatment plant



Figure C4 Fenced production bore 2/99 next to Wedge Pit



Figure C5 New production bore 2/16 next to Wedge Pit



Figure C6 Access gate and fence surrounding Wedge Pit



Figure C7 Stock watering point downstream of Wedge Pit



Figure C8 An old mine pit within the Laverton Water Reserve and Catchment Area



Figure C9 Track within the Laverton Water Reserve and Catchment Area



Figure C10 The fenced compound surrounding the Telegraph Shaft old bore field

Appendix D – Typical contamination risks in surface water and groundwater 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 the 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 microorganisms that are undetectable by sight, taste or smell (NHMRC & NRMCC 2011). Contaminants can also interfere with water treatment processes and damage infrastructure.

The *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011, August 2018 update) outline criteria for acceptable drinking water quality to protect human health, manage aesthetics and maintain water supply infrastructure.

Some commonly seen contamination risks to 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 *Escherichia 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.

In groundwater sources, this occurs indirectly. Faecal material can infiltrate through the soil and into the groundwater. For example, contamination can occur from septic tanks or grazing animals.

In surface water sources, this occurs 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.

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 survival and movement of pathogens in groundwater is influenced by the characteristics of the pathogen (such as its size and inactivation rate) and the groundwater properties (including flow rate, porosity, amount of carbon in the soil, temperature and pH). Inactivation rate (the time it normally takes a pathogen to decay) is one of the most important factors governing how far pathogens may migrate. Typical half-lives of pathogens range from a few hours to a few weeks. For example, some reported migration distances of bacteria in groundwater are:

- 600 m in a sandy aquifer
- 1000–1600 m in channelled limestone
- 250–408 m in glacial silt-sand aquifers (Robertson & Edbery 1997).

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 surface water and groundwater 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. 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 to soil particles, making them more difficult to remove during disinfection and treatment processes.

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. 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 & NRMCC 2011). A number of these chemicals (organic and inorganic) are potentially toxic to humans.

Pesticides include agricultural chemicals used to control weeds (herbicides) and pests (insecticides, rodenticides, nematicides (for worms) and miticides (for mites)). 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 and from septic systems and animal faecal matter that washes through soil and into the groundwater. As well as 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 & NRMCC 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.

Appendices

Appendix E – Assessing and managing risks in public drinking water source areas

Introduction

Drinking water for Western Australia's cities and towns comes from a variety of sources including the traditional dams (surface water catchments) and bores (groundwater), and more contemporary alternatives like desalination and recycled water. Even with climate change leading to a reduced reliance on the traditional water sources, they are still highly valuable. Fortunately, we can use alternative sources to ensure we continue to meet the state's water needs.

Protecting these drinking water sources allows us to maximise water quality benefits for the health and development needs of the state. Additionally, this protection significantly reduces the costs of running our public water supply schemes. The affordable traditional sources act to offset the more expensive alternative sources.

The protection of traditional and alternative public drinking water sources is important to ensure the ongoing availability of safe, reliable, good quality, affordable drinking water for current and future generations.

WA's drinking water protection program is world's best practice and will ensure we can meet the needs of our growing population. It uses a precautionary approach based on preventing risks (i.e. a preventive risk-based approach) that is proven to maximise the protection of water quality and public health. This means that some land uses need to be restricted within public drinking water source areas.

Fortunately, we have large areas of land available for development when compared to the small areas of land that are protected for public drinking water supply.

Sometimes however, especially around existing towns and cities, the competing interests of land development and drinking water source protection means we have to consider a compromise. WA's drinking water protection program recognises this and ensures that state and local government work together to achieve the best possible.

This information sheet explains what the preventive risk-based approach is, how the Department of Water and Environmental Regulation implements it, and the outcomes it achieves.

Public drinking water source areas

Drinking water for cities and towns across WA comes from a combination of surface water catchments, groundwater aquifers, seawater desalination plants, and water recycling. Our surface water catchments and groundwater aquifers are collectively called 'public drinking water source areas' (PDWSAs). Most of these drinking water sources are legally constituted to recognise and protect their drinking water value. Constitution enables by-laws to be applied that help us protect water quality and

public health in these PDWSAs. It also ensures all stakeholders can locate PDWSAs on spatial databases.

Land development and land- or water-based activities within a PDWSA can directly affect the quality of drinking water and the level of treatment it needs to make it safe to drink. Contaminants can enter drinking water sources through runoff over the ground and infiltration through the soil. A wide range of microbiological, chemical and physical contaminants can affect water quality and public health.

