Rous County Council

Purified Recycled Water Investigation

Project Report
July 31, 2024

Rous County Council
Purified Recycled Water for Drinking Investigations
Project Report

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EXECUTIVE SUMMARY

Rous County Council's Future Water Project 2060 considered several potential medium to longer term water sources with potential implementation between 2030 and 2060 (stage 3)[1]. These sources included surface water, groundwater, desalination, water efficiency and purified recycled water from indirect potable reuse. While the Future Water Project considered that indirect potable reuse as unattractive due to operational constraints and expected stakeholder opposition, industry consultation and internal research undertaken by Rous County Council identified that opportunities for potable reuse warranted broader and deeper consideration. To this end, Rous County Council engaged Tyr Group, along with its team of international potable reuse experts, to identify all available opportunities for potable reuse, and then develop and fully evaluate the most feasible of those options. The outputs of this investigation are intended to facilitate the comparison of potable reuse to other possible bulk water supply options under consideration by Rous County Council.

To capture all available opportunities for potable reuse, a systematic approach was applied comprising review of:

- Volume, water quality and reliability of all available sources of sewage treatment plant effluent;
- Existing and projected non-potable recycled water demand;
- Prevailing and projected potable water demand across the region;
- Existing environmental buffers (surface water and groundwater); and,
- Existing storage, treatment and transfer infrastructure.

Using the outputs of the review, forty potential potable reuse scheme options were identified. Of these, four options were short-listed for full quantitative and qualitative development, while a further five options were partially developed to enable consideration at a broad level.

The short-listed scheme options were:

- Lismore indirect potable reuse (IPR) via surface water augmentation (to a new engineered buffer storage);
- Lismore direct potable reuse (DPR) via raw water augmentation (to the inlet of Nightcap water treatment plant);
- Lismore DPR via treated water augmentation (to reservoirs servicing the City of Lismore); and,
- Byron DPR via treated water augmentation (to the main reservoirs servicing Byron and Ballina shires).

Partially developed scheme options included surface water augmentation to Rocky Creek Dam from Lismore and Byron sources, groundwater augmentation from Byron sources and DPR options from Ballina sources.

Minimum pathogen reduction requirements were established to allow development of conceptual treatment trains for each scheme option, with reference to the existing Australian Guidelines for Water Recycling (2008), Australian Drinking Water Guidelines (2022), World Health Organization Potable Reuse Guidance (2017), and contemporary approaches being adopted within the USA. These requirements were developed strictly for the purpose of providing a basis for sizing and subsequent cost estimation of the scheme options. If any of the short-listed scheme options are carried forward, pathogen reduction requirements would need to be the subject of consultation and agreement with the Regulator.

Conceptual treatment process trains were developed to meet the specific requirements of each short-listed scheme option (including the minimum pathogen reduction requirements), drawing on the experience of the project team's specialist advisors. Based on the source water salinity and available options for management of any reverse osmosis concentrate, the conceptual process trains adopted carbon-based treatment for the inland (Lismore) schemes options, and a reverse osmosis-based treatment train for the coastal (Byron) scheme option.

In the absence of source specific chemical occurrence data for the short-listed schemes, a high-level chemical risk assessment methodology was applied based on the paradigms included in US Water Research Foundation Project No. 4960, with consideration of Australia specific conditions. This provided preliminary identification of potential key risks that would need to be further evaluated with site-specific chemical occurrence data if any of these schemes were to be progressed.

[1] Rous Regional Supply: Future Water Project 2060 – Integrated Water Cycle Management – Hydrosphere -April 2022

If a DPR scheme is progressed, there are currently two options in relation to achieving regulatory approval:

- Following the existing Australian Guidelines for Water Recycling framework (which includes an approval pathway for IPR, but does not include a clear approval pathway for DPR), and demonstrating to the regulator that sufficient mechanisms and controls are provided such that public health is protected; or,
- Waiting for update of the Australian Guidelines for Water Recycling framework (or other relevant guidelines) to incorporate DPR, and development of NSW specific guidance on how the requirements will be applied in NSW for potable reuse.

RCC have indicated that seeking approval under the first approach would not be considered without explicit support and endorsement from NSW Health and NSW Department of Climate Change, Energy, the Environment and Water. It is noted that development of national DPR guidelines is largely outside of RCC's sphere of influence.

Gaining regulatory approval by following the existing Australian Guidelines for Water Recycling framework is estimated to have a minimum timeline on the order of nine years.

The future investigations and actions anticipated to be required if any scheme option is progressed were outlined in the study. Key next steps[2] would include:

- Source Characterisation – sampling of the source STPs over a two-year period to establish the water quality characteristics of the source water ($1.6m), this is generally considered to be the first barrier in a multiple barrier approach to water quality risk management;
- Community Engagement – development of a program to inform and educate the community to gain support for the project ($325k per annum);
- Enhanced Source Control – development of a program to establish chemical risks associated with trade waste discharges and means to manage these risks, e.g. by regulating trade waste discharges ($550k for first two years to establish program then $150k per annum to maintain the program);
- Demonstration Plant – a small-scale plant designed to simulate the intended full-scale design and with sufficient flexibility to trial different configurations of process units (where appropriate), different flow rates, and/or different operating and chemical regimes. Benefits of operating the demonstration plant include:
  - Verification that the claimed pathogen reductions can be achieved;
  - Testing of alternative process configurations and/or different vendor equipment (e.g. ultrafiltration membranes) to optimise performance and/or costs;
  - Verification of chemical occurrence and removal performance;
  - Providing an opportunity to review performance data with stakeholders – Regulators in particular
  - Establishing initial setpoints for plant control - in particular critical control points (noting that the applicability of these setpoints to the full scale advanced water treatment plant would need to be verified);
  - Enabling hands-on training for all personnel expected to be involved in operation, maintenance and management of the scheme (with particular importance for Operations staff);
  - Providing an opportunity for community engagement and education (e.g. the demonstration plant could also include a visitor centre).

  Depending on the design approach taken and the facilities included (e.g. visitor's centre) the cost for a demonstration plant could be between about $3m and $10m. Operating costs for a demonstration plant have been estimated to be about $1.1m per annum.

[2] Costs provided are based on the Lismore DPR via raw water augmentation scheme. In addition to the costs shown for these key actions, Rous County Council would incur about $880k per annum in costs for project managers and engineers during the execution of the key actions.

To support cost estimation, the conceptual designs for the advanced water treatment plants and associated transfer infrastructure were developed for each short-listed scheme option, including selection of suitable available sites and pipeline alignments, sizing of each unit process, pipeline and major drive, preliminary layouts, and derivation of chemical dosing and power requirements. The cost estimation and analysis indicated that the Lismore DPR via raw water augmentation scheme option represents the best value on a commercial basis, with:

- Lowest specific capital cost ($16.3m per ML/d of PRW production capacity);
- Second lowest absolute capital cost ($148m). The Lismore DPR via treated water augmentation scheme has the lowest estimated capital cost ($135m), with the estimated capital cost of the Lismore DPR via raw water augmentation scheme option approximately 10% higher.
- Lowest estimated specific whole-of life cost (specific net present cost[3] of $19.8 per ML of PRW produced at design production rate).
- Second lowest absolute whole-of life cost (net present cost of $180m). The Lismore DPR via treated water augmentation scheme has the lowest estimated net present cost ($169m), with the estimated NPC of the Lismore DPR via raw water augmentation scheme option approximately 6% higher.
- Lowest specific operations and maintenance cost ($1.31 per kL). The Lismore IPR via surface water augmentation scheme option had similar specific operations and maintenance cost ($1.33 per kL).

Multiple criteria assessment was applied to the four short-listed options based on their attributes under a technical, financial and social/environmental criteria. An assumption that approval of DPR can be viably achieved in the required timeframe was effectively applied. The assessment indicated that the Lismore DPR via raw water augmentation scheme would have the highest preference. With the short-listed scheme options broadly similar in terms of non-cost criteria, this preferred status is largely the result of the favourable whole-of-life cost per ML of Purified Recycled Water produced for this option.

Overall, it is recommended that the Purified Recycled Water for Drinking Water Investigations be used to inform the following ongoing and future work as applicable:

- **Utilisation in Future Water Project:** The study has identified and developed suitable scheme options to facilitate comparison of Purified Recycled Water to other potential sources of bulk water as a part of RCC's Future Water Project. To support this comparison, the secure yield offered by the potable reuse scheme options should be determined by water balance modelling, then compared in terms of overall value to alternative approaches to meeting the region's projected bulk water demand.
- **Utilisation in development of one or more potable reuse scheme options:** If Purified Recycled Water is to be progressed as a source, the findings and outputs of this study should be used as a reference and guide to inform future work. The validity of the assumptions applied need to be confirmed, including ongoing developments in potable reuse.
- **Utilisation as a model for other regional areas as applicable:** While this study is highly specific to the requirements and attributes of the Rous County Council service area, the *Purified Recycled Water for Drinking Water Investigations* may provide insights to inform the identification, development and assessment of Purified Recycled Water options at a planning-level in the context of other areas of regional Australia.

[3] Net present cost is based on 40 years, 5% discount rate and 0% inflation

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ABBREVIATIONS

ADWF	Average Dry Weather Flow
ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AOP	Advanced Oxidation Process
ARB	Antibiotic Resistant Bacteria
ARG	Antibiotic Resistance Genes
AWTP	Advanced Water Treatment Plant
AWRP	Advanced Water Recycling Plant
BAC	Biologically Activate Carbon
BOD	Biochemical Oxygen Demand
BOM	Bureau of Meteorology
CCP	Critical Control Point
CEC	Constituents of Emerging Concern
CHAIR	Construction Hazard Assessment Implication Review
CIP	Clean in Place
COD	Chemical Oxygen Demand
C.t.	Concentration x Contact Time
DALYd	Disability Adjusted Life Years Dose
DALY	Disability Adjusted Life Years
DICL	Ductile Iron Cement Lined
DOC	Dissolved Organic Carbon
DPR	Direct Potable Reuse
ENM	Engineered Nanomaterials
HACCP	Hazard Analysis and Critical Control Point
HAZOP	Hazard and Operability
IPR	Indirect Potable Reuse
IWCM	Integrated Water Cycle Management
LGA	Local Government Area
MBBR	Moving Bed Biofilm Reactor
MCA	Multiple Criteria Assessment
NPC	Net Present Cost
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PDT	Pressure Decay Test
PFAS	Per- and Polyfluoroalkyl Substances
PWR	Purified Recycled Water
QCRA	Quantitative Chemical Risk Assessment
QMRA	Quantitative Microbial Risk Assessment
RCC	Rous City Council
RO	Reverse Osmosis
RWA	Raw Water Augmentation
STP	Sewage Treatment Plant
SWA	Surface Water Augmentation
TDS	Total Dissolved Solids
TMP	Transmembrane Pressure
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TWA	Treated Water Augmentation
UF	Ultrafiltration
UV	Ultraviolet Light Disinfection
WHO	World Health Organization
WRF	Water Research Foundation
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
ZLD	Zero Liquid Discharge

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- Robert Wise, Lead Civil Engineer (Pipeline and Pump Station Planning and Costing), Planit Consulting;
- Damion Cavanagh, Environmental Engineer Northern Rivers Waterways, BMT; and,
- Paul Mountney, Director (AWTP Capital Cost Estimation), Tallai.

1 PROJECT SUMMARY

Rous County Council's (RCC) Future Water Project 2060 considered several potential medium to longer term water sources with potential implementation between 2030 and 2060 (stage 3) [1]. These sources included surface water, groundwater, desalination, water efficiency and purified recycled water (PRW) from indirect potable reuse (IPR). While the Future Water Project considered that IPR as unattractive due to operational constraints and expected stakeholder opposition, industry consultation and internal research undertaken by RCC identified that opportunities for potable reuse warranted broader and deeper consideration.

Tyr Group, along with a team of international potable reuse experts, was engaged to identify all available opportunities for potable reuse, and then develop and fully evaluate the most feasible of those options. This project, Purified Recycled Water for Drinking Investigations (PRW Investigations), has pursued a comprehensive approach, leveraging the project team's extensive knowledge and Australian and international experience. The outputs of this investigation are intended to facilitate the comparison of potable reuse to other possible bulk water supply options under consideration by RCC.

The options identified for investigation included:

- IPR via Surface Water Augmentation (SWA);
- IPR via Ground Water Augmentation;
- Direct Potable Reuse (DPR) via Raw Water Augmentation (RWA);
- DPR via Treated Water Augmentation (TWA); and,
- Environmental Flow Substitution opportunities.

The scope of work for the PRW Investigations can be summarised as follows:

- Information collection for feasibility assessment;
- Assessment of all wastewater treatment plants (WWTP)[4] in RCC's service area for suitability to supply source water to potential potable reuse schemes (based on quantity, quality and reliability of effluent);
- Review of potable water demands, existing potable water storage, treatment and transfer infrastructure, environmental buffers (surface water and groundwater), and a range of additional local factors, to identify and quantify a comprehensive long-list of potable reuse opportunities;
- Analysis of the long-list options to identify the most suitable options to be carried forward for development, analysis and assessment;
- Development of requirements and specification of various process trains for the short-listed indirect and direct potable reuse scheme options;
- Identification of potential advanced water treatment plant (AWTP) locations and configurations;
- Review of existing drinking water treatment plant (WTP) capacities and capabilities;
- Reverse osmosis (RO) concentrate management and disposal options assessment;
- Identification of routine monitoring and operational requirements;
- Identification of regulatory approval pathways;
- Identification of implications for constituent councils and their sewage treatment plants (STP);
- Identification of operation and maintenance requirements;
- Estimation of capital, operational, and net present costs (NPC) for short-listed scheme options; and,
- Multiple criteria assessment (MCA) of short-listed scheme options.

[4] The terms wastewater treatment plant and sewage treatment plant are used interchangeably in this document.

Key items, including options identification and short-listing, determination of minimum pathogen log reduction value (LRV) targets, development of AWTP conceptual process designs, high-level chemical risk assessment, and conclusions and recommendations derived from the PRW Investigations, are summarised in Section 1.1 through Section 1.6.

1.1 Options Identification

To capture all available opportunities for potable reuse, a systematic approach was applied comprising review of:

- Volume, water quality and reliability of all available sources of STP effluent;
- Existing and projected non-potable recycled water demand;
- Prevailing and projected potable water demand across the region;
- Existing environmental buffers (surface water and groundwater); and,
- Existing storage, treatment and transfer infrastructure.

The outputs of the review were used to develop a long list of forty potable reuse options. Using the outcomes of the investigations conducted to that point and the outcomes of a Coarse-Level Option Assessment (using a coarse-level assessment tool developed by RCC), baseline options were identified for consideration during the Scheme Option Identification, Review and Short-Listing Workshop ("Short-Listing Workshop"). The Short-Listing Workshop was held on July 11, 2023 and attended by RCC stakeholders and representatives from Tyr Group, Planit, IBL Solutions, BMT and Carollo.

Following further refinement based on outcomes of the Short-Listing Workshop, the baseline options were then categorised into the following three levels:

- **Level 1** – Option carried forward and quantitatively and qualitatively developed as part of the PRW Investigations project.
- **Level 2** – Option carried forward at a high level – partial option development (approximation of pipelines and AWTP process train requirements and costs, qualitative discussion of opportunities and risks, including considerations of infrastructure costs, complexities and risks relative to Level 1 options). Option is considered have potential to meet the main aims of a potable reuse scheme for RCC, but with substantial barriers reducing likely viability compared to Level 1 options.
- **Level 3** – Option not carried forward for this investigation. Low or limited viability based on information in hand.

Table 1-1 provides a summary of the options considered and the outcomes thereof, leading to the four schemes assessed in detail in this report. To summarise, the four short-listed (Level 1) schemes are:

- Lismore IPR via surface water augmentation to a new engineered buffer storage (producing 9.1 ML/d of PRW);
- Lismore DPR via raw water augmentation to the inlet of Nightcap WTP (producing 9.1 ML/d of PRW);
- Lismore DPR via treated water augmentation to reservoirs servicing the City of Lismore (producing 5.4 ML/d of PRW); and,
- Byron DPR via treated water augmentation to the main reservoirs servicing Byron and Ballina shires (producing 6.7 ML/d of PRW).

Table 1-1: Summary of Options Identification and Short-Listing Outcomes

<table>
<tr><th rowspan="4">Scheme Type</th><th colspan="3">Local Government Area</th></tr>
<tr><th>Ballina</th><th>Byron</th><th>Lismore</th></tr>
<tr><th colspan="3">Source Plants</th></tr>
<tr><th>Ballina WWTP / Lennox Head WWTP</th><th>Byron STW / Brunswick Valley STP</th><th>East Lismore STP / South Lismore WWTP</th></tr>
<tr><td>Ground Water Augmentation (IPR by groundwater augmentation - in line with AGWR 2008)</td><td>Level 3: Not carried forward for this investigation</td><td>Byron STW / Brunswick Valley STP To Tyagarah aquifer:
Level 2: High level consideration</td><td>Level 3: Not carried forward for this investigation</td></tr>
<tr><td rowspan="3">Surface Water Augmentation (IPR-SWA in line with AGWR 2008)</td><td rowspan="3">Ballina / Lennox to Emigrant Creek Dam:
Level 3: Not carried forward for this investigation</td><td>Byron / Brunswick Valley to RCD via pipeline:
Level 2: High level consideration.</td><td>To Rocky Creek Dam via Wilson River Source Pump Station, co-treatment with Wilson River water.
Level 2: High level consideration.</td></tr>
<tr><td>Byron / Brunswick Valley to Emigrant Creek Dam:
Level 3: Not carried forward for this investigation</td><td rowspan="2">New engineered storage as environmental buffer.
Level 1: Carry forward for consideration.</td></tr>
<tr><td>Byron / Brunswick Valley to Rocky Creek Dam via Byron Creek:
Level 3: Not carried forward for this investigation</td></tr>
<tr><td>Raw Water Augmentation PRW from Augmentation (DPR-RWA)</td><td>To Emigrant Creek WTP:
Level 2: High level consideration.</td><td>Level 3: Not carried forward for this investigation</td><td>To Nightcap WTP via Wilson River Source Pump Station and Pipeline, co-transfer with Wilson River water:
Level 1: Carry forward for consideration.</td></tr>
<tr><td>Treated Water Augmentation (DPR-TWA)</td><td>To Knockrow Reservoir:
Level 2 High level consideration.</td><td>To St Helena Reservoir with reverse flow in existing main to Knockrow Reservoir:
Level 1: Carry forward for consideration.</td><td>To main Lismore reservoirs:
Level 1: Carry forward for consideration.</td></tr>
<tr><td>Environmental Flow Substitution</td><td colspan="3">Level 3. Not carried forward for this investigation.</td></tr>
</table>

1.2 LOG REDUCTION VALUE REQUIREMENTS APPLIED TO SHORTLISTED SCHEMES

The minimum pathogen reduction requirements applied to development of process trains for each Level 1 option were derived in the discussion paper titled *Minimum Pathogen Reductions for Potable Reuse Development* (included in Appendix C), with reference to:

- The Australian Guidelines for Water Recycling (AGWR) [2],
- The Australian Drinking Water Guidelines (ADWG) [3];
- World Health Organization (WHO) Potable Reuse Guidance [4], and,
- Contemporary approaches being adopted within the USA.

Table 1-2 lists the minimum pathogen LRV required using the dose-response relationships, the relationships of infection to illness and the disability adjusted life year (DALY) per illness information provided in the ADWG [3] and raw wastewater pathogen concentrations as defined by the WHO [4]. These values are the minimum pathogen LRV determined by this assessment required to ensure protection of public health.

Table 1-2: Minimum LRV Required for Protection of Public Health

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus	Cryptosporidium	Campylobacter
Pathogen concentration in source water	number per L	20,000	2,700	7,000
DALY dose	number per year	3.6×10^{-3}	4.2×10^{-3}	7.5×10^{-3}
Exposure	L/d	2	2	2
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	5.0×10^{-6}	5.8×10^{-6}	1.0×10^{-5}
Minimum Pathogen Reduction	LRV	9.6	8.7	8.8
Minimum Pathogen Reduction (rounded to next highest 0.5 log)	LRV	10.0	9.0	9.0

Considering this project is in the early investigation stage without knowing future regulatory requirements, the approach for the conceptual AWTP designs and sensitivity analyses is described in Table 1-3. This approach is considered to reflect conservative, but reasonable, LRVs in the Australian context.

The pathogen reduction values shown in Table 1-3 include “excess LRVs”. **This is solely for the purpose of cost estimating and not a reflection of the opinion of the project team of a need due to pathogen risk. The final minimum pathogen LRV requirement used in design of the AWTP (to be agreed with the Regulator) should be based on pathogen barrier failure modelling** with consideration of:

- The maximum LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere[5]);
- The failure mode of each unit process (i.e. instantaneous (e.g. disinfectant dosing system failure) or gradual (e.g. loss of ultrafiltration (UF) membrane integrity which normally occurs slowly and can be seen by monitoring pressure decay test (PDT) trends);
- The response time of online analysers used for Critical Control Points (CCP);
- The reliability of these analysers and any redundancy provided for these analysers (including consideration of the maintenance strategy for the analysers and the frequency of calibration);
- The use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk; and,
- Other design features used to mitigate risk (e.g. use of “off spec” diversions at CCP alert levels, use of engineered storage buffer tank to allow for capture and diversion of water produced between analyser readings, etc.).

[5] Sylvestre et.al. [48] indicate that for a barrier with rapid loss in LRV performance credited with 6.0 LRV, failure durations of 10 seconds per year need to be controlled, whereas for the same process claiming 4 LRV performance can be verified by controlling a failure of 15 minutes per year.

Table 1-3: Approach for Conceptual AWTP Designs and Sensitivity Analyses

Scheme	Baseline AWTP LRV Basis	Sensitivity Analyses
IPR via Surface Water Augmentation	Virus: 10.0 LRV Protozoa: 9.0 LRV Bacteria: 9.0 LRV	None
DPR via Raw Water Augmentation	Virus: 10.0 LRV Protozoa: 9.0 LRV Bacteria: 9.0 LRV Assume blending of source water to and treatment in the downstream WTP is sufficient to manage the risk of barrier failure	Consider a worst case as aligning with an excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV: 12.0 LRV Protozoa LRV: 11.0 LRV Bacteria LRV: 11.0 LRV
DPR via Treated Water Augmentation	Consider a case of excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV: 12.0 LRV Protozoa LRV: 11.0 LRV Bacteria LRV: 11.0 LRV	Consider ***an absolute worst case*** as aligning with an excess LRV of 4 for all pathogen types (i.e. 100% redundancy) – i.e. the process would provide: Virus LRV: 14.0 LRV Protozoa LRV: 13.0 LRV Bacteria LRV: 13.0 LRV It is not the opinion of the project team that this is suitable from a public health risk perspective, and is only presented to represent an extreme worst-case scenario for AWTP costing (with respect to pathogen reduction).

1.3 AWTP PROCESS TRAINS

Conceptual treatment process trains were developed to meet the specific requirements of each short-listed scheme option (including the minimum pathogen reduction requirements), drawing from the experience of the project team's specialist advisors. The conceptual AWTP process trains, presented in detail in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E), have been developed to allow for:

- Development of capital cost estimates for each short-listed potable reuse scheme;
- Identification of site configuration and area requirements (needed to identify suitable locations for each AWTP);
- Determination of return streams and impacts of these on the STP;
- Identification of potential discharges to the environment (e.g. RO concentrate);
- Determination of operation and maintenance requirements and associated costs;
- Engagement with regulators (as part of demonstrating the focus on protection of public health in the investigations); and,
- Setting expectations for RCC stakeholders regarding the nature and attributes of the treatment processes.

The conceptual AWTP process trains have been designed to achieve the pathogen LRV requirements established for the project and to provide removal of compounds of concern.

Based on the source water salinity and available options for management of any RO concentrate, the conceptual process trains adopted carbon-based treatment for the inland (Lismore) schemes options. This process type may be reconsidered if local discharge of RO concentrate to the Wilson River were investigated and found to be acceptable.

An RO-based treatment train was adopted for the coastal (Byron) scheme option owing to the ability to discharge brine to sufficiently saline waters. However, the total dissolved solids (TDS) concentrations in Byron and Brunswick Valley STP effluent are low enough for either RO-based or carbon-based treatment to be considered for this scheme.

The conceptual process trains are intended to provide a reasonable basis on which to develop costs and site area requirements. Significant additional work will be required to verify the pathogen LRVs claimed, including confirming validated LRVs for equipment selected during design (e.g. UV disinfection) and confirming Claimed LRVs by testing in a demonstration AWTP (e.g. LRVs claimed for direct filtration via biologically active carbon (BAC)). The claimed pathogen LRVs would also likely be subject to onsite validation (e.g. challenge testing) and verification testing (e.g. water quality sampling) during commissioning of the plant prior to regulatory approval to add PRW to the drinking water supply.

