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

Kalbarri Water Reserve

drinking water source protection review

Kalbarri and Port Kalbarri town water supply

Water resource protection series
Report WRP191
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Cover photograph: Aerial photo of Kalbarri Water Reserve

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Summary

This drinking water source protection review considers changes that have occurred in and around the Kalbarri Water Reserve (Figure A1) since the *Kalbarri Water Reserve drinking water source protection plan* (DoW 2006) was released. The 2006 plan still contains relevant information, so it is important that these documents are read in conjunction. Both are available on our website at dwer.wa.gov.au or by contacting us.

The main changes since the 2006 plan are:

- Kalbarri bore 1/86 is no longer being used because of contamination from the adjacent industrial area. Its wellhead protection zone (WHPZ) needs to be removed (Figure A2) and after the bore is decommissioned, the water reserve boundary needs to be reviewed.
- The WHPZs for Port Kalbarri bores 1/97 and 2/97 have been extended over the Kalbarri National Park (Figure A2) in accordance with Strategic policy: *Protecting public drinking water source areas in Western Australia* (DoW 2016a).
- The department has updated the assessment of water quality risks within the water reserve (Table 2). The management priority for land uses and activities in the industrial area has been reduced from high to medium as bore 1/86 is no longer used.
- A solar thermal power station is proposed on privately owned rural land near the Port Kalbarri bore field (Figure A3), which poses contamination risks from toxic chemicals and hydrocarbons during construction and operation. These risks will be managed by applying best management practices through the Shire of Northampton's planning approval process.

No changes to the boundary of the Kalbarri Water Reserve or priority areas are proposed in this review.

This review helps implement the *Australian drinking water guidelines* (ADWG; NHMRC & NRMMC 2011), which are endorsed by the State Government. It is also consistent with State planning policy no. 2.7: *Public drinking water source policy* (Western Australian Planning Commission 2003) and Strategic policy: *Protecting public drinking water source areas in Western Australia*.

The Department of Water and Environmental Regulation prepared this document in consultation with key stakeholders:

- Water Corporation
- Department of Biodiversity, Conservation and Attractions
- Shire of Northampton
- Department of Health
- Private landowner.

Important information about the Kalbarri Water Reserve is in Table 1.

Table 1 Key information about the Kalbarri Water Reserve

Kalbarri Water Reserve	
Local government	Shire of Northampton
Locations supplied	Kalbarri and Port Kalbarri
Population supplied	1557 people (Australian Bureau of Statistics 2016)
Water service provider	Water Corporation
Aquifer type	Unconfined, making it vulnerable to contamination from surface-based land uses and activities
Licence to take water	500,000 kL per year, issued under the *Rights in Water and Irrigation Act 1914* groundwater licence 105699
Number of bores	Kalbarri: 3 bores Port Kalbarri: 2 bores
Bore locations	Kalbarri • 1/86 (E 221 650, N 6 930 933, zone 50) – removed from service • 2/86 (E 220 994, N 6 929 580, zone 50) • 3/86 (E 222 263, N 6 929 785, zone 50) • 1/98 (E 221 805, N 6 930 176, zone 50) Port Kalbarri • 1/97 (E 220 949, N 6 925 118, zone 50) • 2/97 (E 221 092, N 6 925 074, zone 50)
Date of bore completion	Kalbarri • 1/86: 1986 – removed from service • 2/86: 1986 • 3/86: 1986 • 1/98: 1998 Port Kalbarri • 1/97: 1997 • 2/97: 1997

Kalbarri Water Reserve	
Screened depth (m below ground level)	Kalbarri • 1/86: 66–180 m – removed from service • 2/86: 60–179 m • 3/86: 56–176 m • 1/98: 60–178 m Port Kalbarri • 1/97: 17–131 m • 2/97: 106–109 m
Dates of drinking water source protection reports	2006 – *Kalbarri Water Reserve water source protection plan* (Department of Water) 2019 – *Kalbarri Water Reserve drinking water source protection review* (this document)
Consultation	2005 – public consultation including letters to government agencies, the water service provider, businesses and private landowners 2019 – consultation with key stakeholders including the Water Corporation, Shire of Northampton, Department of Health, Department of Biodiversity, Conservation and Attractions and the rural landowner
Gazettal history	First gazetted on 22 April 1988 under the *Country Areas Water Supply Act 1947*. An amended water reserve boundary was gazetted on 28 December 2007 under the *Country Areas Water Supply Act 1947*.
Reference documents	*Australian drinking water guidelines* (NHMRC & NRMMC 2011) State planning policy no. 2.7: *Public drinking water source policy* (WAPC 2003) *Mid West regional water supply strategy* (DoW 2015) *Northern Perth Basin: Geology, hydrogeology and groundwater resources* (DoW 2017) *Kalbarri National Park management plan 2015* (DPaW 2015)

1 Review of Kalbarri Water Reserve drinking water source protection plan

1.1 Boundary, priority areas and protection zones

The Kalbarri Water Reserve is east of Kalbarri, about 500 km north of Perth (Figure A1). Its current boundary was gazetted in 2007 under the *Country Areas Water Supply Act 1947* to align with the capture zones of existing bores and allow for future expansion of the bore field.

The majority of the water reserve was assigned priority 1 (P1) over crown land, with priority 2 (P2) and priority 3 (P3) areas assigned over privately owned land and facilities such as the Shire's landfill site and the Water Corporation wastewater treatment plant (figures A2 and A4). No changes to the water reserve boundary or priority areas are proposed in this review.

Since the *Kalbarri Water Reserve drinking water source protection plan* (DoW 2006) was published, Kalbarri bore 1/86 stopped being used for drinking water because of contamination from the adjacent industrial area (Figure A2). After this review is published, the Department of Water and Environmental Regulation (the department) will remove its WHPZ (see section 3.2, recommendation no. 1). After the Water Corporation permanently decommission the bore, the boundary of the Kalbarri Water Reserve should be reviewed in the vicinity of the bore in consultation with the Shire of Kalbarri and landowners (see section 3.2, recommendation no. 10).

The WHPZs for the Port Kalbarri bores will be extended to 500 m in the P1 area over the Kalbarri National Park (Figure A2) in accordance with current departmental policy (see section 3.2, recommendation no. 1). The WHPZs in the P2 area over private land will remain unchanged.

The boundary, priority areas and protection zones for the Kalbarri Water Reserve 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 the department protects drinking water sources.

1.2 Water supply scheme

The department has licensed the Water Corporation to draw 500,000 kL of water per year from the superficial aquifer to supply Kalbarri and Port Kalbarri's drinking water.