Australian drinking water guidelines

The *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011, August 2018 update) outline how best to manage drinking water supplies in Australia. The guidelines recommend a 'catchment to consumer' framework that uses a preventive (or precautionary) risk-based approach in conjunction with addressing contamination risks through multiple barriers. The National Health and Medical Research Council (NHMRC) and the Natural Resource Management Ministerial Council of Australia (NRMCC) regularly update the ADWG to ensure it consistently meets the highest global standards.

In May 2019, the WA Minister for Health endorsed that the ADWG be followed in WA. The Department of Water and Environmental Regulation, the Department of Health, the Water Corporation and other water service providers all support and implement the ADWG.

The World Health Organization (WHO) also encourages a preventive risk-based approach with a focus on protecting PDWSAs in combination with treatment. Australian Standards also recommend that similar preventive risk approaches are used.

'Catchment to consumer' and multiple barriers (element three of the ADWG)

The ADWG's 'catchment to consumer' framework consists of 12 elements that apply to the entire drinking water supply system – from the catchment of the water source to the taps in our homes (see Figure 1). The framework assesses and manages risks at every stage of the system, ensuring a holistic approach to delivering safe and reliable drinking water.

The department looks at the 'catchment' part of the framework (elements two and three of the ADWG), in consultation with the Department of Health and licensed water service providers. Once the water leaves the catchment (or the 'PDWSA'), the Department of Health and the licensed water service provider assess and manage the risks for the rest of the supply system.

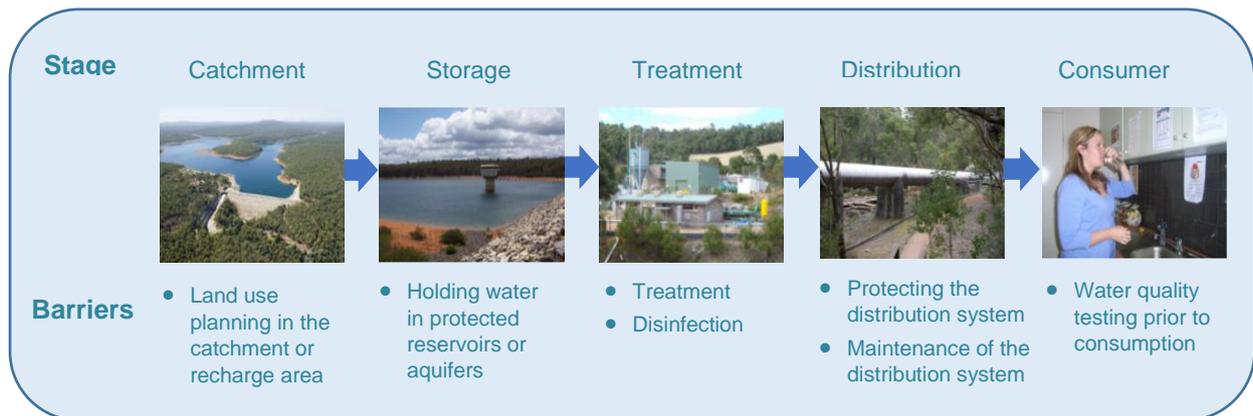


Figure E1: The ‘catchment to consumer’ framework

Different barriers against contamination are used at different stages of the ‘catchment to consumer’ system to ensure the maximum protection for consumers. The first and most important barrier is protecting the source of drinking water (the PDWSA). This is the first barrier and its protection has a flow-on effect, reducing the complexity of barriers required at other stages. Other barriers against contamination include the storage of water to help reduce contaminant levels; treatment plant disinfection of the water (such as chlorination to reduce the number of pathogens) and other treatment; maintenance and treatment within distribution piping and water quality testing at the tap.

Prevention is an essential feature of modern drinking water quality management. Research and experience shows that a combination of catchment protection (e.g. sound land use planning) and water treatment is safer than relying on either barrier on its own. The more land uses and activities that occur in an area the higher the risk of contamination. Therefore, as land uses are intensified, more mitigation is needed to address contamination risks. In PDWSAs the aim is to maintain or improve water quality through measures such as restrictions on land use intensification. Figure 2 shows the risk profiles of land use intensification and development against the level of protection applied.

