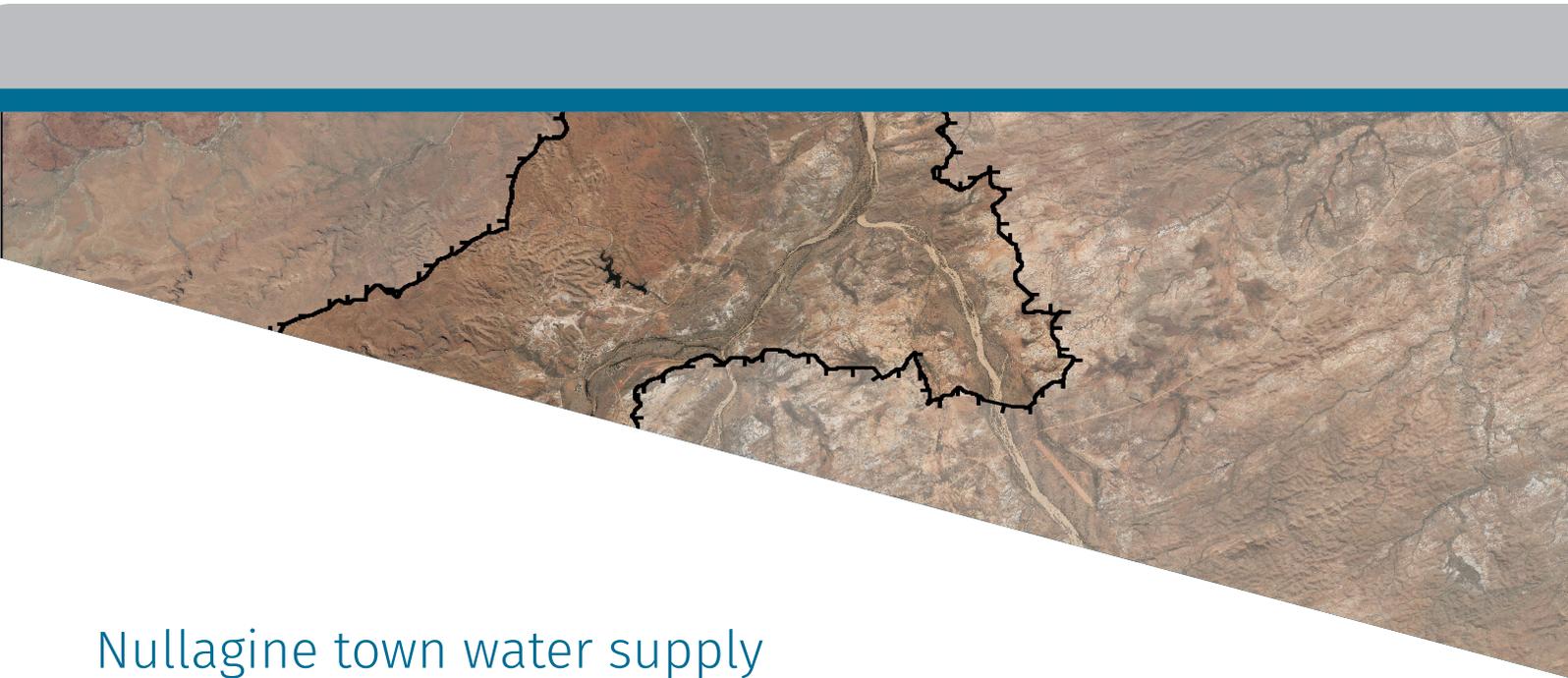




Nullagine Water Reserve

drinking water source protection review



Nullagine town water supply

Nullagine Water Reserve drinking water source protection review

Nullagine town water supply

Department of Water and Environmental Regulation

Water resource protection series

Report no. 173

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Cover photograph: Aerial photo of Nullagine Water Reserve

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

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

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Summary

This report was prepared by the former Department of Water. On 1 July 2017, the Government of Western Australia established the Department of Water and Environmental Regulation, resulting from the amalgamation of the Department of Water, the Department of Environment Regulation and the Office of the Environmental Protection Authority. As such, this publication contains references to previous government departments and programs. Please email drinkingwater@dwer.wa.gov.au to clarify any specific information.

This drinking water source protection review considers changes that have occurred in and around the Nullagine Water Reserve since completion of the *Nullagine Water Reserve water source protection plan* (Water and Rivers Commission 1999). The plan still contains relevant information, so it is important that these documents are read in conjunction. Both are available on our website or by contacting us.

Nullagine is a small town located approximately 250 km south-east of Port Hedland between Marble Bar and Newman (Figure A1). It is a service town for the local tourism, mining and pastoral industries. The Irrungadji Aboriginal community is located just south of the town and is also serviced from the Nullagine Water Reserve (Figure A3).

We prepared this document in consultation with key stakeholders including mining tenement and Crown lease holders, Aboriginal representative groups, the Shire of East Pilbara, Water Corporation, Department of Health, former Department of Mines and Petroleum, former Department of Lands and former Department of Planning. No contentious issues were raised during these consultations.

The main changes since the 1999 plan are:

- A smaller Nullagine Water Reserve boundary is proposed based on current catchment modelling (Figure A2). This boundary will better reflect the principal catchment and recharge areas of the bores that supply drinking water, enhancing protection of Nullagine's public drinking water source.
- Town bore is now used for public water supply (historically used for irrigation purposes) in addition to production bores 6/92 and 7/92.
- Bores 7/87 and 1/91 are no longer used as production wells and are decommissioned.
- Two additional bores at Garden Pool (5/92 and 1/92) have been identified for potential future use.
- Well head protection zones (WHPZs) have been assigned around all current and potential production bores in the Nullagine Water Reserve (Figure A3).
- Water quality testing is now conducted on samples taken directly from the production bores and from various points post-abstraction. Monitoring from separate bores ceased in 2014.

This review is consistent with the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011), State planning policy no. 2.7: *Public drinking water*

source policy (Western Australian Planning Commission 2003) and Strategic policy: *Protecting public drinking water source areas in Western Australia* (Department of Water 2016a).

Important information about the Nullagine Water Reserve is shown in Table 1 below.

