Narromine Water Supply System

WATER QUALITY
OPTIONS REPORT

Narromine Shire Council

November 2023

2.0

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Executive Summary

Project background

Narromine's drinking water is currently supplied from four bores. Prior to 2020 these were all shallow bores in the upper and lower quaternary aquifers connected to the Macquarie River between Dubbo and Narromine.

To increase the water supply, new deeper bores were drilled into the upper and lower tertiary aquifers. The water drawn from these bores was high in iron and manganese which consumed chlorine and caused dirty water. A temporary water treatment plant (WTP) was built in 2020 to remove the iron and manganese.

Narromine's raw water is sourced from groundwater, however the aquifer is not contained and potentially contaminated by:

- current and abandoned bores on private land that are not sealed,
- sewage treatment effluent including from onsite systems, and
- livestock grazing in catchment.

Narromine was assessed under the NSW Safe and Secure Water Risk Rating Framework as having a Level 5 risk score for water quality due to *Cryptosporidium* risk. The Integrated Water Cycle Management (IWCM) Strategy Issues Paper (PWA, 2023) identified there was a very high risk of chlorine resistant pathogens in the drinking water as there is currently no treatment barriers to control these pathogens.

Alternative water sources such as the Macquarie River are likely to have the same risks as the existing bores.

Additional treatment is therefore required to manage water quality risk and continue to supply safe water to Narromine.

Options assessment

The following options were assessed to improve Narromine's drinking water quality:

1. Conventional treatment with sedimentation lagoons
2. Conventional treatment with sedimentation tank and sludge lagoons
3. Conventional treatment with sedimentation tank and mechanical sludge dewatering
4. Upgrade existing temporary plant.

A triple bottom line methodology was used to assess the environmental, social and financial impacts of each option. This methodology aligns with NSW Government Integrated Water Cycle Management Information Sheet 2 (DOI, 2019)

Environmental assessment

All options are proposed to be located on the same site adjacent to the existing temporary plant. Option 1 has a footprint of 2.19 hectares compared with 1.6 hectares for Option 2, 0.88 hectares for Option 3 and 0.53 hectares for Option 4. The potential for impact on biodiversity, heritage and pollution on receiving environments is therefore greater for Options 1 and 2.

The earthen ponds used in Option 1 and 2 also have risks of leaks in the structure which may impact on the adjacent environment or groundwater.

Option 1 and 2 also require large amounts of imported fill and protrude into the adjacent wetland/stormwater management area. Option 4 utilises less power and chemicals than the other options.

Social assessment

The sedimentation lagoons in Option 1 offer little for optimisation by the operator. The performance of filtration as a barrier to chlorine resistant pathogens is improved by well performing upstream sedimentation. High filtered water turbidity will also reduce the effectiveness of downstream chlorine and ultraviolet disinfection processes. This option therefore has the highest risk of process failure causing reduced water quality or treatment capacity.

The ponds used in Options 1 and 2 are more at risk of contamination by intense or sustained wet weather compared with Options 3 and 4 which are above ground. Stormwater ingress to the ponds in Options 1 and 2 could compromise water quality or treatment capacity.

Options 1 and 2 utilise most of the available area at the proposed site and therefore any future upgrades to cater for unforeseen development would have a long lead time. Option 4 is a modular design that can be easily upgraded to increase capacity if required.

Financial assessment

A preliminary high level concept was developed for each options to prepare a high level estimate of the capital cost for each item. Operating and maintenance costs were based on NSC's current costs for electricity, current chemical rates and an allowance for maintenance.

Option 3 has the lowest capital cost while Option 4 has the lowest operation and maintenance costs. Option 4 has the lowest whole of life costs (present value) after 30 years and the additional capital investment over Option 3 is paid back in less than 10 years

Triple bottom line

The overall environmental and social scores and the present value were used to calculate and overall score and ranking for the options (see Table i-i).

Table i-i. Results from the triple bottom line assessment

Assessment	Option			
	1	2	3	4
Environmental	2.30	3.10	5.20	6.30
Social	2.80	4.40	5.80	7.20
Environmental & social score (ESS)	**5.10**	**7.50**	**11.00**	**13.50**
Total present value (PV)	**51.71**	**42.37**	**35.42**	**33.30**
ESS/PV	**0.10**	**0.18**	**0.31**	**0.41**
Ranking	**4**	**3**	**2**	**1**

Based on this assessment, Option 4 is preferred with lower costs and better outcomes for environmental and social factors.

Recommendation

Based on the options assessment, it is recommended that Option 4 be taken forward to concept design. This option consists of the following:

- Purchase of existing temporary WTP by NSC
- Upgrade of existing plant to a capacity to produce 7.5 ML/day in 20 hours operation
- Two new sedimentation tanks with a combined capacity of 7.5 ML/day
- Additional ozone disinfection and membrane filtration to provide the required log reduction values (LRV's)
- New clear water tank and high lift pump station
- Relocation of the existing chlorination system to the WTP site
- Sludge thickening and dewatering
- Detailed environmental assessment
- Approval under Section 60 of the *Local Government Act (NSW)* 1993.

Contents

Tables

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Glossary

Item	Detail
ACH	Aluminium chlorhydrate
ADWG	Australian Drinking Water Guidelines
C.t	Chlorine contact time multiplied by chlorine concentration
$CaCO_3$	Calcium carbonate
CCP	Critical Control Point
DALY	Disability Adjusted Life Years
DOI	Department of Industry
DPE	Department of Planning and Environment
DWMS	Drinking Water Management System
ESS	Environmental and Social Score
GAC	Granular Activated Carbon
GDE	Groundwater Dependent Ecosystems
HBT	Health Based Targets
HU	Hazen units (measure of colour)
ISO	International Organisation for Standardisation
IWCM	Integrated Water Resources Management
LOS	Levels of Service
LRV	log10 reduction value (1 LRV = 90% removal, 2 LRV = 99% removal. 3 LRV = 99.9% removal etc.)
LWU	Local Water Utility
mg	Milligram
ML	Megalitre
NHMRC	National Health and Medical Research Council
NPV	Net present value
NSC	Narromine Shire Council
NSW	New South Wales
NSW Health	NSW Ministry of Health
NTU	Nephelometric turbidity unit
PLC	Programmable Logic Controller
PV	Present Value
PWA	Public Works Advisory
SCADA	Supervisory Control and Data Acquisition
TEF	The Environmental Factor
TRB	Typical Residential Bill
UV	Ultraviolet
WTP	Water Treatment Plant

1 Introduction

1.1 Project background

Narromine Shire located in central NSW approximately 330 km north-west of Sydney and about 40 km west of Dubbo. The major urban centre in the Narromine Shire is the Narromine township, along with two other towns Trangie and Tomingley.

Narromine's drinking water is currently supplied by four bores. Bores 6, 8 and 9 receive treatment to remove iron and manganese before being combined with Bore 3 and chlorinated. Chlorination is currently the only validated disinfection barrier before distributed to customers. Prior to 2020 these were all shallow bores in the upper and lower quaternary and tertiary aquifers connected to the Macquarie River between Dubbo and Narromine.

To increase the water supply, new deeper bores were drilled into the upper and lower tertiary aquifers. The water drawn from these bores was high in iron and manganese which consumed chlorine and caused dirty water. A temporary water treatment plant was built in 2020 to remove the iron and manganese.

The raw water is sourced from groundwater, however the aquifer is not contained and is potentially contaminated by:

- current and abandoned bores on private land that are not sealed,
- sewage treatment effluent including from onsite systems, and
- livestock grazing in catchment.

Narromine was assessed under the NSW Safe and Secure Water Risk Rating Framework as having a Level 5 risk score for water quality due to *Cryptosporidium* risk. The Integrated Water Cycle Management (IWCM) Strategy Issues Paper (PWA, 2023) therefore identified there was a very high risk of chlorine resistant pathogens in the drinking water as there is currently no treatment barriers to control these pathogens.

Alternative water sources such as the Macquarie River are likely to have the similar water quality risks as the existing bores.

Additional treatment is therefore required to manage water quality risk and continue to supply safe water to Narromine.

1.2 Document purpose

The purpose of this report is to document the options assessment for water treatment to supply drinking water to the town of Narromine. The preferred option will need to meet NSW legislative requirements and the levels of service acceptable to the community.

1.3 Current Narromine water supply system

1.3.1 Catchment

Narromine Shire sits within the Macquarie – Bogan River Catchment, which is 74,800 km^2. This catchment provides water to around 180,000 people, and includes a number of major cities and towns, including Dubbo and Nyngan, and also provides water to some of the smaller towns such as Warren and Narromine. Land use in this catchment is dominated by grazing (82%), with dryland cropping accounting for the second highest level of land use (9%) (Narromine DWMS, 2018).

Narromine gets its water from bores that are drilled along the Lower Macquarie Alluvium sediments associated with ancient channels of the Macquarie River, downstream of Narromine. Water in the aquifer is part replenished by water that leaks from the river, or is pumped from the river and then seeps into the aquifer from irrigation channels and irrigated fields (Narromine DWMS, 2018)

Raw water characteristics of Narromine Water supply vary depending on which bore is being used. Typical characteristics include:

- neutral pH,
- variable turbidity (for a bore supply), and
- high iron and manganese.

1.3.2 Water treatment and distribution

Water extracted from Bores 6, 8D and 9 is processed through the temporary iron and manganese removal plant. This treated water is then combined with raw water from Bore 3 and chlorinated and distributed to customers.

The Narromine water supply systems are shown in Figure 1-1 and Figure 1-2.

Supply system changes in 2022 have included the installation of a temporary iron and manganese removal system to treat water from bore 6, 8 and 9. The plant was brought online for the first time in June 2020. It is owned and operated by an external contractor.

Table 1-1. Summary of water supply systems

Category	Description
Customers	1,718
Consumers	567 private dwellings (census 2016),7 Hotels/Motels, Caravan Park, 11 schools, 2 Hospitals, 3 Nursing Homes and 216 businesses (including industrial). Irrigation of parks and ovals by separate surface water licence for extraction from the Macquarie River. (Swan 2016)
Temporary iron and manganese removal plant	Temporary water treatment plant (WTP) (bore 6, 8D and 9 only) • ISO reactor (aeration, ozonation, pH correction with Sodium Hydroxide) • Green sand filtration • GAC filtration • Clarified backwash water recycled to head of works

Category	Description
Aeration & disinfection	The water supply is pumped into the aeration tank which is not currently operating but provides storage for high lift pumping. It is then pumped through duty/standby high lift pumps and flow paced disinfected with gaseous chlorine (Gas chlorine installed January 2018, previously Sodium Hypochlorite).
Reservoirs	Two 4.0 ML steel reservoirs, one on Nymagee St and the other on Duffy St both have top fill and bottom discharge. Reservoirs are interconnected through the rising main, with flow to Duffy St reservoir restricted to manage the flow to both reservoirs.
Critical control point (CCP) monitoring	Free & total chlorine, turbidity and pH are monitored through online instrumentation on the outlet of Duffy St and Nymagee St reservoirs. Free chlorine is also monitored by online instrumentation on the inlet to Nymagee St Reservoir.

Figure 1-1. Narromine water supply system flow diagram

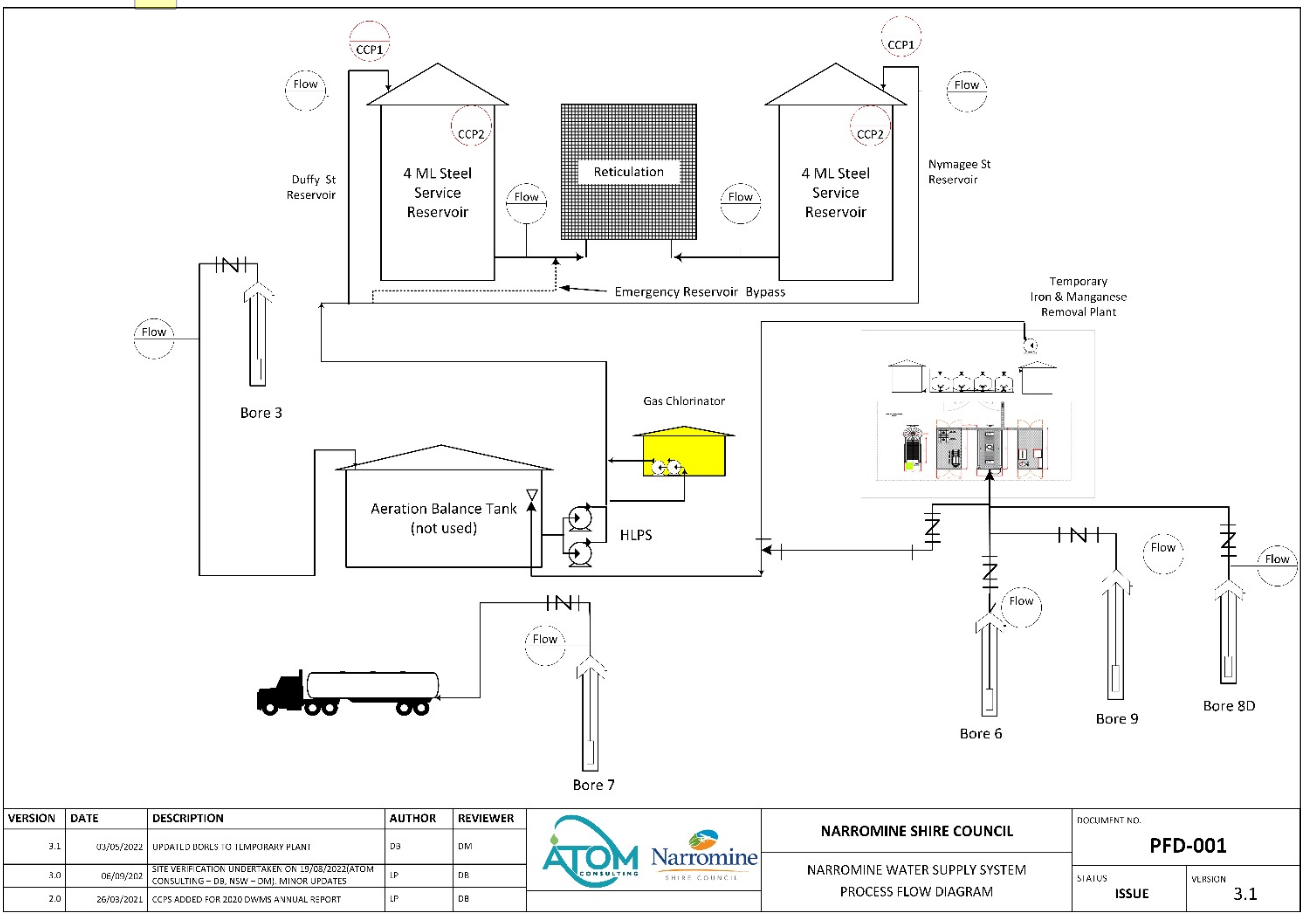
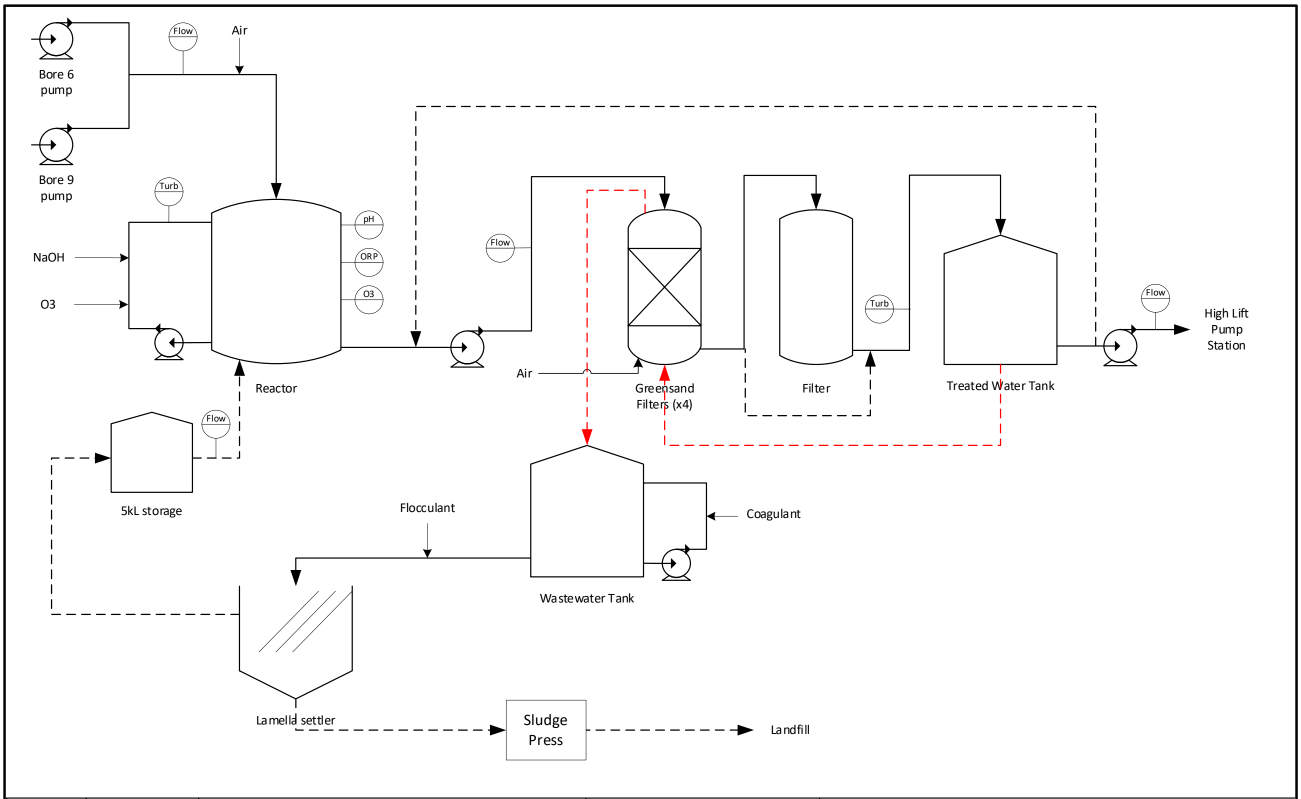


Figure 1-2. Narromine temporary WTP flow diagram



Version	Date	Details	Author	
1.0	06/09/2022	Developed from site drawings	ALM	Narromine temporary water treatment plant Process flow diagram

1.4 Integrated Water Cycle Management

The IWCM Strategy is a local water utility's (LWU) 30-year strategy for the provision of appropriate, affordable, cost-effective and sustainable urban water services that meet community needs and protect public health and the environment. The IWCM Strategy:

- Identifies the water supply and sewerage needs of LWU
- Appropriately sizes' any infrastructure projects and determines their priority, and considering of whole-of-life costs
- Identifies the lowest level of sustainable Typical Residential Bill (TRB) to meet the levels of service, while maintaining cost recovery
- Includes a 30-year Total Asset Management Plan and Financial Plan.

The process of preparing an IWCM Strategy broadly includes the following:

- Preparation of an IWCM Issues Paper
- Evaluation of feasible options
- Creation of IWCM Scenarios
- Developing the IWCM Strategy
- Preparation of a Total Asset Management Plan and Financial Plan
- Public exhibition
- Concurrence by Department of Planning and Environment (DPE) and adoption by Narromine Shire Council (NSC).

The IWCM Issues Paper (PWA, 2022) identified that water quality from the Narromine Water Supply System has a very high risk from chlorine resistant and chlorine sensitive pathogens. This was due to uncapped and failed bores adjacent to NSC's water supply bores.

This report assesses options to reduce the water quality risks in the Narromine Water Supply System.

1.5 Levels of Service

The levels of service for drinking water quality proposed in Table 6-1 of the IWCM Issues Paper (PWA, 2022) are shown in Table 1-2.

Table 1-2. Current levels of service

Objective	Service standard	Performance indicator	Target
Adequate potable water for current and future generations with reasonable level of restrictions	5/10/10 rule based on 99th percentile unrestricted future demand based on DPE Water's draft guidelines "Assuring future urban water security, Assessment and Adaption guidelines for NSW local water utilities"	Average duration of drought-related restrictions	Restrictions no more than 5% of time
		Frequency (average number) of drought-related Level 3 restrictions	Less than one event per 10 years
		Supply capacity during normal worst recorded drought demand	90% of normal demand
Protects public health	100% compliance with the Australian Drinking Water Guidelines (ADWG) for health-based parameter	Number of boil water alerts	Nil boiled water alerts per year
	Compliance with the Drinking Water Management System (DWMS)	DWMS – annual reviewed and regularly audited	100% compliance with annual review and audit
	100% compliance with critical control points (CCPs)	Number of CCP exceedances	Nil CCP critical limit exceedances per year
Aesthetically fit for purpose	95% compliance with the ADWG for aesthetic parameters	Discoloured water complaints	Zero complaints per year
		Complaints of taste (e.g. chlorine, palatability, hardness, staining of fitting/fixtures)	Zero complaints per year
		Complaints of odour	Zero complaints per year

Source: PWA, 2022

2 Regulatory context

2.1 NSW Public Health Act

The *Public Health Act 2010 (NSW)* s25 (1) requires all drinking water suppliers to establish, and adhere to, a quality assurance program that addresses the elements of the Framework for Management of Drinking Water Quality (as set out in the Australian Drinking Water Guidelines published by the National Health and Medical Research Council) that are relevant to the operations of the supplier of drinking water concerned. To assist suppliers in preparing the drinking water systems NSW Health and NSW Department of Primary Industries - Office of Water have published the NSW Guidelines for Drinking Water Management Systems (NSW Ministry of Health 2013).

The Public Health Regulation (NSW) was updated on 1 October 2018 to include specific DWMS aspects. The regulation requires (Clause 34B):

(i) an assessment of the risks to the drinking water supply system

(ii) an assessment of the maximum and residual risks to the drinking water supply system

(iii) identification of hazards to the drinking water supply system

(iv) measures to prevent any hazards to the drinking water supply system (preventive measures)

(v) actions to improve the drinking water supply system

(vi) management, if possible, of any risks to the drinking water supply system assessed (control points)

(vii) communication to staff about control points that are critical to the drinking water supply system and drinking water quality (critical control points).

2.2 NSW Local Government Act

The *Local Government Act 1993 (NSW)* s60 requires councils to gain approval prior to constructing or extending any water treatment works. NSC will therefore need to seek approval through DPE to construct any water treatment options recommended by this report.

2.3 Australian Drinking Water Guidelines

The ADWG is the authoritative document for drinking water management in Australia. It contains information about management of drinking water systems, monitoring regimes and contaminants that may be present in drinking water. As the knowledge base has increased, the document has grown in both detail and complexity. The guiding principles have been developed to outline fundamental considerations for safe drinking water:

- The greatest risks to consumers of drinking water are pathogenic microorganisms
- Protection of water sources and treatment are of paramount importance and must

never be compromised

- The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply
- Any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) should arouse suspicion that drinking water might become contaminated
- System operators must be able to respond quickly and effectively to adverse monitoring signals
- System operators must maintain a personal sense of responsibility and dedication to providing consumers with safe water and should never ignore a consumer complaint about water quality
- Ensuring drinking water safety and quality requires the application of a considered risk management approach.

2.3.1 Health based targets

The ADWG (NHMRC 2011 Version 3.8) was updated in September 2022 with guidance on microbial health-based targets (HBTs).

HBTs provide an assessment of enteric pathogen risks in the source water and inform appropriate risk management measures (barriers). These assessment and preventive measures support Elements 2 and 3 of the Framework.

The microbial health based target (HBT, expressed as log_{10} reduction values or LRVs) are based on meeting a 1×10^{-6} Disability Adjusted Life Years (DALYs) per person per year (pppy). DALYs provide a measure of the impacts of diseases and injuries in terms of loss of good health where 1 DALY represents one lost year of healthy life.

Shortfalls in achieving required treatment targets to manage source water pathogen risks should be used to prioritise improvements.

Vulnerability assessment and microbial indicator assessment is combined to give a classification of source water risk. A vulnerability assessment consists of identifying sources of pathogenic contamination within the water supply catchment and potential protection measures within the catchment. Source water catchment category classifications are shown in Table 1-2-1.

Table 1-2-1. Treatment targets given the source water type and *E. coli* results

Source water category (assessment)	Indicative source water category (vulnerability classification)	Maximum or 95th percentile *E. coli* results from raw water monitoring (number/100 mL) (band allocation)	Log reduction value (LRV) target to achieve 1x10^{-6} DALYs per person per year		
			Protozoa	Virus	Bacteria
Category 1	Surface water or groundwater under the influence of surface water, which is fully protected. or Secure groundwater	<20 (*E. coli* band 1)	0	0	4
Category 2	Surface water, or groundwater under the influence of surface water with moderate levels of protection	20 to 2000	3	4	4
Category 3	Surface water, or groundwater under the influence of surface water with poor levels of protection	20 to 2,000 (*E. coli* band 2)	4	5	5
Category 4	Unprotected surface water or groundwater under the influence of surface water that is unprotected	>2,000 to 20,000 (E. coli band 3)	5	6	6

Source: Table 5.5 of the ADWG, 2022

2.3.2 *Cryptosporidium* risk assessment

A *Cryptosporidium* risk assessment of the Narromine water supply was undertaken by NSW Health in 2020. This assessment gave the Narromine water supply system a preliminary risk rating of high based on the following:

- Stock in the catchment
- Sewage treatment plant and onsite sewerage systems in the catchment
- Shallow bores in unprotected aquifer.

The catchment has therefore been assessed as Category 4.

3 Water quality assessment

3.1 Review of water quality data

A detailed water quality review was undertaken as part of the Narromine Water Supply System Drinking Water Quality Risk Assessment Briefing Paper (Atom Consulting, 2022a).

A summary of the water quality issues identified during this review are shown in Table 3-1.

Table 3-1. Water quality issues summary

Parameter	Issues
Cryptosporidium	The Narromine water supply system has been assessed as high risk for *Cryptosporidium*. There are currently no treatment barriers for Cryptosporidium.
Iron and manganese	Raw water from bores 6,8and 9 have elevated levels of iron and manganese. Currently bores 6 and 9 are treated by the temporary WTP which uses ozone and filtration to remove iron and manganese. A sample collected from the Macquarie River on 2/11/2022 also had elevated manganese.
Lead	One sample from bore 6 on 2/11/2022 had a lead concentration of 0.013 mg/L which is above the ADWG guideline value of 0.01 mg/L
Free chlorine	Free chlorine in the reticulation is occasionally below the target of 0.5 mg/L (see **Error! Reference source not found.**). However there have been no instances since 2018 of free chlorine in the reticulation being recorded below the ADWG guideline of 0.2 mg/L
Turbidity	Reservoir turbidity is regularly above the ADWG guideline value for chlorination of 1 mg/L.
Hardness	Total hardness in the reticulation has been above the ADWG guideline value of 200 mg/L as CaCO3.

3.2 Water quality risk assessment

A water quality risk assessment for the Narromine water supply system was undertaken on 22 November 2022 and attended by representatives from NSC, DPE and NSW Health. The output paper from this workshop (Atom Consulting, 2022b), identified inherent and residual risk and proposed risk outlook following the implementation of the identified actions. The risks that relate to water quality are shown in Table 3-2. There are four events that have a residual risk of very high under the current water treatment barriers without any additional treatment.

Table 3-2. Summary of water quality risks

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health risk outlook following implementation of identified actions
Aquifer contamination by pathogens	Community illness from chlorine resistant pathogens	Health (ADWG)	Very high (5A)	Very high (5A)	High (5E)
	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)
	Community illness from *Naegleria fowleri*	Health (ADWG)	Moderate (3E)	Moderate (3E)	N/A
Aquifer contamination by chemicals	Chronic/acute health impacts from chemicals	Health (ADWG)	Very high (3A)	High (3C)	High (3C)
River contamination by pathogens	Community illness from chlorine resistant pathogens	Health (ADWG)	Very high (5A)	Very high (5A)	High (5E)
	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)
	Community illness from *Naegleria fowleri*	Health (ADWG)	Moderate (3E)	Moderate (3E)	N/A
River contamination by chemicals	Chronic/acute health impacts from chemicals	Health (ADWG)	Very high (3A)	High (3C)	High (3C)
Algal bloom in Macquarie River	Community illness from toxins	Health (ADWG)	Moderate (3D)	Moderate (3D)	Low (1D)

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health risk outlook following implementation of identified actions
	Aesthetic impacts at customers tap	Aesthetic (ADWG)	Very high (3A)	Moderate (3D)	Moderate (3D)
Water in service reservoirs has not had adequate C.t to achieve primary kill	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5D)	High (5E)	High (5E)
	Community illness from *Naegleria fowleri*	Health (ADWG)	Moderate (3E)	Moderate (3E)	N/A
Ineffective iron and Manganese removal	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very High (5A)	High (5E)	High (5E)
	Taste and odour complaints due to levels above ADWG limits	Aesthetic (ADWG)	Moderate (3E)	Moderate (3E)	N/A
Ineffective organic removal	Disinfection by-products above ADWG limits in customers water	Health (ADWG)	Very high (3A)	Very high (3A	High (3C)

3.3 Jar testing

Jar testing of the raw bore water and the Macquarie River was undertaken in September 2022. The purpose of this jar testing was to determine:

- if the water quality from each source could be treated with conventional processes
- the optimal coagulant and dose.

Samples were collected from each bore and the Macquarie River and jar testing undertaken on each source as well as blended sources. For all sources aluminium chlorhydrate (ACH) was found to be the optimal coagulant. The detailed results of the jar testing are shown in Appendix B and summarised in Table 3-3.

Table 3-3. Summary of jar testing results

Source	Raw turbidity (NTU)	Optimal ACH dose (mg/L)	Filtered turbidity (NTU)
Bore 3	0.3	25	<0.20
Bore 6	421	38	0.37
Bore 7	3.8	30	0.34
Bore 8	5.9	30	<0.20
Bore 9	3.7	25	0.34
River	38.2	25	0.49
All bores (20% each)	23.0	38	0.37
River 60%, Bore 3 40%	32.9	32	0.17
River 40%, Bore 3 60%	16.4	38	0.16

All source waters were able to achieve a filtered water turbidity of less than 0.5 NTU with an ACH dose of between 25 and 38 mg/L and settling time of 20 to 30 minutes.

To consistently achieve filtered water turbidity less than 0.2 NTU, coagulant aid polymer may be required. There is also some uncertainty of the river water quality as laboratory analysis was only available for one sample. It is therefore recommended that further jar testing be undertaken during the concept design phase to assess the performance of polymer dosing and using Macquarie River samples during different river conditions.

4 Water treatment options

4.1 Treatment requirements

The treatment options are required to meet the levels of service described in Table 1-2. Further details on the treatment requirements to achieve these levels of service is provided in the following sections.

4.1.1 Production requirements

The IWCM Issues Paper (PWA, 2022) Table 8-14 provides peak day demand for the Narromine water supply scheme. This demand peaks at 7.5 ML/day in 2042 and this has been used for the peak capacity of the water treatment options. As the minimum daily demand is currently around 2.5 ML/day, the treatment options will also need to be capable of being turned down to achieve this production without frequent starting and stopping. The treatment options must be capable of achieving the treated water quality described in Section 4.1.2 over the full range of flows.

4.1.2 Quality requirements

Health requirements

As a minimum the treatment options must meet the health requirements from the ADWG and NSW Health. As discussed in Section 2.3, the current source water has been assessed as Category 4. If water is sourced from the Macquarie River the combined source water will be Category 4. The overall treatment process therefore needs to achieve LRVs of 5.0 for protozoa, 6.0 for viruses and 6.0 for bacteria.

As the maximum LRV from each treatment process type is 4.0, at least two treatment barriers are required for each pathogen type.

All treatment options will include filtration and chlorination. The LRV requirement for other processes is shown in Table 4-1. The LRVs for filtration and chlorination were sourced from ADWG Table 5.6.

Table 4-1. Treatment option log removal requirements

Treatment process	Log reduction values		
	Protozoa	Viruses	Bacteria
Filtration	4.0	0	4.0
Chlorination	0	4.0	4.0
Total	**4.0**	**4.0**	**8.0**
Category 4 requirement	5.0	6.0	6.0
Shortfall (to be addressed by other processes)	1.0	2.0	0

To achieve a log reduction of 4.0 for protozoa, filters need to be operated to achieve turbidity of less than 0.2 NTU 95% of the time (ADWG). Similarly, chlorination should be operated at a C.t of at least 15 mg.min/L with a turbidity of less than 1 NTU at the point of disinfection (NSW Health).

The mandatory requirements for treatment to ensure drinking water achieves the minimum health requirements is shown in Table 4-2.

Table 4-2. Minimum treatment requirements for health

Location	Parameter	Requirement
Filtered water	Turbidity	<0.2 NTU 95% of the time Always <0.5 NTU
Chlorination	Turbidity	<1 NTU
	pH	<8.0
	C.t	> 15 mg.min/L
Reticulation	Free chlorine	>0.2 mg/L
	Manganese	<0.5 mg/L

Aesthetic requirements

In addition to the health requirements, the ADWG recommends aesthetic limits. Treated water quality outside these parameters can result in dirty water or taste and odour experienced by customers. The key aesthetic parameters for Narromine are shown in Table 4-3.

In addition, the treated water should not be corrosive or scale forming.

Table 4-3. Aesthetic water quality requirements

Parameter	Units	Requirement
Dissolved oxygen	% saturation	>85
Hardness	mg/L as $CaCO_3$	<200
pH	-	6.5 to 8.5
Total chlorine	mg/L	<5
Total iron	mg/L	<0.05[1]
Total manganese	mg/L	<0.02[1]
True colour	Hazen units (HU)	<15
Turbidity	NTU	<5

Source: ADWG (except 1 WaterRA 2020)

Raw water quality envelope

The design the new WTP was based on the peak raw water quality measured in samples collected during September 2022. The operational cost (e.g. chemical dosing) was based an equal blend of Bores 3, 6, 7, 8 and 9. The raw water quality envelope is shown in Table 4-4

Table 4-4. Raw water quality envelope

Parameter	Units	Average	Worst case
Alkalinity	mg/L as CaCO3	150	130

Parameter	Units	Average	Worst case
pH	-	7.7	7.0 to 8.0
Turbidity	NTU	23	420
True colour	HU	50	500
Iron (soluble)	mg/L	0.3	1.6
Manganese (soluble)	mg/L	0.2	0.4

4.2 Options assessment

4.2.1 Treatment options

The treatment options that have been assessed for meeting the water quality targets in Section 4.1 are outlined in the following sections.

All options will require a review of the CCPs to include the new barriers to pathogens and approval under Section 60 of the *Local Government Act (NSW)* 1993.

Option 1 – Conventional treatment with sedimentation lagoons

This option includes the following processes:

- Potassium permanganate dosing
- Coagulant and soda ash dosing
- Sedimentation lagoons
- Settled water pump station
- Pressure sand filters
- Ultraviolet (UV) disinfection
- Chlorination (relocated from existing high lift pump site)
- Clear water tank
- High lift pumps.

The flow diagram and site layout for this option are shown in Figure 4-1 and Figure 4-2 respectively. This option can achieve the log reduction values shown in Table 4-5.

Table 4-5. Option 1 log reduction values

Process	Protozoa	Viruses	Bacteria
Pressure filters	4	0	2
UV disinfection	4	2	4
Chlorination	0	4	4
Total	**8**	**6**	**10**

This option can meet all the health and aesthetic requirements except for reducing the hardness.

The purpose and sizing of each process unit is described in Table 4-6.

Table 4-6. Option 1 process sizing

Process	Purpose	Quantity	Sizing
Potassium permanganate dosing	Oxidation of iron and manganese	1 x dosing skid	7.5 L/h
ACH dosing	Coagulation of turbidity and organics	1 x storage tank Duty/standby pumps	25 kL
		Duty/standby pumps	7.5 L/h
Soda ash dosing	• Raise pH for optimal coagulation • Reduce corrosiveness of water	1 x dosing skid	7.5 L/h
Sedimentation lagoons	• Settling of coagulated solids	2	92m L x 31m W x 2.5mD
Settled water pump station	• Transfer settled water to filters	Duty/standby	105 L/s each
Pressure sand filters	• Filtration of unsettled turbidity • Barrier to chlorine resistant pathogens	2 skids each with 3 filters	2m diameter 1m media depth
UV disinfection	• Disinfection barrier	1	100mJ/cm^2 2 x Trojan Swift D06
Chlorination	• Disinfection barrier • Residual in water network	2 x 920kg drums Relocate from current high lift pumps	-
Clear water tank	• Contact time for chlorination • Storage for WTP breakdowns and maintenance	Panel tank with liner	2,500 kL
High lift pumps	• Transfer of treated water to reservoirs	Duty/standby	105 L/s each

Option 2 – Conventional treatment with sedimentation tank and sludge lagoons

This option includes the following processes:

- Potassium permanganate dosing
- Coagulant and soda ash dosing
- Sedimentation tank
- Settled water pump station
- Pressure sand filters
- UV disinfection
- Chlorination (relocated from existing high lift pump site)

- Clear water tank
- High lift pumps
- Sludge lagoons.

The flow diagram and site layout for this option are shown in Figure 4-3 and Figure 4-4 respectively. This option can achieve the log reduction values shown in Table 4-5.

Table 4-7. Option 2 log reduction values

Process	Protozoa	Viruses	Bacteria
Pressure filters	4	0	2
UV disinfection	4	2	4
Chlorination	0	4	4
Total	**8**	**6**	**10**

This option can meet all the health and aesthetic requirements except for reducing the hardness.

The purpose and sizing of each process unit is described in Table 4-6.

Table 4-8. Option 2 process sizing

Process	Purpose	Quantity	Sizing
Potassium permanganate dosing	Oxidation of iron and manganese	1 x dosing skid	7.5 L/h
ACH dosing	Coagulation of turbidity and organics	1 x storage tank Duty/standby pumps	25 kL
		Duty/standby pumps	7.5 L/h
Soda ash dosing	• Raise pH for optimal coagulation • Reduce corrosiveness of water	1 x dosing skid	7.5 L/h
Sedimentation tank	Settling of coagulated solids	1	Comag ballasted clarifier
Settled water pump station	Transfer settled water to filters	Duty/standby	105 L/s each
Pressure sand filters	• Filtration of unsettled turbidity • Barrier to chlorine resistant pathogens	2 skids each with 3 filters	2m diameter 1m media depth
UV disinfection	Disinfection barrier	1	100mJ/cm^2 2 x Trojan Swift D06
Chlorination	• Disinfection barrier • Residual in water network	2 x 920kg drums Relocate from current high lift pumps	-

Process	Purpose	Quantity	Sizing
Clear water tank	• Contact time for chlorination • Storage for WTP breakdowns and maintenance	1	2,500 kL
High lift pumps	Transfer of treated water to reservoirs	Duty/standby	105 L/s each
Sludge lagoons	Settlement of sludge for dewatering	3	1,400 m^3 each

Option 3 – Conventional treatment with sedimentation tank and mechanical dewatering

This option includes the following processes:

- Potassium permanganate dosing
- Coagulant and soda ash dosing
- Sedimentation tank
- Settled water pump station
- Pressure sand filters
- UV disinfection
- Chlorination (relocated from existing high lift pump site)
- Clear water tank
- High lift pumps
- Sludge thickening
- Sludge dewatering.

The flow diagram and site layout for this option are shown in Figure 4-5 and Figure 4-6 respectively. This option can achieve the log reduction values shown in Table 4-5.

Table 4-9. Option 3 log reduction values

Process	Protozoa	Viruses	Bacteria
Pressure filters	4	0	2
UV disinfection	4	2	4
Chlorination	0	4	4
Total	**8**	**6**	**10**

This option can meet all the health and aesthetic requirements except for reducing the hardness. There is a sub option to add lime softening to this process which can be used to reduce the hardness.

The purpose and sizing of each process unit is described in Table 4-6.

Table 4-10. Option 3 process sizing

Process	Purpose	Quantity	Sizing
Potassium permanganate dosing	Oxidation of iron and manganese	1 x dosing skid	7.5 L/h

Process	Purpose	Quantity	Sizing
ACH dosing	Coagulation of turbidity and organics	1 x storage tank Duty/standby pumps	25 kL
		Duty/standby pumps	7.5 L/h
Soda ash dosing	• Raise pH for optimal coagulation • Reduce corrosiveness of water	1 x dosing skid	7.5 L/h
Sedimentation tank	Settling of coagulated solids	1	Comag ballasted clarifier
Settled water pump station	Transfer settled water to filters	Duty/standby	105 L/s each
Pressure sand filters	• Filtration of unsettled turbidity • Barrier to chlorine resistant pathogens	2 skids each with 3 filters	2m diameter 1m media depth
UV disinfection	Disinfection barrier	1	100mJ/cm^2 2 x Trojan Swift D06
Chlorination	• Disinfection barrier • Residual in water network	2 x 920kg drums Relocate from current high lift pumps	-
Clear water tank	• Contact time for chlorination • Storage for WTP breakdowns and maintenance	1	2,500 kL
High lift pumps	Transfer of treated water to reservoirs	Duty/standby	105 L/s each
Sludge press	Dewatering of sludge to reduce volume for transport and disposal	1	Huber Q press Q440 Capacity 8.5 m^3/h

Option 4 – Upgrade exiting temporary plant

This option includes the following processes:

- Coagulant and soda ash dosing
- Ozone generation
- Ozone reactor tank
- Greensand pressure filters
- Submerged membrane filtration
- Ozone disinfection
- Chlorination (relocated from existing high lift pump site)

- Clear water tank
- High lift pumps
- Sludge thickening
- Sludge dewatering.

Ozone has been selected for disinfection as there is excess ozone generation capacity and ozone is more effective and achieving virus LRVs than UV disinfection.

The flow diagram and site layout for this option are shown in Figure 4-7 and Figure 4-8 respectively. This option can achieve the log reduction values shown in Table 4-5.

Table 4-11. Option 4 log reduction values

Process	Protozoa	Viruses	Bacteria
Membrane filters	4	0	4
Ozone disinfection	4	4	4
Chlorination	0	4	4
Total	**8**	**8**	**12**

This option can meet all the health and aesthetic requirements.

The purpose and sizing of each process unit is described in Table 4-6.

Table 4-12. Option 4 process sizing

Process	Purpose	Quantity	Sizing
ACH dosing	Coagulation of turbidity and organics	1 x storage tank Duty/standby pumps	25 kL
		Duty/standby pumps	
Soda ash dosing	• Raise pH for optimal coagulation • Reduce corrosiveness of water	1 x dosing skid	
Ozone generation	• Oxidation of iron & manganese • Disinfection barrier		
Sedimentation tank	Settling of coagulated solids	2	High-rate ballasted clarifiers
Greensand pressure filters	• Adsorption of iron and manganese		
Membrane filtration	• Filtration of unsettled turbidity • Barrier to chlorine resistant pathogens		Containerised ceramic membrane modules

Process	Purpose	Quantity	Sizing
Chlorination	• Disinfection barrier • Residual in water network	2 x 920kg drums Relocate from current high lift pumps	
Clear water tank	• Contact time for chlorination • Storage for WTP breakdowns and maintenance	1	2,500 kL
High lift pumps	Transfer of treated water to reservoirs	Duty/standby	105 L/s each
Gravity thickener	Settlement of sludge for dewatering	1	
Sludge press	Dewatering of sludge to reduce volume for transport and disposal	1	-

Two options were considered for the delivery of the upgrade to the current temporary plant:

a. NSC pays for upgrade and contractor operates and maintains plant for a monthly fee
b. NSC pays for upgrade and purchase existing temporary plant and operates and maintains the plant.

For the purposes of the options evaluation, it has been assumed that NSC will purchase the temporary plant, pay for the upgrade, and operate and maintain the plant. This is consistent with the procurement basis for the other options. The procurement options can be assessed further at concept design.