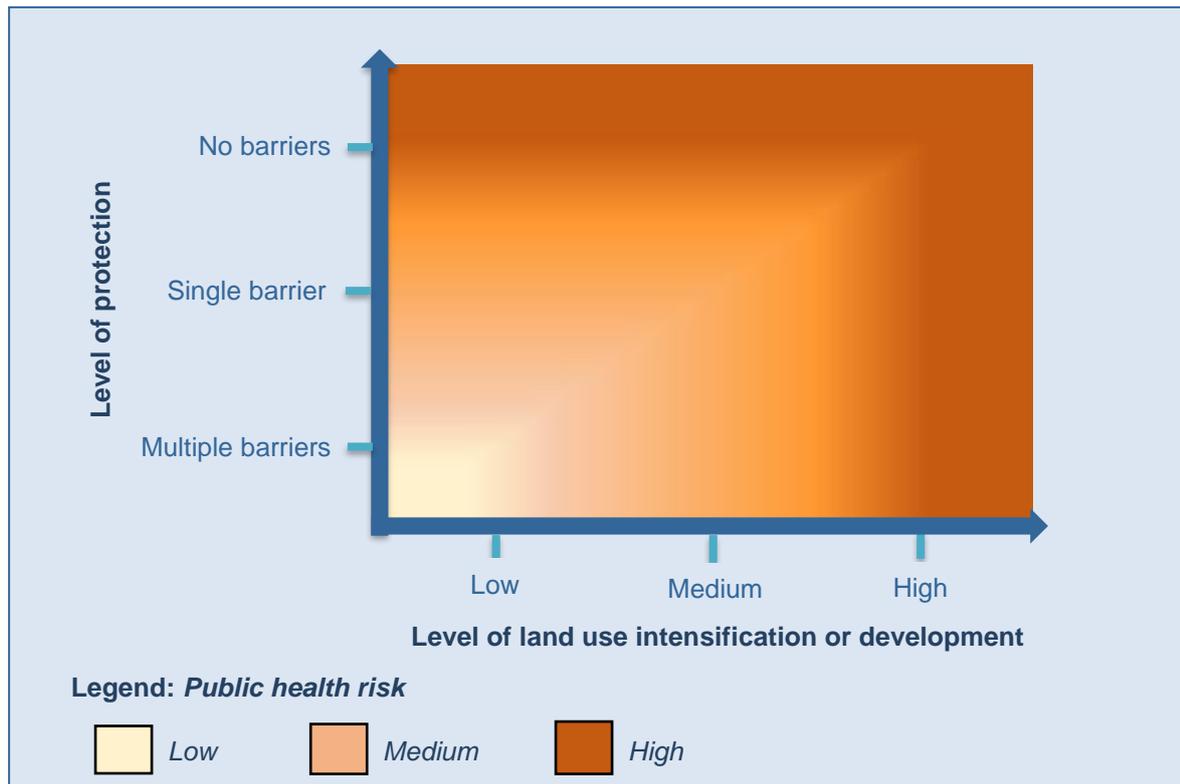


Figure E2: Public health risks comparing different levels of protection and land use intensification

Preventive risk-based approach explained

A risk assessment is not just about how often something happens (likelihood), or the results if the event did happen (consequence) but a combination of the two (risk). When we are talking about risks to a PDWSA and drinking water, even a contamination incident with a very low chance of happening could result in extremely serious consequences. Consequences could include outbreaks of illness and hospitalisation affecting a high proportion of the community, and in extreme cases causing death – even in developed countries like Australia¹. This means that something that has a low likelihood can still end up with a high risk because the consequences can be so severe.

A preventive risk-based approach recognises that risk mitigation measures can fail. For example, under ‘normal’ circumstances, water treatment (disinfection) will reduce the number of pathogens² to a safe amount. However, heavy rain can wash soil into

¹ Examples of these consequences are described in *Ensuring Safe Drinking Water: Learning from Frontline Experience with Contamination* (Hrudey & Hrudey 2014), which focuses on 21 real-life case studies (10 waterborne disease outbreaks, 7 cases of severe chemical contamination and 4 close calls).