Table 1 Key information about the Nullagine Water Reserve

Nullagine Water Reserve	
Local government authority	Shire of East Pilbara
Location/s supplied	Nullagine and Irrungadji Aboriginal Community
Water service provider	Water Corporation
Aquifer type	Unconfined alluvial and sandstone fractured rock aquifers
Licensed abstraction	80 000 kL per year; 69 services
Number of bores	3 current production bores 2 bores for future use
Bore names and GPS coordinates	Bore 7/92 (E 206 183, N 7 582 787, zone 51) current bore Bore 6/92 (E 206 220, N 7 582 385, zone 51) current bore Town Bore (E 201 294, N 7 576 490, zone 51) current bore Bore 5/92 (E 198 633, N 7 573 877, zone 51) future use Bore 1/92 (E 198 905, N 7 573 452, zone 51) future use
Date/s of drinking water source protection reports	1999 – <i>Nullagine Water Reserve water source protection plan</i> (Water and Rivers Commission) 2017 – <i>Nullagine Water Reserve drinking water source protection review</i> published (this document)
Consultation	1999 – advertised public consultation as part of the water source protection plan 2015–16 – consultation with key stakeholders including mining tenement and Crown lease holders, Aboriginal representative groups, the Shire of East Pilbara, Water Corporation, Department of Health, Department of Mines and Petroleum, Department of Lands and Department of Planning; no contentious issues raised
Proclamation status	Proclaimed on 2 March 2001 under the <i>Country Areas Water Supply Act 1947</i> .

Nullagine Water Reserve	
	Proclamation of the 2016 proposed boundary will need to be progressed under the <i>Country Areas Water Supply Act 1947</i> when this report is finalised.
References	<p><i>Hydrogeology report 1992/39 Nullagine town water supply groundwater drilling investigation</i> (Davidson 1992)</p> <p><i>Nullagine Water Reserve water source protection plan</i> (Water and Rivers Commission 1999)</p> <p><i>Nullagine town water supply review</i> (Water Corporation 2000)</p> <p><i>Nullagine water resource management operating strategy</i> (Water Corporation 2012)</p> <p><i>Australian drinking water guidelines</i> (NHMRC & NRMMC 2011)</p> <p>State planning policy no. 2.7: <i>Public drinking water source policy</i> (Western Australian Planning Commission 2003)</p>

1 Review of Nullagine's drinking water source protection plan

1.1 Boundary, priority areas and protection zones

The Nullagine Water Reserve (Figure A2) was proclaimed in 2001 under the *Country Areas Water Supply Act 1947*. The Department of Water and Environmental Regulation plans to amend the existing boundary, making it smaller. We developed this new boundary (Figure A3) using catchment modelling techniques, so it will better protect the principal recharge areas for the existing production bores, and it will also protect areas that may be used for public water supply in the future. The boundary change will result in an extension of the original Nullagine Water Reserve boundary in the north-east and west and a reduction in the north-west and south (Figure A2).

All land within the proposed Nullagine Water Reserve will be assigned a priority 1 (P1) area except for the town site, which will remain as priority 3 (P3). P1 areas are defined and managed to ensure there is no degradation of the water source with the objective of risk avoidance. P1 areas typically include Crown land. P3 areas are defined and managed to maintain the quality of the drinking water source with the objective of risk management. These generally occur over land zoned for urban, commercial and light industrial use.

Wellhead protection zones (WHPZs) will be placed around all current production bores and the potential future production bores at Garden Pool, protecting all water supply options for the town. WHPZs are defined in the immediate vicinity of drinking water extraction points as these areas are the most vulnerable to contamination. WHPZs in P1 areas will have a 500 m radius. The Town Bore, in the P3 area, will have a 300 m radius (Figure A3).

The boundary, priority areas and protection zones above have been determined in accordance with current departmental policy (Department of Water 2016a).

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

1.2 Update on water supply scheme

The Nullagine water supply scheme is run remotely from Port Hedland. Water Corporation staff visit fortnightly for maintenance and other service requirements. A local custodian has been employed by Water Corporation to oversee the day-to-day operations. The former Department of Water issued Groundwater licence 65335 to the Water Corporation to draw 80 000 kL of water per year from the Pilbara Groundwater Area to supply drinking water to Nullagine. This scheme supplies 69 services.

There have been some infrastructure changes to the Nullagine scheme since the 1999 plan. Bores 1/91 and 7/87 are no longer used and are decommissioned. The

Nullagine bore field now consists of three current production wells used to supply drinking water to Nullagine; Bore 7/92, 6/92 and Town Bore (Figure A3). Bores 5/92 and 1/92 near Garden Pool have been identified for possible future water supply, so they will also be protected. These bores have provided a reliable source of water to mining companies in recent years and are therefore considered to be a viable source of drinking water in the future. However, at this stage, there is no infrastructure in place to transport water abstracted from these bores to the treatment plant and storage tanks in town.

Water abstracted from the Nullagine Water Reserve production bores undergoes chlorination at the Town Bore Water Treatment Plant. The Town Bore also has a small sock filter on its outlet to counteract turbidity. Treated water is then pumped to two 225 kL storage tanks after which it is gravity fed to serviced residences. When the storage tanks are refilled, residents may receive reticulated water supply directly from the water treatment plant. Source water is monitored directly from the production bores and at various points post-abstraction.

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

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

1.3 Aboriginal sites of significance and native title claims

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

There are six Aboriginal sites of significance within the Nullagine Water Reserve. These are Irrungadji (P06327), Nullagine Burial 1 (P06133), Nullagine Burial 2 (P06134), Cajuput Creek (P00183), Nullagine Engraving 1 (P07358) and Nullagine Binmal (P00184).

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

There are two native title claims within the Nullagine Water Reserve. These are Njamal (WAD6028_1998) and Palyku (WAD6287/1998).

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

1.4 Enforcing by-laws, surveying the area and maintenance

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

- erecting and maintaining signs to protect and identify this water source and its infrastructure
- maintaining security and fencing around bores
- ongoing regular surveillance and inspections.

1.5 Other departmental work

Other department projects that incorporate management of water in the Nullagine area include:

- *Pilbara regional water plan 2010–2030* (Department of Water 2010); sets strategic direction for managing and developing the Pilbara region's water resources
- *Pilbara regional water supply strategy A long term outlook of water demand and supply* (Department of Water 2013a); identifies medium- and long-term water resources across the Pilbara
- *Pilbara groundwater allocation plan* (Department of Water 2013b); sets out how the department will manage groundwater in the Pilbara through allocation limits, water licensing and ongoing monitoring and evaluation over the next seven years or longer.

These documents are referenced at the end of this document and are available on the department's website www.dwer.wa.gov.au.

1.6 Update on water quality risks

As part of this review, the department conducted a new assessment of water quality contamination risks in the Nullagine Water Reserve, in accordance with the ADWG. Table 2 shows risks to groundwater quality from land uses within the proposed Nullagine Water Reserve.

The proposed and existing Nullagine Water Reserves have similar land tenure and land uses within them and therefore have similar risks to water quality. These include

risks from the town site and from mining, roads, pastoral leases, tourism, recreational activities and fossicking.

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.

1.6.1 Other groundwater bores

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

It is therefore important to ensure that any bores are appropriately located and constructed to prevent contamination of the public drinking water source. This will be assessed through 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).

There are currently four other licensed groundwater users within the Nullagine Water Reserve, all associated with mining operations.

