Government of **Western Australia**
Department of **Water**

Lancelin Water Reserve

Drinking water source protection review

Lancelin town water supply

Securing Western Australia's water future

Water resource protection series
Report WRP 156
June 2017

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Cover photograph: Aerial photograph of the Lancelin Water Reserve

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Summary

This drinking water source protection review considers changes that have occurred in and around the Lancelin Water Reserve since completion of the *Lancelin Water Reserve water source protection plan* (Taylor 1997). Both of these documents are available on the Department of Water website or by contacting us.

Lancelin is a small holiday and fishing town located on the Western Australian coast about 130 km north of Perth, in the Shire of Gingin (Figure A1). Water is supplied to the town by the Water Corporation from four bores which draw water from a superficial aquifer in sand and fractured rock (Tamala Limestone). The aquifer is unconfined and is considered vulnerable to contamination from land uses.

The main risks to water quality within the Lancelin Water Reserve are hydrocarbons and chemical spills from off-road vehicle use and sand mining, and pathogens from unauthorised recreation near the production bores (Figure A2).

We prepared this document in consultation with key stakeholders, including the Water Corporation and the Shire of Gingin.

The main changes in the water reserve since the 1997 plan are:

- production bore 3/65 was decommissioned
- production bore 1/81 is now used only as a standby bore
- the boundary of the Lancelin off-road vehicle area (LORVA) was revised and no longer covers any part of the water reserve.

This review consolidates the ongoing recommendations from the 1997 plan with the following new recommendations:

- erect additional signs at the information area for the LORVA
- consider additional measures for discouraging unauthorised access into the Lancelin Water Reserve for off-road vehicle use and other activities
- review the boundary of the water reserve when this review is next updated or if there are significant changes to the layout of the bore field, based on hydrogeological modelling of the recharge area and consultation with the Shire of Gingin and any landowners.

This review is consistent with the *Australian drinking water guidelines* (ADWG) (NHMRC & NRMMC 2011) and State planning policy no. 2.7: *Public drinking water source policy* (Western Australian Planning Commission 2003).

Table 1, below, shows important information about the Lancelin Water Reserve.

Table 1 Key information about the Lancelin Water Reserve

Lancelin Water Reserve	
Status of this report	this report has been prepared based on information for the 2014/15 financial year
Location supplied	Lancelin
Water service provider	Water Corporation
Aquifer type	unconfined (vulnerable to contamination)
Licensed abstraction	280 000 kL per year
Number of bores	four
Bore names and GPS coordinates	2/65 (E 341 644.2, N 6 567 901.2, zone 50) 1/74 (E 341 705, N 6 567 980.1, zone 50) 1/81 (E 341 721.3, N 6 567 370.7, zone 50) 3/81 (E 341 767.5, N 6 567 175.6, zone 50)
Date of bore completion	2/65 – 17 July 1965 1/74 – 4 September 1974 1/81 – 27 March 1981 3/81 – 15 April 1981
Dates of drinking water source protection reports	1997 – *Lancelin Water Reserve water source protection plan* 2015 – *Lancelin Water Reserve drinking water source protection review* (this document)
Consultation	1996 – stakeholder consultation as part of the water source protection plan 2014 – consultation with key stakeholders including the Shire of Gingin and the Water Corporation
Proclamation status	Proclaimed on 23 July 1999 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* (Western Australian Planning Commission 2003)

Lancelin Water Reserve	
	Gingin groundwater allocation plan (Department of Water 2015)

1 Review of Lancelin's drinking water source protection plan

1.1 Boundary, priority areas and protection zones

The Lancelin Water Reserve was proclaimed in 1999 under the *Country Areas Water Supply Act 1947*. This public drinking water source area (PDWSA) includes 500 m wellhead protection zones (WHPZs) around each of the production bores in use at that time (2/65, 3/65, 1/74, 1/81 and 3/81) and is managed as a priority 1 (P1) area (Figure A1). As production bore 3/65 was decommissioned in 1996, the WHPZ for this bore has been removed.

The boundary of the Lancelin Water Reserve should be reviewed if there are significant changes to the layout of the bore field. The boundary review should be based on hydrogeological modelling of the recharge area and consultation with the Shire of Gingin and any landowners.

If you require more information about how we protect drinking water sources, please read Appendix E.

1.2 Update on water supply scheme

The Department of Water renewed Water Corporation's groundwater allocation licence no. 65344 in 2011. The licence allows Water Corporation to draw 280 000 kL of water from the superficial aquifer (unconfined) to supply Lancelin's drinking water from the four production bores.

The Lancelin bore field now consists of four of the original production bores (2/65, 1/74, 1/81 and 3/81, see Figures C1 to C4), with the fifth production bore (3/65) decommissioned in 1996. The production bores draw water from between about 14 m and 24 m below ground level. Production bore 3/81 is currently used as the main duty bore, while bores 2/65 and 1/74 are used as duty bores on a rotational basis. Production bore 1/81 – the only bore equipped with a diesel motor – is a standby bore and is rarely used.

Groundwater from this source is pumped to a ground-level storage tank. Chlorination is carried out to disinfect the water to ensure microbiological quality for consumers. It is then treated with Calgon to reduce hardness and pumped into elevated storage tanks for distribution via gravity to the town scheme. Water Corporation upgraded Lancelin's water quality treatment system in 2004.