1.4 Chemical Risk Assessment

In the absence of source specific chemical occurrence data for the short-listed schemes, a high-level chemical risk assessment methodology was applied based on the paradigms included in US Water Research Foundation Project No. 4960, with consideration of Australia specific conditions. The high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW is detailed in the *Chemical Risk Assessment Memorandum* in Appendix D and summarised in Section 7. Further assessment of chemical risk will need to be conducted when sufficient catchment specific data becomes available, with the approach described in the *Chemical Risk Assessment Memorandum* provided to guide the future detailed, quantitative chemical risk assessment (QCRA). Further investigations required to support a future detailed chemical risk assessment would include, but not be limited to:

- Source characterisation;
- Development of an enhanced source water control program (including a detailed study of all dischargers and the chemicals they use that could end up in the sewer);
- Demonstration plant testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water and their removal through the various unit processes within the demonstration plant; and,
- Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available.

Based on this assessment, per- and polyfluoroalkyl Substances (PFAS) appears to be a broad concern for all proposed treatment trains. This concern is driven almost solely by the risk to human health posed by these compounds (rather than the capability of the AWTP process trains to remove PFAS). A further concern is the origin of PFAS. While landfill leachate may contribute a significant load, it is equally possible that a substantial PFAS load originates from households. If any scheme option is progressed, it is recommended that chemical characterisation of leachate be compared to raw wastewater to determine the potential extent of contamination for this source. If leachate is shown to be a significant contributor of chemical load, then segregation from a potable reuse scheme or enhanced point source treatment may be more effective than addition of further unit operations to the potable reuse treatment train.

An assessment of chemicals of industrial concern in the raw wastewater should be conducted for any scheme options carried forward for further consideration to better understand if these industries contribute significantly to chemical load. While chemical risk is highly specific to individual catchments, the high-level analysis of the catchments (i.e. lower percentage trade waste, limited heavy industry) gives some indication that risks could be similar to (or lower than) a typical catchment.

1.5 Short-Listed Option Assessment

To support robust capital and operating cost estimation, each of the AWTPs and their associated transfer infrastructure were developed, including selection of suitable available sites and pipeline alignments, sizing of each unit process, pipeline and major drive, preliminary layouts, and derivation of chemical dosing and power requirements.

Table 1-4 summarises the capital cost estimates developed for the short-listed options. Also included in Table 1-4 is specific capital cost (capital cost per ML/d of PRW production capacity).

Table 1-4: Capital Cost Estimate Summary

Scheme	Transfer Cost	AWTP Cost	Engineered Environmental Buffer Storage Cost	Total Estimated Cost	Daily PRW Produced (ML)	Specific Capital Cost
Lismore IPR via Surface Water Augmentation – 0.6 GL Buffer Storage	$48.7m	$129.2m	$40m	$218m	9.1	$24.0m per ML/d
Lismore IPR via Surface Water Augmentation – 1.2 GL Buffer Storage	$48.7m	$129.2m	$54m	$232m	9.1	$25.5m per ML/d
Lismore DPR via Raw Water Augmentation	$17.8m	$130.4m	N/A	$148m	9.1	**$16.3m per ML/d**
Lismore DPR via Treated Water Augmentation	$31.2m	$104.2m	N/A	**$135m**	5.4	$25.0m per ML/d
Byron DPR via Treated Water Augmentation	$52.9m	$130.6m	N/A	$184m	6.7	$27.5m per ML/d

Given the early stage of the project and the associated unknowns, capital cost sensitivities were evaluated for the addition of unit processes to mitigate chemical or pathogen risk, in the event that further investigations deem this necessary. The sensitivity cases are presented in Table 1-5.

Table 1-5: Summary of Sensitivity Case Cost Impacts

Scheme	Item	Sensitivity	Capital Cost Increase
Lismore IPR via Surface Water Augmentation	Secondary Granular Activated Carbon (GAC)	Chemical	$16.3m
Lismore DPR via Raw Water Augmentation	Secondary GAC	Chemical	$16.3m
Lismore DPR via Treated Water Augmentation	Secondary GAC	Chemical	$8.1m
	Secondary UV	Pathogen	$3.0m
Byron DPR via Treated Water Augmentation	GAC	Chemical	$9.8m

The estimated operating costs for each of the short-listed scheme options are provided in Table 1-6. The figures listed are based on continuous operation of the scheme option at the design production rate. For intermittent PRW production, the variable operating costs would be lower, but the specific operations and maintenance costs (i.e. $/kL) would likely be increased by any fixed cost elements which persist when the scheme is not producing water.

Table 1-6: Scheme Operating Cost Summary

Scheme	Total Estimated Annual Cost ($AUD 2024 p.a.)						
	Electricity	Chemicals	Sampling Note 1	Labour Note 2	Maintenance Note 3	Total (Year 2 onwards)	
Lismore IPR via Surface Water Augmentation	$810,600	$206,600	Year one: $145,200 Subsequent years: $114,500.	$2,555,000	$723,900	**$4.41m p.a.**	**$1.33 /kL**
Lismore DPR via Raw Water Augmentation	$751,500	$206,600			$723,900	**$4.35m p.a.**	**$1.31 /kL**
Lismore DPR via Treated Water Augmentation	$338,000	$136,200			$491,000	**$3.63m p.a.**	**$1.84 /kL**
Byron DPR via Treated Water Augmentation	$920,700	$329,000			$869,800	**$4.79m p.a.**	**$1.92 /kL**

Note 1: Costs for sampling after the first year of operation. Sampling costs for the first year of operation have been estimated to be $145,200.

Note 2: Costs for RCC labour commencing from handover of assets (assumed to be year nine of the project). Inclusive of chief operator, operators, process engineers, maintenance supervisor, fitters, electrician, analyser specialist, project manager (plus support staff), community engagement specialist, source control specialist, water quality specialist and bi-annual auditing (assumed to be performed by an appropriately qualified consultant.

Note 3: Maintenance cost is assumed to be 3% of equipment supply cost plus an annual contribution is made to cover costs of consumables (e.g. membranes, UV lamps, etc.).

Significant work would be required to attain regulatory approval for any of the short-listed schemes. Table 1-7 summarises these items and their associated estimated costs.

Table 1-7: Estimated Costs Associated with Attaining Regulatory Approval Note 1

Item	Scheme	Comment
Source Characterisation	$800k to $1.6m	Lismore DPR via TWA assumes one STP is characterised, all others assume two STPs are characterised.
Community Engagement	$325k	Costs assume to be incurred each year from the start of the project to attainment of regulatory approval (estimated to be nine years).
Enhanced Source Control - 1	$550k	Costs assumed to be incurred during first two years of the project to establish the program.
Enhanced Source Control - 2	$150k	Costs assumed to be incurred from year three through nine of the project (after year nine costs for this item are included in the "Ongoing Labour Costs" category).
Management team and process engineers during the Regulatory approval period	$800k	Costs assumed to be incurred from the start of the project through year nine (after year nine costs for this item are included in the "Ongoing Labour Costs" category).
Demonstration Plant Capital Cost	$6.5m	Depending on the design approach taken and the facilities included (e.g. visitor's centre) the cost for a demonstration plant could be between about $3M and $10M.
Demonstration Plant Operating Cost	$1.1m	Annual cost for operation of the demonstration plant

Note 1: Not including design and construction costs for AWTPs or transfer infrastructure.

NPCs calculated for each short-listed scheme option are summarised in Table 1-8. The NPCs are based on the following criteria provided by RCC:

- 40-year term;
- 5% discount (interest) rate (with sensitivity at 3% and 7%);
- 0% inflation; and

- Continuous operation of the scheme option at the design production rate. For intermittent PRW production, the specific NPC would be higher.

Sensitivity analyses at discount rates of 3% and 7% did not change the ranking of NPC nor Specific NPC.

Table 1-8: NPC Summary – Based on 5% Discount Rate

Item	NPC	PRW Produced (ML/d)	Specific NPC
Lismore IPR via Surface Water Augmentation – 0.6 GL Buffer Storage	$231.2m	9.1	$25.4m per ML/d
Lismore IPR via Surface Water Augmentation – 1.2 GL Buffer Storage	$241.5m	9.1	$26.5m per ML/d
Lismore DPR via Raw Water Augmentation	$179.8m	9.1	**$19.8m per ML/d**
Lismore DPR via Treated Water Augmentation	**$169.0m**	5.4	$31.3m per ML/d
Byron DPR via Treated Water Augmentation	$206.5m	6.7	$30.8 m per ML/d

Multiple criteria assessment was applied to the four short-listed scheme options based on the assumption that approval of DPR can be viably achieved in the required timeframe. Two versions of MCA were undertaken - one considering NPC and the other considering Specific NPC. Table 1-9 summarises the total scores and scheme preference ranking from these analyses.

Table 1-9: MCA Total Score Summary and Ranking of Scheme Preference based on Specific NPC

Scheme	Specific NPC Score Note 1	Specific NPC Ranking
Lismore IPR via Surface Water Augmentation	4.2	2
Lismore DPR via Raw Water Augmentation	4.6	1
Lismore DPR via Treated Water Augmentation	3.7	3
Byron DPR via Treated Water Augmentation	3.2	4

Note 1: Scores are based on a scale of 1 to 5, with 5 being most favourable and 1 being least favourable.

The MCA ranked the Lismore DPR via raw water augmentation scheme highest based on Specific NPC.

With respect to selecting a preferred option, the following should be taken into consideration:

- The Specific NPC for the Lismore DPR via raw water augmentation scheme is about 20% lower than the Specific NPC for second ranked option (Lismore IPR via surface water augmentation scheme);
- The capital cost for the Lismore DPR via raw water augmentation scheme is about 10% greater than the capital cost for the lowest capital cost option (Lismore DPR via treated water augmentation scheme); and,
- The Lismore DPR via raw water augmentation scheme provides almost 70% more PRW than the Lismore DPR via treated water augmentation scheme.

1.6 Investigation Conclusions and Recommendations

The following conclusions and recommendation can be drawn from the PRW Investigations:

1. If any scheme option is progressed, it is strongly recommended that a demonstration plant be developed and utilised for the following (as appropriate for the specific project needs):
   - Verification that the Claimed LRVs for pathogens can be achieved;
   - Testing of alternative process configurations and/or different vendor equipment (e.g. UF membranes) to optimise performance and/or costs;
   - Verification of chemical occurrence and removal performance;
   - Providing an opportunity to review performance data with stakeholders – Regulators in particular;

- Establishing initial setpoints for plant control – in particular CCPs (noting that the applicability of these setpoint to the full scale AWTP would need to be verified);
- Enabling hands on training for all personnel expected to be involved in operation, maintenance and management of the scheme (with particular importance for operations staff); and,
- Providing an opportunity for community engagement and education (e.g. the demonstration plant could also include a visitor centre).

The demonstration plant should be designed to adequately simulate the intended full-scale design and be designed with sufficient flexibility to trial different configuration of the process units (where appropriate), different flow rates, etc.

A demonstration plant plan should be developed in conjunction with the design, to ensure the design incorporates the features required to execute the plan. The demonstration plant plan and design should be reviewed with relevant stakeholders, in particular operations staff and the Regulator.

2. If any scheme option is progressed, future investigations likely to be required include:
   - Source characterisation;
   - Assessment of Rous County Council institutional capacity;
   - Enhanced source control;
   - Land acquisition, easements, cultural heritage, native title and environmental issues;
   - Procurement and funding options;
   - Electrical supply;
   - Engineered Environmental Buffer Storage options (for Lismore IPR via surface water augmentation option);
   - RO concentrate discharge (for Byron DPR via treated water augmentation option);
   - Impacts on existing infrastructure;
   - Treated water blending (for treated water augmentation options);
   - Design, construction and operation of a demonstration plant;
   - AWTP and transfer infrastructure design; and
   - Refinement of cost estimates.

   Additional investigations may become required as the planning develops.

3. If a potable reuse scheme option is progressed, there are currently two options in relation to achieving regulatory approval:
   - Following the existing AGWR framework and demonstrating to the regulator that sufficient mechanisms and controls are provided such that public health is protected; or,
   - Waiting for update of the AGWR framework (or other relevant guidelines) to incorporate DPR, and development of NSW specific guidance on how the requirements will be applied in NSW for potable reuse.

   RCC have indicated that seeking approval under the first approach would not be considered without explicit support and endorsement from NSW Health and NSW Department of Climate Change, Energy, the Environment and Water. It is noted that development of national DPR guidelines is largely outside of RCC's sphere of influence.

   Gaining regulatory approval by following the existing AGWR framework is estimated to have a <u>minimum</u> timeline in the order of nine years.

4. Cost estimation and analysis of the four short-listed schemes indicated that the Lismore DPR via raw water augmentation scheme option represents the best value on a commercial basis, with:
   - Lowest specific capital cost ($16.3m per ML/d of PRW production capacity) estimate indicates the Lismore DPR via raw water augmentation scheme provides the highest value.

- Second lowest absolute capital cost ($148m). The Lismore DPR via treated water augmentation scheme option has the lowest estimated capital cost ($135m), with the estimated capital cost of the Lismore DPR via raw water augmentation scheme option approximately 10% higher.
- Lowest estimated specific whole of life cost (NPC[6] of $19.8m per ML/d of PRW produced at design production rate).
- Second lowest absolute whole-of life cost (NPC of $180m). The Lismore DPR via treated water augmentation scheme option has the lowest estimated NPC ($169m), with the estimated NPC of the Lismore DPR via raw water augmentation scheme option approximately 6% higher.
- Lowest specific operations and maintenance cost ($1.31 per kL). The Lismore IPR via surface water augmentation scheme option had similar specific operations and maintenance cost ($1.33 per kL).

5. Multiple criteria assessment was applied to the four short-listed options based on the assumption that approval of DPR can be viably achieved in the required timeframe. The assessment indicated that the Lismore DPR via raw water augmentation scheme would have the highest preference. With the short-listed scheme options broadly similar in terms of non-cost criteria, this preferred status is largely the result of the favourable whole-of-life cost.

Overall, it is recommended that the Purified Recycled Water for Drinking Water Investigations be used to inform the following ongoing and future work as applicable:

- **Utilisation in Future Water Project:** The study has identified and developed suitable scheme options to facilitate comparison of PRW to other potential sources of bulk water as a part of RCC's Future Water Project. To support this comparison, the secure yield offered by the potable reuse scheme options should be determined by water balance modelling, then compared in terms of overall value to alternative approaches to meeting the region's projected bulk water demand.
- **Utilisation in development of one or more potable reuse scheme options:** If PRW is to be progressed as a source, the findings and outputs of this study should be used as a reference and guide to inform future work. The validity of the assumptions applied need to be confirmed, including ongoing developments in potable reuse.
- **Utilisation as a model for other regional areas as applicable:** While this study is highly specific to the requirements and attributes of the Rous County Council service area, the *Purified Recycled Water for Drinking Water Investigations* may provide insights to inform the identification, development and assessment of PRW options at a planning-level in the context of other areas of regional Australia.

[6] NPC based on 40 years, 5% discount rate and 0% inflation

2 BACKGROUND AND SCOPE

RCC is responsible for the bulk supply of potable water to the Lismore, Ballina, Byron, and Richmond Valley Local Government Areas (LGAs). RCC has undertaken extensive assessment through the Future Water Project 2060 to identify additional water supplies to provide long-term water security to the region through the Future Water Project 2060.

RCC's Integrated Water Cycle Management (IWCM) Strategy (2022) collated the findings of the investigations undertaken to date, including a preliminary feasibility investigation which considered some configurations for potable reuse. RCC identified that this preliminary feasibility study (and hence the IWCM strategy) did not consider the full range of opportunities for production and utilisation of PRW, including the omission of options based on groundwater augmentation and DPR, and utilisation of options using effluent from Byron Shire Council's effluent streams.

On the basis of this review, RCC identified that PRW should be further investigated as a potential source of bulk water - both more broadly and in greater detail. This project, Purified Recycled Water for Drinking Investigations, has pursued a comprehensive approach to identify all potential options for potable reuse. The options identified include:

- IPR via Surface Water Augmentation;
- IPR via Groundwater Augmentation;
- DPR via Raw Water Augmentation;
- DPR via Treated Water Augmentation; and,
- Environmental Flow Substitution opportunities.

While the project scope was divided into two parts, Separable Portion 1 and Separable Portion 2, this report provides a single reference document for the investigations undertaken through both portions.

In summary, the scope of Separable Portion 1 comprised:

Task 1-2: Reuse Opportunity Identification and Quantification

- Identification, quantification, compilation and mapping of information in hand for key elements with potential to be utilised in potable reuse schemes, including:
    - Estimates of effluent flows from all WWTPs available for potable reuse;
    - Review and rationalisation of the existing and projected demand for non-potable recycled water;
    - Identification and review of potential surface water bodies that could be used as an environmental buffer in a SWA scheme;
    - Review of groundwater aquifers considered in the Future Water Project 2060, and consideration of their potential utilisation as environmental buffers as part of managed aquifer recharge;
    - Identification of capacity and locations of existing and planned WTPs;
    - Identification of key elements within the existing and planned bulk drinking water supply network;
    - Review and consideration of flow obligations in local waterways to identify EFS opportunities;
- Use of the key attributes to develop a comprehensive long-list of potential schemes; and,
- Systematic and comprehensive scheme option identification, review and short-listing (via a stakeholder workshop). To maximise the value of the investigation, schemes based on both IPR and DPR options were short-listed.

Task 1-3: Information Collection for Feasibility Assessment

- Site visits to source WWTPs, RCC WTPs and other relevant locations;
- Preparation of request for information from each Constituent Council;
- Meeting with each Constituent Council;
- Collation, analysis and validation of data from each relevant WWTP;

- Development of WWTP effluent sampling programme for relevant parameters;
- Compilation and review of sampling programme results; and,
- Identification of potential for RO concentrate discharge.

Task 1-4: RO Concentrate Management and Disposal Options Assessment

- Identification of viability of ozone/carbon based AWTP based on source water TDS;
- Review of best practice zero liquid discharge energy usage and capital cost impacts;
- High level assessment of viability of evaporation ponds for RO concentrate disposal for the Northern Rivers climate; and
- Review of RO concentrate discharge options, and viability for each shortlisted scheme.

Task 1-5: Receiving Surface Waters Assessment

- Collection and collation of information on receiving water bodies (surface waters, dams, rivers and creeks, aquifers) for each short-listed scheme; and,
- Collation of information on prevailing and planned water licencing and gauging.

Task 1-6: Transfer Infrastructure Assessment

- Estimation of transfer infrastructure requirements for each short-listed scheme; and,
- Estimate cost for transfer infrastructure for each short-listed scheme.

Task 1-7: AWTP Locations and Configurations

- Identification and review of suitability of potential AWTP locations for each short-listed scheme; and
- Preliminary identification of anticipated most suitable AWTP process train for each short-listed scheme.

Task 1-8: Review Existing WTP Capacities and Capabilities

- Review capacity and process of existing WTPs; and,
- Estimate validated pathogen LRVs for existing WTPs, and the associated validation and verification requirements.

Task 1-9: Identify Routine Monitoring and Operation Requirements

- Determine routine recycled water monitoring requirements for each short-listed scheme option;
- Identify laboratory requirements for the relevant analytes;
- Identify skill requirements for operation, auditing; and,
- Outline anticipated requirements for operational redundancy, critical instruments, sampling equipment.

Task 1-10: Identify Planning Pathways and Regulatory Approval Pathways

- Outline regulatory approval processes required for each shortlisted scheme option.

Task 1-11: Identify Implications for Constituent Councils

- Identify impacts of each short-listed scheme on WWTP effluent quality and compliance.

Task 1-12: Reporting and Presentation

- Identify scope for future investigations to support additional planning, approvals, concept and detailed design.

The Separable Portion 2 scope comprised:

Task 2-2: Development of various process trains for indirect and direct potable reuse

- Estimation of pathogen for WWTP processes;
- Development of a high level quantitative microbial risk assessment (QMRA) for each scheme type;

- Advising on requirement for an additional 4,4,4 LRVs for DPR (as per California DPR Regulations, 2023);
- Development of a high level QCRA for each scheme type;
- Consideration of estimated validated LRV values for existing WTPs; and,
- Development and documentation of process trains for each short-listed scheme type.

Task 2-3: Capital cost model development

- Development of data sheets for each process unit for range of capacities;
- Obtaining pricing from Australian market for each process unit;
- Deriving and applying costs for additional items and balance of plant;
- Creation of cost curves for main process units; and,
- Development of AWTP layouts for each short-listed scheme.

Task 2-4: Outline Operation and Maintenance Requirements

- Collation and analysis of resource consumption, renewal and maintenance costs;
- Estimation of specific consumption for power and consumables for process train options / size options;
- Outlining of staffing levels, auditing requirements, and monitoring requirements, and estimate associated costs; and,
- Comparison of mothballing the AWTP to ongoing utilisation at reduced flow rate.

Task 2-5: Collate Costings for Short-Listed Potable Reuse Schemes and Evaluate

- Development of fully inclusive capital and operating cost estimates for each scheme option;
- Development of NPCs for each scheme; and,
- MCA for schemes and identification of most viable potable reuse schemes.

Task 2-6: Reporting and Presentation

This report summarises the outcomes of the scope items listed above.

3 OVERVIEW OF KEY EXISTING ELEMENTS TO SUPPORT POTABLE REUSE SCHEME OPTIONS

To support a comprehensive approach to the identification and shortlisting of potable reuse schemes options, the key attributes of relevant existing assets and features within the RCC supply region have been compiled and analysed in the following sections. Specific items included comprise:

- Municipal WWTPs, and the source water they may provide to potable reuse;
- Potential environmental buffers, including surface water bodies and areas with potential for groundwater extraction;
- WTPs, water mains and water pump stations, and,
- Constituent Council local government area boundaries.

To provide context of the region's topography and the existing water and wastewater infrastructure, Figure 3-1 through Figure 3-5 provide overview mapping of the RCC region. Full resolution versions of the maps are provided in Appendix A.

3.1 SOURCE WASTEWATER TREATMENT PLANTS

The key attributes of each wastewater treatment plant in the RCC area were compiled and reviewed based on the information in hand to identify their likely suitability to supply source water for a potable reuse scheme, including:

- The current and projected effluent flow available for potable reuse;
- The nominal capacity of the existing plant relative to current and future projected loads;
- The typical effluent quality achieved for relevant monitored parameters including suspended solids, nitrogen and phosphorus, and the plant's current discharge location;
- The salinity or TDS in the effluent stream (where available), and,
- An overview of each plant's treatment process and impacts the process type has on the quality and variability in the effluent stream.

Full details of this work are provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A.

The review identified several WWTPs identified as potentially suitable sources of feed water to supply AWTPs for potable reuse schemes. This section summarises the key considerations regarding these WWTPs.

The AWTPs treating the water supplied by the candidate WWTPs could be either carbon-based (utilising ozone, biological activated carbon (BAC) and granular activated carbon (GAC)) or RO-based. Carbon-based treatment does not reduce the TDS of the feed water, whereas RO-based treatment does.

For initial consideration of potential effluent sources an effluent TDS above 600 mg/L[7] was considered unsuitable for carbon-based treatment (i.e. RO-based treatment is required), with source waters below 600 mg/L able to be either carbon-based or RO-based depending on scheme-specific considerations. While this simplified approach was applied to the scheme option short-listing, the TDS balance for short-listed carbon-based schemes was subject to specific analysis (see *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E)).

Where RO-based treatment is required, the concentrate produced by the process needs to be managed. This section evaluates, at a high-level, the potential for discharge of RO concentrate at each candidate WWTP site.

Richmond Valley Council STPs were reviewed and considered not suitable to support potable reuse schemes in the context of this investigation.

[7] Based on the ADWG aesthetic guideline value of 600 mg/L for TDS [3].

