



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

Mount Magnet Water Reserve

drinking water source protection review



Mount Magnet town water supply

Water resource protection series
Report WRP 182
March 2019

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Department of Water and Environmental Regulation

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Cover photograph: Aerial photo of Mount Magnet Water Reserve

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

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Summary

This drinking water source protection review considers changes that have occurred in and around the Mount Magnet Water Reserve since completion of the *Mount Magnet Water Reserve drinking water source protection plan* (DoE 2005). The plan still contains relevant information, so it is important that these documents are read in conjunction. Both are available on our website or by contacting us (see inside cover of this report for contact details).

Mount Magnet is a small town about 600 km north-east of Perth, in the Shire of Mount Magnet. It is a support centre for surrounding gold mining and pastoral stations.

There are 532 people living in the town of Mount Magnet (Australian Bureau of Statistics 2011). This number can vary depending on the mining activities in the area.

The Mount Magnet Water Reserve has two separate sections: Genga, which is south-west of the town of Mount Magnet; and Lennonville, which is north-west of the town.

There was previously a constituted Mount Magnet Catchment Area for a surface water dam, but as this was no longer used for public drinking water supply, it was abolished in 2007.

The Water Corporation supplies public drinking water to Mount Magnet from five production bores located in the Genga water reserve approximately 10 km south-west of the town. These bores draw water from an unconfined aquifer which makes the source vulnerable to contamination. Maintaining wellhead protection zones around the production bores, managing the key recharge area as priority 1 and managing the wider catchment as priority 2, will reduce the water quality contamination risks.

The Lennonville water reserve is a priority 1 area, to maintain protection for a future water source. There are no production bores here at this time.

The main changes since the 2005 plan are:

- the surface water dam catchment area was abolished in 2007
- two production bores in the eastern Genga borefield are no longer used
- new hydrological and hydrogeological assessments undertaken by DWER have determined that:
 - an area previously proposed to be included into the Genga water reserve is not required
 - the boundary should be amended to better reflect the recharge area for the current production bores.

We prepared this document in consultation with key stakeholders including the Water Corporation, the Shire of Mount Magnet and Ramelius Resources Ltd.

This review helps implement:

- the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011)
- State planning policy no. 2.7: *Public drinking water source policy* (WAPC 2003)
- Strategic policy: *Protecting public drinking water source areas in Western Australia* (DoW 2016a).

Important information about the Mount Magnet Water Reserve is in Table 1.

Table 1 Key information about the Mount Magnet Water Reserve

Mount Magnet Water Reserve	
Status of this report	This report is based on information from the 2017–18 financial year. Public drinking water source area boundaries, priority areas, bore locations, wellhead protection zones and other data may be subject to change. For up-to-date information, please email drinkingwater@dwer.wa.gov.au .
Local government authority	Shire of Mount Magnet
Location supplied	Mount Magnet
Water service provider	Water Corporation
Aquifer type	Unconfined, alluvial and fractured rock aquifers (vulnerable to water quality contamination)
Licensed abstraction	350 ML/year
Number of bores	5 (as at 2017) The production bores are screened at depths ranging between 30 m and 72 m
Bore names and GPS coordinates	Western Genga borefield: • 35/86 (E 573 440, N 6 887 491, zone 50) • 36/86 (E 573 090, N 6 886 561, zone 50) • 38/86 (E 572 728, N 6 888 334, zone 50) • 40/86 (E 572 030, N 6 888 091, zone 50) Eastern Genga borefield: • 7/82 (E 575 957, N 6 888 598, zone 50)

Mount Magnet Water Reserve	
Water treatment	Calgon dosing to reduce the hardness. Chlorination to remove microbes
Dates of drinking water source protection reports	2005 – <i>Mount Magnet Water Reserve drinking water source protection plan</i> 2018 – <i>Mount Magnet Water Reserve drinking water source protection review</i> (this document)
Consultation	2000–2005: Public consultation occurred during development of the water source protection plan and included the Water Corporation, Department for Planning and Infrastructure (now Department of Planning, Lands and Heritage), Department of Land Information (now Landgate), Department of Industry and Resources (now Department of Mines, Industry Regulation and Safety), Midwest Development Commission, Shire of Mount Magnet, Main Roads, Harmony Gold (now Ramelius Resources Ltd), Aboriginal interests and other affected mining tenement owners and landowners. 2017: While developing this drinking water source protection review, we consulted with key stakeholders. The Water Corporation, the Shire of Mount Magnet and Ramelius Resources Ltd.
Constitution history	The Mount Magnet Catchment Area (town dam surface water catchment) was constituted in March 1985 under the <i>Country Areas Water Supply Act 1947</i>. The groundwater portion of the water reserve was constituted in August 1991 as the Mount Magnet Water Reserve under the <i>Country Areas Water Supply Act 1947</i>. Abolition of the Mount Magnet Catchment Area and constitution of the current Mount Magnet Water Reserve occurred on 29 June 2007 under the <i>Country Areas Water Supply Act 1947</i>. If supported, a new Mount Magnet Water Reserve boundary is proposed to be constituted in 2018–19 (see Figure A1).
Reference documents	<i>Australian drinking water guidelines</i> (NHMRC & NRMCC 2011) State planning policy no. 2.7: <i>Public drinking water source policy</i> (WAPC 2003)

1 Review of Mount Magnet's drinking water source protection plan

1.1 Boundary, priority areas and protection zones

The existing Mount Magnet Water Reserve was constituted in 2007 under the *Country Areas Water Supply Act 1947*. The water reserve is made up of two parts: the Lennonville water reserve in the north, and the Genga water reserve in the south. Please refer to Figure A1 for the location of the water reserve.

The Lennonville water reserve is reserved for future drinking water supply and is managed as a priority 1 (P1) area. The *Mount Magnet Water Reserve drinking water source protection plan* (Department of Environment 2005) discussed the possibility of the Lennonville water reserve being used as a new source for a reverse osmosis plant. The Water Corporation has not yet established a reverse osmosis plant in Mount Magnet, but this review proposes to retain the Lennonville water reserve in the event that this occurs, or if a new water source with lower contamination risks is required.