Figure 4-1. Option 1 flow diagram

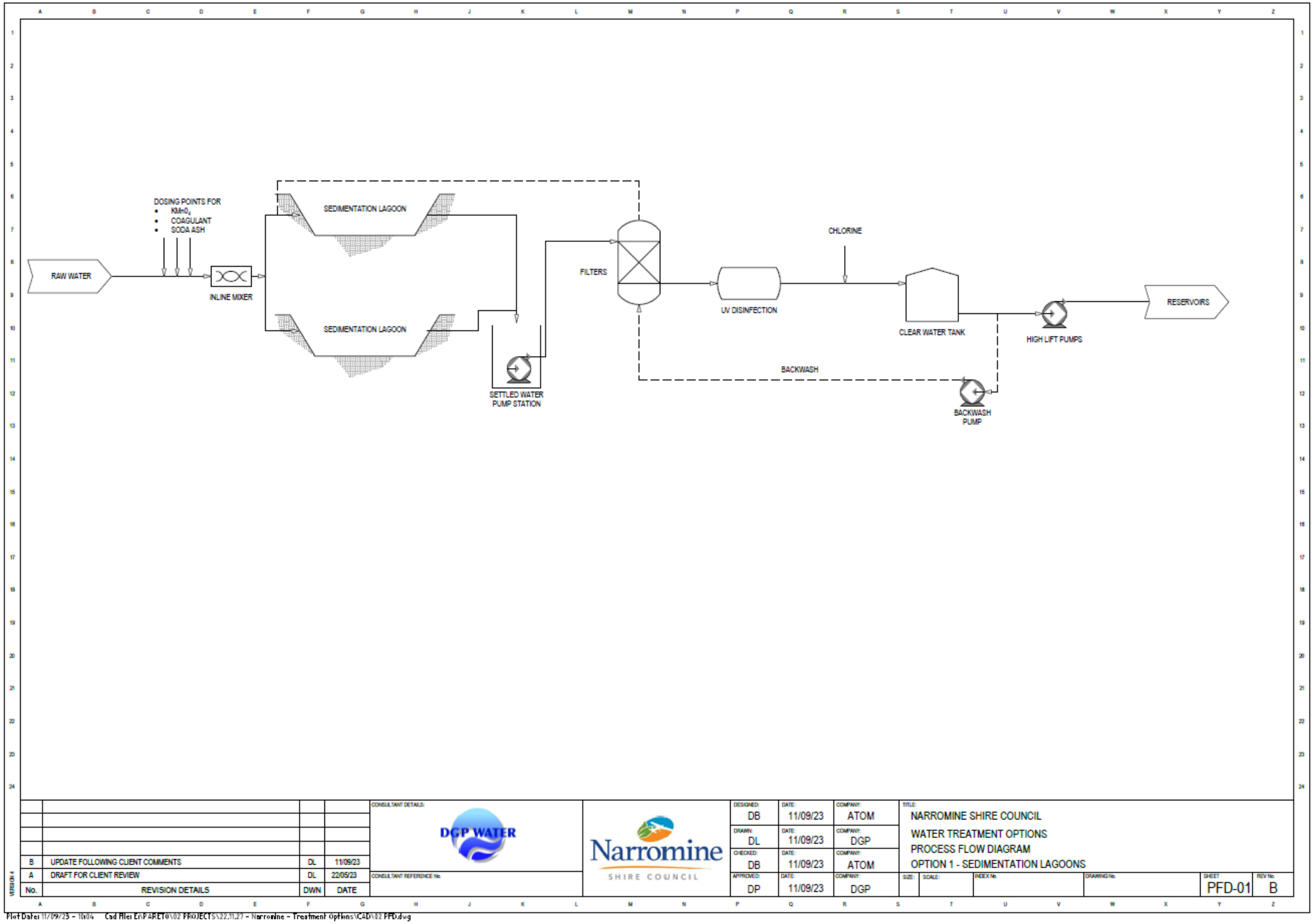


Figure 4-2. Option 1 site layout

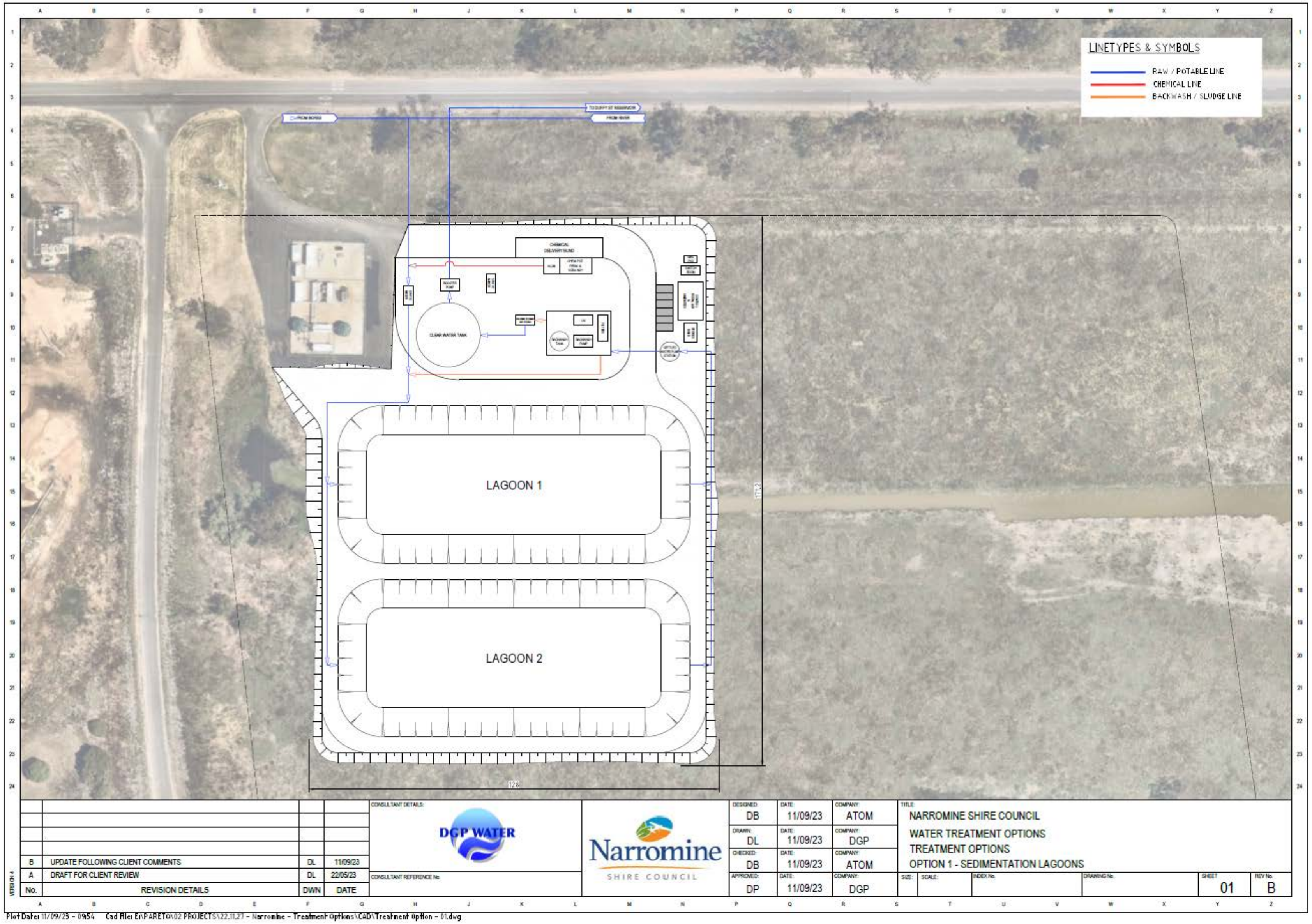


Figure 4-3. Option 2 flow diagram

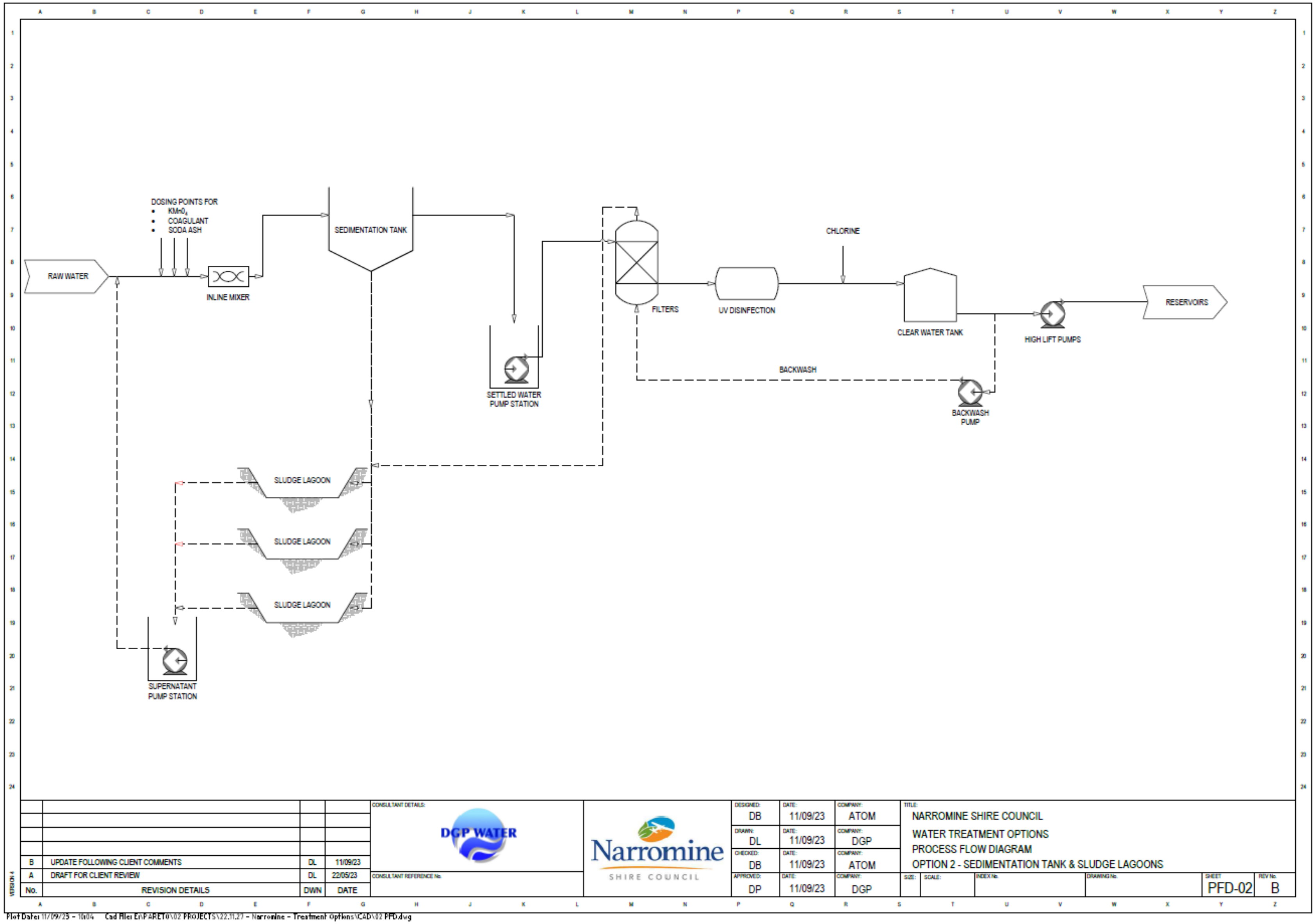


Figure 4-4. Option 2 site layout

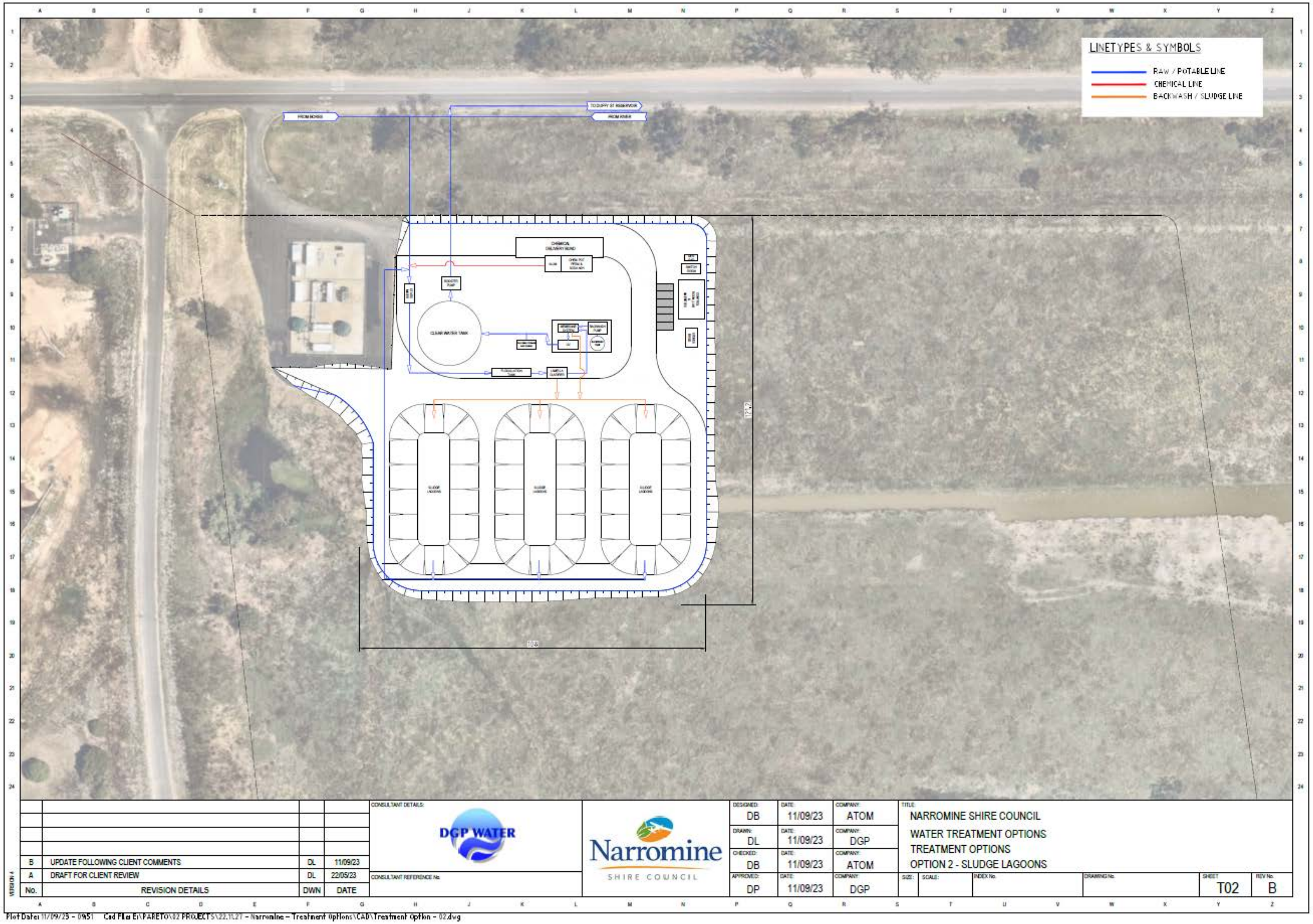


Figure 4-5. Option 3 flow diagram

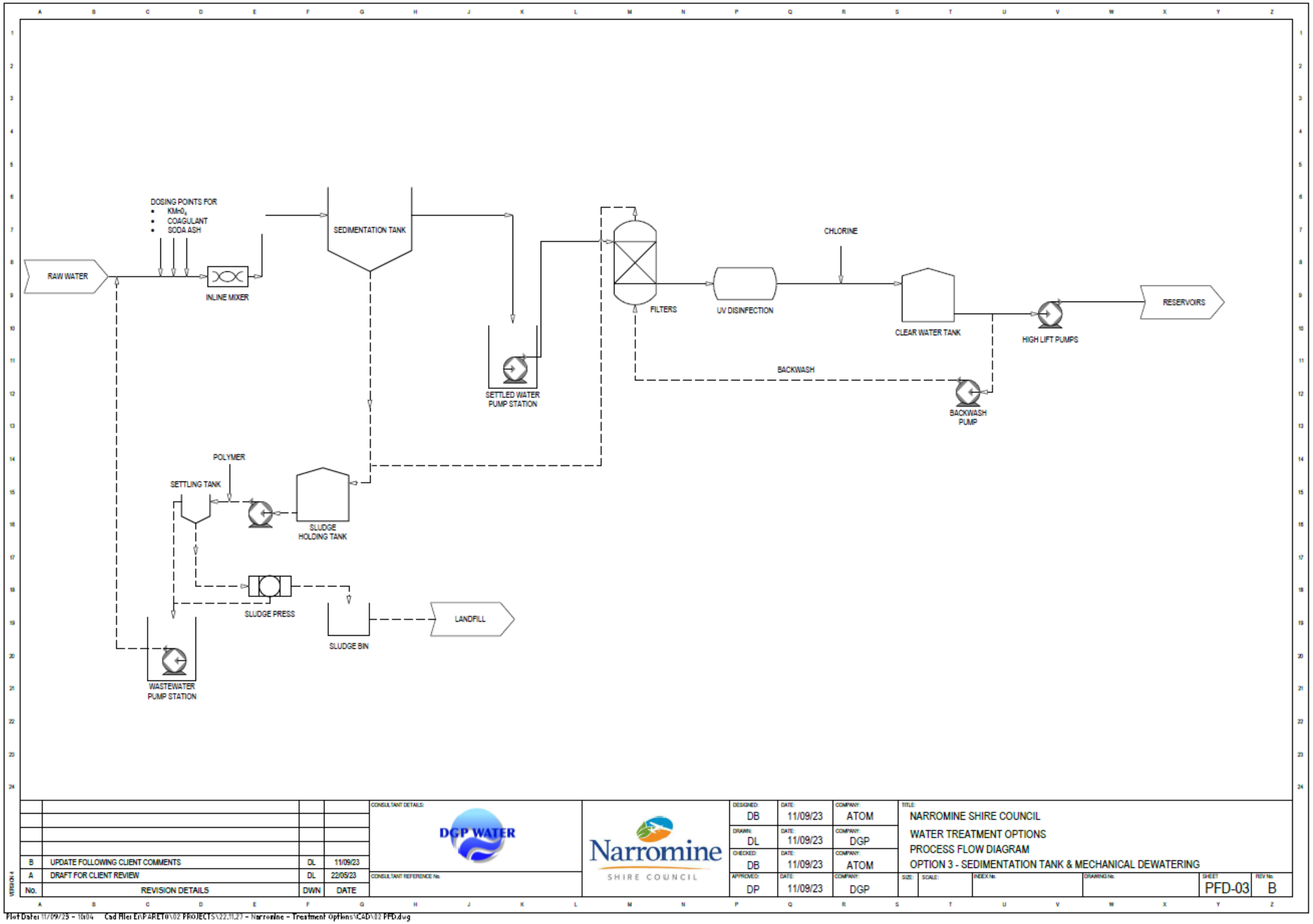


Figure 4-6. Option 3 site layout

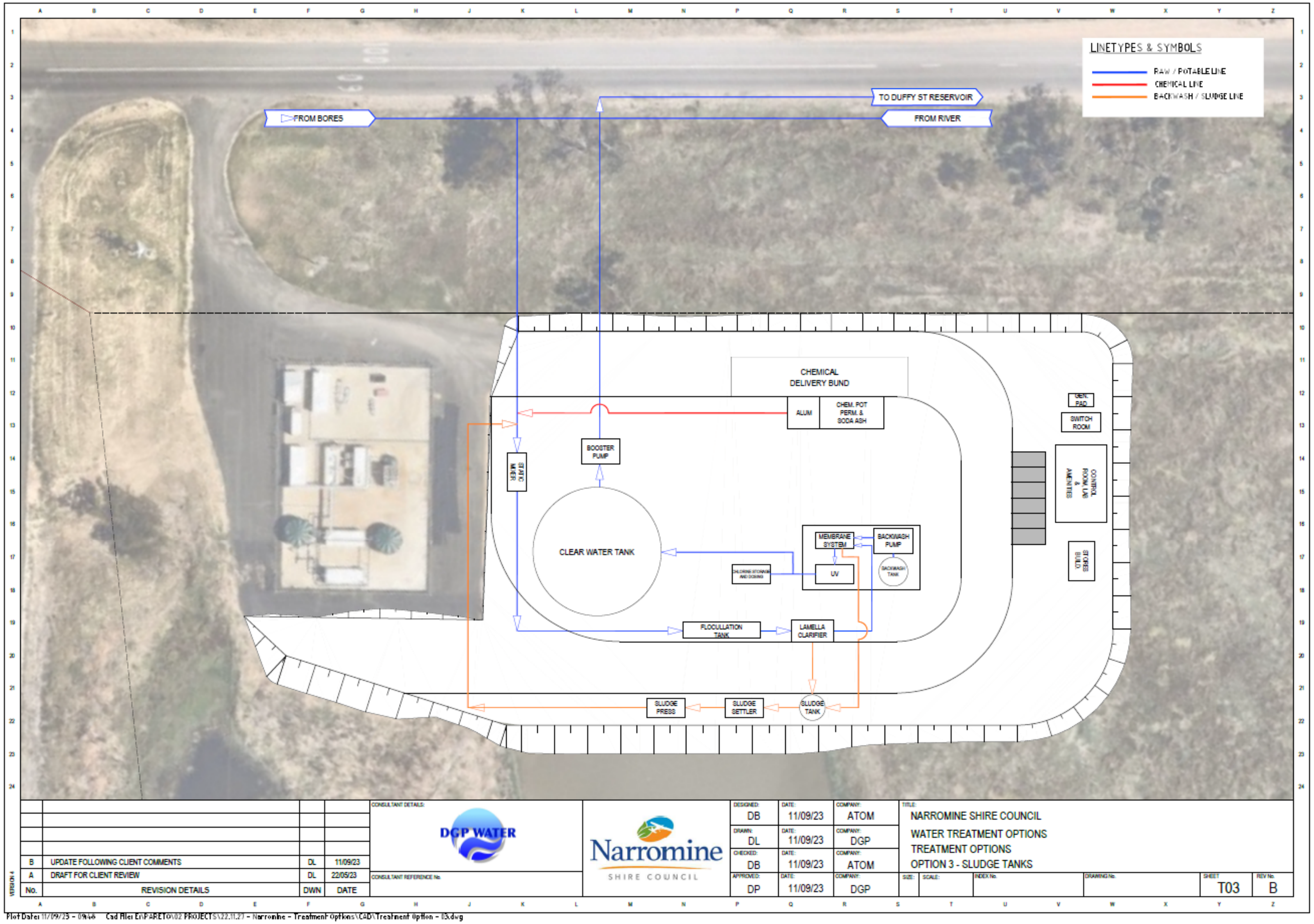


Figure 4-7. Option 4 flow diagram

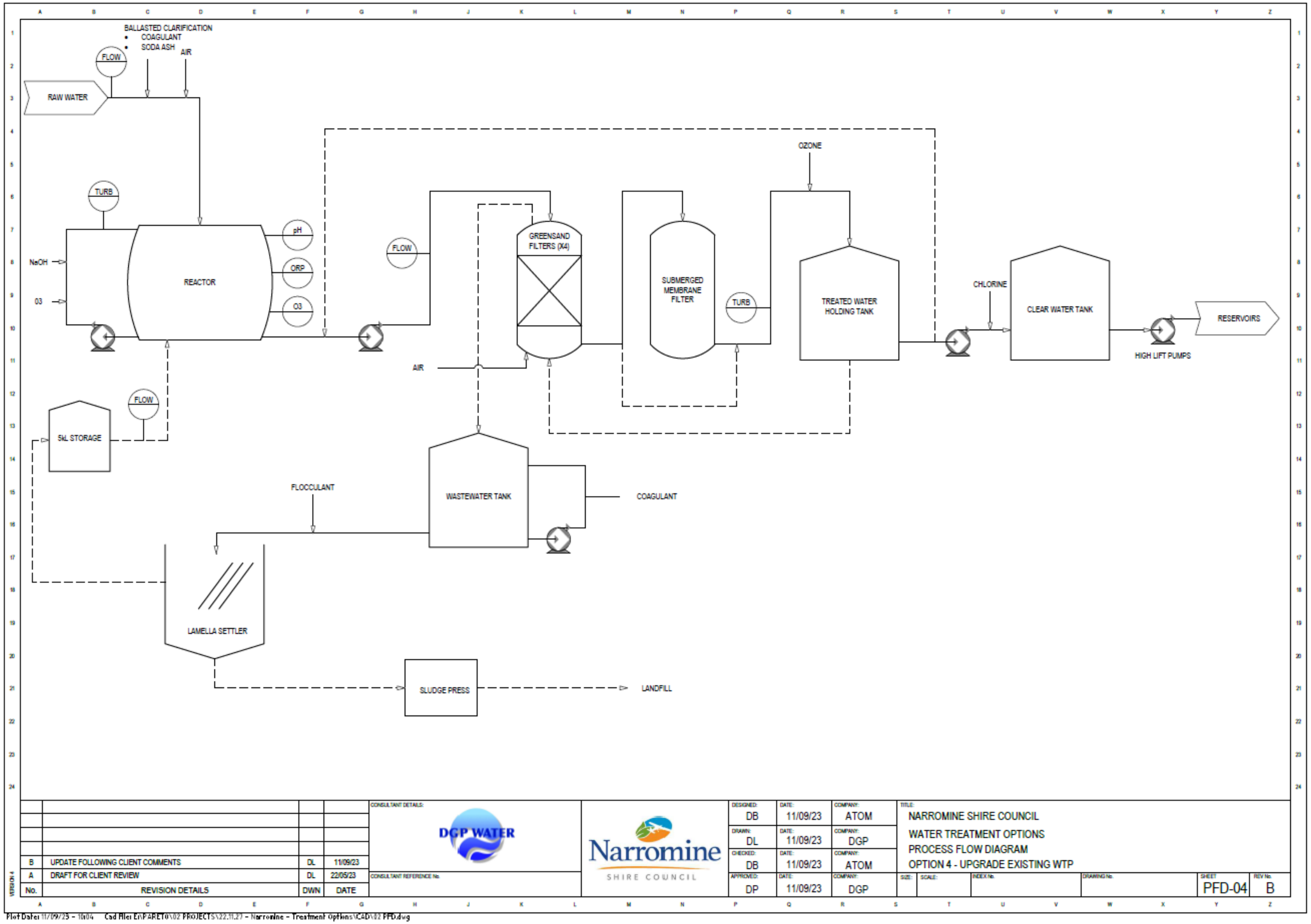
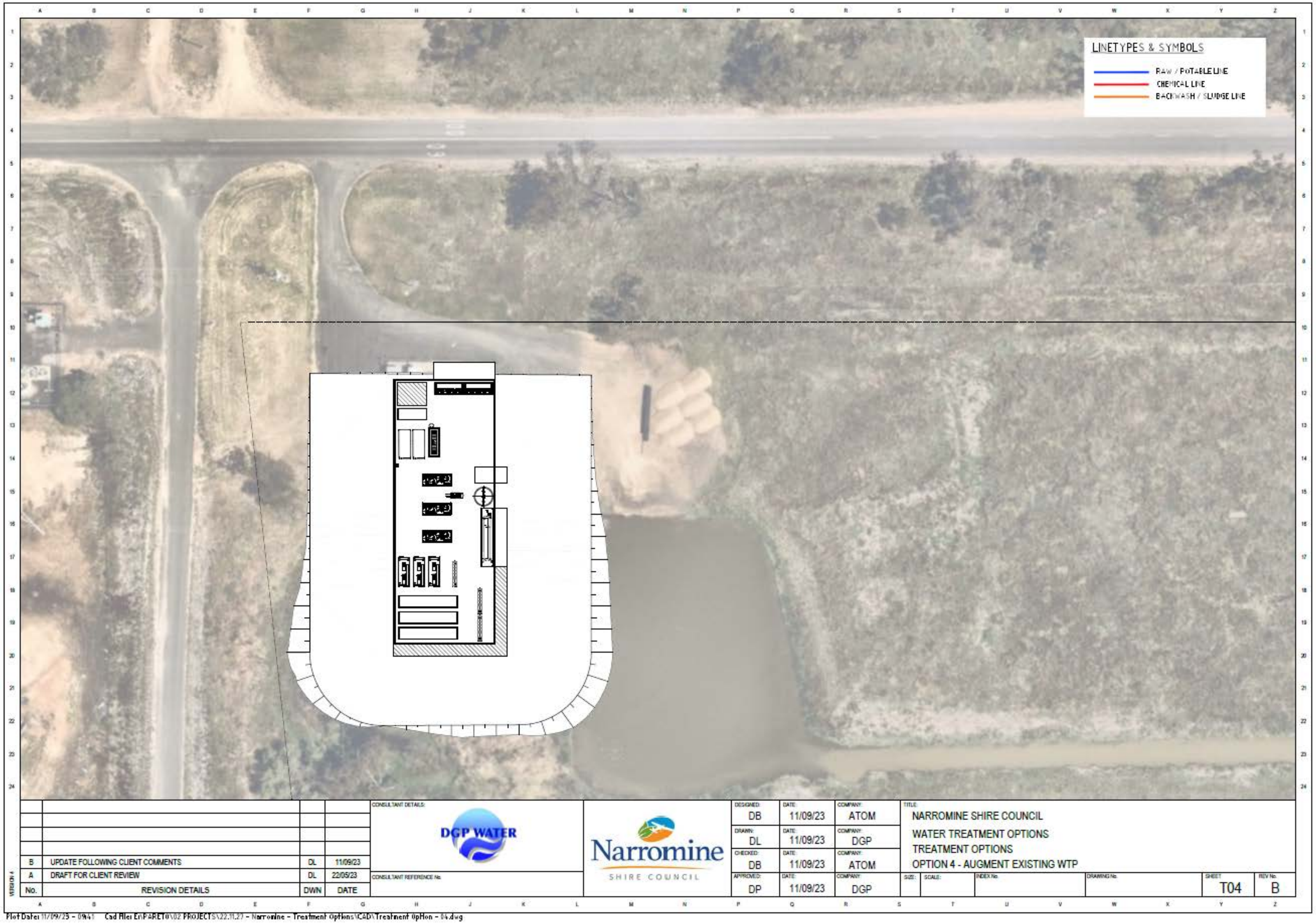


Figure 4-8. Option 4 site layout



4.2.2 Triple bottom line assessment

The water quality options have been assessed using a triple bottom line assessment. This assessment method compares the environmental, social and financial aspects of each option and therefore assists NSC to ensure the options selected is the most sustainable.

The step to undertake the triple bottom line assessment were:

1. The key criteria and weightings for the environmental and social impacts were agreed upon during a meeting on 29 September 2023 between NSC, Atom Consulting and The Environmental Factor. This meeting was undertaken before the financial assessment was completed to ensure it did not influence the criteria.
2. A performance score from 1 to 10 was assigned to each criterion for each option
3. The total weighted score for each option was calculated by summing the product of the performance score and the weighing
4. The present value (PV) of each option was calculated from the estimated capital cost and estimated operations and maintenance cost of each option. The PV was calculated over 30 years using a discount rate of 7% per annum.
5. The triple bottom line score for each option was calculated using the following formula:

$$TBL\ score = \frac{Total\ environmetal\ score + Total\ social\ score}{Present\ value}$$

Environmental assessment

The environmental assessment and scores were undertaken by The Environmental Factor (TEF, 2023). A copy of TEF's report is included as **Error! Reference source not found.**. As all options are located on the same site, the key environmental issues for the site are the same for each option although the scale of impact will vary depending on the footprint. These environmental issues for the site are:

- The area surrounding each of the WTP options is predominantly cleared agricultural land on the outskirts of town, with patches of remnant native vegetation occurring along road reserves and waterways in the locality. Most of this area is mapped as 'non-native vegetation'.
- One species of threatened waterbird has been observed in the area and a plant community and threatened ecological community have been mapped in the road reserve near the site.
- Potential impacts to aquatic ecology associated with all options include release of sediment and soil into waterways via drainage lines from vegetation clearing, excavation works and the movement of machinery. Any drilling or deep excavation work has the potential to impact on Groundwater Dependent Ecosystems (GDE) present in the vicinity.
- Potential for impacts to heritage items from construction of all options is anticipated to be low, as the proposed impact footprint is relatively small.
- All options being assessed are not anticipated to include activities that are likely to generate significant pollution as part of construction activities or operations.

- The site will need future assessment for aboriginal heritage items in the proposed footprint.

The estimated waste and resource consumption during the operation of each option to produce 825 ML/year are shown in Table 4-13.

Table 4-13. Estimated waste and resource consumption

Resource	Option 1	Option 2	Option 3	Option 4
Energy (kWh/year)	2,386,408	2,461,523	2,242,505	2,382,260
Sludge production (m^3/year)	66.22	66.22	66.22	36.3
Coagulant (kg/year)	31,350	31,350	31,350	31,350
Potassium permanganate (kg/year)	2,145	2,145	2,145	0
Polymer (kg/year)	0	0	0	167
Chlorine (kg/year)	1,238	1,238	1,238	1,238

The environmental issues specific to each option are discussed in the following sections.

Option 1 – Conventional treatment with sedimentation lagoons

This option has the largest footprint and therefore the greatest potential to impact on the adjacent wetland and will intrude into the stormwater management area.

During the operation phase, the sedimentation lagoons will need to be desludged. This typically involves mechanical earthmoving equipment with the potential to damage the pond liner and cause pollution.

Option 1 is the second highest consumer of resources for operations and the largest requirement for imported fill.

Option 2 – Conventional treatment with sedimentation tank and sludge lagoons

This option has the second largest footprint and therefore a larger potential to impact on the adjacent wetland and will intrude into the stormwater management area.

During the operation phase, the sludge lagoons will need to be desludged. This typically involves mechanical equipment such as pumps on floating pontoons. While lower than Option 1, there is the potential to damage the pond liner and cause pollution.

Option 2 is the highest consumer of resources for operations and has a large requirement for imported fill.

Option 3 – Conventional treatment with sedimentation tank and mechanical dewatering

This option has the second smallest footprint and therefore a lower potential to impact on biodiversity, heritage receiving environment during construction phase.

Option 2 is the second lowest consumer of resources for operations and has a less requirement for imported fill.

Option 4 – Upgrade existing temporary plant

Option 4 has the lowest footprint and therefore the lowest potential to impact on biodiversity, heritage receiving environment during construction phase. This option also utilises the existing temporary plant which would need to be removed in the other options

While consumer more power than the other options, there is less requirements for chemical (potassium permanganate is not required) and will produce less sludge.

Environmental scoring

The environmental scoring is shown in Table 4-14. Scoring of each factor was from 1 to 10 with the higher scores having the least potential impact. Scoring was based on the following:

- High impact (1-3)
- Moderate impact (4-6)
- Low impact (7-10).

Table 4-14. Environmental scoring

Criteria	Weighting	Option			
		1	2	3	4
Impact on terrestrial and aquatic biodiversity	40%	2.0	3.0	5.0	6.0
Environmental pollution risk (i.e POEO Act)	30%	3.0	4.0	6.0	6.0
Waste and resources	20%	2.0	2.0	4.0	7.0
Impact on land – use and area (ha)	10%	2.0	3.0	6.0	7.0
Total weighted score	**100%**	**2.30**	**3.10**	**5.20**	**6.30**

Social assessment

Option 1 – Conventional treatment with sedimentation lagoons

The sedimentation lagoons in this options offer little for optimisation by the operator other than frequency of desludging and chemical dose rates. Sedimentation lagoons can also be prone to temperature changes causing settled sludge to float.

The performance of filtration as barrier to chlorine resistant pathogens is improved by well performing upstream sedimentation. High filtered water turbidity will also reduce the effectiveness of downstream chlorine and ultraviolet disinfection processes.

There is also some risk that the sedimentation ponds become inundated in prolonged wet weather and therefore compromise treatment capacity or water quality.

This option utilises most of the available site and offers little opportunity for expansion to cater for unforeseen population growth in the town.

Option 2 – Conventional treatment with sedimentation tank and sludge lagoons

The risk that the WTP fails to operate as per design parameters is lower than for Option 1 as there is more control of the sedimentation tank and it is less susceptible to environmental conditions & stochastic events.

There is also some risk that the sludge lagoons become inundated in prolonged wet weather causing high volumes of supernatant to be returned to the plant and therefore compromise treatment capacity or water quality.

This option still utilises most of the available site and offers little opportunity for expansion to cater for unforeseen population growth in the town.

Option 3 – Conventional treatment with sedimentation tank and mechanical dewatering

The risk that the WTP fails to operate as per design parameters is similar to Option 2 as there is more control of the sedimentation tank and it is less susceptible to environmental conditions & stochastic events.

As there is not ponds and the plant is mostly above ground there is lower risk caused by sustained or intense wet weather.

This option still much less of the available site than Options 1 and 2. However, expansion to cater for unforeseen population growth in the town would require significant lead time for design and construction.

Option 4 – Upgrade existing temporary plant

This option is based on the current temporary plant with expansion for increased capacity and sedimentation to allow treatment of higher turbidity source waters. The process is already proven to meet the requirements of the ADWG with additional filtration and ozone disinfection to comply with HBTs.

This option utilises the least amount of land providing space for expansion. The modular design will allow expansion to cater for unforeseen population growth in the town in a shorter timeframe than the other options.

Social scoring

The social scoring is shown in Table 4-15. Scoring of each factor was from 1 to 10 with the higher scores having the least potential impact. Scoring was based on the following:

- High impact (1-3)
- Moderate impact (4-6)
- Low impact (7-10).

Table 4-15. Social scoring

Criteria	Weighting	Option			
		1	2	3	4
Risk of not meeting levels of service (LOS, health and aesthetic criteria)	40%	4.0	6.0	6.0	7.0
Impact on land – use and area (ha)/disruption to community	20%	2.0	3.0	6.0	7.0
Planned for future changes in development (right sizing)	20%	2.0	3.0	6.0	8.0
Community attraction/liveability	20%	2.0	4.0	5.0	7.0
Total weighted score	**100%**	**2.80**	**4.40**	**5.80**	**7.20**

Financial assessment

A preliminary high level concept was developed for each options to prepare a high level estimate using the following:

- Sixmaps imagery
- Rawlinsons Australian Construction Handbook Edition 35
- Hunter Water Corporation Estimating Manual
- Quotes from suppliers for similar projects where appropriate
- Engineering judgement and experience from previous projects

Where supplier quotes were not current they have been indexed to 2023 costs based on published consumer price indexes.

Preliminaries were estimated using the Hunter Water Estimating Manual which contains percentages for various preliminary items based on the construction value.

The following allowances were made for design and project management:

- Design – 10% of estimated construction cost
- Design project management – 16% of design estimate
- Construction project management – 9% of estimated construction cost

No survey, geotechnical investigations or other preliminary design studies have been undertaken.

A contingency of 35% was added to allow for unforeseen scope and increased costs following detailed survey, geotechnical investigation and environmental assessment. An escalation factor of 12% was added to allow for increased construction costs between the date of the estimated and when the construction will be undertaken.

Ongoing operating and maintenance costs for each option were estimated based on equipment power usage from suppliers, estimated pumping energy, chemical usage from jar testing and current chlorine dose rates. The cost of soda ash was not estimated as this would only be dosed when the water quality required and would be similar for all options. Labour cost for operators was based on 1 full time equivalent (FTE) for Options 1 to 3 and 1.5 FTE for Option 4. The estimate was based on the following rates:

- Electricity costs of $0.22/kWh
- ACH at $2.79/kg
- Potassium permanganate $13/kg
- Chlorine at $4.90/kg
- Sludge disposal $23.64 (NSC current rates for skip bins)
- Maintenance as 1% of capital
- Labour cost for operators $90,000/year

Table 4-16. Financial assessment

Option	Capital cost ($M)	Annual O&M cost ($k)	PV (20 years, 7%) $M
1	40.50	736+213/ML	51.71
2	32.46	632+213/ML	42.37
3	26.97	514+213/ML	35.42
4	28.72	222+189/ML	33.30

Option 3 has the lowest capital while Option 4 has the lowest operation and maintenance costs. Option 4 has the lowest whole of life costs (present value) after 30 years and the additional capital investment over Option 3 is paid back in less than 10 years.

Triple bottom line

Based on the environmental, social and present value of each option, the triple bottom line assessment is shown in Table 4-17.

Table 4-17. Triple bottom line

Assessment	Option			
	1	2	3	4
Environmental	2.30	3.10	5.20	6.30
Social	2.80	4.40	5.80	7.20
Environmental & social score (ESS)	**5.10**	**7.50**	**11.00**	**13.50**
Total PV	**51.71**	**42.37**	**35.42**	**33.30**
ESS/PV	**0.10**	**0.18**	**0.31**	**0.41**
Ranking	**4**	**3**	**2**	**1**

Based on this assessment, Option 2 is preferred with lower costs and better outcomes for environmental and social factors.

5 Recommendations

Based on the options assessment, it is recommended that Option 4 be taken forward to concept design. This option consists of the following:

- Purchase of existing temporary WTP by NSC
- Upgrade of existing plant to a capacity to produce 7.5ML/day in 20 hours operation
- Two new sedimentation tanks with a combined capacity of 7.5 ML/day
- Additional ozone disinfection and membrane filtration to provide the required LRVs
- New clear water tank and high lift pump station
- Relocate existing chlorination system to the WTP site
- Sludge thickening and dewatering
- Detailed environmental assessment
- Approval under Section 60 of the *Local Government Act (NSW)* 1993.

6 References

ADWG see Australian Drinking Water Guidelines 6 National Water Quality Management Strategy - Natural Resource Management Ministerial Council

Atom Consulting, 2022a, Narromine Water Supply System Drinking Water Quality Risk Assessment Briefing Paper

Atom Consulting, 2022b, Narromine Water Supply System Drinking Water Quality Risk Assessment Output Paper

DGP Water, 2023, Narromine Water Security and Water Quality Investigation Basis of Estimate Report

DOI, 2019, Integrated Water Cycle Management Information Sheet 2 – Evaluation of integrated water cycle management scenarios

PWA, 2022, Narromine Shire Council Integrated Water Cycle Management Strategy Issues Paper

NHMRC (2011) Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. Version 3 Updated March 2015, National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

TEF, 2023, Narromine Water Quality Project – Preliminary Environmental Assessment

WaterRA 2020, Good Practice Guide to the Operation of Drinking Water Supply Systems for the Management of Microbial Risk Second Edition, Water Research Australia

Appendix A Risk assessment output paper

Narromine Water Supply System

DRINKING WATER QUALITY RISK ASSESSMENT

OUTPUT PAPER

Narromine Shire Council

December 2022

2.0

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Authors:	Lucy Parsons, Hugo Brouwers, Megan Ryder			
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File Name:	NAR2203A Narromine WQRA output paper			

Executive Summary

Project background

Under the *Public Health Act 2010* (NSW) and the *Public Health Regulation*, Narromine Shire Council is required to periodically review its drinking water quality risk assessment. The previous drinking water quality risk assessment for Narromine water supply system was undertaken in May 2018.

Council are also assessing options for a new water treatment plant for Narromine.

A facilitated risk review workshop was held on 22 November 2022 for the Narromine water supply scheme.

Document purpose

This document records the output from the Narromine water supply scheme risk assessment workshop.

Risk assessment workshop

The purpose of this workshop was to:

- review the estimated the level of risk for each identified hazard or hazardous event
- evaluate the major sources of uncertainty associated with each hazard and hazardous event and consider actions to reduce uncertainty
- determine significant risks and document priorities for risk management
- review the current critical control points and limits
- assess what additional treatment is required to meet health requirements

Risk analysis and assessment

Nine bow ties were developed for the Narromine water supply scheme.

Consequences were reviewed for maximum risk - those without identified controls in place and residual risk - those with identified controls in place. Consequences were also reviewed for future risk after the implementation of the new WTP. Participants ranked risks from a health or operational perspective using a risk assessment matrix.

There were a total of 2 aesthetic risks and 11 health risks ranked as part of the process. The risk assessment workshop reviewed 40 causes and 13 consequences of these hazardous events.

A summary of the very high residual health risks is shown in Table i-i. Residual risks for community illnesses remain very high as the consequences remain as catastrophic. The full risk register is included in Appendix H.

Table i-i. Narromine risk analysis summary – very high residual health risks

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health	Uncertainty
Aquifer contamination by pathogens	Community illness from chlorine resistant pathogens	Health (ADWG)	Very high (5A)	Very high (5A)	High (5E)	C
	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)	C
River contamination by pathogens	Community illness from chlorine resistant pathogens	Health (ADWG)	Very high (5A)	Very high (5A)	High (5E)	C
	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)	C
Insufficient bore water supply to meet demand	Customers provided with insufficient water supply	Health (ADWG)	Very high (5B)	Very high (5C)	High (5E)	U
Water in service reservoirs has not had adequate CT to achieve primary kill	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)	C
Ineffective organic removal	Disinfection by-products above ADWG limits in customers water	Health (ADWG)	Very high (3A)	Very high (3A)	High (3C)	C

Contents

Tables

Figures

This document is designed for double sided printing

1 Project Background

Narromine Shire Council currently operates two drinking water supply systems and one non-potable drinking water system:

- Narromine
- Trangie
- Tomingley (currently non-potable)

The previous risk assessment of the Narromine system was undertaken in 2018.

1.1 Document purpose

This document records the output from the Narromine water supply scheme risk assessment workshop held on 22 November 2022. A risk assessment was undertaken on the Narromine water supply scheme as it has not had a risk assessment since the 2018 risk assessment. Council is also assessing options for a water treatment plant to service Narromine.

1.2 ADWG principles

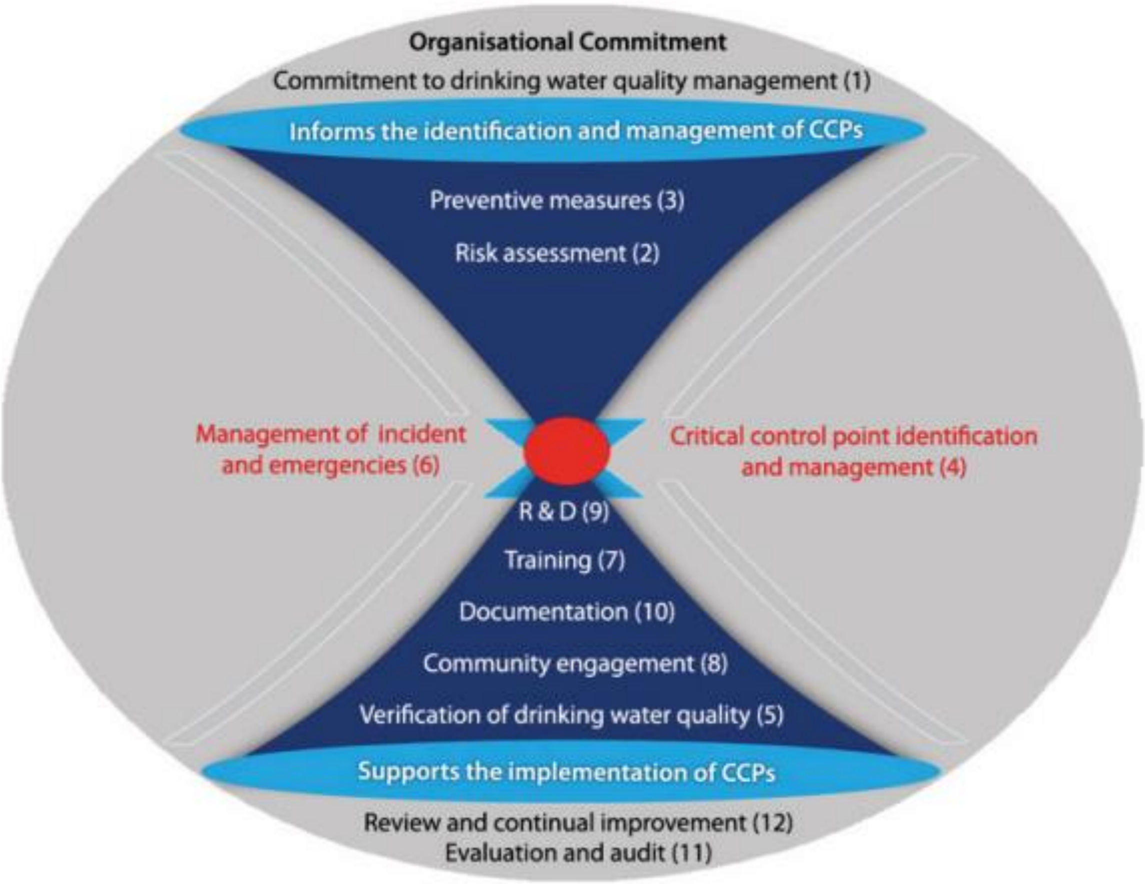
The Australian Drinking Water Guidelines (ADWG) is the authoritative document for drinking water management in Australia. It contains information about management of drinking water systems, monitoring regimes and contaminants that may be present in drinking water. As the knowledge base has increased, the document has grown in both detail and complexity. The guiding principles have been developed to outline fundamental considerations for safe drinking water:

- The greatest risks to consumers of drinking water are pathogenic microorganisms.
- Protection of water sources and treatment are of paramount importance and must never be compromised
- The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply
- Any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) should arouse suspicion that drinking water might become contaminated
- System operators must be able to respond quickly and effectively to adverse monitoring signals
- System operators must maintain a personal sense of responsibility and dedication to providing consumers with safe water and should never ignore a consumer complaint about water quality
- Ensuring drinking water safety and quality requires the application of a considered risk management approach

1.3 ADWG framework

The ADWG contains the Framework for the Management of Drinking Water Quality (the Framework) which was developed to guide the design of a structured and systematic approach, from catchment to consumer, to assure safety and reliability. The Framework is made up of twelve elements underpinned by a preventive risk management approach. (Figure 1-1; NSW Ministry of Health 2013).

Figure 1-1. Framework for the Management of Drinking Water Quality



Central to the provision of safe water is the identification and management of critical control points (CCPs; Element 4). A CCP is an activity, procedure or process that is essential to prevent a water quality hazard or reduce it to an acceptable level. Appropriate selection of CCPs is important, as CCPs are the focus of process control for the production of safe drinking water. Also critical for ensuring the safety of consumers are the procedures for incidents and emergencies (Element 6). Understanding the risks to drinking water and their management is essential to the development of the CCPs (Elements 2-3) and forms the basis of the current work.

1.4 Regulatory context

The *Public Health Act 2010 (NSW)* s25 (1) requires all drinking water suppliers to establish, and adhere to, a quality assurance program that addresses the elements of the Framework for Management of Drinking Water Quality (as set out in the Australian Drinking Water Guidelines published by the National Health and Medical Research Council) that are relevant to the operations of the supplier of drinking water concerned. To assist suppliers in preparing the drinking water systems NSW Health and NSW Department of Primary Industries - Office of Water have published the NSW Guidelines for Drinking Water Management Systems (NSW Ministry of Health 2013).

The Public Health Regulation (NSW) was updated on 1 October 2018. The regulation requires (Clause 34B):

- (i) an assessment of the risks to the drinking water supply system
- (ii) an assessment of the maximum and residual risks to the drinking water supply system
- (iii) identification of hazards to the drinking water supply system
- (iv) measures to prevent any hazards to the drinking water supply system (preventive measures)
- (v) actions to improve the drinking water supply system
- (vi) management, if possible, of any risks to the drinking water supply system assessed (control points)
- (vii) communication to staff about control points that are critical to the drinking water supply system and drinking water quality (critical control points).

These risk assessment and review workshops demonstrates how Council is meeting the above requirements of this regulation.

1.5 Framework element 2: water quality risk assessment

Element 2 (Risk Assessment) of the Framework contains the following components and actions to be considered when undertaking a risk assessment on a water supply system. The section where each Framework action is addressed in this paper is shown in brackets.

Water supply system analysis

- Assemble a team with appropriate knowledge and expertise (Section A.2).
- Construct a flow diagram of the water supply system from catchment to consumer (Section 2.3).
- Assemble pertinent information and document key characteristics of the water supply to be considered (Section 2).

Assessment of water quality data

- Assemble historical data from source waters, treatment plants and finished water supplied to consumers (Section 2.4, Appendix A and Appendix C).
- List and examine exceedances (Section 2.5.1).
- Assess data using tools such as control charts and trend analysis to identify trends and potential problems (Section 2.4 and Appendix D).

Hazard identification and risk assessment

- Define the approach and methodology to be used for hazard identification and risk assessment (Section 2.5.1).
- Identify and document hazards, sources and hazardous events for each component of the water supply system (Appendix A).
- Estimate the level of risk for each identified hazard or hazardous event (Appendix A).
- Evaluate the major sources of uncertainty associated with each hazard and hazardous event and consider actions to reduce uncertainty (Appendix A).
- Determine significant risks and document priorities for risk management (Appendix A).
- Periodically review and update the hazard identification and risk assessment to incorporate any changes (Appendix A).

1.6 Health based targets

The ADWG (NHMRC 2011 Version 3.8) was updated in September 2022 with guidance on microbial health-based targets (HBTs).

HBTs provide an assessment of enteric pathogen risks in the source water and inform appropriate risk management measures (barriers). These assessment and preventive measures support Elements 2 and 3 of the Framework.

The microbial HBT (expressed as $\log_{10}$ reduction values or LRVs) are based on meeting a 1 x 10^{-6} Disability Adjusted Life Years (DALYs) per person per year (pppy). DALYs provide a measure of the impacts of diseases and injuries in terms of loss of good health where 1 DALY represents one lost year of healthy life.

Shortfalls in achieving required treatment targets to manage source water pathogen risks should be used to prioritise improvements. Health based targets are not a pass/fail matrix, they provide the basis for assessing the level of treatment required.

Vulnerability assessment and microbial indicator assessment is combined to give a classification of source water risk. A vulnerability assessment consists of identifying sources of pathogenic contamination within the water supply catchment and potential protection measures within the catchment. Source water catchment category classifications are shown in Table 1-1.

Table 1-1. Treatment targets for protozoa, bacteria and viruses given the source water type and *E. coli* results

Source water category (assessment)	Indicative source water category (vulnerability classification)	Maximum or 95th percentile *E. coli* results from raw water monitoring (number/100 mL) (band allocation)	LRV target to achieve 1x10^{-6} DALYs per person per year		
			Protozoa	Virus	Bacteria
Category 1	Surface water or groundwater under the influence of surface water, which is fully protected. or Secure groundwater	<20 (*E. coli* band 1)	0	0	4
Category 2	Surface water, or groundwater under the influence of surface water with moderate levels of protection	20 to 2000	3	4	4
Category 3	Surface water, or groundwater under the influence of surface water with poor levels of protection	20 to 2,000 (*E. coli* band 2)	4	5	5
Category 4	Unprotected surface water or groundwater under the influence of surface water that is unprotected	>2,000 to 20,000 (E. coli band 3)	5	6	6

Source: Table 5.5 of the ADWG, 2022

1.6.1 *Cryptosporidium* risk assessment

A *Cryptosporidium* risk assessment of the Narromine water supply was undertaken by NSW Health in 2020. This assessment gave the Narromine water supply system a preliminary risk rating of high based on the following:

- Stock in the catchment
- Sewage treatment plant and onsite sewerage systems in the catchment
- Shallow bores in unprotected aquifer

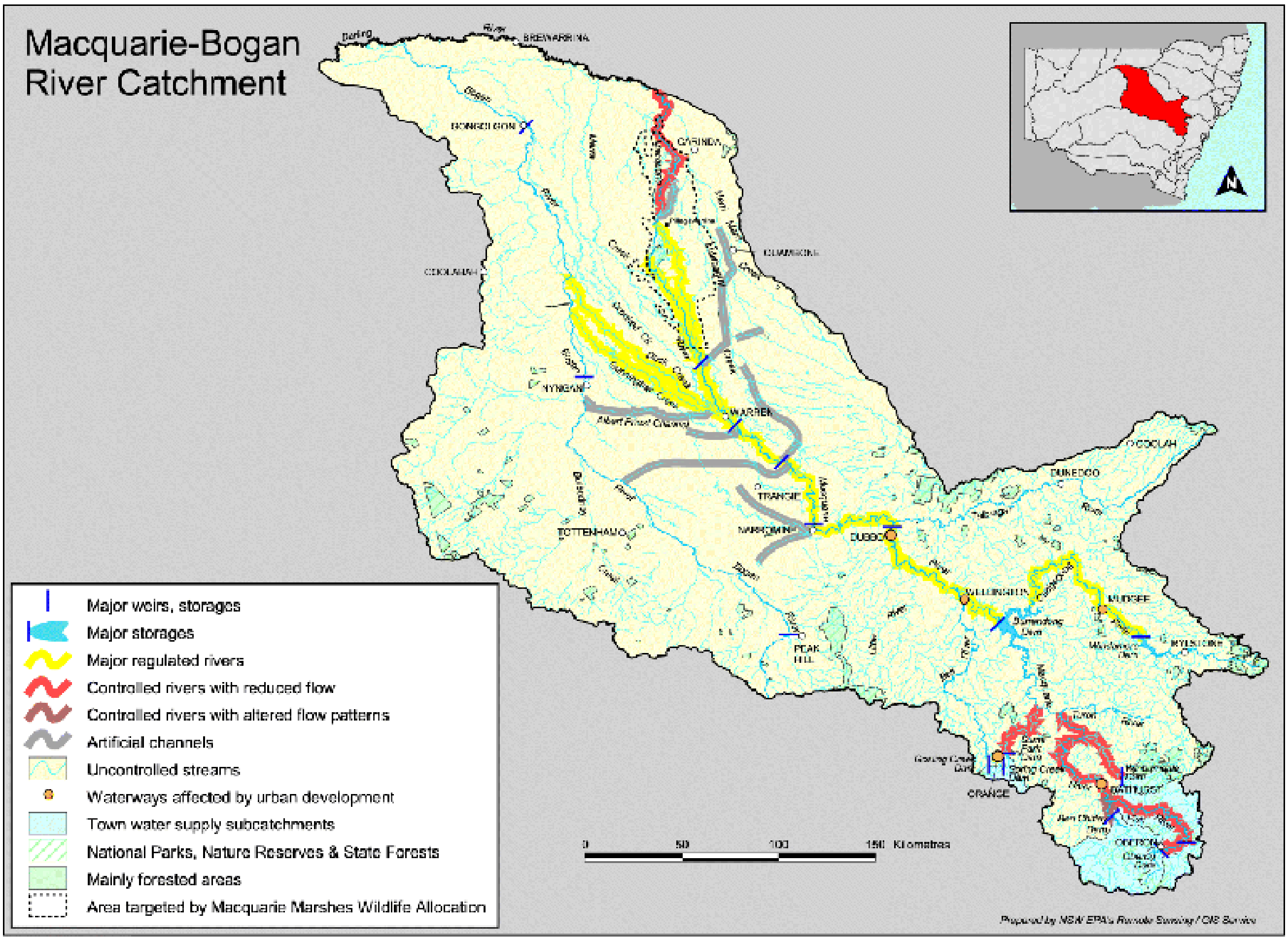
The catchment has therefore been assessed as Category 4.

2 Narromine Water Supply System

2.1 Catchment

Narromine Shire sits within the Macquarie – Bogan River Catchment, which is 74,800 km^2. This catchment provides water to around 180,000 people, and includes a number of major cities and towns, including Dubbo and Nyngan, and also provides water to some of the smaller towns such as Warren and Narromine. Land use in this catchment is dominated by grazing (82%), with dryland cropping accounting for the second highest level of land use (9%) (Narromine DWMS, 2018). Macquarie Bogan catchment area is included in Figure 2-1.

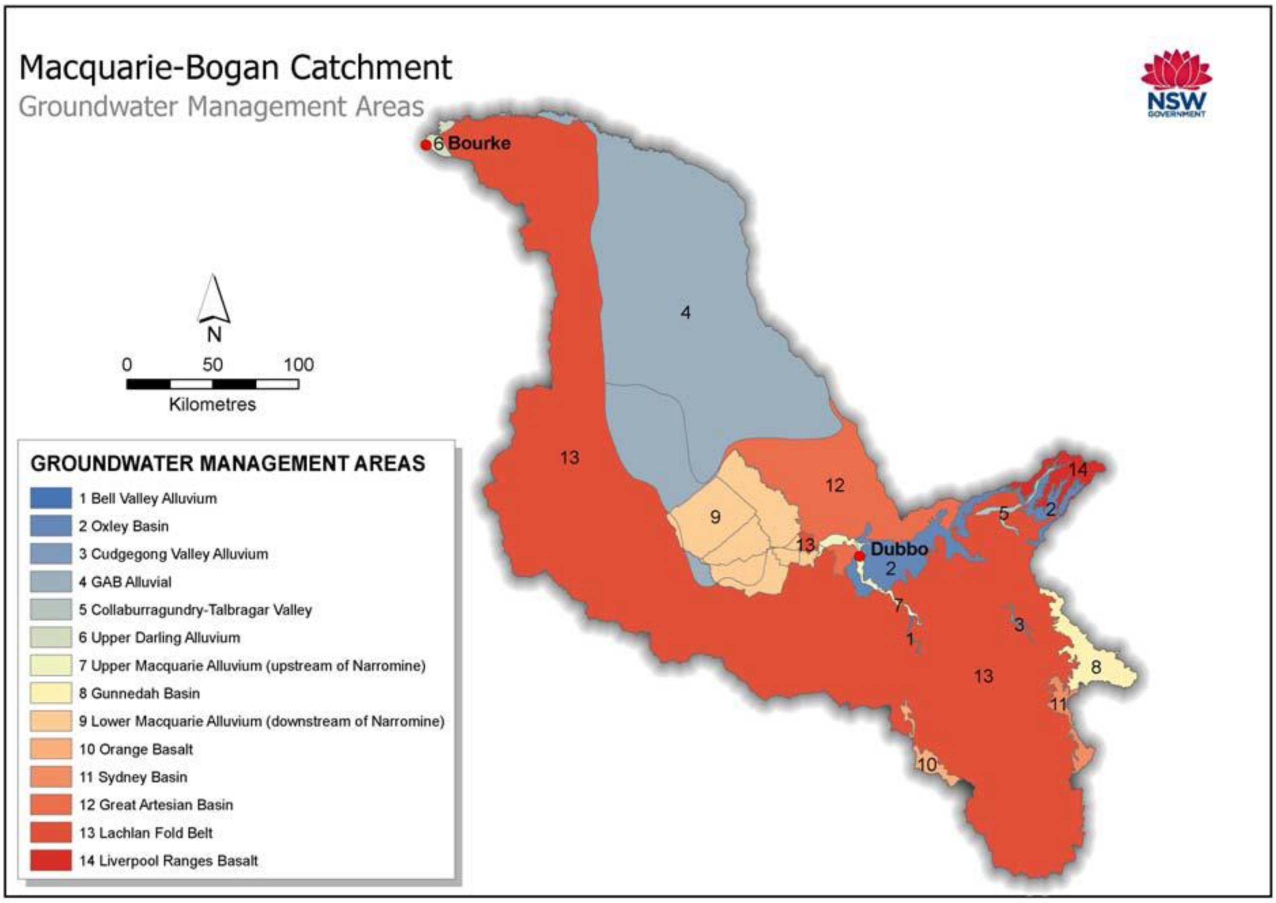
Figure 2-1. Macquarie Bogan catchment



Source: DPE Water

Narromine gets its water from bores that are drilled along the Lower Macquarie Alluvium sediments associated with ancient channels of the Macquarie River, downstream of Narromine (Figure 2-2). Water in the aquifer is part replenished by water that leaks from the river, or is pumped from the river and then seeps into the aquifer from irrigation channels and irrigated fields (Narromine DWMS, 2018)

Figure 2-2. Groundwater management areas, Macquarie-Bogan River Catchment



Source: DPE Water

Water is extracted from the Narromine bore field in the Macquarie Alluvial Aquifer. Recharge of the aquifer is dependent upon rainfall, leakage from the river channel and irrigation flows derived from pumping from the river.