Figure 3-1: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 1 of 5

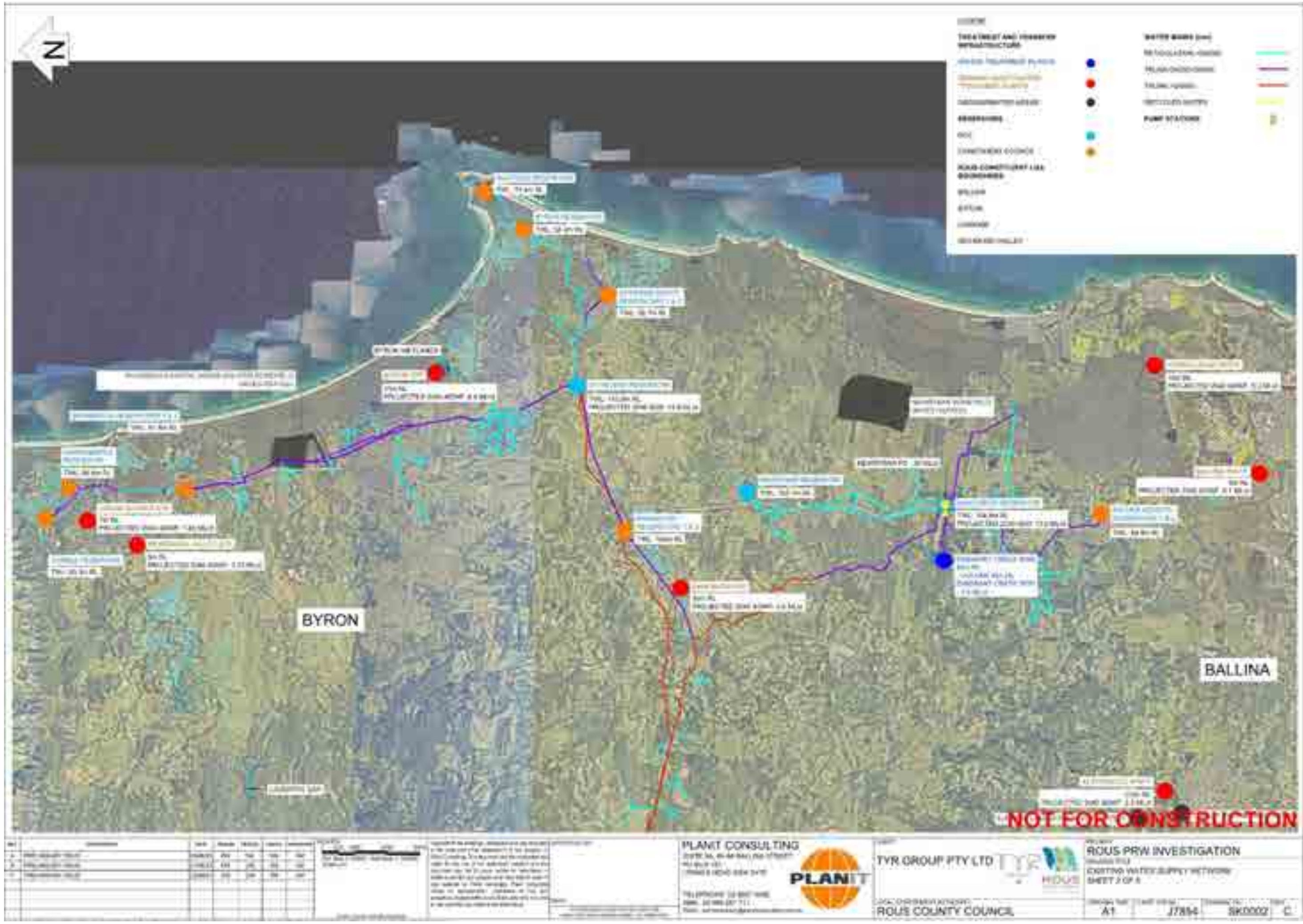

Figure 3-2: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 2 of 5

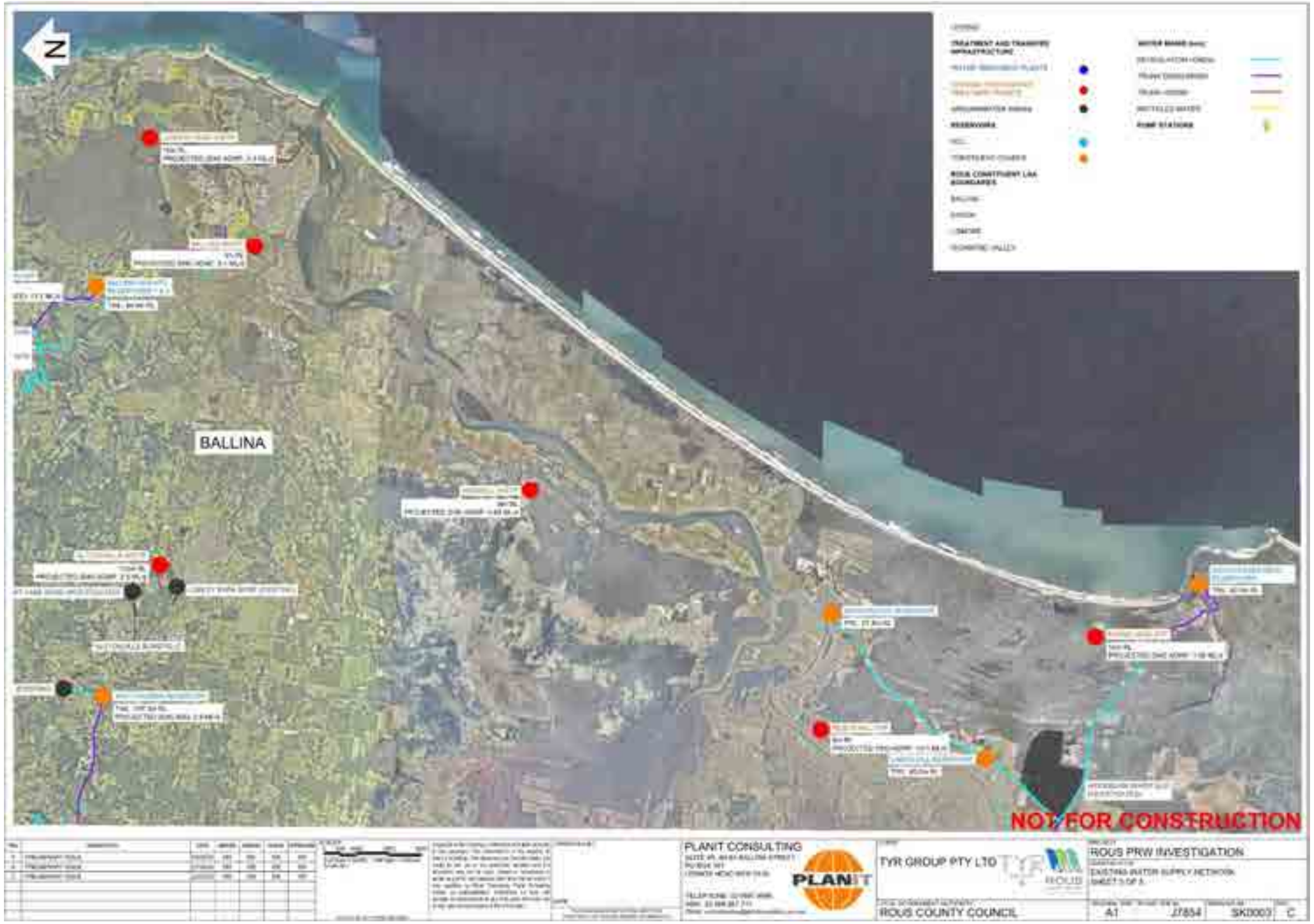

Figure 3-3: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 3 of 5

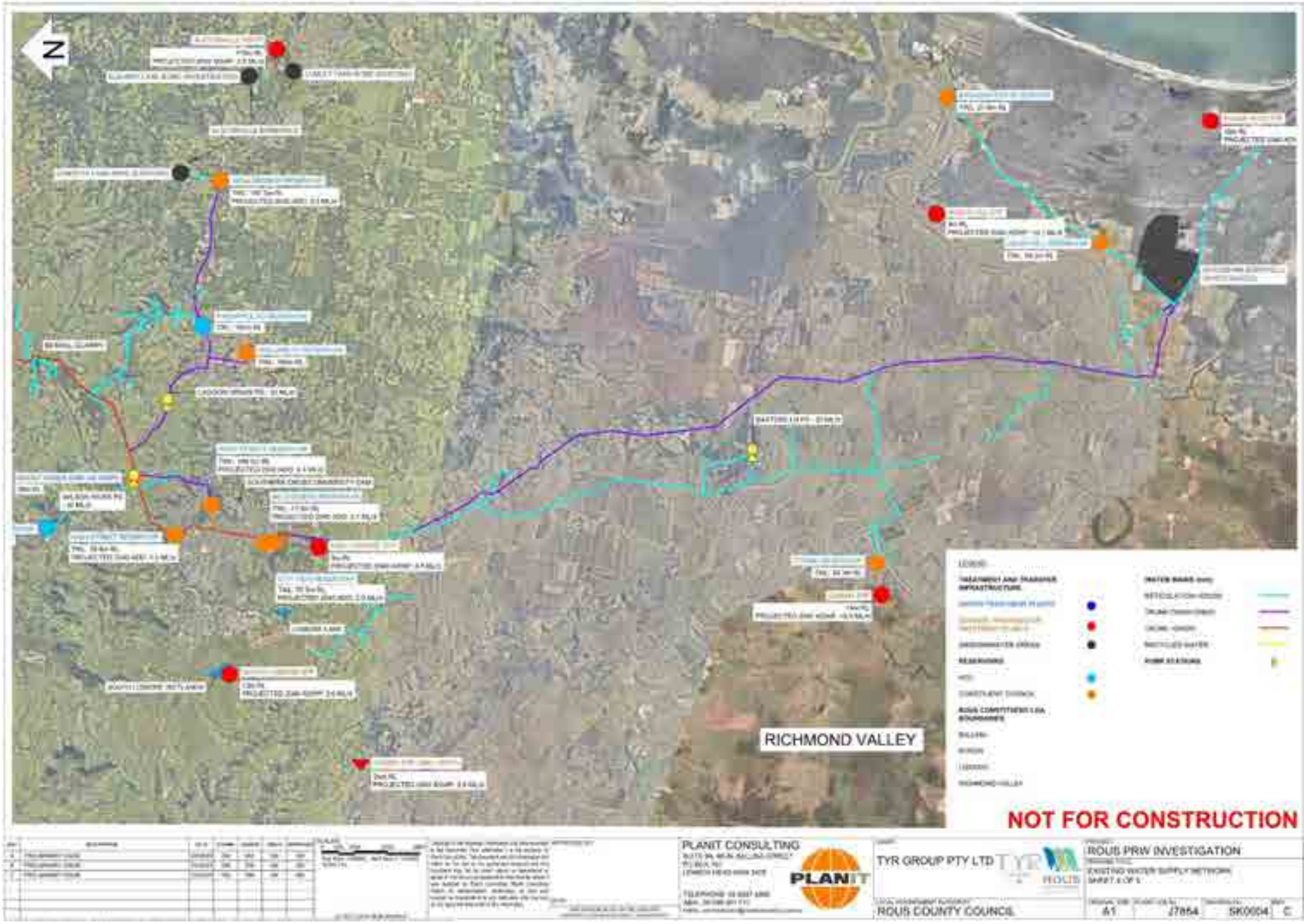

Figure 3-4: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 4 of 5

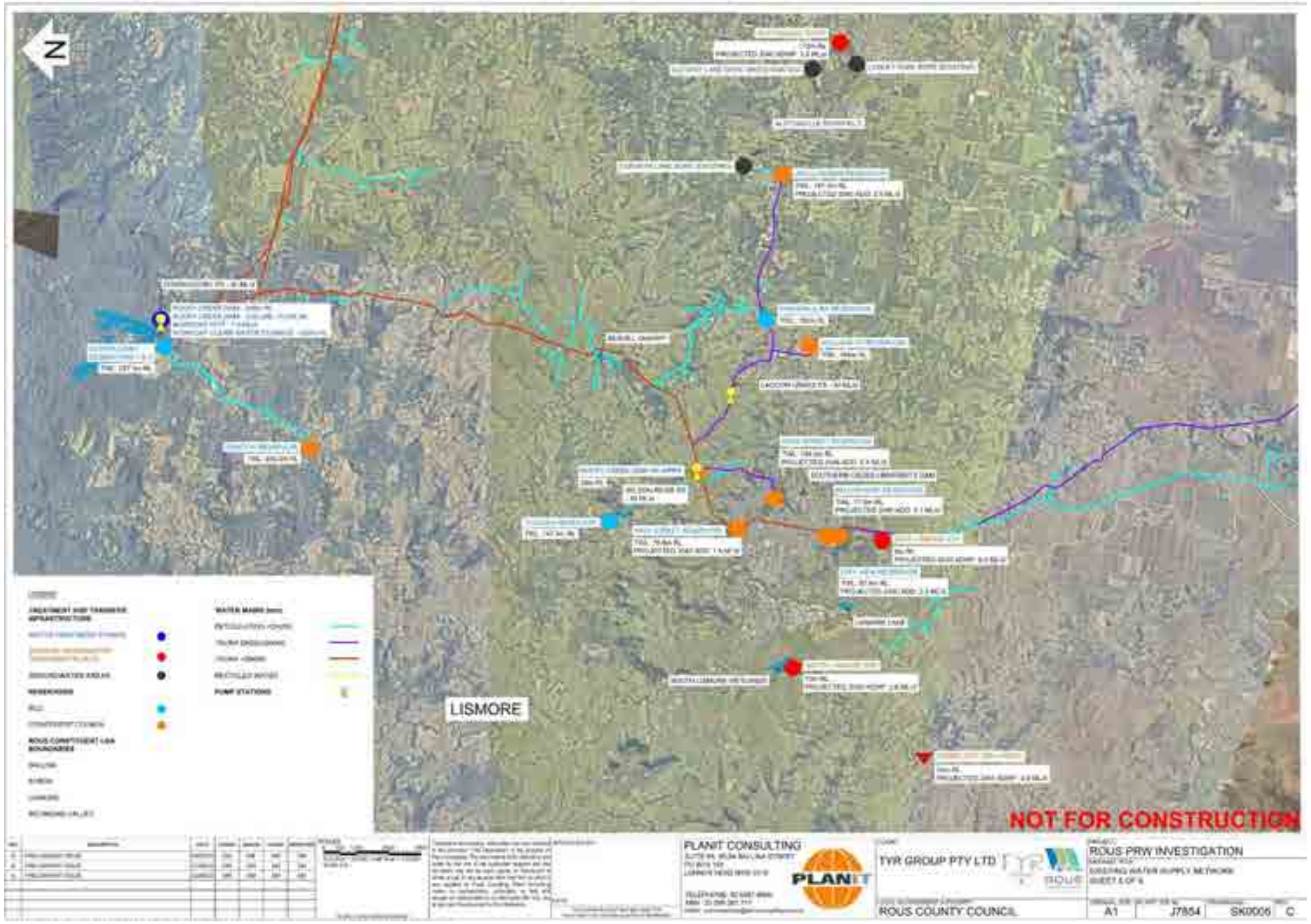

Figure 3-5: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 5 of 5

3.1.1 Ballina Shire Council

The four WWTPs within Ballina Shire Council were investigated as potential sources to supply potable reuse schemes. While flows from the Alstonville WWTP and Wardell WWTP were determined to be too low to be of value for potable reuse, the Ballina and Lennox Head WWTPs are of sufficient scale, and are discussed in Section 3.1.1.1 and 3.1.1.2.

3.1.1.1 Ballina WWTP

Ballina WWTP is projected to have an average dry weather flow (ADWF) of 8.1 ML/d in 2040. Effluent quality from Ballina WWTP based on historic plant data, summarised in Table 3-1, suggests this effluent is suitable for supply to a potable reuse scheme.

Table 3-1: Ballina WWTP Effluent Quality

Parameter	Median	90th Percentile
Biochemical Oxygen Demand	1 mg/L	2 mg/L
Ammonia	0.06 mg/L as N	0.16 mg/L as N
Total Nitrogen	4.8 mg/L	7.5 mg/L
Total Phosphorus	0.1 mg/L	0.3 mg/L
Total Suspended Solids	2.5 mg/L	6 mg/L
Fats, Oil and Grease	2.5 mg/L	6 mg/L
Thermotolerant Coliforms	10 cfu/100 mL	35 cfu/100 mL
pH	7.6 – 8.2	
Total Organic Carbon	7.5 – 19 mg/L	
Total Dissolved Solids	1,035 – 2,054 mg/L	
Electrical Conductivity	1,893 – 3,459 µS/cm	

As the TDS of Ballina WWTP effluent is in the range of 1,000 mg/L to 2,000 mg/L, RO-based treatment would be required for this source water. As the plant effluent is currently discharged to tidally influenced saline waters, the discharge of the concentrate stream from an RO-based AWTP is considered likely to be acceptable.

3.1.1.2 Lennox Head WWTP

The Lennox Head WWTP is projected to have an ADWF 5.3 ML/d in 2040. Effluent quality from Lennox Head WWTP based on historic plant data, summarised in Table 3-2, suggests this effluent is suitable for supply to a potable reuse scheme.

Table 3-2: Lennox Head WWTP Effluent Quality

Parameter	Median	90th Percentile
Biochemical Oxygen Demand	3 mg/L	4 mg/L
Total Nitrogen	6.6 mg/L	9.9 mg/L
Ammonia	0.5 mg/L as N	0.8 mg/L as N
Nitrate	4.9 mg/L	8.2 mg/L
Total Phosphorus	0.2 mg/L	0.4 mg/L
Total Suspended Solids	2.5 mg/L	2.5 mg/L
Fats, Oil and Grease	2.5 mg/L	2.5 mg/L
Thermotolerant Coliforms	4 cfu/100 mL	1,050 cfu/100 mL
pH	6.8 – 9.6 (90^{th} Percentile – 7.7)	
Total Organic Carbon	4 – 7 mg/L	
Total Dissolved Solids	240 – 461 mg/L	

As the TDS of the Lennox Head WWTP effluent is in the range of 200 mg/L to 500 mg/L, either carbon-based or RO-based treatment could be used for this source water. As the plant effluent is current discharged to the ocean, the discharge of the concentrate stream from an RO-based AWTP treating effluent from Lennox Head is considered likely to be acceptable.

3.1.1.3 Ballina Shire Council Non-Potable Reuse

Details of the current and planned non-potable reuse provided by Ballina Shire Council current and planned non-potable reuse indicate that a substantial portion of the secondary effluent from the Ballina and Lennox Head WWTPs is allocated to their non-potable reuse scheme. Ballina Shire Council staff have indicated that any diversion of effluent to a potable reuse scheme which constrains the availability of non-potable recycled water to their existing and future customers may be challenging due to:

- The long-standing commitment of Ballina Shire to non-potable reuse in recognition of community preferences to minimise the discharge of effluent to the environment, and,
- The substantial investment by the Ballina Shire Council and developers into infrastructure and systems for the treatment and reticulation of non-potable recycled water.

3.1.2 Byron Shire Council

The four WWTPs within Byron Shire Council were investigated as potential sources to supply potable reuse schemes. Flows from the Ocean Shores STP and Bangalow STP were determined to be too low to justify their inclusion. The Byron and Brunswick Valley STPs are of sufficient scale to warrant consideration, and are discussed in Section 3.1.2.1 and 3.1.2.2.

3.1.2.1 Byron STP

The Byron STP is projected to have an ADWF in 2040 of 6.6 ML/d. Effluent quality from Byron STP based on historic plant data, summarised in Table 3-3, suggests this effluent is suitable for supply to a potable reuse scheme.

Table 3-3: Byron STP Effluent Quality (Discharge to Wetlands)

Parameter	Mean	Maximum
Biochemical Oxygen Demand	1.3 mg/L	3 mg/L
Total Nitrogen	1.5 mg/L	3.9 mg/L
Total Phosphorus	0.1 mg/L	0.25 mg/L
Total Suspended Solids	5.6 mg/L	14 mg/L
Fats, Oil and Grease	1.1 mg/L	2 mg/L
Thermotolerant Coliforms	12 cfu/100 mL	113 cfu/100 mL
pH	7.0 – 7.3	
Electrical Conductivity Note 1	830 – 872 µS/cm	

Note 1: Electrical conductivity value is for the influent to Byron STP

The conductivity of the Byron STP effluent shown in Table 3-3 suggests a TDS on the order of 500 mg/L. Additional sampling conducted between November 15, 2023 and December 20, 2023 (six sample events), as discussed further in Section 5.2, indicates the Byron STP effluent TDS was generally below 500 mg/L. While further sampling would be required to confirm whether carbon-based treatment could be used for this source water the data currently available suggests that either carbon-based or RO-based treatment could be used for this source water.

Effluent from Byron WWTP is reused for irrigation of sporting fields and nurseries, parks and gardens, and in dual reticulation for toilet flushing in public and private bathrooms. Additionally, up to 400 ML/annum of plant effluent is reused through the Byron Bay Integrated Water Management Reserve, a combination of wetlands and Melaleuca Forest, and is utilised to mitigate acid sulphate solids, and wetland and catchment degradation [5].

Byron STP currently discharges the majority of its effluent to wetlands, which subsequently gravitates to the Union Drain (a man-made drain to the Belongil Creek Estuary). Water in the Union Drain and the upper portion of the Belongil Creek Estuary have low TDS (i.e. fresh water). As a result, any RO concentrate would need to be directed to a point in the Belongil Creek Estuary where the TDS is the same or higher concentration as the RO concentrate. This is discussed further in Section 11.1.1.

3.1.2.2 Brunswick Valley STP

The Brunswick Valley STP is projected to have an ADWF of 1.75 ML/d in 2040. Effluent quality from Brunswick Valley STP based on historic plant data, summarised in Table 3-4, suggests this effluent is suitable for supply to a potable reuse scheme.

Table 3-4: Brunswick Valley STP Effluent Quality

Parameter	Mean	Maximum
Biochemical Oxygen Demand	0.9 mg/L	2.7 mg/L
Total Nitrogen	1.3 mg/L	3.4 mg/L
Total Phosphorus	0.1 mg/L	0.14 mg/L
Total Suspended Solids	2.8 mg/L	8.4 mg/L
Fats, Oil and Grease	1.1 mg/L	3 mg/L
Faecal Coliforms	500 cfu/100 mL	55 cfu/100 mL
pH	6.8 – 7.8	

No historic data were available to determine the TDS of the Brunswick Valley STP. Additional sampling conducted between November 15, 2023 and December 20, 2023 (six sample events, as discussed further in Section 5.2) indicates the Brunswick Valley STP effluent TDS varied between about 400 mg/L and 600 mg/L. While further sampling would be required to confirm whether carbon-based treatment could be used for this source water the data currently available suggests that either carbon-based or RO-based treatment may be possible for this source water.

The Brunswick Valley STP discharges effluent to the Brunswick River (approximately 3 km upstream of the river mouth). No information on TDS concentration at the discharge point in the Brunswick River was available during the investigation. It may be possible to discharge RO concentrate at the STP discharge point (further investigation would be required to determine). If the TDS in the Brunswick River is too low for RO concentrate discharge to be acceptable, the concentrate would need to be piped downstream to a point where the prevailing TDS levels are suitably high.

3.1.3 Lismore City Council

The city of Lismore has two STPs, South Lismore and East Lismore. Both plants are of sufficient scale and hence are discussed in Section 3.1.3.1 and 3.1.3.2.

3.1.3.1 South Lismore STP

The South Lismore STP is projected to have an ADWF of 2.6 ML/d in 2040. Effluent quality from South Lismore STP based on historic plant data, summarised in Table 3-5, suggests this effluent is suitable for supply to a potable reuse scheme.

Table 3-5: South Lismore STP Effluent Quality

Parameter	Median	90th Percentile
Biochemical Oxygen Demand	1.0 mg/L	2.5 mg/L
Total Nitrogen	3.5 mg/L	5.0 mg/L
Ammonia	0.1 mg/L as N	3.1 mg/L as N
Total Phosphorus	0.2 mg/L	0.7 mg/L
Total Suspended Solids	0.9 mg/L	4.8 mg/L
Fats, Oil and Grease	1.8 mg/L	4 mg/L
Faecal Coliforms	45 cfu/100 mL	1,200 cfu/100 mL
pH	6.8 – 7.6	
Total Dissolved Solids	450 mg/L	490 mg/L
Electrical Conductivity	660 µS/cm	720 µS/cm

Based on historic data, and additional sampling conducted between November 2, 2023 and November 15, 2023 (three sample events, discussed further in Section 5.1) the TDS of the South Lismore WWTP effluent is below 500 mg/L. Hence either carbon-based or RO-based treatment could be used for this source water.

The South Lismore STP's inland location makes discharge of RO concentrate to the environment more challenging than for the Ballina and Byron plants. for the specific challenges related to RO concentrate discharge for this area are discussed further in Section 11.1.

3.1.3.2 East Lismore STP

The East Lismore STP is an inland plant that was fully inundated during a flood event in February and March of 2022. This event resulted in a series of temporary works being undertaken to re-establish the treatment process during 2022. As a result of the significant damage to the plant, East Lismore STP is expected to be upgraded, with a new treatment train providing sewage treatment on an elevated area of the existing site.

The East Lismore STP is projected to have an ADWF of 6.5 ML/d in 2040. Table 3-6 provides a summary of East Lismore STP's current effluent quality (noting that the future treatment process type and performance requirements are not currently confirmed.

Table 3-6: East Lismore STP Effluent Quality

Parameter	Median	95th Percentile
Biochemical Oxygen Demand	1.8 mg/L	5.4 mg/L
Ammonia	0.7 mg/L as N	2.6 mg/L as N
Total Nitrogen	6.3 mg/L	10.3 mg/L
Total Phosphorus	0.4 mg/L	1.2 mg/L
Total Suspended Solids	2.5 mg/L	10.4 mg/L
Fats, Oil and Grease	1.8	5.8 mg/L

The existing plant's effluent is substantially superior to that required under its environment protection licence and is suitable for supply to a potable reuse scheme. Effluent from the upgraded plant would generally be expected to be as good as (or better than) than that from the existing plant.

No historic data were available to determine the TDS of the East Lismore STP. Additional sampling conducted between October 23, 2023 and November 15, 2023 (four sample events) indicated the effluent TDS from the existing plant was below 400 mg/L. Further sampling would be required to confirm whether carbon-based treatment could be used for this source water, however based on the currently available data this investigation assumes that either carbon-based or RO-based treatment could be used for this source water (based on TDS).

The East Lismore STP's inland location makes discharge of RO concentrate to the environment more challenging than for the Ballina and Byron plants. The specific challenges related to RO concentrate discharge for this area are discussed further in Section 11.1.