Bores used for domestic and/or stock watering purposes, which do not require a licence, may be present on other lots throughout the reserve, including the Bonney Downs pastoral station.

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
Landfill site	Chemicals, nutrients, pathogens and hydrocarbons from waste leachate into groundwater and/or offsite via stormwater runoff.	Medium	<p>In P1 area, close to Nullagine River but downstream of Town Bore.</p> <p>Licensed by Department of Water and Environmental Regulation.</p> <p>Unauthorised access and illegal dumping of (mainly) domestic and septage waste has been a problem. Local government is taking steps to address this.</p> <p>Unlined/uncapped cells and inadequate stormwater containment have been noted in the past.</p>	<p>WQPN no. 24: <i>Land filling with inert materials</i></p> <p>WQPN no. 30: <i>Groundwater monitoring bores</i></p> <p>WQPN no. 111: <i>Landfills for disposal of putrescible waste</i></p>
<p>Swimming in the Nullagine River</p> <p>Fossicking</p> <p>Camping</p>	<p>Pathogens from direct body contact with water.</p> <p>Nutrients and pathogens from human and animal waste.</p> <p>Hydrocarbons from vehicle use.</p>	Medium	Particular concern in WHPZs, especially around Town Bore which is very shallow.	<p>Signage and education of locals and tourists</p> <p>Operational policy 13: <i>Recreation within public drinking water source areas on crown land</i> (Department of Water 2013)</p>

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
Mining activities	<p>Pathogens and nutrients from human waste.</p> <p>Hydrocarbons from vehicle use, fuel storage and spills.</p> <p>Chemicals from onsite use, leaks and spills.</p>	High	<p>Mining occurs over P1 land, with tenements covering a large proportion of the reserve.</p> <p>A large mine operation is planned to the north-west of town, close to Town Bore and the river.</p> <p>The mine and processing plant south of the reserve is no longer part of the proposed Nullagine Water Reserve.</p>	<i>Water quality protection guidelines no. 1–11</i>
Nullagine dam(s)	<p>Water may become polluted from mining and recreational activity (pathogens, hydrocarbons and chemicals).</p> <p>Contaminated water may leak into the environment if the dam structure is damaged or overflows.</p>	Low	There are two artificial water impoundments about 2 km north of town which collect catchment rainfall and runoff, used for mining and recreation since the 1980s. These dams are inland from the Nullagine River, downstream of Town Bore.	<p>Operational policy 13: <i>Recreation within public drinking water source areas on crown land</i> (Department of Water 2013)</p> <p><i>Water quality protection guidelines no. 1–11</i></p>
Town site, including: roadhouse, local school, water treatment plant,	<p>Pathogens and nutrients from domestic waste and septic tanks.</p> <p>Hydrocarbons from vehicle use, storage and spills.</p>	Medium	<p>P3 area with objective of pollution risk management.</p> <p>Close to river and Town Bore. A 300 m WHPZ has been assigned around Town Bore for extra</p>	Refer to specific land use in WQPN no. 25: <i>Land use compatibility tables for public drinking water source areas</i>

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
caravan park, mechanical servicing, works depot, motel and workers' accommodation, housing, Irrungadji Aboriginal community	Herbicides and chemicals from leaks, spills and normal use.		protection. Town Bore is in a very shallow aquifer. Old power station has closed and is listed as a 'contaminated – restricted use site' by former Department of Environment Regulation.	Circular no: PSC88: <i>Use of herbicides in water catchment areas</i>
Roads	Hydrocarbon and chemicals from vehicles and their loads. Herbicides for road maintenance.	Medium	Major and minor roads pass through the reserve, including the WHPZ around the Town Bore.	WQPN no. 44: <i>Roads near sensitive water resources</i> WQPN no. 10: <i>Contaminant spills – emergency response</i> Circular no: PSC88: <i>Use of herbicides in water catchment areas</i>
Bonney Downs pastoral station	Pathogens and nutrients from stock and human waste.	Medium	P1 area with objective of pollution risk avoidance. Extensive grazing with low stocking rates, but stock may have access to the river and WHPZ (excluding Town Bore).	WQPN no. 35: <i>Pastoral activities within rangelands</i>

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance ¹
Water bores and treatment plant	<p>Chemicals (chlorine) and hydrocarbons at water treatment plant.</p> <p>Hydrocarbons (diesel) storage at bore sites out of town.</p> <p>Herbicides for weed control.</p>	Medium	<p>Bores are adequately banded but frequent checking is required to identify any leaks.</p> <p>Town Bore is electrified.</p> <p>History of burst water pipes at bores 6/92 and 7/92.</p>	<p>WQPN no. 56: <i>Tanks for elevated chemical storage</i></p> <p>WQPN no. 65 <i>Toxic and hazardous substances: storage and use</i></p> <p>Circular no: PSC88: <i>Use of herbicides in water catchment areas</i></p>
Solar–diesel hybrid power station	<p>Hydrocarbons and chemicals from power production and storage.</p> <p>Pathogens and nutrients from onsite contractor facilities, including overnight facilities.</p>	Medium	<p>P1 area with objective of risk avoidance.</p> <p>Supplies electricity to town.</p> <p>Large amounts of diesel stored on site mainly in above ground storage tanks (two 70 000 kL tanks).</p>	<p>WQPN no. 56: <i>Tanks for elevated chemical storage</i></p> <p>WQPN no. 65 <i>Toxic and hazardous substances: storage and use</i></p>

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

1.7 Water quality information

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

Elevated levels of salts and hardness have been detected in the raw water at times. These are naturally occurring in the environment and treatment will mitigate this. No exceedances of health guidelines were present in the raw water. All reticulated water supplied to Nullagine conformed to the ADWG.

2 Implementation of Nullagine's drinking water source protection plan

2.1 Status of previous recommendations

Table 3 outlines recommendations from the 1999 plan and their current status.

Table 3 Implementation status for Nullagine Water Reserve

No.	Recommendation	Comments
1	Gazettal of water reserve.	Gazetted on 2 March 2001 under the <i>Country Areas Water Supply Act 1947</i> . An amendment to proclaim the proposed Nullagine Water Reserve is required (section 2.2; recommendation no. 1).
2	Incorporation into land planning strategies.	The Nullagine Water Reserve is included as a Special Control Area in the <i>Shire of East Pilbara's Town Planning Scheme no. 4, 2005</i> . The town planning scheme will need to be updated to include the new boundary (section 2.2; recommendation 2).
3	Referral of development proposals: <ul style="list-style-type: none"> • Department of Water and Environmental Regulation (formerly Department of Water and Water and Rivers Commission) to provide the Shire of East Pilbara with guidelines for referral of development proposals. • Referral of development proposals. 	Guidelines have been provided through the department's WQPN series. Development proposals within the Nullagine Water Reserve are referred to the North West Region office of the Department of Water and Environmental Regulation. This has been continued (section 2.2; recommendation no. 2).
4	Erection of signs: <ul style="list-style-type: none"> • Development of guidelines for signage. • Determine number and location of signs required. • Erect signs. 	Signs advising on the location of the Nullagine Water Reserve have been erected. Sign locations will need to be updated to correctly identify the amended Nullagine Water Reserve boundary once proclaimed (section 2.2; recommendation no. 5).