² Pathogens are micro-organisms that cause illness in people and animals. Pathogens include bacteria (*Salmonella*, *Escherichia coli*, *Cholera*), protozoa (*Cryptosporidium*, *Giardia*), viruses (*Hepatitis*) and parasitic worms. Pathogens can come from animal manure, for example, cows near a drinking water source pose a pathogen risk. See further information in the Department of Water and Department of Health brochure, *Risks from pathogenic micro-organisms in public drinking water source areas*, 2008.

storage dams, causing turbidity (cloudy water). This makes treatment unreliable, because pathogens can attach to soil particles and be shielded from disinfection. Pathogens could then reach the consumer’s tap, which puts them at a higher risk. Also, treatment system failures are not uncommon and when they fail the risks can be high. A preventive risk-based approach recognises these issues and aims to prevent the event from happening to avoid the pathogen risk in the first place (e.g. by not allowing cattle near a drinking water source).

WA’s approach aims to first prevent risks when guiding land use planning. This is because in PDWSAs, the state has recognised the high drinking water value and the primacy of the need to protect water quality and public health. A preventive risk-based approach means that the maximum and residual risks to water quality and public health remain low (see Figure 3). This is different to other risk-based approaches, in which most risks are addressed only by mitigation measures (e.g. conditions of approval).

More traditional risk-based approaches are often suggested as a way to address contamination risks from land uses in PDWSAs. These approaches are often appropriate outside PDWSAs but they are not appropriate within PDWSAs. Adopting them in a PDWSA will result in a higher risk to water quality and public health. The ADWG requires a more a preventive risk-based approach.

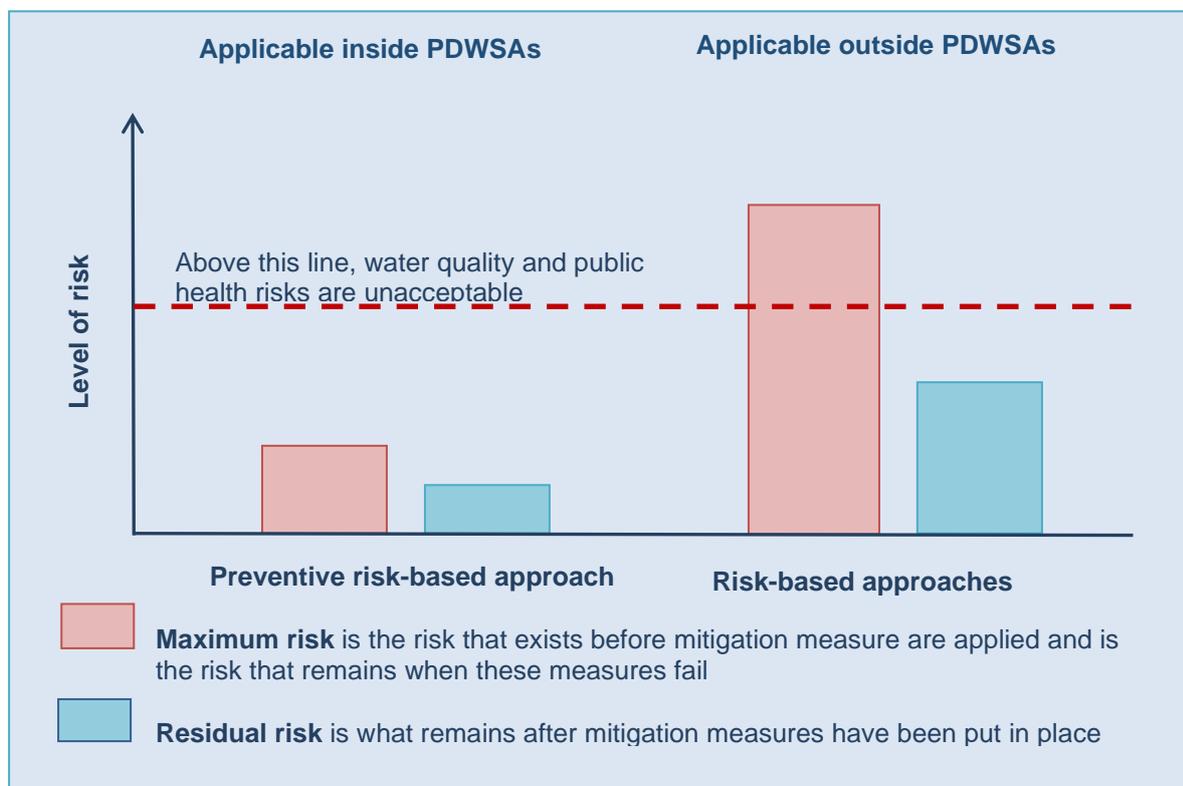


Figure E3: Risk profiles of ‘preventive’ versus risk-based approaches

Possible consequences

Some stakeholders feel that our preventive risk-based approach is too restrictive, but experience and scientific evidence shows that we should continue to be cautious when it comes to protecting drinking water quality and public health. The ADWG and WHO agree with this approach.