It should be recognised that although treatment and disinfection are essential barriers against contamination, 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 & NRMMC 2011) and reflects a preventive, risk-based, multiple-barrier approach for providing safe drinking water to consumers. This combination of catchment protection and water treatment will

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

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

1.3 Planning for future land uses

The Lancelin Water Reserve is located adjacent to the town of Lancelin, and extends north and east into an area of sparsely vegetated sands and mobile, unconsolidated dunes. Most of this area is considered unsuitable for infrastructure or development.

The bore field and drinking water treatment plant are located on Crown reserve vested in Water Corporation, while the remainder of the water reserve is located on unallocated Crown land (Figure A1). The Lancelin Water Reserve is identified in the *Shire of Gingin Local Planning Scheme no. 9* (Department of Planning 2012) through a special control area. However, the water reserve is not currently recognised in the shire's draft *Local planning strategy* (Shire of Gingin 2010).

Development pressure within the Lancelin Water Reserve is currently minimal due to the constraints posed by the mobile dune system and limited control over the release of Crown land. The development of the nearby Lancelin South urban area may further decrease development pressure within the water reserve.

1.4 Aboriginal sites of significance and native title claims

Aboriginal sites of significance are those areas that Aboriginal people value as important and significant to their cultural heritage. The sites are significant because they link Aboriginal culture and tradition to place, land and people over time. These areas form an integral part of Aboriginal identity and the heritage of Western Australia. The *Aboriginal Heritage Act 1972* protects all Aboriginal sites in the state.

There are two Aboriginal sites of significance within the Lancelin Water Reserve (Figure A3). These are Ledge Point (S00542) and Lancelin (S00543).

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 Lancelin Water Reserve; Yued (WAD6192/98).

The Department of Water 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

This review recommends that Water Corporation continue by-law enforcement under the existing delegation arrangement. This also includes:

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

1.6 Other Department of Water work

The *Gingin groundwater allocation plan* (Department of Water 2015) was released in March 2015. The allocation plan presents updated allocation limits and licensing rules designed to maintain the reliability of current groundwater entitlements. These limits and rules reduce the risks to the groundwater-dependent environment from abstraction.

The public water supply reserves were adjusted for each groundwater area as part of revising the allocation limits for the *Gingin groundwater allocation plan*. For the Lancelin groundwater subarea, 5.5 GL per year has been reserved for future public water supply from the superficial aquifer.

1.7 Update on water quality risks

As part of this review, we have conducted a new assessment of water quality contamination risks to Lancelin's drinking water source, in accordance with the ADWG. Table 2 shows a summary of the assessment of the risks to water quality.

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

1.7.1 Unauthorised access from the Lancelin off-road vehicle area

Off-road vehicle use is an incompatible recreational activity in groundwater PDWSAs under our Operational policy no. 13: *Recreation within public drinking water source areas on Crown land* (Department of Water 2012). Off-road vehicles pose risks of hydrocarbon and chemical contamination from fuel and oil spills, leaks, crashes and abandoned vehicle wrecks.

Since publication of the 1997 *Lancelin Water Reserve water source protection plan*, the boundary of the Lancelin off-road vehicle area (LORVA) has been revised. The LORVA is now located immediately to the north of the Lancelin Water Reserve and no longer overlaps the water reserve (Figure A2). The main sign at the entrance to the LORVA appears to depict the area extending into the Lancelin Water Reserve

and into the WHPZs for production bores 2/65 and 1/74 (Figure C5). However, the physical boundary between the LORVA and the water reserve appears to be correctly marked by fencing and signs (Figure C6).

There is evidence of vehicles entering the water reserve from the LORVA through damaged or missing fencing. Vehicle wrecks, including burnt out vehicles, have been observed within the water reserve. The Shire of Gingin manages the LORVA and issues infringement notices for non-compliance with the regulations.

Improved signage advising of the location of the Lancelin Water Reserve, increased surveillance, remote surveillance and/or maintaining the existing fence line should be considered to deter vehicle entry into the water reserve from the LORVA.

1.7.2 Unauthorised access and activities

Existing signage on tracks near the bore field (Figure C7) advises of the location of the water reserve and prohibits dumping and vehicle access. However, unauthorised access into the Lancelin Water Reserve has been observed along tracks from the town site into the bore field and the broader water reserve.

Surveillance by Water Corporation has documented rubbish dumping, vehicle wrecks, infrastructure damage and gatherings of people within the bore field. A site visit in December 2013 identified evidence of off-road vehicle use, gatherings of people (such as shoes, glass bottles and campfires) and rubbish dumping (building supplies and 44-gallon drums) within WHPZs, sometimes within several metres of production bores.

Water quality risks associated with these activities include pathogens from human activities, hydrocarbons from vehicles and hydrocarbons, nutrients and chemicals from rubbish dumping.

The potential for pathogen contamination near the production bores is of particular concern as the highly transmissive sands and shallow groundwater could allow pathogens to be rapidly transported into the production bores. However, pathogens have not been detected in the bore field during the review period.

Increased signage, gates across the two main tracks into the bore field, increased surveillance and/or remote surveillance could be considered to deter unauthorised entry into the bore field for recreation activities.