3.1.4 Impact of Water Restrictions on Available Effluent Flows

While potable reuse primarily represents a "climate independent" water source, reductions in the effluent flow available for production of PRW due to drought and severe water restrictions are anticipated and will influence the secure yield delivered by the scheme options.

To estimate the impact of sustained dry weather on sewage flows, the minimum wastewater flows for each substantial plant have been estimated from the data provided by the constituent councils. In particular, the minimum monthly flows have been estimated (including during the severe drought period of 2019) and compared to the annual ADWFs over the longer term. Additionally, the available data was reviewed in an effort to estimate the impact of water restrictions on sewage flows. Table 3-7 summarises the indoor water saving measures for each level of water restrictions, and the impact on the available measured sewage flows during previous restriction periods. While the data available to support this analysis for the RCC service area are limited, the following key observations have been applied for this assessment:

- Level 1 and 2 Water Restrictions have a negligible impact on sewage flows. Review of the influent sewage flow data from the Ballina, Lennox Head, Byron and Brunswick Valley plants indicated higher dry weather flows during the Level 1 and Level 2 restriction periods of December 2019 through February 2022 than during the same months in the 2018-2019 and 2021-22 years. This is consistent with:
    - Level 1 and 2 Water Restrictions primarily targeting outdoor water use (which is expected to impact water demand without impacting sewer flows) rather than indoor water use, and,
    - The prevailing dry weather flow being much more strongly impacted by sustained infiltration than these water restriction measures.
- As water restrictions beyond Level 2 have not been applied in the RCC service area since 2003, it was not possible to correlate the impact of water restrictions beyond Level 2 to measured influent flow data for STPs in the RCC service area. However, as Level 3 does remains primarily focused on outdoor water use, it is not expected to result in substantial reductions in sewage flows (relative to changes in sustained sewer infiltration).

- Published data has been used to support estimates of the impact of water saving measures on sewage flows at each restriction level, including:
  - Flow records from Melbourne Water's two major wastewater treatment plants (Western Treatment Plant and Eastern Treatment Plant) for the period 2001-2009. Data from this period, as collated and reported in [6], including the sustained "Millenium Drought".
  - Data from six Californian (Bay Area) Wastewater Treatment Plants for the period 2000-2017, as collated and reported in [7]. This period included two droughts which extended over multiple years.
  - Data from the Inland Empire Utilities Agency's Regional Water Recycling Plant #1 (southern California) for the period 2011-2016, as collated and reported in [8]. This period showed a decline of 14% in wastewater flows to the plant associated with a Drought State of Emergency proclamation in January 2014.

Table 3-7: High-Level Estimate of Impact of Water Restrictions on Sewage Flows

Restriction Level Note 1	Target Demand Reduction	Residential and Non-Residential - Indoor Use	Additional measures for Non-Residential Uses	Previous Application Periods	Estimated reduction in wastewater flow from Baseline
Level 1: Moderate	2016: 5% Interim 2024: 7.5%	All users are requested to conserve water wherever possible.	Nil	Dec 4 to 19 2019	Negligible (flow higher in restriction period than same period in unrestricted years)
Level 2: High	2016: 15% Draft 2025: 15%		Water Management Plan to be prepared.	Dec 20, 2019 – mid-Feb 2020	
Level 3: Very High	2016: 25% Draft 2025: 22.5%		Consumption in accordance with approved Water Management Plan only.	Sep-Oct 2002	Assumed Negligible based on restrictions focussing on outdoor water use
Level 4: Severe	2016: 35% Draft 2025: 30%	Essential uses only.		Nov 2002 to Jan 2003	14% Assumed from Literature Data
Emergency	2016: 45% Draft 2025: 37.5%		Not Permitted	Feb-Mar 2003	18% Assumed from Literature Data

Note 1: Water restrictions primarily target outdoor water use at Levels 1-3, only water saving measures pertaining to indoor use listed

It is recommended that the variations in sewage flows, including the impact of severe water restrictions, be considered in determining the secure yield of any potable reuse scheme.

3.1.5 Summary of Estimated Effluent Available for Purified Recycled Water Production

Due to the relatively small scale of the STPs within the region (relative to the additional secure yield required from 2035-40), utilisation of flows from the two treatment plants in each of the three major population centres were initially considered to identify larger capacity schemes. Estimated maximum PRW production rates from these plants (independent of blend ratio limitations) are summarised in Table 3-8. Schemes utilising a single plant's effluent stream were considered as sub-options where relevant.

Table 3-8: Combined Treatment Plant Effluent Schemes - Estimated Maximum PRW Production Rates (independent of blend ratio limitations)

<table>
<tr><th colspan="2">Local Government Area</th><th>Lismore</th><th>Ballina</th><th colspan="2">Byron</th></tr>
<tr><td colspan="2">Effluent Sources</td><td>East Lismore STP
(6.5 ML/d)
+
South Lismore STP
(2.6 ML/d)</td><td>Lennox Head WWTP
(5.3 ML/d)
+
Ballina WWTP
(8.1 ML/d)</td><td colspan="2">Brunswick Valley STP Note 1
(1.75 ML/d)
+
Byron STW
(6.6 ML/d)</td></tr>
<tr><td colspan="2">Projected 2040 ADWF</td><td>9.1 ML/d</td><td>13.4 ML/d</td><td colspan="2">8.35 ML/d ADWF</td></tr>
<tr><td colspan="2">Non-potable reuse</td><td>Nil</td><td>Actual recent: 0.77 ML/d
Est. 2040 Target: 2.35 ML/d
2040 Peak Day Demand:
5.9 ML/d</td><td colspan="2">Actual recent: ~1.15 ML/d</td></tr>
<tr><td colspan="2">AWTP Type</td><td>Carbon based</td><td>RO based
(at 80% recovery)</td><td>RO based
(at 80% recovery)</td><td>Carbon based</td></tr>
<tr><td rowspan="3">Estimated Maximum Dry Weather PRW Production ADWF (without blending limitations)</td><td>With no non-potable reuse</td><td>9.1 ML/d</td><td>10.7 ML/d</td><td>6.7 ML/d</td><td>8.35 ML/d</td></tr>
<tr><td>With recent non-potable reuse</td><td></td><td>10.0 ML/d</td><td>5.6 ML/d</td><td>7.2 ML/d</td></tr>
<tr><td>With target non-potable reuse</td><td></td><td>8.4 ML/d</td><td></td><td></td></tr>
</table>

Note 1: Available effluent flow from Brunswick Valley STP could be up to 2.2 ML/d if flow from Ocean Shores STP is transferred to Brunswick Valley STP. For the purpose of this investigation the maximum PRW production rate does not consider the transfer from Ocean Shores STP to Brunswick Valley STP.

3.2 EXISTING SURFACE WATER SUPPLIES AND TREATMENT PLANTS

The RCC potable water supply system includes two significant existing surface water storages - Rocky Creek Dam which supplies Nightcap WTP, and Emigrant Creek Dam which supplies Emigrant Creek WTP. Nightcap WTP is additionally supplied with bulk water from the Wilsons River. The key attributes of these sources and plants are summarised in the following sections. Further information is provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A.

3.2.1 Rocky Creek Dam and Nightcap Water Treatment Plant

The Rocky Creek Dam is the main supply source for the RCC's potable water system, with the associated Nightcap WTP positioned to supply the entirety of RCC's potable water network.

Located inland, and at a higher elevation than all supply reservoirs in the region, the dam and its associated WTP comprise the only source in the region that are able to provide supply to all reservoirs in the bulk water supply network (excluding Casino).

Table 3-9 provides brief details of the Rocky Creek Dam and Nightcap WTP. The water quality within the dam is of note, with very low TDS and hardness, and low turbidity and nutrient concentrations.

Table 3-9: Rocky Creek Dam and Nightcap WTP [9]

Surface Water Storage	Rocky Creek Dam				
Full Supply Volume	13,524 ML				
Dead Storage Volume	150 ML				
Location	Whian Whian State Forest				
Indicative Elevation	187.1 m AHD at spillway				
Operating Principle	Always in use				
Environmental Release	Not Required				
Dam Water Quality	**Parameter**	**Units**	**5th Percentile**	**Average**	**95% Percentile**
	pH	pH Units	6.23	6.65	7.29
	Turbidity	NTU	1.2	2.5	3.8
	Total Hardness	mg/L as $CaCO_3$	5	5.8	7
	TDS	mg/L	28	34	39
	Conductivity	µS/cm	44	53	62
	Total Nitrogen	mg/L	0.3	0.4	0.5
	Total Phosphorus	mg/L	0.02	0.04	0.05
Water Treatment Plant	Nightcap WTP				
Treatment Type	pH correction→Dissolved Air Flotation in-Filter (DAFF)→Ozone→Biological Activated Carbon→Chlorine Disinfection				
Capacity	70 ML/d				

3.2.2 Emigrant Creek Dam and Emigrant Creek Water Treatment Plant

Emigrant Creek Dam acts as a secondary source of potable water in the RCC Region, providing potable water supply to the Ballina Shire Region through the Emigrant Creek WTP via Knockrow Reservoir when Rocky Creek Dam is below 95% of its storage capacity. The attributes of the dam and its associated WTP are summarised in Table 3-10.

Table 3-10: Emigrant Creek Dam and Water Treatment Plant [9]

Surface Water Storage	Emigrant Creek Dam				
Full Supply Volume	854 ML				
Dead Storage Volume	50 ML				
Location	Knockrow				
Indicative Elevation	62.3 m AHD at spillway				
Associated WTP	Emigrant Creek WTP (Existing Nominal Capacity 7.5 ML/d, Existing Actual Capacity 6.5 ML/d)				
Operating Principle	WTP brought online when Rocky Creek Dam reaches 95% storage				
Environmental Release	10 L/s				
Dam Water Quality	**Parameter**	**Units**	**5th Percentile**	**Average**	**95% Percentile**
	pH	pH Units	6.30	6.81	7.25
	Turbidity	NTU	1.9	6.6	12.4
	Total Hardness	mg/L as $CaCO_3$	14.4	19	23
	TDS	mg/L	52	66	77
	Conductivity	µS/cm	85	106	130
	Total Nitrogen	mg/L	0.3	0.6	1.1
	Phosphate as P	mg/L	0	0.03	0.03
Water Treatment Plant	**Emigrant Creek WTP**				
Treatment Type	Iron and Manganese Removal→pH Correction→Ultrafiltration Membrane→Ozone→Biological Activated Carbon→Chlorine Disinfection				
Capacity	7.5 ML/d Nominal, 6.5 ML/d Actual				

3.2.3 Wilsons River Source

The Wilsons River Source comprises:

- The Low Lift (Intake) Wilsons River Source Pump Station on the bank of the upper reaches of the Wilsons River tidal pool at Howards Grass;
- A small buffer tank and the High Lift (Intake) Wilsons River Source Pump Station, and,
- A 19.6 km pressure main from High Lift Pump Station to the inlet chamber of Nightcap WTP.

RCC's current licence entitlement for the Wilson River Source is 5,400 ML/annum (14.8 ML/d annual average), with extraction of water from the Wilsons River Source only occurring when Rocky Creek Dam is below 95% storage volume. There is currently no storage provided for water from the Wilsons River Source.

Rous County Council's licence to extract flow from the Wilsons River Source is limited based on the measured flow in the river, with differing volumes available to use in summer and winter periods. The peak extraction rate is capped at 30 ML/d. Table 3-11 summarises the permissible daily extraction volume from the Wilsons River based on the observed flow recorded at the Eltham Gauge under these scenarios.

Table 3-11: Wilsons River Source – Allowable Daily Extraction Volume [9]

Summer (September to February)		Winter (March – August)	
River Flow (ML/d)	Maximum Extraction to Nightcap WTP (ML/d)	River Flow (ML/d)	Maximum Extraction to Nightcap WTP (ML/d)
<29	0	<33	0
29-42	5	33-41	5
42-54	10	41-50	10
54-66	15	50-58	15
66 – 78	20	58-67	20
78-90	25	67-75	25
>= 90	30	>=75	30

The Wilsons River Source Pump Station comprises four pumps, with two pumps configured as single stage units (600 kW each) and two smaller pumps operating in series (375 kW each). With a standby pump available, the pump station can deliver up to 405 L/s (35 ML/d). Under test, the peak output of the pump station with all pumps operating was reported as 580 L/s (50 ML/d). However, it is understood that this peak flow rate can be realised in practice or sustained without an electrical upgrade at the site.

As summarised in Table 3-12, the typical water quality supplied to Nightcap WTP from the Wilsons River Source is substantially inferior to the water quality supplied from Rocky Creek Dam.

Table 3-12: Wilsons River Water Quality – January 2010 to March 2021 [10]

Parameter	Units	5th Percentile	Average	95th Percentile
pH	pH Units	6.6	7.2	7.7
Turbidity	NTU	6	15	34
Alkalinity	mg/L as $CaCO_3$	20	27	42
Total Hardness	mg/L as $CaCO_3$	15	21	32
TDS	mg/L	54	69	95
Conductivity	µs/cm	94	122	162
Total Nitrogen	mg/L	0.2	0.38	0.69
Total Phosphorus	mg/L	0.05	0.09	0.22

3.3 Surface Water Environmental Buffers

To support the identification of SWA options, consideration was given to:

- The two existing surface water storages utilised in the RCC potable water network - Rocky Creek Dam and Emigrant Creek Dam;
- Additional existing surface water storages in the RCC region, and;
- The potential for engineered surface water storages in the RCC region.

Relevant information related to each of these potential surface water buffers is summarised in the following sections. Further information is provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A.

The AGWR do not provide definitive direction of sizing requirements for environmental buffers, but provide the following general direction [2]:

Indirect augmentation schemes should be designed so that the time in receiving waters is sufficient to enable operators and regulators to assess recycled water treatment and recycled water quality and, where necessary, to intervene before water is supplied to consumers.

Assuming routine sampling of the PRW occurs monthly, a minimum retention time of 70 days has been applied for preliminary consideration of the minimum residence time in environmental buffers based on:

- 30 days between sampling events;
- 14 days to obtain laboratory results;
- 7 days to organise resampling if required;
- 14 days to obtain laboratory results for second sample event; and,
- 5 days contingency.

3.3.1 Rocky Creek Dam

While the Rocky Creek Dam would provide sufficient volume to act as an environmental buffer, there are several issues of concern to RCC with respect to implementation of an SWA scheme utilising the existing dam. Key amongst these, the criticality of Rocky Creek Dam as the primary water source for the vast majority of the region's water supply means RCC would be concerned by any PRW scheme that could potentially require cessation of supply from the dam as a corrective action. While SWA to primary water sources occurs in a number of large-scale IPR schemes, RCC has elected to not carry this forward for detailed consideration on a risk basis.

The most promising schemes for SWA of Rocky Creek Dam are from the Lismore WWTPs due to shorter transfer distances, and large-scale savings in transfer infrastructure through utilisation of the existing Wilson River Source pipeline and pump station.

However, utilising Rocky Creek Dam for surface water augmentation of PRW produced in Lismore would be complicated by:

- The very high water quality in the dam, which would require detailed analysis and modelling to ascertain the impacts on the prevailing ecology of adding PRW at different temperature, salinity, and nutrient levels;
- The need to mitigate co-mingling of PRW and the Wilsons River Source water, which would impose water quality risks to any proposed SWA augmentation scheme. The Wilsons River Source is not a protected catchment, and therefore any transfer of Wilsons River Source water into Rocky Creek Dam would likely be unacceptable.
- The cost and complexity of additional treatment to improve the water quality of the Wilsons River Source water to a level required to make it acceptable for discharge to the Rocky Creek Dam.
- The ownership of the land surrounding the dam, and the associated difficulties in placing new pipework through areas with such high environmental values, and,
- The potential for additional challenges in discharge of PRW from a carbon-based AWTP to the dam (in the absence of detailed modelling and analysis). The Lismore schemes do not have a clear avenue for RO concentrate disposal, making RO-based treatment less viable. For carbon-based treatment there will less ability to mitigate the salt content and nutrient levels of the produced PRW water, and therefore limited ability to adjust the baseline water quality should the modelling identify it as problematic in terms of the prevailing ecology.

While SWA to Rocky Creek Dam has not been short-listed for detailed consideration as part of this investigation, surface water augmentation to the Rocky Creek Dam from PRW produced in the Byron STPs has been carried forward for higher level consideration (see Section 4).

3.3.2 Emigrant Creek Dam

Based on a PRW production rate of 8 ML/d, the current capacity of Emigrant Creek WTP of 6.5 ML/d, and a minimum required environmental flow of 0.8 ML/d (see Section 3.5), the maximum sustained total outflow from the dam could be up to 15.3 ML/d. At this throughflow, the theoretical retention time would be 55 days when the dam is 100% full. Hence, at this maximum throughput, the dam would be insufficient to provide the minimum 70-day theoretical retention time under this scenario.

An alternative approach could include using PRW to replenish the dam when natural inflow is low. For this scenario, assuming the outflow is equivalent to the current WTP capacity plus the minimum environmental flow, and the inflow is only PRW, the dam would provide 70 days of theoretical retention time until dam levels drop to 70% full. At less than 70%, the dam would need to be operated in a batch mode to ensure the minimum 70-day criteria is met. This has potential to negatively impact yield from the dam.

As an additional challenge, it is noted that the Emigrant Creek WTP site is very constrained, likely adding complexity and cost to any upgrade to the plant.

For the purposes of this investigation, use of Emigrant Creek Dam as an environmental buffer as part of a SWA scheme is not considered viable due to the small available volume in the dam (and challenges with upgrading the Emigrant Creek WTP due to site constraints).

3.3.3 Additional Existing Surface Waters

The investigation also considered the following existing surface waters for potential use in potable reuse schemes in the RCC region:

- Lismore Lake;
- Bexhill Quarry;
- South Lismore Wetlands;
- Byron Wetlands; and,
- Byron Creek located between St Helena and the Wilsons River.

None of the above listed surface waters have been recommended for inclusion in any of the potable reuse schemes (refer to the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A for further details).

3.3.4 Engineered Off-Stream Storages

As noted in Sections 3.3.1 and 3.3.2, the criticality of Rocky Creek Dam and the small scale of Emigrant Creek Dam means there is limited scope to use existing dams to provide an extended failure response time without imposing risks on the existing secure yield from those systems. Where an extended failure response time is required (i.e. under traditional IPR), then off-stream storages could be specifically engineered to provide an extended delay between supply of PRW to the storage system and subsequent supply to customers.

Given the regional nature of Rous County, there are expected to be multiple locations of limited ecological value (such as cleared grazing land) where an engineered environmental buffer storage could be constructed. RCC has completed high-level investigations to estimate costs for an engineered off-stream storage in the general vicinity of the Wilsons River Source. RCC has determined that, "based on the rudimentary cost estimates, it can be inferred that the business case for this kind of environmental buffer would not be supportable purely based on a PRW scheme. However, if such a water storage was to exist in future, it could potentially enable a PRW scheme."

The construction of large off-stream storages has been specifically considered in one of the options at this stage – primarily to retain an IPR option with potential to align with the expectations of the existing AGWR [2]. Despite this, it is important to note that:

- The additional approvals and construction works associated with large new storages may impose significant additional challenges and costs as compared to an IPR scheme that utilises an existing storage.
- Practices in potable reuse internationally are moving towards somewhat increased robustness in treatment design in combination with small engineered storages (i.e. T_{10} of 30-60 minutes). From cost and environmental perspectives, a DPR scheme is likely favourable to an IPR scheme that requires construction of a purpose-built environmental buffer.

3.4 Groundwater Environmental Buffers

Existing and planned groundwater schemes were reviewed for potential suitability for IPR via groundwater augmentation. Further information is provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A. This review included groundwater schemes utilising the following aquifers:

- Alstonville basalt aquifer;
- Clarence Moreton basin;
- Woodburn aquifer;
- Newrybar aquifer; and,
- Tyagarah coastal sand aquifer.

Based on the information in hand, none of the existing and planned groundwater schemes in the region appear suitable for short-listing of groundwater augmentation options (the short-listing process is discussed in Section 4).

While groundwater is part of RCC's water supply strategy, the aquifers are not expected to be routinely depleted when operated as bulk water supply sources based on power the available information currently available., As a result, artificial recharge through groundwater augmentation with PRW appears unlikely to provide a clear benefit. If groundwater sources become more heavily utilised in future, then potential benefit of groundwater augmentation can be reconsidered. Section 25.1.2 discusses a potential option for a groundwater augmentation scheme for the Tyagarah aquifer.

It is recommended that an ongoing watching brief for groundwater replenishment with PRW be considered as additional information on the groundwater resources and utilisation of these resources becomes available.

3.5 ENVIRONMENTAL FLOW SUBSTITUTION OPPORTUNITIES

Opportunities for environmental flow substitution using PRW have been reviewed for:

- Rocky Creek Dam – which has no specific requirement for environmental flow releases under its current water access licence.
- Emigrant Creek Dam – which is required to provide visible flow (at Tintenbar downstream of the dam) when flow is entering the dam. At present, a flow of ~10 L/s is provided outlet pipe at the base of the dam [1]. RCC operations have also indicated that there are ongoing losses through the dam wall. Given the impacts of the limited flow release from the dam in dry weather periods, it is not expected that any substantial additional sustainable yield would be able to be provided from Emigrant Creek Dam via environmental flow substitution.
- The Wilsons River Pump Station - As indicated in Section 3.2.3, the volume that may extracted from the Wilsons River Source for use in the potable water network is governed by the flow in the river system as measured at the Eltham Gauge. As the two STPs in close proximity to the Wilsons River Source Pump Station (South and East Lismore STPs) are currently discharging their treated effluent to the Wilsons River downstream of the abstraction point (effectively providing environmental flows to the river), RCC does not expect that access licences for additional sustainable yield from the Wilsons River Source Pump Station would be granted for environmental flow substitution to the Wilsons River.

Overall, the review found no opportunities for environmental flow substitution suitable for further assessment. Further information is provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A.

3.6 EXISTING AND PLANNED BULK SUPPLY NETWORK

The major existing potable water distribution infrastructure in the region is shown in Figure 3-1 through 3-5 (above).

In considering options based on TWA, the size, throughflow and connectivity of the existing reservoirs are of key interest. In determining the most suitable reservoirs for TWA, consideration was given to all reservoirs within the network, however only those listed in Table 3-13 have the capacity and throughflow to be considered viable (with the major four parallel reservoirs in Lismore considered on a combined basis).

Table 3-13: Major Reservoirs Considered for Treated Water Augmentation

Characteristic	LGA					
	Lismore Reservoirs				Ballina Reservoir	Byron Reservoir
	Ross St	City View	High St	Belvedere Dr.	Knockrow	St Helena
Volume	6.56 ML	9.05 ML	4.36 ML	3.4 ML	10.4 ML	9.05 ML
	23.4 ML (combined)				19.45 ML (for St Helena with Knockrow backfeed)	
Elevation (TWL)	RL 145.3m	RL 97.5m	RL 76.8m	RL 77.9m	RL 104.8m	RL 115.8m
Projected 2040 Average Daily Demand	3.4 ML/d	2.98 ML/d	1.47 ML/d	2.98 ML/d	13.2 ML/d	8.95 ML/d
	10.8 ML/d with all four main reservoirs 7.4 ML/d without Ross St				22.15 ML (for St Helena with Knockrow backfeed (or vice-versa))	

For each of these regions, the reservoirs identified in Table 3-13 form the key supply points for the major demand points of the RCC region, servicing Lismore, Ballina and Byron respectively. The Lismore reservoirs have the additional benefit of servicing Woodburn, Evans Head, Broadwater and Coraki via the City View reservoir.

Additional features of RCC's potable water network, including opportunities to provide additional supply in locations that service multiple demand areas, have been considered. The key opportunity identified to provide this broader supply was via backfeed of Knockrow Reservoir from Saint Helena reservoir. This was indicated as worthy of further investigation by RCC.

Further details of the assessment of the system reservoirs are provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A.

4 IDENTIFICATION AND ASSESSMENT OF REUSE SCHEMES

This section summarises the outcomes of the options identification and short-listing process. Full details are provided in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A.

Based on the information developed during the initial investigation, as summarised in Section 3, a long list of forty potable reuse scheme options was developed, considering:

- Source water drawn from each individual viable WWTP identified, and for each pair of potential source WWTPs in each LGA (as a combined source with one AWTP treating flow from both plants); and,
- All potential forms of indirect and direct potable reuse - groundwater augmentation, surface water augmentation, raw water augmentation and treated water augmentation.

Using the outcomes of the investigations summarised in Section 3, the forty scheme options were subjected to an initial coarse-level assessment using a spreadsheet tool developed by RCC. The tool systematically applied a series of criteria to identify the most promising schemes based on quantitative and semi-quantitative assessment of:

- PRW which can be generated, with:
  - A target capacity of 8 ML/d with no constraints in regard to the blend ratio in the receiving stream, and,
  - A target capacity of 5 ML/d with a maximum blend ratio of 50% in the receiving stream.
- Capacity of downstream system to accommodate and utilise the PRW; and,
- New pipeline and pump stations requirements for transfer of PRW.