There are well-documented incidents of drinking water contamination in affluent and developed countries around the world. The consequences of these incidents include widespread illness, hospitalisation, lifelong health complications and in some cases, death. Financial and political consequences were significant and resulted in a public lack of trust (Hrudey & Hrudey 2014). These events occurred even when seemingly acceptable systems were in place to prevent contamination.

For example, in 2000 in Walkerton, Canada, a drinking water contamination incident resulted in seven fatalities and illness in over 2300 people in a population of around 5000. It was estimated that the cost of the water contamination was as high as \$155 million and a \$1 billion class-action lawsuit was filed by the community.

A more recent outbreak occurred in 2016 in Havelock North, New Zealand and resulted in 5500 people becoming ill and 45 others being hospitalised. The local school had to be shut down. The outbreak was also possibly related to three deaths and an unknown number of residents continue to suffer health complications.

A recent study of 24 waterborne disease outbreaks concluded that complacency, naiveté and ignorance were the biggest contributors to these incidents (Hrudey & Hrudey 2019). This tells us we must remain vigilant when it comes to drinking water source protection.

WA's drinking water source protection framework

The Department of Water and Environmental Regulation protects PDWSAs by implementing the ADWG and legislation, preparing policies, reports and guidelines, and providing expert advice about protecting drinking water quality to agencies that are responsible for land use planning and other relevant stakeholders.

Legislation and PDWSA boundaries

The *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* provide the department with the tools to protect water quality in PDWSAs.

We use these acts to legally constitute the boundary of a PDWSA, which is generally based on the physical (topographical) catchment area for a dam, and the groundwater flow pathways and recharge area for bores. The department has a team of expert hydrologists and hydrogeologists to delineate these boundaries using technical data and modelling.

By-laws apply under these acts, which help to protect drinking water sources from contaminating activities. Penalties may apply for not meeting these by-laws.

Drinking water source protection reports

The department prepares a drinking water source protection report for each PDWSA as recommended by the ADWG. Each report defines the PDWSA's boundary and assigns priority areas and protection zones; assesses its characteristics and water quality contamination risks; and makes recommendations to deal with those risks. We work cooperatively with the community, land; mining; and industrial developers; and other state and local government agencies to develop these reports. There are four different types of drinking water source protection reports – each providing for different needs (see Table E1).

With approximately 140 PDWSAs across WA, the department aims to update each report every seven years, or based on changes to risks.

Table E1: Types of drinking water source protection reports

Drinking water source protection report	Scope and outcome	Consultation	Time to prepare	Gazettal
Assessment	Desktop assessment of readily available information	Preliminary	Up to 3 months	All types of consulted drinking water source protection reports can recommend to constitute a source's boundary under legislation. This helps protect water quality and guides land use planning.
Plan	Full investigation of risks to water quality building on information in the assessment (above)	Public	6–12 months	
Review	Review changes in land and water factors and implementation of previous recommendations Sometimes prepared to consider specific issues in a PDWSA	Key stakeholders	1–6 months	
Land use and water management strategy	Prepared by the Western Australian Planning Commission Strategic planning document for a PDWSA in metropolitan area	Public	12 months or more	

Assessing existing risks

As part of a drinking water source protection report the department looks at the zoning, land tenure, land uses and activities within the PDWSA. We then look at the hazards, determine what contaminants might arise from them, and predict what might happen if that contaminant was to enter the drinking water source.

We think about things such as pathogens from human activities, chemicals from commercial or residential development, nutrients from fertilisers applied to surrounding crops or hydrocarbons that might leak from machinery or vehicles.

Then we look at how to address these risks and recommend management measures to help mitigate them.

Although our primary goal is to avoid risks in PDWSAs, we also need to consider land uses, activities and zonings that were present before the PDWSA was constituted, or are required to support population growth, housing, jobs and essential infrastructure. So there may be times when some risks cannot be prevented or avoided. In such cases, we need to minimise or manage the risks as much as is reasonably practical.

Priority areas and protection zones

Within each PDWSA, the department defines special areas via a drinking water source protection report (see Table 1), to maximise the protection of water quality and public health. These special areas help guide land use planning and identify where legislation applies.

These are called 'priority areas' and 'protection zones'. There are three different priority areas, and two types of protection zones, as follows.