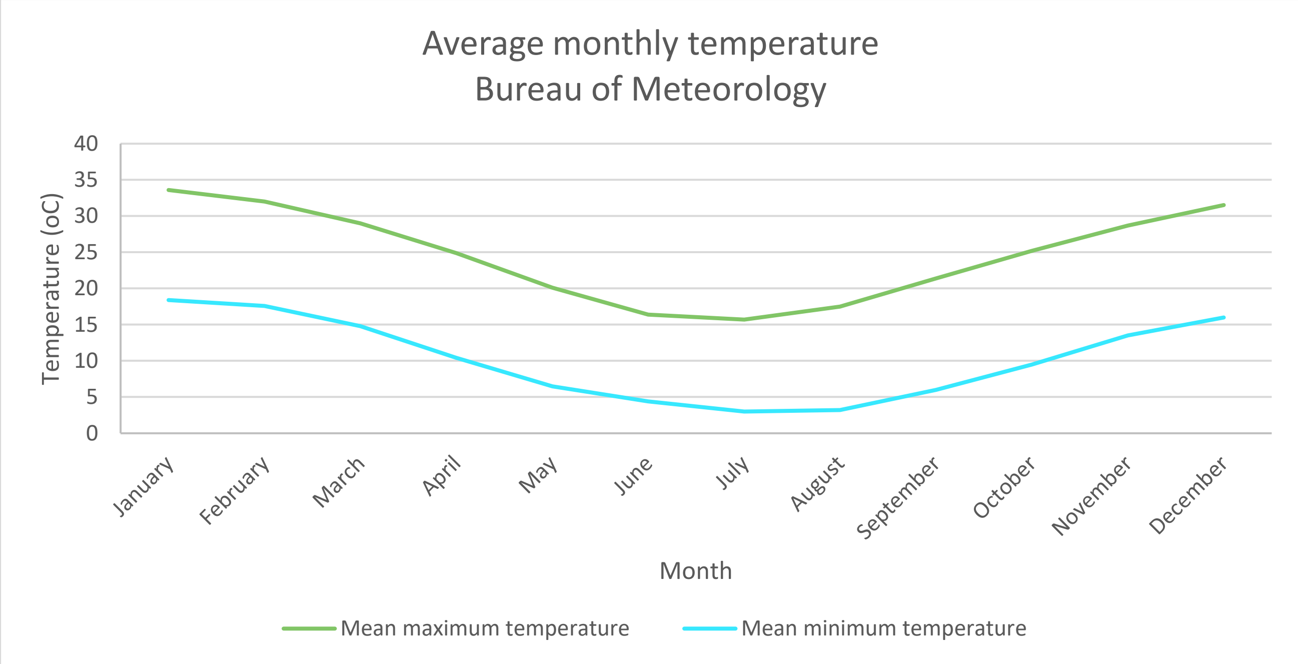
Raw water characteristics of Narromine Water supply vary depending on which bore is being used. Typical characteristics include:

- neutral pH
- variable turbidity (for a bore supply)
- high iron and manganese

2.2 Climate

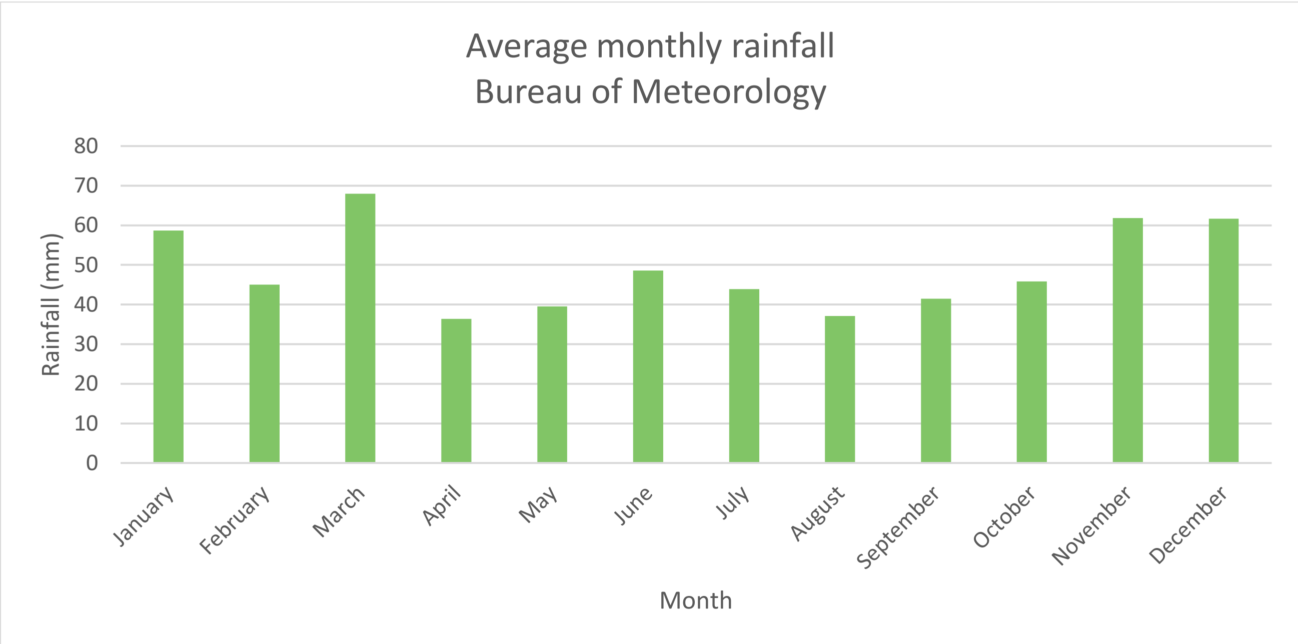
The nearest Bureau of Meteorology monitoring point to the Narromine catchment is Dubbo Airport. The historical average minimum and maximum temperatures are graphed in Figure 2-3. The average monthly rainfall is graphed in Figure 2-4.

Figure 2-3. Dubbo airport average temperature



Source: Dubbo Airport 1946 to 2022, BOM climate data online

Figure 2-4. Dubbo airport average rainfall



Source: Dubbo Airport 1946 to 2022, BOM climate data online

2.3 Water treatment and distribution

Water extracted from Bores 6 and 9 is processed through the temporary iron and manganese removal plant. This treated water is then combined with water from Bores 8D and Bore 3, aerated and chlorinated, and distributed to customers. A summary of the water supply system is shown in Table 2-1.

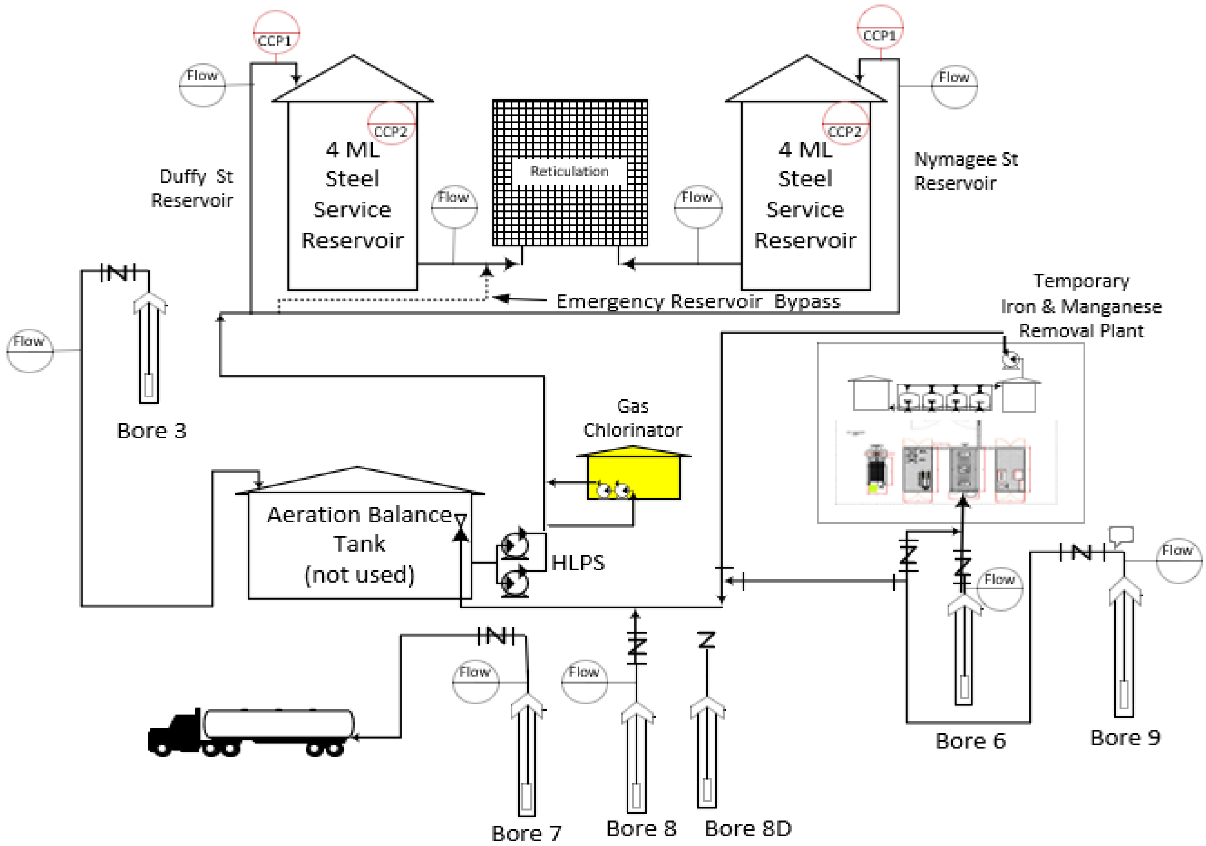
The Narromine water supply systems are shown in Figure 2-5 and Figure 2-6.

Supply system changes since 2018 have included the installation of a temporary iron and manganese removal system to treat water from bore 6 and 9. The plant was brought online for the first time in June 2020. It is owned and operated by an external contractor.

Table 2-1. Summary of water supply systems

Category	Description
Customers	1,718
Consumers	567 private dwellings (census 2016),7 Hotels/Motels, Caravan Park, 11 schools, 2 Hospitals, 3 Nursing Homes and 216 businesses (including industrial). Irrigation of parks and ovals by separate surface water licence for extraction from the Macquarie River. (Swan 2016)
Temporary iron and manganese removal plant	Temporary WTP (bore 6 and 9 only) • ISO reactor (aeration, ozonation, pH correction with Sodium Hydroxide) • Green sand filtration • GAC filtration • Clarified backwash water recycled to head of works
Aeration & Disinfection	The water supply is pumped into the aeration tank which is not currently operating but provides storage for high lift pumping. It is then pumped through duty/standby high lift pumps and flow paced disinfected with gaseous chlorine (Gas chlorine installed January 2018, previously Sodium Hypochlorite).
Reservoirs	Two 4.0 ML steel reservoirs, one on Nymagee St and the other on Duffy St both have top fill and bottom discharge. Reservoirs are interconnected through the rising main, with flow to Duffy St reservoir restricted to manage the flow to both reservoirs.
CCP Monitoring	Free & total chlorine, turbidity and pH are monitored through online instrumentation on the outlet of Duffy St and Nymagee St reservoirs. Free chlorine is also monitored by online instrumentation on the inlet to Nymagee St Reservoir.

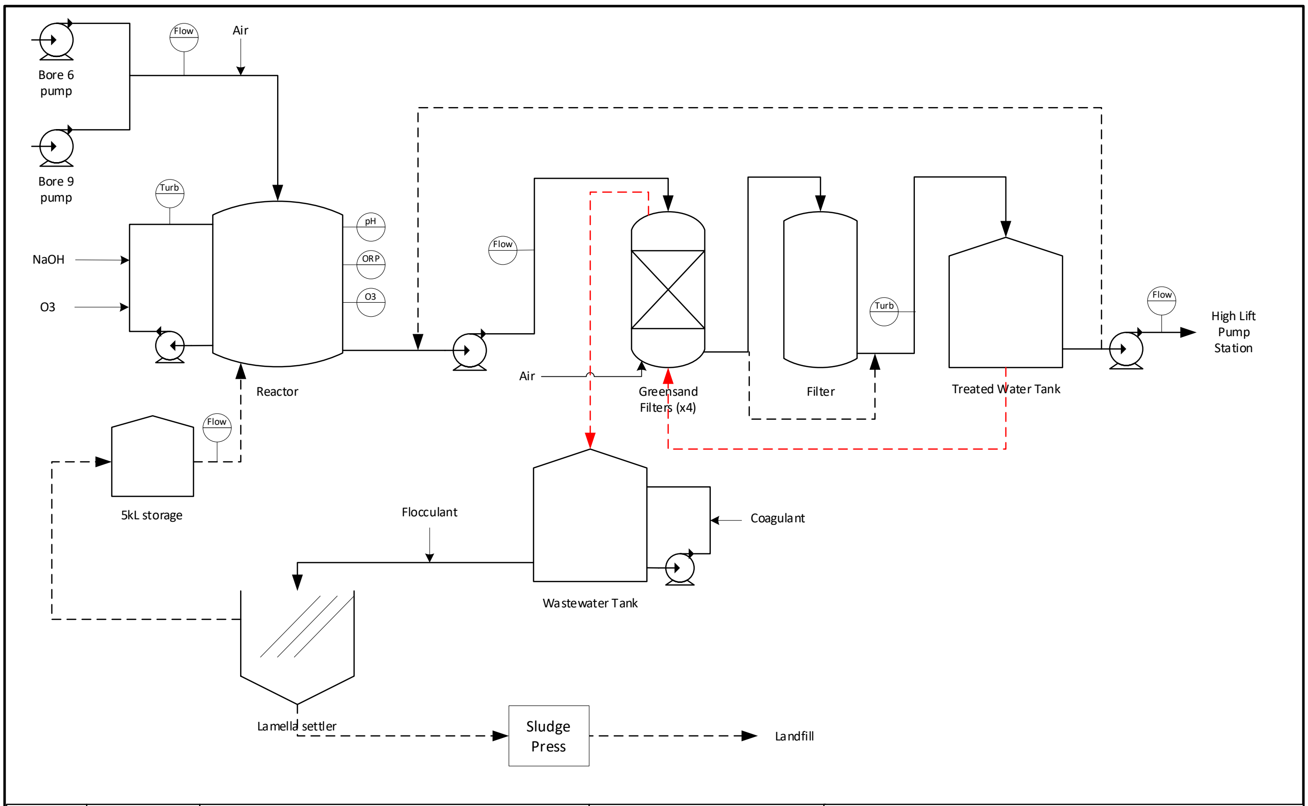
Figure 2-5. Narromine water supply system flow diagram



Version	Date	Details	Author
1.0	2020	Developed for IWCM brief	Doug Moorby
2.0	26/03/2021	CCPs added for 2020 DWMS annual report	Lucy Parsons
2.0	26/03/2021	CCPs added for 2020 DWMS annual report	Lucy Parsons

Narromine water supply system
Process flow diagram

Figure 2-6. Narromine Temporary WTP flow diagram



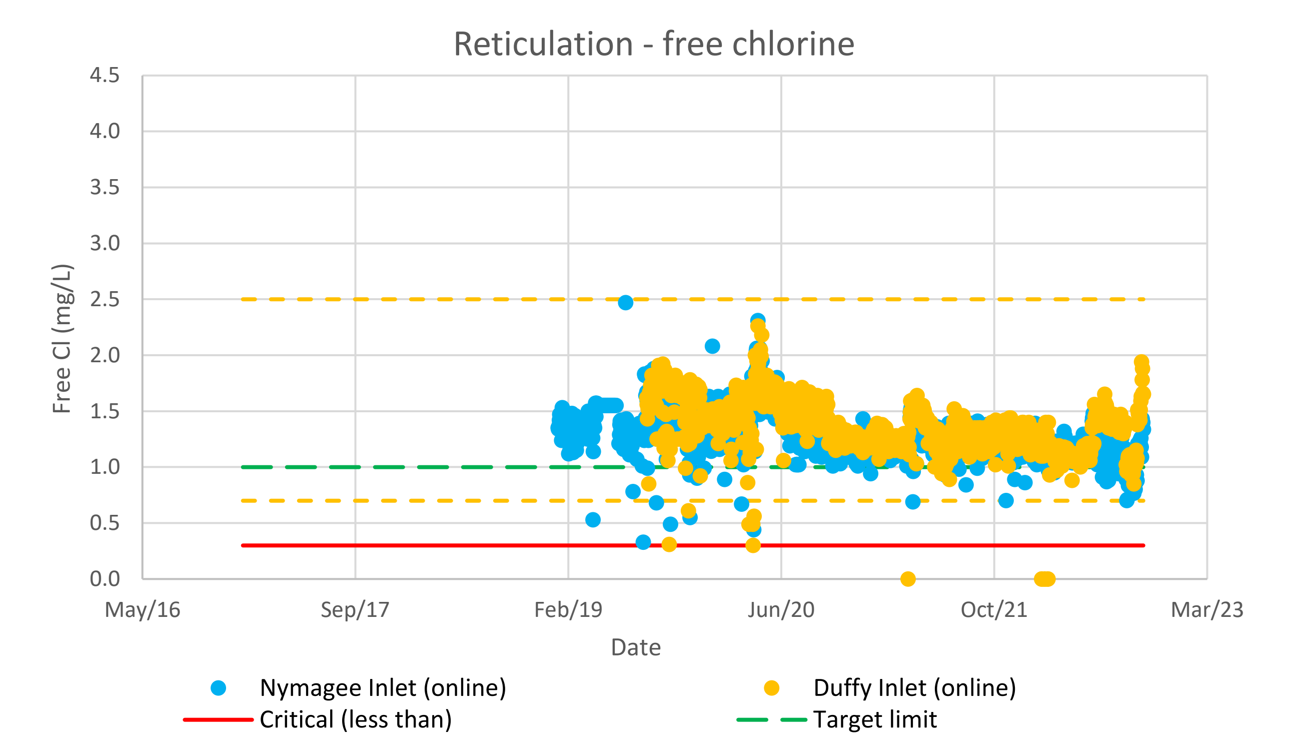
Version	Date	Details	Author	
1.0	06/09/2022	Developed from site drawings	ALM	Narromine temporary water treatment plant Process flow diagram

2.4 Water quality data

2.4.1 Operational water quality data

Performance of the Narromine WTP disinfection CCP is graphed in Figure 2-7.

Figure 2-7. Narromine WTP disinfection CCP



Source: Narromine operational monitoring data

2.4.2 Health based targets high level assessment

Indicative pathogen LRVs from the current Narromine treatment barriers, compared to the potential source water category requirements is shown in Table 2-2. A range of validated LRVs provides an indication of the range that might be seen at a WTP dependent on process performance.

Table 2-2. Indicative treatment barrier LRV compared to category requirements

Treatment process	Validated LRVs			Basis for validation
	Protozoa	Virus	Bacteria	
Chlorine	0.0	4.0	4.0	For bacteria and viruses, a default of 15 mg.min/L is given as an acceptable value in the Guidelines
Total	**0.0**	**4.0**	**4.0**	
Category 4	5.0	6.0	6.0	Additional process barriers would be required

Source: Table 5.6 of the ADWG (2011) Version 3.8, September 2022

2.5 Summary of water quality issues

A summary of the water quality characteristics that affect drinking water is shown in Table 2-3.

Table 2-3. Water quality issues summary

Parameter	Issues
Cryptosporidium	The Narromine water supply system has been assessed as high risk for *Cryptosporidium*. There are currently no treatment barriers for Cryptosporidium.
Iron and Manganese	Raw water from bores 6,7 and 9 have elevated levels of iron and manganese. Currently bores 6 and 9 are treated by the temporary WTP which uses ozone and filtration to remove iron and manganese. The sample collected from the Macquarie River on 2/11/2022 also had elevated manganese.
Lead	One sample from bore 6 on 2/11/2022 had lead of 0.013 mg/L which is above the ADWG guideline value of 0.01 mg/L
Free chlorine	Free chlorine in the reticulation is occasionally below the target of 0.5 mg/L (see Figure 2-8). However there have been no instances since 2018 of free chlorine below the ADWG guideline of 0.2 mg/L
Turbidity	Reservoir turbidity is regularly above the ADWG guideline value for chlorination of 1 NTU (see Figure 2-9).
Hardness	Total hardness in the reticulation has been above the ADWG guideline value of 200 mg/L as CaCO3 (see Figure 2-10)

Figure 2-8. Reticulation free chlorine

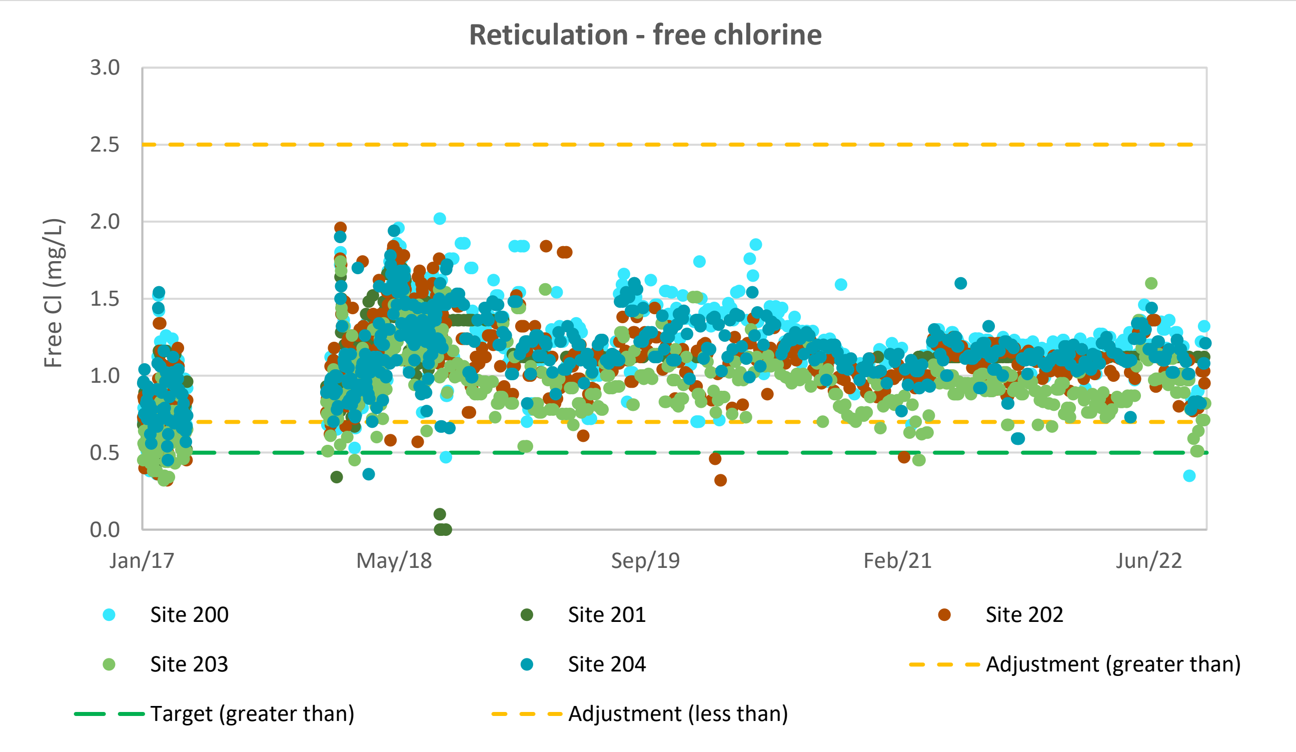


Figure 2-9. Reservoir turbidity

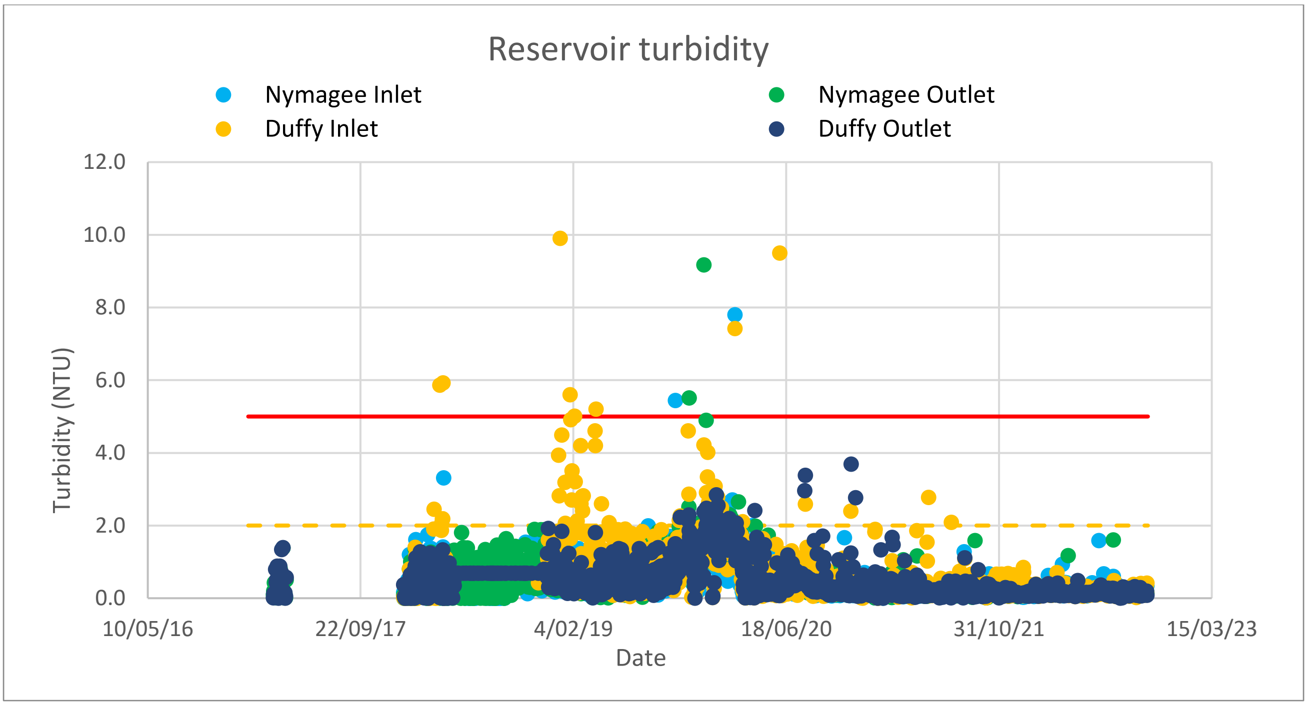
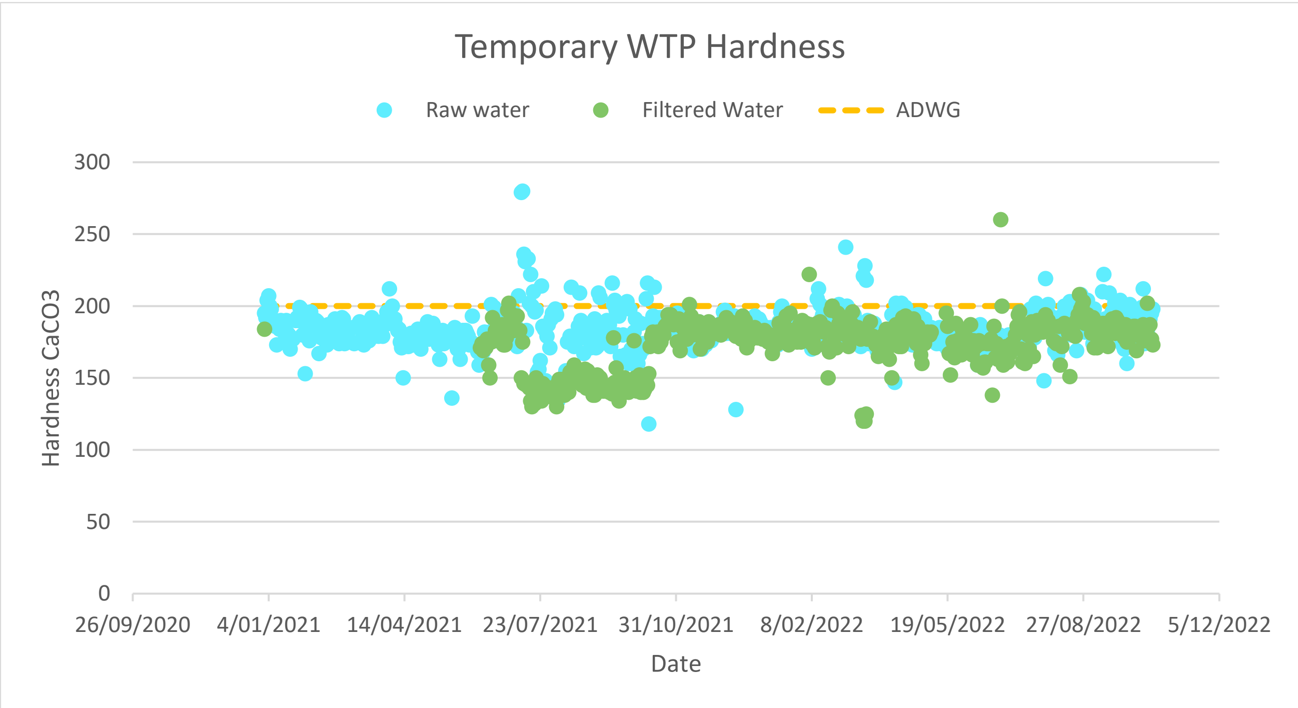


Figure 2-10. Temporary WTP hardness



2.5.1 Water quality exceptions

Water quality CCP exceptions are summarised in Table 2-4.

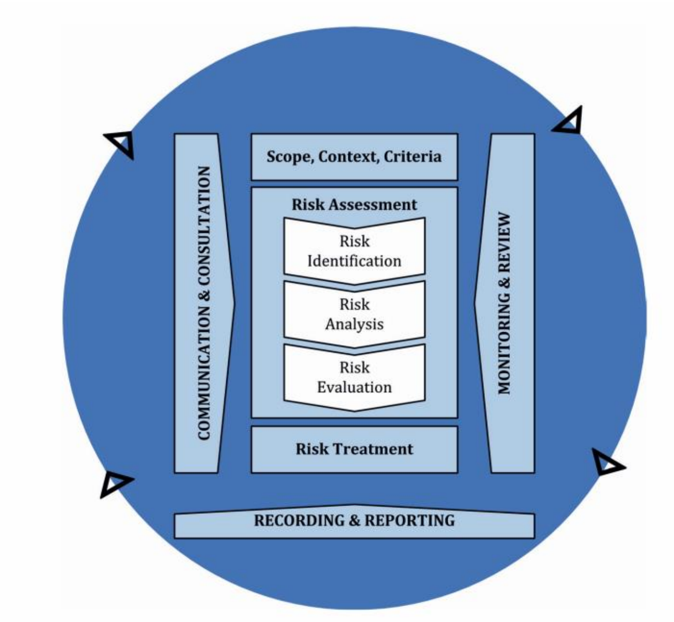
Table 2-4. Water quality CCP exceptions

Date	Location	Result	Response
13/04/2020	Duffy Inlet Chlorine (Online)	0.30	High raw water iron and manganese in the raw water consumed the chlorine in the reservoir. At the time there was no treatment capable of removing iron and manganese at the time. The temporary WTP commenced operation in June 2020.
12/04/2021	Duffy Inlet Chlorine (Online)	0.00	Attributable to a Communications Failure of the online monitoring equipment, this did not last very long and in fact was not long enough to breach the debounce timer on the high lift lock out system

3 Risk assessment methodology

The methodology for this water quality risk assessment review has been developed considering the risk management process of ISO 31000:2018 (Figure 3-1).

Figure 3-1. Risk management process

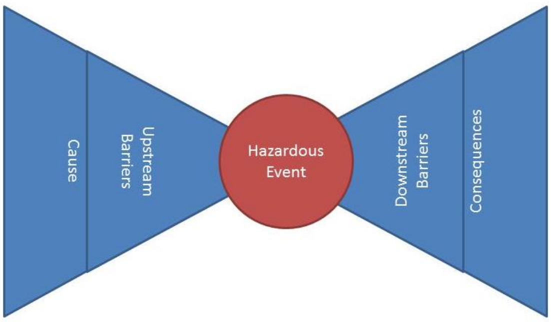


Source: ISO 31000:2018

3.1 Bow tie analysis

The risk assessment was conducted using bow tie analysis. Bow tie diagrams describe the pathways of a risk from its cause to its consequence and illustrate the barriers in place to reduce the risk (ISO/IEC 31010). When used as part of a risk assessment the focus is shifted from the outcome of the hazardous event to the effectiveness of the barriers – an approach well suited to water quality risk assessment. The components of a bow tie diagram are shown in Figure 3-2.

Figure 3-2. Basic Bow Tie Diagram



Bow tie analysis combines fault tree analysis which examines the cause of an event, with event tree analysis which examines the consequences.

At the centre of the bow tie is the hazardous event. The focus for analysis is the barriers between the cause and the event and the barriers between event and the consequence. The barrier-focussed analysis means it is well suited to documenting how a scheme is achieving a multiple barrier approach to water quality.

3.2 Identification of causes, consequences and barriers

For each hazardous event, participants were asked to identify causes, consequences and barriers for each pathway. The components of the diagram are listed in Table 3-1 and information captured Table 3-2.

Table 3-1. Components of a bow tie

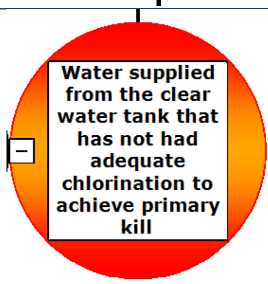
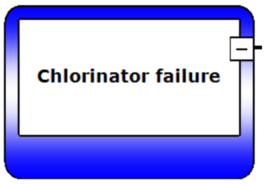
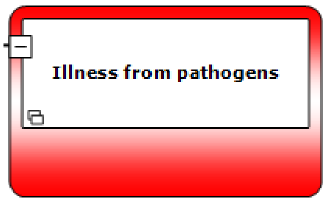
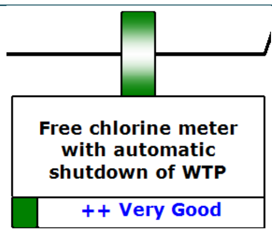
Item	Description	
Hazard	Describe the hazard in its controlled state e.g. Transporting fuel from A to B, Chlorine sensitive pathogens in the clearwater tank	
Top event	Top event when control of the hazard is lost. Examples include: Supply of water from clearwater tank with ineffective disinfection (which may include distribution residual), failure to achieve primary kill, ineffective filtration	
Causes	Causes lead directly and independently to the top event. Causes should not be barrier failures. Consider: 1. Primary equipment not performing within normal operating limits 2. Environment influences 3. Operational issues (human error, co-current operations)	
Consequence	Consequences are *damage* due to the *event* e.g. illness due to disinfection failure	
Controls	Controls eliminate the threat or prevents it reaching the top event. Controls must be independent. Active control should incorporate detect-decide-act	

Table 3-2. Information captured using the bow-tie methodology

Component	Items	Example
Causes	Frequency	Continuous, daily, weekly, monthly, yearly
	Contribution	High, medium and low contribution

Component	Items	Example
Consequence	Risk assessment	Public health, operational risk rankings
	Uncertainty	Certain, estimate, uncertain
Barriers	Effectiveness	Very good, good, poor, very poor
	Criticality	Critical control point, operational control point, quality control point

3.2.1 Consideration of human factors

As part of the risk assessment, human factors were considered. Human factors refer to environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety (UK Health and Safety Executive 1999). Further details are included in Appendix E.

3.3 Control Effectiveness

Controls were assessed to determine how effective they are in reducing or eliminating the hazard. Each control was assessed for viability (Table 3-3) and impact (Table 3-4) to determine the control effectiveness (Table 3-5).

Viability is the likelihood that the control is going to exist when needed and work as designed or intended, and can be assessed using the following criteria:

- Availability – exists and is present when needed
- Survivability – robust when in high demand
- Reliance – reliance on operators or third parties
- Maintainability – there is access to parts, equipment or specialist skills when needed

Impact of the control is the assessment of functionality and fitness for purpose. Impact is the actual impact that the control will have on the element which is intended to be controlled. Where available, reference to the literature has been used to assess the impact that the control will have.

Table 3-3. Control viability table

Descriptor	Example description
Very good	Control is in place and used all the time Control has very good reliability with clear limits of operation Control is robust and able to deal with high or very high levels of contamination Control requires little or no maintenance
Good	Control is nearly always available or is often used Control is reliable to implement with operational limits Control is robust and able to deal with lower levels of contamination
Poor	Control is available but not often used Control is of a procedural or administrative nature e.g. monitoring or maintenance activities
Very poor	Control is often not available or not in use Control is reliant on third parties for operation or implementation Control is reliant on specialist skills / parts that are not readily available

Table 3-4. Control impact table

Descriptor	Example description
Very good	High levels of prevention or removal of contaminants
Good	Good level of prevention or removal of contaminants
Poor	Poor level of prevention or removal of contaminant
Very poor	Very poor level of prevention or removal of contaminants

Table 3-5. Control effectiveness matrix

Control Impact	Control viability			
	Very good	Good	Poor	Very poor
Very good	Very good	Very good	Good	Poor
Good	Very good	Good	Poor	Poor
Poor	Good	Poor	Poor	Very poor
Very poor	Poor	Very Poor	Very Poor	Very poor

3.4 Uncertainty

Uncertainty of the risk ranking was assessed using the descriptors in Table 3-6.

Table 3-6. Uncertainty descriptors

Certainty Level	Possible Sources of Uncertainty		
	Data	Surveillance	Event/Hazard
Confident	Sound body of information available	Monitoring is robust	Event or hazard have happened before at our organisation or within the system
Estimate	Some data available	Monitoring could be improved	Event or hazard have happened before to another organisation or industry but not yet to us
Uncertain	No or limited data available	Ad hoc, or no monitoring in place or hazard not yet possible to monitor, even with surrogates	Event or hazard has just ‘appeared on the radar’

3.5 Risk ranking

Risks were assessed as Likelihood (Table 3-7) x Consequence (Table 3-8). A risk assessment matrix (ADWG 2011) was used to assess risks for maximum and residual risks (Table 3-9).

Table 3-7. Likelihood table

Level	Descriptor	Example description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur or should occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

Source: ADWG (2011)

Table 3-8. Consequence table

Level	Descriptor	Example description
1	Insignificant	Insignificant impact, little disruption to normal operation, low increase in normal operation costs
2	Minor	Minor impact for small population, some manageable operation disruption, some increase in operating costs
3	Moderate	Minor impact for large population, significant modification to normal operation but manageable, operation costs increased, increased monitoring
4	Major	Major impact for small population, systems significantly compromised and abnormal operation if at all, high level of monitoring required
5	Catastrophic	Major impact for large population, complete failure of systems

Source: ADWG (2011)

Table 3-9. Risk matrix

	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A (almost certain)	Moderate	High	Very high	Very high	Very high
B (likely)	Moderate	High	High	Very high	Very high
C (possible)	Low	Moderate	High	Very high	Very high
D (unlikely)	Low	Low	Moderate	High	Very high
E (rare)	Low	Low	Moderate	High	High

Source: ADWG (2011)

4 Risk assessment results

4.1 Workshop details

The Narromine Water Supply System risk assessment was previously reviewed in 2018. A risk assessment review workshop was held on 22 November 2022. The agenda for the risk assessment is included in Appendix A.

To ensure an appropriate level of expertise and knowledge, the risk assessment team comprised of managerial and operational staff from Council, contractors, regulators and technical experts. A list of participants who attended the workshops are listed in Table 4-1. Workshop sign in sheets are included in Appendix A.

Table 4-1. Risk assessment workshop participants

Organisation	Name	Role
Narromine Shire Council	Doug Moorby	Manager Utilities
	Victoria Finlayson	Cadet Engineer
	James Cleasby	Manager Health / Building / Environment
	Duane Donnelly	Water & Sewer
	David Kent	Water & Sewer
	Anthony Everett	Utilities Technical Assistant
NSW Health	Mark Nave	Environmental Health Officer, Western NSW LHD
	Leslie Jarvis	Senior Policy Advisor - Water Unit
DPE Water	Bruce Lamont	Regional Inspector – Western Region
	Cindy Houston	Senior Project Officer
Atom Consulting	David Bartley	Workshop facilitator
	Steven Contos	Workshop recorder/technical advice

4.2 Risk assessment summary

Nine bow ties were developed for the Narromine WTP. Participants ranked risks from a health or operational perspective using a risk assessment matrix.

There was a total of 2 aesthetic risks and 11 health risks ranked as part of the process. The risk assessment workshop reviewed 40 causes and 13 consequences of these hazardous events.

A summary of the system risks is shown in Table 4-2 and Table 4-3. Residual risks for community illnesses remain very high as the consequences remain assessed as catastrophic. The full risk register is included in Appendix H. Bow tie diagrams are included in the following section.

Table 4-2. Narromine risk analysis summary – catchment

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health	Uncertainty
Aquifer contamination by pathogens	Community illness from chlorine resistant pathogens	Health (ADWG)	Very high (5A)	Very high (5A)	High (5E)	C

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health	Uncertainty
	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)	C
	Community illness from Naegleria Fowleri	Health (ADWG)	Moderate (3E)	Moderate (3E)		C
Aquifer contamination by chemicals	Chronic/acute health impacts from chemicals	Health (ADWG)	Very high (3A)	High (3C)	High (3C)	C
River contamination by pathogens	Community illness from chlorine resistant pathogens	Health (ADWG)	Very high (5A)	Very high (5A)	High (5E)	C
	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)	C
	Community illness from Naegleria Fowleri	Health (ADWG)	Moderate (3E)	Moderate (3E)		C
River contamination by chemicals	Chronic/acute health impacts from chemicals	Health (ADWG)	Very high (3A)	High (3C)	High (3C)	C
Algal bloom in Macquarie River	Community illness from toxins	Health (ADWG)	Moderate (3D)	Moderate (3D)	Low (1D)	C
	Aesthetic impacts at customers tap	Aesthetic (ADWG)	Very high (3A)	Moderate (3D)	Moderate (3D)	C

Table 4-3. Narromine risk analysis summary – Narromine WTP

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health	Uncertainty
Insufficient bore water supply to meet demand	Customers provided with insufficient water supply	Health (ADWG)	Very high (5B)	Very high (5C)	High (5E)	U
Water in service reservoirs has not had adequate CT to achieve primary kill	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	Very high (5D)	High (5E)	C
	Community illness from Naegleria Fowleri	Health (ADWG)	Moderate (3E)	Moderate (3E)		C
Ineffective iron and	Community illness from chlorine sensitive pathogens	Health (ADWG)	Very high (5A)	High (5E)	High (5E)	C

Hazardous event	Consequence	Risk	Inherent	Residual	Proposed health	Uncertainty
Manganese removal	Taste and odour complaints due to levels above ADWG limits	Aesthetic (ADWG)	Very high (3A)	Moderate (3E)		C
Ineffective organic removal	Disinfection by-products above ADWG limits in customers water	Health (ADWG)	Very high (3A)	Very high (3A)	High (3C)	C

4.3 Bow ties

Bow ties were developed for the following events for the Narromine catchment;

- Aquifer contamination by pathogens (Figure 4-1)
- Aquifer contamination by chemicals (Figure 4-2)
- River contamination by pathogens (Figure 4-3)
- River contamination by chemicals (Figure 4-4)
- Algal bloom in Macquarie River (Figure 4-5).

Bow ties were developed for the following events for the Narromine WTP;

- Insufficient bore water supply to meet demand (Figure 4-6)
- Water in service reservoirs has not had adequate CT to achieve primary kill (Figure 4-7)
- Ineffective iron and manganese removal (Figure 4-8)
- Ineffective organic removal (Figure 4-9).