The Genga water reserve reflects the recharge area for the existing production bores, based on topographical and hydrogeological information. The key recharge area is a P1 area, and the rest of the Genga water reserve, which represents the surface water catchment area of the borefield, is a priority 2 (P2) area. This is consistent with the decisions made in 2005 plan.

There was a third proposed part of the Genga water reserve discussed in the 2005 *Mount Magnet Water Reserve drinking water source protection plan*. This area was not constituted because several drainage diversions were thought to be excluding this area from contributing recharge to the water reserve. A recent hydrological and hydrogeological assessment has confirmed that most of this area does not contribute recharge to the production bores regardless of drainage diversions. Therefore this area is not included in the proposed Genga water reserve.

This hydrological assessment did define some boundary amendments that are required to more accurately depict the recharge area for the current production bores. This includes some expansion to the east, west and south-west in both the P1 and P2 areas and a reduction in the south-west. Please refer to Figure A4 for the new proposed boundary, priority areas and wellhead protection zones (WHPZs).

Since the 2005 plan, two bores (1/75 and 7/74) are now out of service and have been removed from the Water Corporation's groundwater allocation licence. This review recommends that production bores that are no longer used are appropriately decommissioned to avoid risks to groundwater. Decommissioning should be consistent with *Minimum construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2012).

The Genga water reserve contains five active drinking water production bores, all within the P1 area and each protected by a 500 m WHPZ (Figure A4).

The bores are divided into two different borefields within the Genga water reserve. There is an eastern borefield and a western borefield, which are thought to be separated by a basalt ridge groundwater divide. This suggests that there is a buffer between the two groundwater flow systems of each borefield and therefore they have separate catchment areas.

The two production bores that are out of service (1/75 and 7/74) are in the eastern Genga borefield, leaving only one active production bore (7/82) in that borefield. The majority of Mount Magnet's public drinking water supply comes from the western side of Genga borefield, where the water quality risks are lower. This review recommends that, subject to water availability, any future production bores should be drilled in the western side of the Genga borefield or the Lennonville water reserve, to minimise water quality risks from neighbouring mining activities.F

Future reviews should consider amending the boundary to remove the eastern side of the Genga borefield from the Mount Magnet Water Reserve if production bore 7/82 is no longer required and all three bores are appropriately decommissioned.

The boundary, priority areas and protection zones in this review have been determined in accordance with our Strategic policy: *Protecting public drinking water source areas in Western Australia* (DoW 2016a).

Please read Appendix E for more information about how we protect drinking water sources.

1.2 Update on water supply scheme

The Mount Magnet borefield consists of five active production bores (7/82, 35/86, 36/86, 38/86 and 40/86) which draw water from the unconfined alluvial and fractured rock aquifer. The production bores are screened at depths ranging between 30 m and 72 m.

Groundwater from the borefield is transported to treatment facilities where it undergoes Calgon dosing to reduce the hardness of the water. Chlorination is carried out to disinfect the water to ensure microbiological quality for consumers. The treated water is then pumped into storage tanks (Figure C3), approximately 500 m west of Mount Magnet, from where it is distributed via gravity to the town scheme.

Water Corporation's groundwater allocation licence for Mount Magnet was last renewed in September 2016, and is due to expire in June 2026. The licence allows the Water Corporation to draw 350 000 kL of water from the alluvial and fractured rock aquifer (unconfined) to supply Mount Magnet's drinking water from the five production bores.

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

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

For more information on why it is so important to protect our catchments, and the DWER's approach based on preventive risk, read Appendix E.

1.3 Aboriginal sites of significance and native title claims

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* 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 eight registered Aboriginal sites of significance within the Lennonville water reserve. These are: Couttes bore (P07946) and on the north-eastern tip of the water reserve is: Carved Cave Spring (P00742), Mirrawanni 1 (P05934), Mirrawanni 2 (P05935), Mirrawanni 3 (P05936), Mirrawanni 4 (P05937), Mirrawanni 5 (P05938), and Merawanee/Cave Well (P00307).

There are six registered Aboriginal sites of significance within the Genga water reserve. These are:

- Boogardi Road (S02757)
- Boogardi (S02790)
- Boogardie Camp (S03103)
- Jones Creek (S03101)
- Tula Rockshelter (S03106)
- Hughie King's Camp (S03107).

Native title is the recognition in Australian law that some Aboriginal people continue to hold native title rights to lands and water arising from their traditional laws and customs. There is one native title claim within the Mount Magnet Water Reserve. This is the Badimia People's claim (WAD6123/1998).

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

1.4 Enforcing by-laws, surveying the area and maintenance

Water Corporation's operators visit the borefield on a weekly basis and a catchment ranger conducts surveillance of the production bores and surrounding catchment on a six-monthly basis.

This review recommends that the Water Corporation continue by-law enforcement under the existing delegation arrangement (see section 2.2, recommendation no. 7). This includes:

- erecting and maintaining signs in accordance with *S111 Source protection signage* (Water Corporation 2013)
- maintaining security and fencing surrounding the bores and treatment compound
- ongoing regular surveillance and inspections.

1.5 Other Department of Water and Environmental Regulation work

1.5.1 Mid West regional water supply strategy – A long-term outlook of water demand and supply, 2015

This strategy considers a range of water demand scenarios for mining, industry, agriculture and towns (including Mount Magnet) in the region. It identifies supply options to meet this demand.

1.5.2 Selection of future climate projections for Western Australia (DoW 2015)

This study aims to assist with providing climate scenarios for the consistent and transparent management of water resources. The report uses different scenarios, variables and regions (including Mount Magnet) to produce standard monthly climate anomalies for different time horizons.