No.	Recommendation	Comments
5	<p>Emergency response via Westplan–HAZMAT:</p> <ul style="list-style-type: none"> • Ensure emergency personnel are aware of the Nullagine Water Reserve and are aware of special considerations in a PDWSA. • Shire of East Pilbara Local Emergency Management Committee. 	<p>Emergency protocol is in place and managed by the Shire of East Pilbara Local Emergency Advisory Committee through the Karratha Emergency Management District.</p> <p>This recommendation has continued (section 2.2; recommendation no. 4).</p>
6	<p>Surveillance program:</p> <ul style="list-style-type: none"> • Develop guidelines for the surveillance of water reserves. • Implement the surveillance program. 	<p>Water Corporation has developed and implemented a surveillance program. Operators visit every two weeks for maintenance and other service requirements. A local custodian has been employed by Water Corporation to oversee the day-to-day operations.</p> <p>This recommendation has continued (section 2.2; recommendation no. 6).</p>
7	<p>Nullagine tip:</p> <ul style="list-style-type: none"> • Water quality impacts investigated. • Line with impervious material. 	<p>Some water quality investigations have occurred and should continue as per Department of Water and Environment Regulation licence conditions.</p> <p>A management plan has been developed by the shire to address dumping of unauthorised waste.</p> <p>The tip may qualify as a contaminated site if it is not lined.</p> <p>This recommendation has been continued (section 2.2; recommendation no. 7).</p>
8.	<p>Old cyanide leach pad:</p> <ul style="list-style-type: none"> • Rehabilitate. • Remove chemicals stored on-site. 	<p>Some ore has been reprocessed in small mining operations but largely not rehabilitated.</p> <p>Potential to be rehabilitated and/or be re-used in future mining operations or through the Mining Rehabilitation Fund.</p> <p>Chemicals are no longer stored on-site but residual chemicals within heap may leach or travel off-site due to lack of stormwater containment.</p>

No.	Recommendation	Comments
9.	Fuel storage tanks at Conglomerate Hotel and Nullagine Roadhouse to be upgraded to Department of Water and Environmental Regulation (formerly Water and Rivers Commission) guidelines.	The status of this recommendation is unknown because no confirmation has been received. This will continue as a new recommendation of this review (section 2.2; recommendation no. 8)
10.	Shire of East Pilbara depot: <ul style="list-style-type: none"> • Bund to be upgraded to meet WRC guidelines. 	The 15 000 kL diesel storage tank bunding has been upgraded.
11.	Power station site: <ul style="list-style-type: none"> • Contaminated soils to be removed. • Bunding assessed. 	<p>The power station was closed in 2001.</p> <p>Horizon Power is not required to remove contaminated soil from the power station site during future decommissioning/demolition works. The former Department of Environment Regulation confirmed 'no further action in relation to contamination at this site is required provided that the restrictions on use of the site are adhered to'.</p> <p>Horizon Power is planning to relinquish the management order for this site, and a new management order will likely be re-issued to the Shire of East Pilbara for future use as a depot.</p>
12.	Production bores: <ul style="list-style-type: none"> • Contaminated soil to be removed. • Bunding assessed. • Pursue electrification of 1/91. 	<p>Contaminated soil was removed during Water Corporation's ongoing maintenance operations.</p> <p>Bunding appears adequate but should be inspected regularly.</p> <p>Bore 1/91 has been decommissioned.</p>
13.	Review of the plan and recommendations.	Undertaken through the preparation of this review document. A future review is recommended (section 2.2; recommendation 10.)

2.2 Consolidated recommendations

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

1. Amend the boundary of the Nullagine Water Reserve under the *Country Areas Water Supply Act 1947*. (Department of Water and Environmental Regulation)
2. Notify the Shire of East Pilbara to update their local planning scheme to reflect the amended boundary of the Nullagine Water Reserve (including its priority areas and protection zones) in accordance with the Western Australian Planning Commission's State planning policy no. 2.7: *Public drinking water source policy*. (Shire of East Pilbara)
3. Refer development proposals within the Nullagine Water Reserve that are inconsistent with WQPN no.25: *Land use compatibility tables for public drinking water source areas* or recommendations in this review to the department's North West office for advice. (Department of Planning, Lands and Heritage, Department of Mines, Industry Regulation and Safety, Shire of East Pilbara, proponents of proposals)
4. Ensure incidents covered by Westplan–HAZMAT in the Nullagine Water Reserve are addressed by ensuring that:
 - the Shire of East Pilbara local emergency management committee is aware of the new location and purpose of the Nullagine Water Reserve
 - the updated locality plan for the Nullagine 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 Nullagine Water Reserve
 - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a revised locality map of the Nullagine Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality.(Water Corporation)
5. Place or remove signs as necessary to adequately capture and advertise the amended Nullagine Water Reserve boundary to members of the public. Signs should be maintained to ensure they are clearly legible and should list an emergency contact telephone number. (Water Corporation)
6. Water Corporation should continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. (Water Corporation)
7. Continue investigation into water quality impacts from the Nullagine landfill and improve best management practices at the site. The site should be assessed

under contaminated site eligibility. (Shire of East Pilbara, Department of Water and Environmental Regulation)

8. Determine if the bunding at sites with bulk fuel storage tanks within the Nullagine Water Reserve is adequate including the Shire of East Pilbara depot, the Nullagine Roadhouse/Conglomerate Hotel, the solar–diesel electricity station and around production bores. Bunding should be inspected regularly and meet department’s best management practice guidelines. If not, tanks should be upgraded to these standards at the next available opportunity. (Site owners/managers, Water Corporation, Horizon Power, Department of Water and Environmental Regulation)
9. Update this review within seven years. (Department of Water and Environmental Regulation)