Figure 4-1. Aquifer contamination by pathogens

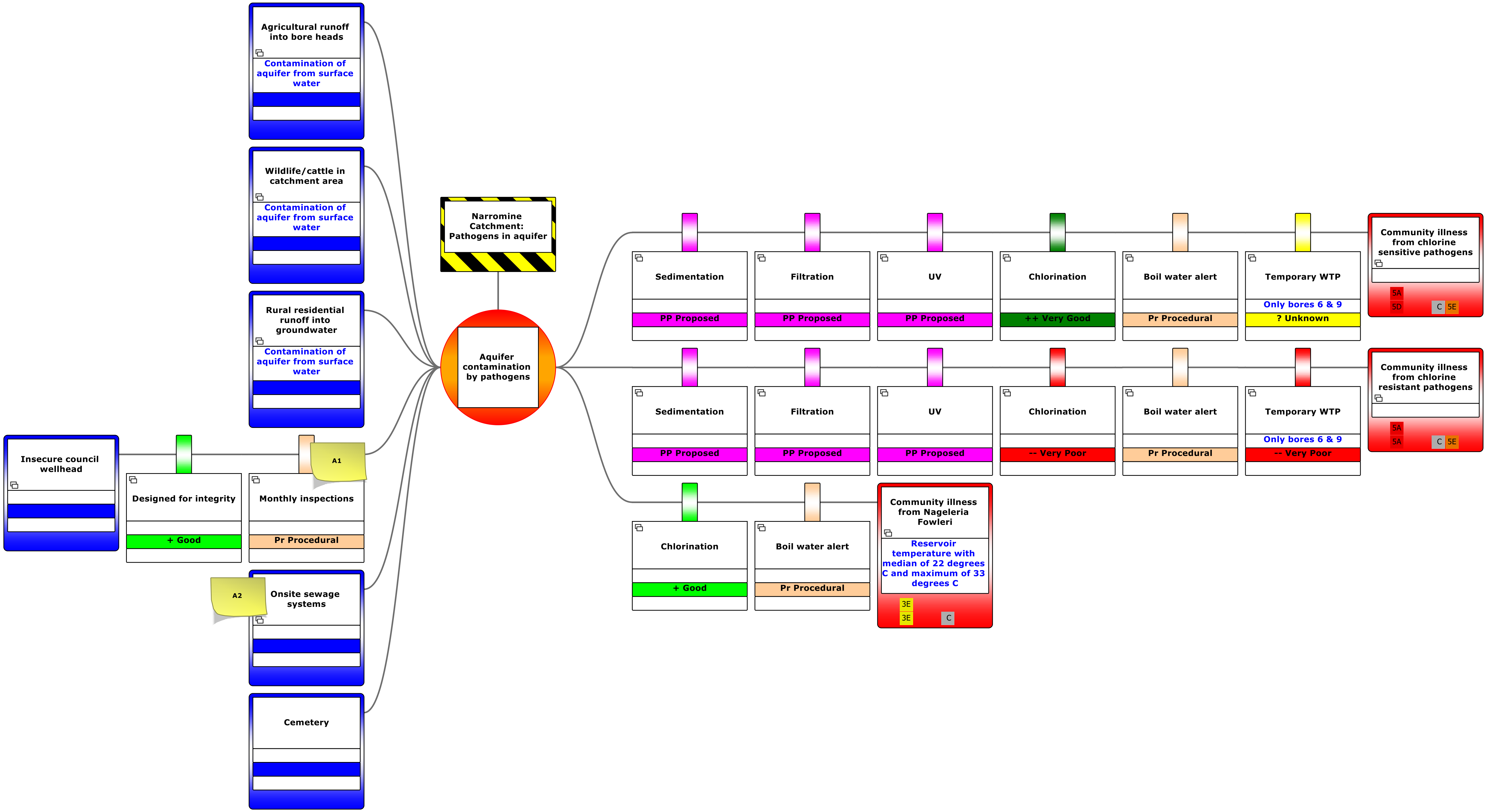


Figure 4-2. Aquifer contamination by chemicals

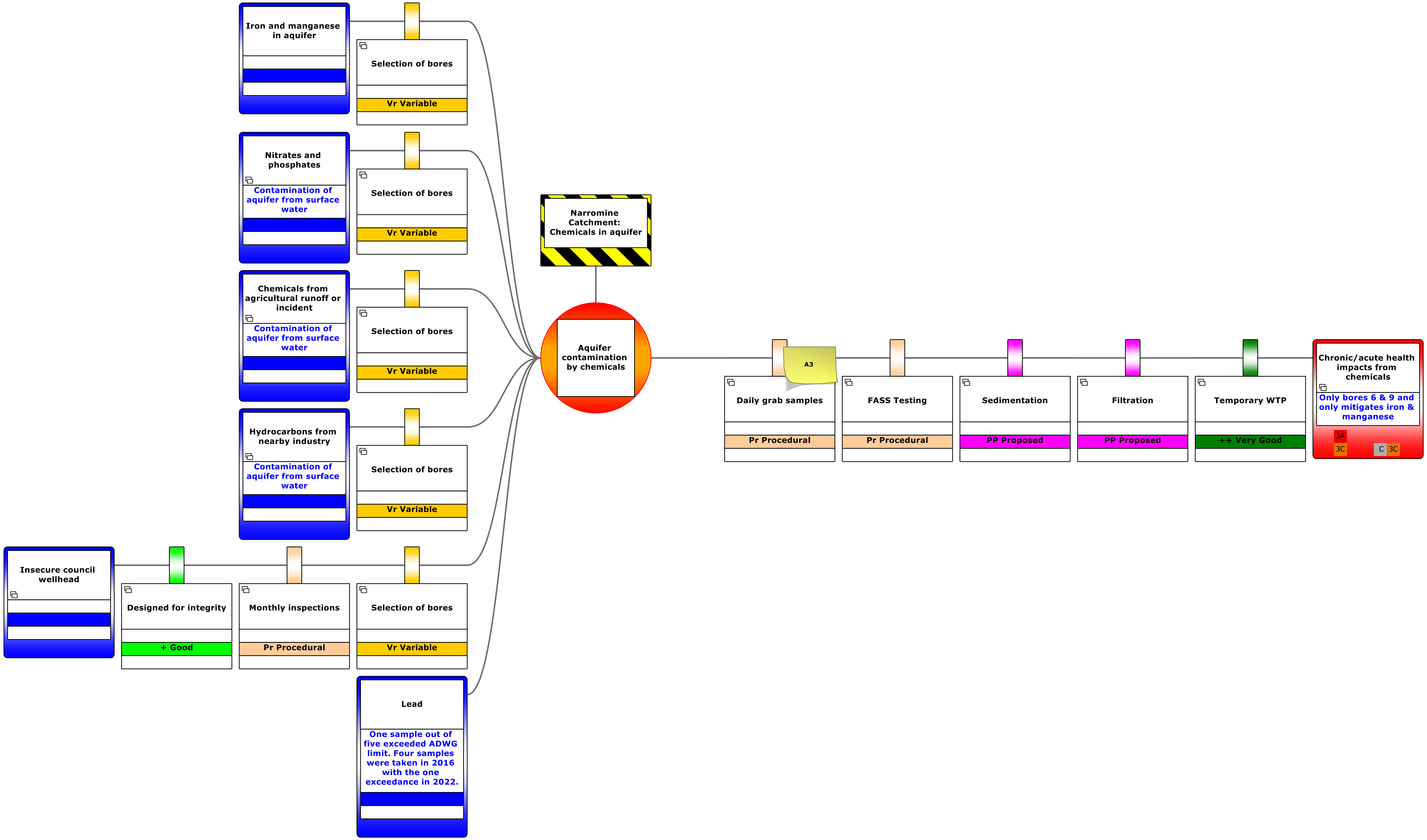


Figure 4-3. River contamination by pathogens

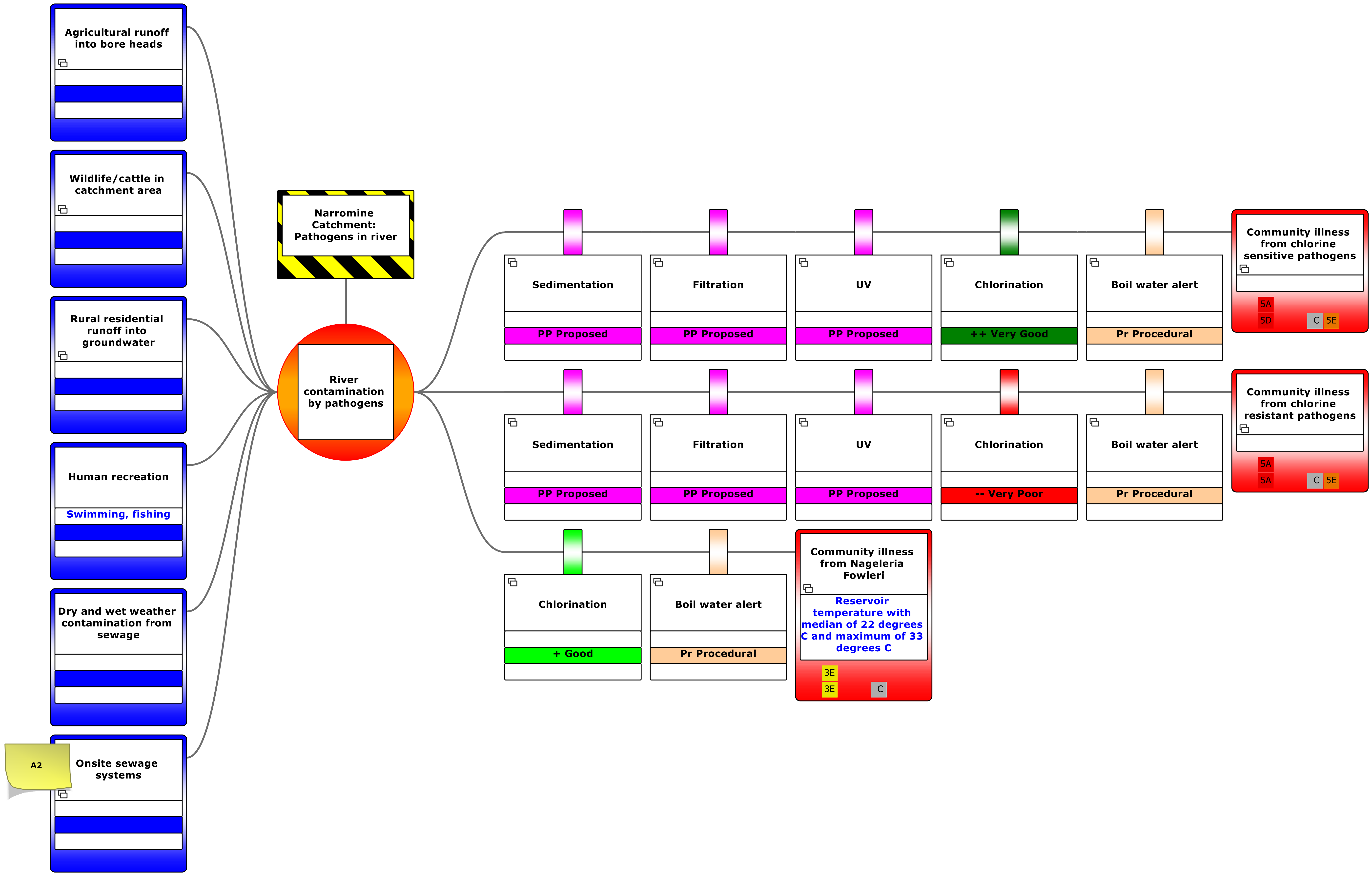


Figure 4-4. River contamination by chemicals

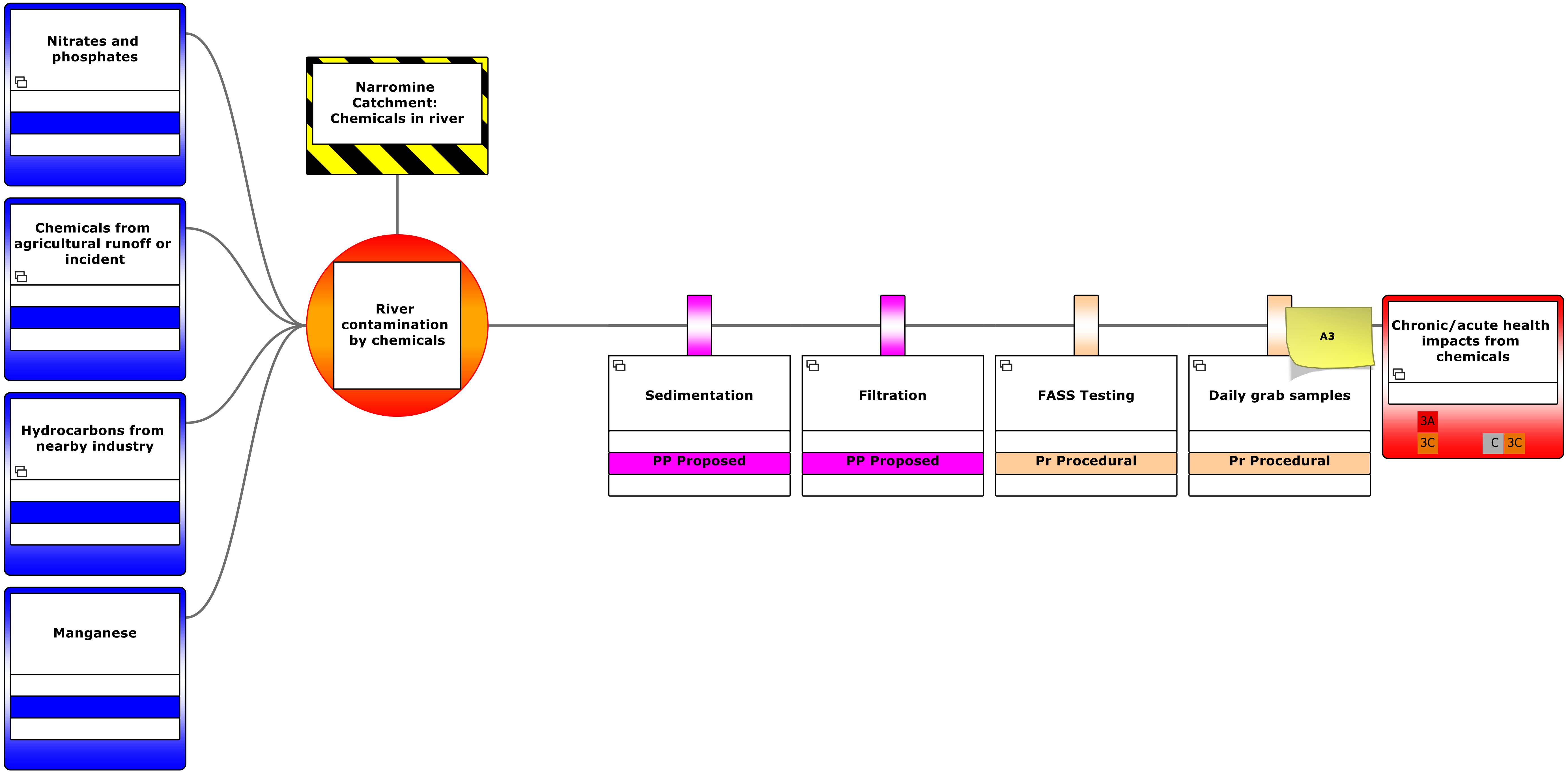


Figure 4-5. Algal bloom in Macquarie River

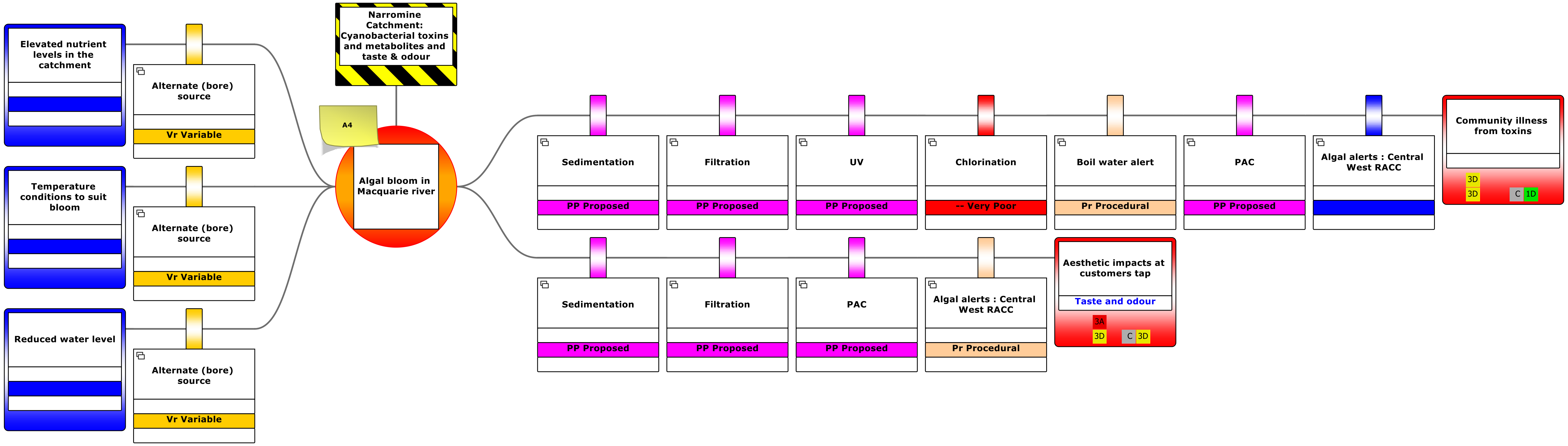


Figure 4-6. Insufficient bore water supply to meet demand

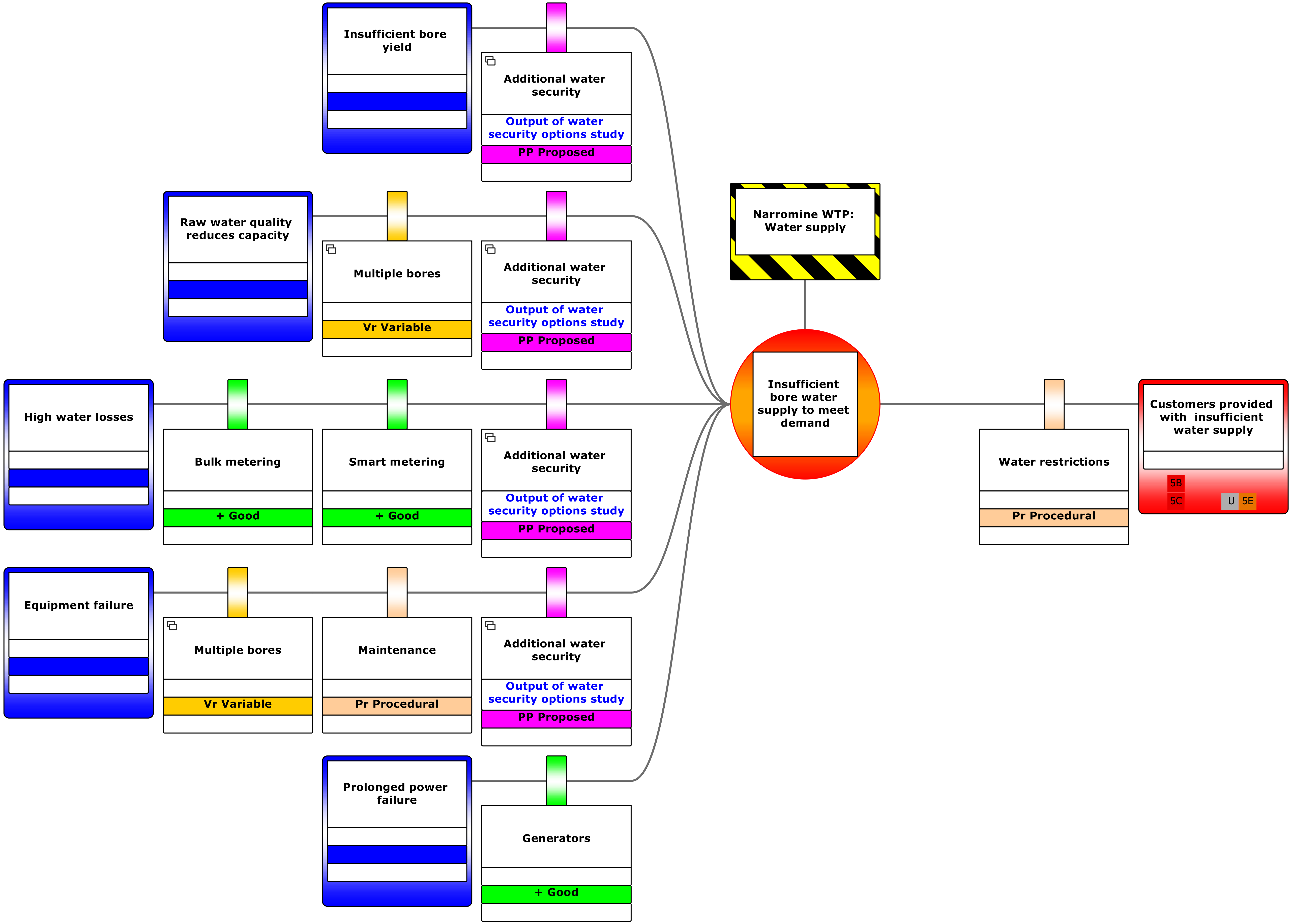


Figure 4-7. Water in service reservoirs has not had adequate CT to achieve primary kill

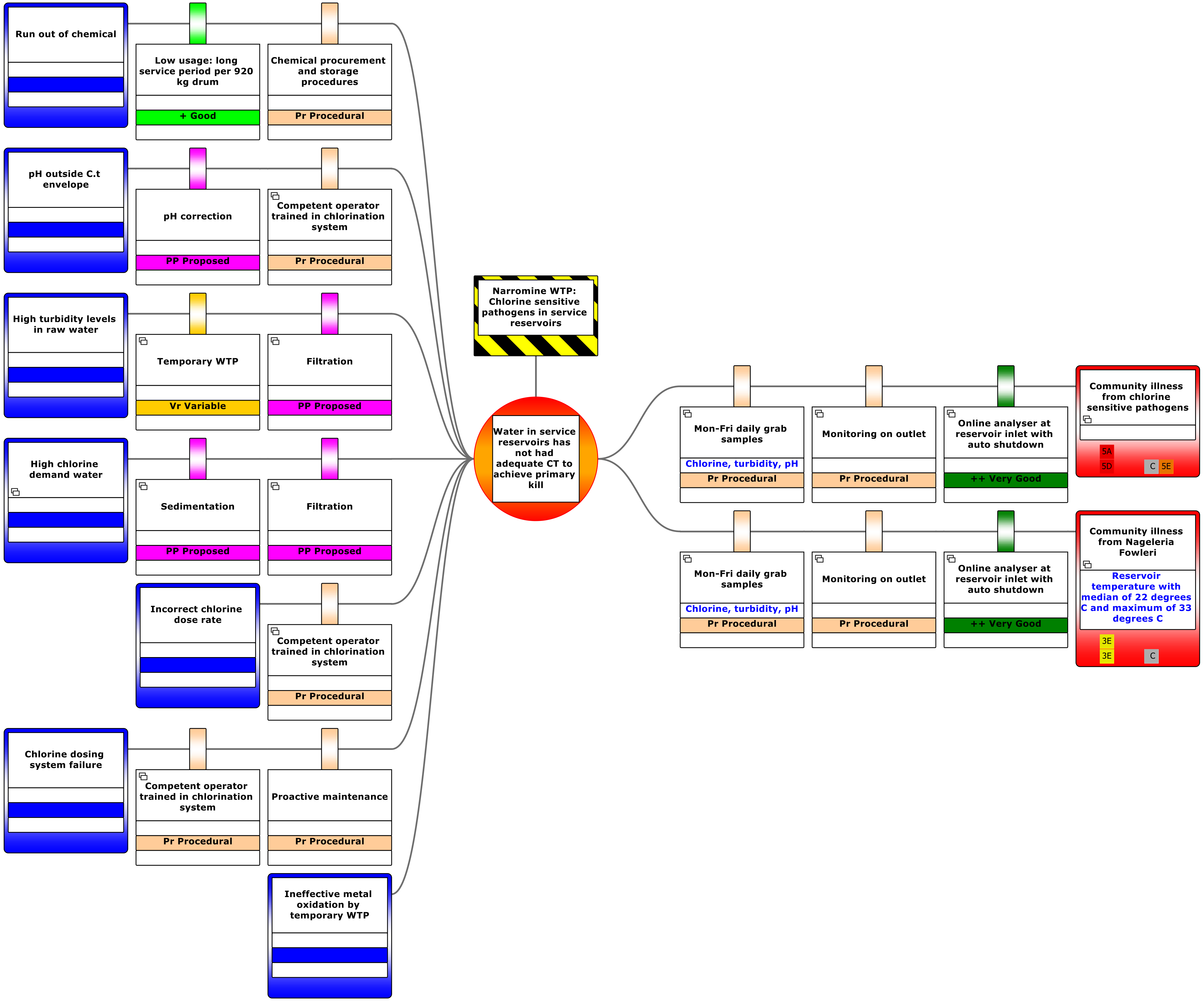


Figure 4-8. Ineffective iron and manganese removal

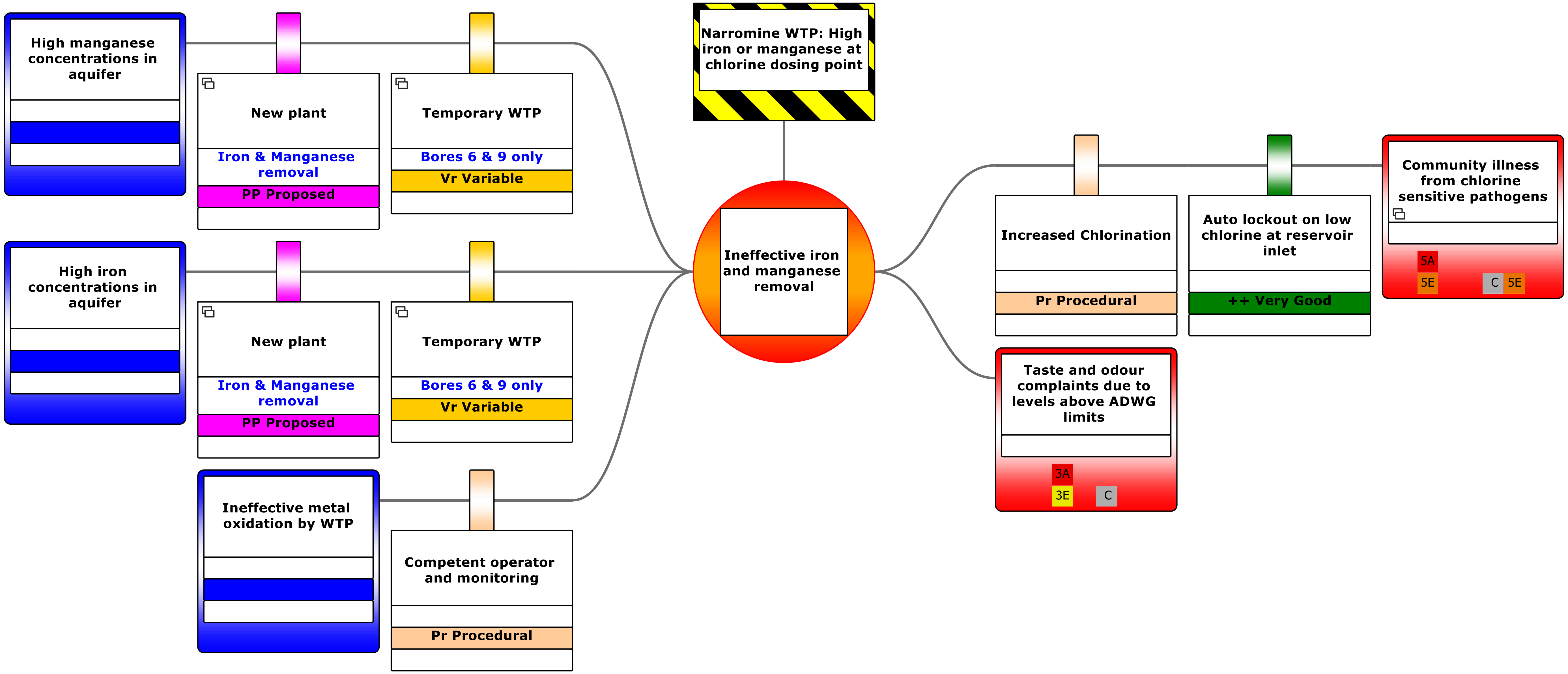
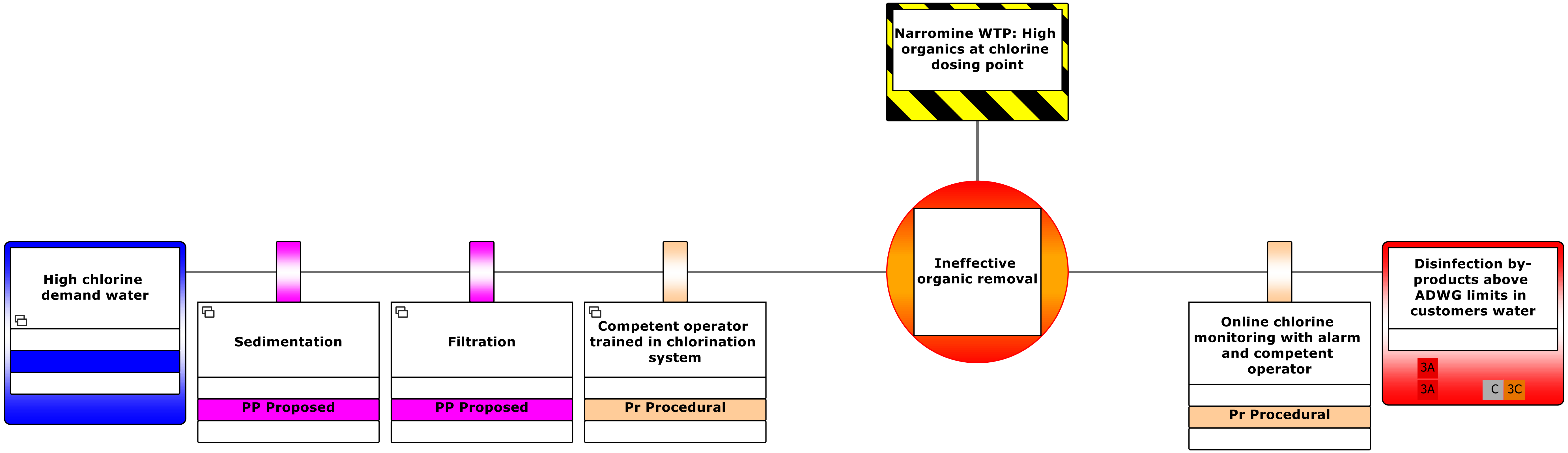


Figure 4-9. Ineffective organic removal



5 Critical control points

Critical control points (CCPs) are the operational core of the drinking water management system. For a point to be considered critical it must:

1. Control hazards that represent a significant risk and require elimination or reduction to assure supply of safe drinking water.
2. Have a parameter (surrogate) that can be measured in a timely manner to detect the hazardous event
3. Be able to have a correction applied in response to a deviation in the process

A review of critical control points (CCP), critical operational points (COP) and Quality Points (QP) was undertaken as part of the risk assessment workshop. CCPs protocols were also reviewed and are included in Appendix F.

Updated CCPs are shown in Table 5-1. The CCP limits were last updated in November 2022.

Table 5-1. Summary of Narromine WTP critical control points

CCP number	Control point	Monitoring parameter	Target criterion	Adjustment limit	Critical limit
1	Chlorine disinfection	Free chlorine at reservoir outlet (online)	1 mg/L	Less than 0.7 mg/L or greater than 2.5 mg/ L	Less than 0.3 mg/L or greater than 4.0 mg/L
		Turbidity at dosing point	Less than 0.2 NTU	Greater than 0.5 NTU after 24 hours	Greater than 1.0 NTU after 1 hour
2	Reservoirs	Reservoir integrity inspection (daily, weekly, monthly)	No breach of integrity	Any sign of integrity breach	Evidence of contamination

6 Actions

The workshop and CCP review identified four new actions shown in Table 6-1. The action number corresponds to the yellow sticky note shown on the bow tie diagrams (A#). These actions should be assigned to the appropriate person, the action undertaken and the effectiveness of the action reviewed to ensure the issue has been addressed.

Table 6-1. Risk assessment action summary

No.	Action	Hazard event	System
A1	Develop and implement a procedure for weekly wellhead inspections	Aquifer contamination by pathogens	Narromine
A2	Perform inspections of onsite systems	Aquifer contamination by pathogens	Narromine
A3	Fortnightly sample SP1 when operators available	Aquifer contamination by chemicals	Narromine
A4	Share data with upstream users (Dubbo)	Algal bloom in Macquarie River	Narromine

7 References

ADWG see Australian Drinking Water Guidelines 6 National Water Quality Management Strategy - Natural Resource Management Ministerial Council

AGWQMR see Australian Guidelines for Water Quality Monitoring and Reporting - Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand

AS/NZS ISO, 2019, AS/NZS ISO 31000: Risk management - Principles and guidelines

Bureau of Meteorology, 2020, Climate statistics for Australian locations, Canberra AU.

Department of Planning, Industry and Environment, Catchment snapshots – Macquarie-Bogan, NSW Government. https://www.industry.nsw.gov.au/water/basins-catchments/snapshots/macquarie-bogan . Viewed 15/11/2022.

ISO/IEC, 2009, ISO/IEC 31010 Management – Risk Assessment Techniques, Geneva, Switzerland

NHMRC (2011) Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. Version 3 Updated March 2015, National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

NSW Health, 2005, Drinking Water Monitoring Program December 2005 (Updated 2011).

NSW Ministry of Health, 2013, NSW Guidelines for Drinking Water Management Systems

Appendix A Workshop details

A.1 Workshop scope

A facilitated drinking water quality risk review workshop was undertaken on the 22 November 2022 for the Narromine water supply scheme.

A.2 Workshop details

The agenda for the risk assessment workshop is shown in Table A-1.

Table A-1. Risk assessment workshop agenda

Location: Narromine Council Chambers

Date	Time	Item
22 November 2022	9:00	Introduction roundtable, workshop methodology
	9:10	Risk assessment methodology
	9:15	Narromine system description • Review flow diagram • Discussion on water quality data • Operational issues • *Cryptosporidium* risk • Health based targets
	10:30	*Break*
	10:45	Narromine risk review
	12:30	*Lunch*
	1:00	Review current CCPs
	1:30	New WTP requirements • Health based targets • Aesthetic parameters
	2:30	Review of recommendations and next steps
	3:00	*Finish*

A.3 Sign in sheet

Narromine Shire Council
Narromine Water Quality Risk Assessment
List of Attendees, 22 November 2022

Name	Organisation	Role	Phone number	Signature
David Bartley	Atom Consulting	Facilitator	0409845326	
Doug Moorby	NSC	MANAGER UTILITIES	0427-221902	
Victoria Finlayson	NSC	Cadet Engineer	0417 070 363	
James Clark	NSC	Manager Health/Building/Environment	0468 938 208	
Duane Donnelly.	NSC	WATER & SEWER,	0473 522580	
David Kent	NSC	Water & Sewer	0499246527	
Anthony Everett	NSC	" "	0458888674	
MARK NAUE	Dubbo PHU	EHO	0407551548	

Atom Consulting for Narromine Shire Council

Narromine Shire Council

Narromine Water Quality Risk Assessment

List of Attendees, 22 November 2022

Name	Organisation	Role	Phone number	Signature
Leslie Jarvis	NSW Health	Senior Policy Advisor	9391 9885	[signature]
Steven Carter	Atom Consulting	Workshop recorder	0414659322	[signature]
Cindy Houston	DPE	Senior Project Officer	0417496670	[signature]
Bruce Lamont	DPE	Inspector	0458268453	[signature]

Appendix B Operational water quality data summary

B.1 Raw water quality

Treated water guideline values included to inform plant design decisions with guideline exceedances highlighted green.

B.1.1 Laboratory analysis

Table B-1. Narromine bore 3 raw water quality summary

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exceptions	
							Count	%
Aluminium (mg/L)	0.2	A	2	0.005	0.005	0.005	0	
Antimony (mg/L)	0.003	H	2	0.001	0.001	0.001	0	
Arsenic (mg/L)	0.01	H	3	0	0.001	0.001	0	
Barium (mg/L)	2	H	3	0.114	0.123	0.132	0	
Boron (mg/L)	4	H	3	0	0.032	0.050	0	
Cadmium (mg/L)	0.002	H	3	0	0.001	0.001	0	
Calcium (mg/L)	-		3	35.6	37.8	40.0	0	
Chloride (mg/L)	250	A	3	95.0	98.0	101	0	
Chromium (mg/L)	0.05	H	3	0	0.001	0.003	0	
Copper (mg/L)	2	H	3	0.001	0.003	0.004	0	
Fluoride (mg/L)	1.5	H	3	0.110	0.143	0.200	0	
Iodine (mg/L)	-		2	0.100	0.105	0.110	0	
Iron (mg/L)	0.3	A	2	0.005	0.005	0.005	0	
Lead (mg/L)	0.01	H	3	0	0.001	0.001	0	
Magnesium (mg/L)	-		3	17.4	19.5	21.0	0	
Manganese (mg/L)	0.1	A	3	0	0.001	0.003	0	
Mercury (mg/L)	0.001	H	3	0	0.001	0.001	0	
Molybdenum (mg/L)	0.05	H	2	0.001	0.001	0.0025	0	
Nickel (mg/L)	0.02	H	3	0.001	0.002	0.005	0	
Nitrate (mg/L)	50	H	2	19.7	19.9	20.0	0	
Nitrite (mg/L)	3	H	2	0.050	0.050	0.050	0	
pH	6.5-8.5	A	3	6.70	6.9	7.4	0	
Selenium (mg/L)	0.01	H	3	0	0.002	0.004	0	
Silver (mg/L)	0.1	H	2	0.001	0.001	0.001	0	
Sodium (mg/L)	180	A	3	62.0	66.6	71.0	0	
Sulfate (mg/L)	250	A	3	23.0	24.0	26.0	0	
Total Dissolved Solids (TDS) (mg/L)	600	A	3	331	390	479	0	

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exceptions	
							Count	%
Total Hardness as CaCO3 (mg/L)	200	A	3	160	174	186	0	
True Colour (Hazen Units (HU))	15	A	3	0.500	1.00	2.00	0	
Turbidity (NTU)	5	A	2	0.400	0.850	1.30	0	
Uranium (mg/L)	0.017	H	1	0.001	0.001	0.001	0	
Zinc (mg/L)	3	A	3	0.005	0.03	0.05	0	

Source: Narromine Shire Council

Table B-2. Narromine bore 6 raw water quality summary

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception	
							Count	%
Aluminium (mg/L)	0.2	A	4	0.005	0.041	0.060	0	
Antimony (mg/L)	0.003	H	4	0.0001	0.0001	0.0001	0	
Arsenic (mg/L)	0.01	H	5	0.001	0.002	0.003	0	
Barium (mg/L)	2	H	5	0.014	0.025	0.045	0	
Boron (mg/L)	4	H	5	0	0.040	0.050	0	
Cadmium (mg/L)	0.002	H	5	0	0.001	0.001	0	
Calcium (mg/L)	-		5	20.8	23.1	27.0	0	
Chloride (mg/L)	250	A	5	31.0	45.4	79.0	0	
Chromium (mg/L)	0.05	H	5	0.002	0.003	0.005	0	
Copper (mg/L)	2	H	5	0.003	0.010	0.010	0	
Fluoride (mg/L)	1.5	H	5	0.100	0.114	0.140	0	
Iodine (mg/L)	-		4	0.020	0.030	0.060	0	
Iron (mg/L)	0.3	A	4	0.005	1.08	1.48	3	75%
Lead (mg/L)	0.01	H	5	0.001	0.003	0.013	1	20%
Magnesium (mg/L)	-		5	13.5	14.4	16.0	0	
Manganese (mg/L)	0.1	A	5	0.003	0.151	0.300	4	80%
Mercury (mg/L)	0.001	H	5	0	0.00005	0.0001	0	
Molybdenum (mg/L)	0.05	H	4	0.003	0.003	0.003	0	
Nickel (mg/L)	0.02	H	5	0.003	0.004	0.005	0	
Nitrate (mg/L)	50	H	4	0.500	2.20	7.30	0	
Nitrite (mg/L)	3	H	4	0.050	0.050	0.050	0	
pH	6.5-8.5	A	5	6.50	6.78	7.09	0	
Selenium (mg/L)	0.01	H	5	0	0.001	0.003	0	
Silver (mg/L)	0.1	H	4	0.001	0.001	0.001	0	
Sodium (mg/L)	180	A	5	30.0	36.8	55.0	0	

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception	
							Count	%
Sulfate (mg/L)	250	A	5	13.0	15.8	20.0	0	
Total Dissolved Solids (TDS) (mg/L)	600	A	5	182	228	307	0	
Total Hardness as CaCO3 (mg/L)	200	A	5	107	117	133	0	
True Colour (Hazen Units (HU))	15	A	5	0.500	1.30	2.00	0	
Turbidity (NTU)	5	A	4	0.05	2.04	3.20	0	
Zinc (mg/L)	3	A	5	0.005	0.020	0.03	0	

Source: Narromine Shire Council

Table B-3. Narromine bore 7 raw water quality summary

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception	
							Count	%
Aluminium (mg/L)	0.2	A	1	0.05	0.05	0.05	0	
Antimony (mg/L)	0.003	H	1	0.0005	0.0005	0.0005	0	
Arsenic (mg/L)	0.01	H	2	0.002	0.0025	0.003	0	
Barium (mg/L)	2	H	2	0.091	0.0965	0.102	0	
Boron (mg/L)	4	H	2	0	0.025	0.05	0	
Cadmium (mg/L)	0.002	H	2	0	0.000125	0.00025	0	
Calcium (mg/L)	-		2	22.4	24.2	26	0	
Chloride (mg/L)	250	A	2	44	47.5	51	0	
Chromium (mg/L)	0.05	H	2	0	0.00125	0.0025	0	
Copper (mg/L)	2	H	2	0	0.00125	0.0025	0	
Fluoride (mg/L)	1.5	H	2	0.05	0.075	0.1	0	
Iodine (mg/L)	-		1	0.02	0.02	0.02	0	
Iron (mg/L)	0.3	A	1	2.42	2.42	2.42	1	100%
Lead (mg/L)	0.01	H	2	0	0.0005	0.001	0	
Magnesium (mg/L)	-		2	13.06	14.03	15	0	
Manganese (mg/L)	0.1	A	2	0.388	0.419	0.45	2	100%
Mercury (mg/L)	0.001	H	2	0	0.000025	0.00005	0	

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception	
							Count	%
Molybdenum (mg/L)	0.05	H	1	0.00025	0.00025	0.00025	0	
Nickel (mg/L)	0.02	H	2	0.004	0.007	0.01	0	
Nitrate (mg/L)	50	H	1	0.5	0.5	0.5	0	
Nitrite (mg/L)	3	H	1	0.05	0.05	0.05	0	
pH	6.5-8.5	A	2	6.9	7.085	7.27	0	
Selenium (mg/L)	0.01	H	2	0	0.0005	0.001	0	
Silver (mg/L)	0.1	H	1	0.001	0.001	0.001	0	
Sodium (mg/L)	180	A	2	35	42.5	50	0	
Sulfate (mg/L)	250	A	2	16	17	18	0	
Total Dissolved Solids (TDS) (mg/L)	600	A	2	210	258.5	307	0	
Total Hardness as CaCO3 (mg/L)	200	A	2	109.7	121.35	133	0	
True Colour (Hazen Units (HU))	15	A	2	0.5	7.75	15	0	
Turbidity (NTU)	5	A	1	24.4	24.4	24.4	1	100 %
Zinc (mg/L)	3	A	2	0	0.005	0.01	0	

Source: Narromine Shire Council

Table B-4. Narromine bore 8 raw water quality summary

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exceptions	
							Count	%
Aluminium (mg/L)	0.2	A	2	0.005	0.005	0.005	0	
Antimony (mg/L)	0.003	H	2	0.00005	0.000275	0.0005	0	
Arsenic (mg/L)	0.01	H	3	0.001	0.001333	0.002	0	
Barium (mg/L)	2	H	3	0.06	0.0689	0.0807	0	
Boron (mg/L)	4	H	3	0	0.031267	0.05	0	
Cadmium (mg/L)	0.002	H	3	0	0.0001	0.00025	0	
Calcium (mg/L)	-		3	34.3	34.73333	35	0	
Chloride (mg/L)	250	A	3	95	117.3333	135	0	
Chromium (mg/L)	0.05	H	3	0	0.001	0.0025	0	
Copper (mg/L)	2	H	3	0	0.001167	0.0025	0	
Fluoride (mg/L)	1.5	H	3	0.1	0.14	0.17	0	
Iodine (mg/L)	-		2	0.1	0.11	0.12	0	

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exceptions	
							Count	%
Iron (mg/L)	0.3	A	2	0.005	0.0075	0.01	0	
Lead (mg/L)	0.01	H	3	0	0.000433	0.001	0	
Magnesium (mg/L)	-		3	19.35	19.96	20.53	0	
Manganese (mg/L)	0.1	A	3	0.00015	0.00655	0.017	0	
Mercury (mg/L)	0.001	H	3	0	0.00015	0.0004	0	
Molybdenum (mg/L)	0.05	H	2	0.0001	0.0013	0.0025	0	
Nickel (mg/L)	0.02	H	3	0.0004	0.0068	0.015	0	
Nitrate (mg/L)	50	H	2	18.8	18.9	19	0	
Nitrite (mg/L)	3	H	2	0.05	0.05	0.05	0	
pH	6.5-8.5	A	3	6.8	7.1	7.3	0	
Selenium (mg/L)	0.01	H	3	0	0.002167	0.0035	0	
Silver (mg/L)	0.1	H	2	0.0001	0.00055	0.001	0	
Sodium (mg/L)	180	A	3	84	90	97	0	
Sulfate (mg/L)	250	A	3	28	31.33333	33	0	
Total Dissolved Solids (TDS) (mg/L)	600	A	3	411	443	482	0	
Total Hardness as CaCO3 (mg/L)	200	A	3	165.3	169	171.7	0	
True Colour (Hazen Units (HU))	15	A	3	0.5	1	2	0	
Turbidity (NTU)	5	A	2	0.05	0.625	1.2	0	
Uranium (mg/L)	0.017	H	1	0.0012	0.0012	0.0012	0	
Zinc (mg/L)	3	A	3	0.005	0.023333	0.05	0	

Source: Narromine Shire Council

Table B-5. Narromine bore 9 raw water quality summary

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception Count	%
Aluminium (mg/L)	0.2	A	5	0.005	0.01	0.03	0	
Antimony (mg/L)	0.003	H	5	0.00005	0.00041	0.0005	0	
Arsenic (mg/L)	0.01	H	6	0	0.003333	0.009	0	
Barium (mg/L)	2	H	6	0.0416	0.0461	0.053	0	

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception Count	%
Boron (mg/L)	4	H	6	0	0.039383	0.05	0	
Cadmium (mg/L)	0.002	H	6	0	0.000175	0.00025	0	
Calcium (mg/L)	-		6	30.2	32.08333	37.2	0	
Chloride (mg/L)	250	A	6	99	127.6667	202	0	
Chromium (mg/L)	0.05	H	6	0	0.002167	0.005	0	
Copper (mg/L)	2	H	6	0.0025	0.002667	0.003	0	
Fluoride (mg/L)	1.5	H	6	0.05	0.131667	0.2	0	
Iodine (mg/L)	-		5	0.03	0.042	0.07	0	
Iron (mg/L)	0.3	A	5	0.005	0.503	1.04	3	60%
Lead (mg/L)	0.01	H	6	0	0.000767	0.001	0	
Magnesium (mg/L)	-		6	19.61	21.42833	24	0	
Manganese (mg/L)	0.1	A	6	0.0025	0.172367	0.318	4	67%
Mercury (mg/L)	0.001	H	6	0	0.0001	0.0004	0	
Molybdenum (mg/L)	0.05	H	5	0.0001	0.00202	0.0025	0	
Nickel (mg/L)	0.02	H	6	0	0.003517	0.005	0	
Nitrate (mg/L)	50	H	5	1.6	3.72	11	0	
Nitrite (mg/L)	3	H	5	0.05	0.05	0.05	0	
pH	6.5-8.5	A	6	6.6	6.741667	7.25	0	
Selenium (mg/L)	0.01	H	6	0	0.004333	0.008	0	
Silver (mg/L)	0.1	H	5	0.0001	0.00082	0.001	0	
Sodium (mg/L)	180	A	6	51	73	112	0	
Sulfate (mg/L)	250	A	6	18	25.33333	39	0	
Total Dissolved Solids (TDS) (mg/L)	600	A	6	299	389	532	0	
Total Hardness as CaCO3 (mg/L)	200	A	6	157.2	168.3167	185.8	0	
True Colour (Hazen Units (HU))	15	A	6	0.5	1.333333	2	0	

Parameter	Guideline Value (>)	Health or Aesthetic	Count	Min	Mean	Max	Exception Count	%
Turbidity (NTU)	5	A	5	0.05	2.49	5.1	1	20 %
			1	0.0003	0.0003	0.0003	0	
Zinc (mg/L)	3	A	6	0.005	0.019167	0.06	0	

Source: Swam Environmental Project Management Options Report

Table B-6. Narromine river raw water quality summary

Parameter	Guideline Value (>)	Health or Aesthetic	2/11/2022
Arsenic (mg/L)	0.01	H	0.004
Barium (mg/L)	2	H	0.102
Boron (mg/L)	4	H	0
Cadmium (mg/L)	0.002	H	0
Calcium (mg/L)			22
Chloride (mg/L)	250	A	63
Chromium (mg/L)	0.05	H	0.012
Copper (mg/L)	2	H	0.016
Fluoride (mg/L)	1.5	H	0.2
Lead (mg/L)	0.01	H	0.007
Magnesium (mg/L)	-		14
Manganese (mg/L)	0.1	A	0.457
Mercury (mg/L)	0.001	H	0
Nickel (mg/L)	0.02	H	0.012
pH	6.5-8.5	A	7.76
Selenium (mg/L)	0.01	H	0
Sodium (mg/L)	180	A	34
Sulfate (mg/L)	250	A	13
Total Dissolved Solids (TDS) (mg/L)	600	A	273
Total Hardness as $CaCO_3$ (mg/L)	200	A	112
True Colour (Hazen Units (HU))	15	A	100
Zinc (mg/L)	3	A	0.022

B.1.2 Operational testing

Table B-7. Narromine bore 9 iron, manganese and turbidity

Parameter	Guideline Value (>)	Health or Aesthetic	Min	5th %ile	Median	95th %ile	Max	Count	Exceptions Count	
Iron (mg/L)	0.3	A	0.05	0.14	0.3	0.40	0.75	142	64	45%
Manganese (mg/L)	0.1	A	0.024	0.066	0.09	0.17	0.20	138	36	26%

Parameter	Guideline Value (>)	Health or Aesthetic	Min	5th %ile	Median	95th %ile	Max	Count	Exceptions Count	
Turbidity (NTU)	5	A	0.21	0.34	1.14	2.60	5.77	144	2	1%

Source: Narromine Detailed Spreadsheet (September 2019 to March 2020)

Table B-8. Narromine bore 6 and 9 manganese and iron summary

Location	Parameter	Min	Mean	Max	Count
Bore 6	Manganese (mg/L)	0.005	0.125	0.189	10
	Iron (mg/L)	0.025	0.6965	1.32	10
Bore 9	Manganese (mg/L)	0.002	0.007429	0.009	7
	Iron (mg/L)	0.025	0.025	0.025	7

Source: Narromine Shire Council April 2020 Report to NSW Health

B.2 Temporary WTP water quality

Table B-9. Temporary WTP raw water summary

Parameter	Guideline Value (>)	Health or Aesthetic	Min	5th %ile	Median	95th %ile	Max	Sample Count
Turbidity (NTU)	5	A	0.12	0.37	0.96	3.49	27.3	625
Iron (mg/L)	0.3	A	0.00	0.06	0.15	0.64	3.23	624
pH	6.5-8.5	A	0.00	6.62	6.97	7.13	7.57	626
Manganese (mg/L)	0.1	A	0	0.004	0.08	0.14	0.82	623
Total Hardness as $CaCO_3$ (mg/L)	200	A	118	166	183	204	280	628

Source: Narromine WTP Water Quality Spreadsheet (January 2020 to October 2022)

Table B-10. Temporary WTP treated water summary

Parameter	Guideline Value (>)	Health or Aesthetic	Min	5th %ile	Median	95th %ile	Max	Sample Count	Exception Count	
Turbidity (NTU)	5	A	0.01	0.05	0.11	0.32	0.72	642	0	
Iron (mg/L)	0.30	A	0.00	0	0.01	0.04	0.30	642	0	
pH	6.5-8.5	A	6.55	6.89	7.26	7.78	8.14	642	0	
Manganese (mg/L)	0.1	A	0.00	0	0.02	0.026	0.15	640	1	0.2%
Total Hardness as $CaCO_3$ (mg/L)	200	A	120	140	178	194	260	475	7	1%

Source: Narromine WTP Water Quality Spreadsheet (January 2020 to October 2022)

Table B-11. Temporary WTP dissolved iron and manganese summary

Parameter		Min	5th %ile	Median	95th %ile	Max	Count
Raw	Dissolved Iron (mg/L)	0	0	0.05	0.52	1.60	624
	Dissolved Manganese (mg/L)	0	0	0.07	0.14	0.54	623

Parameter		Min	5th %ile	Median	95th %ile	Max	Count
Treated	Dissolved Iron (mg/L)	0	0	0	0	0.21	642
	Dissolved Manganese (mg/L)	0	0	0.013	0.03	0.12	639

Source: Narromine WTP Water Quality Spreadsheet (January 2020 to October 2022)

B.3 Reservoir water quality

Table B-12. Reservoir water quality summary

Area	Parameter	Units	Operational limit	Min	Median	Max	Count	Exceptions	
								Count	%
Nymagee St Reservoir Inlet	Free Cl	mg/L (grab)	0.3 - 4	0.46	1.28	3.10	1660	0	
		mg/L (online)	0.3 - 4	0.33	1.27	2.47	1357	0	
	Total Cl	mg/L (grab)		0.51	1.34	3.22	1629	0	
	pH	pH units (grab)		1.01	7.10	8.26	1628	0	
	Turbidity	NTU (grab)	< 5	0.00	0.27	7.80	1566	2	0.1%
Nymagee St Reservoir Outlet	Free Cl	mg/L (grab)	0.3 - 4	0.49	1.19	2.20	1655	0	
		mg/L (online)	0.3 - 4	0.00	1.21	1.84	1768	67	4%
	Total Cl	mg/L (grab)		0.58	1.23	6.95	1648	0	
		mg/L (online)		0.00	1.29	2.05	1367	0	
	pH	pH units (grab)		6.40	7.14	8.32	1648	0	
		pH units (online)		6.48	7.04	7.98	1367	0	
	Temperature	°C (grab)		11.80	19.30	30.20	1031	0	
		°C (online)		11.00	19.60	33.30	1149	0	
	Turbidity	NTU (grab)	< 5	0.00	0.28	9.17	1645	2	0.1%
		NTU (online)	< 5	0.00	0.24	3.98	1367	0	
Duffy St Reservoir Inlet	Free Cl	mg/L (grab)	0.3 - 4	0.06	1.31	3.00	1440		
		mg/L (online)	0.3 - 4	0.00	1.34	2.26	1156		
	Total Cl	mg/L (grab)		0.05	1.36	3.10	1411	0	
	pH	pH units (grab)		6.15	7.15	8.03	1412	0	
	Turbidity	NTU (grab)	< 5	0.00	0.29	9.90	1392	8	0.6%
Duffy Street Reservoir Outlet	Free Cl	mg/L (grab)	0.3 - 4	0.08	1.16	2.10	1481	1	0.1%
		mg/L (online)	0.3 - 4	0.00	1.09	2.09	1737	26	1.5%
	Total Cl	mg/L (grab)		0.37	1.21	2.10	1475	0	
		mg/L (online)		0.00	1.29	2.51	1737	0	
	pH	pH units (grab)		6.39	7.06	7.96	1475	0	
		pH units (online)		6.28	6.75	7.88	1737	0	
	Temperature	°C (grab)		0.36	19.90	31.20	1039	0	
		°C (online)		14.20	21.90	32.20	1149	0	
	Turbidity	NTU (grab)	< 5	0.00	0.26	3.69	1472	0	
		NTU (online)	< 5	0.00	0.38	8.11	1737	2	0.1%

Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

B.4 Reticulation water quality

ADWG aesthetic guideline exceedances are highlighted green and ADWG health exceedances or microbiological detections are highlighted orange.

Table B-13. Reticulated water quality summary

Parameter	Units	ADWG guideline	Min	5th %ile	Median	95th %ile	Max	Count	Exceptions	
									Count	%
Free Cl	mg/L	> 0.2	0.00	0.64	1.11	1.56	2.02	2656	4	0.2%
Total Cl	mg/L		0.35	0.66	1.18	7.42	2.20	2655		
pH	pH units	6.5 – 8.5	6.47	0.69	7.20	7.82	8.70	2655	5	0.2%
Turbidity	NTU	< 5	0.00	0.74	0.70	7.88	10.00	2545	9	0.4%

Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

Appendix C Verification water quality data summary

A summary of key lab data is shown in the following sections. Any microbiological readings '< 1' were taken as zero, all other less than readings were taken as half of their upper limits, that is '< 0.1' became '0.05'. Values listed as greater than were taken as their lower limit, '> 200' became '200'.

ADWG aesthetic guideline exceedances are highlighted green and ADWG health exceedances or microbiological detections are highlighted orange.