1.5.3 Capacity of water resources in the Mid West to meet mining and industrial growth (DoW 2011)

This document is an addendum to *Mid West Minerals Province – groundwater resource appraisal* (DoW 2006) published as part of the Mid West regional minerals study. The report summarises current information on the availability of water resources in the Mid West, in the context of expected mining and industrial growth in the region.

1.6 Update on water quality risks

As part of this review, DWER has conducted an updated assessment of water quality contamination risks to Mount Magnet's drinking water source, in accordance with the ADWG. Table 2 shows the risks that are new or have changed since the 2005 plan, and also includes risks that are still considered high.

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

Land uses in the Mount Magnet Water Reserve have remained the same since the 2005 plan. Land uses include low-density sheep grazing (Figure C6) and exploration and mining activities (Figure C2).

Mining has continued to expand to the north-east and within the Genga water reserve. Proposals will be assessed through the state's environmental approvals process, including consideration of the potential impacts on the Mount Magnet Water Reserve and whether the project poses an unacceptable risk to water quality and public health.

Illegal recreation such as off-road driving, camping and associated camp fires occurs within the water reserve (Figure C4).

Illegal rubbish dumping within the water reserve has been identified. There is an area where significant dumping has occurred and the rubbish has been previously collected and removed from the water reserve. However, this area continues to be used for illegal rubbish dumping (Figure C5).

The production bores are fenced, but some of them are only protected by low stock fencing (see Figure C1 low stock fencing around production bore 7/82) rather than the more effective and secure cyclone fencing.

There has been occasional vandalism to the bore compounds.

1.6.1 Other groundwater bores

Bores drilled near a public drinking water supply bore (such as for irrigation or private 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 DWER's water licensing process where applicable under the *Rights in Water and Irrigation Act 1914*. All bores should be constructed and decommissioned 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 is one other licensed user in the Lennonville water reserve. There are no other licensed users in the Genga water reserve, but there are a number nearby.

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 guidance¹
Roads and tracks	Hydrocarbons and other chemical spills	Low	Existing sealed roads are acceptable. Unsealed roads need to be managed to control access.	WQPN no. 44: <i>Roads near sensitive water resources</i> WQPN no.10: <i>Contaminant spills – emergency response</i>
Mining activities	Hydrocarbons from vehicles and machinery	Medium	Mining is primarily gold mining and processing. Best practice is implemented by mining companies.	Water quality protection guidelines 1–11: <i>Mining and mineral processing</i>
	Chemicals from mineral processing	Medium		
Pastoral lease	Pathogens from animal faeces	Medium	Stocking rates are low.	WQPN no. 35: <i>Pastoral activities within rangelands</i>
Illegal recreation, off-road driving, hunting and camping	Pathogens from human access and rubbish	Medium	Illegal recreation numbers are low.	Operational policy 13: <i>Recreation within public drinking water source areas on Crown land</i>
	Hydrocarbons from fuel leaks and spills	Low		

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
Illegal rubbish dumping	Pathogens from human access and rubbish	Medium	Rubbish dumping is illegal – penalties may apply.	
	Hydrocarbons from fuel leaks and rubbish	Low		
	Chemical leaching from rubbish	Low		

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

1.7 Water quality information

The Water Corporation has provided updated water quality information for the Mount Magnet Water Reserve. The monitoring period was from August 2012 to July 2017. This is shown in Appendix B.

Raw water from the production bores is considered hard but has consistently been of good quality. With the exception of high levels of turbidity, nitrite and nitrates, the water has generally met the ADWG.

Hardness, turbidity and high nitrates are naturally occurring. Water hardness is treated before water is supplied to consumers. Nitrate levels are higher than the ADWG value for bottle-fed infants less than three months old. An exemption has been granted by the Department of Health for this source and the Water Corporation supplies bottled water for infants under three months. The water is within the guideline range for safe consumption by adults and infants over three months of age.

Escherichia coli was detected in two samples at low levels (below 20MPN/100mL) and no detections have occurred since 2013. The source of this contamination was unknown.

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.

2 Implementing Mount Magnet's drinking water source protection plan

2.1 Status of previous recommendations

Table 3 outlines recommendations from the 2005 plan and their current status.

Table 3 *Implementation status of the 2005 Mount Magnet Water Reserve plan recommendations*

No.	Recommendation (2005)	Comments (2018)
1	Constitution of modified water reserve and town dam catchment abolished.	Complete. The water reserve was constituted and the town dam catchment was abolished in 2007 under the <i>Country Areas Water Supply Act 1947</i> .
2	Establish 500 m WHPZs around each production bore.	Complete. This occurred through the 2005 <i>Mount Magnet Water Reserve drinking water source protection plan</i> .
3	Incorporation into land planning strategies, incorporating the management principles of WQPN no. 25: <i>Land use compatibility in PDWSAs</i> and reflecting P1 and P2 areas.	The water reserve has been partly incorporated into the Mount Magnet local planning scheme (LPS). The P2 northern part of the Genga water reserve has not been included. This review recommends that it is included into the LPS.
4	Referral of development proposals.	Ongoing. This recommendation will be carried forward. Development proposals within the water reserve are referred to the Mid West Gascoyne Region office of DWER.
5	A locality map and management priorities should be provided to Department of Industry and Resources (now Department of Mines, Industry Regulation and Safety), local shire and Water Corporation.	This information will again be sent to the Shire of Mount Magnet and Water Corporation as part of this review.