The Kalbarri bore field consists of three bores (2/86, 3/86 and 1/98) about 1.5 km south-east of the Kalbarri town site (Figure A2). Bore 1/86 has not supplied drinking water since July 2012 because of ongoing concerns of groundwater contamination from the adjacent industrial area. The bore has been isolated from the water supply system, removed from the licence and needs to be permanently decommissioned.

Bore 2/86 continues to supply most of Kalbarri's drinking water, supported by bores 3/86 and 1/98.

Raw water from the Kalbarri bore field is aerated to correct pH and disinfected via chlorination before distribution to the Kalbarri scheme.

The Port Kalbarri bore field remains unchanged since the 2006 plan (Figure A2). Bore 1/97 continues to supply the majority of Port Kalbarri's drinking water, with bore 2/97 on stand-by.

Raw water from the Port Kalbarri bore field is disinfected via chlorination before distribution to the Port Kalbarri 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 barrier, as advocated by the *Australian drinking water guidelines* (ADWG; NHMRC & NRMMC 2011). The ADWG is based on preventing risks and installing 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 about how the department protects PDWSAs, read Appendix E. For more information about our preventive risk management approach, read Appendix F.

1.3 Future water needs

Since the 2006 plan, abstraction has averaged about 400,000 kL per year and remained consistently below the licensed allocation of 500,000 kL per year. Further residential development in Kalbarri and Port Kalbarri will continue to increase the number of homes supplied by the Water Corporation. However, the current allocation is considered adequate for at least the next five years.

When needed in the future, additional bores may be located to the north-east and south-east of the existing Kalbarri bore field in the Kalbarri National Park. The location of new bores will need to consider water quality risks from current and future land uses and activities in the area.

1.4 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; however, this at the discretion of the Minister.

There are 10 recorded Aboriginal sites of significance within the Kalbarri Water Reserve (Figure A5). These are Wittecarra Spring (P01972), Brownes Farm, Kalbarri (P06420), Meanarra Hill (P01958), Meanarra Soak (P02139), Meanarra Hill 1 (P01906), Meanarra Hill 2 (P01909), Murchison House Station (P01329), Bula-Guda (P05743), Nanny Goat Well (P01948) and Gregory Rocks (P01980). Not all Aboriginal sites of significance and heritage have been recorded and are on the register of Aboriginal sites, so it is important that traditional custodians are always consulted in regards to their country.

No changes are proposed to the Kalbarri Water Reserve that would affect access to these sites.

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 Kalbarri Water Reserve lies within the Nanda People claim area. No changes are proposed in this review that affect the current claim.

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.

1.5 Enforcing by-laws, surveying the area and maintenance

The Kalbarri and Port Kalbarri bores are in fenced and locked compounds to help prevent unauthorised access and vandalism (Figure C2). Each bore is in a separate compound throughout the water reserve.

This review recommends that Water Corporation continues by-law enforcement under the existing delegation arrangement (see section 3.2, recommendation no. 6). This also includes:

- erecting and maintaining signs in accordance with *S111 Source protection signage* (Water Corporation 2013) (see section 3.2, recommendation no. 5)
- maintaining security and fencing surrounding the bores and compounds
- ongoing regular surveillance and inspections.

1.6 Related water source management work

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

1.6.1 Mid West regional water supply strategy

The *Mid West regional water supply strategy* (DoW 2015) helps to ensure water supply investment is aligned with state development objectives and land-use

planning at a regional scale. The strategy considers water availability and projects water demand over the next 30 years. It identifies timeframes, water supply planning actions and options to inform future planning, investigations and decision-making in support of regional development.

1.6.2 Northern Perth Basin: Geology, hydrogeology and groundwater resources

The *Northern Perth Basin: geology, hydrogeology and groundwater resources* (DoW 2017) provides a compilation and analysis of all available information on the groundwater resources of the northern Perth Basin, from Gingin Brook in the south to the Murchison River in the north. The bulletin also considers groundwater-dependent ecosystems, river baseflows, current and future groundwater use, water availability and groundwater management.

1.7 Update on water quality risks

As part of this review, the department has conducted an updated assessment of water quality contamination risks to the Kalbarri drinking water source, in accordance with the ADWG.

The Kalbarri Water Reserve predominantly comprises national park and crown reserve covered by native vegetation (Figure A4). Other land uses and activities within the water reserve include an undeveloped rural lot, a light industrial area within the former WHPZ for bore 1/86, a wastewater treatment plant, a landfill and gravel extraction (Figure A3).

Future land uses include a solar thermal power station on rural land near the Port Kalbarri bore field and a commercial development area north of the Kalbarri bore field identified in Shire of Northampton planning documents (Figure A3) (DPLH 2017).

Risks to groundwater quality from these current and future land uses are discussed below. Table 2 shows the risks that are new or have changed since the 2006 plan. 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 the department uses for PDWSAs.

1.7.1 National Park and crown reserve

Since the 2006 plan, the Department of Biodiversity, Conservation and Attractions released an updated management plan for the Kalbarri National Park (DPaW 2015). The plan focuses on managing the natural environment, resources and cultural heritage while providing opportunities for recreation and community engagement. The plan puts forward management actions to help protect water quality within the national park, including ensuring that proposed developments, operations and activities are managed to minimise impacts on water values.

The plan also identifies pressures on the natural environment within the national park that have the potential to affect water quality, such as feral animals, human activities,

unauthorised off-road vehicle use, unplanned fire and inappropriate land uses. The few recreational facilities, recreation sites and walk trails within the Kalbarri Water Reserve are not near the Kalbarri or Port Kalbarri bore fields.

Unauthorised activities such as camping, hunting and rubbish dumping are uncommon near the bore fields. These activities pose risks to groundwater from hydrocarbons, toxic chemicals, heavy metals and pathogens.

There are low levels of unauthorised off-road vehicle use near the Kalbarri bore field along tracks and clearances for power lines (Figure C3). The Water Corporation has upgraded signs in the area to deter access (Figure C4) and uses surveillance technology to monitor off-road vehicle use.

1.7.2 Rural land

Since the 2006 plan, no development of rural land has occurred within the P2 area near the Port Kalbarri bore field (Figure A3). Grazing has not occurred on the property for more than 30 years. If the property is grazed in the future, domestic animals within the Port Kalbarri bore WHPZs and natural soak (see below) would pose a risk of pathogen contamination.