Appendices

Appendix A – Figures

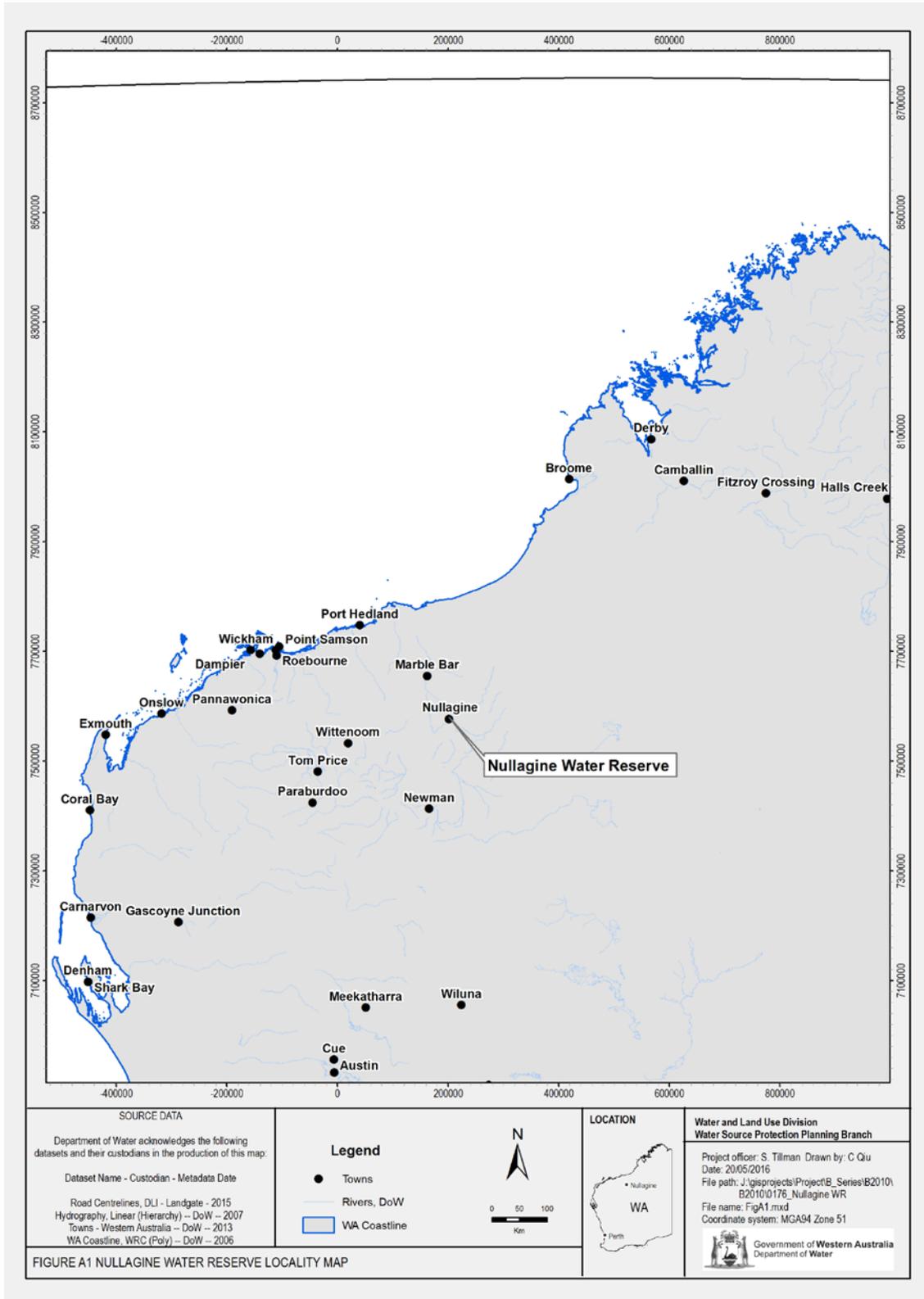


Figure A1 Nullagine Water Reserve locality map

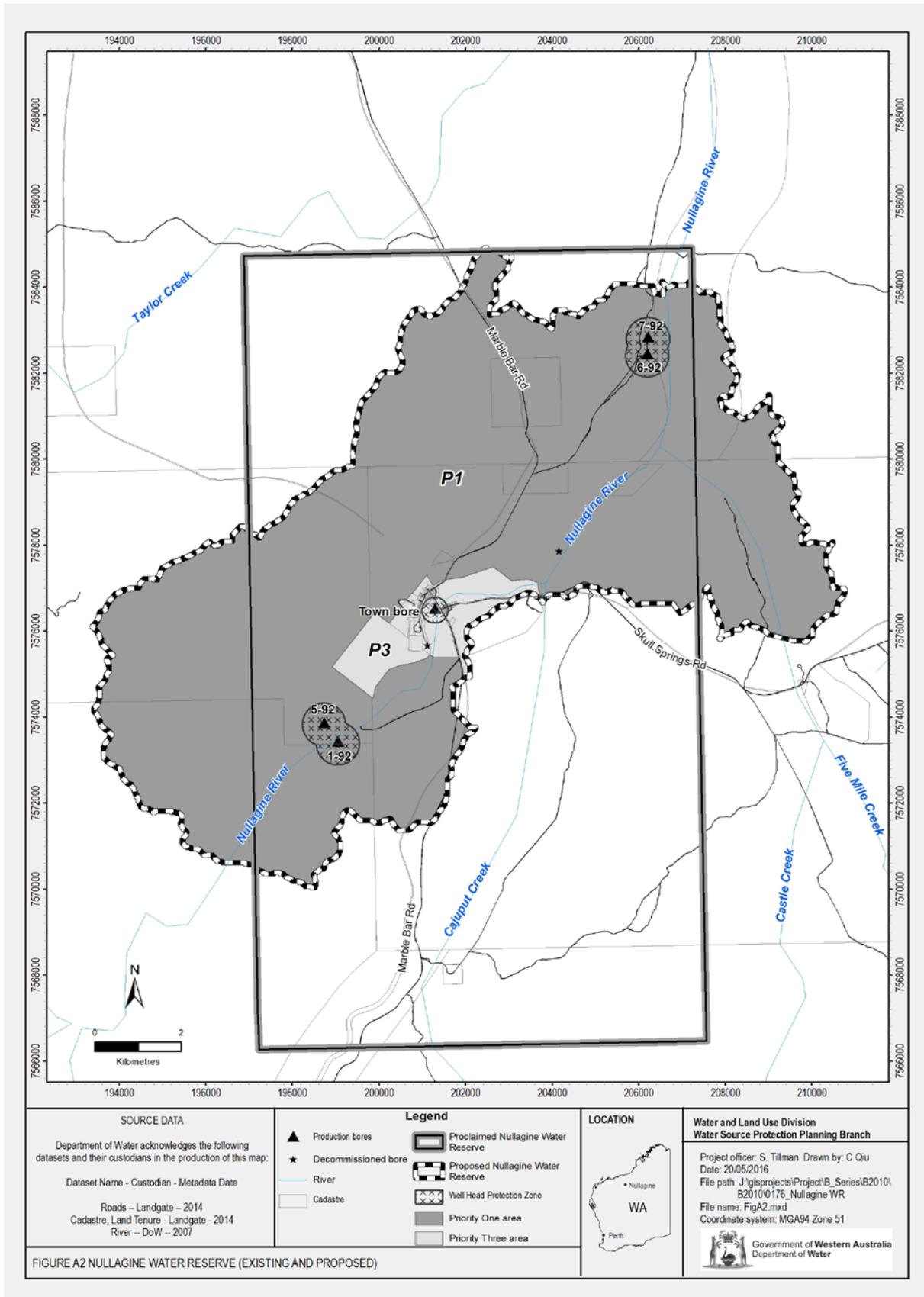


Figure A2 Nullagine Water Reserve (existing and proposed)