No.	Recommendation (2005)	Comments (2018)
6	Erection of signs.	Signs exist on production bore compounds (Figure C1), storage and treatment compounds and at some locations in the water reserve. However, some additional catchment signage should also be installed in the Mount Magnet Water Reserve. All signs need to be maintained in accordance with the Water Corporation's <i>S111 Source protection signage</i> (2013).
7	Emergency response: • given access to a locality map and training • in case of emergency Water Corporation and the Department of Water and Environmental Regulation should provide an advisory role.	Emergency response protocols have changed since 2005 to the jurisdiction of HAZMAT and the local emergency management committee (LEMC). This review will be provided to the Shire of Mount Magnet, Water Corporation and the Mount Magnet LEMC.
8	Monitoring program for the production bores should be reviewed. Ongoing reviews of water quality data should continue to identify adverse trends.	Water Corporation completed a Mount Magnet water monitoring review in 2010. Water Corporation continue to monitor the water quality of the water reserve as part of their requirement as a licensed water service provider.
9	Continue to advise residents and visitors of high nitrate levels in drinking water for infants under three months old.	Ongoing. This recommendation will be carried forward. The town's doctors and the hospital inform expecting and new mothers about the high nitrates in the drinking water and the hospital supplies bottled water to babies.
10	Shire of Mount Magnet and Main Roads should ensure measures to reduce risks of potential spills from traffic on the Geraldton to Mount Magnet road are considered and implemented where practicable.	The road has been widened near the petrol station and it is occasionally graded. Additional measures to increase road safety on the borefield stretch of road should be investigated and implemented.

No.	Recommendation (2005)	Comments (2018)
11	The Water Corporation should continue surveillance and by-law enforcement to identify and ameliorate potential risks.	Ongoing. This recommendation will be carried forward. Water Corporation undertakes regular surveillance of water supply infrastructure within the water reserve.
12	Review of the plan and recommendations including protecting any new sources of the proposed reverse osmosis plant.	Undertaken through the preparation of this review document. This recommendation will be carried forward.

2.2 Consolidated recommendations

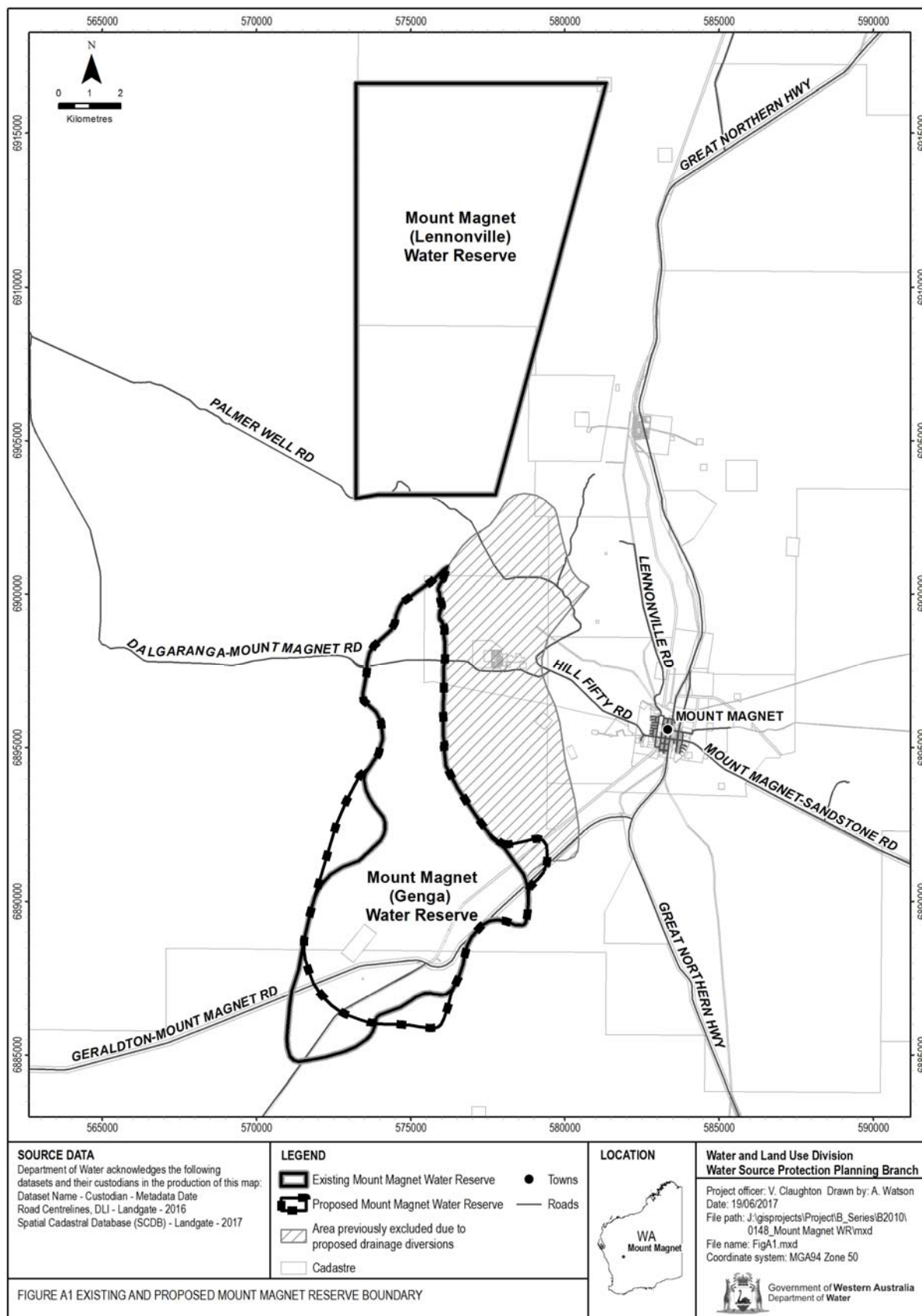
Based on the findings of this review the following recommendations will now be applied to the Mount Magnet Water Reserve. The bracketed stakeholders are those expected to have a responsibility for, or an interest in, the implementation of that recommendation.