1.7.3 Sand mining

There are five mining tenements (M70/249, M70/692, M70/994, M70/250 and M70/1147) within the Lancelin Water Reserve (Figure A3).

Sand mine operators should be kept aware of best management practices to minimise the risks of groundwater contamination within the Lancelin Water Reserve. These risks include fuel and lubricant leaks from heavy machinery and vehicles and spills from fuel storage facilities and refuelling equipment.

1.7.4 Other groundwater bores in the area

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 Department of Water'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).

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]**
Off-road vehicle access from the Lancelin off-road vehicle area (LORVA)	Hydrocarbons and chemicals	Medium	Signage and boundary fencing needs to be maintained between the LORVA and the Lancelin Water Reserve.	Operational policy no. 13: *Recreation within public drinking water source areas on Crown land* WQPN no. 44: *Roads near sensitive water resources*
Unauthorised access and activities	Pathogens Hydrocarbons and turbidity	High Medium	Vehicle access, dumping and human activities are occurring in the WHPZs. Unsealed roads need to be managed to control access. Signs prohibit dumping and off-road vehicles access.	Operational policy no. 13: *Recreation within public drinking water source areas on Crown land*
Sand mining	Hydrocarbons	Low	Sand mines are located on Crown reserve.	WQPG No. 1: *Water quality management in mining and mineral processing: An overview* WQPN no. 15: *Extractive activities near sensitive water resources*

[1]Water quality protection notes (WQPNs) and water quality protection guidelines (WQPGs) are available <http://drinkingwater.water.wa.gov.au> and scroll down to the link for *water quality protection notes* or *water quality protection guidelines.*

1.8 Water quality information

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

Hardness and total filterable solids by summation (TFSS) have exceeded the ADWG aesthetic values over the review period. Naturally occurring hardness is characteristic of the superficial aquifer in the area.

Microbial contaminants were not detected during the review period.

2 Implementation of Lancelin's drinking water source protection plan

2.1 Status of previous recommendations

Table 3 outlines recommendations from the 1997 plan and their current status.

Table 3 Implementation status for the Lancelin Water Reserve

No.	Recommendation	Comments
1	Gazette the water reserve.	Gazetted in 1999 under the *Country Areas Water Supply Act 1947.*
2	Incorporate the water reserve into land planning strategies.	*Shire of Gingin local planning scheme no. 9* (Department of Planning 2012) identifies the location of the Lancelin Water Reserve through a special control area. Shire of Gingin's draft *Local planning strategy* needs to incorporate the Lancelin Water Reserve (section 2.2, recommendation 1).
3	Refer development proposals which are likely to impact on water quality within the water reserve to the Department of Water (formerly Water and Rivers Commission).	Development proposals within the water reserve are referred to the Swan Avon Region office of the Department of Water. This is continued as a new recommendation in this review (section 2.2, recommendation 2).
4	Erect signs along the boundary of the water reserve.	Water Corporation signs are displayed on the bore compounds and drinking water treatment plant. Additional signs advising on the location of the Lancelin Water Reserve should be erected, especially at the entry point of off-road vehicle tracks and along the boundary of the LORVA (section 2.2, recommendation no. 4).

No.	Recommendation	Comments
5	Emergency response: • Develop response plan. • Inform Westplan-HAZMAT (formerly WAHMEMS) personnel of special requirements for the Lancelin Water Reserve.	Water Corporation has spill response procedures in place. This is continued as a new recommendation in this review (section 2.2, recommendation no. 3).
6	Establish a surveillance program to identify incompatible land uses or potential contamination threats within the water reserve.	Water Corporation undertakes surveillance of the water reserve. This has been continued as a recommendation of this review (section 2.2, recommendation no. 5).
7	Water Corporation should construct a bund for fuel storage or consider electrification or abandonment of the diesel-operated pump near bore 1/81.	Water Corporation has constructed bunding for the diesel fuel storage at production bore 1/81. As it is now a stand-by bore, diesel is only stored at the bore when it is in use, so this recommendation is no longer applicable.
8	Review of the plan and recommendations.	Undertaken through the preparation of this review document.

2.2 Consolidated recommendations

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

1. Incorporate the Lancelin Water Reserve into the Shire of Gingin's draft *Local planning strategy*. (Shire of Gingin)
2. Refer development proposals within the Lancelin Water Reserve that are inconsistent with the Department of Water's WQPN no.25: *Land use compatibility in public drinking water source areas* or recommendations in this review to the Department of Water regional office for advice. (Department of Planning, Shire of Gingin, proponents of proposals)
3. Ensure incidents covered by Westplan–HAZMAT in the Lancelin Water Reserve are addressed by ensuring that:
    - the Shire of Gingin's local emergency management committee (LEMC) is aware of the location and purpose of the Lancelin Water Reserve

- the locality plan for the Lancelin Water Reserve is provided to the Department of Fire and Emergency Services headquarters for the HAZMAT emergency advisory team
- Water Corporation acts in an advisory role during incidents in the Lancelin Water Reserve
- personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Lancelin Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality. (Water Corporation)