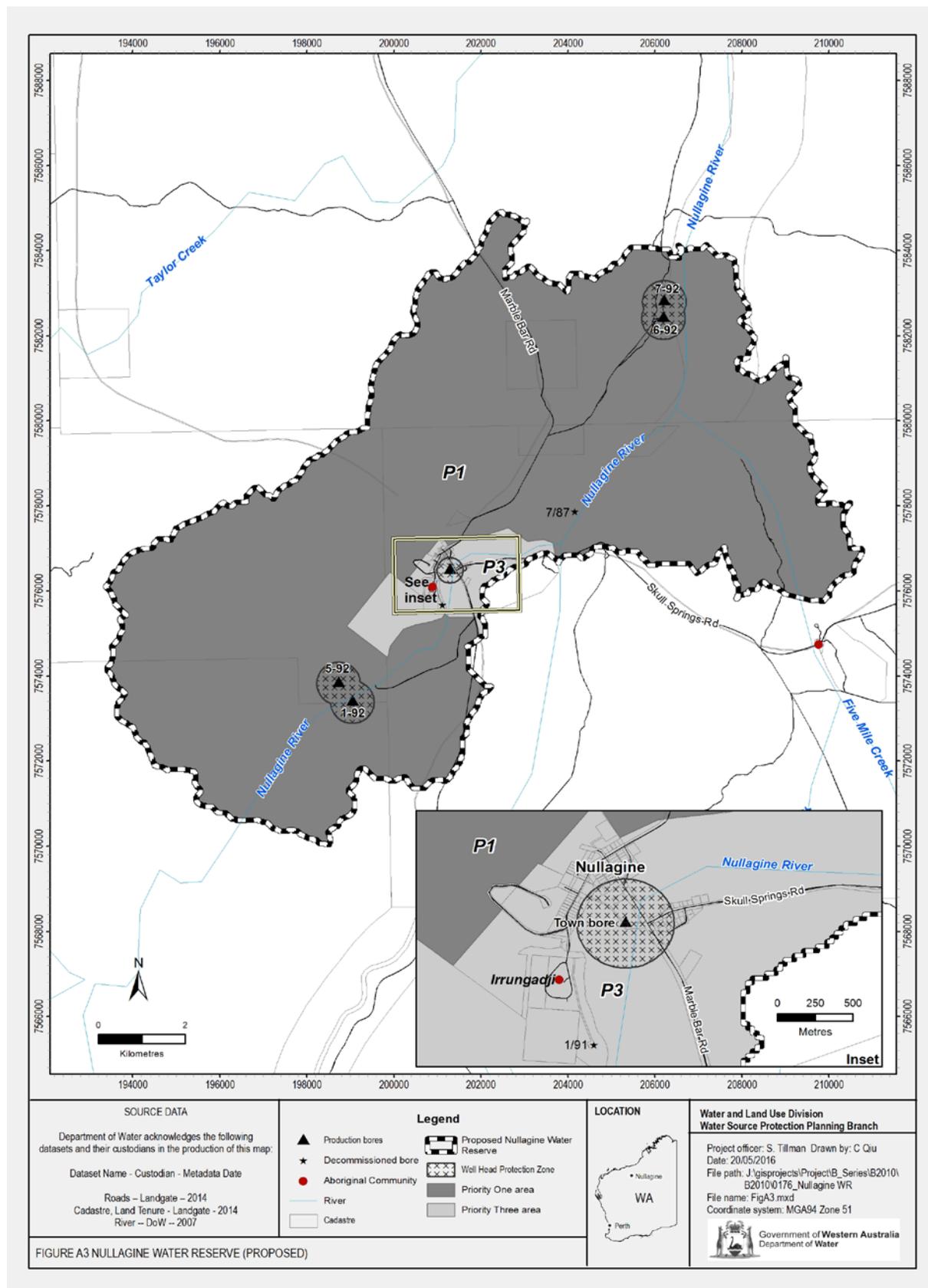


Figure A3 Nullagine Water Reserve (proposed) boundary, priority areas and protection zones