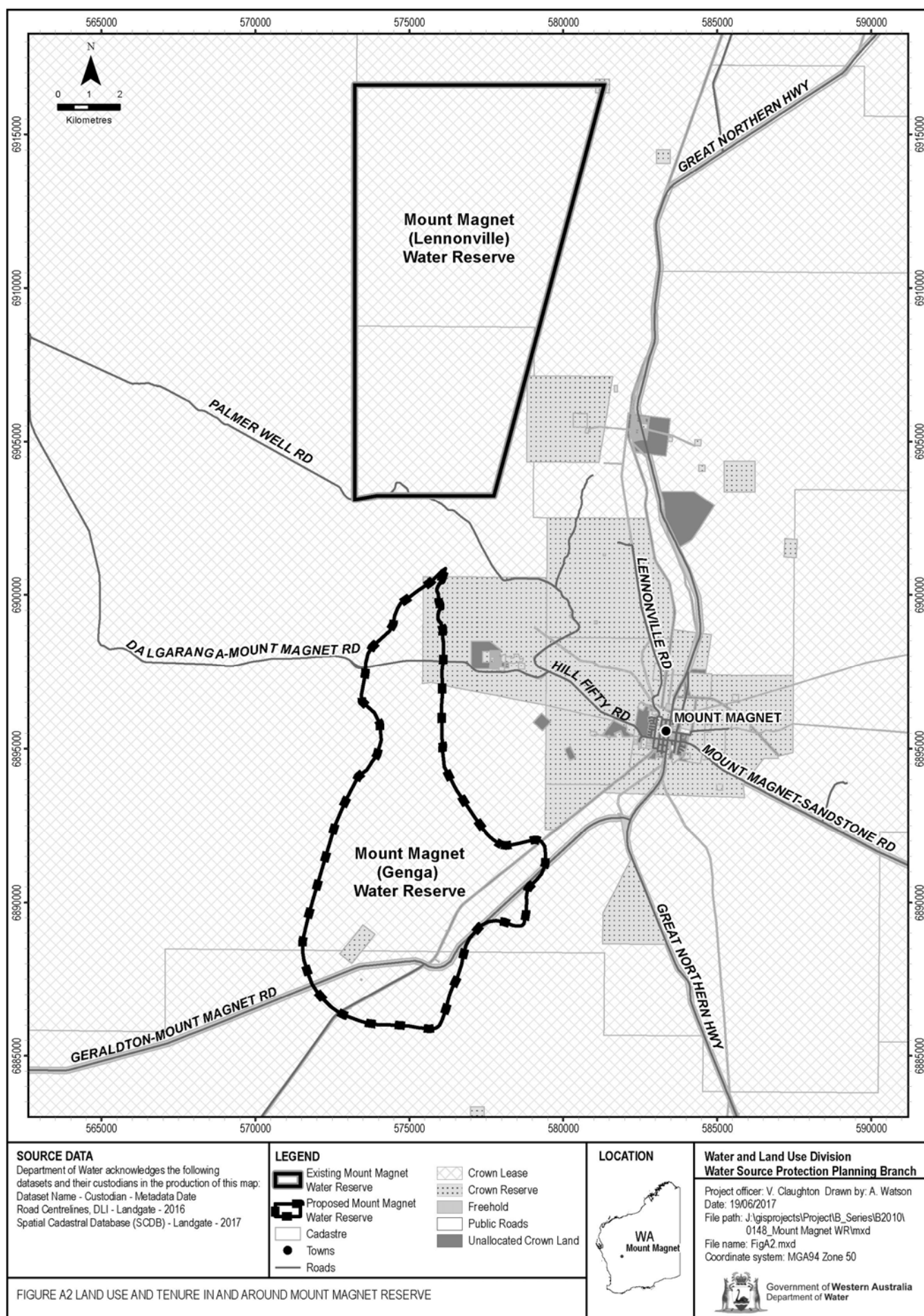
1. After this report is published, the Department of Water and Environmental Regulation will arrange constitution of the amended boundary of the Mount Magnet Water Reserve under the *Country Areas Water Supply Act 1947*. (DWER)
2. Incorporate the findings of this review and location of the Mount Magnet Water Reserve (including its priority areas and protection zones) in the Shire of Mount Magnet local planning scheme in accordance with Western Australian Planning Commission's State planning policy no. 2.7: *Public drinking water source policy*. (Shire of Mount Magnet)
3. Refer development proposals within the Mount Magnet Water Reserve that are inconsistent with the DWER's WQPN no.25: *Land use compatibility tables for public drinking water source areas* or recommendations in this review to the DWER regional office for advice. (Department of Planning Lands and Heritage, Shire of Mount Magnet, proponents of proposals)
4. Investigate and implement practical additional measures to increase road safety on the borefield stretch of the Geraldton to Mount Magnet road. (Shire of Mount Magnet, Main Roads)
5. Ensure incidents covered by Westplan–HAZMAT in the Mount Magnet Water Reserve are addressed by ensuring that:
 - the Mount Magnet LEMC is aware of the location and purpose of the Mount Magnet Water Reserve
 - the locality plan for the Mount Magnet Water Reserve is provided to the Department of Fire and Emergency Services headquarters for the HAZMAT emergency advisory team