4. Increase awareness of the Lancelin Water Reserve through additional signs at the Lancelin off-road vehicle area and tracks into the bore field. Maintain existing signs along the boundary of the Lancelin Water Reserve, including an emergency contact telephone number, in accordance with Water Corporation's *S111 Source protection signage* (2013). (Water Corporation)
5. Consider increased surveillance, remote surveillance and/or maintaining the fencing to deter off-road vehicles from entering the Lancelin Water Reserve from the Lancelin off-road vehicle area. (Shire of Gingin and Water Corporation)
6. Water Corporation should continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. Consider additional measures to deter unauthorised off-road vehicles and activities within the water reserve. (Water Corporation)
7. Review the boundary of the Lancelin Water Reserve when this review is next updated or there are significant changes to the layout of the bore field. Any revisions to the boundary should be based on hydrogeological modelling of the recharge area for existing and future production bores and be consulted with the Shire of Gingin and any landowners. (Department of Water)
8. Update this review within seven years. (Department of Water).

Appendices

Appendix A — Figures

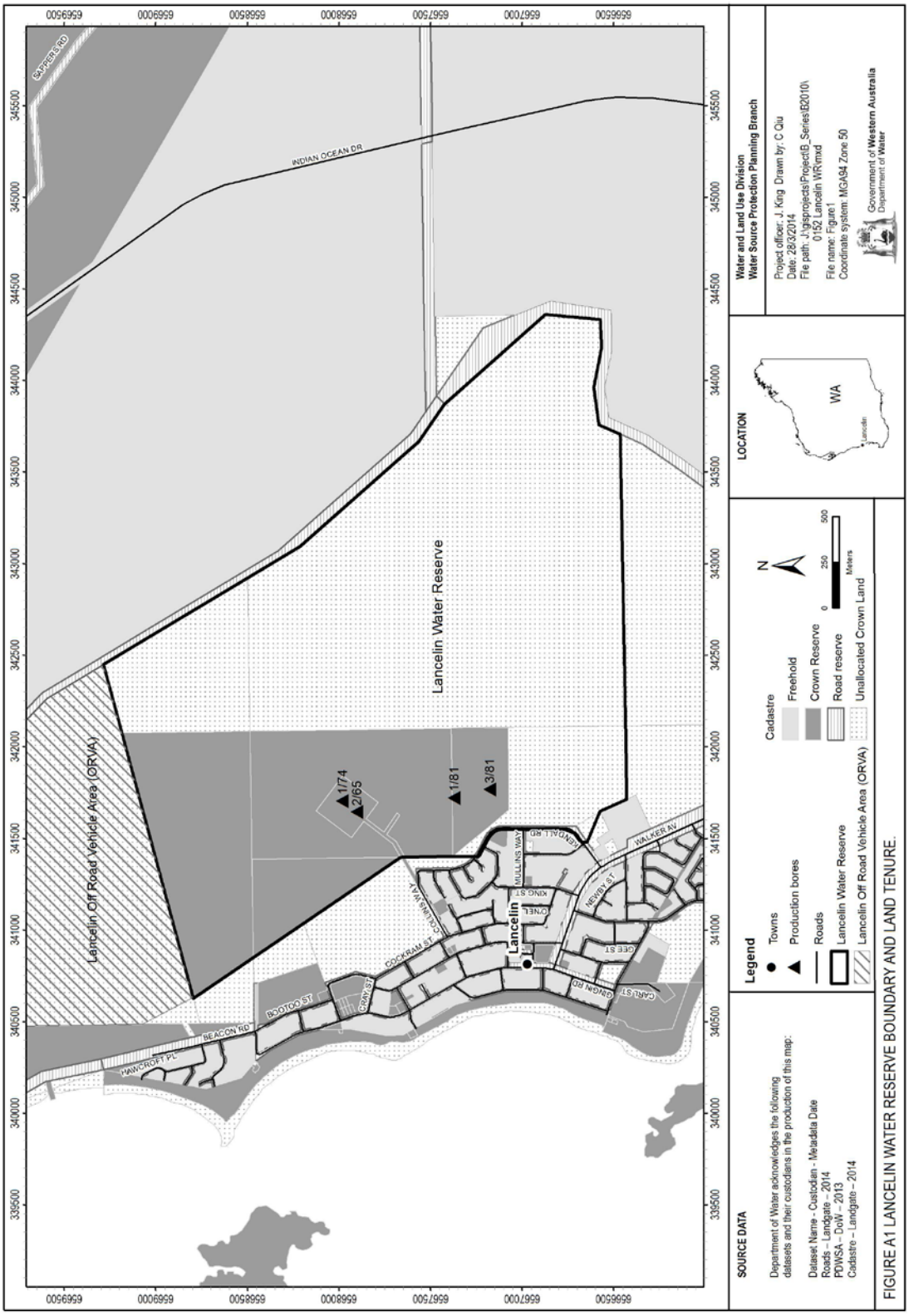

Figure A1 Lancelin Water Reserve boundary and land tenure

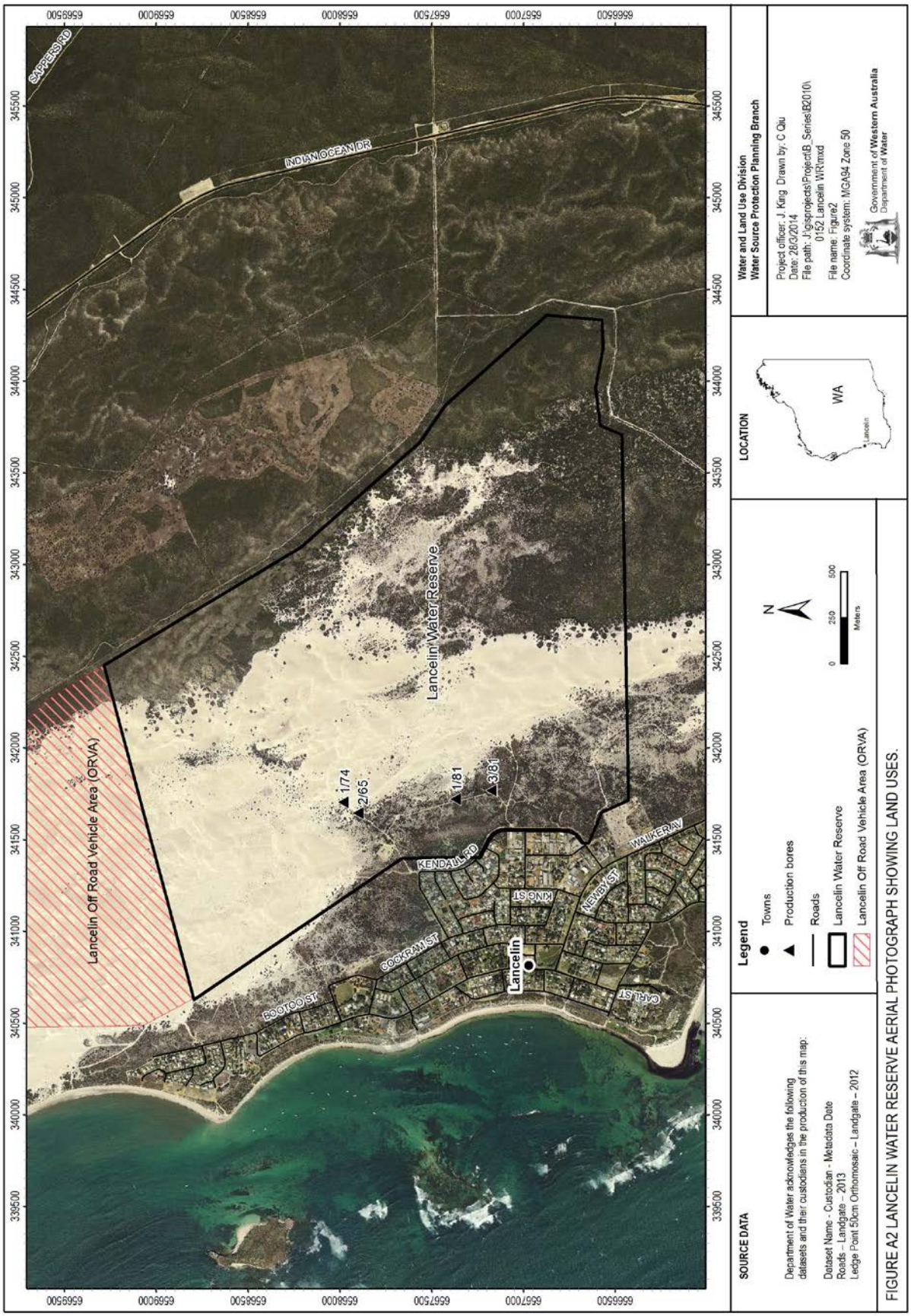

Figure A2 Lancelin Water Reserve aerial photograph showing land uses

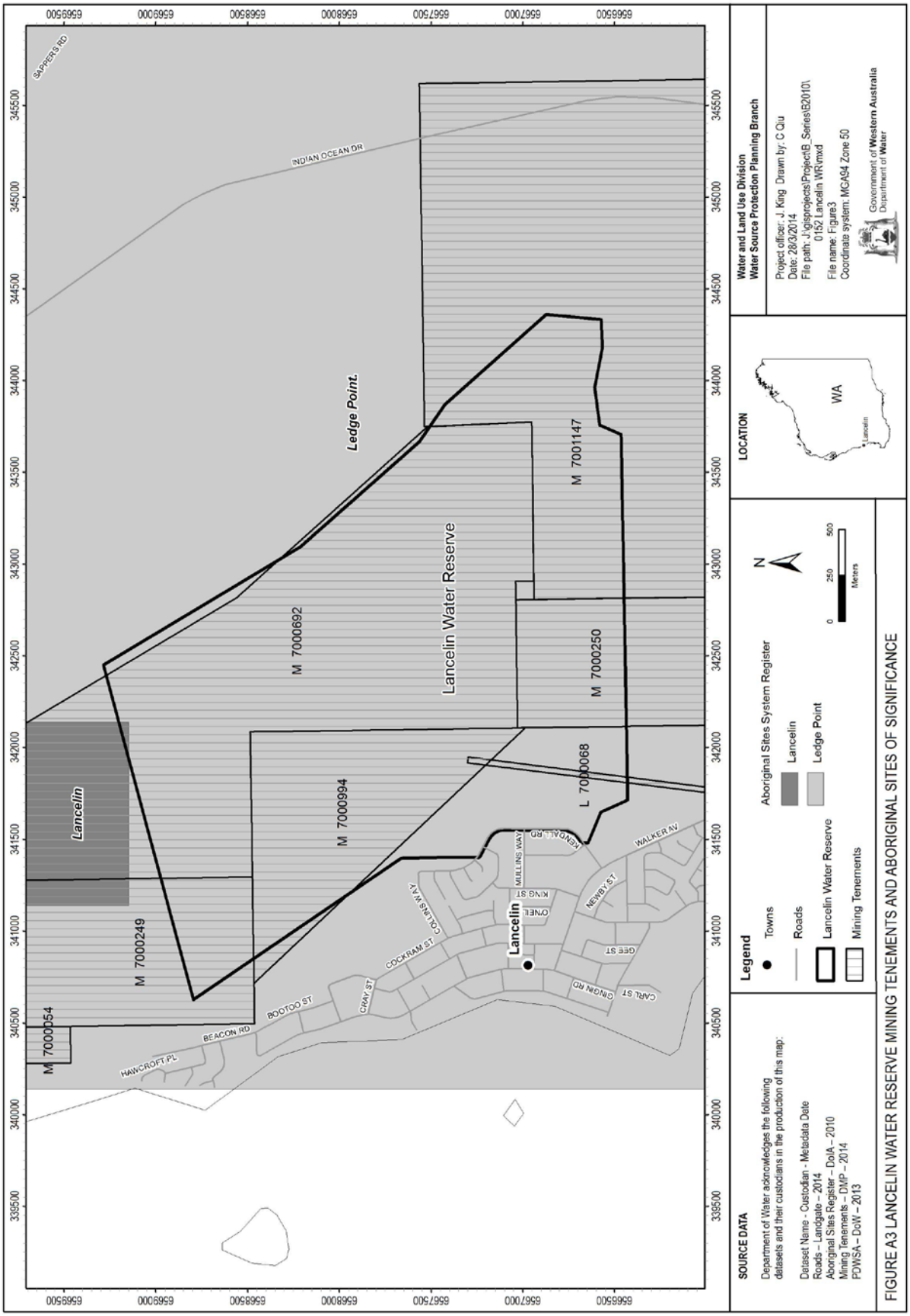

Figure A3 Lancelin Water Reserve mining tenements and Aboriginal Sites of Significance