A solar thermal power station is proposed within the P2 area up-gradient of Port Kalbarri bores 1/97 and 2/97 (Figure A3). This land use is considered compatible with conditions in a P2 area. To minimise water quality risks, only solar receivers will be within the P2 area and no development will occur with the WHPZs. All generation and transmission equipment, staff facilities, ablution facilities and access tracks are proposed to be outside the P2 area. Water quality risks from hydrocarbons and toxic chemicals during construction and operation will be minimised though adoption of best management practices within the water reserve implemented through the Shire of Northampton's planning approval process (see section 3.2, recommendation no. 11).

A natural soak within the WHPZ of Port Kalbarri bore 2/97 (Figure A3) attracts native and feral animals and is used as an apiary site. Human activity, animal contact with the water body, decaying carcasses and animal droppings pose a risk of pathogen contamination to the nearby bores (Figure C1). However, regular water quality monitoring has not detected pathogens in either bore over the review period. Ongoing feral animal control by the Department of Biodiversity, Conservation and Attractions is expected to help reduce feral animal activity at the soak.

1.7.3 Wastewater treatment plant

The Water Corporation's wastewater treatment plant is within a P3 area of the Kalbarri Water Reserve. Wastewater treatment plants can pose a risk of nutrient and pathogen contamination of groundwater. Treated wastewater is reused outside the Kalbarri Water Reserve to irrigate the Kalbarri golf course.

This treatment plant is managed via licence conditions set by the department. The Water Corporation has prepared a nutrient irrigation management plan, including

groundwater monitoring, as part of the long-term management of the wastewater reuse scheme.

1.7.4 Shire of Northampton landfill

The Kalbarri landfill is about 3 km up-gradient from the Kalbarri bore field. Landfills can pose a risk of groundwater contamination from toxic chemicals, hydrocarbons, heavy metals, nutrients and pathogens. The site is managed by the Shire of Northampton in accordance with licence conditions set by the department. A groundwater monitoring program has not detected leaching of contaminants from the landfill site.

1.7.5 Light industrial area

Kalbarri bore 1/86 has stopped being used for drinking water supply because of contamination from the surrounding light industrial area. Risks from the industrial area include hydrocarbon, chemical, nutrient and pathogen contamination.

Once this report is published, the department will remove the associated WHPZ. Although the industrial area will no longer be in a WHPZ, best management practices should still be employed to prevent further contamination and protect water quality within the water reserve (see section 3.2, recommendation no. 9). Best management practice guidance for these types of land uses is listed in Table 2. This applies particularly to storage and use of hydrocarbons and chemicals.

Since the 2006 plan, expansions to the industrial area have been connected to deep sewerage and stormwater management has been implemented to help protect water quality. The older industrial area is recommended to be connected to deep sewerage when feasible (see section 3.2, recommendation no. 8).

1.7.6 Future commercial development area

The *Shire of Northampton local planning scheme 11 Kalbarri townsite* (Department of Planning, Lands and Heritage 2017) identifies a future commercial development area that partially overlaps P1 land within the Kalbarri Water Reserve (Figure A3). The site is within the former WHPZ for bore 1/86 on the western edge of the water reserve. Risks from commercial land uses can include contamination from hydrocarbons, toxic chemicals, nutrients and pathogens.

After bore 1/86 is decommissioned, the boundary of the water reserve in this area should be reviewed in consultation with the Shire of Northampton to assist planning and design of the future commercial area.

1.7.7 Contaminated sites

Three sites in this PDWSA have been reported as known or suspected contaminated sites under the *Contaminated Sites Act 2003*, which is administered by the department. One site has been classified and two others are awaiting classification.

The decommissioned unauthorised landfill site on Lot 564 was reclassified in 2014 to 'Contaminated – remediation required' (Figure A3). An investigation of the site reported that groundwater investigations were not undertaken because of the depth to groundwater and the low leaching potential of the identified contaminants. The site is no longer within a WHPZ since bore 1/86 was removed from the Kalbarri water supply scheme.

Any sites that are classified as requiring remediation should be addressed as soon as possible to reduce the risk of groundwater contamination.

1.7.8 Mining, geothermal energy and other commodities

The Kalbarri Water Reserve is within the Carnarvon basin. The Carnarvon basin is a prospective area for a range of commodities such as minerals, petroleum and geothermal energy. These activities are regulated by the Department of Mines, Industry Regulation and Safety.

There are no petroleum titles, mining tenements or geothermal titles within the Kalbarri Water Reserve.

Government has accepted the recommendations of the *Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia* (Government of Western Australia 2018). Those recommendations and the Government response requires that any petroleum proposals for the extraction of shale or tight gas within the Kalbarri Water Reserve must be referred to the Environmental Protection Authority for assessment under Pt IV of the *Environmental Protection Act 1986*. The Environmental Protection Authority is developing guidance material relating to formal assessment of all hydraulic fracture stimulation exploration and production proposals, which includes the requirement for the separation of any proposal to be 2 km from PDWSAs.

Mining activities (excluding mineral processing and tailing dams using chemical processing) are compatible with conditions in PDWSAs. Best management practices for the mining industry are provided in our Water quality protection guidelines 1–11: *Mining and mineral processing* (DoW 2000). Operators should follow these guidelines to help reduce potential water quality risks associated with mining and exploration activities.

1.7.9 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 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 four licensed users near the Kalbarri bore field and one licensed user near the Port Kalbarri bore field.

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]
Natural soak	• Pathogens	High	The soak is about 300 m from bore 2/97. Native and feral animals enter the waterbody. Carcasses have been observed nearby. Ongoing water quality monitoring and surveillance is necessary to manage the risks to water quality.	• WQPN 96: *Pest animal management in public drinking water source areas*
Proposed solar thermal power station	• Toxic chemicals • Hydrocarbons	Medium	The majority of the proposed station will be outside the water reserve. Only solar receivers will be within the P2 area, posing low risks to water quality. Water quality risks associated with construction activities can be managed through best management practices applied via the land use planning approvals process.	• WQPN 52: *Stormwater management at industrial sites* • WQPN 65: *Toxic and hazardous substances: storage and use* • WQPN 68: *Mechanical equipment wash down*

Unauthorised rubbish dumping	• Nutrients • Pathogens • Pesticides • Toxic chemicals • Heavy metals	Medium	Rubbish dumping is uncommon within the water reserve. Hazardous material dumped near the bores has the potential to contaminate groundwater. Surveillance by Water Corporation and Department of Biodiverity, Conservation and Attractions officers helps identify rubbish dumps for assessment and remediation.	• *Environmental Protection Act 1986*
Unauthorised off-road vehicle use	• Hydrocarbons	Medium	Off-road vehicle use occurs within the water reserve and WHPZs.	• Country Areas Water Supply By-laws 1957 • WQPN 81: *Tracks and trails near sensitive water resources*
Tourism, recreational facilities and ranger residences	• Hydrocarbons • Pathogens	Medium	Existing tourism and ablution facilities are located away from drinking water bores.	• *Kalbarri National Park management plan 2015* (DPaW) • WQPN 70: *Wastewater treatment and disposal – domestic systems*