Additionally, coarse assessment considered the following potential challenges for each scheme on a non-cost basis:

- Proximity to the ocean for discharge RO concentrate from an RO-based AWTP; and,
- Potential suitability of a carbon-based AWTP process train (specifically based on the TDS and pollutant levels in the STP effluent stream).

The coarse-level assessment provided a general guide to the selection and short-listing of options, and informed the manual development and detailing of a list of fourteen baseline options for consideration during the Scheme Option Identification, Review and Short-Listing Workshop ("Short-Listing Workshop"). The Short-Listing Workshop was held on July 11, 2023 and attended by RCC stakeholders and representatives from Tyr Group, Planit, IBL Solutions, BMT and Carollo.

Following further refinement using the outcomes of the Short-Listing Workshop, the baseline options were categorised into the following three levels:

- **Level 1** – Option carried forward and quantitatively and qualitatively developed as part of the PRW Investigations project.
- **Level 2** – Option carried forward at a high level – partial option development (approximation of pipelines and AWTP process train requirements and costs, qualitative discussion of opportunities and risks, including considerations of infrastructure costs, complexities and risks relative to Level 1 options). Option is considered have potential to meet the main aims of a potable reuse scheme for RCC, but with substantial barriers reducing likely viability compared to Level 1 options.
- **Level 3** – Option not carried forward for this investigation. Low or limited viability based on information in hand.

The baseline schemes, classified into the above three levels, are shown in Table 4-1. Options categorised as Level 1 are shown diagrammatically in Figure 4-1 through Figure 4-4 (Note: these figures have been updated to capture changes since completion of the *Potable Reuse Scheme Identification and Short-Listing Memorandum*).

Table 4-1: Classification of Baseline Potable Reuse Scheme Options

Scheme Type	LGA		
	Ballina	Byron	Lismore
	Source Plants		
	Ballina STP/Lennox Head STP	Byron STW/ Brunswick Valley STW	East Lismore STP/ South Lismore STP
Ground Water Augmentation (IPR by groundwater augmentation - in line with AGWR 2008)	**Level 3 – Not carried forward for this investigation** Long distance or elevation to known aquifers. Benefit or value of aquifer augmentation not clear or considered likely based on information in hand. Consultation required on emergency conditions as limited effluent available for PRW production based on established Ballina planning and focus on non-potable reuse.	**To Tyagarah aquifer:** **Level 2 – High level consideration** Not clear whether Tyagarah aquifer will be developed as a source, or the value/need for augmentation. Apply watching brief to Tyagarah aquifer. Consideration based on RO-based AWTP option for BDOC reduction.	**Level 3 – Not carried forward for this investigation** Long distance or elevation to known aquifers. Benefit or value of aquifer augmentation not clear or considered likely based on information in hand.
Surface Water Augmentation (IPR-SWA in line with AGWR 2008)	**Ballina / Lennox to ECD:** **Level 3 – Not carried forward for this investigation** ○ ECD likely too small to meet the Regulatory expectations for ""indirect augmentation"" without relatively complex ""batch operation"" of the dam. Given the implications of this for existing ECD secure yield and utilisation of PRW infrastructure, not considered likely to be viable. ○ Large engineered storage to provide hydraulic retention time required for IPR under existing guidelines not likely to be cost effective compared to other areas.	**Byron / Brunswick Valley to RCD via pipeline:** **Level 2 – High level consideration** Included as comparison point for RO-based AWTP with pipeline back to RCD for nominal fit to requirements of AGWR 2008	**To Rocky Creek Dam via Wilson River Source Pump Station, co-treatment with Wilson River water:** **Level 2 – High level consideration** Considered unsuitable by RCC on risk to RCD source. Discuss additional hurdles to implementation.
		Byron / Brunswick Valley to ECD: **Level 3 – Not carried forward for this investigation** Could be considered to Emigrant Creek Dam as element of scheme if Byron source otherwise viable.	**New engineered storage as environmental buffer.** **Level 1 – Carry forward for further development** New engineered storage also provides potential for improved utilisation of Wilson River Source, improving viability.
		Byron / Brunswick Valley to RCD via Byron Creek: **Level 3 – Not carried forward for this investigation** Meaningful advantage to permitted take from the Wilsons River Source unlikely.	
Raw Water Augmentation (DPR-RWA)	**To Emigrant Creek WTP:** **Level 2 – High level consideration** With augmentation to WTP as required to maintain existing source secure yield. Not adopted as Level 1 based on high target for utilisation of source water for non-potable reuse by Ballina Shire Council and limited site area within existing Emigrant Creek WTP.	**Level 3 – Not carried forward for this investigation** Long distances to existing WTPs. Could be considered if Tyagarah Aquifer WTP is developed. Limited value over TWA option.	**To Nightcap WTP via Wilson River Source Pump Station and Pipeline, co-transfer with Wilson River water:** **Level 1 – Carry forward for further development**
Treated Water Augmentation (DPR-TWA)	**To Knockrow Reservoir:** **Level 2 – High level consideration** Not adopted as Level 1 based on high target for utilisation of source water for non-potable reuse by Ballina Shire Council and lower blend ratio available than anticipated for Byron option.	**To St Helena Reservoir with reverse flow in existing main to Knockrow Reservoir:** **Level 1 – Carry forward for further development**	**To main Lismore reservoirs:** **Level 1 – Carry forward for further development** Utilise existing mains from Woodlawn for City View, High Street, and Belvedere Drive and new line to Ross St, OR New connection from AWTP at East Lismore Site to City View with feed from there to Belvedere, City View and Ross St.
Environmental Flow Substitution	**Level 3 – Not carried forward for this investigation** Not viable for providing additional source water due to limited environmental flow requirements for Rocky Creek and Emigrant Creek.		

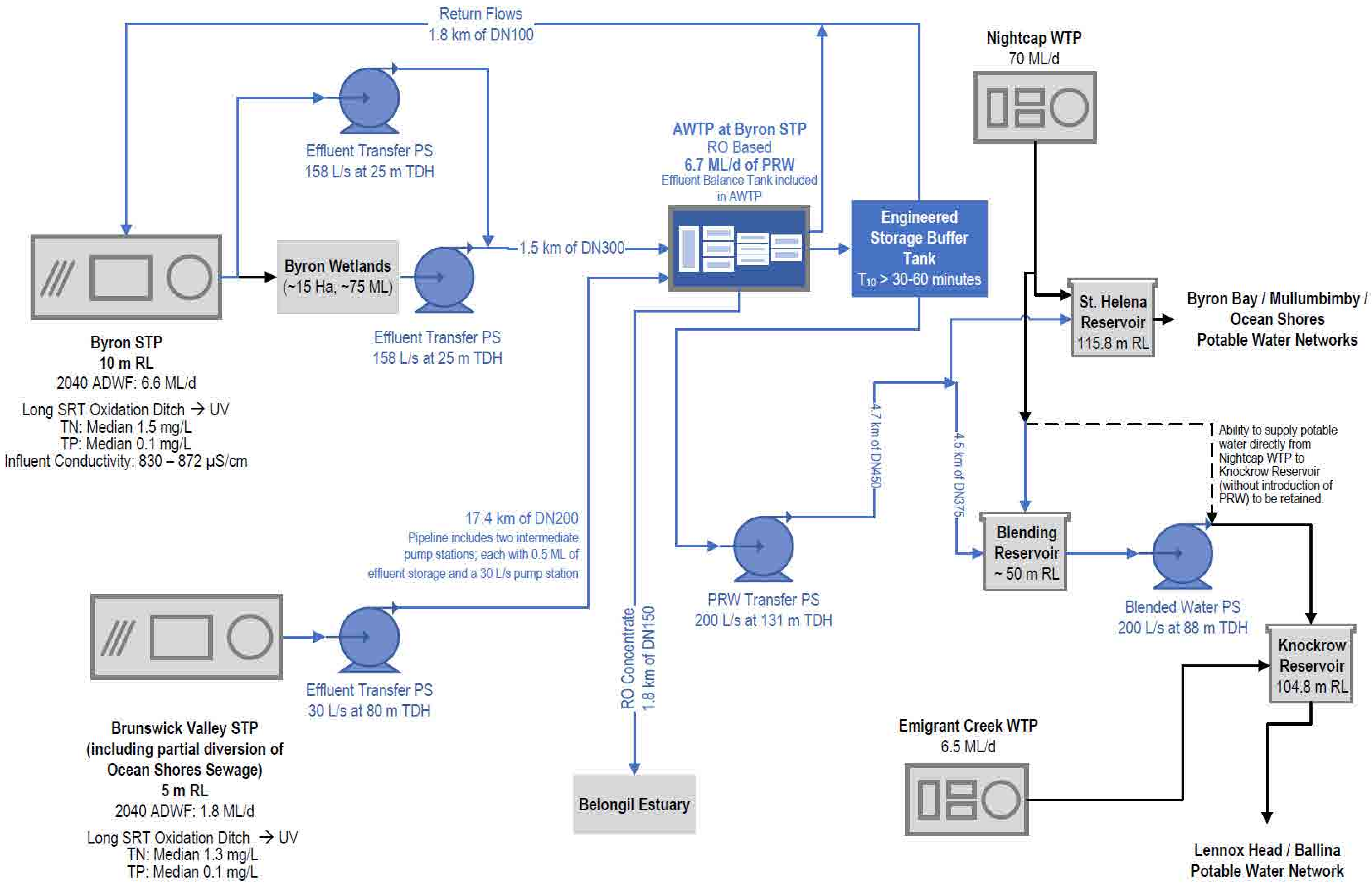

Figure 4-1: Byron STP/Brunswick Valley STP Effluent to Treated Water Augmentation

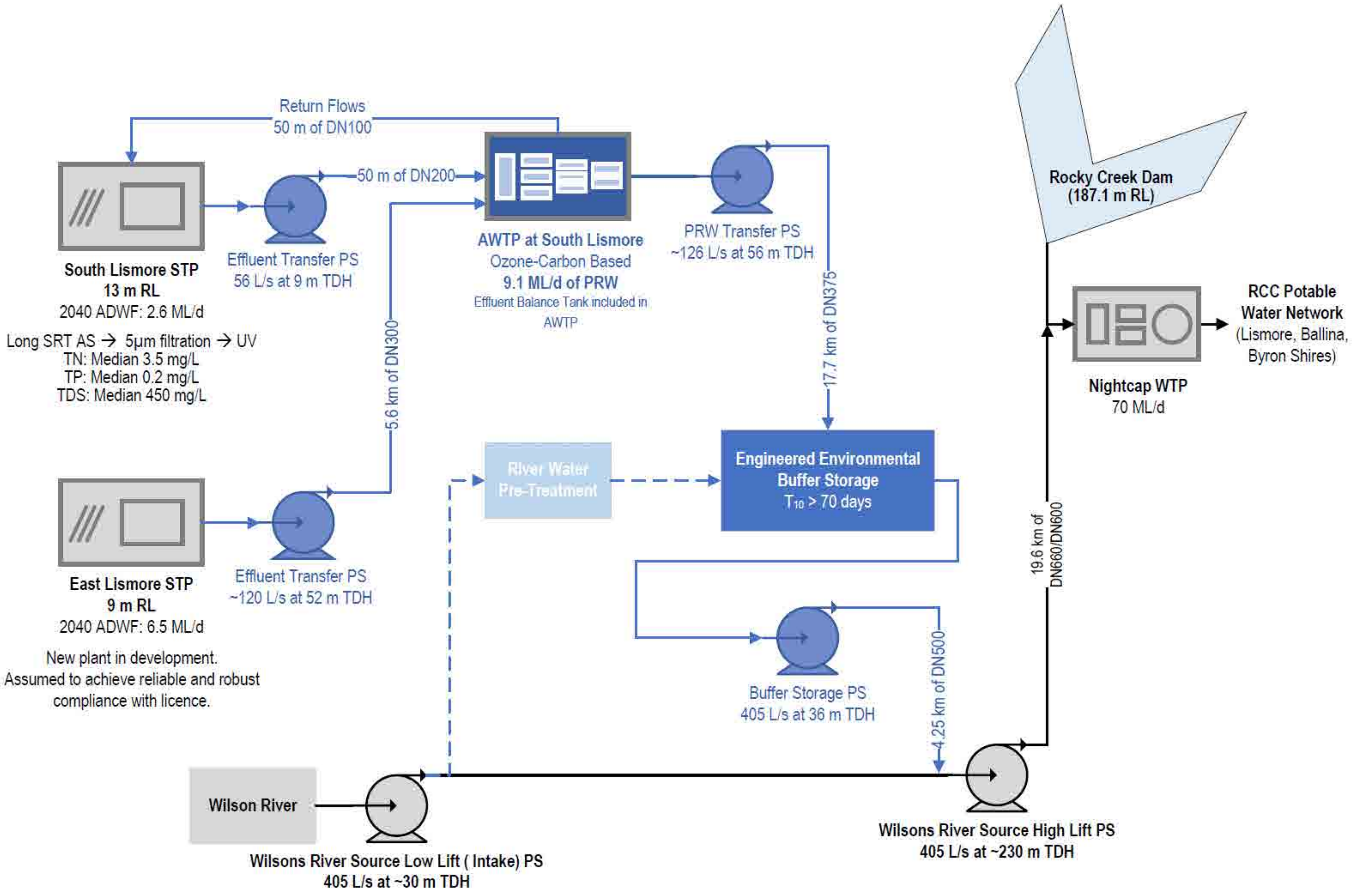

Figure 4-2: South Lismore STP / East Lismore STP Effluent to Surface Water Augmentation – Co-storage and co-transfer with Wilsons River Source

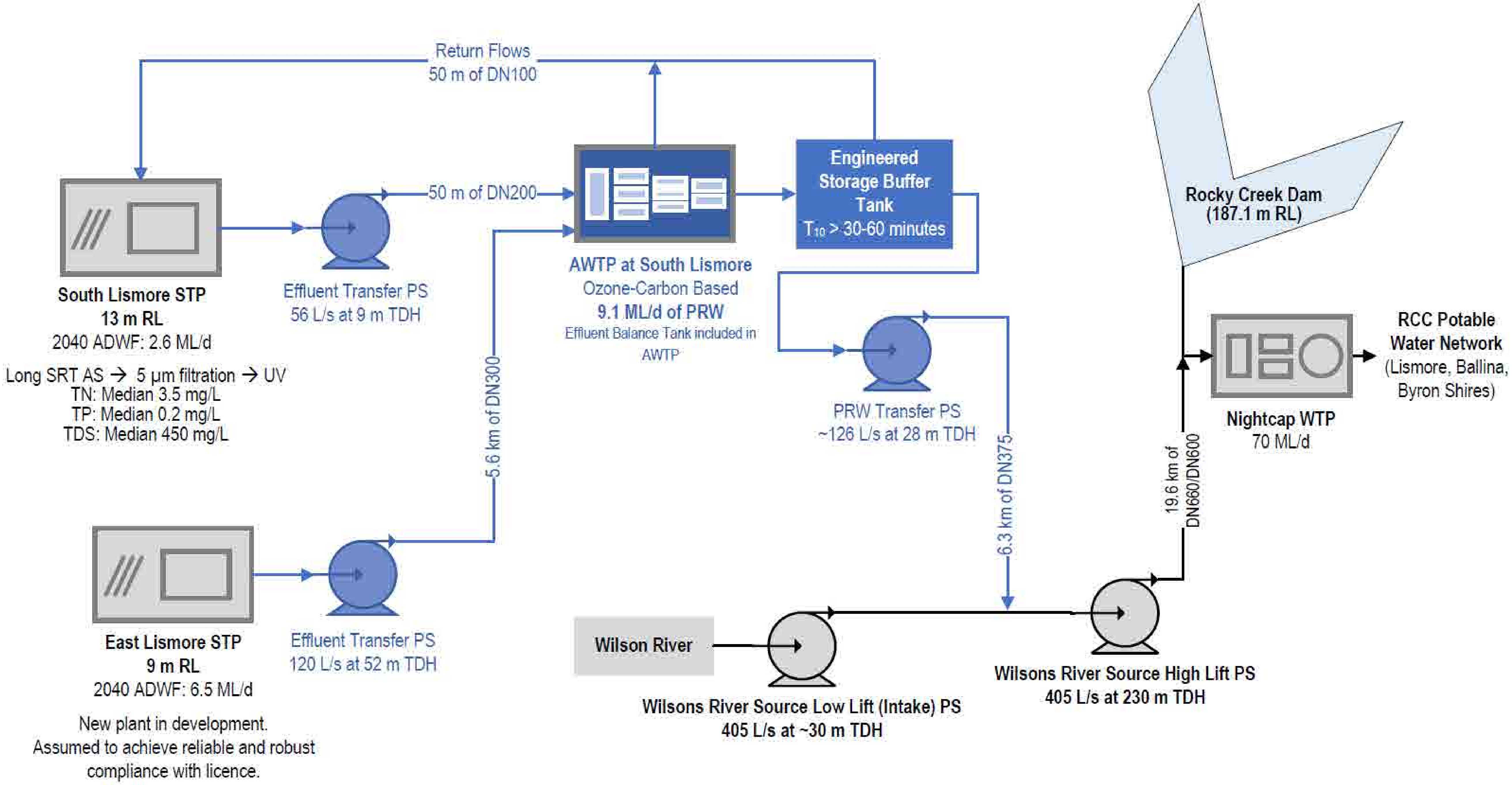

Figure 4-3: South Lismore STP / East Lismore STP Effluent to Raw Water Augmentation

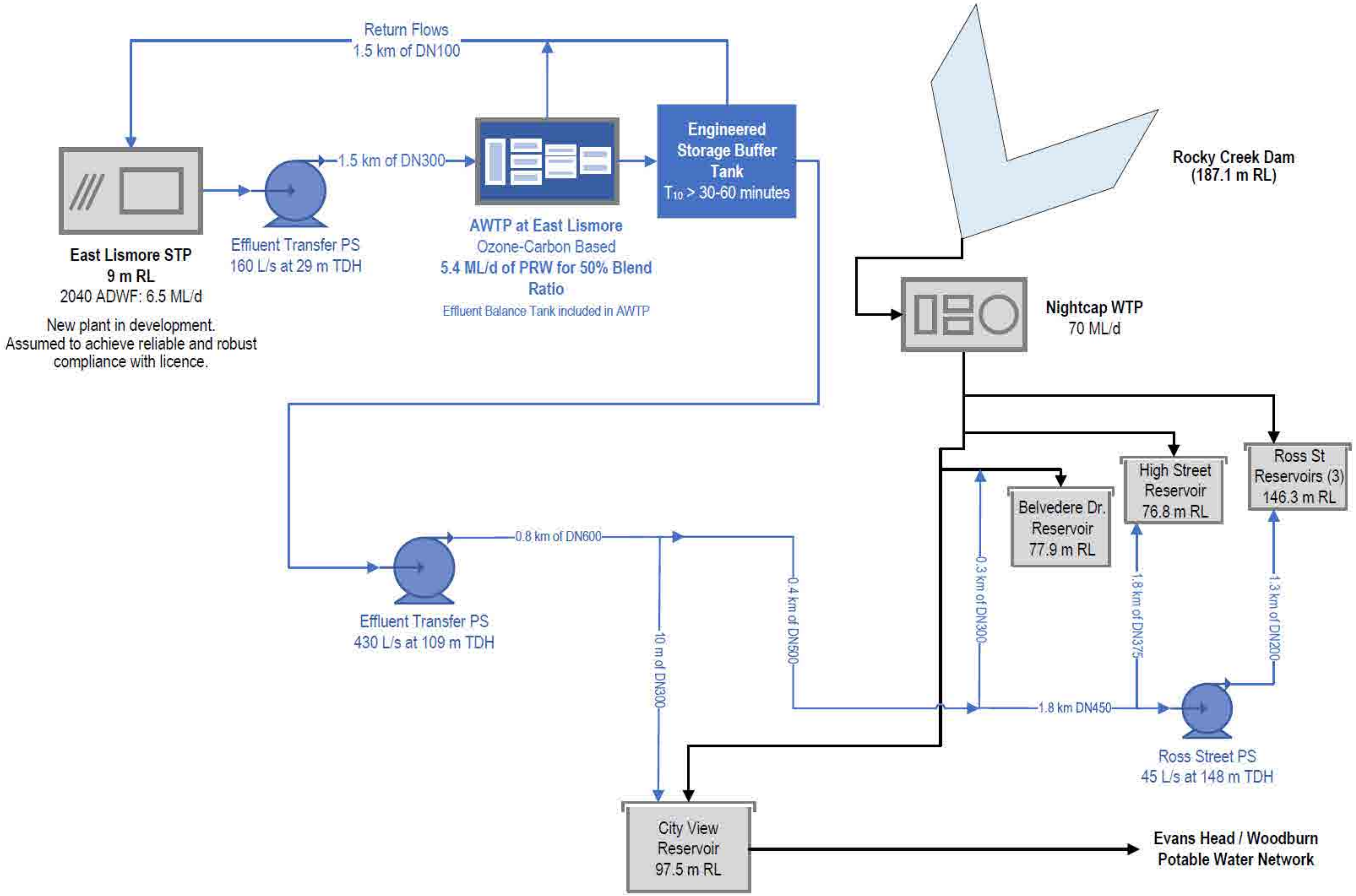

Figure 4-4: South Lismore STP / East Lismore STP Effluent to Treated Water Augmentation

5 ADDITIONAL SAMPLING OF SEWAGE TREATMENT PLANT EFFLUENT

Sampling programs were developed to gather additional information on effluent quality from the plants identified in "Level 1" short listed options - Byron STP, Brunswick Valley STP, South Lismore STP and East Lismore STP. Each analyte was selected for its relevance to the planning of a potable reuse scheme. Where historic STP effluent quality data were available for parameters that were included in this additional sampling campaign, these historic valves are also listed in Table 5-1 through Table 5-5.

Byron Shire Council conducted sampling (six sample events) between November 15, 2023 and December 20, 2023 and Lismore City Council conducted sampling between October 23, 2023 and November 15, 2023 (three sample events for South Lismore STP and four sample events for East Lismore STP). The results of the sampling are summarised in Section 5.1 and 5.2, with full results included in Appendix B.

5.1 LISMORE CITY COUNCIL STPS

Results were obtained from four effluent sampling events at East Lismore STP (on October 23, November 2, 9 and 15, 2023) and from three events at South Lismore STP (on November 2, 9 and 15, 2023). Sampling was ceased in late November at both plants due to wet weather events and subsequent holidays.

Table 5-1 and Table 5-2 summarise the analytes measured during this sampling programme at East Lismore STP and South Lismore STP respectively.

TDS concentrations averaged 322 mg/L at East Lismore STP and 391 mg/L at South Lismore STP. No individual values were above 430 mg/L in either plant's effluent within this sample set.

Other parameters in this dataset that are instructive in the evaluation of carbon-based treatment include total organic carbon (TOC), dissolved organic carbon (DOC), nitrite and bromide. TOC and DOC are useful for the estimation of ozone demand (and hence sizing of ozone generation equipment). Nitrite reacts with ozone and hence needs to be taken into account in determining ozone dose requirements (and hence sizing of ozone generation equipment). Bromide reacts with ozone to produce the disinfection byproduct bromate.

The TOC at both facilities was consistently less than 10 mg/L, with the exception of one sample from East Lismore STP measuring 15.5 mg/L (on November 15, 2023). This higher TOC result corresponds to a high total suspended solids (TSS) measurement of 75 mg/L. The high TSS value also corresponds to high concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, total phosphorus and aluminium, as well as high turbidity. The reason(s) for this higher TSS result, and corresponding other high results noted previously, are unclear[8]. The summary statistics shown in Table 5-1 exclude results from November 15, 2023 for TSS, turbidity, BOD, COD, total nitrogen, total phosphorus, TOC and aluminium.

The TOC concentrations measured in the East Lismore STP and South Lismore STP effluent are in a typical range and should pose no significant issues with respect to use of ozone. Nitrite levels for East Lismore are higher than expected and would need to be accounted for in the estimation of ozone dose, noting that this plant is scheduled to be replaced and the new plant would likely be designed to achieve full nitrification (and hence lower nitrite concentration). Bromide levels are not unexpected and will need to be considered in the design development of the system (in particular for the Lismore IPR and DPR via raw water augmentation options where the PRW would be dosed with ozone a second time as it is treated through Nightcap WTP).

A selection of inorganic parameters was also included in the analysis (e.g. metals), as these can be used to assess scaling risk in membrane system (mainly in RO systems, but they do need consideration in the design of UF as well). None of the results for these parameters raise any significant concerns with respect to design of a membrane system.

[8] The high TSS value could be related to high TSS in the plant effluent or could be related to an issue with sample collection. The day the sample was collected was not associated with a wet weather event,

Where historic data are available for comparison to the sampling program results, the sampling program did not highlight any significant discrepancy from historic data. To this end, none of the results from the additional sampling programme change any previous conclusions drawn from the historic data.