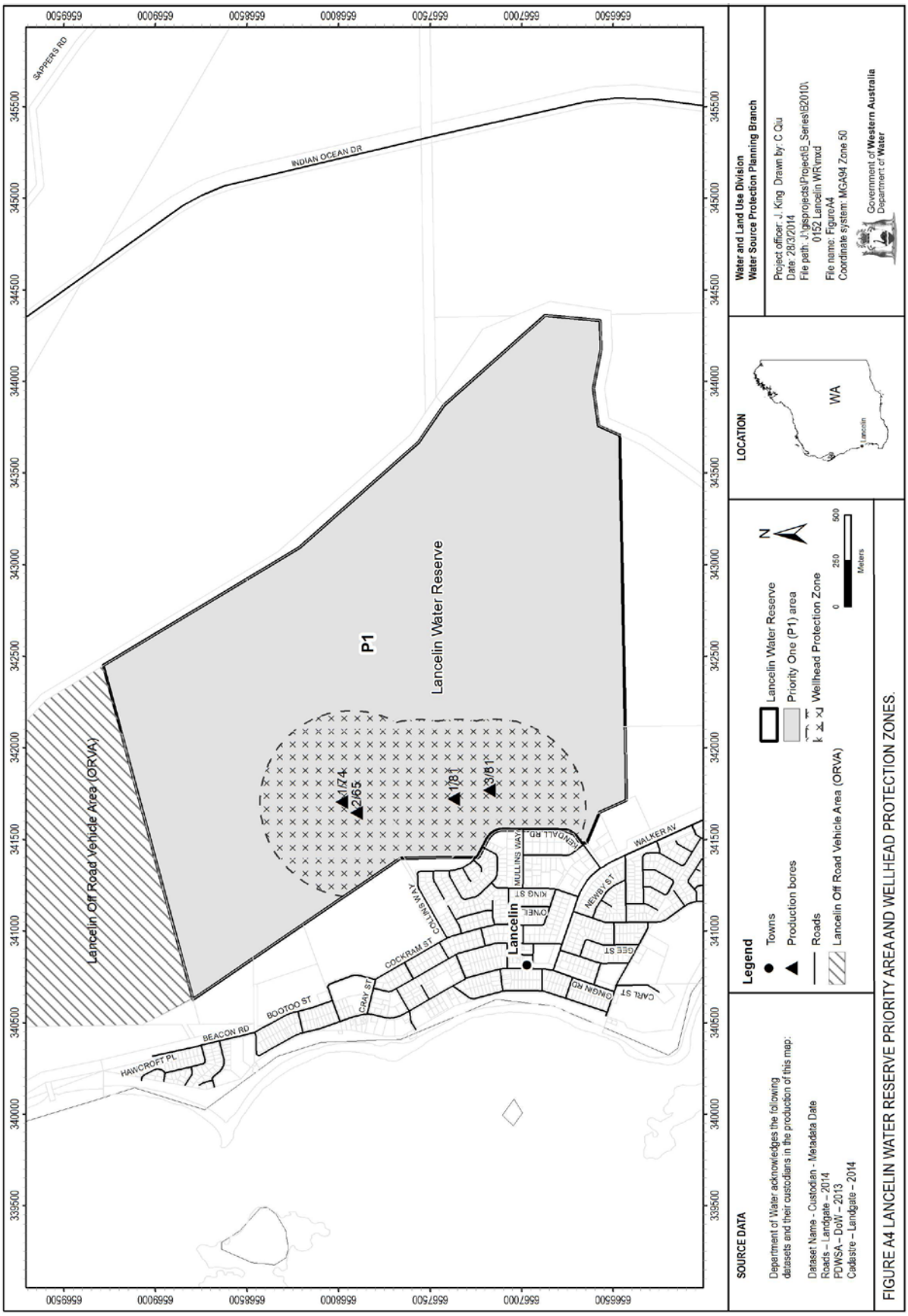

Figure A4 Lancelin Water Reserve priority areas and protection zones (note, these remain the same as the 1999 plan)

Appendix B — Water quality data

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

Water Corporation has monitored the raw (source) water quality from Lancelin 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 catchment. The raw water is regularly monitored 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 the Lancelin bore field. 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 February 2009 to January 2014.

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 Lancelin refer to the most recent Water Corporation drinking water quality annual report at watercorporation.com.au > What we do > Water quality > Water quality publications > Most recent *Drinking water quality annual report*.

Aesthetic characteristics

The aesthetic water quality analyses for raw water from Lancelin bore field are summarised in the following table.

Aesthetic detections for Lancelin

Parameter	Units	ADWG aesthetic guideline value*	Lancelin bore field	
			Range	Median
Chloride	mg/L	250	180– 240	200
Colour (true)	TCU	15	<1–1	<1
Copper	mg/L	1	0.003–0.004	0.0035
Hardness as $CaCO_3$	mg/L	200	***260–290***	***280***
Iron unfiltered	mg/L	0.3	<0.003–***0.36***	<0.003
Silicon as SiO_2	mg/L	80	11–16	15
Sodium	mg/L	180	81–120	102.5
Sulfate	mg/L	250	15–22	18.5
TFSS	mg/L	600	***630–750***	***688.5***
Turbidity	NTU	5	<0.1–1	<0.1
pH measured in laboratory	no unit	8.5	7.39–7.78	7.56

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

Health-related detections for Lancelin

Parameter	Units	ADWG health guideline value*	Lancelin bore field	
			Range	Median
Barium	mg/L	0.7	0.06–0.06	0.06
Boron	mg/L	4	0.04–0.09	0.065
Chromium	mg/L	0.05	0.0012–0.0014	0.0013
Copper	mg/L	2	0.003–0.004	0.0035
Fluoride measured in laboratory	mg/L	1.5	0.2–0.2	0.2
Nitrite plus nitrate as N	mg/L	11.29†	0.45–1.2	0.7
Radon-222	Bq/L	100	0.716–1.46	1.1
Sulfate	mg/L	500	15–22	18.5

* 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 (NHRMC & ARMCANZ, 2011).

† The 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 Lancelin bore field 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 abstracted from any bore may indicate contamination of faecal material through ingress into the bore, or recharge through to the aquifer (depending on aquifer type).