Priority 1 (P1) areas: The objective of P1 areas is risk avoidance – ensuring there is no degradation of the water quality. P1 areas are normally assigned over areas such as state forest and crown land.

Where it is not possible to assign a P1 area due to existing land uses or zoning, we have P2 or P3 areas.

Priority 2 (P2) areas: The objective of P2 areas is risk minimisation – maintaining or improving water quality for existing land uses and zoning only. P2 areas are usually assigned over rural-zoned land.

Priority 3 (P3) and Priority 3* (P3*) areas: The objective of P3 and P3* areas is risk management for existing land uses and zoning only – maintaining the water quality for as long as possible. P3 areas are usually assigned over urban or light industrial land. P3* areas are assigned in the Perth Metropolitan Region Scheme area where WAPC-approved strategic planning decisions have resulted in a change from P1 or P2 to P3*. P3* areas recognise the additional risk to the drinking water source by limiting some of the more risky land uses and activities that are allowed in P3 areas.

Protection zones surround drinking water abstraction points so that the most vulnerable areas are protected from contamination. Protection zones overlies priority areas and do not extend outside of the PDWSA boundary.

For surface water sources, these are called 'reservoir protection zones', which cover the water body behind the dam wall and extend back into the catchment for 2 km (or a similar distance designated by the Minister for Water) from the high water mark of the water body. It does not extend downstream below the dam wall or outside the proclaimed boundary of a PDWSA.

For groundwater sources, these are called 'wellhead protection zones' and generally form a circle around each bore, with different radius depending what priority area they are in. In P1 areas, they are a 500 m radius, in P2 and P3 areas, they are 300 m. Other sizes and shapes may be determined based on available data.

Protection zones overlies priority areas but do not extend outside of the boundary of the PDWSA. Refer to the department's Strategic policy: *Protecting public drinking water source areas in Western Australia* (Department of Water 2016a) for further information and figures showing priority areas and protection zones.

Land use planning in PDWSAs

Managing land uses in PDWSAs is a crucial step to protecting water quality within them. This is because land uses may introduce contaminants from people, animals, vehicles, agricultural and industrial processes, and more. In WA, water resource management and land use planning is integrated via government policies prepared by the Western Australian Planning Commission. These policies are:

- State planning policy (SPP) 2.2: *Gnangara groundwater protection*
- SPP 2.3: *Jandakot groundwater protection*
- SPP 2.7: *Public drinking water source policy*
- SPP 2.9: *Water resources*.

The Commission is currently reviewing these policies, with a view to amalgamating them.

The department also has a policy framework to protect PDWSAs, as follows:

- Strategic policy: *Protecting public drinking water source areas in Western Australia* (Department of Water 2016a)
- Operational policy 13: *Recreation within public drinking water source areas on Crown land* (Department of Water and Environmental Regulation 2019)

Water quality protection note 25: *Land use compatibility tables for public drinking water source areas* (Department of Water 2016b), which outlines appropriate development and activities within each priority area. This note is called up in both the Commission's and the department's policies.

Shortened forms

List of shortened forms

ADWG	<i>Australian drinking water guidelines</i>
ANZECC	Australian and New Zealand Environment Conservation Council
HAZMAT	hazardous materials
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
P1, P2, P3	priority 1, priority 2, priority 3
PDWSA	public drinking water source area
State Hazard Plan–HAZMAT	Western Australian plan for hazardous materials (previously named Westplan–HAZMAT and WAHMEMS)
RPZ	reservoir protection zone
Westplan–HAZMAT	Western Australian plan for hazardous materials (previous name for State Hazard Plan–HAZMAT)
WHPZ	wellhead protection zone
WQPN	water quality protection note

Units of measurement

km	kilometres	A measure of distance, 1 km equals 1000 m.
km²	square kilometres	A measure of area.
m	metres	A measure of distance.
mg/L	milligrams per litre	A measure of concentration of a substance in a solution.
MPN	most probable number	A method used to measure the occurrence of microbes in a sample of water. The procedure uses tubes or microtitre plates and presence/absence tests (WHO 2011).
NTU	nephelometric turbidity units	A measure of turbidity in water.
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.
TCU	true colour units	A measure of degree of colour in water.
TDS	total dissolved solids	Consists 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 micrometre filter membrane can also contribute to TDS. TDS comprises sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate, carbonate, silica, organic matter, fluoride, iron, manganese, nitrate (and nitrite) and phosphate (NHMRC & NRMCC 2011).
TFSS	total filterable solids by summation	A water quality test which is a total of the following ions: Na (sodium), K (potassium), Ca (calcium), Mg (magnesium), Cl equivalent (chloride), alkalinity equivalent, SO ₄ equivalent (sulfate) or S (sulfur) in grams, Fe (iron), Mn (manganese), and SiO ₂ (silicon oxide). It is used as a more accurate measure than TDS. The higher the value, the more solids that are present and generally the saltier the taste.