Table C-1. Narromine NSW Health verification monitoring data summary

Characteristic	Guideline Value (>)	Health or Aesthetic	Min	5th %ile	Median	95th %ile	Max	Sample Count	Exception Count	
Aluminium (mg/L)	0.2	A	0.005	0.005	0.005	0.03	0.04	12	0	0%
Antimony (mg/L)	0.003	H	0.00005	0.00005	0.0005	0.0005	0.0005	12	0	0%
Arsenic (mg/L)	0.01	H	0.001	0.001	0.001	0.001	0.001	12	0	0%
Barium (mg/L)	2	H	0.07	0.07	0.08	0.10	0.11	12	0	0%
Boron (mg/L)	4	H	0.04	0.04	0.05	0.05	0.05	12	0	0%
Cadmium (mg/L)	0.002	H	0.00005	0.00005	0.00045	0.00045	0.00045	12	0	0%
Calcium (mg/L)	-	0	30.3	32.7	38.2	44.4	45.3	12	0	0%
Chloride (mg/L)	250	A	81	97.5	125	150.8	153	12	0	0%
Chromium (mg/L)	0.05	H	0.001	0.001	0.005	0.005	0.005	12	0	0%
Copper (mg/L)	2	H	0.005	0.005	0.014	0.038	0.047	12	0	0%
E. coli	0	H	0	0	0	0	0	285	0	0%
Fluoride (mg/L)	1.5	H	0.11	0.12	0.14	0.15	0.15	12	0	0%
Free chlorine (mg/L)		0	0.05	0.63	1.10	1.62	2.70	286	0	0%
Iodine (mg/L)		0	0.02	0.05	0.08	0.10	0.10	12	0	0%
Iron (mg/L)	0.3	0	0.005	0.005	0.005	0.04	0.04	12	0	0%
Lead (mg/L)	0.01	0	0.0002	0.0004	0.0015	0.0016	0.0017	12	0	0%
Magnesium (mg/L)	-	A	17.38	18.28	21.69	25.00	26.33	12	0	0%
Manganese (mg/L)	0.5	H	0.0003	0.0004	0.0045	0.0101	0.0169	12	0	0%
Mercury (mg/L)	0.001	0	0.0001	0.0001	0.0001	0.0008	0.0008	12	0	0%
Molybdenum (mg/L)	0.05	H	0.0001	0.0001	0.0045	0.0045	0.0045	12	0	0%
Nickel (mg/L)	0.02	H	0.0004	0.0004	0.0050	0.0050	0.0050	12	0	0%
Nitrate (mg/L)	50	H	8.0	9.1	14.6	19.0	20.0	12	0	0%
Nitrite (mg/L)	3	H	0.05	0.05	0.05	0.07	0.10	12	0	0%
pH	6.5 - 8.5	H	6.44	6.71	7.20	7.83	8.14	298	2	1%

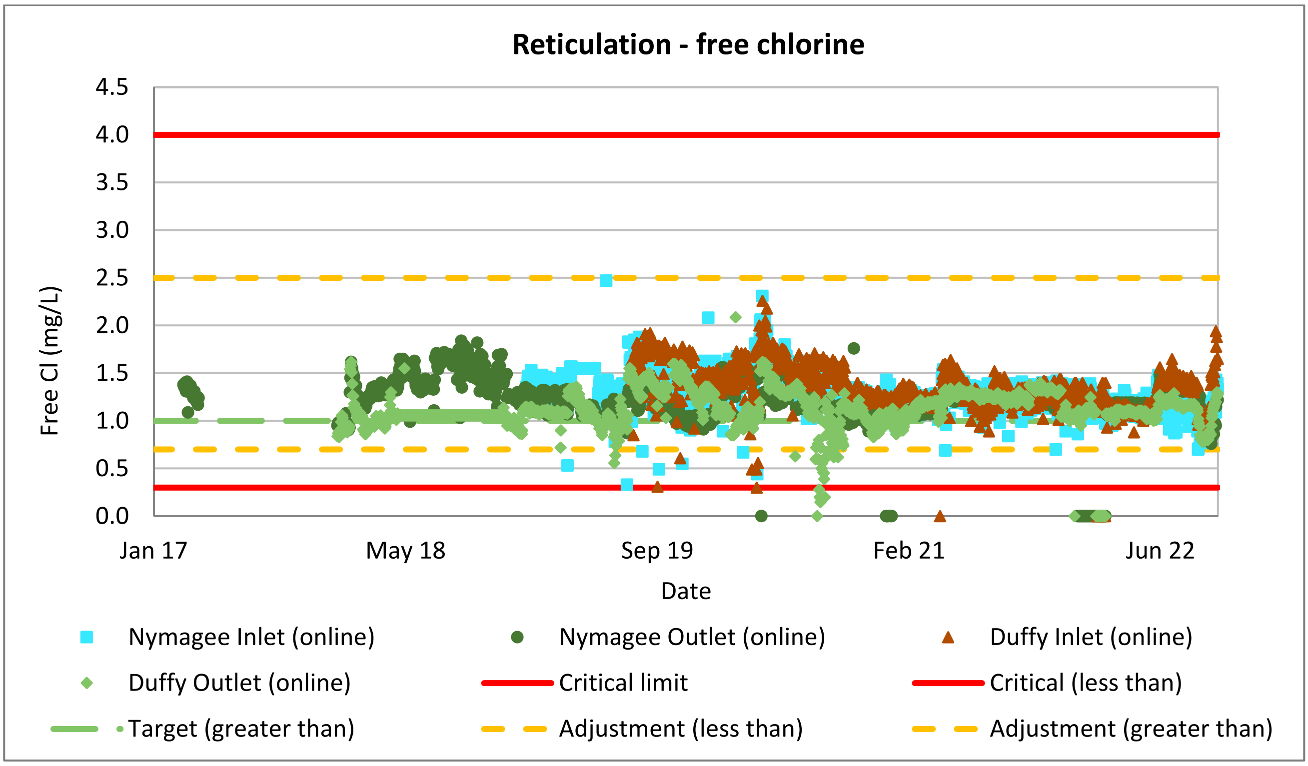
Characteristic	Guideline Value (>)	Health or Aesthetic	Min	5th %ile	Median	95th %ile	Max	Sample Count		Exception Count
Selenium (mg/L)	0.01	H	0.002	0.002	0.003	0.008	0.009	12	0	0%
Silver (mg/L)	0.1	A	0.0002	0.0002	0.0015	0.0015	0.0015	12	0	0%
Sodium (mg/L)	180	H	68.0	71.9	88.5	115.5	116.0	12	0	0%
Sulfate (mg/L)	250	H	21	25.95	31	34.9	36	12	0	0%
Total Chlorine (mg/L)	5	A	0.51	0.74	1.16	1.69	2.80	286	0	0%
Total Coliforms (cfu/100 mL)	30		0	0	0	0	200	285	3	1%
Temperature	30		14.4	15.5	22.3	29.6	33.0	197	6	3%
Total Dissolved Solids (TDS) (mg/L)	600	H	328	358	453	489	492	12	0	0%
Total Hardness as $CaCO_3$ (mg/L)	200	0	147.2	158.6	183.8	213.7	221.5	12	2	17%
True Colour (Hazen Units (HU))	15	A	0.5	0.5	0.5	1.45	2	12	0	0%
Turbidity (NTU)	5	A	0.00	0.09	0.42	1.49	1.95	211	0	0%
Uranium (mg/L)	0.017	A	0.0004	0.00045	0.0045	0.0045	0.0045	11	0	0%
Zinc (mg/L)	3	A	0.01	0.01	0.05	0.1915	0.23	12	0	0%

Source: Narromine Detailed Spreadsheet (January 2017 to October 2022)

Appendix D Water quality data graphs

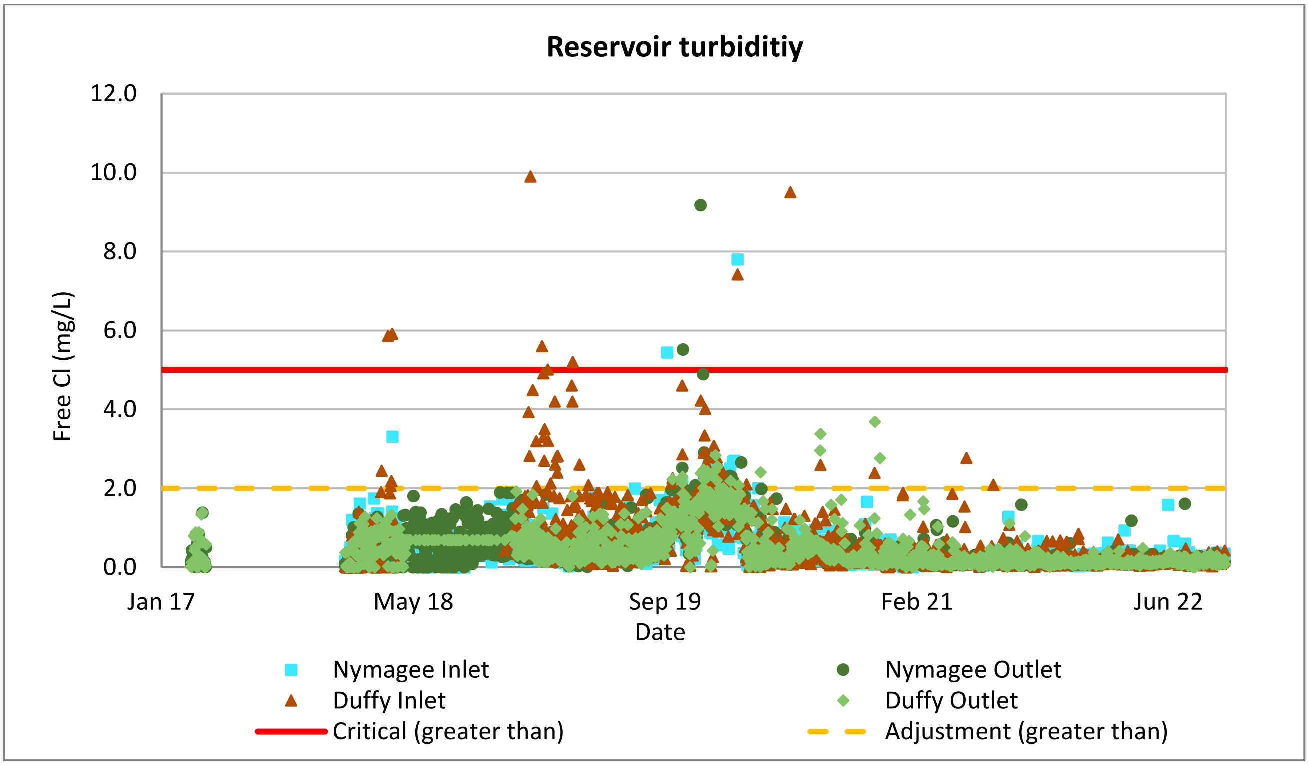
D.1 Reservoir water quality

Figure D-1. Reservoir free chlorine



Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

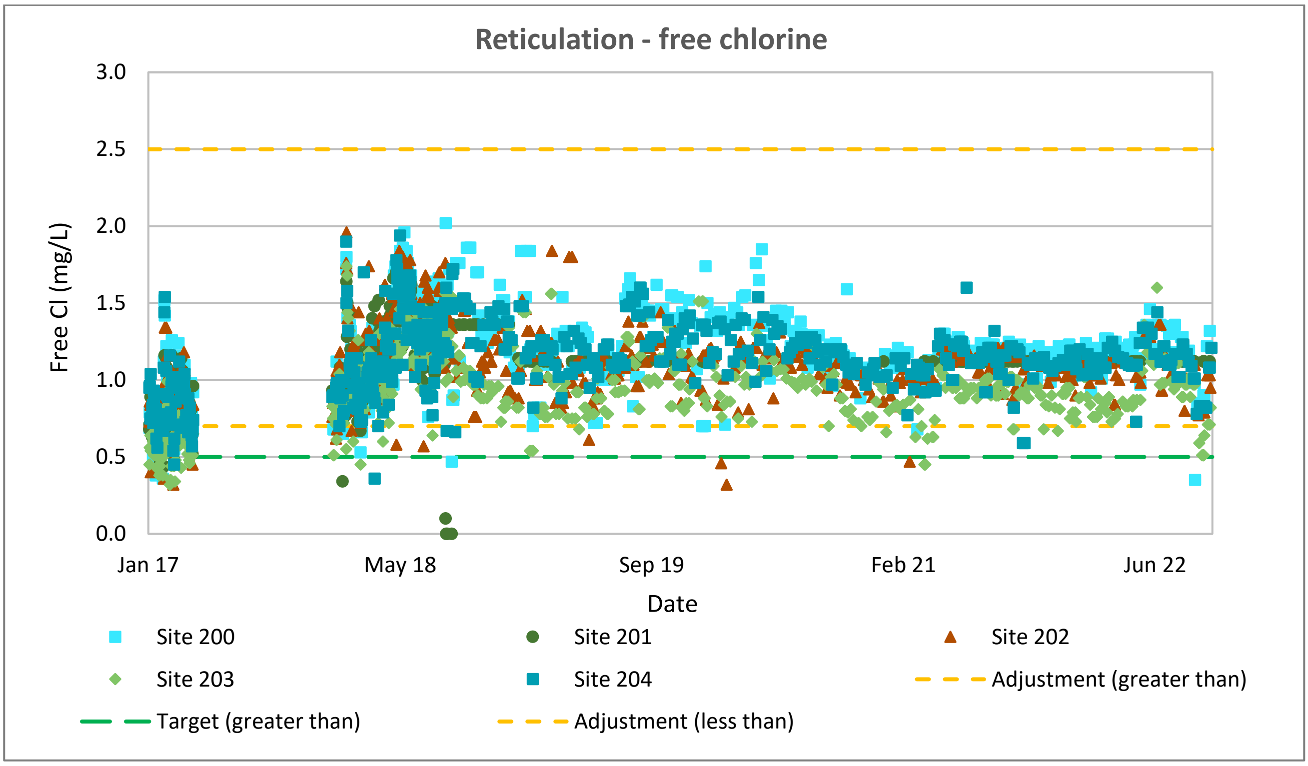
Figure D-2. Reservoir turbidity



Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

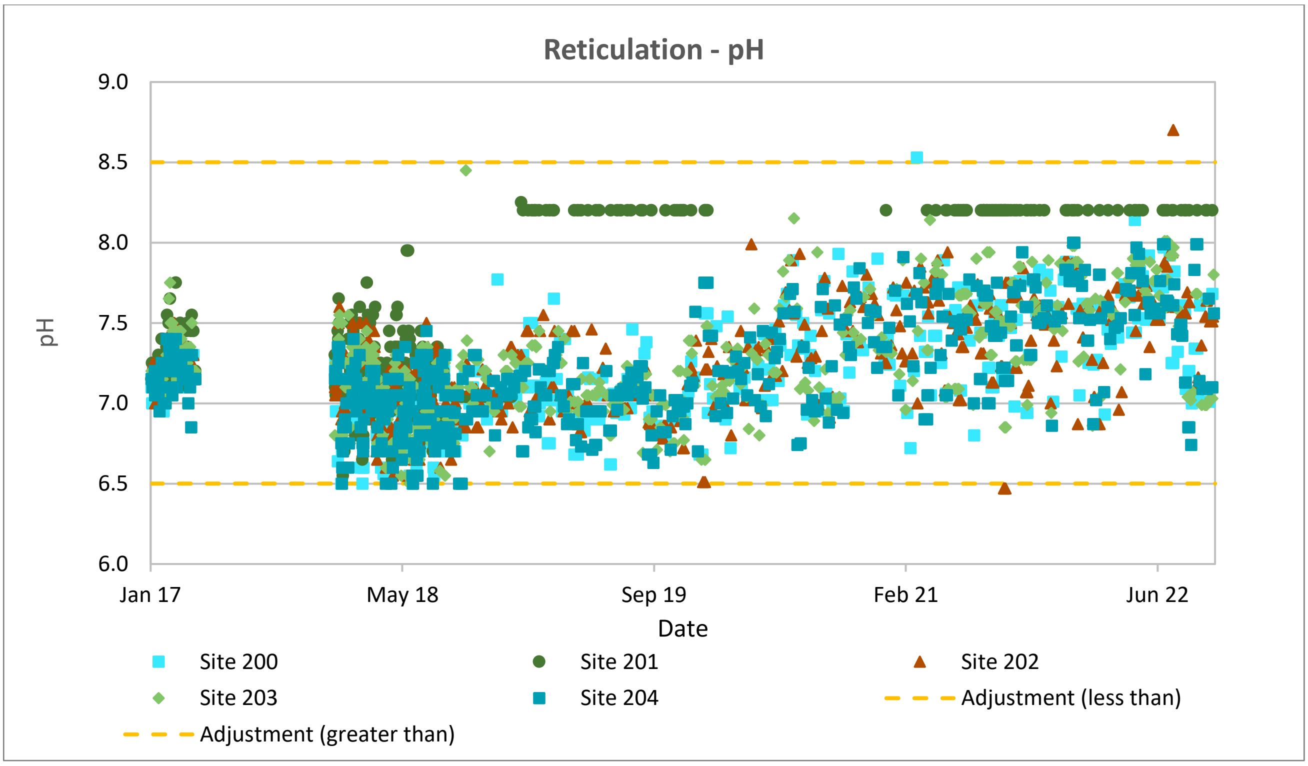
D.2 Reticulation water quality

Figure D-3. Reticulation free chlorine



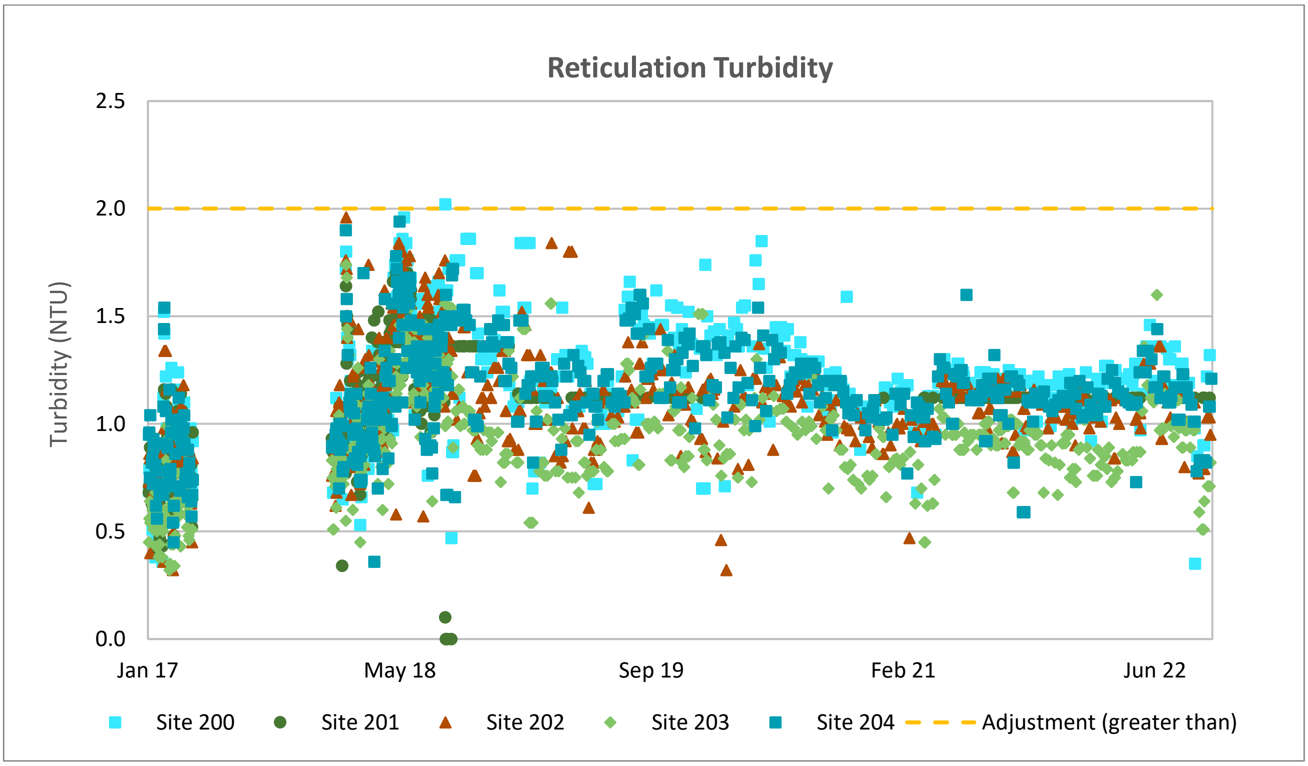
Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

Figure D-4. Reticulation pH



Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

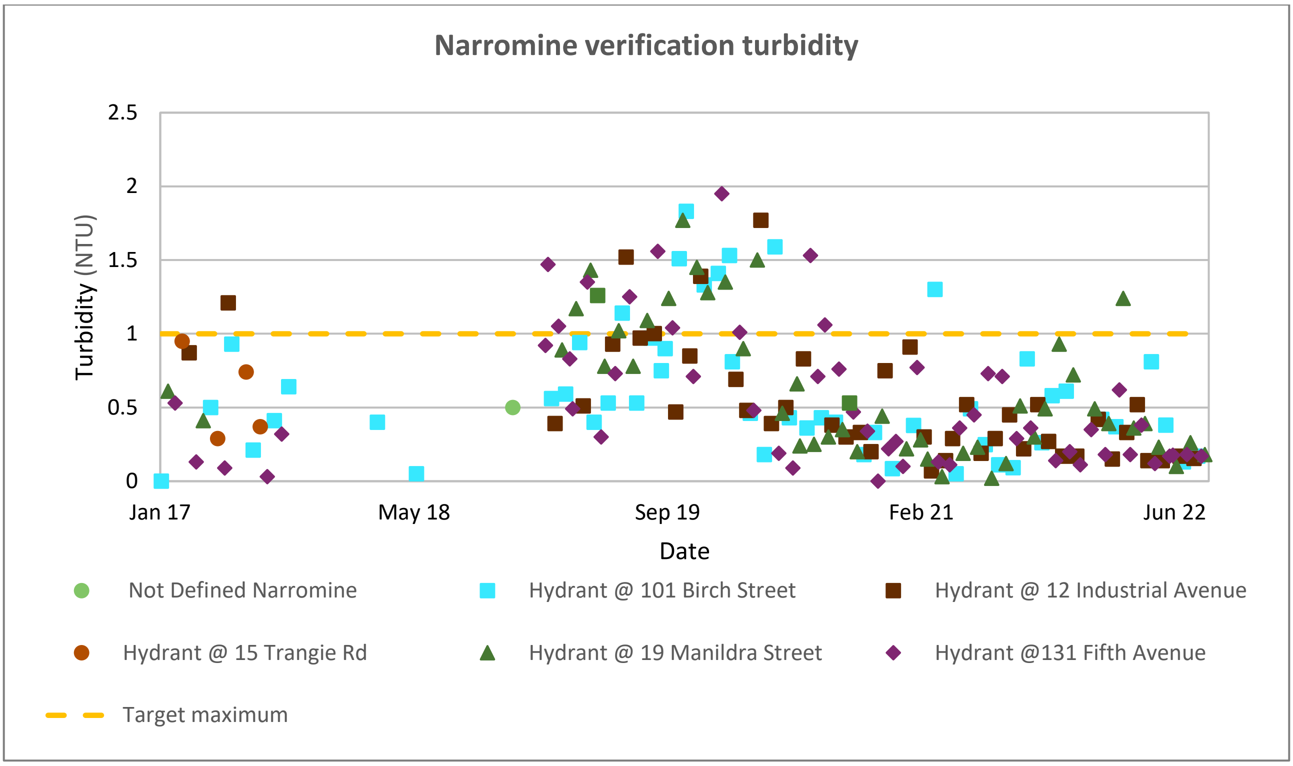
Figure D-5. Reticulation turbidity



Source: Narromine Operational Monitoring Spreadsheet (January 2017 to October 2022)

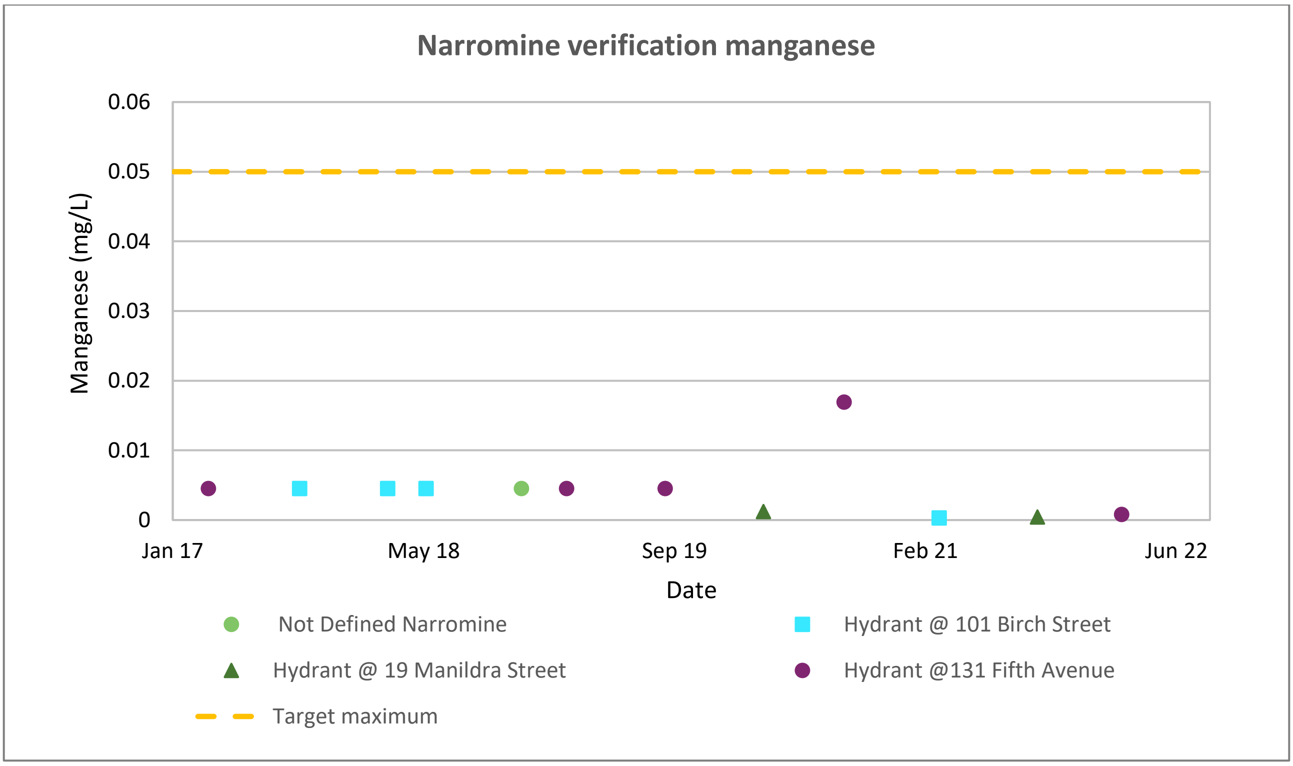
D.3 Verification water quality

Figure D-6. Narromine verification turbidity data



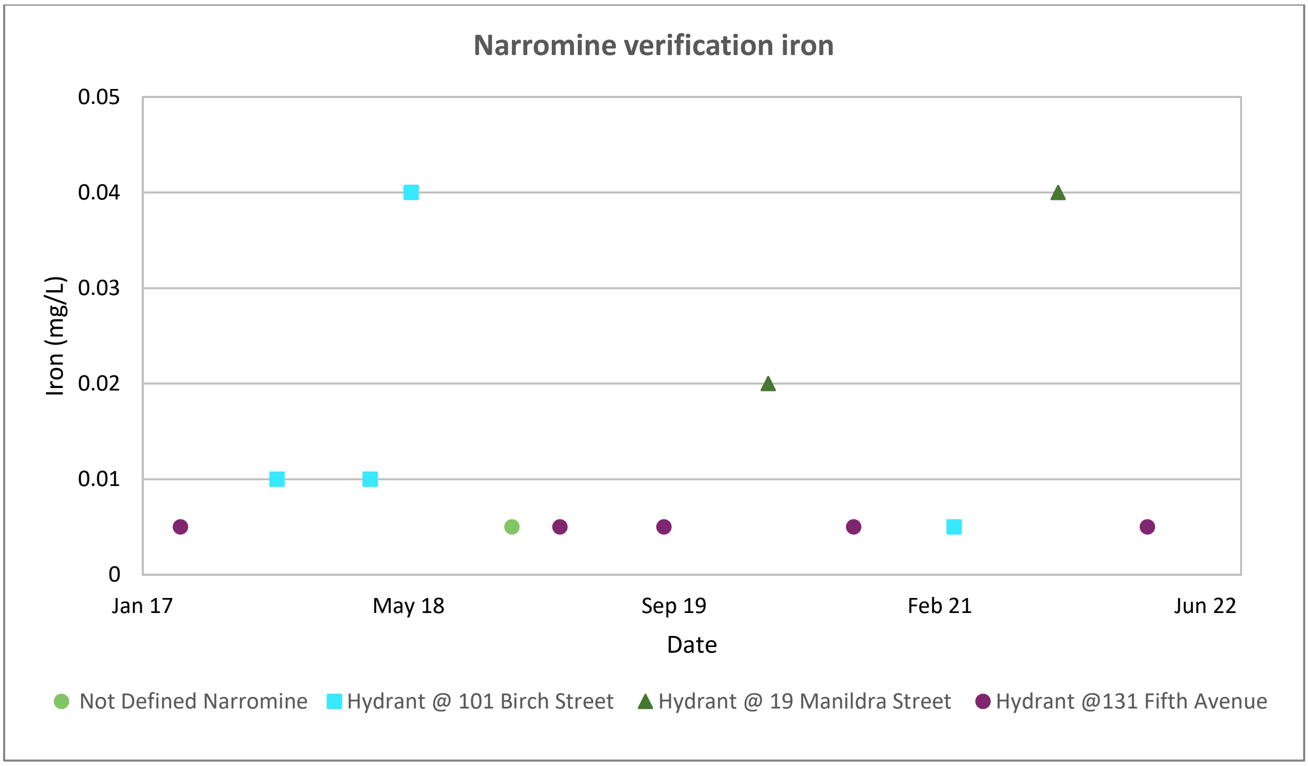
Note: Guideline aesthetic value of < 5 NTU not pictured.

Figure D-7. Narromine verification manganese data



Note: Guideline health value of < 0.5 mg/L and aesthetic value of < 0.1 mg/L not pictured.

Figure D-8. Narromine verification iron data



Note: Guideline aesthetic value of < 0.3 mg/L not pictured.

Appendix E Human factors

The UK Health and Safety Executive (1999) breaks human failures into errors and violations as shown in Figure E-1. Each failure is considered in more detail in Table E-1.

Figure E-1. Types of human failures

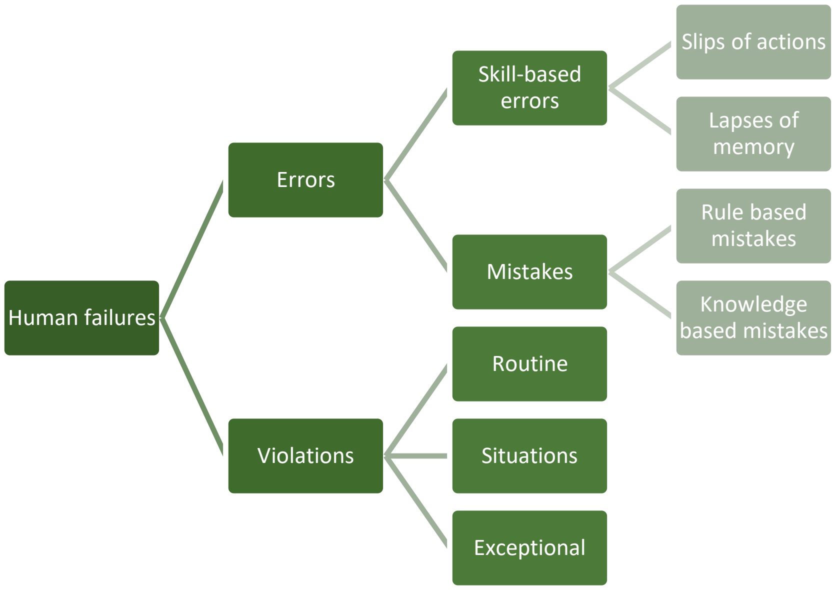


Table E-1. Types of human failures

Error	Description	Example
Skill based errors	Experienced person performing a familiar and well-practiced task Error may arise from confusing layouts, incorrect selection, mental workload or distractions.	Change channel not volume. Press up button not down. Write down wrong phone number.
Mistakes	Rule based mistakes occur when relying on stereotypes and not recognising a change in circumstances.	Using the windscreen wipers instead of indicators in a hire car.
	Knowledge based mistakes occur when the wrong information is relied upon.	Using procedures that are wrong or inaccurate.
Violations	Routine: normalisation of inappropriate behaviour	Not wearing PPE in the fluoride dosing room.
	Situational: incentives outweigh perceived risks in not following rules	Skip steps in a procedure to restart the plant quickly.
	Exceptional: intuitive, overwhelming incentive for not following rules, typically in unfamiliar situations	Running red lights to get to casualty.

Appendix F Updated CCPs

Appendix G Hazard screening

Hazard	Certainty	Assessment	Screening
Algae and cyanobacteria metabolites	Estimate	Surface water source	Included in risk assessment
Ammonia	Uncertain	Not a risk from a health perspective but increases algal bloom potential	Not included in risk assessment
Antibiotic resistant bacteria	Uncertain	Noted as an emerging contaminant	Not included in risk assessment
Antimony	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Arsenic	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Barium	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Pesticides	Uncertain		Not included in risk assessment
Boron	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Cadmium	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Calcium	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Chlorine	Confident	Dosed at WTP	Included in risk assessment
Chlorine sensitive pathogens	Confident	Surface water source	Included in risk assessment
Copper	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Cyanide	Uncertain		Not included in risk assessment
Cyanotoxins	Estimate	Surface water source	Included in risk assessment
Disinfection by-products (e.g. THMs, NDMA & HAAs)	Estimate		Included in risk assessment
Engineered nanomaterials	Uncertain	Noted as an emerging contaminant	Not included in risk assessment
Fluoride	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Hydrocarbons	Uncertain	From nearby industry	Included in risk assessment
Industrial chemicals	Uncertain	From nearby industry	Included in risk assessment
Iodine	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Iron	Confident	Elevated levels in aquifers	Included in risk assessment
Lead	Estimate	Exceedance recorded in Bore 6	Included in risk assessment
Manganese	Confident	Elevated levels in aquifers	Included in risk assessment
Mercury	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Microplastics	Uncertain	Noted as an emerging contaminant	Not included in risk assessment
Molybdenum	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Nickel	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Nitrate	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Nitrate	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Opportunistic pathogens (Naegleria & Legionella)	Estimate	Surface water source	Included in risk assessment
PFAS/PFOS	Uncertain		Included in risk assessment
pH	Confident	Exceedances recorded in verification data	Included in risk assessment
Pharmaceuticals and EDCs	Uncertain	Noted as an emerging contaminant	Not included in risk assessment
Phosphorous	Uncertain	Not a risk from a health perspective but increases algal bloom potential	Included in risk assessment

Hazard	Certainty	Assessment	Screening
Protozoa	Estimate	Surface water source	Included in risk assessment
Radiological parameters	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Selenium	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Silver	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Sodium	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Sulphate	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program
Taste and odour	Uncertain	Surface water source	Included in risk assessment
Tin	Uncertain		Not included in risk assessment
TOC (including colour)	Estimate	Surface water source	Included in risk assessment
Turbidity	Confident		Included in risk assessment
Zinc	Confident	Below ADWG threshold values in raw and treated water	Not included in risk assessment, maintain monitoring program

Appendix H Risk register

Refer to Appendix H Risk Register

Appendix B Jar testing report

Technical Note

Narromine raw water jar testing

1 Introduction

The drinking water for Narromine was provided from five shallow bores. Throughout the millennium drought, these bores either failed or their yield dropped significantly. During the drought, additional deeper bores were drilled; however, the current yield of these bores is not sufficient to service the expected population growth in Narromine.

The bore water currently receives disinfection using chlorine gas. Water quality from some of the bores is not suitable for drinking water without additional treatment. In 2020, a temporary water treatment plant was installed to treat water from bores 6 and 9 which are high in iron and manganese.

This technical note presents jar testing results undertaken as part of the assessment of water treatment options for Narromine.

1.1 Background

Narromine Regional Council (NRC) engaged Atom Consulting to assess treatment options for Narromine drinking water. Jar testing was carried out on 17 and 18 October 2022. Aluminium chlorohydrate (ACH) was used as a coagulant. Water was sourced from all five bores and Macquarie River.

2 Jar testing approach

Jar testing was conducted at different doses to determine optimal dosage and compare performance between raw water sources. NRC staff supplied the raw water samples. The samples were taken from Bores 3, 6, 7 8, 9 and the Macquarie River on 18 and 19 October 2022 as shown in Table 2-1. Three blended raw water samples were prepared by blending all the bores (one sample) and blends ofriver water and Bore 3 (two samples)

Table 2-1 Raw water sources

Source	Date of sampling	Date of testing	ACH dose range tested (mg/L)
Bore 3	17 October 2022	18 October 2022	15-30
Bore 6	18 October 2022	18 October 2022	15-44
Bore 7	18 October 2022	18 October 2022	15-30
Bore 8	18 October 2022	18 October 2022	
Bore 9	18 October 2022	18 October 2022	
Macquarie River	18 October 2022	19 October 2022	
All bores blended (20% each)	19 October 2022	19 October 2022	32-38

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Source	Date of sampling	Date of testing	ACH dose range tested (mg/L)
River and Bore 3 blended (60%- 40%)	18 October 2022	19 October 2022	25-35
River and Bore 3 blended (40%- 60%)	18 October 2022	18 October 2022	32-38

The jar testing mixing conditions used are shown in Table 2-2.

Table 2-2 Jar testing mixing conditions

Parameter	Rapid mixing	Slow mixing	Sedimentation	Filtration (Whatman paper No. 1)
Time (min)	2	15	20-30 min	5
RPM	200	20	0	Not applicable

Samples were taken after 20 minutes of the settling to measure the residual turbidity of the supernatant. After settling, 200 mL of supernatant was taken and filtered using Whatman No 1 filter paper. Residual turbidity and pH were measured for the filtered water. Floc size was observed after 5 min and 15 min of slow mixing (coagulation) and 10 and 20 min during settling.

The water quality parameters measured before the jar testing (raw water) and after the test (supernatant and filtered water) are listed in Table 2-3. The equipment used for the testing is also shown in the table.

Table 2-3 Jar testing measured parameters and laboratory instruments

Parameter	Raw water	Supernatant	Filtered water	Equipment
Alkalinity	✓			Hach SL1000
Apparent colour	✓			Hach DR6000
Dissolved iron	✓			Hach SL1000
Total iron	✓			Palin test 7100
Dissolved manganese	✓			Hach DR3900
Total Manganese	✓			Hach DR3900
pH	✓		✓	Hach SL1000
Turbidity	✓	✓	✓	Hach DR6000

3 Results and discussion

The water quality of the raw water samples is presented in Table 3-1. The overall Bore 3 sample had the best water quality while Bore 6 sample had the worst quality. The Bore 7 sample had the highest concentration of manganese and iron for all bore samples. The Bore 3 and 9 had the lowest iron content. Bore 9 also had the lowest manganese concentration.

Table 3-1 Raw water quality

Parameter	Units	20% all Bores	60% River 40% Bore 3	40% River 60% Bore 3	Bore No.					River
					3	6	7	8	9	
Alkalinity	mg/L as $CaCO_3$	153	129	137	**176**	128	143	165	140	*78*
Apparent colour	HU	187	239	133	175	**500**	143	51	140	286
Dissolved iron	mg/L	0.09		0.04	*0.01*	0.15	**1.6**	0.03	*0.01*	0.19
Total iron	mg/L	0.31	0.65	0.026	*0.01*	0.3	**1.65**	0.1	*0.01*	0.75
Dissolved manganese	mg/L	**0.15**	0.02	0.02	*0.02*	0.13	**0.37**	0.03	0.13	*0.02*
Total Manganese	mg/L	**0.19**	0.10	0.4	*0.01*	0.60	**0.41**	0.06	0.14	0.14
pH	-	7.67	**8.04**	7.89	7.38	*7.03*	7.41	7.07	7.28	8.03
Turbidity	NTU	23	32.9	16.4	*0.3*	**421**	3.8	5.9	3.7	38.2

Note: the highest value measured for each parameter is shown in bold and the lowest in italic and highlighted in grey.

3.1 Turbidity removal

The comparison of raw water turbidity and residual turbidity after sedimentation and filtration for the different raw water samples is summarised in Figure 3-1. Detailed results are shown in Appendix A. The lowest residual turbidity was in Bore 3 attributed to the water quality of this bore. The residual filtered turbidity was lower than 0.2 NTU.

Bore 7, 8 and 9 had an overall turbidity of less than 5 NTU after sedimentation and less than 3 NTU after filtration for the ACH doses tested (Figure 3-2). The lowest residual turbidity was measured using 25 mg/L ACH to achieve approximately 0.3 NTU, which may indicate that the optimal dose for these bores is between 23 to 27 mg/L. Further jar testing for these samples is required to refine the optimal coagulant dose to find the optimal dose to achieve the required target.

R1 Conduct jar testing for Bore 7,8 and 9 using ACH dose of 23-27 mg/L ACH

The highest ACH dose range assessed was for Bore 6 sample, as it had the highest raw water turbidity. The lowest residual turbidity for this sample after filtration was measured at 1.23 NTU using 44 mg/L of ACH. It was noticed that with 30 min of sedimentation rather than 20 min, the filtered turbidity dropped to 0.53 NTU using the same ACH dose (Figure 3-3). There were no flocs in the supernatant, and a white sand-like sediment on the bottom of the jar was observed after 30 min of sedimentation (Figure 3-4). This indicates that Bore 6 has particles that can easily settle after 30 min of sedimentation.

Figure 3-1 Raw water and treated water turbidity vs ACH dose (20 min sedimentation)

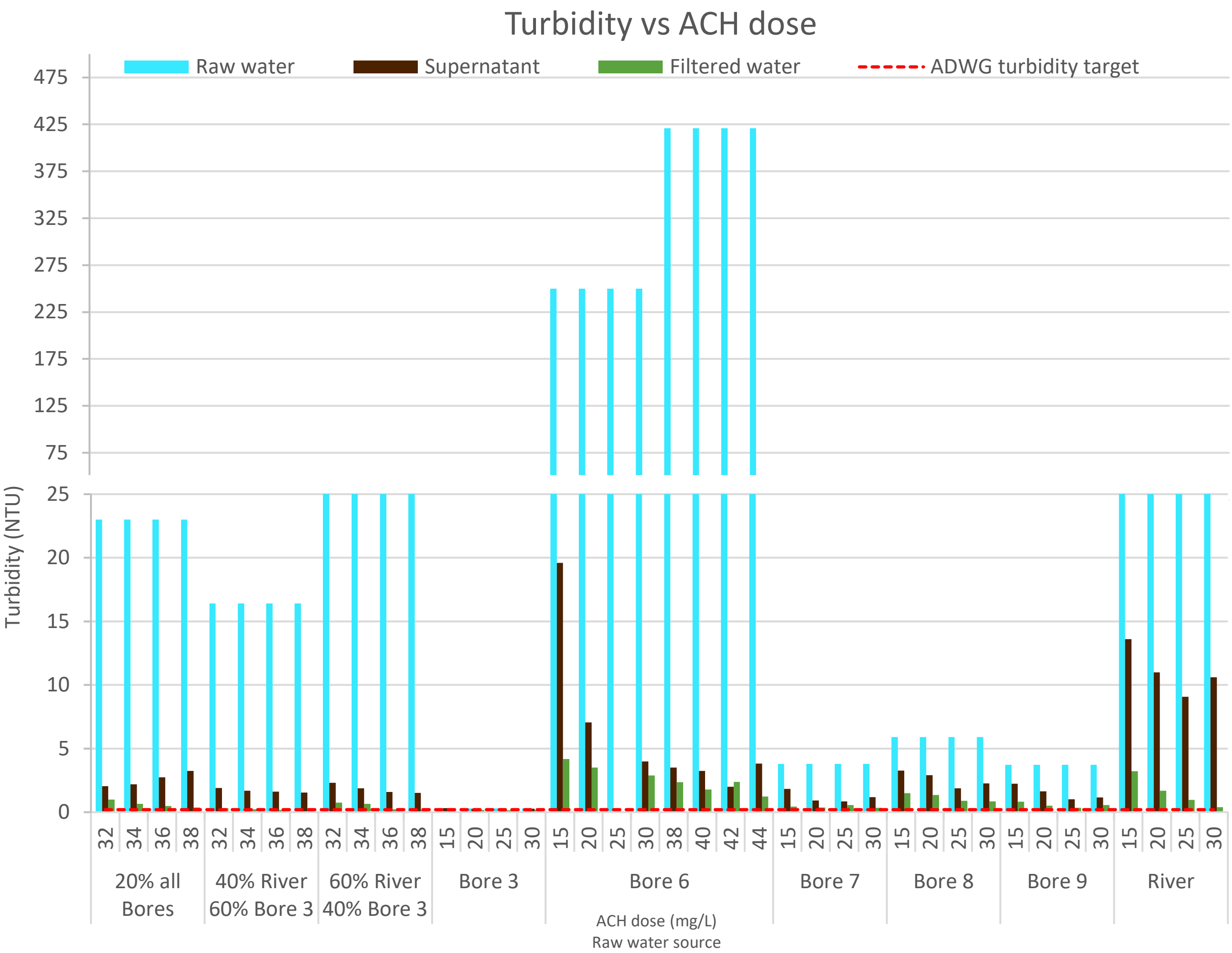
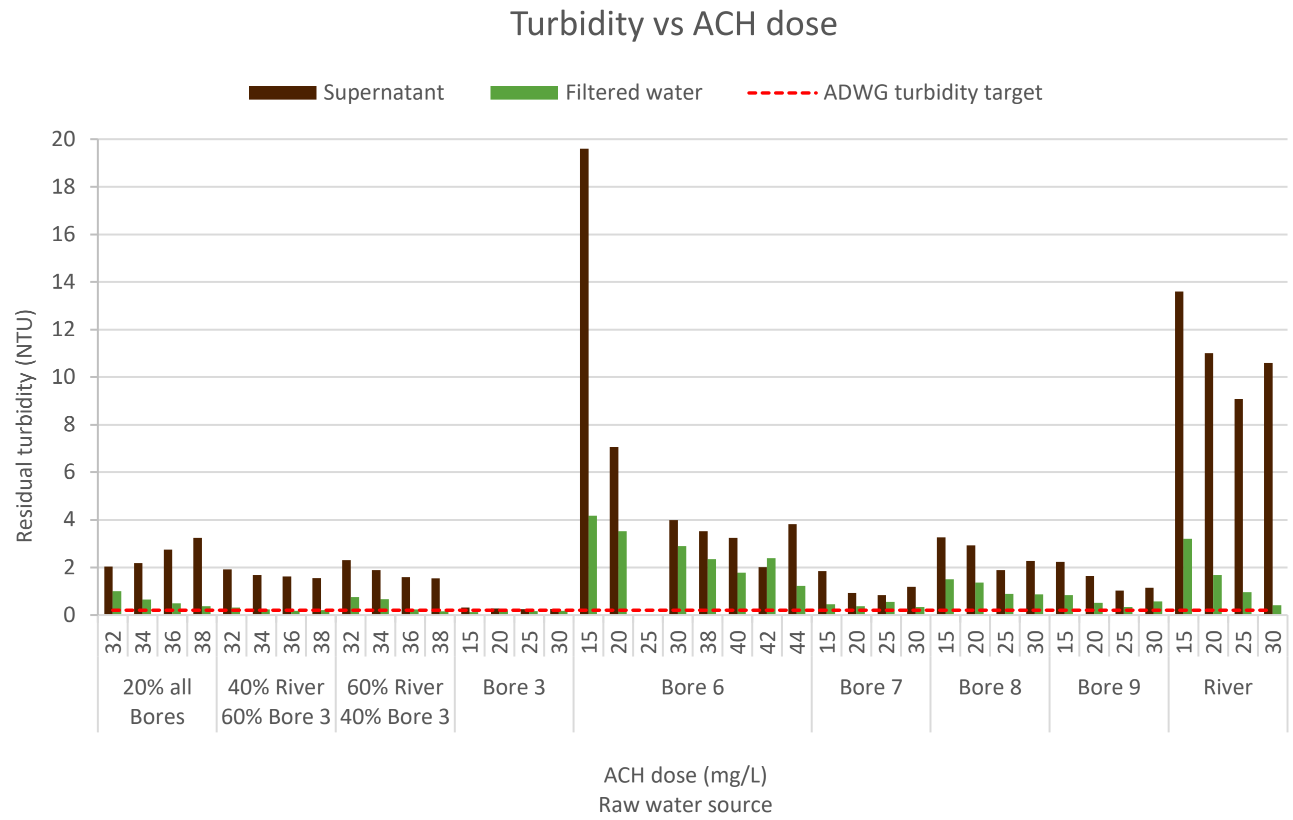


Figure 3-2 Residual turbidity of supernatant (20 min sedimentation) and filtered water



The blended samples using the river and Bore 3 raw water samples showed the turbidity reached approximately 0.2 NTU after filtration using a coagulant dose of 38 mg/L ACH (Figure 3-2). It is considered that a dose between 36 to 40 mg/L is optimal to treat the river and Bore 3 blended raw water source. Slight difference in the supernatant and filtered water turbidity when 40% of the river was used instead of 60%. For example, the filtered water turbidity was 0.172 and 0.234 at 36 mg/L ACH, respectively.

The samples with the blend of all bores showed that filtered turbidity can reach 0.3 NTU using 38 mg/L of ACH. A higher the dose, the supernatant increased while filtered water reduced, indicating that the flocs are bigger and less dense but can easily be filtered.

Figure 3-3 Residual turbidity of supernatant (20 and 30 min sedimentation) and filtered water

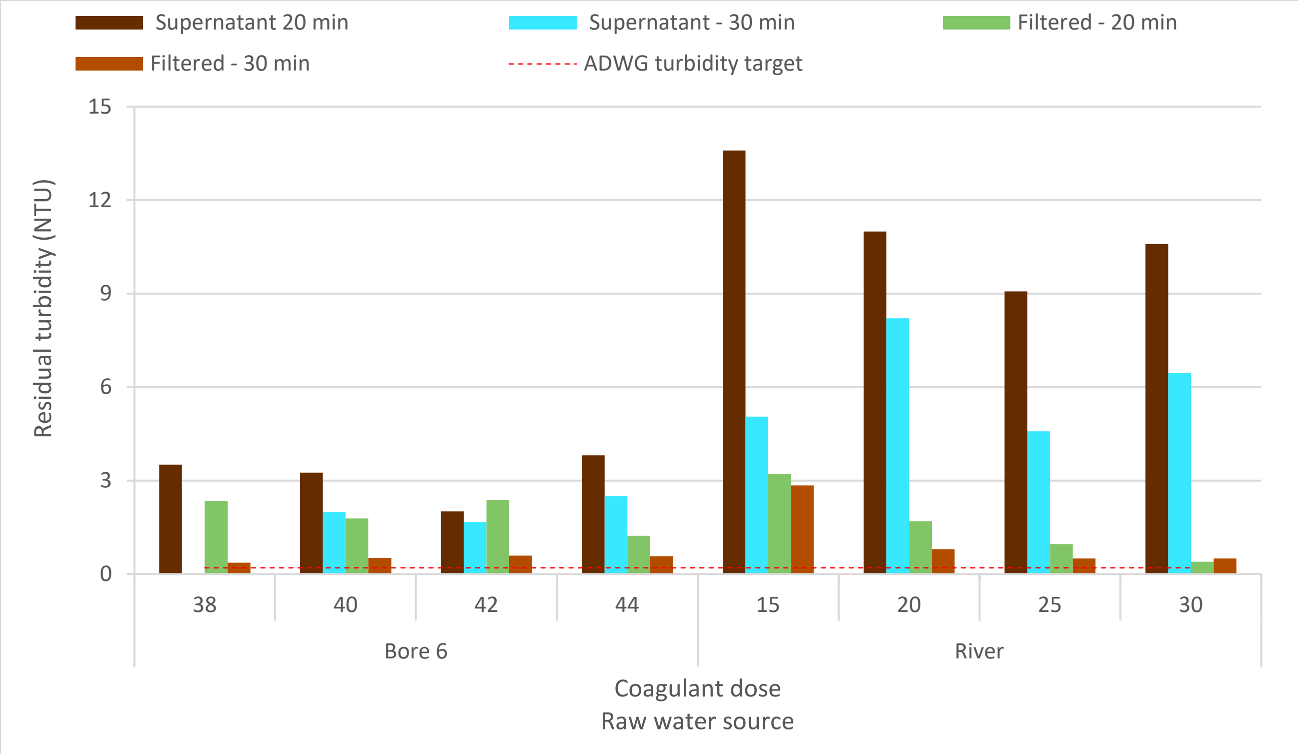


Figure 3-4 Bore 6 jars during sedimentation

(a) 20 min

(b) 30 min

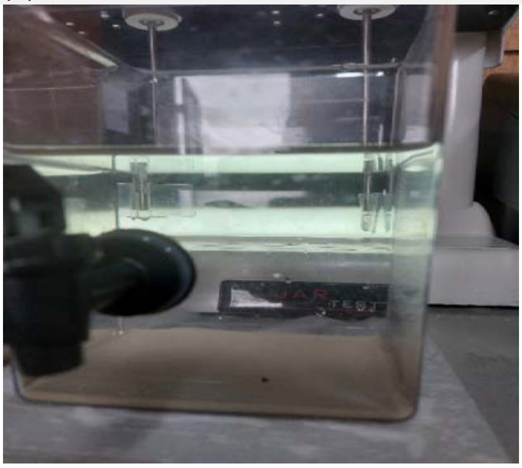
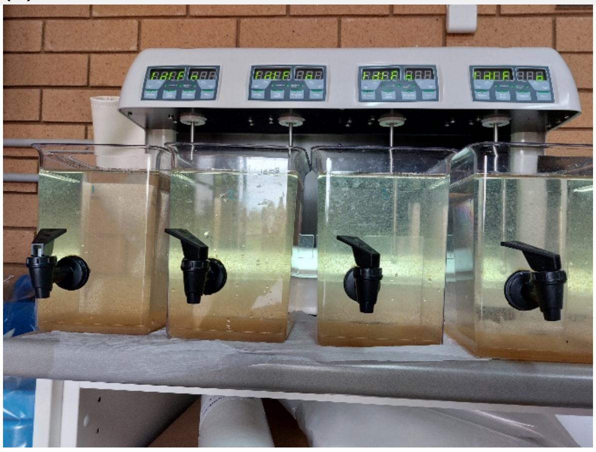


Figure 3-5 River jars during sedimentation

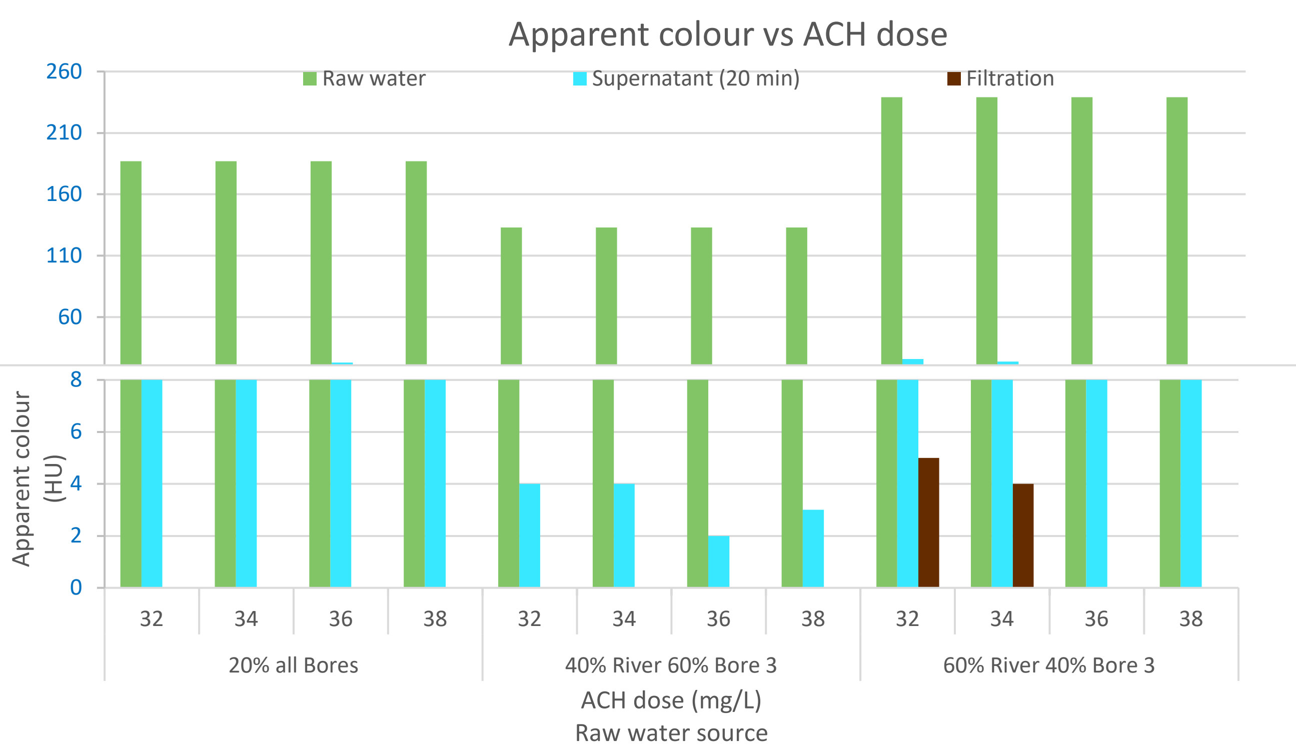
(a) 20 min of sedimentation	(b) 30 min of sedimentation
	

3.2 Colour removal

The residual colour of the supernatant and filtered water was only measured for the blended samples. There was a logistic problem with the cell used for the colour measurement when the testing the other samples.

For all the blended samples, the colour was removed after filtration except for the blended 60% river, and 40% Bore 3 sample in which, using a dose of 32 and 34 mg/L of ACH, the apparent colour was 26 and 24 HU respectively (Figure 3-6). True colour was only detected at an ACH dose of 32 mg/L. It is, therefore, inferred that the colour compounds in the blended samples are easily removed by coagulation, sedimentation, and filtration.