Current landfill	• Nutrients • Pathogens • Pesticides • Toxic chemicals • Heavy metals	Medium	The landfill site is about 3 km up-gradient of the Kalbarri bore field. The landfill is operated by the Shire of Northampton following conditions set under the DWER licence, including groundwater monitoring. Future drinking water bores should be located away from landfill sites.	• DWER licence conditions and regulations • WQPN 24: *Land filling with inert materials* • WQPN 30: *Groundwater monitoring bores* • WQPN 90: *Organic material – storage and recycling* • WQPN 111: *Landfills for disposal of putrescible materials*
Light industry	• Toxic chemicals • Heavy metals • Pathogens • Nutrients • Hydrocarbons	Medium	Water quality monitoring identified groundwater contamination around bore 1/86. Removal of bore 1/86 from the Kalbarri water supply scheme means that the industrial area is no longer within a WHPZ, but is still within the water reserve. The older industrial area is not connected to deep sewerage.	• WQPN 29: *Mobile mechanical servicing and cleaning* • WQPN 32: *Nurseries and garden centres* • WQPN 51: *Industrial wastewater management and disposal* • WQPN 52: *Stormwater management at industrial sites* • WQPN 65: *Toxic and hazardous substances: storage and use* • WQPN 68: *Mechanical equipment wash down* • WQPN 70: *Wastewater treatment and disposal – domestic systems*

Decommissioned landfill	• Nutrients • Pathogens • Pesticides • Toxic chemicals • Heavy metals	Medium	Investigation of the decommissioned landfill found that groundwater contamination risks were low because of the depth to groundwater and limited leachability of identified contaminants. The site is no longer within a WHPZ as bore 1/86 was removed from service.	• *Contaminated Sites Act 2003* • *Assessment and management of contaminated sites* (DWER 2014)
Grazing	• Nutrients • Pathogens	Medium	Current activities in the P2 area pose very low risks to water quality as the property is not used for grazing. If grazing occurs in future, pathogen risks from domestic animals should be assessed and managed, especially within the Port Kalbarri WHPZs and the natural soak.	• WQPN 35: *Pastoral activities within rangelands* • WQPN 96: *Pest animal management in public drinking water source areas*

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

1.8 Water quality information

The Water Corporation has provided updated water quality information for the Kalbarri and Port Kalbarri bore fields. This is shown in Appendix B.

The Kalbarri and Port Kalbarri bore fields supply high-quality drinking water. During the review period there were no detections of water quality parameters that exceeded ADWG health-related guideline values.

Both Kalbarri and Port Kalbarri bore fields have naturally occurring low pH outside ADWG aesthetic guidelines, while salinity-related characteristics (sodium, chloride and total filterable solids by summation) above ADWG aesthetic guidelines are characteristic of the Port Kalbarri bore field.

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 Consultation

2.1 Stakeholder consultation process

We consulted with the Shire of Northampton, the Water Corporation, the Department of Health, Department of Biodiversity, Conservation and Attractions and the rural landowner to prepare this review, by providing draft copies for their comment.

All issues raised during consultation were addressed during the preparation of this plan.

3 Implementing Kalbarri Water Reserve drinking water source protection plan

3.1 Status of previous recommendations

Table 3 outlines recommendations from the 2006 plan and their current status.

Table 3 Implementation status for Kalbarri Water Reserve

No.	Recommendation	Comments
1	Gazette the amended boundary of water reserve.	Amended boundary gazetted in 2007 under the *Country Areas Water Supply Act 1947.* Complete.
2	Incorporation into land planning strategies.	The water reserve was partially incorporated in the Shire of Northampton's local planning scheme. This review recommends to include it (section 3.2, recommendation no. 2). Carry forward.
3	Referral of development proposals to DWER (formerly Department of Water).	Development proposals within this PDWSA are referred to the Mid West Region office of DWER. This has been continued as a recommendation of this review (section 3.2, recommendation no. 3). Ongoing.
4	Erection of signs: • determine number and location of signs required • erect signs.	Signs advising of the location of the Kalbarri Water Reserve have been erected. Erecting and maintaining signs has been continued as a new recommendation of this review (section 3.2, recommendation no. 5). Ongoing.
5	Emergency response: • develop response plan • inform local emergency management advisory committee of special requirements for the Kalbarri Water Reserve.	This has been continued as a new recommendation of this review (section 3.2, recommendation no. 4). Ongoing.

No.	Recommendation	Comments
6	Implement recommended management strategies for potential contamination risks detailed in Table 1 of the 2006 plan.	This has been continued as a new recommendation of this review (section 3.2, recommendation no. 7).
7	Surveillance program: • develop guidelines for the surveillance of water reserves • implement the surveillance program.	The Water Corporation undertakes surveillance within the water reserve under formal delegation from DWER. This has been continued as a new recommendation of this review (section 3.2, recommendation no. 6). Ongoing.
8	Minimise four-wheel drive and motorbike access within the Water Reserve.	Signs have been erected to deter access and the Water Corporation regularly patrols and enforces the by-laws (section 3.2, recommendation no. 5). Complete.
9	Connect future extensions to the industrial area to deep sewerage. Investigate options for connecting the existing industrial area to deep sewerage.	Expansions to the industrial area near bore 1/86 have been connected to deep sewerage. Investigating options for connecting the older industrial area to deep sewerage has been continued as a new recommendation of this review (section 3.2, recommendation no. 8), noting that bore 1/86 has been removed from the water supply scheme. Continue.
10	Direct stormwater runoff from the industrial area away from bore 1/86.	The design of the stormwater drainage system for the expansion of the industrial area was designed to protect groundwater quality and approved by DWER. Complete.

No.	Recommendation	Comments
11	Adopt best management practices within the industrial area.	This has been continued as a new recommendation of this review (section 3.2, recommendation no. 9), noting that bore 1/86 has been removed from the water supply scheme. Ongoing.
12	Restrict access to the decommissioned landfill. Investigate groundwater contamination risks and remediate if necessary.	The decommissioned landfill has been fenced and investigated. The site has been reclassified under the *Contaminated Sites Act 2003* as 'Contaminated – remediation required'. Groundwater investigations were not undertaken due to the depth to groundwater and the low leaching potential of the identified contaminants. Complete.
13	Cap the completed waste columns of the current landfill.	The Shire of Northampton operates the current landfill in accordance with licence conditions, including capping completed waste columns. Complete.
14	Develop an effluent management plan of excess treated wastewater from the wastewater treatment plant.	The Water Corporation has prepared a nutrient irrigation management plan for the use of recycled water on the Kalbarri Golf Course. Complete.