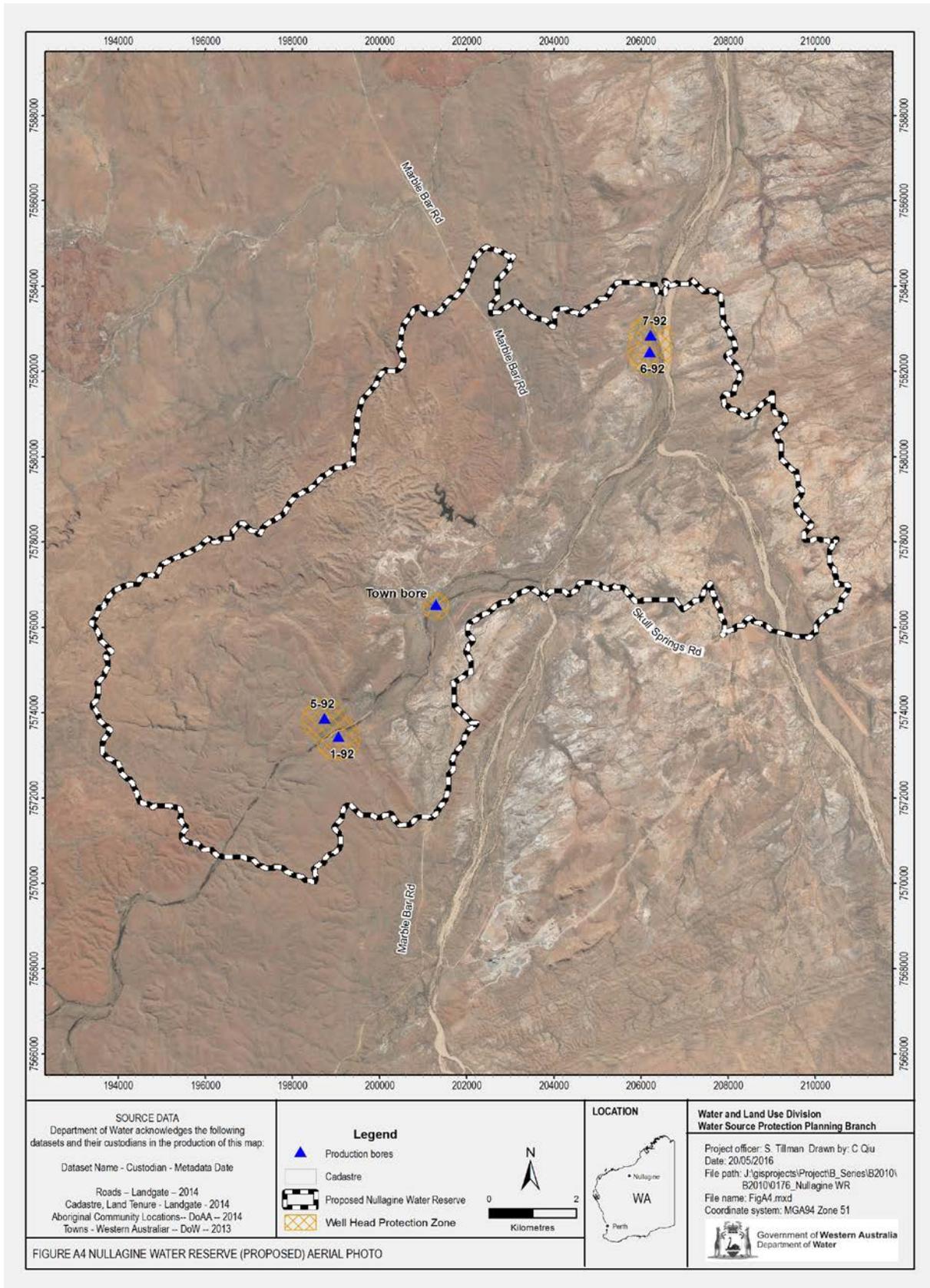


Figure A4 Nullagine Water Reserve (proposed) aerial photo

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

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

The following data represents the quality of raw water from Nullagine. 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 January 2011 to December 2015.

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

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

Aesthetic characteristics

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

Aesthetic detections for Nullagine

Parameter	Units	ADWG aesthetic guideline value*	Nullagine	
			Range	Median
Chloride	mg/L	250	44–100	75
Colour – true	TCU	15	<1–4	<1
Copper	mg/L	1	<0.002–0.07	0.004
Hardness as CaCO ₃	mg/L	200	110– 220	170
Iron unfiltered	mg/L	0.3	<0.003–0.035	<0.003
Manganese unfiltered	mg/L	0.1	<0.002 - <0.002	<0.002
Silicon as SiO ₂	mg/L	80	24–34	30
Sodium	mg/L	180	53–98	64
Sulfate	mg/L	250	36–64	50
Total filterable solids by summation	mg/L	600	433–555	491
Turbidity	NTU	5	<0.1–0.8	<0.1
pH measured in laboratory		8.5	6.96–7.64	7.29
Zinc	mg/L	3	<0.02–0.02	<0.02

* 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 Nullagine 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 Nullagine

Parameter	Units	ADWG health guideline value*	Nullagine	
			Range	Median
Barium	mg/L	2	0.007–0.012	0.009
Boron	mg/L	4	0.09–0.2	0.12
Fluoride	mg/L	1.5	0.3–0.7	0.45
Manganese unfiltered	mg/L	0.5	<0.002–<0.002	<0.002
Molybdenum	mg/L	0.05	<0.005–0.0018	0.0011
Nitrite plus nitrate as N	mg/L	11.29	<0.05–1.2	0.75
Selenium	mg/L	0.01	<0.003–0.004	<0.003
Sulfate	mg/L	500	36–64	50
Uranium	mg/L	0.017	<0.001–0.001	<0.001

* A health guideline value is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & NRMCC 2004).

† 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 Nullagine is currently conducted on a monthly basis. *Escherichia coli* counts are used as an indicator of the degree of recent faecal contamination of the raw water from warm-blooded animals.

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

During the reviewed period, positive *E. coli* counts were recorded in 7.8 per cent of samples. Of these, none had *E. coli* counts greater than 20 MPN/100mL.

Appendix C – Photographs



Figure C1 Drinking water signage along Marble Bar Highway in the Nullagine Water Reserve, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C2 A portion of Nullagine town site from a vantage point, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C3 Diesel storage at a Nullagine Water Reserve drinking water bore site, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C4 Nullagine Dam located in the Nullagine Water Reserve, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C5 An old cyanide heaped leach facility (mining) found in the Nullagine Water Reserve, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C6 A portion of the Nullagine River (not flowing) taken at a road crossing, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C7 Fenced drinking water storage tank along a gravel road in the Nullagine Water Reserve, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C8 Nullagine Tip exists within the Nullagine Water Reserve, photograph by N. Mantle, Department of Water and Environmental Regulation



Figure C9 The Nullagine Roadhouse (foreground) and Hotel in the (background) photograph by N. Mantle, Department of Water and Environmental Regulation

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 a 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 & NRMCC 2011). Contaminants can also interfere with water treatment processes, and damage water supply infrastructure (such as iron corroding pipes).

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

Some commonly seen contamination risks relevant to 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 & NRMCC 2011).

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

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

A number of pathogens are commonly known to contaminate water supplies worldwide. These include bacteria (for example *Salmonella*, *Escherichia coli* and cholera), protozoa (such as *Cryptosporidium* and *Giardia*) and viruses. Monitoring for

the presence of *E. coli* in water supplies provides an indication of the level of recent faecal contamination.

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

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

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

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

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

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

Physical risks

Turbidity is the result of soil or organic particles becoming suspended in water. Increased turbidity can result in cloudy or muddy-looking water, which is not aesthetically appealing to consumers. Turbidity can also reduce the effectiveness of treatment processes (such as disinfection). This is because pathogens and chemicals can attach onto soil particles, make them more difficult to remove during disinfection and treatment processes.

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

Chemical risks

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

Pesticides include agricultural chemicals used to control weeds (herbicides) and pests (insecticides, rodenticides, nematicides (for worms) and miticides (for mites)). Contamination of a drinking water source by pesticides (and other chemicals) may occur as a result of accidental spills, incorrect use or leakage from storage areas. In these cases, the relevant authorities should be notified promptly and the spill cleaned up to prevent contamination of the drinking water source.

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

Drinking water sources can also be contaminated by nutrients such as nitrogen and phosphorus. Nutrients can be introduced into a catchment via the application of fertiliser, 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 & NRMCC 2011).

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

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

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

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

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

The first and most important barrier is protecting the public drinking water source area (PDWSA) (the area from which water is captured to supply drinking water). If we get this barrier right, it has a flow-on effect that can result in a lower cost, safer drinking water supply. Other barriers against contamination include storage of water to help reduce contaminant levels, disinfecting the water (for example chlorination to inactivate pathogens), maintenance of pipes 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 and Environmental Regulation protects PDWSAs by implementing the ADWG, writing reports, policies and guidelines, and providing input into land use planning.