Figure 3-6 Raw water and residual apparent colour of raw water blended samples



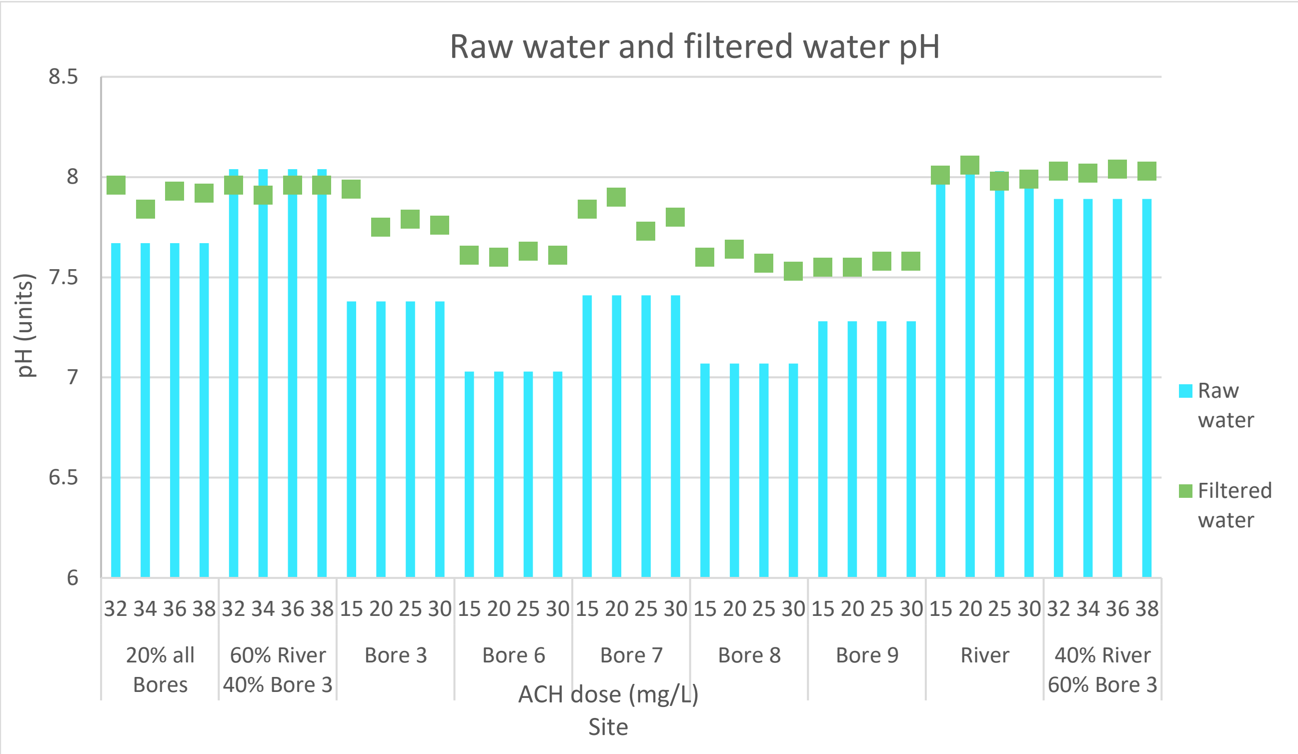
It is recommended that colour removal is assessed during dry a wet weather events for this source to assess the changes of NOM during different weather events.

R2 Conduct jar testing using river samples during dry and wet weather events and assess the colour removal at different coagulant doses with a duplicate set of experiments to corroborate results

3.3 pH

The pH was measured in the raw water and after filtration for all samples (Figure 3-7). ACH did not significantly change the pH which is one of the benefits of using this coagulant. The pH increased by approximately 0.5 units on average for all the samples. The lowest pH measured for raw and filtered water was from Bore 6 and 8.

Figure 3-7 Raw water and filtered water pH



A summary of the optimal dose, the residual turbidity after filtration under the optimal dose, and floc size for coagulation and sedimentation for all the raw water samples is shown in Table 3-2.

Table 3-2 Jar testing summary

Water sample	Comment raw water quality	Coagulant dose range tested (mg/L)	Best coagulant dose (mg/L)	Floc type (coagulation/ sedimentation)	Filtration turbidity at an optimal dose (NTU)	Comment jar testing
Bore 3	Best raw water quality overall	15-30	25	Very fine/ fine		
Bore 6	Worst water quality overall	15-44	38	Fine/fine	2.35 (20 min)/0.367 (30 min)	Best results after 30 min sedimentation
Bore 7	High iron content	15-30	30	Very fine/none	0.336	No flocs observed after 20 min sedimentation
Bore 8				Fine/ medium	0.857	Fluffy flocs
Bore 9	High manganese content	15-30	25	Very fine/fine	0.339	
River	High iron content	15-30	25	Very fine/ medium	0.961 (20 min)/0.495 (30 min)	Best results after 30 min sedimentation
All bores (20% each)	High iron content	32-38	38	Very fine/ very coarse	0.369	Coarse flocs but they can be filtrated
River 60%, Bore 3 40%		25-35	32	Fine/coarse	0.172	Coarse flocs, but they can be filtrated
River 40%, Bore 3 60%		32-38	38	Fine/coarse	0.155	Coarse flocs, but they can be filtrated

4 Conclusion

The ability of ACH to treat different raw water sources for Narromine was compared through jar testing to simulate coagulation-flocculation, sedimentation, and filtration. These treatment processes can achieve residual turbidity targets of less than 0.5 NTU for all the tested samples at optimal doses. Higher sedimentation time, higher ACH dose range and use of polymer can be tested to assess if a filtered turbidity of less than 0.2 NTU can be achieved.

The following recommendations were made as part of this investigation:

R1 Conduct jar testing for Bore 7,8 and 9 using ACH dose of 23-27 mg/L ACH

R2 Conduct jar testing for river samples using ACH dose of 29-33 mg/L ACH combined with polymer (e.g. LT20)

R3 Conduct jar testing using river samples during dry and wet weather events and assess the colour removal at different coagulant doses with a duplicate set of experiments to corroborate results

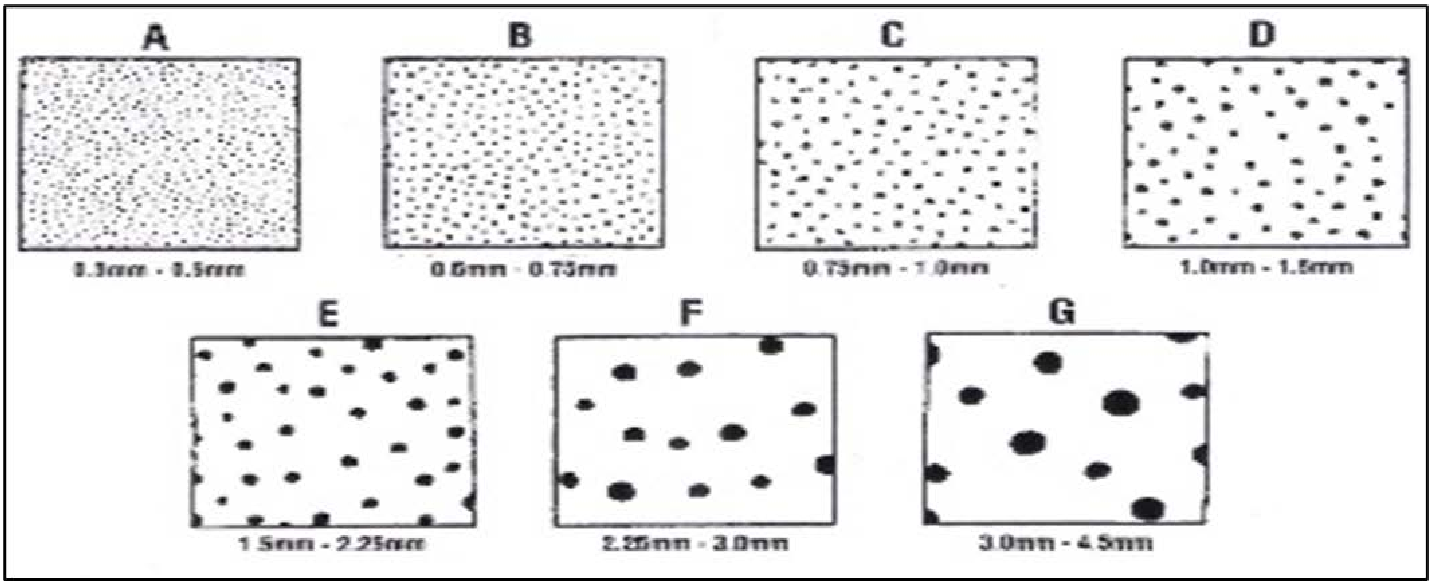
Appendix A Jar testing log

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH dose	Jar test record No.	1
		Raw water total Mn/Fe (mg/L)	0.012 / 0.01
Date sampling/ testing	17-10/18-10	Raw water dissolved Mn/Fe (mg/L)	0.0177 / 0.01
Time		Raw water alkalinity (mg/L)	176
Raw water source	Bore 3	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	0
Water source blend (%)		Raw water pH	7.38
		Raw water turbidity (NTU)	0.267(17-10) / 0.306
Coagulant/dose		ACH 27.4g/L stock st / 10960 mg/L Actl	
Polymer/ dose			
Potassium permanganate/dose			

Jar	1	2	3	4
Coagulant dose (mg/L)	15	20	25	30
Coagulant vol (mL)	2.7	3.6	4.6	5.5
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	None	None	VF	VF
Floc size 15 min	None	None	VF	VF
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	None	None	VF	VF
Floc size 20 min	None	None	None	None
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH	7.94	7.75	7.79	7.76
Turbidity (NTU)	0.315	0.27	0.25	0.263
Apparent/ true colour (Pt-co)				
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	0.123	0.173	0.157	0.183
Apparent/ true colour (Pt-co)				

VF: very fine F: fine M: medium C:Course



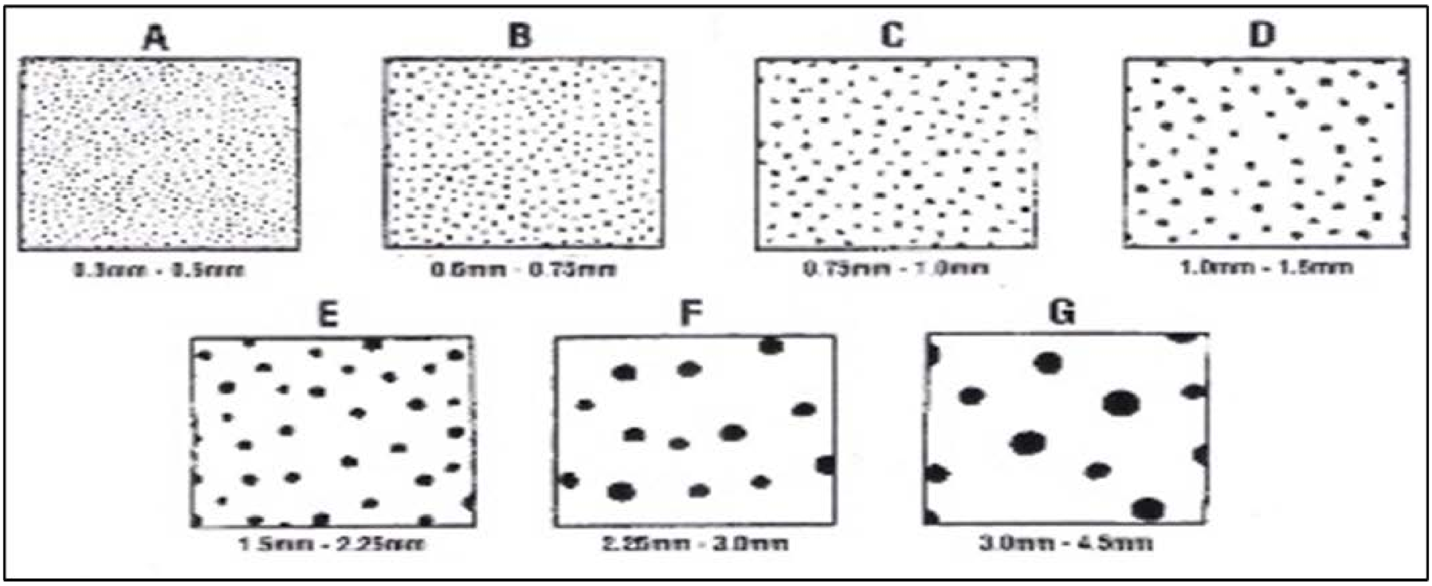
VC: very course EC: extra course L: Large

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH	Jar test record No.	2
		Raw water total Mn/Fe (mg/L)	0.137 / 0.01
Date sampling/ testing		Raw water dissolved Mn/Fe (mg/L)	0.133 / 0.01
Time		Raw water alkalinity (mg/L)	140
Raw water source	Bore 9	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	0
Water source blend (%)		Raw water pH	7.28
		Raw water turbidity (NTU)	1.34 (17-10) 3.72
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose			

Jar	1	2	3	4
Coagulant dose (mg/L)	15	20	25	30
Coagulant vol (mL)	2.7	3.6	4.6	5.5
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	VF	VF	VF	VF
Floc size 15 min	F	F	F	F
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	F	F	F	F
Floc size 20 min	F	F	F	F
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH filtrate	7.55	7.55	6.58	7.58
Turbidity (NTU)	2.23	1.65	1.02	1.15
Apparent/ true colour (Pt-co)				
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	0.833	0.514	0.339	0.562
Apparent/ true colour (Pt-co)				

VF: very fine F: fine M: medium C:Course



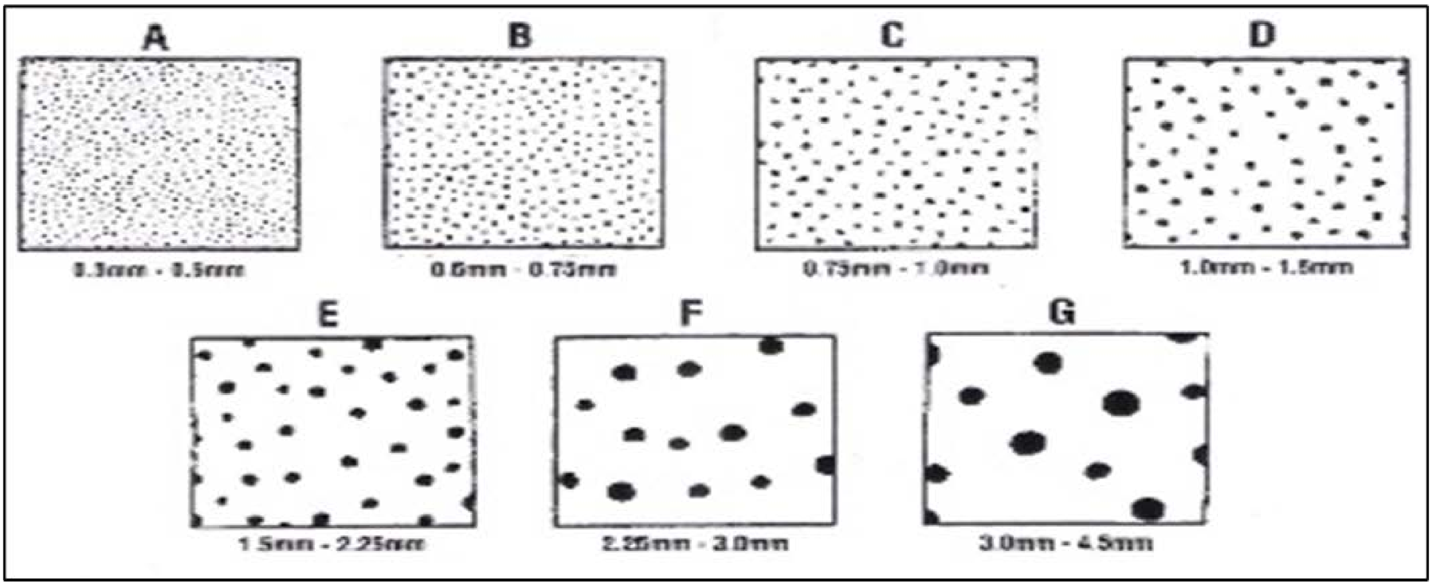
VC: very course EC: extra course L: Large

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH dose	Jar test record No.	3
		Raw water total Mn/Fe (mg/L)	0.601 / 3
Date sampling/ testing	18/10/22	Raw water dissolved Mn/Fe (mg/L)	0.128 / 0.15
Time	9:30	Raw water alkalinity (mg/L)	128
Raw water source	Bore 6	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	
Water source blend (%)		Raw water pH	7.03
		Raw water turbidity (NTU)	250
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose			

Jar	1	2	3	4
Coagulant dose (mg/L)	15	20	25	30
Coagulant vol (mL)	2.7	3.6	4.6	5.5
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	M		C	C
Floc size 15 min	C		C	C
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	F	F	F	F
Floc size 20 min	VF	VF	VF	VF
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH (fil)	7.61			
Turbidity (NTU)	19.6	7.07		3.99
Apparent/ true colour (Pt-co)				
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	4.18	3.51		2.89
Apparent/ true colour (Pt-co)				

VF: very fine F: fine M: medium C:Course



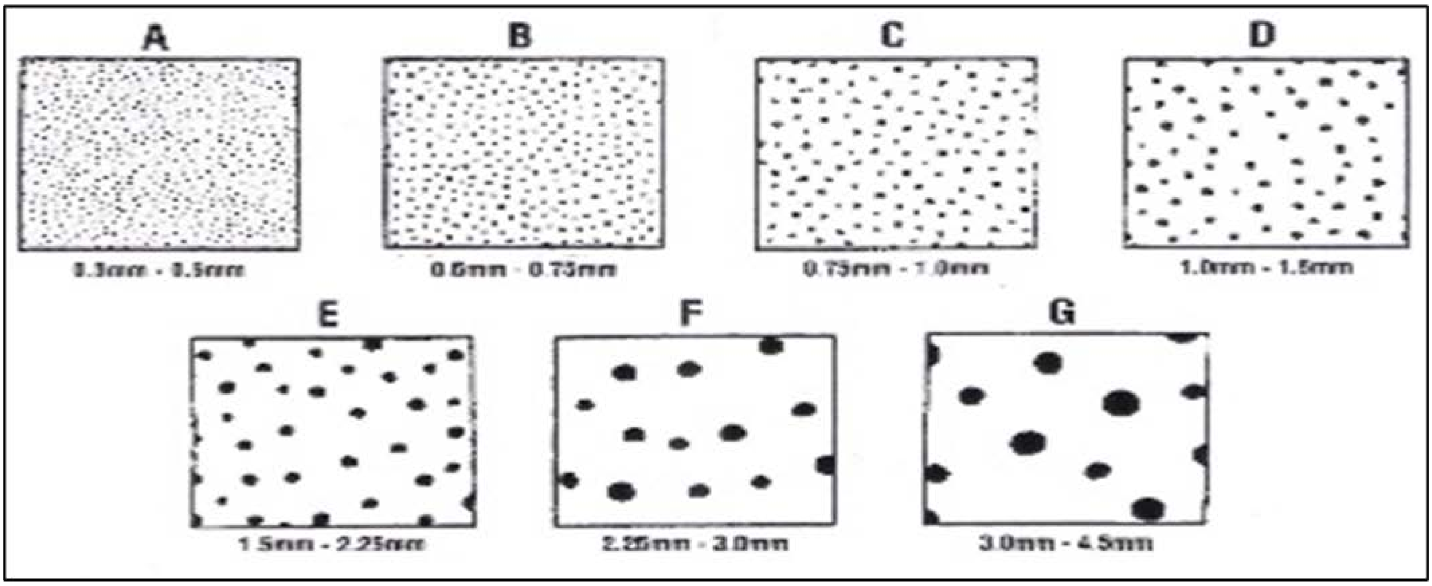
VC: very course EC: extra course L: Large

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH Dose	Jar test record No.	4
		Raw water total Mn/Fe (mg/L)	0.409 / 1.65
Date sampling/ testing	18-10/22	Raw water dissolved Mn/Fe (mg/L)	0.371 / 1.60
Time	12:00	Raw water alkalinity (mg/L)	143
Raw water source	Bore 7	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	
Water source blend (%)		Raw water pH	7.41
		Raw water turbidity (NTU)	3.79
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose			

Jar	1	2	3	4
Coagulant dose (mg/L)	15	20	25	30
Coagulant vol (mL)	3.7	3.6	4.6	5.5
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	VF	VF	F	F
Floc size 15 min	F	F	F	F
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	None	None	None	None
Floc size 20 min	None	None	None	None
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH (fil)	7.84	7.90	7.73	7.80
Turbidity (NTU)	1.84	0.925	0.839	1.18
Apparent/ true colour (Pt-co)				
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	0.444	0.362	0.549	0.336
Apparent/ true colour (Pt-co)				

VF: very fine F: fine M: medium C:Course



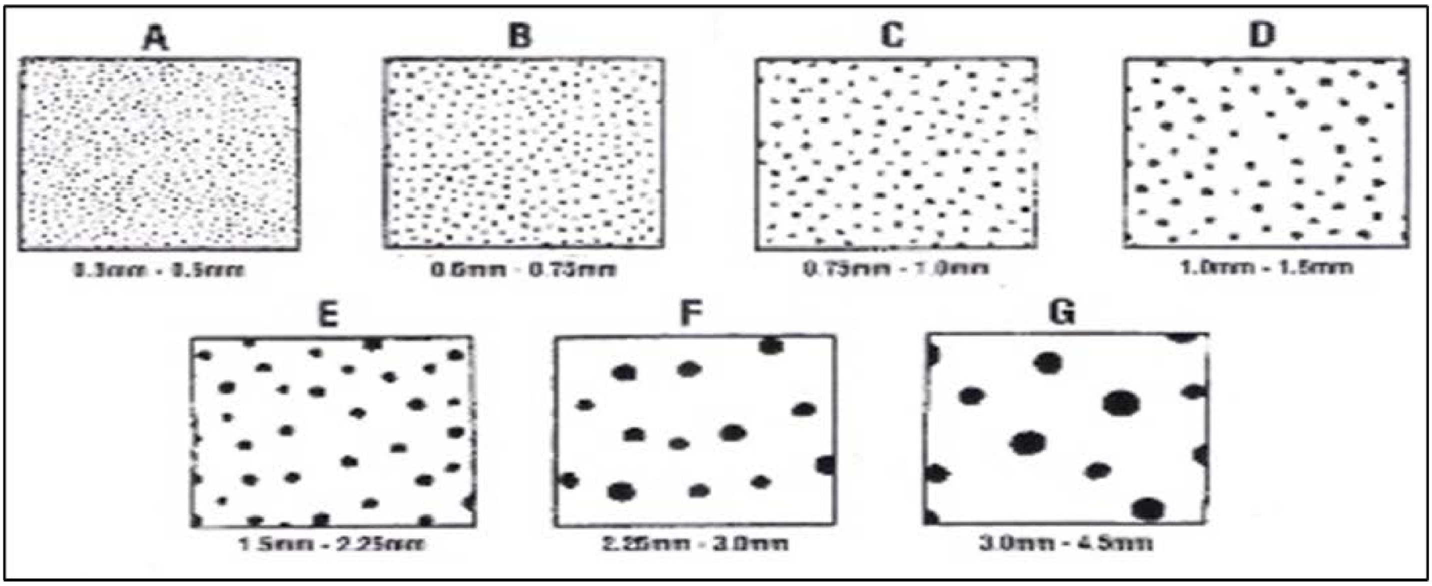
VC: very course EC: extra course L: Large

Narromine Laboratory Jar Test Recording Sheet

Jar objective	ACH optimal Dose	Jar test record No.	5
		Raw water total Mn/Fe (mg/L)	0.059 / 0.1
Date sampling/ testing	18-10/22	Raw water dissolved Mn/Fe (mg/L)	0.03 / 0.03
Time	10:30 – 12:00	Raw water alkalinity (mg/L)	165
Raw water source	Bore 8	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	
Water source blend (%)		Raw water pH	7.07
		Raw water turbidity (NTU)	5.90
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose			

Jar	1	2	3	4
Coagulant dose (mg/L)	15	20	25	30
Coagulant vol (mL)	2.7	3.6	4.6	5.5
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	VF	VF	VF	VF
Floc size 15 min	F	F	F	F
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	M	M	M	M
Floc size 20 min	M	M	M	M
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH	7.60	7.64	7.57	7.53
Turbidity (NTU)	3.26	2.92	1.88	2.27
Apparent/ true colour (Pt-co)				
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	1.49	1.36	0.890	0.857
Apparent/ true colour (Pt-co)				

VF: very fine F: fine M: medium C:Course



VC: very course EC: extra course L: Large

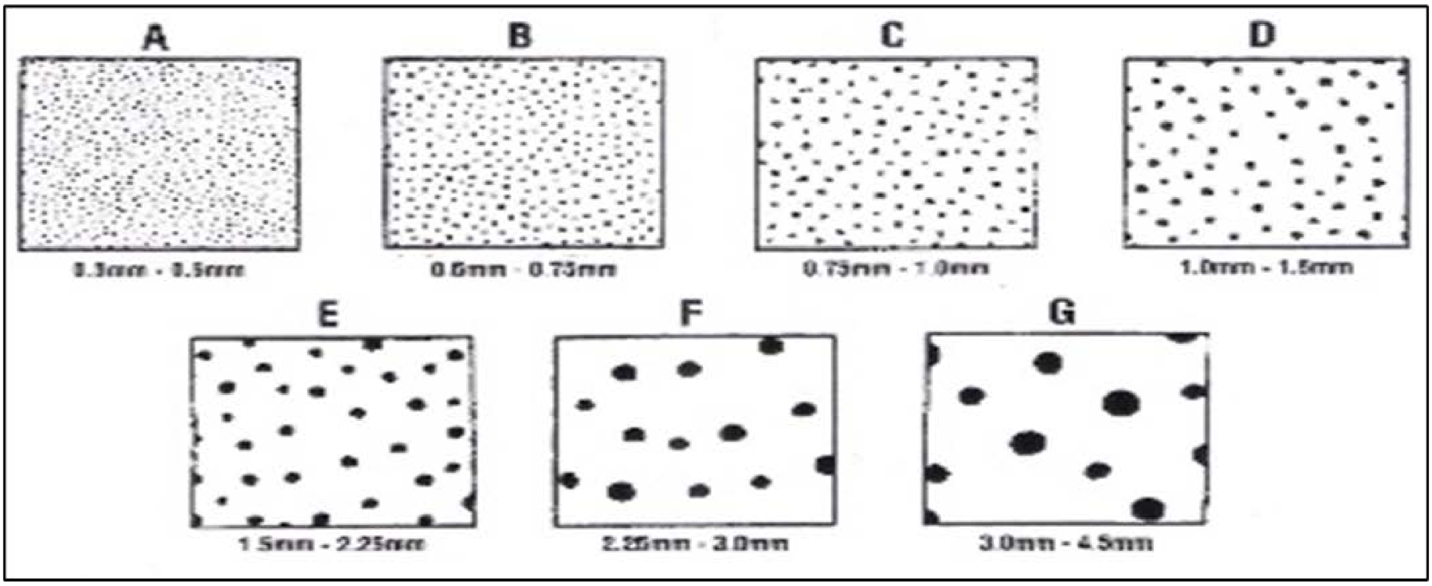
Attachment No. 2

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH dose	Jar test record No.	6
		Raw water total Mn/Fe (mg/L)	0.135 / 0.75
Date sampling/ testing	18-10/22	Raw water dissolved Mn/Fe (mg/L)	0.015 / 0.19
Time	10:00 – 2:30	Raw water alkalinity (mg/L)	78
Raw water source	River	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	
Water source blend (%)		Raw water pH	8.03
		Raw water turbidity (NTU)	38.2
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose		Note that RW is yellow due to flooding	

Jar	1		2		3		4	
Coagulant dose (mg/L)	15		20		25		30	
Coagulant vol (mL)	2.7		3.6		4.6		5.5	
Floc mix speed FAST (200 RPM for 2 min)								
Floc mix speed SLOW (20 rpm for 15 mins)								
Floc size 5 min	VF		VF		VF		VF	
Floc size 15 min	F		F		F		F	
STOP stirrers (20 mins sedimentation)								
Floc size 10 min	M		M		C		C	
Floc size 20 min	M		M		C		C	
Treated water (after 20 min sedimentation)								
Supernatant water quality								
time	20 min	30 min	20 min	30 min	20 min	30 min	20 min	30 min
Turbidity (NTU)	13.6	5.05	11	8.21	9.07	4.58	10.6	6.46
pH	8.01		8.06		7.98		7.99	
Filtered water quality (settled water filtered through Whatman #1 filter paper)								
Turbidity (NTU)	3.21	2.84	1.69	0.798	0.96	0.495	0.4	0.505
Apparent/ true colour (Pt-co)								

VF: very fine F: fine M: medium C:Course



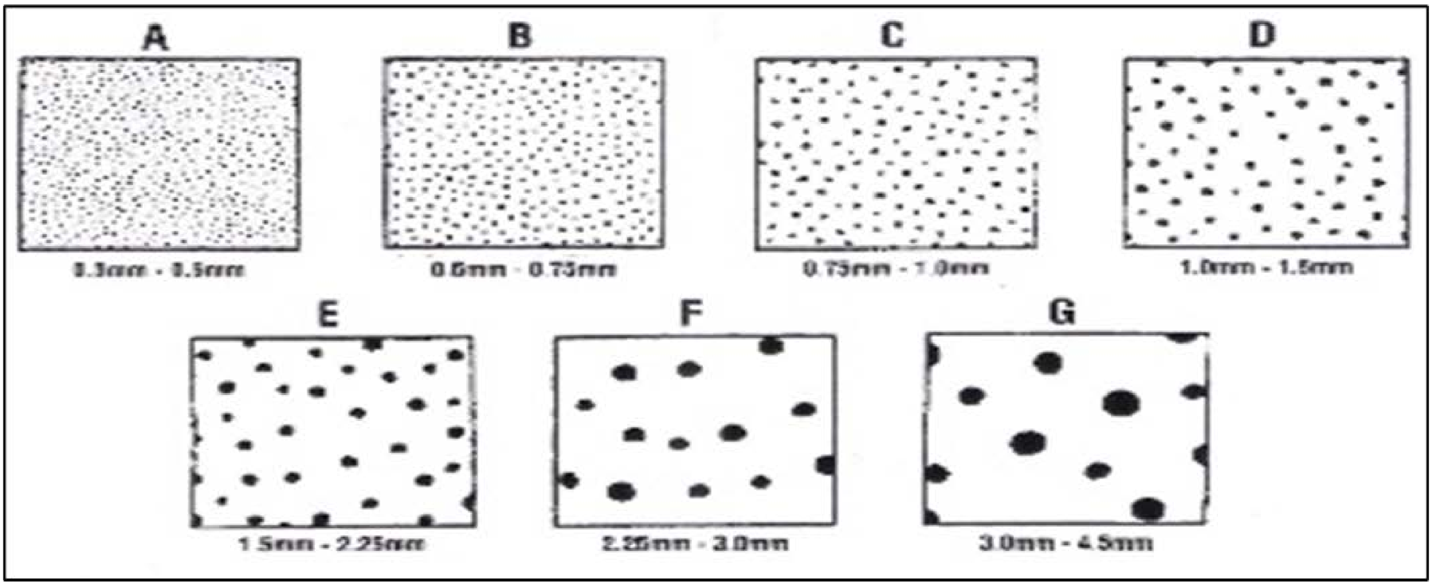
VC: very course EC: extra course L: Large

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH	Jar test record No.	7
		Raw water total Mn/Fe (mg/L)	0.103 / 0
Date sampling/ testing	19-10/22	Raw water dissolved Mn/Fe (mg/L)	0.019 / 0.65
Time	10:00	Raw water alkalinity (mg/L)	129
Raw water source	River/ Bore 3	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	239 / 25
Water source blend (%)	60% river	Raw water pH	8.04
	40% Bore 3	Raw water turbidity (NTU)	32.9
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose			

Jar	1	2	3	4
Coagulant dose (mg/L)	32	34	36	38
Coagulant vol (mL)	5.8	6.2	6.6	6.9
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	F	F	F	F
Floc size 15 min	F	F	F	F
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	F	F	F	F
Floc size 20 min	C	C	C	C
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH	7.96	7.91	7.96	7.96
Turbidity (NTU)	2.30	1.88	1.59	1.53
Apparent/ true colour (HU)	26 / 10	24 / 7	18 / 5	11 / 0
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	0.755	0.655	0.234	0.155
Apparent/ true colour (Pt-co)	5 / 4	4 / 0	0 / 0	0 / 0

VF: very fine F: fine M: medium C:Course

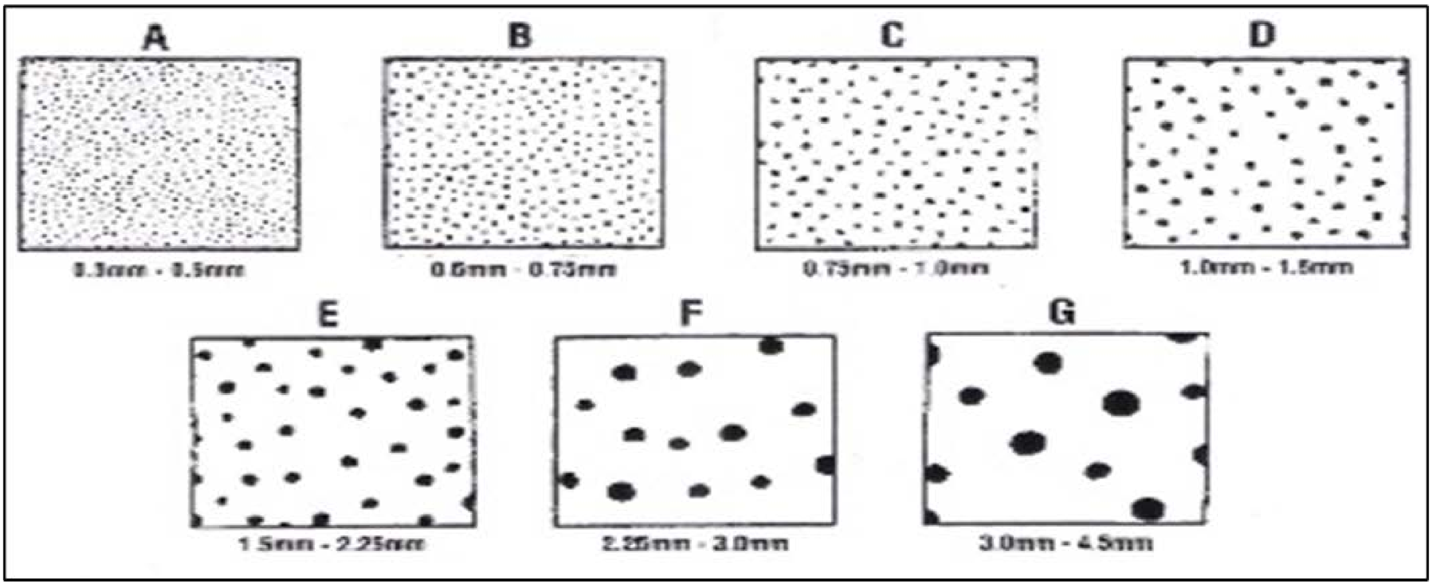


VC: very course EC: extra course L: Large

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH dose	Jar test record No.		8
		Raw water total Mn/Fe (mg/L)		0.19 / 0.31
Date sampling/ testing	19-10/22	Raw water dissolved Mn/Fe (mg/L)		0.146 / 0.09
Time	11:00	Raw water alkalinity (mg/L)		153
Raw water source	All bores	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})		187 / 0
Water source blend (%)	20% bore 3,6,7,8,9	Raw water pH		7.67
		Raw water turbidity (NTU)		23
Coagulant/dose				
Polymer/ dose				
Potassium permanganate/dose				
Jar	**1**	**2**	**3**	**4**
Coagulant dose (mg/L)	32	34	36	38
Coagulant vol (mL)	5.8	6.2	6.6	6.9
Floc mix speed FAST (200 RPM for 2 min)				
Floc mix speed SLOW (20 rpm for 15 mins)				
Floc size 5 min	VF	VF	VF	VF
Floc size 15 min	F	F	F	F
STOP stirrers (20 mins sedimentation)				
Floc size 10 min	C	C	C	C
Floc size 20 min	VC	VC	VC	VC
Treated water (after 20 min sedimentation)				
Supernatant water quality				
pH	7.96	7.84	7.93	7.92
Turbidity (NTU)	2.04	2.18	2.75	3.25
Apparent/ true colour (Pt-co)	21 / 3	17 / 0	23 / 0	21 / 0
Filtered water quality (settled water filtered through Whatman #1 filter paper)				
Turbidity (NTU)	0.993	0.645	0.486	0.369
Apparent/ true colour (Pt-co)	0 / 0	0 / 0	0 / 0	0 / 0

VF: very fine F: fine M: medium C:Course



VC: very course EC: extra course L: Large

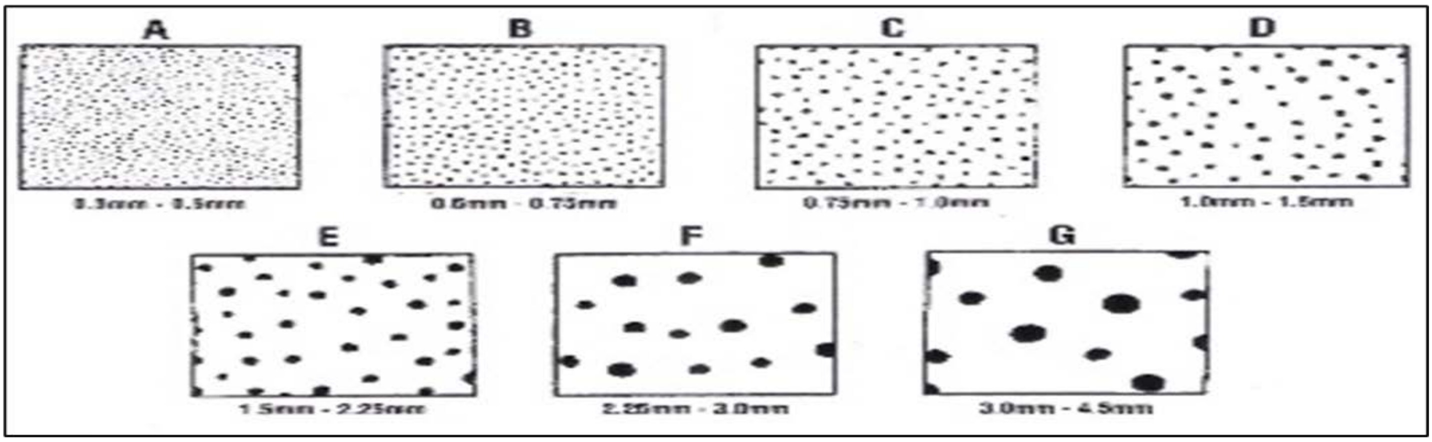
Attachment No. 2

Narromine Laboratory Jar Test Recording Sheet

Jar objective	Optimal ACH dose	Jar test record No.	9
		Raw water total Mn/Fe (mg/L)	
Date sampling/ testing	19-10 / 19-10	Raw water dissolved Mn/Fe (mg/L)	
Time	12:22	Raw water alkalinity (mg/L)	
Raw water source	Bore 6	Raw water apparent/ true colour (Pt-co – 455 cm^{-1})	>500 / 0
Water source blend (%)		Raw water pH	
		Raw water turbidity (NTU)	421
Coagulant/dose			
Polymer/ dose			
Potassium permanganate/dose			

Jar	1		2		3		4	
Coagulant dose (mg/L)	38		40		42		44	
Coagulant vol (mL)	6.9		7.3		7.7		8.0	
Floc mix speed FAST (200 RPM for 2 min)								
Floc mix speed SLOW (20 rpm for 15 mins)								
Floc size 5 min	F		F		F		F	
Floc size 15 min	F		F		F		F	
STOP stirrers (20 mins sedimentation)								
Floc size 10 min								
Floc size 20 min								
Treated water (after 20 min sedimentation)								
Supernatant water quality								
Time	20min	35min	20min	35min	20min	35min	20min	35min
Turbidity (NTU)	3.51		3.25	1.99	2.01	1.67	3.81	2.5
Apparent/ true colour (Pt-co)	21		1		0		0	
Filtered water quality (settled water filtered through Whatman #1 filter paper)								
Turbidity (NTU)	2.35	0.367	1.78	0.522	2.38	0.591	1.23	0.572
Apparent/ true colour (Pt-co)								
pH	7.74		7.72		7.62		7.73	

VF: very fine F: fine M: medium C:Course



VC: very course EC: extra course L: Large

Appendix C Detailed costing

PROJECT TITLE:	**NARROMINE WATER QUALITY OPTIONS ASSESSMENT**		
PROJECT NO.:	**NSC2308A**		
ESTIMATE TYPE:	**PRELIMINARY**		
OPTION	**1**	**DATE OF ESTIMATE**	**26-Sep-23**
DESCRIPTION	**Sedimenatation lagoons, pressure filters, UV & chlorination**		
NOTES:			

Consumer Price Indeces	**CPI**	**Change**
Jun-23	133.7	
Jun-22	126.1	6.03%
Jun-20	118.8	12.54%
Jun-14	105.9	26.25%

ITEM	DESCRIPTION	QTY	UNIT	RATE	YEAR	SUB-TOTAL (inc CPI)	TOTAL	ASSUMPTIONS
1	**General**							
1.1	Preliminaries	1	ea	$ 1,088,000	2023	$ 1,373,613		
1.2	Bulk site filling	1	ea	$ 1,138,385	2023	$ 1,437,224		
1.3	Amentities (includes switchroom)	1	ea	$ 400,000	2023	$ 505,005		
							$ 3,315,842	
2	**Sedimentation lagoons**							Hdfk#odjrrq#kdv#iorru#ri#<5p#{#64# 433pp/#Voxgjh#4p/#zdwhu#4p#dqg#318#p#iuhh# erdug1#Zdoo#vorsz#rv#318#y=k
	Sedimentation lagoons	2	ea	$ 3,057,095	2023	$ 6,114,190		
	Settled water pump station	1	ea	$ 530,000	2023	$ 561,943		
							$ 6,676,133	
3	**Filtration**							
	Filtration skids	1	ea	$ 971,766	2022	$ 1,030,334		2 x Skid with three filters and backwash pump
	Filter/UV Building	1	ea	$ 550,000	2023	$ 583,148		
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	900	hrs	$ 120	2023	$ 108,000		3 staff 6 weeks 50 hour week
							$ 1,723,482	
4	**UV Disinfection**							
	UV Disinfection	1	ea	$ 395,916	2022	$ 419,778		
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	600	hrs	$ 120	2023	$ 72,000		3 staff 4 weeks 50 hour week
							$ 493,778	
5	**Chemical dosing**							
	ACH tank	1	ea	$ 8,000	2022	$ 8,482		25kL HDPE tank (Bushmans)
	ACH dosing skid	1	ea	$ 25,000	2022	$ 26,507		Prominent
	Soda ash dosing skid	1	ea	$ 216,473	2022	$ 229,520		Trility
	KMnO4 dosing skid	1	ea	$ 216,473	2022	$ 229,520		Trility
	Chemical building	1	ea	$ 488,750	2023	$ 518,207		
	Crane for dosing skids	16	ea	$ 250	2023	$ 4,000		
	Installation of dosing skids	1800	hrs	$ 120	2023	$ 216,000		3 staff 12 weeks 50 hour week
	Relocate chlorination	1	ea	$ 65,700	2023	$ 69,660		
							$ 1,301,895	
6	**Clear water tank**							
	CWT & install	1	ea	$ 2,100,000	2014	$ 2,651,275		
							$ 2,651,275	
8	**High lift pump station**							
	Pump station and pumps	1	ea	$ 1,357,420	2023	$ 1,713,759		
							$ 1,713,759	
9	**Pipework**							
	Interconnecting pipework	1	ea	$ 1,165,000	2023	$ 1,470,826		
							$ 1,470,826	
10	**EI&C**							
	Site electrical reticulation	1	ea	$ 600,000	2023	$ 757,507		
	Transformer	1	ea	$ 365,000	2023	$ 460,817		
							$ 1,218,324	
11	**Miscellaneous**							
	Site fencing	1	ea	$ 35,880	2023	$ 45,299		
	Roads	1	ea	$ 346,500	2023	$ 437,460		
	Storage shed	1	ea	$ 50,000	2023	$ 63,126		
							$ 545,885	
Total Estimated Construction Cost							**$ 21,111,198**	
Design & Management								
	Design			10%		$ 2,111,120		
	Design Project management			16%		$ 337,779		
	Construction management			9%		$ 1,900,008		
							$ 4,348,907	
Total Estimated Design & Construction							**$ 25,460,105**	
	Contingency			30%		$ 7,638,032		
	Escalation			12%		$ 3,055,213		
							$ 15,042,151	
TOTAL ESTIMATED CAPITAL COST								
					say		**$ 40,502,256**	

OPERATION & MAINTENANCE COSTS

NOTES:

VARIABLE OPERATING COSTS

Flow basis 7.5 ML/d

ITEM	DESCRIPTION	QTY	UNIT	RATE	RATE UNITS	ANNUAL TOTAL	TOTAL	ASSUMPTIONS
1	**Chemicals**							
	ACH	38	mg/L	$ 2.79	$/kg	$ 290,421		
	KMnO4	2.6	mg/L	$ 13.00	$/kg	$ 92,588		
	Chlorine	1.5	mg/L	$ 4.90	$/kg	$ 20,134		
							$ 403,143	
2	**Electricity**							
	UV Disinfection	6.2	kW	$ 0.22	$/kWh	$ 11,956		
	Settled Water Pump	20	kW	$ 0.22	$/kWh	$ 38,569		
							$ 50,526	
3	**Sludge disposal**							
	Sludge production	301	dry kg/d					

	Dewatered sludge thickness		50%	w/w							
	Wet sludge production		220	m3/yr	$	24	$/m3	$	5,198		
										$ 5,198	
TOTAL VARIABLE OPERATING COSTS											
	Total cost/ML							$	168		
	Contingency					15%		$	25		
	Escalation					12%		$	20		
										$ 213	/ML
FIXED OPERATING COSTS											
1	**Maintenance**										
	Maintenance		1%	of capital				$	405,023		
										$ 405,023	
2	**Electricity**										
	Backwash Pump		20	kW		0.17	hours/day	$	268		Each filter every 2 days for 20 minutes
										$ 268	
3	**Sedimentation lagoon desludging**										
	Lagoon floor area		2,852	m2							
	Depth of sludge		1.0	m							
	Volume of sludge		2,852.0	m3							
	Lagoon sludge thickness		4%	w/w							
	Dry solids		114.08	tonnes							
	Desludge freqency		12	months	$	350	/dry tonne	$	39,928		
										$ 39,928	
4	**Labour**										
	Operators	FTE	1.5		$	90,000	/year/operatc	$	135,000		
										$ 135,000	
TOTAL FIXED OPERATING COSTS											
	Total Cost/year							$	580,218		
	Continency					15%		$	87,033		
	Escalation					12%		$	69,626		
										$ 736,877	/year

PROJECT TITLE:	**NARROMINE WATER QUALITY OPTIONS ASSESSMENT**
PROJECT NO.:	**NSC2308A**
ESTIMATE TYPE:	**PRELIMINARY**

OPTION	**2**	**DATE OF ESTIMATE**	**26-Sep-23**
DESCRIPTION	**Sedimenatation tank, pressure filters, UV & chlorination, sludge lagoons**		
NOTES:			

Consumer Price Indeces	**CPI**	**Change**
Jun-23	133.7	
Jun-22	126.1	6.03%
Jun-20	118.8	12.54%
Jun-14	105.9	26.25%

ITEM	DESCRIPTION	QTY	UNIT	RATE	YEAR	SUB-TOTAL (inc CPI)	TOTAL	ASSUMPTIONS
1	**General**							
1.1	Preliminaries	1	ea	$ 1,088,000	2023	$ 1,373,613		
1.2	Bulk site filling	1	ea	$ 696,730	2023	$ 879,630		
1.3	Amentities (includes switchroom)	1	ea	$ 400,000	2023	$ 505,005		
							$ 2,758,247	
2	**Sedimentation tank**							
	Sedimentation tank	1	ea	$ 1,265,591	2022	$ 1,341,868		CoMag ballasted filter
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	900	hrs	$ 120	2023	$ 108,000		3 staff 6 weeks 50 hour week
	Settled water pump station	1	ea	$ 530,000	2023	$ 561,943		
							$ 2,013,811	
3	**Filtration**							
	Filtration skids	1	ea	$ 971,766	2022	$ 1,030,334		2 x Skid with three filters and backwash pump
	Filter/UV Building	1	ea	$ 550,000	2023	$ 583,148		
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	900	hrs	$ 120	2023	$ 108,000		3 staff 6 weeks 50 hour week
							$ 1,723,482	
4	**UV Disinfection**							
	UV Disinfection	1	ea	$ 395,916	2022	$ 419,778		Containerised UV system from Trility
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	600	hrs	$ 120	2023	$ 72,000		3 staff 4 weeks 50 hour week
							$ 493,778	
5	**Chemical dosing**							
	ACH tank	1	ea	$ 8,000	2022	$ 8,482		25kL HDPE tank (Bushmans)
	ACH dosing skid	1	ea	$ 25,000	2022	$ 26,507		Prominent
	Soda ash dosing skid	1	ea	$ 216,473	2022	$ 229,520		Trility
	KMnO4 dosing skid	1	ea	$ 216,473	2022	$ 229,520		Trility
	Chemical building	1	ea	$ 488,750	2023	$ 518,207		
	Crane for dosing skids	16	ea	$ 250	2023	$ 4,000		
	Installation of dosing skids	1800	hrs	$ 120	2023	$ 216,000		3 staff 12 weeks 50 hour week
	Relocate chlorination	1	ea	$ 65,700	2023	$ 69,660		
							$ 1,301,895	
6	**Clear water tank**							
	CWT & install	1	ea	$ 2,100,000	2014	$ 2,651,275		NSW Reference rates for 10ML steel tank
							$ 2,651,275	
7	**Sludge lagoons**							
	Sludge lagoons	1	ea	$ 3,057,096	2023	$ 3,057,096		3 x sludge lagoons ??? m3 each
							$ 3,057,096	
8	**High lift pump station**							
	Pump station and pumps	1	ea	$ 1,357,420	2023	$ 1,713,759		
							$ 1,713,759	
9	**Pipework**							
	Interconnecting pipework	1	ea	$ 1,165,000	2023	$ 1,470,826		
							$ 1,470,826	
10	**EI&C**							
	Site electrical reticulation	1	ea	$ 600,000	2023	$ 757,507		
	Transformer	1	ea	$ 365,000	2023	$ 460,817		
							$ 1,218,324	
11	**Miscellaneous**							
	Site fencing	1	ea	$ 41,220	2023	$ 52,041		
	Roads	1	ea	$ 346,500	2023	$ 437,460		
	Storage shed	1	ea	$ 50,000	2023	$ 63,126		
							$ 552,627	
Total Estimated Construction Cost							**$ 18,955,119**	
Design & Management								
	Design			10%		$ 1,895,512		
	Design Project management			16%		$ 303,282		
	Construction management			9%		$ 1,705,961		
							$ 3,904,755	
Total Estimated Design & Construction							**$ 22,859,874**	
	Contingency			30%		$ 6,857,962		
	Escalation			12%		$ 2,743,185		
							$ 9,601,147	
TOTAL ESTIMATED CAPITAL COST							**$ 32,461,021**	

OPERATION & MAINTENANCE COSTS

NOTES:

VARIABLE OPERATING COSTS

Flow basis 7.5 ML/d

ITEM	DESCRIPTION	QTY	UNIT	RATE	RATE UNITS	ANNUAL TOTAL	TOTAL	ASSUMPTIONS
1	**Chemicals**							
	ACH	38	mg/L	$ 2.79	$/kg	$ 290,421		
	KMnO4	2.6	mg/L	$ 13.00	$/kg	$ 92,588		
	Chlorine	1.5	mg/L	$ 4.90	$/kg	$ 20,134		
							$ 403,143	
2	**Electricity**							
	UV Disinfection	6.2	kW	$ 0.22	$/kWh	$ 11,956		
	Settled Water Pump	20	kW	$ 0.22	$/kWh	$ 38,569		
							$ 50,526	
3	**Sludge disposal**							

	Sludge production		301	dry kg/d						
	Dewaterd sludge thickness		50%	w/w						
	Wet sludge production		220	m3/yr	$	24	$/m3	$	5,198	
										$ 5,198
TOTAL VARIABLE OPERATING COSTS										
	Total cost/ML							$	168	
	Contingency					15%		$	25	
	Escalation					12%		$	20	
										$ 213 /ML
FIXED OPERATING COSTS										
1	**Maintenance**									
	Maintenance		1%	of capital				$	324,610	
										$ 324,610
2	**Electricity**									
	Backwash Pump		20	kW		0.17	hours/day	$	268	Each filter every 2 days for 20 minutes
										$ 268
3	**Sludge lagoon desludging**									
	Lagoon volume		1,355	m3						
	Lagoon sludge thickness		4%	w/w						
	Dry solids		54.20	tonnes						
	Desludge freqency		6	months	$	350	/dry tonne	$	37,940	
										$ 37,940
4	**Labour**									
	Operators	FTE	1.5		$	90,000	/year/operato	$	135,000	
										$ 135,000
TOTAL FIXED OPERATING COSTS										
	Total Cost/year							$	497,818	
	Continency					15%		$	74,673	
	Escalation					12%		$	59,738	
										$ 632,229 /year

PROJECT TITLE:	**NARROMINE WATER QUALITY OPTIONS ASSESSMENT**
PROJECT NO.:	**NSC2308A**
ESTIMATE TYPE:	**PRELIMINARY**

OPTION	**2**	**DATE OF ESTIMATE**	**26-Sep-23**
DESCRIPTION	**Sedimenatation tank, pressure filters, UV & chlorination, sludge lagoons**		
NOTES:			