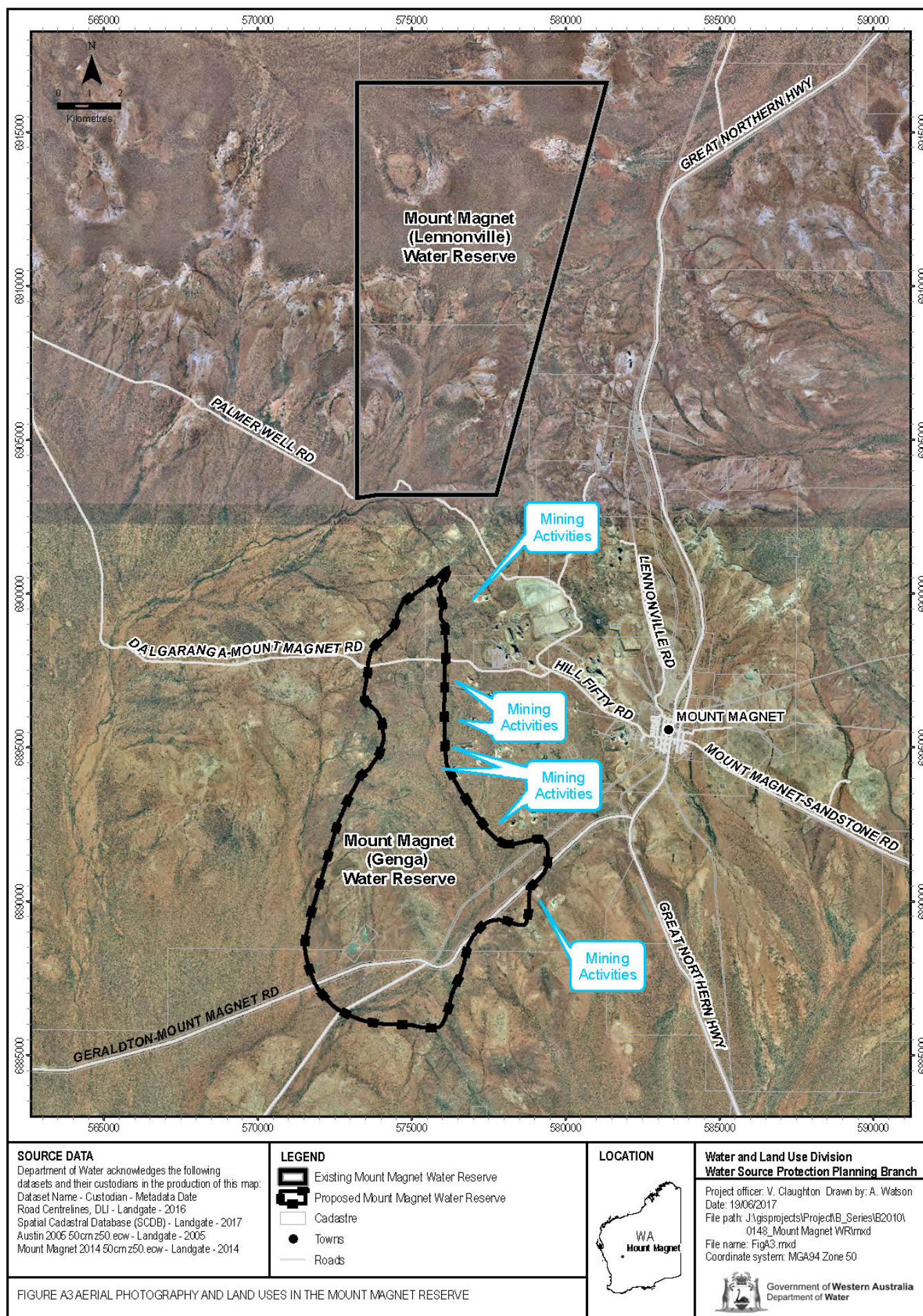
- the Water Corporation acts in an advisory role during incidents in the Mount Magnet Water Reserve
 - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Mount Magnet Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality. (Water Corporation)
6. Erect additional signs along the boundary of the Mount Magnet Water Reserve including an emergency contact telephone number, in accordance with the Water Corporation's *S111 Source protection signage* (2013). (Water Corporation)
 7. Water Corporation should continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. (Water Corporation)
 8. Subject to the availability of water, any future production bores should be drilled into the western Genga borefield or the Lennonville water reserve to minimise water quality risks. (Water Corporation)
 9. Appropriately decommission out of service bores that are no longer required in accordance with *Minimum construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2012). (Water Corporation/other licensed users)
 10. If all production bores in the eastern side of the Genga borefield are decommissioned, amend the Mount Magnet Water Reserve boundary to exclude the catchment area for that side of the groundwater divide. (DWER)
 11. Continue to advise residents and visitors of high nitrate levels in drinking water for infants under three months old, in particular expecting and new mothers. (Shire of Mount Magnet, hospital, local doctors, Department of Health)
 12. This report will be reviewed in seven years or in response to changes in water quality contamination risks. (DWER)