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

The *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* provide us with important tools to protect water quality in proclaimed PDWSAs. These Acts allow us to assess and manage the water quality contamination risks from different land uses and activities. The department works

cooperatively with other agencies and the community to implement this legislation and develop drinking water source protection reports. For example, the Western Australian Planning Commission 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's Water quality protection note (WQPN) no. 25: *Land use compatibility in PDWSAs* outlines appropriate development and activities within each of the priority areas (P1, P2 and P3). With 129 proclaimed PDWSAs across Western Australia, the department prioritises the update of drinking water source protection reports (such as this document). Our aim is to update each report every seven years. In some locations, more frequent updates may be required to address changing water quality risks and land uses. These updates allow us to make changes to the PDWSA boundary, priority areas and protection zones if required. They also allow solutions to new water quality risks to be considered.

There are three different types of drinking water source protection 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 former 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 www.dwer.wa.gov.au. You can also contact the Department of Water and Environmental Regulation's Water source protection planning branch on +61 8 6364 7600 or email drinkingwater@dwer.wa.gov.au.

Drinking water source protection reports

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 risk prevention-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, an assessment based on preventing risk that considers both the maximum and residual risks is required. This means that in some cases, the maximum risks from land uses will still be considered unacceptable, even after mitigation has reduced the risk. This is a more conservative approach needed to protect the health of consumers.

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

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

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

For example, just because a drinking water contamination incident has not occurred for many years (low likelihood) does not mean that the risk is low, 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	<i>Australian drinking water guidelines</i>
ANZECC	Australian and New Zealand Environment Conservation Council
MPN	most probable number
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NTU	nephelometric turbidity units
P1, P2, P3	priority 1, priority 2, priority 3
PSC 88	Public sector circular number 88
PDWSA	public drinking water source area
TCU	true colour units
Westplan– HAZMAT	Western Australian plan for hazardous materials
WHPZ	wellhead protection zone
WQPN	water quality protection note

Units of measurement

mg/L	milligram per litre
km	kilometre

Volumes of water

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

Glossary

Abstraction	The pumping of groundwater from an aquifer, or the removal of water from a waterway or water body.
Aesthetic guideline value	The concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer, for example appearance, taste and odour (NHMRC & NRMCC 2011).
Allocation	The volume of water that a licensee is permitted to abstract, usually specified in kilolitres per annum (kL/a).
Aquifer	A geological formation or group of formations able to receive, store and transmit significant quantities of water.
Australian drinking water guidelines	The <i>National water quality management strategy: Australian drinking water guidelines 6, 2011</i> (NHMRC & NRMCC 2011) (ADWG) outlines acceptable criteria for the quality of drinking water in Australia (see <i>References</i>).
Bore	A narrow, lined hole drilled into the ground to monitor or draw groundwater (also called a well).
Bore field	A group of bores to monitor or withdraw groundwater (also see <i>wellfield</i>).
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
Contamination	A substance present at concentrations exceeding background levels that presents – or has the potential to present – a risk of harm to human health, the environment, water resources or any environmental value.
Dissipate	To become scattered or dispersed.
Drinking water source protection report	A report on water quality hazards and risk levels within a public drinking water source area; includes recommendations to avoid, minimise, or manage those risks for the protection of the water supply in the provision of safe drinking water supply.
Fractured rock aquifer	An aquifer where groundwater is present in the fractures, joints, solution cavities, bedding planes and zones of rocks. Fractured rock aquifers are highly susceptible to contamination from land uses when aquifers crop-out or sub-crop close to the land surface.

Health guideline value	The concentration or measure of a water quality characteristic that, based on current knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & NRMCC 2011).
Hydrocarbons	A class of compounds containing only hydrogen and carbon, such as methane, ethylene, acetylene and benzene. Fossil fuels such as oil, petroleum and natural gas all contain hydrocarbons.
Hydrogeology	The branch of geology that deals with the occurrence, distribution and effects of groundwater. It is the study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Hydrology	The science dealing with water on the land, including such things as its properties, laws and geographical distribution.
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 measurement of something (such as salinity) in a solution, i.e. 0.001 grams per litre.
Most probable number	MPN is statistical calculation used to estimate the number of viable microorganisms living in a test sample
Nephelometric turbidity units	A measure of turbidity in water.
Nutrients	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.
Pathogen	A disease-producing organism that can cause sickness and sometimes death through the consumption of water, including bacteria (such as <i>Escherichia coli</i>), protozoa (such as <i>Cryptosporidium</i> and <i>Giardia</i>) and viruses.
Pesticides	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
pH	A logarithmic scale for expressing the acidity or alkalinity of a solution. A pH below 7 indicates an acidic solution and above 7 indicates an alkaline solution.

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.
Porosity	The ratio of water (or air) filled pore spaces to the total volume of the rock or soil, expressed as a percentage or fraction.
Public drinking water source area	The area from which water is captured to supply drinking water. It includes all underground water pollution control areas, catchment areas and water reserves constituted under the <i>Metropolitan Water Supply, Sewerage, and Drainage Act 1909</i> or the <i>Country Areas Water Supply Act 1947</i> .
Priority 1, 2 and 3	Three different priority areas are assigned within PDWSAs to guide land use decisions. The objective of priority 1 (P1) areas is <i>risk avoidance</i> , priority 1 (P2) areas is <i>risk minimisation</i> and priority 3 (P3) areas is <i>risk management</i> .
Recharge	The action of water infiltrating through the soil/ground to replenish an aquifer.
Recharge area	An area through which water from a groundwater catchment percolates to replenish (recharge) an aquifer. An unconfined aquifer is recharged by rainfall throughout its distribution. Confined aquifers are recharged in specific areas where water leaks from overlying aquifers, or where the aquifer rises to meet the surface.
Runoff	Water that flows over the surface from a catchment area, including streams.
Scheme supply	Water diverted from a source or sources by a water authority or private company and supplied via a distribution network to customers for urban and industrial use or for irrigation.
Sedimentary rocks	Rocks that have been formed by the deposition of materials. Examples are limestone, sandstone and siltstone.
Sedimentary aquifer	Aquifers occurring in sedimentary rocks.
Semi-confined aquifer	A leaky aquifer, saturated and bounded above by a semi-permeable layer and below by a layer that is either impermeable or semi-permeable.
Stormwater	Rainwater that has runoff 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.
True colour units	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 where the upper boundary is the watertable and therefore is in contact with the atmosphere through the pore spaces in the unsaturated zone. Typically (but not always) it is the shallowest aquifer at a given location.
Water quality	Collective term for the physical, aesthetic, chemical and biological properties of water.
Water reserve	An area proclaimed under the <i>Country Areas Water Supply Act 1947</i> or the <i>Metropolitan Water Supply, Sewerage, and Drainage Act 1909</i> for the purposes of protecting a drinking water supply.
Watertable	The upper saturated level of the unconfined groundwater.
Wellfield	A group of bores located in the same area used to monitor or withdraw 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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