3.2 Consolidated recommendations

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

1. Remove the WHPZ for bore 1/86 and extend the WHPZs for Port Kalbarri bores 1/97 and 2/97 to 500 m over the Kalbarri National Park. (DWER)
2. Incorporate the Kalbarri Water Reserve, as per Figure A2, in the Shire of Northampton local planning scheme in accordance with the WAPC's State planning policy no. 2.7: *Public drinking water source policy*. (Shire of Northampton)

3. Refer development proposals within the Kalbarri Water Reserve that are inconsistent with DWER's WQPN no. 25: *Land use compatibility tables for public drinking water source areas* or recommendations in this review to the Department of Water and Environmental Regulation regional office for advice. (Department of Planning, Lands and Heritage, Shire of Northampton, proponents of proposals)
4. Ensure incidents covered by Westplan–HAZMAT in the Kalbarri Water Reserve are addressed by ensuring that:
    - the Kalbarri local emergency management committee is aware of the location and purpose of the Kalbarri Water Reserve
    - the locality plan for the Kalbarri 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 Kalbarri Water Reserve
    - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Kalbarri Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality. (Water Corporation)
5. Maintain signs along the boundary of the Kalbarri Water Reserve including an emergency contact telephone number, in accordance with the Water Corporation's *S111 Source protection signage* (2013). (Water Corporation)
6. Continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. (Water Corporation)
7. Continue implementing the recommended strategies for managing water quality risks detailed in Table 1 of the 2006 plan. (DWER)
8. Investigate options to connect unsewered industrial properties to deep sewerage. (Water Corporation)
9. Continue to adopt best management practices within the industrial area to minimise risks to groundwater quality. (DWER, Water Corporation, landowners)
10. Review the boundary of the Kalbarri Water Reserve near bore 1/86 when the bore is permanently decommissioned. (DWER, Water Corporation, Shire of Northampton)
11. Ensure best management practices to protect groundwater quality are implemented during construction and operation of the solar thermal power station. (DWER, Shire of Northampton)
12. This report will be reviewed in seven years or in response to changes in water quality contamination risks. (DWER)