Table 5-1: East Lismore STP – Effluent Sampling Programme Results Historic Data

Parameter	Units	Sampling Programme Data, Oct/Nov 2023 (4 samples)		Historic Effluent, Dec 2011 – Mar 2022 (>400 samples)	
		Mean	Max	Mean	95th Percentile
Conductivity	µS/cm	660	831	640	770
Total Suspended Solids Note 1	mg/L	9	20	4	11
Algal Biomass	mg/L	1.0	1.4		
Total Suspended Solids less algal biomass (calculated) Note 2	*mg/L*	*9*	*19*	*3*	*9*
BOD_5	mg/L	10	15	2	5
COD	mg/L	29	37		
Oil and Grease Note 3	mg/L	ND	-	3	6
pH		7.5	7.8	7.5	7.8
Total Dissolved Solids	mg/L	447	565	434	524
Turbidity	NTU	5	10		
Total Phosphorus	mg/L	0.6	0.9	0.5	1.2
Phosphate as P	mg/L	0.3	0.5	0.4	0.9
Total Nitrogen	mg/L	4.9	5.4	6.6	10.3
Total Kjeldahl Nitrogen	mg/L	1.4	2.0		
Organic Nitrogen (calculated)	*mg/L*	*3.3*	*4.7*		
Nitrite as N	mg/L	0.3	0.4		
Nitrate as N Note 4	mg/L	3.0	3.8	4.0	6.6
Ammonia as N	mg/L	0.3	0.5	1.0	2.6
UV Transmissivity	%	67.2	74.6	69	79
Total Organic Carbon	mg/L	7	8		
Dissolved Organic Carbon	mg/L	6	8		
Total Alkalinity as $CaCO_3$	mg/L	110	123		
Aluminium	mg/L	0.2	0.4		
Boron	mg/L	0.05	0.06		
Bromide	mg/L	0.11	0.13		
Calcium	mg/L	26	30		
Chloride	mg/L	73	81		
Iron Note 5	mg/L	0.04	0.1		
Fluoride Note 6	mg/L	0.3	0.7		
Magnesium	mg/L	4.8	5.9		
Manganese	mg/L	0.04	0.05		
Potassium	mg/L	15	19		
Sodium	mg/L	71	79		
Sulphur	mg/L	10	11		

Notes 1: Not adjusted for algal biomass.

Note 2: Adjustment for algal biomass was performed, to provide an indication of TSS if effluent were to be sourced from upstream of the wetland, by subtracting the algal biomass value reported from the laboratory from the unadjusted TSS value, assuming adjusted TSS does not fall below zero. Note that one sample returned a larger algal biomass reading than TSS, likely within the margin of error for one or both measurements. This sample was assumed to have an adjusted TSS or zero (rather than a negative TSS which is not physically possible).

Note 3: ND = Non-detect. All samples were below the limit of reporting of 2 mg/L.

Note 4: Only three samples were measured for nitrate.

Note 5: Two out of the four samples were non-detect for iron. Results show summary statistics based on these two samples each having a concentration of half of the limit of reporting of 0.02 mg/L.

Note 6: One out of the four samples was below the limit of reporting. Results show summary statistics based on this sample having a concentration of half of the limit of reporting of 0.1 mg/L.

Table 5-2: South Lismore STP – Effluent Sampling Programme Results and Historic Data

Parameter	Units	Sampling Programme Data, Nov 2023 (3 samples)		Historic Effluent, Nov 2018 – May 2023 (>200 samples)	
		Mean	Max	Mean	95th Percentile
Conductivity	µS/cm	608	703	525	720
Total Suspended Solids Note 1	mg/L	1	2	3	16
Algal Biomass	mg/L	0.6	1.5		
Total Suspended Solids less algal biomass (calculated) Note 2	*mg/L*	*0.7*	*0.9*	*2.0*	*10.8*
BOD_5	mg/L	1.9	2.2	1.7	5.4
COD	mg/L	20	26	17	32
Oil and Grease Note 3	mg/L	10	10	2	5
pH		7.5	7.7	7.1	7.3
Total Dissolved Solids	mg/L	391	428	403	489
Turbidity	NTU	0.9	1.2		
Total Phosphorus	mg/L	0.2	0.4	0.5	2.0
Phosphate as P	mg/L	0.2	0.3	0.3	1.6
Total Nitrogen	mg/L	1.5	2.1	3.4	6.1
Total Kjeldahl Nitrogen	mg/L	0.9	1.0		
Organic Nitrogen (calculated)	*mg/L*	*0.87*	*0.89*		
Nitrite as N	mg/L	0.02	0.04		
Nitrate as N	mg/L	0.6	1.1	2.0	4.2
Ammonia as N	mg/L	0.06	0.08	0.5	3.1
UV Transmissivity	%	63.3	68.1		
Total Organic Carbon	mg/L	8	9		
Dissolved Organic Carbon	mg/L	7	9		
Total Alkalinity as $CaCO_3$	mg/L	113	134		
Aluminium	mg/L	0.050	0.054		
Boron	mg/L	0.04	0.05		
Bromide	mg/L	0.20	0.25		
Calcium	mg/L	29	31		
Chloride	mg/L	77	88		
Iron	mg/L	0.5	0.7		
Fluoride	mg/L	0.18	0.24		
Magnesium	mg/L	7.1	7.7		
Manganese	mg/L	0.07	0.08		
Potassium	mg/L	12	14		
Sodium	mg/L	89	104		
Sulphur	mg/L	20	22		

Notes 1: Not adjusted for algal biomass.

Note 2: Adjustment for algal biomass was performed, to provide an indication of TSS if effluent were to be sourced from upstream of the wetland, by subtracting the algal biomass value reported from the laboratory from the unadjusted TSS value, assuming adjusted TSS does not fall below zero.

Note 3: Only one out of three samples was above the limit of reporting. Results show summary statistics based on these two samples each having a concentration of half of the limit of reporting of 2 mg/L.

5.2 BYRON STPS

Results were obtained from six weekly effluent sampling events over November and December 2023, at three locations from two Byron Shire Council STPs:

- Byron STP: Plant effluent discharged to constructed wetlands (EPA 1);
- Byron STP Wetland: Effluent from the constructed wetlands (EPA 4); and,
- Brunswick Valley STP: Plant effluent.

Table 5-3, Table 5-4 and Table 5-5 summarise the results from the sampling programme at these three locations.

TDS concentrations at Byron STP were comparable in the STP effluent and wetland effluent, with a maximum of 520 mg/L in the wetland effluent. Brunswick Valley STP showed similar concentrations, with a maximum value of 570 mg/L. As identified for Lismore STPs above, these TDS results indicate that an AWTP sourcing water from Byron STP and/or Brunswick Valley STP could be either carbon-based or RO-based (from a TDS perspective).

As with the Lismore plants, TOC, DOC, nitrite and bromide analysis have been performed for the Byron plants to inform design of a carbon-based system should that option be preferred.

The TOC concentration at Byron STP ranged from 6 mg/L to 11 mg/L (for both the STP effluent and the wetland effluent). The Brunswick Valley STP TOC concentration ranged from 5 mg/L to 9 mg/L. These TOC concentrations are in a typical range and should pose no significant issues with respect to use of ozone.

Nitrite levels for all samples collected from the Byron STP wetland effluent were below the limit of reporting (0.02 mg/L as N) and for Brunswick Valley STP ranged from below the limit of reporting to 0.04 mg/L. Nitrite analysis was not conducted for Byron STP effluent. The nitrite values measured for the Byron STP wetlands and Brunswick Valley STP are very low and would not result in any significant impact with respect to ozonation. If the AWTP for this scheme is carbon-based and is to be fed from the Byron STP effluent, sampling of the Byron STP effluent for nitrite will be required to confirm concentration in that source (as the STP effluent values could be different to the wetland effluent values).

Bromide levels are not unexpected and would need to be considered in the design of an ozone system if carbon-based treatment is preferred for this scheme.

A selection of inorganic parameters was also included in the analysis (e.g. metals), as these can be used to assess scaling risk in membrane system. None of the results for these parameters appear to be atypical or raise any significant concerns with respect to design of a membrane system.

As for the Lismore STPs, the results from the sampling program did not highlight any significant discrepancies from the available historic data. To this end, none of the results from the additional sampling programme change any previous conclusions drawn from the historic data.

Table 5-3: Byron STP – Effluent Sampling Programme Results and Historic Data

Parameter	Units	Sampling Programme Data, Nov-Dec 2023 (6 samples)		Historic Effluent, Apr 2021 – Apr 2022 (24 samples)	
		Mean	Max	Mean	Max
Total Suspended Solids	mg/L			6	14
BOD_5	mg/L			1	3
Oil and Grease	mg/L			1	2
pH				7.1	7.3
Total Dissolved Solids	mg/L	443	490		
Total Phosphorus	mg/L			0.1	0.2
Total Nitrogen	mg/L			1.5	3.9
Ammonia as N	mg/L			0.1	1.4
UV Transmissivity	%	67	70		
Total Organic Carbon	mg/L	8	9		
Dissolved Organic Carbon	mg/L	7	8		

Table 5-4: Byron STP Wetlands – Effluent Sampling Programme Results and Historic Data

Parameter	Units	No. of Samples above Limit of Reporting Note 1	Sampling Programme Data, Nov-Dec 2023 (6 samples)	
			Mean	Max
Conductivity	µS/cm		800	906
Total Suspended Solids Note 2	mg/L	2	2	4
Algal Biomass Note 3	mg/L	4	2	3
Total Suspended Solids less algal biomass (calculated) Note 3	*mg/L*		*1*	*2*
BOD_5	mg/L	2	1	3
COD	mg/L		27	32
Oil and Grease	mg/L	1	1	2
pH	-		7.0	7.1
Total Dissolved Solids	mg/L		455	520
Turbidity	NTU		1.5	2.0
Total Phosphorus	mg/L		0.15	0.21
Phosphate as P	mg/L		0.1	0.2
Total Nitrogen	mg/L		0.7	0.8
Total Kjeldahl Nitrogen Note 4	mg/L		0.7	0.8
Organic Nitrogen (calculated)	*mg/L*		*0.7*	*0.8*
Nitrite as N	mg/L	0	ND	-
Nitrate as N	mg/L	0	ND	-
Ammonia as N	mg/L		0.06	0.10
UV Transmissivity	%		42	49
Total Organic Carbon	mg/L		10	12
Dissolved Organic Carbon	mg/L		10	11
Total Alkalinity as $CaCO_3$	mg/L		95	109
Aluminium	mg/L	4	0.01	0.03
Arsenic (III & V)	mg/L	0	ND	-
Barium	mg/L		0.01	0.01
Boron	mg/L	4	0.04	0.07
Bromide	mg/L		0.3	0.4
Calcium	mg/L		22	25

Table 5-4: Byron STP Wetlands – Effluent Sampling Programme Results and Historic Data (continued)

Parameter	Units	No. of Samples above Limit of Reporting Note 1	Sampling Programme Data, Nov-Dec 2023 (6 samples)	
			Mean	Max
Chloride	mg/L		153	180
Chromium (VI) Note 5	mg/L	0	ND	
Ferric Iron Note 5	mg/L	0	ND	-
Ferrous Iron	mg/L	4	0.1	0.2
Fluoride	mg/L		0.05	0.06
Magnesium	mg/L		7	8
Manganese	mg/L		0.09	0.14
Potassium	mg/L		17	21
Sodium	mg/L		111	133
Silica as SiO_2	mg/L		10	13
Strontium	mg/L		0.09	0.10
Sulphate	mg/L		45	54

Notes 1: Value shown where one or more non-detect results in the data (below the limit or reporting). Blank cells indicate all samples were above the limit of reporting. The summary statistics were performed assuming the concentration for non-detect samples is half of the limit of reporting.

Note 2: Not adjusted for algal biomass.

Note 3: Calculated using laboratory's in-house relationship using TSS and chlorophyll-a measurements.

Note 4: Calculated by laboratory by subtracting total oxidised nitrogen results from total nitrogen results.

Note 5: ND = Non-Detect

Table 5-5: Brunswick Valley STP – Effluent Sampling Programme Results and Historic Data

Parameter	Units	No. of Samples above MDL Note 1	Sampling Programme Data, Nov-Dec 2023 (6 samples)		Historic Effluent, Apr 2021 – Apr 2022 (24 samples)	
			Mean	Max	Mean	Max
Conductivity	µS/cm		825	980		
Total Suspended Solids	mg/L		3	5	3	8
BOD_5	mg/L	3	1	3	1	3
COD	mg/L		17	24		
Oil and Grease	mg/L	0	ND	-	1	3
pH	-		7.3	7.7	7.2	7.8
Total Dissolved Solids	mg/L		487	570		
Turbidity	NTU		2	3		
Total Phosphorus	mg/L		0.1	0.2	0.07	0.14
Phosphate as P	mg/L	3	0.03	0.07		
Total Nitrogen Note 2	mg/L		2.5	9.1	1	3
Total Kjeldahl Nitrogen Note 3	mg/L		2.3	8.8		
Organic Nitrogen (calculated)	*mg/L*		*0.6*	*0.9*		
Nitrite as N	mg/L	2	0.02	0.04		
Nitrate as N	mg/L		0.2	0.3		
Ammonia as N	mg/L	5	1.7	8.8	0.02	0.09
UV Transmissivity	%		71	73		
Total Organic Carbon	mg/L		7	9		
Dissolved Organic Carbon	mg/L		6	8		
Total Alkalinity as $CaCO_3$	mg/L		91	104		

Table 5-5: Brunswick Valley STP – Effluent Sampling Programme Results and Historic Data (continued)

Parameter	Units	No. of Samples above MDL Note 1	Sampling Programme Data, Nov-Dec 2023 (6 samples)		Historic Effluent, Apr 2021 – Apr 2022 (24 samples)	
			Mean	Max		
Aluminium	mg/L		0.1	0.2		
Arsenic (III & V)	mg/L	0	ND	-		
Barium	mg/L		0.017	0.019		
Boron	mg/L	4	0.06	0.09		
Bromide	mg/L		0.3	0.4		
Calcium	mg/L		16	20		
Chloride	mg/L		120	140		
Chromium (VI) Note 4	mg/L	0	ND			
Ferric Iron Note 4	mg/L	0	ND			
Ferrous Iron	mg/L	3	0.04	0.07		
Fluoride	mg/L		0.05	0.06		
Magnesium	mg/L		8	9		
Manganese	mg/L		0.1	0.2		
Potassium	mg/L		19	23		
Sodium	mg/L		121	150		
Silica as SiO_2	mg/L		13.6	14.0		
Strontium	mg/L		0.09	0.10		
Sulphur	mg/L		39	48		

Note 1: Values shown where one or more non-detect results in the data (below the limit or reporting). Blank cells indicate all samples were above the limit of reporting. The summary statistics were performed assuming the concentration for non-detect samples is half of the limit of reporting.

Note 2: A high Total Nitrogen concentration was noted in November 22, 2023 sample, at about 9 mg/L. This value is included in the summary statistics.

Note 3: Calculated by laboratory by subtracting total oxidised nitrogen results from total nitrogen results.

Note 4: ND = Non-Detect

6 MINIMUM PATHOGEN LOG REDUCTION TARGETS

A detailed assessment of minimum pathogen reduction requirements to be applied in the development of conceptual process trains was undertaken in the discussion paper *Minimum Pathogen Reductions for Potable Reuse Development* (included in Appendix C). The key aim of the discussion paper was to establish the proposed pathogen reduction requirements for each scheme type (for costing purposes) that:

1. Were consistent with robust protection of public health, while,
2. Not imposing excessive treatment requirements that increase costs or complexity without providing meaningful improvements to public health protection.

In combination with the chemical removal requirements, the minimum pathogen LRVs have a strong bearing on the key attributes of the schemes.

Minimum LRV requirements presented in the discussion paper (and carried forward to this report) were developed based on high-level QMRA. The high-level QMRAs provide a broad overview to specifically highlight or eliminate concerns. In the absence of substantial scheme-specific data, the QMRAs:

- Applied documented typical and literature values, assessment methodology and data (as sourced from the AGWR [2], ADWG [3] and WHO guidance [4]);
- Developed minimum pathogen LRV requirements based on the AGWR methodology using typical pathogen densities and DALY values, and,
- Included limited modelling of failure scenarios.

It is important to note that it is not viable for the minimum pathogen reductions required for DPR schemes in the Australian context to be derived or specified as a part of this investigation – the prevailing guidelines and lack of precedent within Australian (or NSW) regulations makes this impractical. To this end, the proposed considerations of minimum pathogen LRVs for DPR in this document are not intended to provide direction or guidance on what minimum pathogen LRV requirement may ultimately be required. Rather, this element of the investigation develops reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes (and consider the sensitivity to higher, but still realistic in the Australian context, LRVs). That is, the derived pathogen reduction requirements are **for the purpose of providing cost estimates for RCC's forward planning. Substantial additional input information, analysis and consultation (such as site-specific testing/demonstration, engagement with the regulator, etc.) would be required to establish the pathogen reduction criteria for future stages of design**.

This section summarises the minimum pathogen reduction requirements output from the detailed discussion paper, and applied to the development of the conceptual process trains for each Level 1 option.

6.1 BASELINE MINIMUM LRV REQUIREMENTS BASED ON AUSTRALIAN AND WHO GUIDELINES

The AGWR [2] uses DALYs to convert the likelihood of infection or illness into burdens of disease, and sets a tolerable risk as 10^{-6} DALYs per person per year for each pathogen type (virus, protozoa and bacteria). The latest version of the ADWG [3]sets the same DALY target as an operational benchmark (rather than a pass/fail criteria). Disability-adjusted life years dose (DALYd) is the dose of pathogens equivalent to a DALY of 10^{-6}. DALYd includes consideration of dose response[9], ratios of infection to illness and severity weighting of the illness.

Table 6-1 lists the DALYd values and the resultant minimum LRV that would need to be met under:

- The ADWG values for Norovirus dose-response;
- A raw wastewater concentration of Adenovirus based on WHO guidance [4], and,
- Ingestion of 2 L/d.

[9] Relationship between dose of organism and incidence or likelihood of illness.

Table 6-1: Minimum LRV Required Based on ADWG [2] combined with WHO [4] [1]

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water (i.e. raw sewage)	number per L	20,000	2,700	7,000
DALYd	number per year	3.6×10^{-3}	4.2×10^{-3}	7.5×10^{-3}
Equivalent tolerable pathogen concentration in drinking water	number per L	5.0×10^{-6}	5.8×10^{-6}	1.0×10^{-5}
Minimum Pathogen Reduction	LRV	9.6	8.7	8.8
Minimum Pathogen Reduction (rounded to next highest 0.5 log)	LRV	10.0	9.0	9.0

6.2 ADOPTED APPROACH FOR CONCEPTUAL AWTP DESIGNS AND SENSITIVITY ANALYSES

Considering this project is in the early investigation stage and future regulatory requirements are not known, the approach for the conceptual AWTP designs and sensitivity analyses specifically pursued conservative, but reasonable, LRVs for the Australian context. This approach is described in Table 6-2.

Some LRVs shown in Table 6-2 include "excess LRVs"[10]. **This is solely for the purpose of cost estimating and not a reflection of the opinion of the project team of a need due to pathogen risk. The final minimum pathogen LRV requirement used in design of the AWTP (to be agreed with the Regulator) should be based on pathogen barrier failure modelling** with consideration of:

- The maximum LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere[11]);
- The failure mode of each unit process (i.e. instantaneous (e.g. disinfectant dosing system failure) or gradual (e.g. loss of UF membrane integrity which normally occurs slowly and can be seen by monitoring PDT trends);
- The response time of online analysers used for CCPs;
- The reliability of these analysers and any redundancy provided for these analysers (including consideration of the maintenance strategy for the analysers and the frequency of calibration);
- The use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk; and,
- Other design features used to mitigate risk (e.g. use of "off spec" diversions at CCP alert levels, use of engineered storage buffer tank to allow for capture and diversion of water produced between analyser readings, etc.).

[10] To better understand the potential impact of AWTP process unit failures on LRV requirements, RCC undertook preliminary analysis of possible failure scenarios using DPRisk - a calculation tool developed by Water Research Foundation for DPR systems. The outputs from this preliminary analysis have been considered in the values shown in Table 6-2.

[11] Sylvestre et.al. [48] indicate that for a barrier with rapid loss in LRV performance credited with 6.0 LRV, failure durations of 10 seconds per year need to be controlled, whereas for the same process claiming 4 LRV performance can be verified by controlling a failure of 15 minutes per year.

Table 6-2: Minimum Pathogen Reduction – Approach for Conceptual AWTP Designs and Sensitivity Analyses Note 1

Scheme	Baseline AWTP LRV Basis	Sensitivity Analyses
IPR via Surface Water Augmentation	Apply values from Table 6-1: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0	None
DPR via Raw Water Augmentation	Apply values from Table 6-1: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0 Assume blending of source water and treatment in the downstream WTP is sufficient to manage the risk of barrier failure	Consider a worst case as aligning with an excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0
DPR via Treated Water Augmentation	Consider a case of excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0	Consider ***an absolute worst case*** as aligning with an excess LRV of 4 for all pathogen types (i.e. 100% redundancy) – i.e. the process would provide: Virus LRV – 14.0 Protozoa LRV – 13.0 Bacteria LRV – 13.0 It is not the opinion of the project team that this is suitable from a public health risk perspective, and is only presented to represent an extreme worst-case scenario for AWTP costing (with respect to pathogen reduction).

Note 1: See the *Minimum Pathogen Reductions for Potable Reuse Development* discussion paper (Appendix C) for further information on the approach presented in Table 6-2.

6.3 COMPARISON TO CALIFORNIA DPR MINIMUM LRV TARGETS

For reference, the discussion paper (Appendix C) also considered three examples of regulatory approaches to DPR applied in the United States. As the approach to derivation of LRV requirements in these United States examples is vastly different to that used in Australia and as endorsed by WHO [4], it is essential to note that the comparisons are for reference only.

Of the three US examples, the recently legislated minimum target LRVs for DPR [11] from California are of particular interest. The discussion paper demonstrates that the California DPR minimum LRV targets are excessively conservative for use as a basis for the purposes of this investigation, based on:

- Different raw wastewater pathogen loads as compared to AGWR/WHO;
- Different tolerable drinking water pathogen concentration as compared to AGWR/ADWG/WHO (based on the difference between achieving 10^{-6} DALYs per person per year and limiting infections to 1 in 10,000 per person per year, which is the California approach); and,
- Different assumptions for maximum claimable LRV per process unit (6 for California versus 4 assumed for the purposes of this investigation).

Application of the proposed California DPR regulations would result in excessive treatment requirements that increase costs and complexity without providing meaningful improvements to public health protection.

7 CHEMICAL RISKS

A high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW was conducted to provide an example of how to better understand and prioritise chemicals of concern. As there is currently no catchment specific data available defining chemicals of concern in the source water and their concentration, this high-level assessment of chemical risks is based on:

- The 262 chemicals examined in the Water Research Foundation (WRF) Project No. 4960 (*An Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse*) for which there were available health risk metrics and/or removal data [12]; and,
- Publicly available occurrence data for chemicals in the feed to the Luggage Point AWTP (owned by Seqwater) [13], where compounds found in this source water overlap with the chemicals examined within WRF Project No. 4960.

This first step in understanding potential chemical risks is described in detail the *Chemical Risk Assessment Memorandum* in Appendix D, and summarised in this section. Relative risks for the chemical species were determined for the AWTP process trains based on the example data. These risks are examples only as they are not specific to the catchments of interest due to lack of site-specific chemical occurrence data.

Should one or more PRW schemes be carried forward for development, catchment specific data will need to be collected and analysed to support further assessment of chemical risk (see Section 14.2), and supported with appropriate removal performance data. More specifically, the chemicals included in this risk assessment may or may not be relevant to any RCC potable reuse scheme, based on occurrence, or the risk of occurrence, of specific chemicals in the catchments providing source water for a given scheme. When sufficient catchment specific data becomes available, further assessment of chemical risk will need to be conducted in development of any scheme option including, but not limited to:

- Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available;
- A detailed QCRA (Based on the approach described in the *Chemical Risk Assessment Memorandum* or a suitable alternative methodology);
- Development of an enhanced source water control program (including a detailed study of all dischargers and the chemicals they use that could end up in the sewer, refer to Section 14.1); and,
- Demonstration plant testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water and their removal through the various unit processes within the demonstration plant).

Any future detailed chemical risk assessment should specifically incorporate consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [2]. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, including the ADWG [3], WHO guidelines, and the like, should be consulted. The PRW concentrations would then need to be verified, initially by demonstration plant operation and then subsequently during commissioning and ongoing operation of the full-scale AWTP. The detailed risk assessment would be a "live" document, and subject to routine revision and updates over the operational life of the AWTP based on changes in the source water characteristics and/or changes or additions to guideline values.

Based on the assessment, PFAS appears to be a broad concern for all proposed treatment trains. This concern is driven almost solely by the risk to human health posed by these compounds.

A further concern is the origin of PFAS. While landfill leachate may contribute a significant load, it is equally possible that a significant proportion of the load originates from households. It is recommended that chemical characterisation of leachate be compared to raw wastewater to determine the potential extent of contamination for this source for any schemes carried forward for further consideration. If leachate is shown to be a significant contributor of chemical load, then segregation from a potable reuse scheme or enhanced point source treatment may be more effective than addition of further unit operations to the potable reuse treatment train.