Consumer Price Indeces	**CPI**	**Change**
Jun-23	133.7	
Jun-22	126.1	6.03%
Jun-20	118.8	12.54%
Jun-14	105.9	26.25%

ITEM	DESCRIPTION	QTY	UNIT	RATE	YEAR	SUB-TOTAL (inc CPI)	TOTAL	ASSUMPTIONS
1	**General**							
1.1	Preliminaries	1	ea	$ 1,088,000	2023	$ 1,373,613		
1.2	Bulk site filling	1	ea	$ 406,120	2023	$ 512,731		
1.3	Amentities (includes switchroom)	1	ea	$ 400,000	2023	$ 505,005		
							$ 2,391,349	
2	**Sedimentation tank**							
	Sedimentation tank	1	ea	$ 1,265,591	2022	$ 1,341,868		CoMag ballasted filter
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	900	hrs	$ 120	2023	$ 108,000		3 staff 6 weeks 50 hour week
	Settled water pump station	1	ea	$ 530,000	2023	$ 561,943		
							$ 2,013,811	
3	**Filtration**							
	Filtration skids	1	ea	$ 971,766	2022	$ 1,030,334		2 x Skid with three filters and backwash pump
	Filter/UV Building	1	ea	$ 550,000	2023	$ 583,148		
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	900	hrs	$ 120	2023	$ 108,000		3 staff 6 weeks 50 hour week
							$ 1,723,482	
4	**UV Disinfection**							
	UV Disinfection	1	ea	$ 395,916	2022	$ 419,778		
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	600	hrs	$ 120	2023	$ 72,000		3 staff 4 weeks 50 hour week
							$ 493,778	
5	**Chemical dosing**							
	ACH tank	1	ea	$ 8,000	2022	$ 8,482		25kL HDPE tank (Bushmans)
	ACH dosing skid	1	ea	$ 25,000	2022	$ 26,507		Prominent
	Soda ash dosing skid	1	ea	$ 216,473	2022	$ 229,520		Trility
	KMnO4 dosing skid	1	ea	$ 216,473	2022	$ 229,520		Trility
	Chemical building	1	ea	$ 488,750	2023	$ 518,207		
	Crane for dosing skids	16	ea	$ 250	2023	$ 4,000		
	Installation of dosing skids	1800	hrs	$ 120	2023	$ 216,000		3 staff 12 weeks 50 hour week
	Relocate chlorination	1	ea	$ 65,700	2023	$ 69,660		
							$ 1,301,895	
6	**Sludge press**							
	Sludge Press	1	ea	$ 161,950	2023	$ 161,950		304SS machine 4m3/h from Hydroflux Epco
	Crane hire	8	hrs	$ 250	2023	$ 2,000		
	Installation	600	hrs	$ 120	2023	$ 72,000		3 staff 4 weeks 50 hour week
							$ 235,950	
7	**Clear water tank**							
	CWT & install	1	ea	$ 2,100,000	2014	$ 2,651,275		
							$ 2,651,275	
8	**High lift pump station**							
	Pump station and pumps	1	ea	$ 1,357,420	2023	$ 1,713,759		
							$ 1,713,759	
9	**Pipework**							
	Interconnecting pipework	1	ea	$ 1,165,000	2023	$ 1,470,826		
							$ 1,470,826	
10	**EI&C**							
	Site electrical reticulation	1	ea	$ 600,000	2023	$ 757,507		
	Transformer	1	ea	$ 365,000	2023	$ 460,817		
							$ 1,218,324	
11	**Miscellaneous**							
	Site fencing	1	ea	$ 27,000	2023	$ 34,088		
	Roads	1	ea	$ 346,500	2023	$ 437,460		
	Storage shed	1	ea	$ 50,000	2023	$ 63,126		
							$ 534,674	
Total Estimated Construction Cost							**$ 15,749,122**	
Design & Management								
	Design			10%		$ 1,574,912		
	Design Project management			16%		$ 251,986		
	Construction management			9%		$ 1,417,421		
							$ 3,244,319	
Total Estimated Design & Construction							**$ 18,993,441**	
	Contingency			30%		$ 5,698,032		
	Escalation			12%		$ 2,279,213		
							$ 7,977,245	
TOTAL ESTIMATED CAPITAL COST							**$ 26,970,686**	

OPERATION & MAINTENANCE COSTS

NOTES:

VARIABLE OPERATING COSTS

Flow basis 7.5 ML/d

ITEM	DESCRIPTION	QTY	UNIT	RATE	RATE UNITS	ANNUAL TOTAL	TOTAL	ASSUMPTIONS
1	**Chemicals**							
	ACH	38	mg/L	$ 2.79	$/kg	$ 290,421		
	KMnO4	2.6	mg/L	$ 13.00	$/kg	$ 92,588		
	Chlorine	1.5	mg/L	$ 4.90	$/kg	$ 20,134		
							$ 403,143	
2	**Electricity**							
	UV Disinfection	6.2	kW	$ 0.22	$/kWh	$ 11,956		
	Settled Water Pump	20	kW	$ 0.22	$/kWh	$ 38,569		
							$ 50,526	

3 Sludge disposal											
Sludge production		301	dry kg/d								
Dewaterd sludge thickness		50%	w/w								
Wet sludge production		220	m3/yr	$	24	$/m3	$	5,198			
									$	**5,198**	
TOTAL VARIABLE OPERATING COSTS											
Total cost/ML							$	168			
Contingency					15%		$	25			
Escalation					12%		$	20			
									$	**213**	/ML
FIXED OPERATING COSTS											
1 Maintenance											
Maintenance		1%	of capital				$	269,707			
									$	**269,707**	
2 Electricity											
Backwash Pump		20	kW		0.17	hours/day	$	268			Each filter every 2 days for 20 minutes
									$	**268**	
3 Labour											
Operators	FTE	1.5		$	90,000	/year/operatc	$	135,000			
									$	**135,000**	
TOTAL FIXED OPERATING COSTS											
Total Cost/year							$	404,975			
Continency					15%		$	60,746			
Escalation					12%		$	48,597			
									$	**514,318**	/year

PROJECT TITLE:	**NARROMINE WATER QUALITY OPTIONS ASSESSMENT**
PROJECT NO.:	**NSC2308A**
ESTIMATE TYPE:	**PRELIMINARY**
OPTION	**4**
DESCRIPTION	**Upgrade Existing Temporary WTP**
NOTES:	

DATE OF ESTIMATE **21-Aug-23**

Consumer Price Indeces	**CPI**	**Change**
Jun-23	133.7	
Jun-22	126.1	6.03%
Jun-20	118.8	12.54%
Jun-14	105.9	26.25%

ITEM	DESCRIPTION	QTY	UNIT	RATE	YEAR	SUB-TOTAL (inc CPI)	TOTAL	ASSUMPTIONS
1	**SCIDEV QUOTE**							
1.1	Design Engineering & PM	1	ea	$ 225,000	2023	$ 225,000		
1.2	Procurement	1	ea	$ 8,160,000	2023	$ 8,160,000		
1.3	Mobilisation	1	ea	$ 240,000	2023	$ 240,000		
1.4	Construciton	1	ea	$ 895,000	2023	$ 895,000		
1.5	MCC/PLC Upgrade & Electrical	1	ea	$ 460,000	2023	$ 460,000		
1.6	Commissioning	1	ea	$ 75,000	2023	$ 75,000		
1.4	Travel & Accommodation	1	ea	$ 100,000	2023	$ 100,000		
							$ 10,155,000	
2	**General (non SCIDEV)**							
	Preliminaries	1	ea	$ 272,000	2023	$ 343,403		
	Bulk site filling	1	ea	$ 408,120	2023	$ 515,256		
							$ 858,660	
3	**Construction for SCIDEV site**							
	Bulk Site filling	1	ea	$ 408,120	2023	$ 515,256		
	Building over WTP containers	1	ea	$ 550,000	2024	$ 694,381		
							$ 1,209,638	
4	**Clear water tank**							
	CWT & install	1	ea	$ 2,100,000	2014	$ 2,651,275		
							$ 2,651,275	
5	**High lift pump station**							
	Pump station and pumps	1	ea	$ 1,357,420	2023	$ 1,713,759		
							$ 1,713,759	
6	**Pipework**							
	Interconnecting pipework	1	ea	$ 291,250	2023	$ 367,707		
							$ 367,707	
7	**EI&C**							
	Site electrical reticulation	1	ea	$ 150,000	2023	$ 189,377		
	Transformer	1	ea	$ 365,000	2023	$ 460,817		
							$ 650,194	
8	**Miscellaneous**							
	Site fencing	1	ea	$ 27,000	2023	$ 34,088		
	Roads	1	ea	$ 178,200	2023	$ 224,980		
	Storage shed	1	ea	$ 50,000	2023	$ 63,126		
	Relocate chlorination	1	ea	$ 65,700	2023	$ 69,660		
	Amentities (includes switchroom)	1	ea	$ 400,000	2023	$ 505,005		
							$ 896,857	
Total Estimated Construction Cost							**$ 18,503,088**	
	Non SCIDEV Construction						**$ 8,348,088**	
Design & Management								
	Design			10%		$ 834,809		
	Design Project management			16%		$ 133,569		
	Construction management			9%		$ 751,328		
							$ 1,719,706	
Total Estimated Design & Construction							**$ 20,222,795**	
	Contingency			30%		$ 6,066,838		
	Escalation			12%		$ 2,426,735		
							$ 8,493,574	
TOTAL ESTIMATED CAPITAL COST							**$ 28,716,368**	

OPERATION & MAINTENANCE COSTS

NOTES:

VARIABLE OPERATING COSTS

Flow basis 7.5 ML/d

ITEM	DESCRIPTION	QTY	UNIT	RATE	RATE UNITS	ANNUAL TOTAL	TOTAL	ASSUMPTIONS
1	**Chemicals**							
	Coagulant	285	L/d	$ 3.20	$/kg	$ 332,880		From SCIDEV estimate
	Flocculant	1.51875	L/d	$ 9.57	$/kg	$ 5,305		From SCIDEV estimate
	Chlorine	1.5	mg/L	$ 4.90	$/kg	$ -		
							$ 338,185	
2	**Electricity**							
	Current electricity consumption	110	kWh/ML	$ 0.22	$/kWh	$ 66,291		From current energy bills
							$ 66,291	
3	**Sludge disposal**							
	Sludge production	0.33	m3/day					From SCIDEV estimate with average Raw TSS of 23 NTU
	Wet sludge production	121	m3/yr	$ 24	$/m3	$ 2,849		
							$ 2,849	
TOTAL VARIABLE OPERATING COSTS								
	Total cost/ML					$ 149		
	Contingency			15%		$ 22		
	Escalation			12%		$ 18		
							$ 189 /ML	
FIXED OPERATING COSTS								
1	**Maintenance**							
	Maintenance	1%	of capital			$ 84,936		
							$ 84,936	
3	**Labour**							
	Operators	FTE 1		$ 90,000	/year/FTE	$ 90,000		
							$ 90,000	

TOTAL FIXED OPERATING COSTS				
Total Cost/year		$	174,936	
Continency	15%	$	26,240	
Escalation	12%	$	20,992	
				$ 222,168 /year

Discount rate	7% pa			Option 1				Option 2				Option 3				Option 4		
Year		Production (ML)	Capital cost	Fixed operating	Variable operating	Present cost	Capital cost	Fixed operating	Variable operating	Present cost	Capital cost	Fixed operating	Variable operating	Present cost	Capital cost	Fixed operating	Variable operating	Present cost
2022		**662.0**																
2023		674.8																
2024		687.6																
2025	0	700.4	$ 40,502,256			$ 40,502,256	$ 32,461,021			$ 32,461,021	$ 26,970,686			$ 26,970,686	$ 28,716,368			$ 28,716,368
2026	1	713.2		$ 736,877	$ 151,727	$ 41,332,727		$ 632,229	$ 151,727	$ 33,193,690		$ 514,318	$ 151,727	$ 27,593,158		$ 222,168	$ 134,684	$ 29,049,876
2027	2	**726.0**		$ 736,877	$ 154,450	$ 42,111,247		$ 632,229	$ 154,450	$ 33,880,805		$ 514,318	$ 154,450	$ 28,177,285		$ 222,168	$ 137,102	$ 29,363,676
2028	3	734.8		$ 736,877	$ 156,322	$ 42,840,364		$ 632,229	$ 156,322	$ 34,524,497		$ 514,318	$ 156,322	$ 28,724,727		$ 222,168	$ 138,763	$ 29,658,304
2029	4	743.6		$ 736,877	$ 158,194	$ 43,523,209		$ 632,229	$ 158,194	$ 35,127,507		$ 514,318	$ 158,194	$ 29,237,783		$ 222,168	$ 140,425	$ 29,934,925
2030	5	752.4		$ 736,877	$ 160,066	$ 44,162,717		$ 632,229	$ 160,066	$ 35,692,403		$ 514,318	$ 160,066	$ 29,718,609		$ 222,168	$ 142,087	$ 30,194,634
2031	6	761.2		$ 736,877	$ 161,938	$ 44,761,636		$ 632,229	$ 161,938	$ 36,221,590		$ 514,318	$ 161,938	$ 30,169,227		$ 222,168	$ 143,749	$ 30,438,460
2032	7	**770.0**		$ 736,877	$ 163,810	$ 45,322,539		$ 632,229	$ 163,810	$ 36,717,323		$ 514,318	$ 163,810	$ 30,591,531		$ 222,168	$ 145,411	$ 30,667,370
2033	8	778.8		$ 736,877	$ 165,682	$ 45,847,837		$ 632,229	$ 165,682	$ 37,181,715		$ 514,318	$ 165,682	$ 30,987,298		$ 222,168	$ 147,073	$ 30,882,271
2034	9	787.6		$ 736,877	$ 167,555	$ 46,339,788		$ 632,229	$ 167,555	$ 37,616,744		$ 514,318	$ 167,555	$ 31,358,191		$ 222,168	$ 148,734	$ 31,084,018
2035	10	796.4		$ 736,877	$ 169,427	$ 46,800,507		$ 632,229	$ 169,427	$ 38,024,265		$ 514,318	$ 169,427	$ 31,705,772		$ 222,168	$ 150,396	$ 31,273,411
2036	11	805.2		$ 736,877	$ 171,299	$ 47,231,975		$ 632,229	$ 171,299	$ 38,406,015		$ 514,318	$ 171,299	$ 32,031,504		$ 222,168	$ 152,058	$ 31,451,203
2037	12	**814.0**		$ 736,877	$ 173,171	$ 47,636,047		$ 632,229	$ 173,171	$ 38,763,622		$ 514,318	$ 173,171	$ 32,336,757		$ 222,168	$ 153,720	$ 31,618,102
2038	13	816.2		$ 736,877	$ 173,639	$ 48,013,879		$ 632,229	$ 173,639	$ 39,098,029		$ 514,318	$ 173,639	$ 32,622,234		$ 222,168	$ 154,135	$ 31,774,255
2039	14	818.4		$ 736,877	$ 174,107	$ 48,367,175		$ 632,229	$ 174,107	$ 39,410,740		$ 514,318	$ 174,107	$ 32,889,217		$ 222,168	$ 154,551	$ 31,920,353
2040	15	820.6		$ 736,877	$ 174,575	$ 48,697,527		$ 632,229	$ 174,575	$ 39,703,162		$ 514,318	$ 174,575	$ 33,138,904		$ 222,168	$ 154,966	$ 32,057,044
2041	16	822.8		$ 736,877	$ 175,043	$ 49,006,426		$ 632,229	$ 175,043	$ 39,976,613		$ 514,318	$ 175,043	$ 33,372,414		$ 222,168	$ 155,382	$ 32,184,933
2042	17	**825.0**		$ 736,877	$ 175,511	$ 49,295,265		$ 632,229	$ 175,511	$ 40,232,323		$ 514,318	$ 175,511	$ 33,590,796		$ 222,168	$ 155,797	$ 32,304,587
2043	18	825.0		$ 736,877	$ 175,511	$ 49,565,208		$ 632,229	$ 175,511	$ 40,471,304		$ 514,318	$ 175,511	$ 33,794,892		$ 222,168	$ 155,797	$ 32,416,414
2044	19	825.0		$ 736,877	$ 175,511	$ 49,817,491		$ 632,229	$ 175,511	$ 40,694,651		$ 514,318	$ 175,511	$ 33,985,635		$ 222,168	$ 155,797	$ 32,520,924
2045	20	825.0		$ 736,877	$ 175,511	$ 50,053,269		$ 632,229	$ 175,511	$ 40,903,386		$ 514,318	$ 175,511	$ 34,163,900		$ 222,168	$ 155,797	$ 32,618,598
2046	21	825.0		$ 736,877	$ 175,511	$ 50,273,623		$ 632,229	$ 175,511	$ 41,098,466		$ 514,318	$ 175,511	$ 34,330,503		$ 222,168	$ 155,797	$ 32,709,881
2047	22	825.0		$ 736,877	$ 175,511	$ 50,479,561		$ 632,229	$ 175,511	$ 41,280,784		$ 514,318	$ 175,511	$ 34,486,206		$ 222,168	$ 155,797	$ 32,795,193
2048	23	825.0		$ 736,877	$ 175,511	$ 50,672,026		$ 632,229	$ 175,511	$ 41,451,174		$ 514,318	$ 175,511	$ 34,631,724		$ 222,168	$ 155,797	$ 32,874,924
2049	24	825.0		$ 736,877	$ 175,511	$ 50,851,901		$ 632,229	$ 175,511	$ 41,610,417		$ 514,318	$ 175,511	$ 34,767,721		$ 222,168	$ 155,797	$ 32,949,438
2050	25	825.0		$ 736,877	$ 175,511	$ 51,020,007		$ 632,229	$ 175,511	$ 41,759,243		$ 514,318	$ 175,511	$ 34,894,821		$ 222,168	$ 155,797	$ 33,019,078
2051	26	825.0		$ 736,877	$ 175,511	$ 51,177,117		$ 632,229	$ 175,511	$ 41,898,332		$ 514,318	$ 175,511	$ 35,013,607		$ 222,168	$ 155,797	$ 33,084,162
2052	27	825.0		$ 736,877	$ 175,511	$ 51,323,948		$ 632,229	$ 175,511	$ 42,028,322		$ 514,318	$ 175,511	$ 35,124,621		$ 222,168	$ 155,797	$ 33,144,988
2053	28	825.0		$ 736,877	$ 175,511	$ 51,461,173		$ 632,229	$ 175,511	$ 42,149,807		$ 514,318	$ 175,511	$ 35,228,373		$ 222,168	$ 155,797	$ 33,201,835
2054	29	825.0		$ 736,877	$ 175,511	$ 51,589,421		$ 632,229	$ 175,511	$ 42,263,346		$ 514,318	$ 175,511	$ 35,325,337		$ 222,168	$ 155,797	$ 33,254,963
2055	30	825.0		$ 736,877	$ 175,511	$ 51,709,279		$ 632,229	$ 175,511	$ 42,369,456		$ 514,318	$ 175,511	$ 35,415,958		$ 222,168	$ 155,797	$ 33,304,615

Appendix D Preliminary environmental assessment

Narromine Water Quality Project

Preliminary Environmental Assessment

November 2023

Prepared for Atom Consulting on behalf of Narromine Shire Council

Preliminary Environmental Assessment – Narromine Water Quality Project

Document Verification

Revision	Author/s	Internal review	Date submitted	Client Review and Approval	
				Name	Date
0.1	E Cotterill, K Farrell, G Stirling, J Sanderson	E Cotterill	01/11/2023	D Bartley	3/11/2023
1.0	E Cotterill, G Stirling		03/11/23		
Endorsed by Certified Environmental Practitioner (CEnvP)			E Cotterill		

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This Report has been prepared by The Environmental Factor (TEF) at the request of Atom Consulting (AC) on behalf of Narromine Shire Council (NSC) to identify the potential environmental impacts and any additional approvals required, arising from the proposed Water Security Project in Narromine, NSW. This document is not intended to be utilised or relied upon by any persons other than NSC, nor to be used for any purpose other than that articulated above. Accordingly, TEF accepts no responsibility in any way whatsoever for the use of this report by any other persons or for any other purpose.

The information, statements, recommendations, and commentary (together the "Information") contained in this review have been prepared by TEF from material provided by AC and NSC and from material provided by the NSW Department of Planning and the Environment (DPE) and the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) and through the assessment process.

This report has been developed with consideration to the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act), the *NSW Environmental Planning and Assessment Regulation 2021* (EP&A Regulation) and the Department of Planning and Environment's (DPE) Guidelines for Division 5.1 assessments (DPE Guidelines). TEF has not sought any independent confirmation of the reliability, accuracy, or completeness of this information. It should not be construed that TEF has carried out any form of audit of the information which has been relied upon.

Accordingly, whilst the statements made in this report are given in good faith, TEF accepts no responsibility for any errors in the information provided by AC or NSC nor the effect of any such errors on the analysis undertaken, suggestions provided, or this report. Site conditions may change after the date of this report. TEF does not accept responsibility arising from, or in connection with, any change to the site conditions. TEF is also not responsible for updating this report if site conditions change.

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Figures and Tables

ABBREVIATIONS

Abbreviation	Description
AC	Atom Consulting
ACHA	Aboriginal Cultural Heritage Assessment
AHIMS	Aboriginal Heritage Information Management System
BAM	Biodiversity Assessment Method
BDAR	Biodiversity Development Assessment Report
BC Act	*Biodiversity Conservation Act 2016*
BC Regulatory Act	*Biodiversity Conservation Regulatory Act 2017*
Biosecurity Act	*NSW Biosecurity Act 2015*
BOM	Bureau of Meteorology
BOS	Biodiversity Offset Scheme
BVM	Biodiversity Values Map
CEMP	Construction Environmental Management Plan
CLM Act	*Crown Land Management Act 2016*
DAWE	Department of Agriculture Water and the Environment
DECC	Department of Energy and Climate Change
DEE	Department of Environment and Energy
DEEC	Department of Energy and Climate Change NSW
DEWHA	Department of the Environment, Water, Heritage and the Arts
DPI	Department of Primary Industries
DPE	Department of Planning and Environment (formerly DPIE & OEH)
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
EP&A Act	*Environmental Planning and Assessment Act 1979*
EP&A Regulation	*Environmental Planning and Assessment Regulation 2021*
ERSED	Erosion and Sediment
ESD	Ecologically Sustainable Development
FM Act	*Fisheries Management Act 1994*
GBD	General Biosecurity Duty
GHG	Greenhouse Gasses
ha	Hectare
Heritage Act	*Heritage Act 1997*
IBRA	Interim Biogeographic Region of Australia
KFH	Key Fish Habitat
LALC	Local Aboriginal Land Council

Abbreviation	Description
AC	Atom Consulting
LEP	Local Environmental Plan
LGA	Local Government Area
LLS	Local Land Services
LOO	Likelihood of Occurrence
MNES	Matters of National Environmental Significance
NPW Act	*National Parks and Wildlife Act 1974*
NPWS	National Parks and Wildlife Service
NSC or Council	Narromine Shire Council
NSW	New South Wales
NVR	Transitional Native Vegetation Regulatory Map
OEH	Office of Environment and Heritage (now DPE)
PEA	Preliminary Environmental Assessment
POEO Act	*Protection of the Environment Operations Act 1997*
RF Act	*Rural Fires Act 1997*
RFS	Rural Fire Service
SAII	Serious and Irreversible Impacts
SEPP	State Environmental Planning Policy
SIC	Significant Impact Criteria
SIS	Species Impact Statement
TBC	To be confirmed
TEC	Threatened Ecological Community
TEF	The Environmental Factor
WM Act	Water Management Act 2000
WoNS	Weed of National Significance
WQO	Water Quality Objectives

EXECUTIVE SUMMARY

This Preliminary Environmental Assessment (PEA) has been prepared by The Environmental Factor (TEF) at the request of Atom Consulting (Atom) on behalf of Narromine Shire Council (NSC or Council) to identify the potential environmental impacts and any additional approvals required, arising from the proposed Water Quality Project in Narromine, NSW. The assessment presents findings of investigations undertaken into the anticipated environmental impacts and constraints that may arise from the proposed options presented to treat raw water for potable use within the Narromine Shire Local Government Area (LGA).

Council is currently considering three (3) Options as part of the current assessment, as follows:

- Option 1 – Conventional treatment with sedimentation lagoons
- Option 2 – Conventional treatment with sedimentation tank and sludge lagoon
- Option 3 – Conventional treatment with sedimentation tank and mechanical dewatering
- Option 4 – Upgrade existing temporary plant

The first option would utilize two (2) large lagoons to remove suspended sediments as a pre-treatment phase before the raw water is pumped into the WTP for conventional treatment. The second option is a similar setup but includes a sedimentation tank alongside three (3) lagoons. This allows for a slightly smaller site footprint but would still require excavation works to construct open lagoons on the site. Options 3 and 4 differ in that they don't require the construction of lagoons and therefore will not require excavation works, large volumes of clay or other materials. Options 3 and 4 would utilize a sedimentation tank and mechanical dewatering; Option 4 utilises a treatment method that reduces sludge generation. In options 3 and 4, sedimentation will be contained to a tank and the process involves mechanical dewatering as opposed to evaporation.

All four options were weighed against a range of relevant environmental and socio-economic factors in accordance with the 'Evaluation of integrated water cycle management scenarios' Guideline (the IWCM Evaluation Guidelines; NSW DOI, 2019) to assist Council's decision-making process through consideration of environmental and social factors. Economic considerations have not been completed herein as these are being considered in a separate report.

Based on the outcome of this evaluation, Option 4 arose as the preferred Option. Option 4 has the lowest construction/impact footprint and therefore poses the least likely impacts to biodiversity, Aboriginal and non-Aboriginal heritage and land use. Risk of impacts arising from pollution events is also lower, comparable with the other options, with a reduced potential for migration of soil and sediment into waterways, particularly during construction. Wastes and resource use are also likely to be lower for Option 4; sludge generation is 45% lower compared with all other options; input of treatment chemicals is also lower.

1 INTRODUCTION

This Preliminary Environmental Assessment (PEA) has been prepared by The Environmental Factor (TEF) at the request of Atom Consulting (Atom) on behalf of Narromine Shire Council (NSC or Council) to identify the potential environmental impacts and any additional approvals required, arising from the proposed Water Quality Project in Narromine, NSW. The assessment presents findings of investigations undertaken into the anticipated environmental impacts and constraints that may arise from the proposed options presented as part of the Narromine Water Quality project.

1.1 Background

The NSC Local Government Area (LGA) covers an area of 5,224 km^2 with a population of approximately 6,500 people (ABS, 2023). Drinking water for Narromine is currently supplied by five (5) bores, raw water from which only receives chlorine disinfection before being distributed to customers. Prior to 2020 these were all shallow bores in the upper and lower quaternary and tertiary aquifers connected to the Macquarie River between Dubbo and Narromine.

In an attempt to increase water security for the town, new deeper bores were drilled into the upper and lower tertiary aquifers within the Macquarie Groundwater Source; unfortunately, the water drawn from these bores was high in iron and manganese which caused discoloration of the water and consumed the chlorine. A temporary treatment plant was built by NSC to address this, and remove the iron and manganese.

Narromine was assessed under the NSW Safe Secure Water Risk Rating Framework as having a Level 5 risk score for water quality due to *Cryptosporidium* risk. The Integrated Water Cycle Management (IWCM) Strategy Issues Paper (PWA, 2023) therefore identified there was a very high risk of chlorine resistant pathogens in the drinking water as there is currently no treatment barriers to control these pathogens.

While the water is sourced from groundwater the aquifer is not contained and potentially contaminated by:

- Current and abandoned bores on private land that are not sealed,
- Sewage seepage from onsite effluent management systems on private property,
- Livestock grazing across the broader catchment.

Alternative water sources such as the Macquarie River are likely to have similar risks to the existing bore water.

Additional treatment is therefore required to manage water quality risk and continue to supply safe water to Narromine.

Consequently, Council is seeking a PEA and constraints and opportunities report, to support the Water Quality Options Study for the township of Narromine, NSW. The study will be in-line with the Safe & Secure Water Program Assurance Framework (NSW DoI, 2023) and will include treatment investigations, water quality information, site selection, procurement options analyses and strategy, project cost estimates, community & stakeholder consultation, and development of an approvals register. The data collected will then be used to further develop various project options to improve the town's water quality. As part of this options assessment, Council requested that a PEA be completed to investigate potential constraints and opportunities as well as potential impacts from program delivery.

The water quality aspects of the above assessment have been completed herein. The water security assessment has been completed separately.

1.2 Narromine water treatment system

Water extracted from Bores 6, 8D and 9 is currently processed through the temporary iron and manganese removal plant. This treated water is then combined with raw water from Bore 3 and chlorinated before distribution to customers.

The temporary iron and manganese removal plant was brought online for the first time in June 2020. It is owned and operated by an external contractor.

Narromine requires a permanent and reliable method of water treatment to meet modern standards and improve quality of life for its constituents.

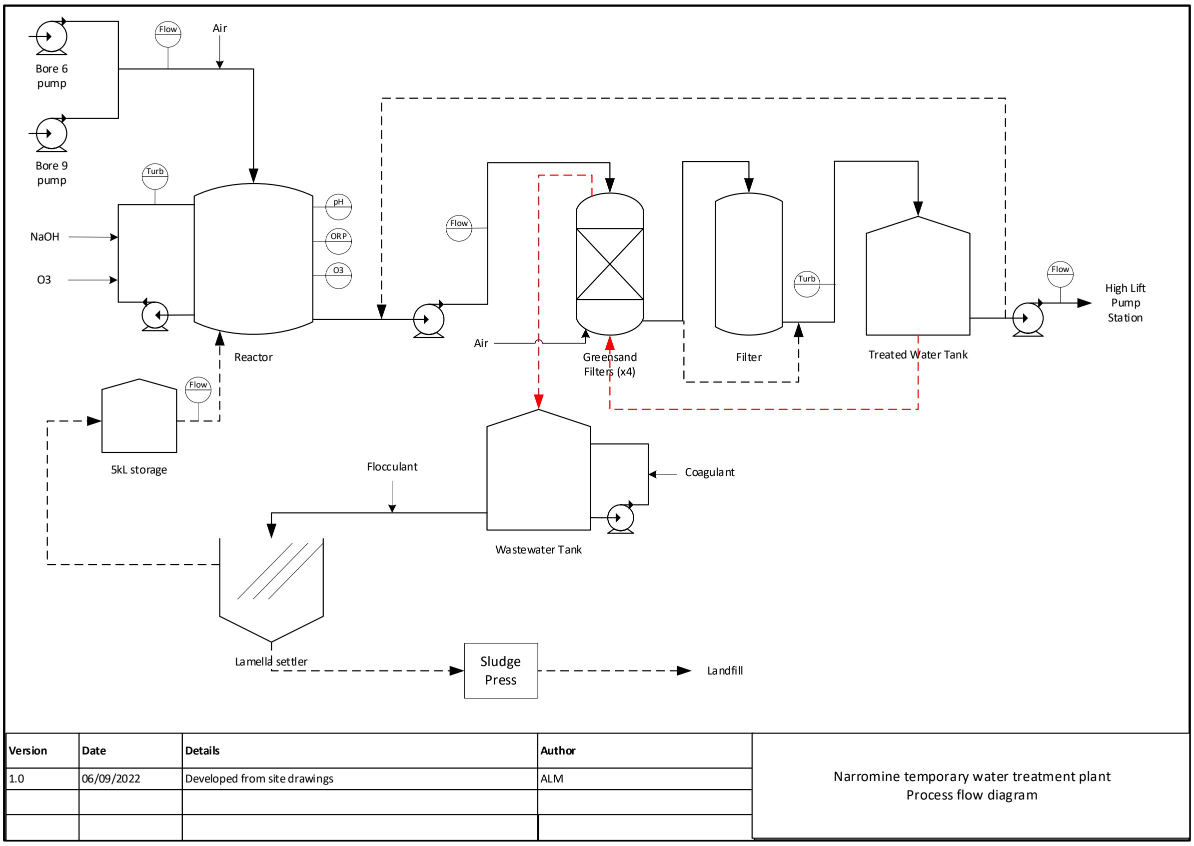


Figure 1 Existing Narromine Temporary WTP flow diagram

1.2.1 Issues identified

Water security

Narromine gets its water from bores that are drilled along the Lower Macquarie Alluvium sediments, associated with the ancient channels of the Macquarie River, downstream of Narromine. Water in the aquifer is in part replenished by water that seeps from the river, or is pumped from the river and then seeps into the aquifer from irrigation channels and irrigated fields (Narromine DWMS, 2018). CSIRO (2008) indicates that the current total entitlement for the Upper Macquarie Aquifer is 38.4 gigalitres per year (GL/yr), and that extraction in 2004 – 2005 was 37 GL. It was also estimated by CSIRO that long term average rainfall recharge to the aquifer is 7.1 GL/yr; this is well below the amount required to recharge the aquifer based on current usage and system pressure.

Despite wet conditions and flooding of the Macquarie River since 2020, there has not been any recovery in the standing water level of the aquifer (NSC, 2022). Water NSW Monitoring Bore GW0365301.1 and GW0365301.2 show the downward trend in water levels which has persisted since 2011, with the only recovery being marginal due to seasonal decreases in irrigation demand due to periods of wet weather. The irrigation demand on the aquifer has increased significantly in the last 10 years due to the introduction of irrigated cotton crops.

It is anticipated that increased demand will occur in future due to rapid growth predicted for Narromine. Under current licensing arrangements, it is understood that NSC has a limited opportunity to apply for additional bores, and consequently the Shire is experiencing compromised water security.

Water quality

The raw water characteristics of Narromine water supply vary depending on which bore is being used. Typical characteristics include:

- Neutral pH
- Variable turbidity, and
- High iron and manganese.

Variable turbidity, coupled with high iron and manganese would contribute to discolouration of the water, which can impact community wellbeing through discoloured clothes, towels, dishes and bathtubs / sinks, and reduced water pressure from residue buildup in pipes.

A *Cryptosporidium* risk assessment of the Narromine water supply was undertaken by NSW Health in 2020, which gave the Narromine water supply system a preliminary risk rating of ‘high’ based on the following:

- Stock in the catchment
- Sewage treatment plant and onsite sewerage systems in the catchment
- Shallow bores in unprotected aquifer

The catchment has therefore been assessed as Category 4.

The Integrated Water Cycle Management (IWCM) Issues Paper (PWA, 2022) identified that water from the current supply system has a very high risk from chlorine-resistant and chlorine sensitive pathogens.

Water extracted from the borefield is processed through a temporary Water Treatment Plant (WTP) which is owned and operated by an external contractor.

1.3 Current and predicted climate scenarios

With the range of pressures on the current system, Narromine is facing both water shortages and water quality issues, in both the current climate and predicted future climate change scenarios. With recharge of the aquifer not occurring reliably to satisfy drawdown since 2010, if usage does not slow and alternative water sources are not sought, Narromine could face the very real threat of running out of water. Climate change predictions for the region include hotter days, reduced rainfall and increase in stochastic events that can result in flooding and extreme heat; further detail on this is provided in Section 1.3.2 below. These changes would exacerbate an already tenuous position for the Shire if changes to the overall system, and more broadly regional usage and water allocations, are not made.

CSIRO (2008) indicates that under the best-estimate 2030 climate there would be an overall 8% reduction in water availability in the Macquarie River and a 9% reduction in end-of-system flows. Under the dry extreme for 2030 there would be a 25% reduction in overall water availability and a 28% reduction in end-of-system flows, whilst the wet extreme indicates corresponding increases of 25% and 41%. These scenarios present very different outcomes for the region. An increase in weather extremes presents a risk to future water quality from increased rainfall/flooding events, higher rates of evaporation and unexpected power outages during extreme heat events. It is critical that all WTP options consider projected future climate scenarios for the region and the associated risks to ensure system resilience, operational flexibility and redundancy are integrated into design.

The below sections describe the current climate for the region, and potential additional impacts on raw water availability and quality in the face of climate change.

1.3.1 Current climate

The Dubbo Airport Automated Weather Station (AWS), which is the nearest AWS for Narromine, has been collecting meteorological data since 1993 and has recorded observations of several meteorological data including temperature, humidity, rainfall and wind speed. Data recorded over the past 30 years indicates that, on average, January is the hottest month of the year, with a mean daily maximum temperature of 33.6°C. July is the coolest month with a mean daily maximum temperature of 15.7°C. Rainfall data indicates that March is recorded as the wettest month with an average rainfall of 66.3 mm falling, with August the driest month at 36.2 mm. The yearly average rainfall stands at 586.5.

Table 1 Long term climate averages for the Dubbo Airport AWS (065070)

Observation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean observations													
Mean maximum temperature (°C)	33.6	32.0	29.1	24.9	20.0	16.4	15.7	12.0	17.6	21.5	25.1	28.6	**24.7**
Mean minimum temperature (°C)	18.4	17.6	14.8	10.3	6.4	4.4	3.1	3.3	6.1	9.5	13.4	15.9	**10.3**
Rainfall (mm)	94.3	83.8	83.9	62.7	63.0	67.6	67.6	63.4	58.9	67.7	70.0	76.1	**858.5**

1.3.2 Climate Change Predictions

The AdaptNSW division 'Climate Change snapshot' for the Central West and Orana (OEH, 2014), states that the region is projected to continue to warm during the near future (2020 – 2039) and far future (2060 – 2079), compared to recent years (1990 – 2009). There is very high confidence that the average temperatures will increase across seasons.

The snapshot outlines the following projections for Dubbo:

- Maximum temperatures are projected to increase in the near future by 0.4°C – 1.0°C, increasing to 1.8°C – 2.7°C in the far future.
- Minimum temperatures are projected to increase in the near future by 0.5°C – 0.9°C, increasing to 1.5°C – 2.6°C in the far future.
- The number of hot days is projected to increase and the number of cold nights is projected to decrease.
- Rainfall is projected to decrease in spring and increase in autumn.
- Both average and severe fire weather is projected to increase in summer, spring and winter.

Climate change projections are presented for emission scenarios that will impact the degree to which the climate is altered in the future; each of these is referred to as a 'representative concentration pathway' (RCP) and is representative of the concentration of global Green House Gas (GHG) emissions in the atmosphere under different emissions scenarios. For example, if GHG emissions are mitigated and reduced, the scenario is for 'low emissions' and is referred to as RCP 2.6; conversely, if little effort is made to reduce emissions and the current scenario is continued globally, a 'high emissions' concentration is referred to as RCP 8.5, indicating a high concentration of GHG emissions in the atmosphere moving forward, with potentially devastating impacts by the year 2100.

Under a high emissions scenario (RCP 8.5), NSW and the ACT can expect an average annual temperature increase of around 1.4 - 2.3 °C, whereas large and sustained reductions in global GHG emissions (RCP 2.6) reduce projected warming to around 0.7 - 1.4 °C. Specifically for Dubbo as the closest analogue to Narromine, under emissions scenario RCP 8.5 for the projected time period of 2090, an increase in temperature of between 3.0 °C to 4.5 °C is expected, combined with a change of average rainfall of between -25 % to -7 % (Climate Change in Australia, Analogues Explorer, 2023).

The Central West and Orana region is predicted to experience an increase in rainfall in Autumn and a decrease in Spring. Rainfall changes are associated with changes in extremes, such as floods and droughts. The changes to water quality, potential for erosion and sediment migration, damage to infrastructure, localised flooding complications and extreme heat are associated with these sudden or extreme changes. In addition, the area selected for construction of the Water Treatment Plant occurs within a designated flood prone area (NSW Flood Data Access Program, 2023). With an increase in rainfall in Autumn predicted in the future (high confidence), there is an increased risk of damage to water supply infrastructure and a strain on capacity of water treatment facilities from potential flooding events.

Potential impacts regarding climate change

Throughout the construction phase of any of the proposed Options there will be use of in-demand materials. Use of these materials diminishes the availability of some resources for future use and contributes to pollution and GHG emissions through both direct use of fuels and the embodied energy used in the production of construction materials, and in association with the disposal of related waste products. The use of fossil fuels would also contribute to impacts on climate and air quality. While these impacts would be negligible on global or national scales, efficient resource use should be adopted as a general operating principle, including use of locally sourced materials and locally based construction crews to reduce 'carbon miles' and increase efficiencies.

Overall, the operation of the Proposal once constructed is anticipated to provide positive support to the community through improved water treatment infrastructure and is considered a responsible long-term decision for Narromine in the face of predicted climate change impacts, to make the upgrade to a long-term solution to infrastructure. Operation of the newly installed water infrastructure will require consumption of electricity and will therefore contribute to generation of GHG emissions assuming the power is derived from a non-renewable source.

1.4 Aims of the assessment

The aim of the Preliminary Environmental Assessment is to determine at a strategic level the potential suite of environmental impacts arising from each Option considered. And, in completing this assessment and assigning each Option a 'score' against the relevant assessment criteria, assist Council in determining the most appropriate Option for increasing water quality for Narromine Shire from an environmental perspective.

Assessment of the financial and engineering aspects of each Option will be completed separately, to ensure transparency and accountability in the selection process.

2 OPTIONS CONSIDERED

The following chapter contain descriptions of the various Options being considered to treat raw water for the township of Narromine, in order to meet the current and future demand and increase water quality for the LGA.

2.1 Option 1 – Conventional treatment with sedimentation lagoons

This option includes the following processes:

- Potassium permanganate dosing
- Coagulant and soda ash dosing
- Sedimentation lagoons
- Settled water pump station
- Pressure sand filters
- UV disinfection
- Chlorination (relocated from existing high lift pump site)
- Clear water tank
- High lift pumps

Option 1 can achieve the log reduction values shown in Table 2. As such, this Option can meet all the health and aesthetic requirements to meet the current standard, with the exception of reducing the hardness.

Table 2 Option 1 log reduction values

Process	Protozoa	Viruses	Bacteria
Pressure filters	4	0	2
UV disinfection	4	2	4
Chlorination	0	4	4
Total	**8**	**6**	**10**

The purpose and sizing of each process unit associated with Option 1 is described in the Options Assessment Report (Atom, 2023).

2.2 Option 2 – Conventional treatment with sedimentation tank and sludge lagoons

This option includes the following processes:

- Potassium permanganate dosing
- Coagulant and soda ash dosing
- Sedimentation tank
- Settled water pump station
- Pressure sand filters
- UV disinfection
- Chlorination (relocated from existing high lift pump site)

- Clear water tank
- High lift pumps
- Sludge lagoons

This option can achieve the log reduction values shown in Table 4.

Table 3 Option 2 log reduction values

Process	Protozoa	Viruses	Bacteria
Pressure filters	4	0	2
UV disinfection	4	2	4
Chlorination	0	4	4
Total	**8**	**6**	**10**

This option can meet all the health and aesthetic requirements with the exception of reducing the hardness. There is a sub option to add lime softening to this process which can be used to reduce the hardness. The purpose and sizing of each process unit associated with Option 2 is described in the Options Assessment Report (Atom, 2023).

2.3 Option 3 – Conventional treatment with sedimentation tank and mechanical dewatering

This option includes the following processes:

- Potassium permanganate dosing
- Coagulant and soda ash dosing
- Sedimentation tank
- Settled water pump station
- Pressure sand filters
- UV disinfection
- Chlorination (relocated from existing high lift pump site)
- Clear water tank
- High lift pumps
- Sludge thickening
- Sludge dewatering

This option can achieve the log reduction values shown in Table 4.

Table 4 Option 3 log reduction values

Process	Protozoa	Viruses	Bacteria
Pressure filters	4	0	2
UV disinfection	4	2	4
Chlorination	0	4	4
Total	**8**	**6**	**10**

This option can meet all the health and aesthetic requirements with the exception of reducing the hardness. There is a sub option to add lime softening to this process which can be used to reduce the hardness. The purpose and sizing of each process unit associated with Option 3 is described in the Options Assessment Report (Atom, 2023).

2.4 Option 4 – Upgrade existing temporary WTP

This option includes the following processes:

- Coagulant and soda ash dosing
- Ozone generation
- Ozone reactor tank
- Greensand pressure filters
- Submerged membrane filtration
- Ozone disinfection
- Chlorination (relocated from existing high lift pump site)
- Clear water tank
- High lift pumps
- Sludge thickening
- Sludge dewatering

This option can achieve the log reduction values shown in Table 5.

Table 5 Option 3 log reduction values

Process	Protozoa	Viruses	Bacteria
Membrane filters	4	0	4
Ozone disinfection	4	4	4
Chlorination	0	4	4
Total	**8**	**8**	**12**

This option can meet all the health and aesthetic requirements for town water quality.

There are two (2) options for delivery of the upgrade to the current temporary plant, as follows:

a. NSC pays for upgrade and contractor operates and maintains plant for a monthly fee
b. NSC pays for upgrade and purchases existing temporary plant and operates and maintains the plant

3 LEGISLATIVE CONTEXT AND STAKEHOLDER CONSULTATION

The following is a summary of the relevant legislation and policies applicable to the NSC water quality Options.

Indication of whether further action is required has also been made in Table 6 below.

Table 6 Legislation checklist

Legislation	Anticipated Implications	Action Required	
Commonwealth			
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	For all Options, potential impacts on relevant MNES must be subject to Assessments of Significance pursuant to the EPBC Act Significant Impact Guidelines (DEWHA 2009). If a significant impact is considered likely, a referral under the EPBC Act must be submitted to the Commonwealth Minister for Environment. MNES can also include world heritage properties, national heritage places and wetlands of international importance.	Yes ☒ No ☐	All Options will require preparation of an REF and the completion of an assessment to assess the potential for impacts on MNES.
NSW / State Legislation, Policies and Guidelines			
State Environmental Planning Policy (Transport and Infrastructure) (Transport and Infrastructure SEPP) 2021	As per Division 24, Section 2.159 (4) Development for the purpose of water treatment facilities may be carried out on or behalf of a public authority without consent on land in a prescribed zone. All Options are proposed for construction in land zoned RU1, which is defined as a prescribed zone. As the proposed works are appropriately characterised as development under the Transport and Infrastructure SEPP, the provisions of the Transport and Infrastructure SEPP apply.	Yes ☐ No ☒	All of the proposed options can be carried out as activities under Division 5.1 of the EP&A Act. Development consent from Council is not required. All options will require preparation of an REF. In addition, there are statutory consultation requirements outlined in Division 1 that will also need to be considered.
Environmental Planning and Assessment Act 1979 (EP&A Act) and the Environmental Planning and Assessment Regulation 2021	Proposed works would require the preparation of a Review of Environmental Factors (REF) to determine if the proposal would be likely to significantly affect the environment.	Yes ☒ No ☐	All Options will require preparation of an REF, which must consider to the fullest extent possible matters affecting or likely to affect the environment in accordance with s5.5 of the EP&A Act and cl

Legislation	Anticipated Implications	Action Required	
(EP&A Regulation 2021).			171(2) of the EP&A Regulation.
Protection of the Environment and Operations Act 1997 (POEO Act)	The POEO Act regulates and requires licensing for environmental protection, including for waste generation and disposal, and for water, air, land and noise pollution. It is anticipated that all options are unlikely to generate significant pollution or result in discharge of waste products as a result of ongoing operations.	Yes ☒ No ☐	All options may require a license from the Environmental Protection Authority (EPA) for operational discharges to the environment. Consultation with the EPA is recommended. In addition, prevention of pollution of soils, water and air is a factor in consideration for construction and operation of all options. In addition, Council would need to develop and implement a plan for sludge disposal.
Biodiversity Conservation Act 2016 (BC Act)	Section 7.3 of the BC Act sets out the tests for determining whether a proposed activity is, or is likely to significantly affect threatened species or ecological communities, or their habitats. Ecological assessment of site to support the preparation of an REF likely required for all options.	Yes ☒ No ☐	Site assessment and preparation of an REF is likely required to consider potential impacts to threatened species or ecological communities, or their habitats in accordance with s7.8 of the BC Act.
Biodiversity Conservation Regulatory Act 2017 (BC Regulatory Act)	Section 6.2(e) of the BC Act provides that the proponent of an activity that is assessed under Division 5.1, Part 5 of the EP&A Act can voluntarily opt out of the Biodiversity Offset Scheme (BOS). However, if any significant impacts to biodiversity are identified through the assessment process, participation in the BOS and the preparation of a Biodiversity Development Assessment Report (BDAR) may be required.	Yes ☐ No ☒	As all options are likely to be assessed under Division 5.1 of the EP&A Act, and Council is the proponent, Council will have the option to elect out of the BOS if it so chooses.
National Parks and Wildlife Act 1974 (NPW Act)	The NPW Act provides for the statutory protection of Aboriginal cultural heritage places, objects and features. To address the requirements of Step 4 of the 'Due Diligence code of practise',	Yes ☒ No ☐	Aboriginal Due Diligence (ADD) assessment will be required as part of the preparation of the REF

Legislation	Anticipated Implications	Action Required	
	a site inspection by a qualified archaeologist and preparation of an Aboriginal Due Diligence (ADD) assessment is likely required for all options. Should any Aboriginal archaeological material be identified during the site inspection and council is unable to avoid impacting on the area, consultation and engagement with the relevant Aboriginal community will be required to support a more detailed Aboriginal Cultural Heritage Assessment (ACHA) and, potentially, an application for an Aboriginal Heritage Impact Permit (AHIP).		for all of the proposed Options.
Heritage Act 1997 (Heritage Act)	Excavation of land on which it is known or where there is reasonable cause to suspect that 'relics' will be exposed, moved, destroyed, discovered or damaged is prohibited unless ordered under an excavation permit (section 139 *Heritage Act*). Assessment will be required to determine if any local, State or National heritage listed items are within the proposed works area. If so, they may require assessment by a qualified heritage officer and the preparation of a Statement of Heritage Impact (SoHI) to determine potential impacts and the necessary mitigation measures that must be implemented.	Yes ☒ No ☐	All options will require preparation of an REF. Confirmation via desktop assessment as to whether the work will require preparation of a Statement of Heritage Impact (SoHI) by a qualified archaeologist.
Fisheries Management Act 1994 (FM Act)	The FM Act aims to conserve threatened species, populations and ecological communities of fish and marine vegetation native to NSW. Permits are required for works within a third order (or higher) streams (based on the Strahler system of stream order classification), and first and second order streams that are known or likely to be habitat for listed threatened species, populations or communities. A permit under the FM Act is required for any work that involves activities involving dredging and reclamation work, activities temporarily or permanently obstructing fish passage,	Yes ☒ No ☐	For all options, a site assessment and preparation of an REF is likely required to consider potential impacts to threatened species, populations and ecological communities covered under the FM Act and whether a permit under the FM Act is required for any proposed works.

Legislation	Anticipated Implications	Action Required	
	using explosives, electrical devices or other dangerous substances in a waterway and harming marine vegetation.		
Water Management Act 2000 (WM Act)	The *Water Management Act 2000* (WM Act), administered by the Water division of NSW Department of Industry, Skills and Regional Development, aims to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations.	Yes ☒ No ☐	Council is exempt from s 91E(1) under the WM Act for proposals approved under Division 5.1 of the EP&A Act, in relation to all controlled activities that it carries out in, on or under waterfront land (cl 41 *Water Management (General) Regulation 2018*) (the anticipated approval pathway for all options). While exempt, it is still recommended that NSC be aware of the WM Act and adhere to the associated guidelines.
NSW Biosecurity Act 2015 (Biosecurity Act)	The Biosecurity Act introduces the legally enforceable concept of a General Biosecurity Duty (GBD) (Part 3 of the Biosecurity Act). Priority weeds are listed within Regional Strategic Weed Management Plans, however the GBD is not restricted to listed weeds. Council has biosecurity duties under the Biosecurity Act; namely, to be aware of surroundings and take action to prevent the introduction and spread of pests, diseases, weeds and contaminants.	Yes ☒ No ☐	Council will need to carry out any relevant biosecurity duties, including weed management as applicable for the construction and operation of the selected Option.
Roads Act 1993	The *Roads Act 1993* regulates the use and management of public roads. Section 138 of the Roads Act requires that consent of the appropriate Roads Authority is obtained for certain work undertaken in, on or over a public road. For any works requiring interaction with a classified State Road or rail corridor,	Yes ☑ No ☐	Council are required to complete a Section 138 application and concurrence must be sought with TfNSW for any works that occur on TfNSW managed roads and / or the rail corridor.

Legislation	Anticipated Implications	Action Required	
	consultation with TfNSW will be required prior to works commencing.		
Crown Land Management Act 2016 (CLM Act)	Where work is proposed on Crown land, the proponent of the proposed activity, must, obtain a right of access to the Crown land in accordance with the CLM Act.	Yes ☒ No ☐	A Crown Land Licence is required for work completed on Crown Land
State Environmental Planning Policy (Biodiversity and Conservation) 2021	Site assessment and preparation of REF would need to determine the likelihood of occurrence of the Koala (*Phascolarctos cinereus*) in the area and assess risk of impact to the species.	Yes ☒ No ☐	Preparation of an REF and determination of the Likelihood of Occurrence of Koala for all options.

Further to the above, per the EP&A Regulations, determining authorities must keep the REF documentation including any appendices or addenda and make available for public access once a determination has been made. The EP&A Regulation Clause 171(4) requires the REF to be published on the determining authority's website or the NSW Planning Portal for an activity with:

- A capital investment value of more than $5 million or,
- An approval or permit for activity that requires approval under:
  - FM Act sections 144, 201, 205 or 219, or
  - *Heritage Act 1977* section 57, or
  - *National Parks and Wildlife Act 1974* section 90 or
  - *Protection of the Environment operations Act 1997* sections 47-49 or 122, or
- If the determining authority considers it to be in the public interest.

There are allowances for exceptional circumstances where publication is not required; this is at the Planning Secretary's discretion. If the REF is to be published, the determining authority must place all relevant information on the determining authority's website or the NSW Planning Portal prior to the commencement of works.