Appendices

Appendix A – Figures

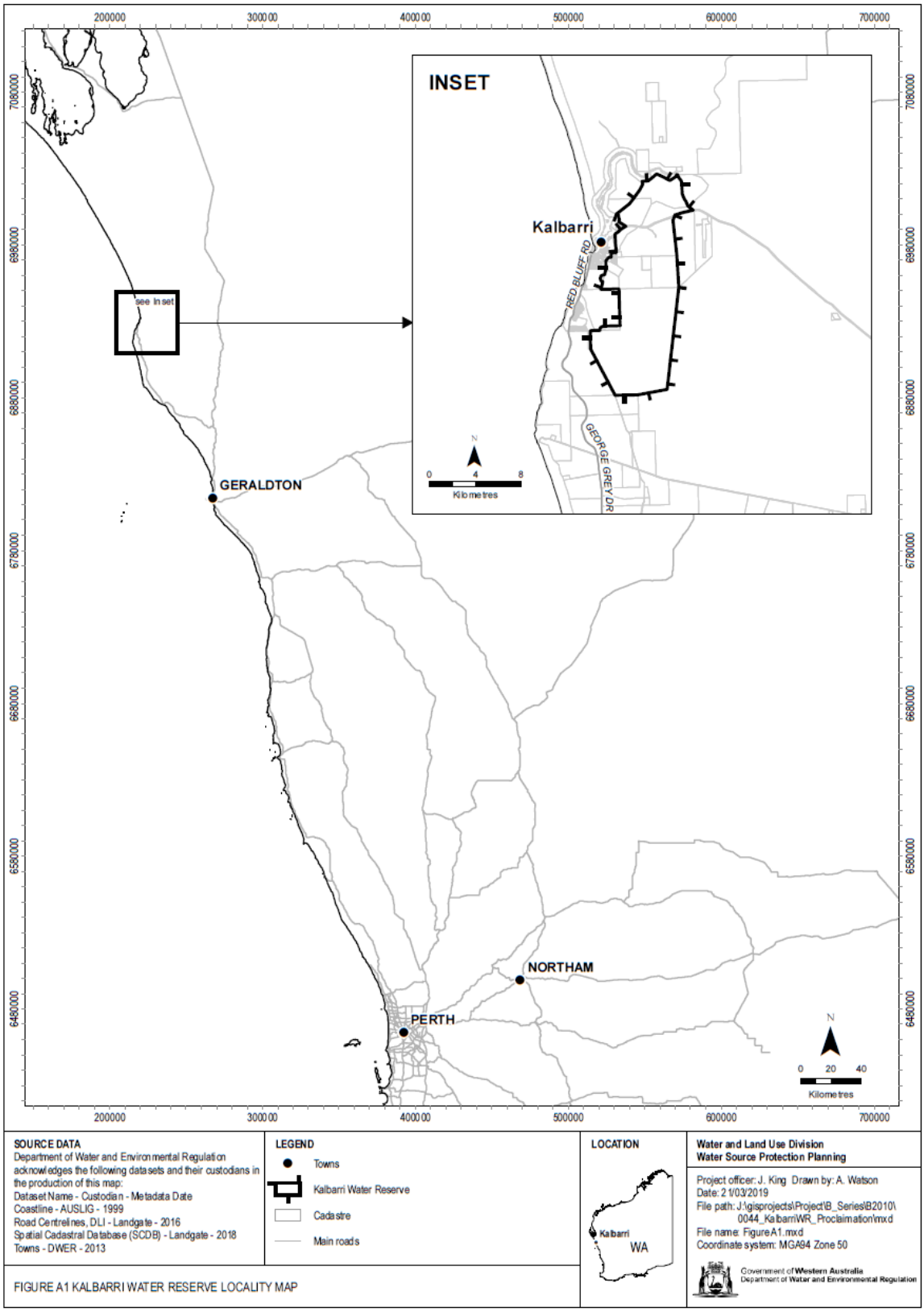

Figure A1 Kalbarri Water Reserve locality map

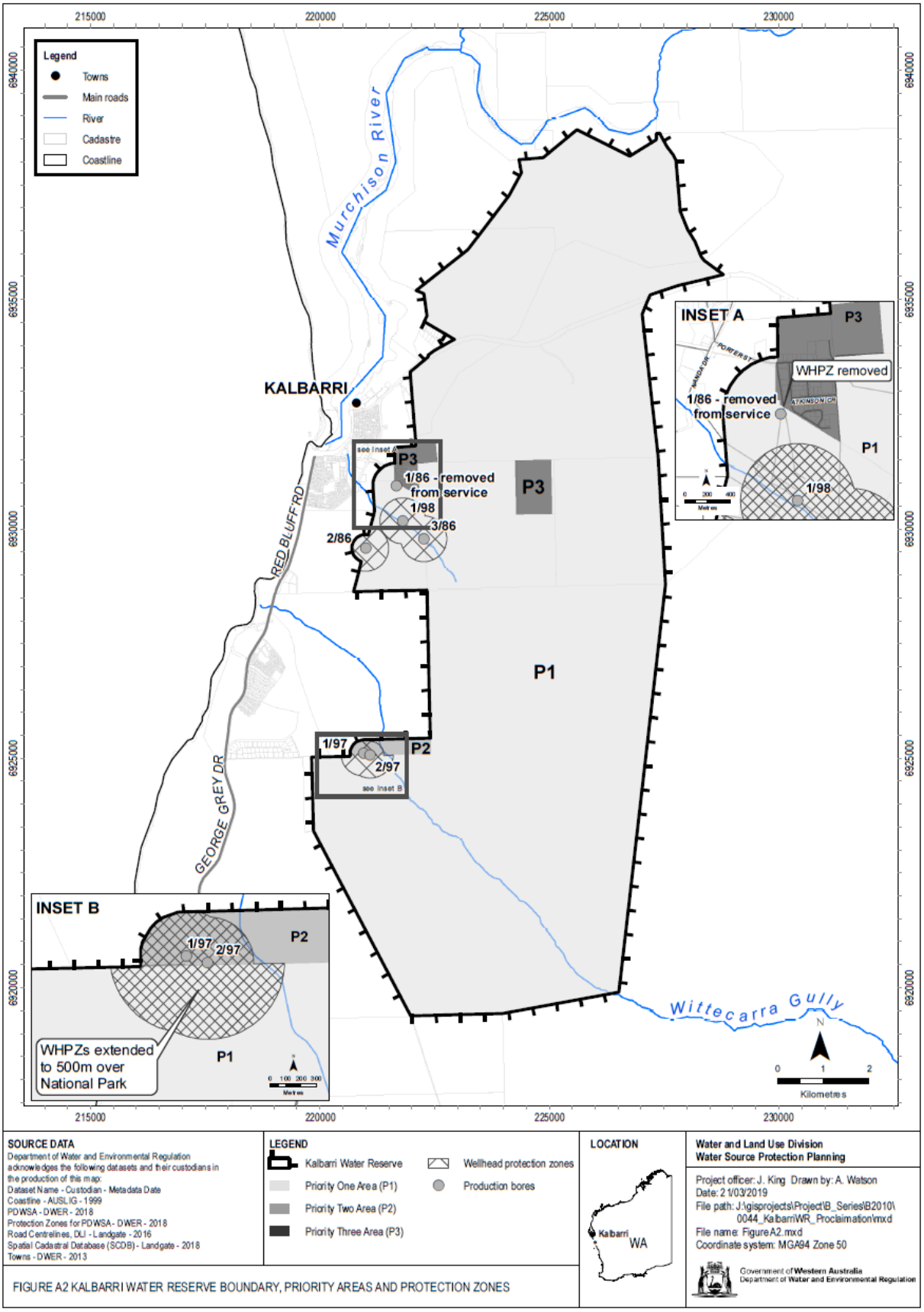

Figure A2 Kalbarri Water Reserve priority areas and protection zones

Figure A3 Kalbarri Water Reserve aerial photo showing land uses

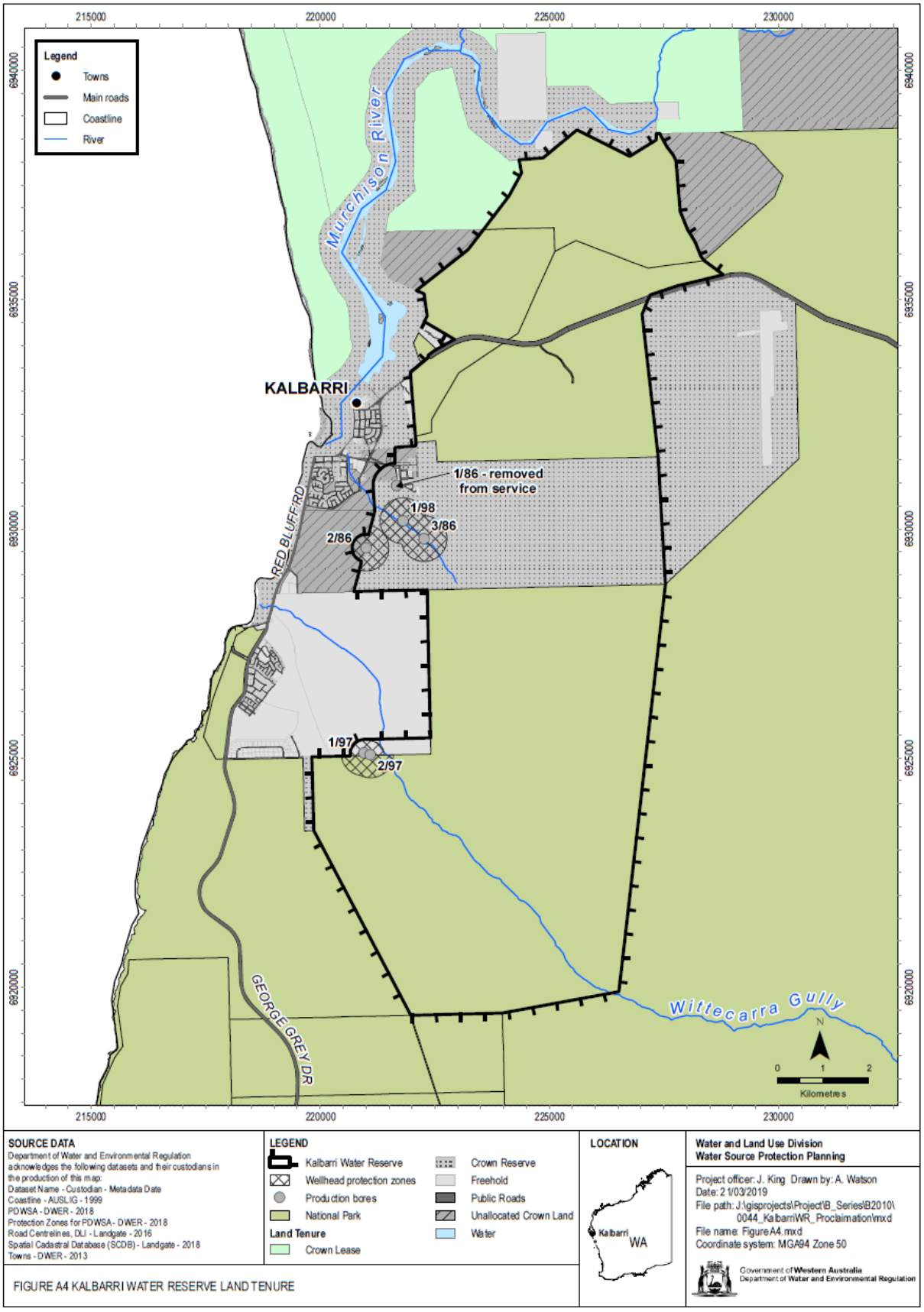

Figure A4 Kalbarri Water Reserve land tenure

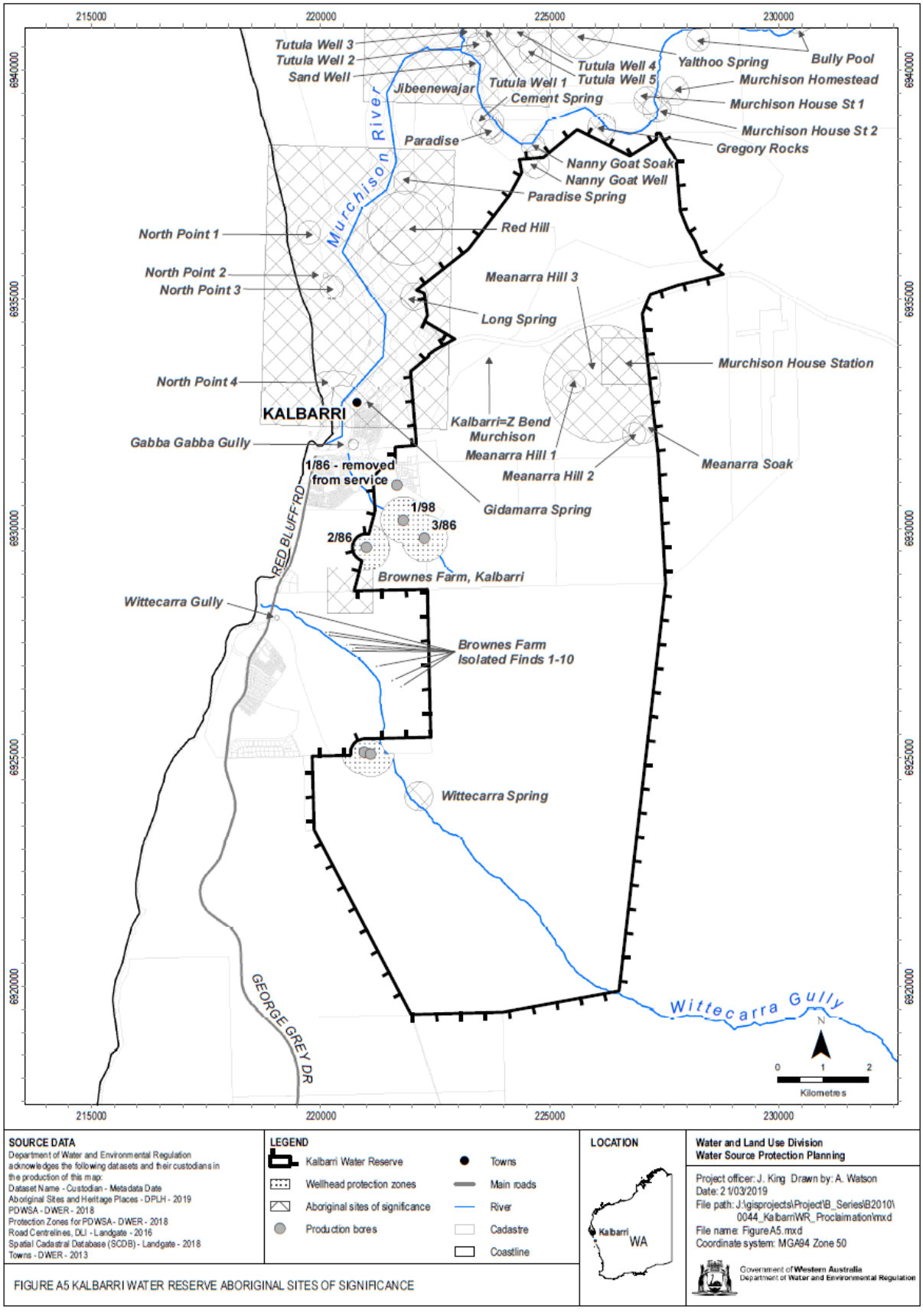

Figure A5 Kalbarri Water Reserve Aboriginal sites of significance

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 Kalbarri and Port Kalbarri in accordance with the requirements of the *Australian drinking water guidelines* (ADWG; NHMRC & NRMMC 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 Kalbarri and Port Kalbarri. 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 November 2013 to October 2018.

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 Kalbarri refer to the most recent Water Corporation drinking water quality annual report at watercorporation.com.au.