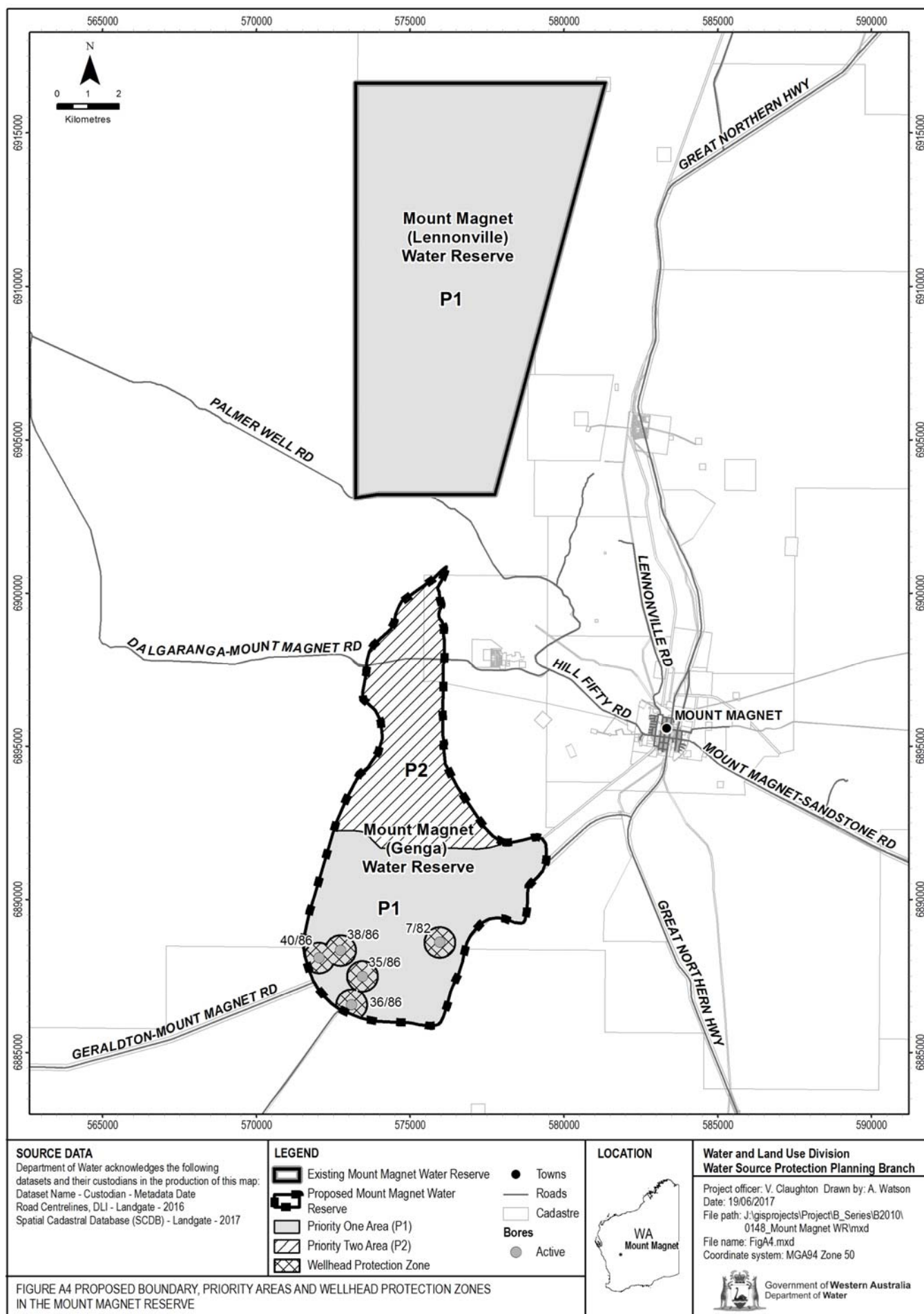
Appendices

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

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

The following data represents the quality of raw water from Mount Magnet (Genga) Water Reserve. In the absence of specific guidelines for raw water quality, the results have been compared with the ADWG values set for drinking water, which defines the quality requirements at the customer's tap. Any water quality parameters that have been detected are reported; those that on occasion have exceeded the ADWG are in bold and italics to give an indication of potential raw water quality issues associated with this source. The values are taken from ongoing monitoring for the period August 2012 to July 2017.

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

For more information on the quality of drinking water supplied to Mount Magnet 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 Mount Magnet (Genga) Water Reserve are summarised in the following table.

Aesthetic detections for Mount Magnet (Genga) Water Reserve

Parameter	Units	ADWG aesthetic guideline value ¹	Mount Magnet (Genga) Water Reserve (raw water)	
			Range	Mean
Hardness as CaCO ₃	mg/L	200	230–300	259.52
Iron unfiltered	mg/L	0.3	0–0.008	0
Silicon as SiO ₂	mg/L	80	70–80	75
Sodium	mg/L	180	145– 200	165
Sulfate	mg/L	250	53–74	62.48
Total filterable solids by summation	mg/L	600	854–1052	927.43

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

Health-related chemicals

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

Health-related detections for Mount Magnet (Genga) Water Reserve

Parameter	Units	ADWG health guideline value ²	Mount Magnet (Genga) Water Reserve (raw water)	
			Range	Mean
Nitrite plus nitrate as N ^{3, 4}	mg/L	11.29	14.1–17.2	15.28
Sulfate	mg/L	500	53–74	62.48
Arsenic	mg/L	0.01	0–0.002	0
Fluoride (lab measured)	mg/L	1.5	0.3–0.3	0.3

² A health guideline value is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & NRMCC 2011).

³ This is reported as nitrite plus nitrate as nitrogen, whereas the ADWG uses nitrate as nitrate, with a health guideline value of 50 mg/L. This has been converted to 11.29 mg/L so as to compare with the nitrite plus nitrate as nitrogen values that were sampled.

⁴ A guideline value of 11.29 mg/L (as nitrogen) has been set to protect bottle-fed infants less than three months of age. Up to 22.58 mg/L (as nitrogen) can be safely consumed by adults and children over three months of age.

Microbiological contaminants

Microbiological testing of raw water samples from Mount Magnet (Genga) Water Reserve 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, positive *E. coli* counts were recorded in 2.9 per cent of samples (two samples). Of these, no samples had *E. coli* counts greater than 20 MPN/100mL. The highest detection was 4 MPN/100mL. There have been no *E. coli* detections in the raw water since August 2013.

Appendix C — Photographs

Photographs by V. Cloughton, DWER



Figure C1 *Fencing and signage around production bore 7/82 within the Mount Magnet Water Reserve*



Figure C2 *Mining activities east of the Mount Magnet Water Reserve*



Figure C3 Mount Magnet water storage tanks



Figure C4 Evidence of a camp fire and recreation within the Mount Magnet Water Reserve near a bore



Figure C5 Evidence of rubbish dumping within the Mount Magnet Water Reserve



Figure C6 Stock watering trough and windmill within the Mount Magnet Water Reserve

Appendix D — Typical contamination risks in groundwater sources

Land development and land or water-based activities within a water reserve 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 reliable, 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 & NRMMC 2011). Contaminants can also interfere with water treatment processes and damage infrastructure.

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

Some commonly seen contamination risks relevant to groundwater 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 & NRMMC 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.

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 onto soil particles, make them more difficult to remove during disinfection and treatment processes.

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

Chemical risks

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

Pesticides include agricultural chemicals used to control:

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

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

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

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

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

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

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

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

An approach based on preventive risk means that we look at all the different risks to water quality. We determine what risks can reasonably be avoided and what risks need to be minimised or managed to protect public health. This approach means that the inherent risks to water quality are as low as possible. A risk-based approach is often suggested as a way to address risks to water quality in a public drinking water source area (PDWSA) - the area from which water is captured to supply drinking water). However, a risk-based approach is not the same as an approach based on preventive risk. A risk-based approach is inadequate for addressing risks to public health and is not recommended by the ADWG.