Certain parts of the REF document may be sensitive, such as sensitive cultural information requested to be redacted by Aboriginal parties or cyber security impacts and mitigation measures. In these instances, the REF document content can be redacted where required. The REF document (excluding sensitive information) needs to be available online.

4 ASSESSMENT

The following chapters outline the preliminary assessment completed against key environmental aspects for each of the presented Options to increase water security for NSC. Also provided is a score for each Option against a series of relevant criteria, in accordance with the evaluation of integrated water cycle management scenarios guideline (NSW Government, 2019).

The environmental context for all four (4) options is shown in Figure 2 Biodiversity and water features within 500 m of WTP Options, Figure 3 Aboriginal and non-Aboriginal Heritage items within 1km of WTP Options, Figure 4 Land use and sensitive receivers within 500 m of WTP Options and Figure 5 Threatened species records within the locality (10 km radius) of the proposed Options.

4.1 Preliminary environmental assessment

4.1.1 Biodiversity – terrestrial and aquatic

Biodiversity aspects in proximity to each of the proposed Water Treatment Plant layouts is limited to patches of native vegetation along the McGrane Way road reserve and the Narromine wetlands, which are located approximately 350 m north east of the proposed WTP construction area (refer Figure 2). There is also a surface water dam and informal wetland system immediately adjacent the existing temporary WTP.

Terrestrial and aquatic ecological features are discussed further below.

Terrestrial ecology

The area surrounding each of the WTP options is predominantly cleared agricultural land on the outskirts of town, with patches of remnant native vegetation occurring along road reserves and waterways in the locality. The majority of this area is mapped as 'non-native vegetation', per the NSW State Vegetation Type Map (SVTM). Infrastructure placement for any of the proposed Options will be kept to cleared areas where possible, to avoid and minimize impacts to biodiversity.

Native vegetation in the road reserve adjacent to the broad WTP construction area is mapped as supporting Plant Community Type (PCT) PCTID 70 – White Cypress Pine woodland on sandy loams in central NSW wheatbelt and PCTID 82 – Western Grey Box – Poplar Box – White Cypress Pine tall woodland on red loams mainly of the eastern Cobar Peneplain Bioregion. PCTID 82 is analogous to Threatened Ecological Community (TEC) *Inland Grey Box Woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions* and is thus afforded protection under both the NSW BC Act and the Commonwealth EPBC Act.

One (1) species of threatened waterbirds, namely Magpie Goose (*Anseranas semipalmata*) has been recorded within the assessment area for all WTP options (500 m buffer from the proposed alignments); care should be taken to ensure this species and its habitat (shallow wetlands with dense growth of rushes or sedges) are avoided.

Aquatic ecology

Potential impacts to aquatic ecology associated with all options include release of sediment and soil into waterways via drainage lines from vegetation clearing, excavation works and the movement of machinery. Any drilling or deep excavation work has the potential to impact on Groundwater Dependent Ecosystems (GDE) present in the vicinity, which may include wetlands, streams, lakes, swamps, aquifers, springs, caves and some vegetation communities. GDEs are important habitats for native fauna such as fish, frogs and waterbirds. There is also the potential for spills of fuels and other contaminants during construction which could enter the catchment.

4.1.2 Heritage – Aboriginal and non-Aboriginal

Narromine is rich in non-Aboriginal heritage, with a series of State and locally significant buildings recorded within and surrounding the township.

Potential for impacts to heritage items from construction of all Options is anticipated to be low, as the proposed impact footprint is relatively small (typically <1 ha in area) and there are no recorded heritage items in proximity to the proposed construction area.

Aboriginal heritage records within the broader region are numerous. While there are no previously recorded Aboriginal heritage sites recorded within 500 m of the WTP location for all options, Due Diligence assessment of the area should be undertaken to determine if there are any unknown heritage sites with the potential to be impacted on, as the broader locality is rich in Aboriginal heritage object and places of significance.

4.1.3 Receiving environment – pollution risk

All Options being assessed are not anticipated to include activities that are likely to generate significant pollution as part of construction activities or operations, however, the following should be considered:

- All options may require an Environment Protection Licence (EPL) for sludge removal and / or regular operational discharges to the environment.
- Due to the requirement for the removal of vegetation, as well as the need for soil disturbance and excavation using heavy machinery in proximity to drainage lines and creeks, careful management is required to ensure waterways are not negatively impacted during the construction phase of the project.
- Use of heavy machinery has the potential for spills of fuels and other contaminants during construction which could pollute soils and waterways.
- All chemical usage and storage during construction will need to be in line with legislated requirements, to prevent Pollution of Land, which is prohibited under Section 142 A of the POEO Act.
- Given the groundwater vulnerability across much of the locality, risk of pollution of groundwater is considered moderate to high where establishment of pipelines and / or excavation and construction of lagoons for the new WTP is required.
- The management of sludge from the settling lagoons as part of ongoing operations will need to be considered including location for disposal and means of transport. Disposal of material would need to be in line with Council and EPA guidelines and requirements. Consultation with the EPA is recommended to determine any licensing requirements.

4.1.4 Waste and resource use

Materials, including concrete, pipelines and connecting works, fill material and general building materials will be required to construct and operate all Options. In addition, likely waste products from the construction phase include, but are not limited to excess soil and spoil and civil construction materials, cleared vegetation, packaging and general waste. Waste materials from operations include sludge, unused chemicals and general waste. In addition, each of the options will consume electricity as part of operations.

Wastes from each Option are anticipated to vary slightly for the construction phase. Wastes and resource consumption for each Option for the operational phase are outlined in Table 7 below. In order of resource consumption, the Options rank as follows (from highest to lowest):

1. Option 2 – highest consumption of energy; same amount of sludge produced, and same amount of coagulant, potassium permanganate and chlorine required to bring water to required treatment level as Options 1 and 3.
2. Option 1 – second highest consumption of energy; same amount of sludge produced, and same amount of coagulant, potassium permanganate and chlorine required to bring water to required treatment level as Options 2 and 3.
3. Option 3 – lowest energy consumption of all Options; same amount of sludge produced, and same amount of coagulant, potassium permanganate and chlorine required to bring water to required treatment level as Options 1 and 2.
4. Option 4 – second lowest energy consumption of all Options; however, lowest sludge production (54.8% of all other Options) and no potassium permanganate required. The same amount of coagulant and chlorine are needed as all others. This Option requires use of 167 kg / year of polymer, which is unique to this WTP proposal.

Table 7 Operational resource consumption for each of the proposed options

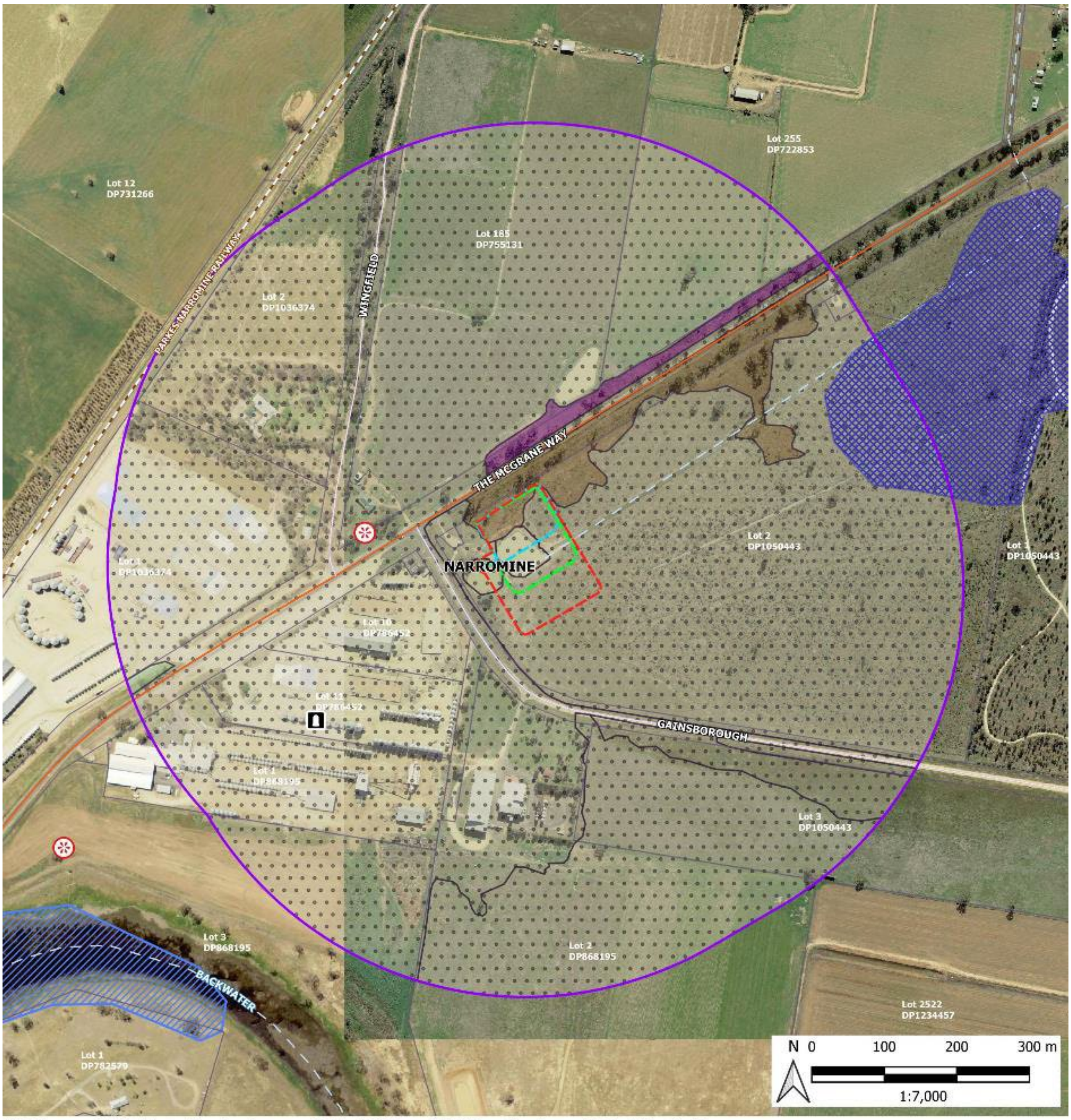
Resource	Option 1	Option 2	Option 3	Option 4
Energy (kWh/year)	2,386,408	2,461,523	2,242,505	2,382,260
Sludge production (m^3/year)	66.22	66.22	66.22	36.3
Coagulant (kg/year)	31,350	31,350	31,350	31,350
Potassium permanganate (kg/year)	2,145	2,145	2,145	0
Polymer (kg/year)	0	0	0	167
Chlorine (kg/year)	1,238	1,238	1,238	1,238

4.1.5 Socio-economic considerations

All Options seek to improve and upgrade the WTP for the Narromine water supply system, and improve the quality and security of drinking water for all potable water users.

All options assessed create greater certainty for Narromine's level of water quality, and alleviate pressure on the existing temporary plant, which has been constructed as a stop-gap measure to make water safe to drink for Narromine residents while a more permanent solution is constructed. The operation of the new WTP is anticipated to provide positive socio-economic impacts during its operation as it will provide safe, reliable water treatment infrastructure for a rural population.

The cost of construction of each Option will vary significantly; this has been assessed separately and will not be considered further within this report.



Water and Biodiversity features within 500m of Water Treatment Facility Options

Legend

Assessment area
Option 1 Footprint
Option 2 Footprint
Option 3 Footprint
Suburb boundary
Lot boundary

Roads

Arterial Road

Local Road
Railway

Waterways

1st & 2nd order; unnamed waterways
Key Fish Habitat
Narromine wetlands

Threatened Species

Magpie Goose

Plant Community Types

PCTID: 0 - Not native vegetation
PCTID: 45 - Plains Grass grassland on alluvial mainly clay soils in the Riverina Bioregion and NSW South Western Slopes Bioregion
PCTID: 70 - White Cypress Pine woodland on sandy loams in central NSW wheatbelt
PCTID: 82 - Western Grey Box - Poplar Box - White Cypress Pine tall woodland on red loams mainly of the eastern Cobar Peneplain Bioregion

Service Layer Credits: Source: ss-sds SIX Maps Satellite Imagery (NSW LPI) DFSI Sixmaps clipship digital cadastral and topological dataset of the Narromine LGA. OEH SVMT PCTS V1.1, EPI Groundwater vulnerability, OEH threatened species. CRS GDA2020 MGA zone 55. Author: K Farrell. Date: 26/10/2023

Figure 2 Biodiversity and water features within 500 m of the WTP Options

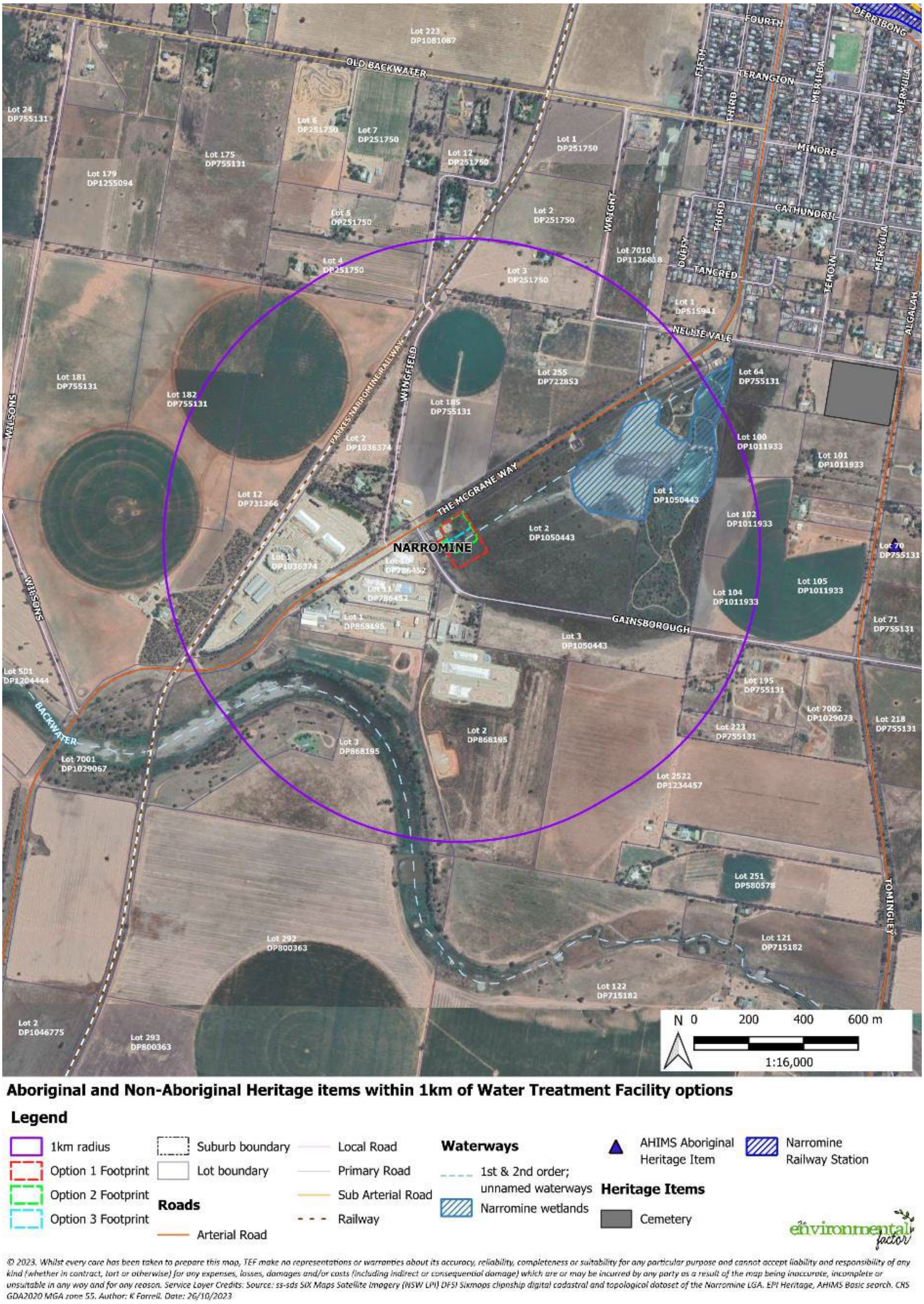


Figure 3 Aboriginal and non-Aboriginal Heritage items within 1km of the WTP Options

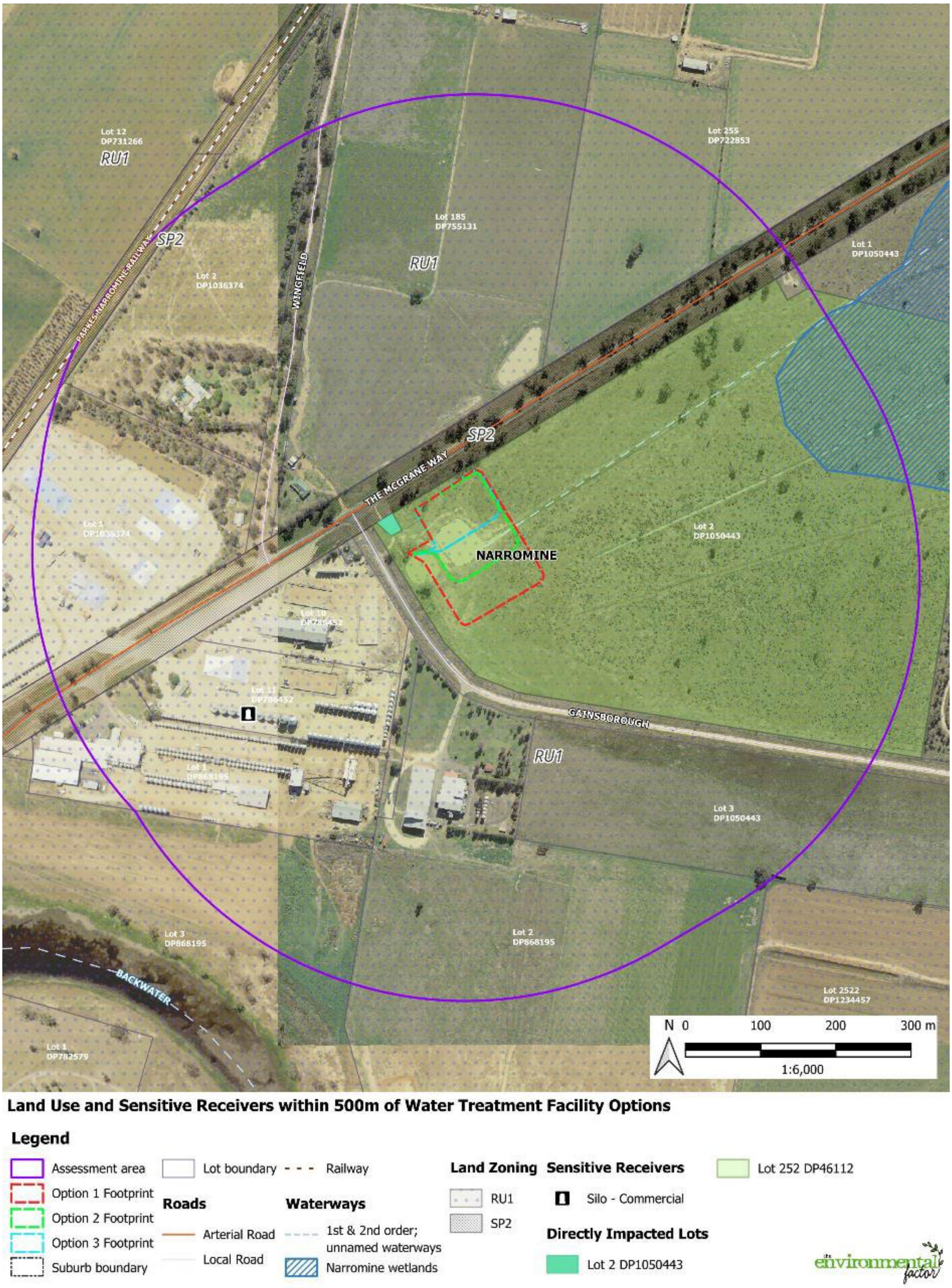


Figure 4 Land use and sensitive receivers within 500 m of the WTP Options

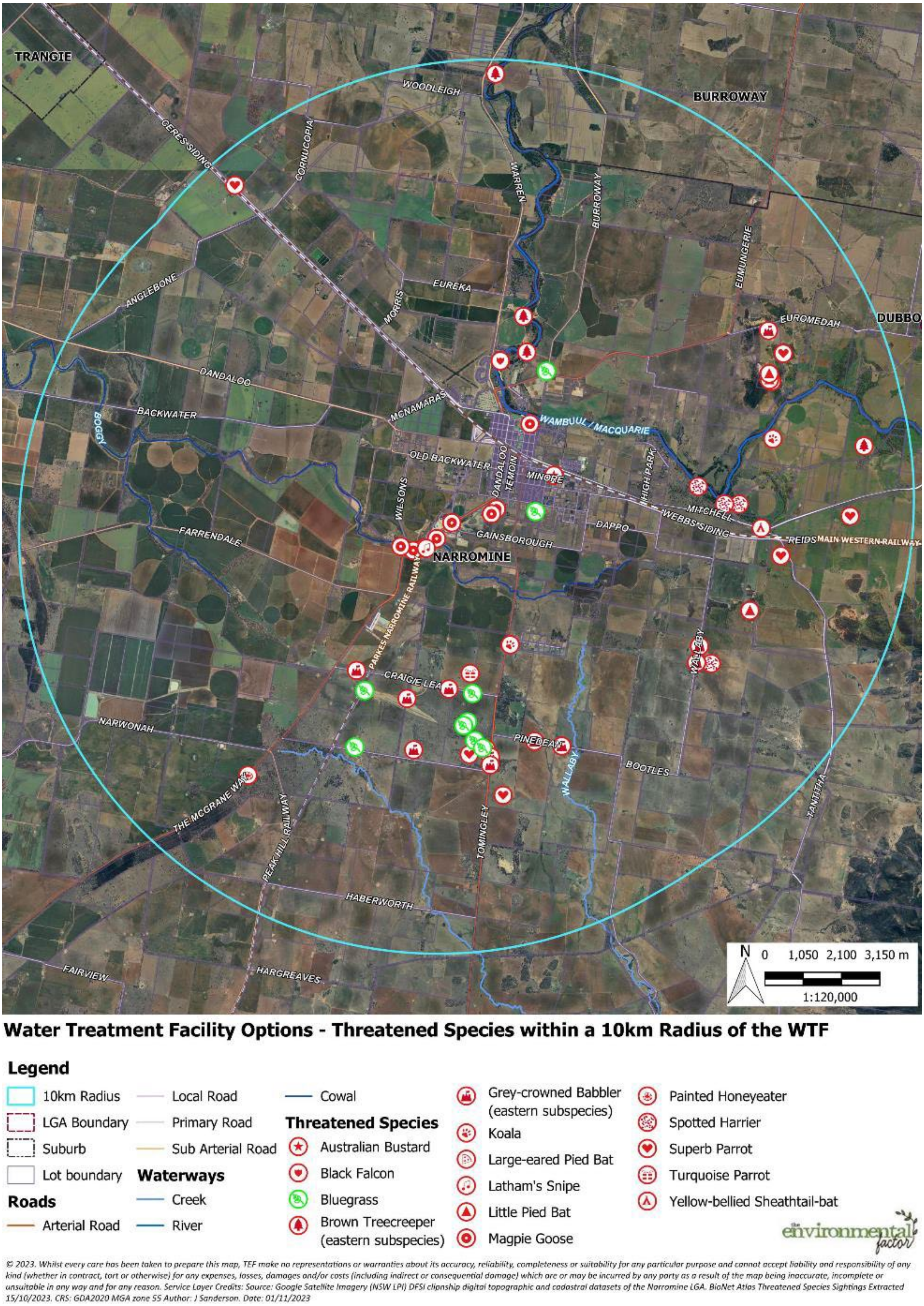


Figure 5 Threatened species records within the locality (10 km radius) of the proposed Options

4.2 Options assessment

Due to the closely aligned impact footprint for each of the proposed Options, the broad environmental impacts for each are similar; potential impacts to terrestrial and aquatic biodiversity and heritage are considered similar for all Options.

In order to assess each Option for the purposes of selecting a preferred option, the focus of the following sections will be predominantly on the total impact footprint size, waste and resource use and pollution risk accordingly.

4.2.1 Option 1 – Conventional treatment with sedimentation lagoons

As for all Options considered, Option 1 presents a viable treatment process which can meet all the health and aesthetic requirements for town water, as described in the ADWG and the IWCM Issues Paper (PWA, 2022). Due to the overlap of each footprint, individual consideration of impacts to biodiversity, surface and groundwater and heritage have been made broadly for the site, in Section 4.1 above.

Consideration of impacts arising from Option 1 specifically is provided below.

- **Biodiversity**
  - **Terrestrial** – potential impacts to terrestrial biodiversity, including native vegetation communities, terrestrial fauna habitats and individual species are considered greatest for this Option, due to the largest overall impact footprint of 2.19 ha.
  - **Aquatic** – potential impacts to aquatic biodiversity are also greater than for the other proposed treatment layouts, due to the need to impact the existing surface water dam on site, as well as the surrounding swamp area, for the development of the WTP and the lagoons. The adjacent Narromine Wetlands support a range of native species which may use the wetlands for breeding and foraging habitat, either permanently, seasonally or transiently, which stand to be impacted by Option 1.
- **Heritage**
  - **Aboriginal heritage** – due to the presence of recorded objects and / or places of Aboriginal Heritage significance within the assessment area, Due Diligence assessment of each Option is a requirement (Figure 3). As Option 1 has the largest footprint, the risk of impact to Aboriginal heritage is proportionally higher than for the other options.
  - **Non-Aboriginal heritage** – potential for impacts to non-Aboriginal heritage for all Options is considered low due to the lack of records in proximity to the site.
- **Receiving environment / pollution risk**

  Option 1 has the largest footprint and would potentially impact upon both surface and groundwater resources for the construction of the sedimentation lagoons. This project carries greatest potential risk for pollution of waters, an offence under the POEO Act.
  All Options will likely require an EPL as a licensed premises and for sludge removal and management of any discharges to the environment.
- **Waste and resource use**

  Option 1 is the second highest consumer of resources for ongoing operations (refer Table 7), and the largest consumer of resources for the construction phase, requiring large volumes of soil and other materials for the construction of the sedimentation lagoons.

Materials required, including clay for lining to the required performance standard, would need to be sourced from a quarry or other borrow pit, impacts from which would also need to be considered as part of the overall proposal. Use of High-Density Polyethylene (HDPE) plastic lining for the two (2) large lagoons would be both costly and less sustainable than development of the other Options.

The existing temporary plant would need to be decommissioned and removed from site as part of establishing this Option.

- **Socio-economic considerations**

  All Options will satisfy requirements for clean and safe drinking water for the Narromine community.

  This Option has the biggest impact footprint and includes construction of two (2) large sedimentation lagoons – this will potentially have the largest visual amenity impact on the current rural vista.

  This Option has the highest risk of Council needing to issue a 'boil water' notice for compromised water quality due to lagoons – lack of operational flexibility and options to treat pathogens.

Consideration of relevant environmental aspects of Option 1 is provided below.

Table 8 Option 1 assessment

Water Quality Option 1

Criterion	Description of Option 1	Score
Environmental Group		
Impact on terrestrial and aquatic biodiversity	Construction of WTP with an impact area of 2.19 ha that includes impacts to existing surface water dam and is adjacent to the Narromine wetlands; intrudes into stormwater management wetland area.	2/10
Environmental pollution risk (i.e POEO Act)	Construction of a new WTP and associated pipelines and infrastructure carries a risk for pollution incidents to groundwater, surface water and land. Sedimentation lagoons risk of leaching; risk of overtopping during floods / heavy rainfall.	3/10
Impact on land – use and area (ha)	Construction of WTP with an impact area of 2.19 ha in an agricultural area on the outskirts of Narromine. Intrudes into stormwater management wetland area.	2/10
Waste and resource use	Construction of WTP would require building materials to construct and generate waste from both construction and operation (sludge, unused chemicals and general waste). In addition, the option would consume the second highest amount of electricity and chemicals as part of ongoing operation.	2/10
	(1) Total weighted environmental	**2.3**
Social Group		
Risk of not meeting LOS (health and aesthetic criteria)	Risk that WTP fails to operate as per design parameters.	4/10

Water Quality Option 1

Criterion	Description of Option 1	Score
Impact on land – use and area (ha)/disruption to community	Construction of WTP with an impact area of 2.19 ha. High opportunity cost from use of large area of land – difficult to upgrade site in the future.	2/10
Planned for future changes in development (right sizing)	Risk that WTP fails to meet future demand – low likelihood of meeting increased demand. No room to expand further with this design.	2/10
Community attraction/liveability	Largest impact footprint; impacts to visual amenity from wetlands and road. Risk to water quality – higher risk of 'boil water' notice.	2/10
	(2) Total weighted social	**2.8**
	(3) Environmental and social score (ESS) (3) = (1) + (2)	**5.1**

Figure 6 Option 1 Conventional treatment with sedimentation lagoons – site layout

4.2.2 Option 2 – Conventional treatment with sedimentation tank and sludge lagoons

Option 2 presents a viable treatment process which can meet all the health and aesthetic requirements for town water, as described in the ADWG and the IWCM Issues Paper (PWA, 2022). Due to the overlap of each footprint, individual consideration of impacts to biodiversity, surface and groundwater and heritage have been made broadly for the site, in Section 4.1 above.

Consideration of impacts arising from Option 2 specifically is provided below.

- **Biodiversity**
  - **Terrestrial** – impacts to terrestrial biodiversity, including native vegetation and terrestrial fauna are considered greatest for this Option, due to the larger overall impact footprint. This Option would require the second largest area of vegetation clearing at 1.6 ha.
  - **Aquatic** – potential impacts to aquatic biodiversity are also greater than for proposed treatment layouts for Options 3 and 4, due to the need to impact the existing surface water dam on site, as well as the surrounding swamp area, for the development of the WTP and the lagoons. The adjacent Narromine Wetlands support a range of native species which may use the wetlands for breeding and foraging habitat, either permanently, seasonally or transiently, which stand to be impacted by Option 2. Option 2 also encroaches on the stormwater management wetland immediately adjacent.
- **Heritage**
  - **Aboriginal heritage** – due to the presence of recorded objects and / or places of Aboriginal Heritage significance within the assessment area, Due Diligence assessment of each Option is a requirement (Figure 3). As Option 2 has the second largest footprint, the risk of impact to Aboriginal heritage is proportionally higher than for Options 3 and 4, though lower risk than for Option 1.
  - **Non-Aboriginal heritage** – potential for impacts to non-Aboriginal heritage for all Options is considered low due to the lack of records in proximity to the site.
- **Receiving environment / pollution risk**

  Option 2 has the second largest footprint and would potentially impact upon both surface and groundwater resources for the construction of the three (3) sludge lagoons. This project carries the second greatest potential risk for pollution of waters, an offence under the POEO Act.

  All Options will likely require an EPL as a licensed premises and for sludge removal and management of any discharges to the environment.
- **Waste and resource use**

  Option 2 is the highest consumer of resources for ongoing operations (refer Table 7), and the largest consumer of resources for the construction phase, requiring a large volume of soil and other materials for the construction of the sludge lagoons.

  Materials required, including clay for lining to the required performance standard, would need to be sourced from a quarry or other borrow pit, impacts from which would also need to be considered as part of the overall proposal. Use of High-Density Polyethylene (HDPE) plastic lining for the three (3) sludge lagoons would be both costly and less sustainable than development of Options 3 or 4.

The existing temporary plant would need to be decommissioned and removed from site as part of establishing this Option.

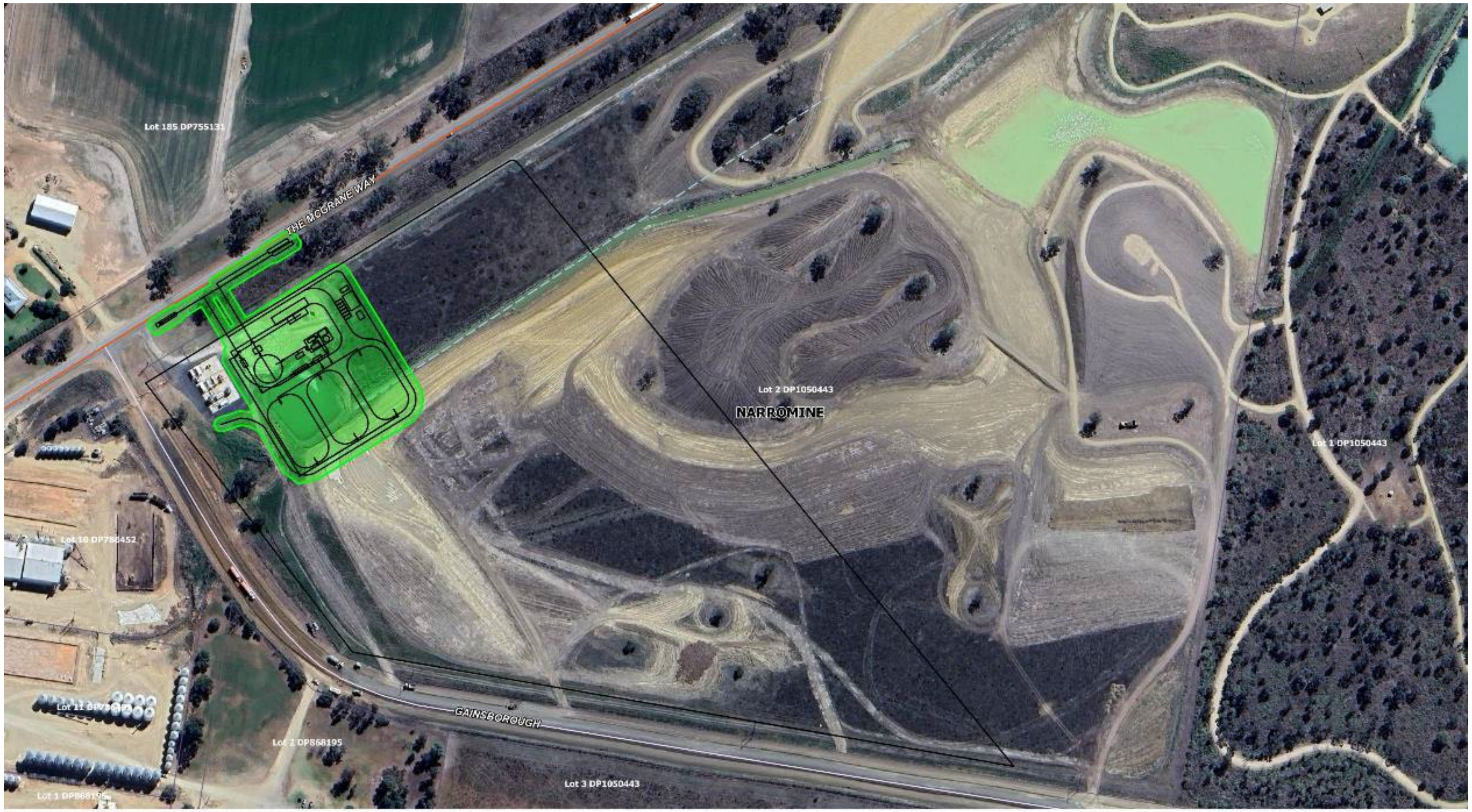
- **Socio-economic considerations**
  All Options will satisfy requirements for clean and safe drinking water for the Narromine community.
  This Option has the second largest impact footprint and includes construction of three (3) sludge lagoons – this will potentially impact upon visual amenity and the existing pleasant rural vista of the area.

Consideration of relevant environmental aspects of Option 2 is provided below.

Table 9 Option 2 assessment

Water Quality Option 2

Criterion	Description of Option 2	Score
Environmental Group		
Impact on terrestrial and aquatic biodiversity	Construction of WTP with an impact area of 1.6 ha that includes impacts to existing surface water dam and is adjacent to the Narromine wetlands; encroaches onto stormwater management wetland area.	3/10
Environmental pollution risk (i.e POEO Act)	Construction of a new WTP and associated pipelines and infrastructure carries a risk for pollution incidents to groundwater, surface water and land; increased risk from sludge lagoons, e.g. overflow or leaching	4/10
Impact on land – use and area (ha)	Construction of WTP with an impact area of 1.6 ha in an agricultural area on the outskirts of Narromine; a portion of the site is wetlands / swamp. Encroaches onto stormwater management wetland area	3/10
Waste and resource use	Construction of WTP would require building materials to construct and generate waste from both construction and operation (sludge, unused chemicals and general waste). In addition, the option would consume the highest amount of electricity and chemicals as part of operations.	2/10
	(1) Total weighted environmental	**3.1**
Social Group		
Risk of not meeting LOS (health and aesthetic criteria)	Risk that WTP fails to operate as per design parameters is lower than for Option 1; sedimentation tank controls sludge draw off, less susceptible to environmental conditions & stochastic events	6/10
Impact on land – use and area (ha)/disruption to community	Construction of WTP with an impact area of 1.6 ha. Moderate opportunity cost from use of large area of land – difficult to upgrade site in the future.	3/10
Planned for future changes in development (right sizing)	Risk that WTP fails to meet future demand is less than for Option 1; some minor area available for future expansion (footprint not as large)	3/10
Community attraction/liveability	Second largest impact footprint; impacts to visual amenity from wetlands and road. Risk to water quality – moderate risk of 'boil water' notice	4/10
	(2) Total weighted social	**4.4**
	(3) Environmental and social score (ESS) (3) = (1) + (2)	**7.5**



Water Treatment Facility Option 2 - Subject Site

Legend

- 5m Construction Footprint
- Development Layout
- Suburb
- Lot Boundary
- **Roads**
  - Arterial Road
  - Local Road
- **Waterways**
  - 1st, 2nd & 3rd order unnamed waterways

Figure 7 Option 2 conventional treatment with sedimentation tank and sludge lagoons – site layout

4.2.3 Option 3 – Conventional treatment with sedimentation tank and mechanical dewatering

As for all Options considered, Option 3 presents a viable treatment process which can meet all the health and aesthetic requirements for town water, as described in the ADWG. Due to the overlap of each footprint, individual consideration of impacts to biodiversity, surface and groundwater and heritage have been made broadly for the site, in Section 4.1 above.

Consideration of impacts arising from Option 3 specifically is provided below.

- **Biodiversity**
  - **Terrestrial** – impacts to terrestrial biodiversity, including native vegetation and terrestrial fauna are considered relatively minor for this Option, due to the smaller overall impact footprint. This Option would require an impact area of 0.88 ha.
  - **Aquatic** – potential impacts to aquatic biodiversity are also lesser than for proposed treatment layouts for Options 1 and 2, due to the restricted layout size; however this layout does extend slightly further northeast from the existing WTP layout to impact upon regenerating vegetation in the vicinity. The adjacent Narromine Wetlands support a range of native species which may use the wetlands for breeding and foraging habitat, either permanently, seasonally or transiently, which may be impacted by Option 3.
- **Heritage**
  - **Aboriginal heritage** – due to the presence of recorded objects and / or places of Aboriginal Heritage significance within the assessment area, Due Diligence assessment of each Option is a requirement (Figure 3). As Option 3 has a reduced impact footprint, the risk of impact to Aboriginal heritage is proportionally lower than for Options 1 and 2.
  - **Non-Aboriginal heritage** – potential for impacts to non-Aboriginal heritage for all Options is considered low due to the lack of records in proximity to the site.
- **Receiving environment / pollution risk**

  Option 3 has the second smallest footprint and will be less likely to impact upon groundwater; however, the surface water dam in proximity will still require infilling. This project carries the third greatest potential risk for pollution of waters, an offence under the POEO Act.

  All Options may require an EPL as a licensed premises and for sludge removal and management of any discharges to the environment.
- **Waste and resource use**

  Option 3 is the second lowest consumer of resources for ongoing operations (refer Table 7), and will not require large volumes of clay or other materials for creation of lagoons, as sedimentation will be contained to a tank and the process involved mechanical dewatering as opposed to evaporation.

  The existing temporary plant would need to be decommissioned and removed from site as part of establishing this Option.
- **Socio-economic considerations**

  All Options will satisfy requirements for clean and safe drinking water for the Narromine community.

This Option has the second smallest impact footprint and will be contained to the existing immediate impact area; impacts to visual amenity from this Option are considered relatively consistent with the existing temporary WTP setup.

Consideration of relevant environmental aspects of Option 3 is provided below.

Table 10 Option 3 assessment

Water Quality Option 3

Criterion	Description of Option 3	Score
Environmental Group		
Impact on terrestrial and aquatic biodiversity	Construction of WTP with an impact area of 0.88 ha that includes impacts to existing surface water dam and is adjacent to the Narromine wetlands.	5/10
Environmental pollution risk (i.e POEO Act)	Construction of a new WTP and associated pipelines and infrastructure carries a risk for pollution incidents to groundwater, surface water and land. Sludge can be removed in smaller quantities more frequently; no lagoons = reduced risk	6/10
Impact on land – use and area (ha)	Construction of WTP with an impact area of 0.88 ha in an agricultural area on the outskirts of Narromine; some encroachment onto adjacent vegetation & surface water dam	6/10
Waste and Resource Use	Construction of WTP would require building materials to construct and generate waste from both construction and operation (sludge, unused chemicals and general waste). No lagoons = fewer resources consumed.	4/10
	(1) Total weighted environmental	**5.2**
Social Group		
Risk of not meeting LOS (health and aesthetic criteria)	Risk that WTP fails to operate as per design parameters is similar as for Options 1 & 2	6/10
Impact on land – use and area (ha)/disruption to community	Construction of WTP with an impact area of 0.88 ha	6/10
Planned for future changes in development (right sizing)	Risk that WTP fails to meet future demand. More space available comparable with options 1 and 2	6/10
Community attraction/liveability	Third largest impact footprint; impacts to visual amenity from wetlands and road. Risk to water quality – moderate risk of 'boil water' notice	5/10
	(2) Total weighted social	**5.8**
	(3) Environmental and social score (ESS) (3) = (1) + (2)	**11.0**

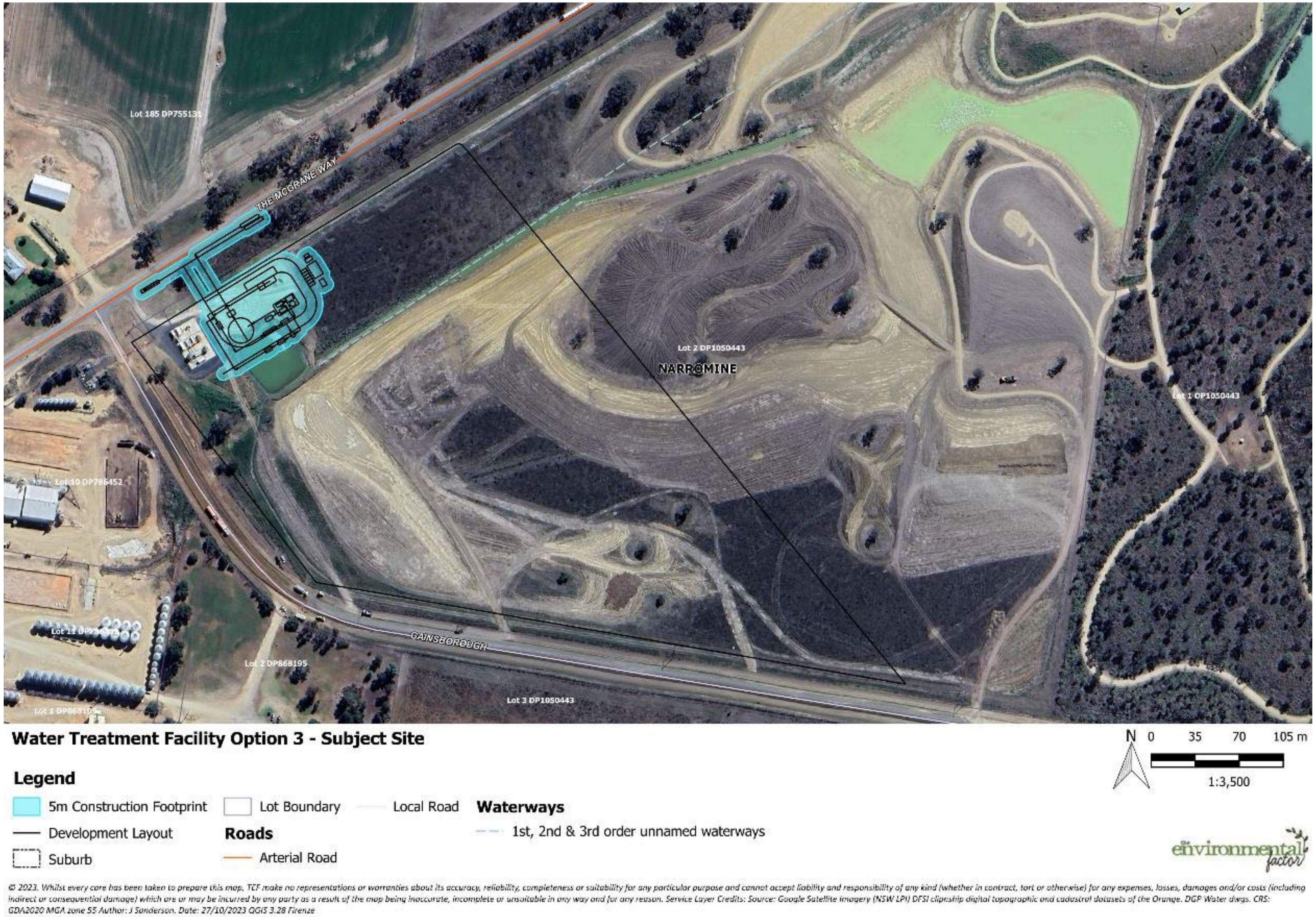


Figure 8 Option 3 conventional treatment with sedimentation tank and mechanical dewatering – site layout

4.3 Option 4 – Upgrade existing temporary plant

As for all Options considered, Option 4 presents a viable treatment process which can meet all the health and aesthetic requirements for town water, as described in the ADWG and IWCM Issues Paper (PWA, 2022). Due to the overlap of each footprint, individual consideration of impacts to biodiversity, surface and groundwater and heritage have been made broadly for the site, in Section 4.1 above.

Consideration of impacts arising from Option 4 specifically is provided below.

- **Biodiversity**
  - **Terrestrial** – impacts to terrestrial biodiversity, including native vegetation and terrestrial fauna are considered lowest for this Option, due to the relatively small overall impact footprint. This Option would require the smallest area of vegetation clearing at 0.53 ha.
  - **Aquatic** – impacts to aquatic biodiversity are also lower than for the other proposed treatment layouts, due to the absence of any impact on the existing surface water dam on site, as well as the surrounding swamp area. The adjacent Narromine Wetlands support a range of native species which may use the wetlands for breeding and foraging habitat, either permanently, seasonally or transiently. Potential direct and indirect impacts on this area are anticipated to be lowest for Option 4.
- **Heritage**
  - **Aboriginal heritage** – due to the large number of recorded objects and places of Aboriginal Heritage significance within the broader locality, Due Diligence assessment of each Option is a requirement. As Option 4 has the smallest footprint, the risk of impact to Aboriginal heritage is slightly decreased compared with the other options.
  - **Non-Aboriginal heritage** – potential for impacts to non-Aboriginal heritage for all Options is considered low.
- **Receiving environment / pollution risk**

  Option 4 has the smallest footprint and conveys a low risk of impact on both surface and groundwater resources due to the absence of large sedimentation lagoons. This option also carries a lower risk for pollution of waters.

  All Options will likely require an EPL as a licensed premises and for sludge removal and management of any discharges to the environment.
- **Waste and resource use**

  Option 4 is the lowest generator of sludge as part of ongoing operations; the option generates 55% sludge waste compared with the other options (refer Table 7). Option 4 also doesn't require the addition of Potassium permanganate as part of dosing, however it is the only treatment option that requires the addition of polymer; polymer is a relatively cost effective and safe treatment option compared potassium permanganate. Option 4 is the lowest consumer of resources for the construction phase, requiring no soil and other materials for construction as no lagoons are required. Additionally, sludge can be removed progressively and in smaller batches, making wastes easier to remove, transport and beneficially reuse.
- **Socio-economic considerations**

  All Options will satisfy requirements for clean and safe drinking water for the Narromine community.

Consideration of relevant environmental aspects of Option 4 is provided below.

Table 11 Option 4 assessment

Water Quality Option 4

Criterion	Description of Option 4	Score
Environmental Group		
Impact on terrestrial and aquatic biodiversity	Construction of WTP with an impact area of 0.53 ha that includes impacts to existing surface water dam and is adjacent to the Narromine wetlands.	6/10
Environmental pollution risk (i.e POEO Act)	Construction of a new WTP and associated pipelines and infrastructure carries a risk for pollution incidents to groundwater, surface water and land. Risk of release of ozone and other contaminants.	6/10
Impact on land – use and area (ha)	Construction of WTP with an impact area of 0.53 ha in an agricultural area on the outskirts of Narromine.	7/10
Waste and resource use	Construction of WTP would utilize the existing temporary plant and so would require less building materials comparable with the other options. The WTP would generate less waste products during operations (sludge, unused chemicals and general waste). The option has greater energy intensity, however it would consume less chemicals for treatment.	7/10
	(1) Total weighted environmental	**6.3**
Social Group		
Risk of not meeting LOS (health and aesthetic criteria)	Risk that WTP fails to operate as per design parameters is reduced compared to the other Options	7/10
Impact on land – use and area (ha)/disruption to community	Construction of WTP with an impact area of 0.53 ha; doesn't encroach into the wetlands, doesn't inhibit future use of surrounding area	7/10
Planned for future changes in development (right sizing)	Risk that WTP fails to meet future demand. More space available comparable with other options and modular design. Design more modular; easier to upgrade.	8/10
Community attraction/liveability	Smallest impact footprint; similar impacts to visual amenity from wetlands and road to existing. Risk to water quality – low risk of 'boil water' notice	7/10
	(2) Total weighted social	**7.2**
	(3) Environmental and social score (ESS) (3) = (1) + (2)	**13.5**

Figure 9 Option 4 upgrade existing temporary plant – site layout

5 PREFERRED OPTION

Given the environmental considerations, in concert with the need to improve the quality of water supply for Narromine, the preferred Option from an environmental and socioeconomic standpoint is Option 4 – upgrade existing temporary plant.

Of the Options proposed, Option 4 has the lowest construction/impact footprint and therefore poses the least likely impacts to biodiversity, Aboriginal and non-Aboriginal heritage and land use. Risk of impacts arising from pollution events is also lower, comparable with the other options, with the potential for migration of soil and sediment into waterways, particularly during construction. Wastes and resource use are also likely to be lower for Option 4; sludge generation is 55% of the volume generated with all other options; input of treatment chemicals is also lower.

Of the Options put forward, Option 1 is the least sustainable, and poses the highest impact from both an environmental, heritage and a socioeconomic viewpoint, given the footprint/impact area of 2.19 ha and the requirement to clear native vegetation that is mapped as a protected TEC, and assumed impacts within the broader stormwater management area and adjacent Narromine Wetlands.

Table 12 below includes a comparison of the environmental criteria considered within this report.

Table 12 Options assessment summary

Water Quality

Criterion	Weighting* (%)	Option 1	Option 2	Option 3	Option 4
Environmental Group					
Impact on terrestrial and aquatic biodiversity	40	2/10	3/10	5/10	6/10
Environmental pollution risk (i.e POEO Act)	30	3/10	4/10	6/10	6/10
Impact on land – use and area	20	2/10	3/10	6/10	7/10
Waste and resource use	10	2/10	2/10	4/10	7/10
(1) Total weighted environmental	**100%**	**2.3**	**3.1**	**5.2**	**6.3**
Social Group					
Risk of not meeting LOS (adequate water sources, water strategies)	40	4/10	6/10	6/10	7/10
Impact on land – use and area (ha)/disruption to community	20	2/10	3/10	6/10	7/10
Not planned for future changes in development (right sizing)	20	2/10	3/10	6/10	8/10
Community attraction/liveability	20	2/10	4/10	5/10	7/10
(2) Total weighted social	**100%**	**2.8**	**4.4**	**5.8**	**7.2**
(3) Environmental and social score (ESS) (3) = (1) + (2)		**5.1**	**7.5**	**11.0**	**13.5**

*Weighting is based on low = poor environmental outcome, high = good / better environmental outcome

6 CONCLUSION AND RECOMMENDATIONS

Option 4, as the preferred option, has the lowest potential for impacts to the environment while still achieving the objectives of the Narromine Water Quality project.

In order to proceed with Option 4, the following is recommended:

- A detailed constraints assessment be undertaken for the proposed construction site to identify if there are any further refinements/design changes that could be made to ensure ecological and heritage values are avoided as much as possible.
- Detailed design

The following investigations and approvals will be required to progress this proposal:

- Ecological assessment of the proposed construction area, including targeted surveys for threatened species and assessment of the significance of these impacts under both the BC Act and EPBC Act (if required).
- Aboriginal Due Diligence assessment to be completed as a minimum. Aboriginal Cultural Heritage Assessment will need to be completed if there is potential for impacts to objects or places of Aboriginal heritage significance that cannot be avoided.
- Preparation of a comprehensive Review of Environmental Factors (REF) needs to be undertaken.
- Third party approvals need to be obtained, including the following as applicable:
    - Environmental Protection Licence (NSW Environment Protection Authority) – may be required. Consultation with EPA is recommended to determine requirements.
    - Aboriginal Heritage Impact Permit (AHIP) to permit harm to Aboriginal objects or places – to be avoided where possible. (Heritage NSW).

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