During the review period, positive *E. coli* counts were not recorded in any samples.

Appendix C — Photographs

Figure C1 Production bore 2/65, photograph by J. King, Department of Water

Figure C2 Production bore 2/74, photograph by J. King, Department of Water

Figure C3 Production bore 1/81 – diesel standby bore, photograph by J. King, Department of Water

Figure C4 Production bore 3/81, photograph by J. King, Department of Water

Figure C5 Sign for the Lancelin off-road vehicle area, photograph by J. King, Department of Water

Figure C6 Damaged fencing between the Lancelin off-road vehicle area and the Lancelin Water Reserve, photograph by J. King, Department of Water

Figure C7 Water Corporation signage on tracks near the bore field, photograph by J. King, Department of Water

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

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

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

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

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

The first and most important barrier is protecting the public drinking water source area (PDWSA) – the area from which water is captured to supply drinking water. If we get this barrier right, it has a flow-on effect that can result in a lower cost and 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. Another community benefit from PDWSA protection is that it complements the state's conservation initiatives.

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

In Western Australia, the Department of Water 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 two and three of the 12 elements in the ADWG recommended for protecting drinking water. It shows the PDWSA's location, its characteristics, existing and potential water quality contamination risks, and makes recommendations to deal with those risks.

The *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* provide us with important tools to protect water quality in proclaimed PDWSAs. These acts allow us to assess and manage the water quality

contamination risks from different land uses and activities. The department works cooperatively with other agencies and the community to implement this legislation and develop drinking water source protection reports. For example, the Western Australian Planning Commission has developed a number of state planning policies to help guide development in public drinking water source areas.