A multiple-barrier approach means that we use different barriers against contamination at different stages of a drinking water supply system. The first and most important barrier is protecting PDWSA. If we get this barrier right, it has a flow-on effect that can result in a lower cost, safer drinking water supply. Other barriers against contamination include storage of water to help reduce contaminant levels, disinfecting the water (for example chlorination to inactivate pathogens), maintenance of pipes and testing of water quality.

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

An additional benefit from PDWSA protection is that it complements the state's conservation initiatives.

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

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

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

An important step in maximising the protection of water quality in PDWSAs is to define their boundaries, priority areas and protection zones to help guide land use planning and to identify where legislation applies. Our Strategic policy: *Protecting public drinking water source areas in Western Australia* (DoW 2016a) describes how we do this. It is available www.dwer.wa.gov.au.

There are three different priority areas:

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

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

Our Water quality protection note (WQPN) no. 25: *Land use compatibility tables for public drinking water source areas* (DoW 2016b) outlines appropriate development and activities within each of the priority areas (P1, P2 and P3).

With more than 120 constituted PDWSAs across Western Australia, the department prioritises the update of drinking water source protection reports (such as this document). Our aim is to update each report every seven years. In some locations, more frequent updates may be required to address changing water quality risks and land uses. These updates allow us to make changes to the PDWSA boundary, priority areas and protection zones if required. They also allow solutions to new water quality risks to be considered.

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

There is also a fourth type of report – Land use and water management strategy – that performs the same functions as a drinking water source protection report. However, these strategies are prepared by the WAPC (with input from the Department of Water and Environmental Regulation) and are strategic documents

that integrate land use planning with water management. There are currently land use and water management strategies for Gnangara, Jandakot and Middle Helena.

If you would like more information about the ADWG and how we protect drinking water in Western Australia, visit www.dwer.wa.gov.au and read our Strategic policy: *Protecting public drinking water source areas in Western Australia* (DoW 2016). You can also contact DWER's Water source protection planning branch on +61 8 6364 7600 or email drinkingwater@dwer.wa.gov.au.

Drinking water source protection reports produced by DWER

Drinking water source protection report	Scope and outcome	Consultation	Time to prepare	Implementation table	Gazettal
Drinking water source protection assessment (DWSPA)	Desktop assessment of readily available information	Preliminary	Up to 3 months	No	Arrange for the constitution and gazettal of the source under legislation. This helps protect water quality and guides land use planning. All types of consulted drinking water source protection reports can recommend to constitute a source's boundary under legislation.
Drinking water source protection plan (DWSPP)	Full investigation of risks to water quality building on information in the DWSPA	Public	6–12 months	Prepared from recommendations in the DWSPA and/or information from public consultation	
Drinking water source protection review (DWSPR)	Review changes in land and water factors and implementation of previous recommendations. Sometimes prepared to consider specific issues in a PDWSA	Key stakeholders	3–6 months	Prepared from recommendations in the DWSPA or DWSPP	

Appendix F — Understanding risks to drinking water quality

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

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

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

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

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

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

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

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

Shortened forms

List of shortened forms

ADWG	<i>Australian drinking water guidelines</i>
ANZECC	Australian and New Zealand Environment Conservation Council
DBCA	Department of Biodiversity, Conservation and Attractions
DoE	Department of Environment
DoW	Department of Water
DWER	Department of Water and Environmental Regulation
HAZMAT	hazardous materials
LEMC	local emergency management committee
LPS	local planning scheme
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
SPP	state planning policy
WAPC	Western Australian Planning Commission
Westplan– HAZMAT	Western Australian plan for hazardous materials
WHPZ	wellhead protection zone
WQPN	water quality protection note

Units of measurement

km	kilometres	A measure of distance, 1 km equals 1000 m.
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).
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.
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 comprise sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate, carbonate, silica, organic matter, fluoride, iron, manganese, nitrate (and nitrite) and phosphate (NHMRC & NRMCC 2011).

Volumes of water

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

Glossary

Abstraction	The pumping of groundwater from an aquifer, or the removal of water from a waterway or water body.
Aesthetic guideline value	The concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer, for example appearance, taste and odour (NHMRC & NRMCC 2011).
Allocation	The volume of water that a licensee is permitted to abstract, usually specified in kilolitres per 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) 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).
Borefield	A group of bores to monitor or withdraw groundwater (also see <i>wellfield</i>).
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
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 the <i>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.
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.
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 & NRMMC 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.
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 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 (NHRMC & NRMMC 2011).
Nutrients	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.
Pathogen	A disease-producing organism that can cause sickness and sometimes death through the consumption of water, including bacteria (such as <i>Escherichia coli</i>), protozoa (such as <i>Cryptosporidium</i> and <i>Giardia</i>) and viruses.
Pesticides	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
Public drinking water source area	The area from which water is captured to supply drinking water. It includes all underground water pollution control areas, catchment areas and water reserves constituted under the <i>Metropolitan Water Supply, Sewerage, and Drainage Act 1909</i> or the <i>Country Areas Water Supply Act 1947</i> .

Priority 1, 2 and 3	Three different priority areas are assigned within PDWSAs to guide land use decisions. The objective of priority 1 (P1) areas is <i>risk avoidance</i> , priority 1 (P2) areas is <i>risk minimisation</i> and priority 3 (P3) areas is <i>risk management</i> .
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.
Residual risk	This is the level of risk after considering preventive measures 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 & NRMMC 2011).
Runoff	Water that flows over the surface from a catchment area, including streams.
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.
Wellhead protection zone	Usually declared around wellheads in public drinking water source areas to protect the groundwater from immediate contamination risks.
Westplan–HAZMAT	State emergency management plan for hazardous materials emergencies.

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