Aesthetic characteristics

The aesthetic quality analyses for raw water from Kalbarri and Port Kalbarri are summarised in the following table.

Table B1 Aesthetic detections for Kalbarri and Port Kalbarri

Parameter	Units	ADWG aesthetic guideline value[1]	Kalbarri bore field		Port Kalbarri bore field	
			Range	Mean	Range	Mean
Chloride	mg/L	250	195–205	200	***325–355***	***338.8***
Hardness as $CaCO_3$	mg/L	200	69–74	70.7	110–120	115.2
Iron unfiltered	mg/L	0.3	0–0.004	0.003	0.02-0.1	0.047
Manganese unfiltered	mg/L	0.1	-	-	0.008–0.05	0.03
Silicon as SiO_2	mg/L	80	42–45	43.7	42–48	45.1
Sodium	mg/L	180	105–105	105	175–***220***	***195***
Sulfate	mg/L	250	20–20	20	43–47	45.5
Total filterable solids by summation	mg/L	500	403–418	409.3	***671–789***	***712.4***
Turbidity	NTU	5	0–0.4	0.13	0–0.7	0.2
pH measured in laboratory	no units	6.5–8.5	***6.1–6.34***	***6.2***	***5.9***–7.2	***6.3***

[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 Kalbarri and Port Kalbarri 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.