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

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 year (kL/y).
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</i> (ADWG; NHMRC & NRMCC 2011, August 2018 update) 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.
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
Catchment area	An area constituted 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.
Constitute	Define the boundaries of any catchment area or water reserve by Order in Council under the <i>Country Areas Water Supply Act 1947</i> or by proclamation under <i>the Metropolitan Water Supply, Sewerage and Drainage Act 1909</i> .
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.
Dissipate	To become scattered or dispersed.
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.

Fractured rock aquifer	An aquifer where groundwater is present in the fractures, joints, solution cavities, bedding planes and zones of rocks. Fractured rock aquifers are highly susceptible to contamination from land uses when aquifers crop-out or sub-crop close to the land surface.
Gazette	Publication within the Government Gazette of Western Australia of the Order in Council or proclamation defining the boundaries of any catchment area or water reserve.
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).
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.
Hydrogeology	The branch of geology that deals with the occurrence, distribution and effects of groundwater. It is the study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
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.
Maximum risk	This is the level of risk in the absence of any preventive measures (barriers) being installed in the system, or assuming that preventive measures have failed. Assessing maximum risk is useful for identifying high priority risks, determining where attention should be focused and preparing for emergencies (NHMRC & NRMCC 2011).
Nutrients	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.
Order in Council	Made under the Governor of Executive Council and published in the Government Gazette to constitute or abolish a catchment area or water reserve under section 9 of the <i>Country Areas Water Supply Act 1947</i> .
Paleochannel	Deposits of unconsolidated sediments or semi-consolidated sedimentary rocks deposited in ancient, currently inactive, river and stream channel systems.

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.
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 2 (P2) areas is <i>risk minimisation</i> and priority 3 (P3) areas is <i>risk management</i> .
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.
Reservoir	A dam, tank, pond or lake that captures water from a surface catchment to create a water supply source.
Reservoir protection zone	A buffer measured from the high water mark of a drinking water reservoir, and inclusive of the reservoir (usually 2 km). This is referred to as a prohibited zone under the Metropolitan Water Supply, Sewerage, and Drainage Act By-laws 1981.
Residual risk	This is the level of risk after considering preventive measures (barriers) that are applied in the drinking water supply system, such as fencing to keep cattle away from drinking water bores, or surveillance to identify people accessing protected areas. Residual risk provides an indication of how effective preventive strategies are, or the need for additional preventive measures (NHRMC & NRMCC 2011).
Runoff	Water that flows over the surface from a catchment area, including streams.

Sole supply	The only harnessed source of drinking water for a given town or community. These sources are important to protect as there are no other current options to supply drinking water for that location.
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 constituted 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.
Watertable	The upper saturated level of the unconfined groundwater.
Wellhead	The top of a well (or bore) used to draw groundwater.
Wellhead protection zone	Usually declared around wellheads in public drinking water source areas to protect the groundwater from immediate contamination risks.
State Hazard Plan–HAZMAT	State emergency management plan for hazardous materials emergencies.

References

- Department of Mineral and Petroleum Resources 2002, *Guidelines for the protection of surface and groundwater resources during exploration drilling*, Government of Western Australia, Perth, available www.dmirs.wa.gov.au.
- Department of Planning & Western Australian Planning Commission 2015, *Goldfields-Esperance Regional Planning and Infrastructure Framework, Part B: Regional Infrastructure Planning*, Government of Western Australia, Perth, available www.dplh.wa.gov.au.
- Department of Planning, Lands and Heritage 2003, *Shire of Laverton, Local planning Scheme no.2*, Updated May 2019, Government of Western Australia, Perth, available www.dplh.wa.gov.au.
- Department of Water 2007, *Laverton Water Reserve and Catchment Area drinking water source protection plan*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2014a, *Water resources inventory 2014 – Water availability, quality and trends*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2014b, *Water for growth, An overview of current and future water management plans in Western Australia*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2016a, *Strategic policy: Protecting public drinking water source areas in Western Australia*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2016b, *Water quality protection note 25: Land use compatibility tables for public drinking water source areas*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Department of Water and Environmental Regulation 2019, *Operational policy 13: Recreation within public drinking water source areas on Crown land*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Department of Water & Department of Mines and Petroleum 2016, *Administrative agreement between the Department of Mines and Petroleum and Department of Water for mineral exploration and mining operations in water resource areas of Western Australia*, Government of Western Australia, Perth, available www.dmirs.wa.gov.au.
- 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*, State Law Publisher, Perth, available www.legislation.wa.gov.au.
- 1914, *Rights in Water and Irrigation Act*, State Law Publisher, Perth, available www.legislation.wa.gov.au.