The assessment indicated that the permitted trade waste volume was likely to be consistently less than 4% of the volumetric load for the Lismore based short-listed scheme) – subject to confirmation through a more detailed evaluation. The volumetric load of trade waste for Byron is also about 4%. Both catchments include landfill leachate. Leachate is treated onsite to some extent for East Lismore[12], but Byron STP receives leachate with no prior treatment.

Hospital and aged care waste may be of concern, but volumetric contributions appear to be low[13]. Similarly, there are automotive and machine work related industries in the catchment. An assessment of chemicals of industrial concern in the raw wastewater should be conducted for any schemes carried forward for further consideration to better understand if these industries contribute significantly to chemical load.

While chemical risk is highly specific to individual catchments, the high-level analysis of the catchments (i.e. lower percentage trade waste, limited heavy industry) gives some indication that risks could be similar to or lower than a typical catchment, including the Seqwater data applied to the example application of the methodology in the *Chemical Risk Assessment Memorandum* in Appendix D.

Both RO-based and carbon-based RBAT and CBAT process trains similar to the conceptual process trains described in Section 10 have been demonstrated to provide robust treatment for compounds of concern. The high-level chemical risk assessment did not identify any issues that would drive recommending additional chemical barriers to be included in the conceptual process trains (noting that the potential need for further unit processes to address chemical risk is considered in the *AWTP Process Trains Memorandum* (Appendix E)).

Therefore, the analysis effectively shows the proposed treatment trains should provide good control of chemical risk in the proposed catchments, where the underlying chemical risk of the proposed catchment is expected to be similar to a typical catchment (or lower). This however does not significantly reduce the overarching uncertainty of actual chemical risk of the source catchments, nor does it negate the need for detailed source characterisation, AWTP demonstration testing, implementation of enhanced source control, or ongoing monitoring of chemical indicators and surrogates.

[12] The treated leachate flow can go either to East Lismore STP or directly to the river.
[13] Systems for management of hospital wastes are likely already in place, however no details have been received to confirm this. This would need to be investigated if any of the short-listed scheme is carried forward.

8 NIGHTCAP WATER TREATMENT PLANT LRVS

Two short-listed Lismore schemes direct PRW to Nightcap WTP, these being:

- IPR via surface water augmentation – engineered environmental buffer storage in the vicinity of Lagoon Grass to store PRW produced from the effluent of Lismore's WWTPs, potentially blended with Wilsons River Source water, to be further treated through Nightcap WTP; and
- DPR via raw water augmentation - PRW produced from the effluent of Lismore's WWTPs, blended with water from Rocky Creek Dam at the inlet to Nightcap WTP.

No pathogen LRVs are being claimed through Nightcap WTP for either of these reuse schemes. However, it is noted that RCC separately claim LRVs for drinking water treatment across the WTP as detailed in Table 8-1[14]. While these additional LRVs **are not theoretically claimed under the potable reuse schemes**, in practice they are likely to provide additional conservatism against the risk associated with barrier failure within the AWTP.

Table 8-1 summarises the Nightcap WTP unit processes for which LRVs are claimed and the basis for verifying the LRV.

Table 8-1: Nightcap WTP LRVs

Treatment Process	Virus	Protozoa	Bacteria	Basis
Dissolved Air Flotation + Filtration	2	3.5	2	Effluent turbidity < 0.2 NTU 95% of the time and not > 0.5 NTU for > 15 min
Ozone	4	0.5	4	Ct value of 3.2 mg-min/L, based on achieving ozone residual of 0.135 mg/L
Biologically Active Carbon	1	0.5	1	Effluent turbidity < 0.15 NTU 95% of the time and not > 0.3 NTU for > 15 min
Chlorine	4	0	4	Ct value of 16 mg-min/L, when > 1.2 mg/L free chlorine residual
Total	11	4.5	11	

Nightcap WTP has two different sets of treatment requirements, depending on the raw water source, to achieve the health-based targets in alignment with ADWG [3]. Table 8-2 compares the total claimed LRVs to the LRVs required for the two different source waters (Rocky Creek Dam and Wilsons River).

Table 8-2: Nightcap WTP Required versus Claimed LRVs

Pathogen	Claimed LRV	Rocky Creek Dam		Wilsons River	
		Required LRV	Difference	Required LRV	Difference
Virus	11	4	+7	6	+5
Protozoa	4.5	3	+1.5	5	-0.5
Bacteria	11	4	+7	6	+5

Table 8-2 shows that the Nightcap WTP provides surplus LRV for virus and bacteria for both water sources and surplus for protozoa for the Rocky Creek Dam source. The shortfall of 0.5 LRV for protozoa for the Wilsons River Source, as noted in Table 8-2, is acceptable under the ADWG as the microbial health outcome target of 10^{-6} DALYs per person per year is applied as an operational benchmark rather than a pass/fail criterion [3].

[14] From an extract of a draft update to RCC's Drinking Water Management System, provided by email from Jeremy Wilson on August 1, 2023.

9 WASTEWATER TREATMENT PATHOGEN REDUCTION

The *Minimum Pathogen Reductions for Potable Reuse Development* discussion paper (Appendix C) discusses pathogen reduction by secondary wastewater treatment.

The secondary wastewater treatment process provides a level of pathogen reduction and hence can be considered as a barrier. Table 9-1 provides indicative achievable and validated pathogen LRV for secondary treatment [14].

Table 9-1: Indicative Pathogen LRV for Secondary Treatment of Wastewater

Treatment Process	Achievable LRVs			Validated LRVs			Online analysers for verification
	Virus	Protozoa	Bacteria	Virus	Protozoa	Bacteria	
Secondary Treatment Note 1	2	2	2	0.5 - 1	0.5 - 1	1 - 2	Ammonia – analysis results returned every 15 to 30 minutes Turbidity – continuously reporting analyser results Note 2

Note 1: Ballina WWTP utilises membrane bioreactor (MBR) technology. MBRs have higher validated LRVs based on the membrane process, but Ballina has historically had issues with the membranes at this plant. Hence, no consideration is given to the potential higher MBR LRVs in this work. The existing membranes are being replaced with new membranes from a different manufacturer. Should any schemes be developed in future that utilise Ballina WWTP effluent, the LRV claimed for this plant should be considered further.

Note 2: CCP would require analyser reading to be above the critical limit for a defined time (e.g. > 10 NTU for more than 5 minutes) before the CCP would be considered breached.

For the purposes of this investigation, a conservative Claimed LRV of 0.5 is applied for each pathogen type for the WWTP. For reference, the Beenyup WWTP is credited with an LRV of 1.0 for each of virus and bacteria and of 0.5 for protozoa as part of Water Corporation's groundwater replenishment scheme [4].

It is possible that additional LRV could be claimed for the WWTPs, but further site-specific study would be required to justify any additional crediting of the processes. This would include collecting an extensive data set over the biological treatment operational range.

10 AWTP PROCESS TRAINS

Conceptual treatment trains have been developed for each of the short-listed options to provide a reasonable and sound basis on which to develop costs and site area requirements. Given the scope of the investigations and context of the schemes, the conceptual AWTP process trains utilise process technologies that have been proven in potable reuse applications elsewhere, and are therefore relatively well understood in terms of pathogen and chemical removal, reliability, operability, efficiency, and monitoring requirements.

The treatment trains for each of the four short-listed schemes are briefly described in Section 10.1 through 10.4, with the sizing of each process unit outlined in Table 10-6. Further details on treatment train development, and attributes of each process unit, are provided in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E).

AWTP sizing for all short-listed schemes is based on the projected 2040 ADWF. For the Byron based scheme, existing reuse is not deducted from the ADWF as there will be times when the full ADWF is available. There is an option to draw effluent from the Byron wetland, however incident rainfall on the Byron Wetland is also not considered in the sizing of the Byron based AWTP. These items would need to be considered when determining secure yield for the scheme (determination of secure yield is not in the scope of the PRW Investigations).

10.1 Lismore IPR via Surface Water Augmentation

For the IPR via surface water augmentation scheme, PRW produced from source water from the Lismore STPs is discharged to a new Engineered Environmental Buffer Storage (water from the Wilsons River Source may also be directed to this storage to potentially provide improved utilisation of this source). The contents of the engineered environmental buffer storage would then be pumped to the inlet of Nightcap WTP via the existing Wilsons River Source Pump Station and pipeline.

Lismore's inland location and climatic conditions make disposal of RO concentrate from an RO system impractical, hence the process train is assumed to be carbon-based (see Section 11.1.2). The TDS concentration of the Lismore wastewater is around 500 mg/L, making carbon-based treatment a viable option.

A schematic process flow diagram of the proposed treatment train for this scheme is provided in Figure 10-1.

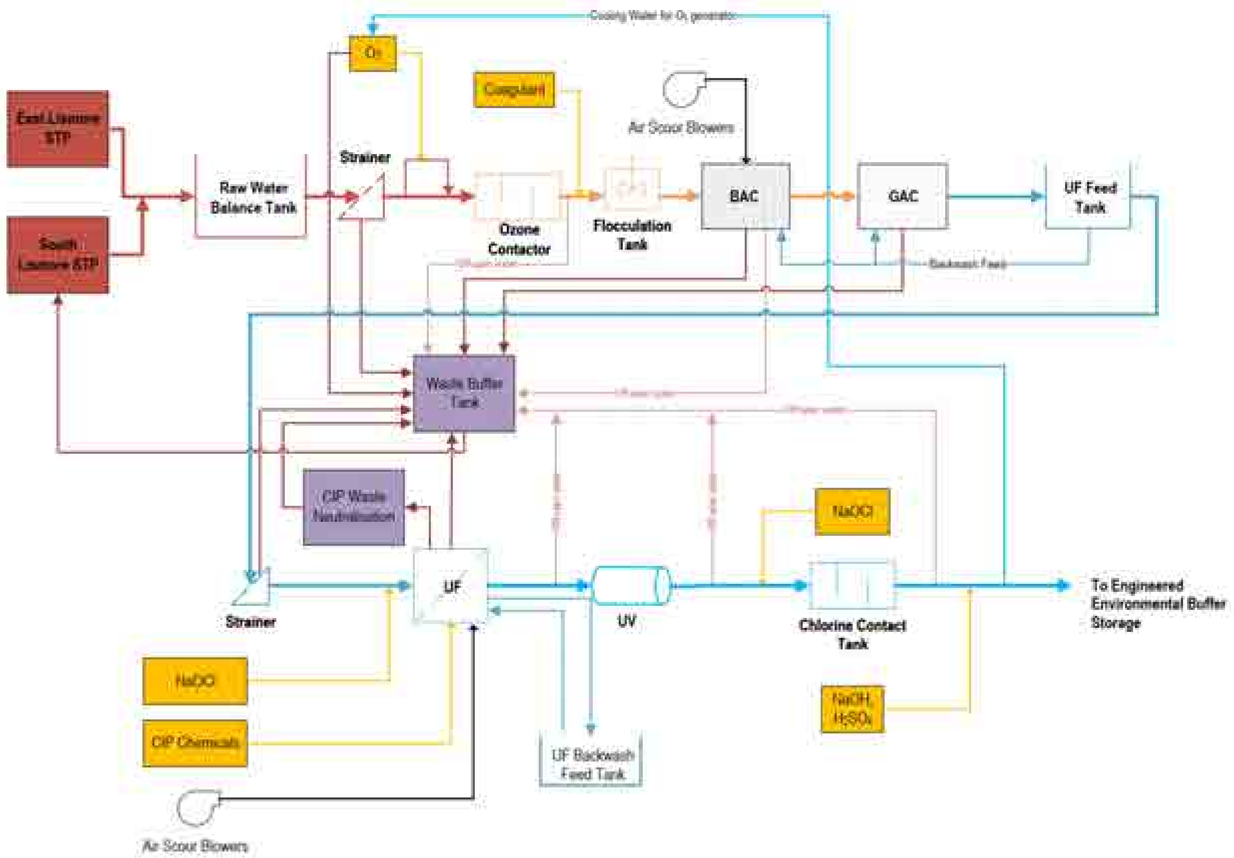

Figure 10-1: Lismore IPR via Surface Water Augmentation Process Flow Diagram

Table 10-1 summarises the main process units of conceptual AWTP process train to produce PRW from the Lismore sources, from raw wastewater to PRW supplied to the Engineered Environmental Buffer Storage as part of the IPR scheme, along with the pathogen LRVs claimed for each unit process. CCPs for each of the barriers are discussed in Section 15.1.2.1.

Table 10-1: Lismore IPR via Surface Water Augmentation – Proposed Process Train

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
Sewage Treatment Plant	0.5	0.5	0.5
Ozone	4.0	0.0	4.0
BAC	1.0	2.0	1.0
GAC	0.0	0.5	0.0
UF	0.0	4.0	4.0
UV Disinfection	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**13.5**	**11.0**	**17.5**
Minimum Required LRVs	**10.0**	**9.0**	**9.0**

Removal of chemical contaminants from the raw wastewater through to the final PRW occurs via:

- Treatment through the STPs (by physical/chemical (e.g. sorption to biomass, stripping via aeration) and biological processes);
- Oxidation and biodegradation within the ozone/BAC (and some adsorption to the media in the BAC filter); and,
- Adsorption to the media in the GAC.

While additional pathogen and chemical reduction will occur via treatment of the PRW through Nightcap WTP, no credits have been applied for these reductions as a part of this investigation.

The AWTP for this option has been sized to process 9.1 ML/d of effluent flow - the projected average dry weather flow in 2040 from both the South and East Lismore STPs (2.6 ML/d from South Lismore and 6.5 ML/d from East Lismore).

10.2 Lismore DPR via Raw Water Augmentation

The Lismore DPR via raw water augmentation scheme is similar to the IPR via surface water augmentation scheme, with the key difference being that the PRW produced by the AWTP is directed to the head of the Nightcap WTP (rather than the engineered environmental buffer).

Engineered Storage Buffer Tanks are included in the AWTP process train for this scheme to allow for capture and diversion of water produced between CCP analyser readings (to ensure water produced from the time of the last verified acceptable CCP reading is not allowed to be discharged to Nightcap WTP). Two tanks would be provided, each providing on the order of 30 minutes of storage time (the actual storage time provided would need to be confirmed based on the design of the AWTP).

10.2.1 Base Case Minimum Pathogen LRV Targets

As shown in Table 6-2, the base case for minimum pathogen LRV targets for this scheme are the same as for the IPR via surface water augmentation scheme described in Section 10.1 As such, the AWTP process train for this scheme is the same as described in Section 10.1, except for the inclusion of the Engineered Storage Buffer Tanks and the subsequent direction of PRW to Nightcap WTP.

A schematic process flow diagram of the proposed treatment train for this scheme is provided in Figure 10-2.

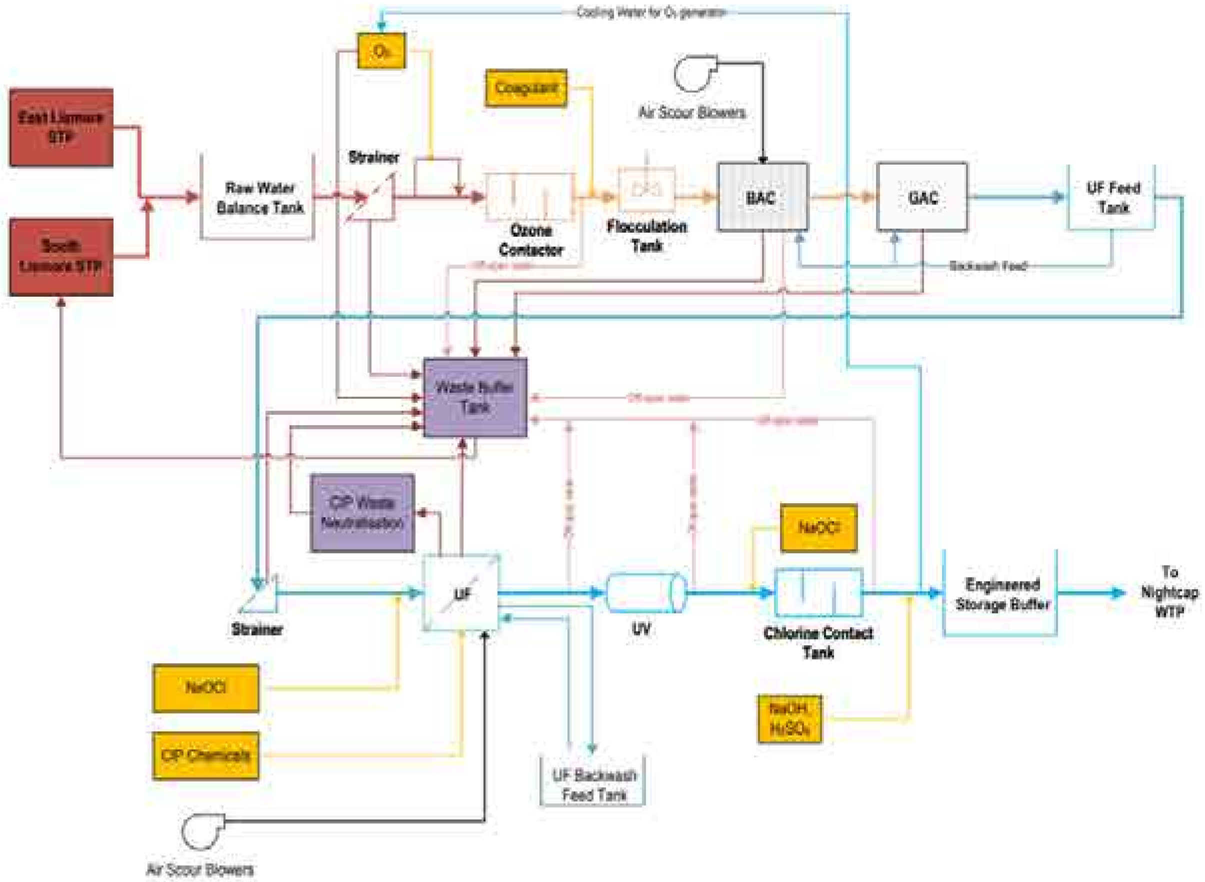

Figure 10-2: Lismore DPR via RWA Process Flow Diagram (Base Case Minimum Pathogen LRV Targets)

The main process units and their associated claimed pathogen LRVs are the same as those shown in Table 10-1 for the Lismore IPR via surface water augmentation scheme. Similar to that scheme option, while additional pathogen and chemical reduction will occur via treatment of the PRW through Nightcap WTP, no credits have been applied for these reductions as a part of this investigation.

10.2.2 Sensitivity Case Minimum Pathogen LRV Targets

As shown in Table 6-2, the sensitivity case assumes minimum pathogen LRV targets that are 2.0 LRV higher than the base case for each pathogen type, based on initial failure assessment and associated excess LRVs. The AWTP process train used for the base case (as discussed in Section 10.2.1) meets the pathogen LRV sensitivity case target, hence no further processes are required to meet the pathogen targets established for this investigation. The process train for this pathogen sensitivity case is the same as for the Lismore DPR via raw water augmentation base case.

Table 10-2 summarises the main process units of conceptual AWTP process train to produce PRW from the Lismore sources (from raw wastewater through to PRW supplied to the Nightcap WTP as part of the DPR scheme), along with the pathogen LRVs claimed for each unit process for the sensitivity case.

Table 10-2: Lismore DPR via RWA – Proposed Process Train for Sensitivity Case Minimum Pathogen LRV Targets

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
Ozone	4.0	0.0	4.0
BAC	1.0	2.0	1.0
GAC	0.0	0.5	0.0
UF	0.0	4.0	4.0
UV Disinfection	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**13.5**	**11.0**	**17.5**
Minimum Required LRVs with Sensitivity Provisions	**12.0**	**11.0**	**11.0**

As for the system described in Section 10.1, removal of chemical contaminants through the AWTP will primarily occur through the ozone/BAC and GAC systems.

While additional pathogen and chemical reduction will occur via treatment of the PRW through Nightcap WTP, no credits have been applied for these reductions as a part of this investigation.

10.3 Lismore DPR via Treated Water Augmentation

The Lismore DPR via treated water augmentation scheme is the similar to the DPR via raw water augmentation scheme, with three key differences being:

- Effluent will be sourced from East Lismore STP only;
- The PRW produced by the AWTP will be blended with treated water from Nightcap WTP within the main reservoirs of drinking water distribution network (rather than being discharged to the inlet of Nightcap WTP); and
- The amount of PRW supplied to the network will be limited (to an assumed maximum of 5.4 ML/d) to align with a blend ratio of 50% (based on predicted 2040 demand from the City View, Belvedere Drive, High Street and Ross Street Reservoirs) to maintain TDS in the supplied drinking water at acceptable level (refer to *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E) for more information on treated water blending TDS). On this basis, the unit process sizes are smaller than those derived for the Lismore IPR via surface water augmentation and DPR via raw water augmentation options.

10.3.1 Base Case Minimum Pathogen LRV Targets

As shown in Table 6-2, the base case for minimum pathogen LRV targets for this scheme are the same as for the sensitivity case for the DPR via raw water augmentation scheme described in Section 10.2.2. Hence, the AWTP process train is identical to that described in Section 10.2.2 - except for the destination of the PRW, the capacity of the system, and the amount of PRW supplied to the system.

A schematic process flow diagram of the proposed treatment train for this scheme is provided in Figure 10-3.

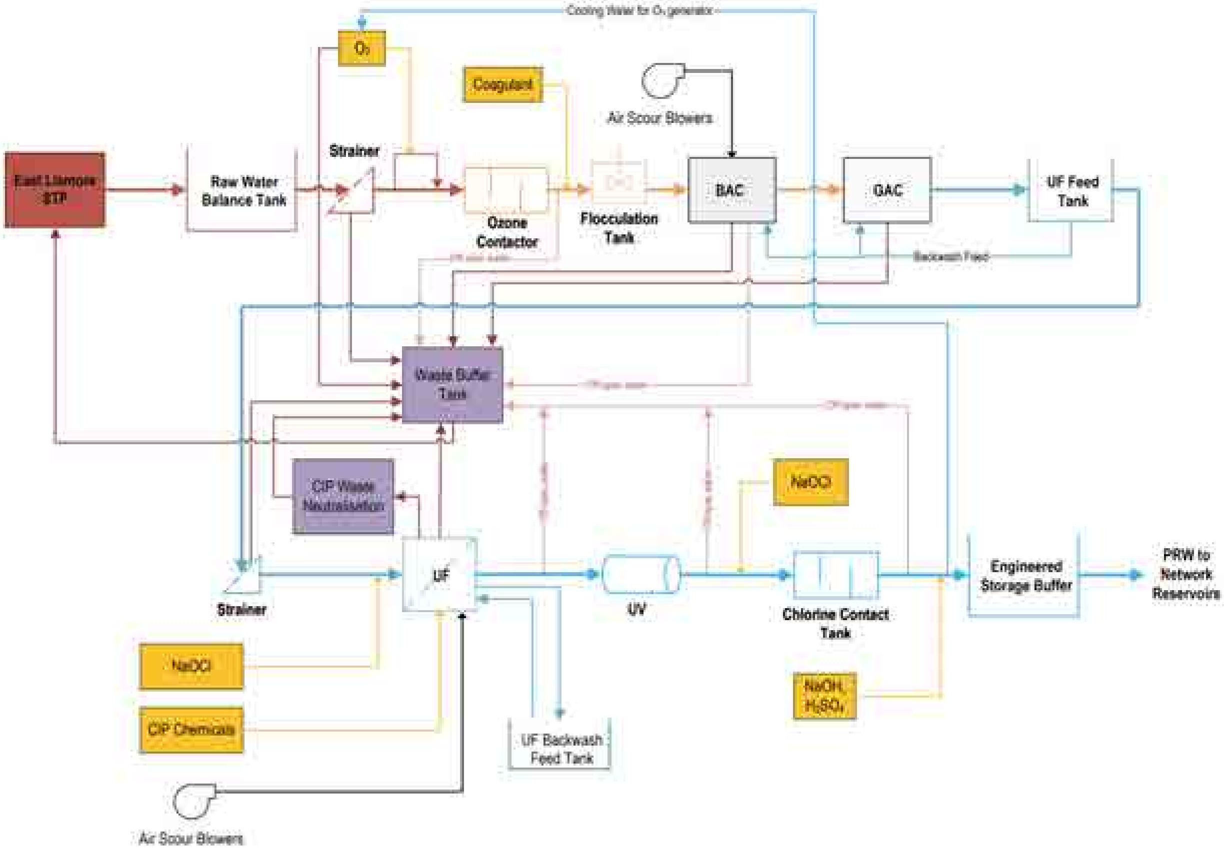

Figure 10-3: Lismore DPR via Treated Water Augmentation Process Flow Diagram (Base Case Minimum Pathogen LRV Targets)

10.3.2 Sensitivity Case Minimum Pathogen LRV Targets

As shown in Table 6-2, the sensitivity case assumes minimum pathogen LRV targets that are 4.0 LRV higher than the minimum required LRVs to meet a DALY of 10^{-6} in drinking water for each pathogen type (based on an absolute worst-case scenario of 4.0 LRV failure 100% of the time). The AWTP process train used for the Lismore DPR via treated water augmentation base case has a shortfall of 0.5 LRV for virus and 2.0 LRV for *Cryptosporidium* compared to the sensitivity case targets.