Table B2 Health-related detections for Kalbarri and Port Kalbarri

Parameter	Units	ADWG health guideline value[2]	Kalbarri bore field		Port Kalbarri bore field	
			Range	Mean	Range	Mean
Fluoride laboratory measurement	mg/L	1.5	n/a–0.1	n/a	0.15–0.15	0.15
Manganese unfiltered	mg/L	0.5	-	-	0.008–0.05	0.03
Nitrite plus nitrate as N[3]	mg/L	11.29[4]	0.64–0.71	0.68	0–0.17	0.1
Sulfate	mg/L	500	20–20	20	43–47	45.5

[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 & NRMMC 2011).

[3] This is reported as 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 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 Kalbarri and Port Kalbarri 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 not recorded in any samples from Kalbarri or Port Kalbarri.

Appendix C – Photographs

Figure C1 Natural soak near Port Kalbarri bores, photograph by J. King, DWER

Figure C2 Fenced and locked bore compound at Port Kalbarri, photograph by J. King, DWER

Figure C3 Unauthorised off-road vehicle access into the bore field via cleared land along power lines, photograph by J. King, DWER

Figure C4 Sign at access track to Kalbarri bore field, photograph by J. King, DWER

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
- 1,000–1,600 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 on to 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) 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. 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 & NRMMC 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 is 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, the Department of Water and Environmental Regulation (the department) 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 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* (DWER 2016a) describes how we do this. It is available from the department's website at 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* (DWER 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 report – each providing for different needs. The following table shows the differences between the types of reports.

There is 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 Western Australian Planning Commission (with input from the department) 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 (DWER 2016a). You can also contact the department's Water source protection planning section on +61 8 6364 7600 or email drinkingwater@dwer.wa.gov.au.

Table E1 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 preventing 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, we use an assessment based on preventing risks, which considers both the maximum risk (before installing barriers) and the residual risk (after installing barriers). This means that in some cases, the maximum risks from land uses will still be considered unacceptable, even after mitigation (installing barriers) has reduced the risk. We need this more conservative approach to protect the health of consumers; those that are drinking the water.

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).

Table F1 Risk matrix: Level of risk (NHRMC & NRMMC 2011)

Likelihood	**Consequence**				
	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

Likelihood	**Consequence**				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
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. This is because 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	*Australian drinking water guidelines*
ANZECC	Australian and New Zealand Environment Conservation Council
DoW	Department of Water (former)
DPaW	Department of Parks and Wildlife (former)
DPLH	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Regulation
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
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 1,000 m.
m	metres	A measure of distance.
mg/L	milligrams per litre	A measure of concentration of a substance in a solution.
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.
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	1,000 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.
Advisory Committee for the Purity of Water	A non-statutory interdepartmental committee chaired by the Department of Health providing advice to the Ministers for Health and Water on drinking water quality.
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 & NRMMC 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 or formations able to receive, store and transmit significant quantities of water.
Australian drinking water guidelines	The *National water quality management strategy: Australian drinking water guidelines 6* (ADWG; NHMRC & NRMMC 2011) outlines acceptable criteria for the quality of drinking water in Australia (see *References*).
Bore	A narrow, lined hole drilled into the ground to monitor or draw groundwater (also called a well).
Bore field	A group of bores to monitor or withdraw groundwater (also see *wellfield*).
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 *Country Areas Water Supply Act 1947* or the *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* for the purposes of protecting a drinking water supply.
Confined aquifer	An aquifer that is overlain by relatively impermeable rock or clay that limits movement of water into and out of the aquifer. Confined aquifers are usually deeper under the ground than unconfined aquifers. Groundwater in a confined aquifer is under pressure and will rise up inside a bore hole that is drilled into the aquifer.
Constitute	Define the boundaries of any catchment area or water reserve by Order in Council under the *Country Areas Water Supply Act 1947* or by proclamation under *the Metropolitan Water Supply, Sewerage and Drainage Act 1909*.

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.
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 & NRMMC 2011).
Hydraulic gradient	The change in hydraulic head per unit of distance, which determines the rate of groundwater flow.
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 (NHRMC & NRMMC 2011).
Microbe	A microorganism, usually one of vegetable nature, a germ. Also known as a bacterium, especially one causing illness.

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 s.9 of the *Country Areas Water Supply Act 1947.*
Pathogen	A disease-producing organism that can cause sickness and sometimes death through the consumption of water, including bacteria (such as *Escherichia coli*), protozoa (such as *Cryptosporidium* and *Giardia*) and viruses.
Pollution	Water pollution occurs when waste products change the physical, chemical or biological properties of the water, adversely affecting water quality, the ecosystem and beneficial uses of the water.
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 *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* or the *Country Areas Water Supply Act 1947*.
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 'risk avoidance', priority 2 (P2) areas is 'risk minimisation' and priority 3 (P3) areas is 'risk management'.
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 (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 & NRMMC 2011).

Scheme supply	Water diverted from a source or sources by a water authority or private company and supplied via a distribution network to customers for urban and industrial use or for irrigation.
Soak	An area where water naturally seeps into a depression in the landscape, directly from groundwater or an ephemeral stream. Sometimes this area is dug out to maximise the water availability.
Sole supply	The only 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.
Stormwater	Rainwater that has run off the ground surface, roads, paved areas etc., and is usually carried away by drains.
Superficial aquifer	Shallow (near to the surface) aquifers which are easily recharged and can be readily accessed by bores.
Treatment	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes, including drinking and discharge to the environment.
Turbidity	The cloudiness or haziness of water caused by the presence of fine suspended matter.
Unconfined aquifer	An aquifer where the upper boundary is the watertable and therefore is in contact with the atmosphere through the pore spaces in the unsaturated zone. Typically (but not always) it is the shallowest aquifer at a given location.
Wastewater	Water that has been used for some purpose and would normally be treated and discarded. Wastewater usually contains significant quantities of pollutant.
Water quality	Collective term for the physical, aesthetic, chemical and biological properties of water.
Water reserve	An area constituted under the *Country Areas Water Supply Act 1947* or the *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* 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.

Westplan–HAZMAT	State emergency management plan for hazardous materials emergencies.

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