An important step in maximising the protection of water quality in PDWSAs is to define their boundaries, priority areas and protection zones to help guide land-use planning and to identify where legislation applies. There are three different priority areas. The objective of priority 1 (P1) areas is risk avoidance – ensuring there is no degradation of the water quality (for example over Crown land). The objective of priority 2 (P2) areas is risk minimisation – maintaining or improving water quality (for example over rural-zoned land). The objective of priority 3 (P3) areas is risk management – maintaining the water quality for as long as possible (for example, urban- or commercial-zoned land). Protection zones surround drinking water abstraction bores and surface water reservoirs so that the most vulnerable areas are protected from contamination.

The Department of Water's Water quality protection note no. 25: *Land use compatibility in PDWSAs* outlines appropriate development and activities within each of the priority areas (P1, P2 and P3) and is available on our website.

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

There are three different types of drinking water source protection 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 of Water) 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 drinkingwater.water.wa.gov.au or refer to our Water quality protection note (WQPN) no. 36: *Protecting public drinking water source areas*. You can also contact the Department of Water's Water source protection planning branch on +61 8 6364 7600 or email drinkingwater@water.wa.gov.au.

Drinking water source protection reports produced by the Department of Water

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

Appendix F — Understanding risks to drinking water quality

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

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

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

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

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

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

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

For example, just because a drinking water contamination incident has not occurred for many years (low likelihood) does not mean that the risk is low, 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.

List of shortened forms

ADWG	*Australian drinking water guidelines*
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
HAZMAT	hazardous materials
LEMC	local emergency management committee
LORVA	Lancelin off-road vehicle area
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NTU	nephelometric turbidity units
PDWSA	public drinking water source area
TCU	true colour units
TFSS	total filterable solids by summation
WAHMEMS	Western Australian hazardous materials emergency management scheme (old name for Westplan–HAZMAT)
Westplan–HAZMAT	Western Australian plan for hazardous materials
WQPG	Water quality protection guideline
WHPZ	wellhead protection zone
WQPN	water quality protection note

Units of measurement

Bμ/L	becquerel per litre
ha	hectare
mSv	millisievert
mS/m	millisiemens per metre
m	metres
mg/L	milligram per litre

mm	millimetre
km	kilometre
km^2	square kilometre

Volumes of water

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

Glossary

Abstraction	The pumping of groundwater from an aquifer, or the removal of water from a waterway or water body.
Adsorb	Adsorb means to accumulate on the surface of something.
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	Is the volume of water that a licensee is permitted to abstract, usually specified in kilolitres per annum (kL/a).
Aquifer	An aquifer is 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*, 2011 (NHMRC & NRMMC 2011) (ADWG) outlines acceptable criteria for the quality of drinking water in Australia (see this plan's References).
Bore	A bore is 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 is referred to as a bore field (also see *wellfield*).
Becquerel	The becquerel is a measure of radioactivity, as per the International System of Units.
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
Confined aquifer	An aquifer that is confined between non-porous rock formations (such as shale and siltstone) and therefore contains water under pressure.
Contamination	A substance present at above background concentrations 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	An aquifer where groundwater is present in the fractures, joints, solution cavities, bedding planes and zones of weathering igneous, metamorphic and deformed sedimentary rocks. Fractured rock aquifers are highly susceptible to contamination from land-use activities 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.
Hydrogeology	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.
mg/L	A milligram per litre (0.001 grams per litre) is a measurement of something (such as salinity) in a solution.
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 *Escherichia coli*), protozoa (such as *Cryptosporidium* and *Giardia*) and viruses.
Pesticides	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
pH	A logarithmic scale for expressing the acidity or alkalinity of a solution. A pH below seven indicates an acidic solution and above seven indicates an alkaline solution.
Porosity	The state of quality of a material to be porous – that is permeable by 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*.
Recharge	Recharge is 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.
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.
Total dissolved solids	Total dissolved solids consist of inorganic salts and small amounts of organic matter that are dissolved in water. Clay particles, colloidal iron and manganese oxides, and silica fine enough to pass through a 0.45 micrometer filter membrane can also contribute to total dissolved solids. Total dissolved solids comprise sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate, carbonate, silica, organic matter, fluoride, iron, manganese, nitrate (and nitrite) and phosphate (NHMRC & NRMMC 2011).
Total filterable solids by summation	TFSS is 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 total dissolved solids (TDS). The higher the value, the more solids that are present and generally the saltier the taste.
Treatment	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes, including drinking and discharge to the environment.
True colour units	True colour units are a measure of degree of colour in water.
Turbidity	The cloudiness or haziness of water caused by the presence of fine suspended matter.

Unconfined aquifer	An aquifer in which the upper surface of water is lower than the top of the aquifer itself. The upper surface of the groundwater within the aquifer is called the watertable. This is also known as a superficial aquifer.
Water quality	Water quality is the collective term for the physical, aesthetic, chemical and biological properties of water.
Water reserve	A water reserve is an area proclaimed 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.
Wellhead	The top of a well (or bore) used to draw groundwater is referred to as a wellhead.
Wellhead protection zone	A wellhead protection zone is usually declared around wellheads in public drinking water source areas to protect the groundwater from immediate contamination threats in the nearby area.
Western Australian hazardous materials emergency management scheme	This is now known as Westplan–HAZMAT.

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