- 1947, *Country Areas Water Supply Act*, State Law Publisher, Perth, available www.legislation.wa.gov.au.
- 1972, *Aboriginal Heritage Act*, State Law Publisher, Perth, available www.legislation.wa.gov.au.
- 1978, *Mining Act*, State Law Publisher, Perth, available www.legislation.wa.gov.au.
- 2018, *Heritage Act*, State Law Publisher, Perth, available www.legislation.wa.gov.au.
- Hrudey SE & Hrudey EJ 2019, 'Common themes contributing to recent drinking water disease outbreaks in affluent nations', *Water supply*, 19 (6):1767-1777, available doi.org/10.2166/ws.2019.051.
- 2014, *Ensuring Safe Drinking Water: Learning from Frontline Experience with Contamination*, American Water Works Association, Denver.
- National Health and Medical Research Council (NHMRC) & Natural Resource Management Ministerial Council (NRMMC) 2011, National water quality management strategy: *Australian drinking water guidelines*, Version 3.5 Updated August 2018, Australian Government, Canberra, available www.nhmrc.gov.au.
- National Uniform Drillers Licensing Committee 2012, *Minimum construction requirements for water bores in Australia*, 3rd edn, Australian Government National Water Commission, Braeside, Victoria, available www.dwer.wa.gov.au.
- 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. 143–78.
- State Emergency Management Committee 2009, State emergency management policy 2.4: *District emergency management arrangements*, as amended 12 April 2010, Government of Western Australia, Perth, available www.semc.wa.gov.au.
- Water Corporation 2004, *Laverton Water Reserve drinking water source protection assessment*, Water Corporation, Leederville.
- 2009, *SG097 Source protection operations manual*, unpublished corporate manual, Water Corporation, Leederville.
- 2013, *S111 Source protection signage*, unpublished corporate standard, Water Corporation, Leederville.
- Western Australian Planning Commission 2003, State planning policy 2.7: *Public drinking water source policy*, 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 Health 2011, *Mine sites, exploration camps and construction villages*, Government of Western Australia, Perth, available www.health.wa.gov.au.
- Department of Water 2006, Water quality protection note 35: *Pastoral activities within rangelands*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2006, Water quality protection note 44: *Roads near sensitive water resources*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2009, Water quality protection note 36: *Protecting public drinking water source areas*, available www.dwer.wa.gov.au.
- 2011, *Living and working in public drinking water source areas*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2016b, Water quality protection note 25: *Land use compatibility tables for public drinking water source areas*, available www.dwer.wa.gov.au.
- Department of Water & Department of Health 2008, *Risks from pathogenic microorganisms in public drinking water source areas*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Department of Water and Environmental Regulation 2020, Water quality protection note 10: *Contaminant spills – emergency response plan*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Hrudey, SE & Hrudey, EJ 2019, 'Common themes contributing to recent drinking water disease outbreaks in affluent nations', *Water Supply*, vol. 19 no. 6, pp. 1767–1777.
- 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 www.nhmrc.gov.au.
- 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.

Water and Rivers Commission 1999, *Water Quality Protection Guidelines (No 1-11), Mining and Mineral Processing*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.

Western Australian Planning Commission 2006, *State planning policy 2.9: Water resources*, Government of Western Australia, Perth, available www.planning.wa.gov.au.

World Health Organization 2011, *Guidelines for drinking-water quality*, 4th edn, World Health Organization, Geneva, www.who.int/.

Department of Water and Environmental Regulation
Prime House
8 Davidson Terrace Joondalup
Western Australia 6027

Locked Bag 10, Joondalup DC WA 6919

Phone: 08 6364 7000
Fax: 08 6364 7001
National Relay Service 13 36 77
dwer.wa.gov.au