To overcome this shortfall a secondary UV disinfection system is included in the process train for this case. This process unit is not required to provide pathogen LRV to meet requirements for protection of public health (as described in Table 6-1), but rather to make up a shortfall that may occur under the sensitivity case (i.e. a 4 LRV failure occurring for four hours four times per year (as per the initial failure assessment). The lack of available additional conventional AWTP treatment processes that could be reasonably added may provide a valid basis under which this duplication of process units may be acceptable[15].

Site-specific testing may show higher (or lower) claimable pathogen LRVs for the process train without the secondary UV system. If sufficiently higher claimable pathogen LRVs can be demonstrated, then the secondary UV system would not be required to meet even this assumed worst case. As noted in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (Appendix C), the proposed considerations of minimum LRVs for DPR in this document are not intended to provide direction or guidance on what minimum LRV requirement may ultimately be required. Rather, the

[15] The addition of an RO unit to this process train to increase pathogen LRV is likely to make the treatment system cost prohibitive, due to the difficulty associated with managing an RO concentrate stream due to Lismore's inland location.

intent is to develop reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes and consider the sensitivity to higher LRVs that remain still potentially realistic in the Australian context.

A schematic process flow diagram of the proposed treatment train for this scheme is provided in Figure 10-4.

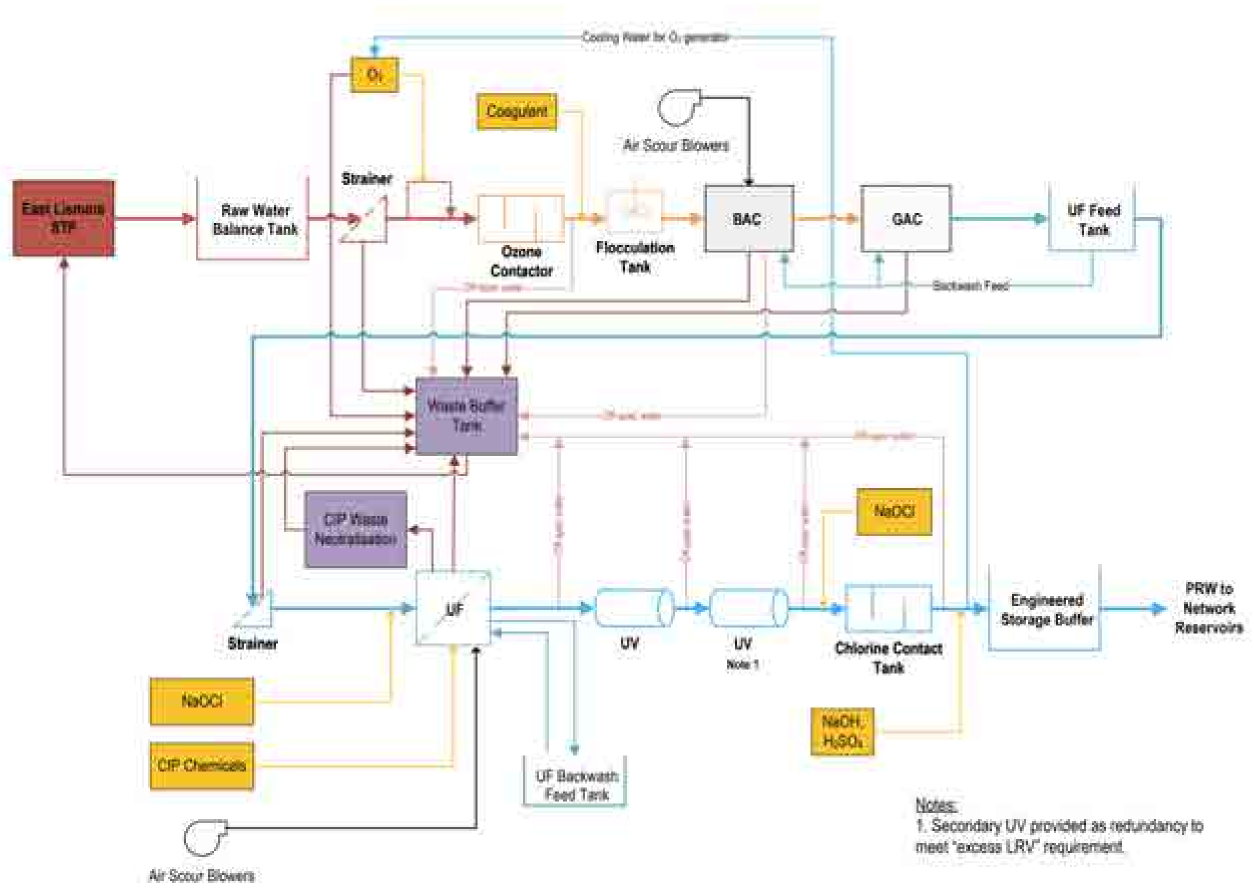

Figure 10-4: Lismore DPR via Treated Water Augmentation Process Flow Diagram (Sensitivity Case Minimum Pathogen LRV Targets)

Table 10-3 summarises the main process units of a conceptual AWTP process train to produce PRW from the Lismore sources (from raw wastewater through to supply of PRW to the drinking water reservoirs), along with the pathogen LRVs claimed for each unit process (inclusive of the secondary UV system).

Table 10-3: Lismore DPR via TWA – Proposed Process Train for Sensitivity Case Minimum Pathogen LRV Targets

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
Ozone	4.0	0.0	4.0
BAC	1.0	2.0	1.0
GAC	0.0	0.5	0.0
UF	0.0	4.0	4.0
UV Disinfection	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**13.5**	**11.0**	**17.5**
Minimum Required LRVs to Meet DALY of 10^{-6} in Drinking Water	**10.0**	**9.0**	**9.0**
Secondary UV Disinfection (to meet sensitivity requirement)	4.0	4.0	4.0
Total Claimed LRVs with Secondary UV	**17.5**	**15.0**	**21.5**
Minimum Required LRVs with Sensitivity Provisions	**14.0**	**13.0**	**13.0**

As for the other Lismore AWTP process trains, removal of chemical contaminants occurs through the ozone/BAC and GAC systems.

10.4 BYRON DPR VIA TREATED WATER AUGMENTATION

For the Byron DPR via treated water augmentation scheme, PRW produced from source water from the Byron STPs is discharged to reservoirs in the drinking water distribution network.

Byron's coastal location provides opportunity for disposal of concentrate from an RO system. The TDS concentration of the Byron wastewater is around 500 mg/L, making either RO-based or carbon-based treatment viable options. For this investigation, the conceptual design has adopted an RO-based solution for this this scheme option. This provides at least one short-listed option utilising this process train.

The discharge of RO concentrate to the environment would require investigation to determine requirements for additional treatment of the concentrate (e.g. nutrient removal). For the purposes of this investigation, it is assumed that processes for nitrification, denitrification and phosphorus removal would be required to treat the RO concentrate stream prior to discharge.

10.4.1 Base Case Minimum Pathogen LRV Targets

Table 10-4 shows the main process units of conceptual AWTP process train to produce PRW from the Byron sources (from raw wastewater through to PRW supply to the drinking water reservoirs as part of the DPR scheme), along with the pathogen LRVs claimed for each unit process.

While an RO-based AWTP process train can meet the minimum LRV requirements for protection of public health (as described in Table 6-1) without duplication of pathogen barriers, the base case for this scheme assumes minimum pathogen LRV targets that are 2.0 LRV higher than the minimum LRV requirements for protection of public health for each pathogen type (based on initial failure assessment and associated excess LRVs). This additional 2.0 LRV target results in a shortfall of 1.5 LRV for virus and 1.0 LRV for *Cryptosporidium* for a "traditional" RO-based AWTP train consisting of UF, RO and ultraviolet light disinfection (UV)/advanced oxidation process (AOP), based on the conservative LRV assumptions made for these unit processes in this investigation.

Provision of a secondary UV system (following the UV/AOP system) would deliver sufficient LRV to make up for this shortfall. This additional process unit is not required to provide pathogen LRV to meet requirements for protection of public health (as described in Table 6-1). Rather, the secondary UV unit makes up a shortfall that may occur as result of a 4 LRV failure occurring for four hours, four times per year (as per the initial failure assessment). Under this approach, there is a valid basis under which this duplication of process units may be acceptable[16] [17].

The inclusion of the secondary UV is driven by the excess LRV assumptions made for this investigation to ensure conservative capital cost estimates are developed. Further work will be required to confirm and agree the final LRV targets with the Regulator and to confirm that claimed pathogen LRVs that can be verified and validated. There is potential that additional pathogen LRVs may be claimable, including:

- Additional virus, protozoa and bacteria LRVs by treatment through the STP;
- Virus LRV through the UF;
- Additional virus, protozoa and bacteria LRVs through the RO system; and,
- Allowing for greater than 4 LRV to be claimed through the UV/AOP and/or the chlorine disinfection system (noting that this would also change the "excess LRV" failure assessment).

As noted in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (Appendix C), the proposed considerations of minimum LRVs for DPR in this document are not intended to provide direction or guidance on what minimum LRV requirement may ultimately be required. Rather, the intent is to develop reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes (and consider the sensitivity to higher, but still realistic in the Australian context, LRVs).

Table 10-4: Byron DPR via TWA – Proposed Process Train for Base Case Minimum Pathogen LRV Targets

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
UF	0.0	4.0	4.0
RO	1.5	1.5	1.5
UV/AOP	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**10.0**	**10.0**	**14.0**
Minimum Required LRVs to Meet DALY of 10^{-6} in Drinking Water	**10.0**	**9.0**	**9.0**
Secondary UV Disinfection (for Excess LRV requirements)	4.0	4.0	4.0
Total Claimed LRVs to Meet Excess LRVs	**14.0**	**14.0**	**18.0**
Minimum Required LRVs including Excess LRVs	**12.0**	**11.0**	**11.0**

A schematic process flow diagram of the proposed treatment train for this scheme is provided in Figure 10-5.

[16] For this scheme ozone/BAC could be considered rather than a secondary UV unit. To provide LRV redundancy for *Cryptosporidium* a high dose of ozone would be required, which would significantly increase the likelihood of bromate formation which would then need to be managed. Using ozone/BAC to provide 4/4/4 LRV redundancy (matching the secondary UV) would increase cost and operational complexity as compared to a secondary UV unit without providing any tangible benefit to protection of public health. Ozone/BAC is discussed further in relation to chemical risks for this scheme in the *AWTP Process Trains* memorandum in Appendix E.

[17] Additional LRV could also be provided by inclusion of media filtration (by either conventional treatment or direct filtration). This would significantly increase the footprint requirement for the plant and add operational and maintenance activities likely in excess of that required for the secondary UV. Hence, this option is less preferable than the secondary UV system.

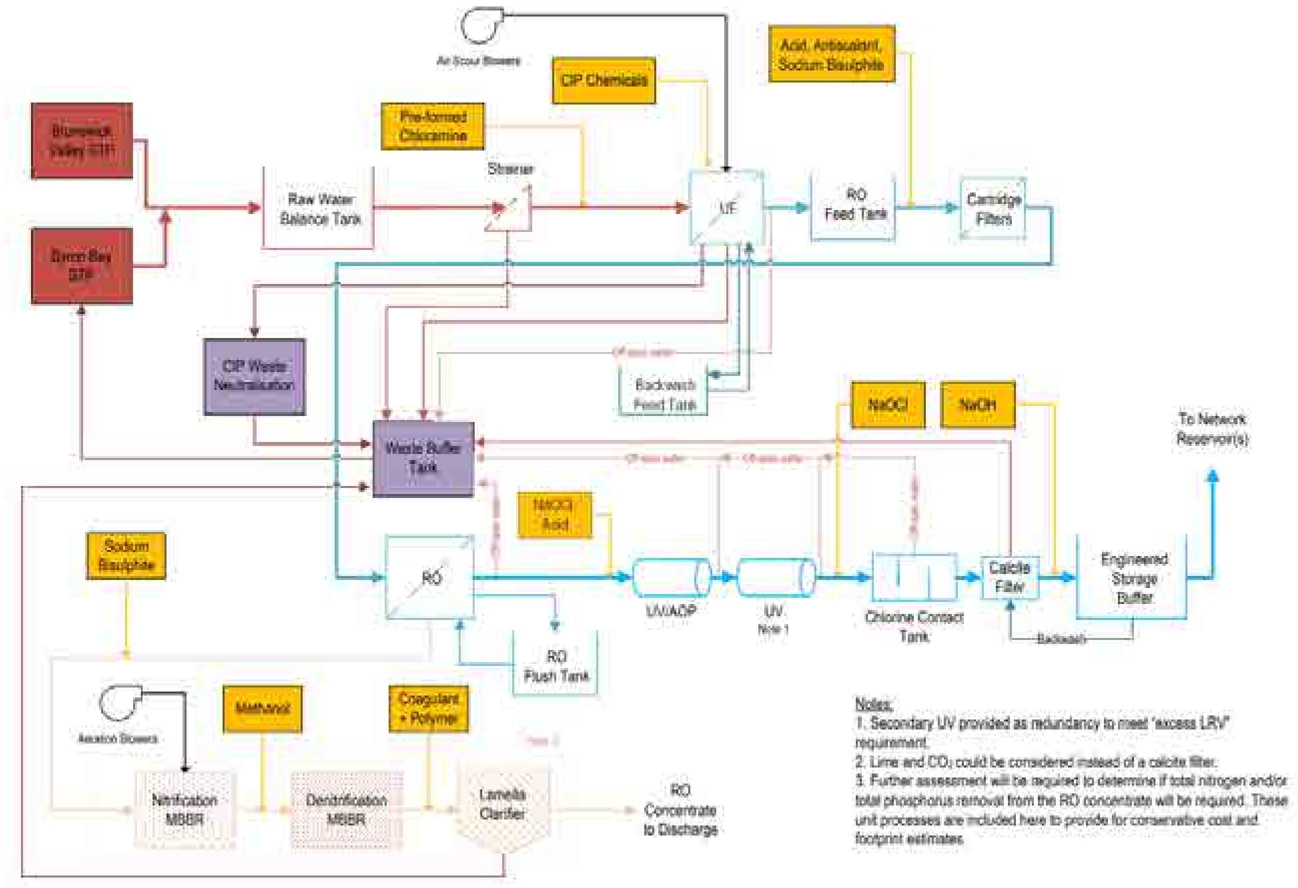

Figure 10-5: Byron DPR via Treated Water Augmentation Process Flow Diagram

In the RO-based process, removal of chemical contaminants occurs through:

- Rejection of these compounds by the RO membranes; and,
- Oxidation of low molecular weight compounds in the subsequent UV/AOP process – specifically compounds which are not well rejected by the RO membranes and therefore may be present in the RO permeate.

10.4.2 Sensitivity Case Minimum Pathogen LRV Targets

As the secondary UV system provides sufficient LRV to meet extreme condition considered under the sensitivity case, the AWTP process train for the sensitivity case is the same as that of the base case for RO-based DPR via treated water augmentation. Table 10-5 compares the claimed LRVs to the minimum LRV target assumed for the sensitivity case. The process flow diagram for this case is the same as shown in Figure 10-5.

Table 10-5: Byron DPR via TWA – Proposed Process Train for Sensitivity Case Minimum Pathogen LRV Targets

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
UF	0.0	4.0	4.0
RO	1.5	1.5	1.5
UV/AOP	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**10.0**	**10.0**	**14.0**
Minimum Required LRVs to Meet DALY of 10^{-6} in Drinking Water	**10.0**	**9.0**	**9.0**
Secondary UV Disinfection (for Excess LRV requirements)	4.0	4.0	4.0
Total Claimed LRVs to Meet Excess LRVs	**14.0**	**14.0**	**18.0**
Minimum Required LRVs including Excess LRVs	**14.0**	**13.0**	**13.0**

10.5 SUMMARY AWTP PROCESS SCHEDULE FOR EACH SHORT-LISED SCHEME

Table 10-6 provides a summary of the design criteria and sizing for the major unit processes for each short-listed scheme. For additional details, see Table 5-14 in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E).

Table 10-6: Summary Process Schedule for Major Unit Processes for Each Short-Listed Scheme

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA
Raw Water Balance Tank					
STP Feed (prior to recycle)	ML/d	9.1	9.1	5.4	8.35
Flow to Raw Water Balance Tank	ML/d	10.7	10.7	6.4	9.3
Raw Water Balance Tank Residence Time	h	4	4	4	4
Raw Water Balance Tank Working Volume	ML	1.8	1.8	1.1	1.6
Ozone System					
Control Basis		Ozone:TOC	Ozone:TOC	Ozone:TOC	N/A
Ozone Dose	mg/L	10.4	10.4	10.4	
Ozone Generator Capacity Required	kg/h	3.7	3.7	2.2	
Ozone Generator Cooling Water	kL/h	6.7	6.7	3.3	
Number of Ozone Generators	No.	2 (N + 1)	2 (N + 1)	2 (N + 1)	
Ozone Contactor Volume	kL	74.6	74.6	44.8	
Ozone Contactor Ventilation Rate	m^3/h	369	369	224	
Flash Mix Tank					
Hydraulic Residence Time	Min	0.5	0.5	0.5	N/A
Tank Volume	kL	3.7	3.7	2.2	
Flocculation Tank					
Hydraulic Residence Time	Min	20	20	20	N/A
Tank volume	kL	149	149	90	
BAC System					
Number of Filters	No.	6	6	5	
EBCT Provided	min	14.2	14.2	14.4	
Hydraulic Loading Rate Provided	m/h	7.8	7.8	7.6	
Backwash Flow	m^3/h	481	481	353	
Air Flow Rate	Nm^3/h	820	820	600	

Table 10-6: Summary Process Schedule for Major Unit Processes for Each Short-Listed Scheme (continued)

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA
GAC System					
Number of Filters	No.	5	5	4	
Hydraulic Loading Rate Provided	m/h	9.3	9.3	9.5	
Backwash Flow	m^3/h	481	481	353	
UF System					
UF Feed Tank Working Volume	kL	224	224	134	
UF System Maximum Instantaneous Flux	LMH	70	70	70	50
UF System Recovery	%	95%	95%	95%	92%
Number of UF Units	No.	3 (N + 1)	3 (N + 1)	3 (N + 1)	3 (N + 1)
UF Backwash Supply Tank Working Volume	kL	224	224	134	194
RO System					
RO Feed Tank Working Volume	kL				175
RO System Maximum Lead Element Flux	LMH				20
RO System Recovery	%				80%
Number of RO Stages	No.				2
Number of RO Units	No.				3 (N + 1)
RO Flush Tank Working Volume	kL				175
Primary UV					
UV Dose	mJ/cm^2	186	186	186	N/A
Minimum UV Transmittance	%	80%	80%	80%	
UV Unit Redundancy	No.	N + 1	N + 1	N + 1	
UV-AOP System					
UV Dose	mJ/cm^2	N/A			> 500
Minimum UV Transmittance	%				95%
Oxidant Dose	mg/L free chlorine				4
UV Unit Redundancy	No.				N + 1

Table 10-6: Summary Process Schedule for Major Unit Processes for Each Short-Listed Scheme (continued)

<table>
<tr><th>Parameter</th><th>Units</th><th>Lismore IPR</th><th>Lismore DPR-RWA</th><th>Lismore DPR-TWA</th><th>Lismore DPR-RWA</th></tr>
<tr><td colspan="6">Secondary UV Unit Note 1</td></tr>
<tr><td>UV Dose</td><td>mJ/cm²</td><td colspan="2" rowspan="3">N/A</td><td>186</td><td>186</td></tr>
<tr><td>Minimum UV Transmittance</td><td>%</td><td>80%</td><td>95%</td></tr>
<tr><td>UV Unit Redundancy</td><td>No.</td><td>N + 1</td><td>N + 1</td></tr>
<tr><td colspan="6">Chlorine Contact Tank</td></tr>
<tr><td>Ct</td><td>mg-min/L</td><td>4</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>Chlorine Residual</td><td>mg/L as Cl_2</td><td>0.5</td><td>0.5</td><td>0.5</td><td>0.5</td></tr>
<tr><td>Hydraulic Residence Time</td><td>min</td><td>15</td><td>15</td><td>15</td><td>15</td></tr>
<tr><td>Chlorine Contact Tank Volume</td><td>kL</td><td>97</td><td>97</td><td>58</td><td>70</td></tr>
<tr><td colspan="6">Calcite Filters</td></tr>
<tr><td>Number of Filters</td><td>No.</td><td colspan="3" rowspan="4">N/A</td><td>4</td></tr>
<tr><td>EBCT Provided</td><td>min</td><td>10</td></tr>
<tr><td>Hydraulic Loading Rate Provided</td><td>m/h</td><td>7.3</td></tr>
<tr><td>Backwash Flow</td><td>m³/h</td><td>282</td></tr>
<tr><td colspan="6">Engineered Storage Buffer Note 2</td></tr>
<tr><td>Buffer Tank Residence Time</td><td>min</td><td rowspan="2">N/A</td><td>30</td><td>30</td><td>30</td></tr>
<tr><td>Buffer Tank Working Volume</td><td>kL</td><td>190</td><td>113</td><td>140</td></tr>
<tr><td colspan="6">Waste Buffer Tank</td></tr>
<tr><td>Sizing Basis</td><td></td><td colspan="4">0.5 h storage of peak flow through process (including recycles)</td></tr>
<tr><td>Waste Buffer Tank Volume</td><td>kL</td><td>224</td><td>224</td><td>134</td><td>195</td></tr>
<tr><td colspan="6">RO Concentrate Treatment</td></tr>
<tr><td colspan="6">Nitrification MBBR</td></tr>
<tr><td>RO Concentrate Ammonia</td><td>mg/L as N</td><td colspan="3" rowspan="4">N/A</td><td>3.3</td></tr>
<tr><td>Effluent Ammonia</td><td>mg/L as N</td><td>0.1</td></tr>
<tr><td>MBBR Volume</td><td>kL</td><td>80</td></tr>
<tr><td>Carrier Fill</td><td>%</td><td>60%</td></tr>
</table>

Table 10-6: Summary Process Schedule for Major Unit Processes for Each Short-Listed Scheme (continued)

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Lismore DPR-RWA
Carrier Specific Surface Area	m^2/m^3				500
Hydraulic Residence Time	min				70
Approximate Airflow Required	Nm^3/h				200
Denitrification MBBR					
Denitrification MBBR Feed Nitrate	mg/L as N	N/A			4.2
Denitrification MBBR Effluent Nitrate	mg/L as N				0.1
Denitrification MBBR Volume	kL				120
Denitrification MBBR Carrier Fill	%				30%
Carrier Specific Surface Area	m^2/m^3				500
Denitrification MBBR Hydraulic Residence Time	min				105
Methanol Dose	mg/L				20
Lamella Clarifier					
Lamella Clarifier Feed Total Phosphorus		N/A			0.5
Lamella Clarifier Effluent Total Phosphorus					0.1
Alum Dose	mg/L as $Al_2(SO_4)_3.14H_2O$				10
Lamella Feed Total Suspended Solids	mg/L				33
Number of Lamella Clarifiers					2
Projected Settling Area	m^2				52
Hydraulic Loading Rate	m/h				0.7
Solids Loading Rate	kg/m^2-h				0.02

Note 1: Secondary UV not included in Lismore IPR via surface water augmentation or Lismore DPR via raw water augmentation base case. Secondary UV is included in Lismore DPR via treated water augmentation for sensitivity case only.

Note 2: Lismore IPR does not include an Engineered Storage Buffer Tank - PRW flows directly to the Engineered Environmental Buffer Storage.

11 RO CONCENTRATE MANAGEMENT

Options for RO concentrate management were considered for Ballina, Byron and Lismore based schemes. Completion of this analysis early in the project (along with the low relatively low secondary effluent TDS for the two Lismore STPs), resulted in the adoption of carbon-based AWTPs for each of the Lismore-based schemes to eliminate the RO concentrate streams. A brief consideration of Lismore RO concentrate disposal via brackish water is provided as a reference in Section 11.1.2 in the event that RO-based treatment is considered further in the future.

11.1 RO Concentrate Discharge to Saline/Brackish Waters

11.1.1 Byron Scheme

While a portion of Byron WWTP's effluent is directed to urban reuse and the Byron Bay Integrated Water Management Reserve, the outflow from the wetland cells on the treatment plant site is directed to the Union Drain, a man-made drain to the Belongil Creek Estuary.

Sampling data for the period from 2016 through 2022 indicate that flow in the Union Drain is low in salinity [15]. Hence, if an RO-based treatment system were to be used in an AWTP in the vicinity of Byron WWTP, it is unlikely that it would be acceptable to discharge the plant's RO concentrate into or upstream of the Union Drain.

Sampling data for the period from 2016 through 2022 indicate that Belongil Creek Estuary is brackish to saline, with TDS ranging from approximately 2,000 mg/L (lowest value at the upstream end of the estuary) to greater than 30,000 mg/L (highest value at the downstream end of the estuary) [15]. From a salinity perspective, discharge of RO concentrate into the Belongil Creek Estuary should be feasible. A pump station and a small diameter pipeline (~DN150) on the order of 2 km in length would be required to transport RO concentrate from the AWTP site to the upper end of the Belongil Creek Estuary. Figure 11-1 indicates a possible route for a pipeline (shown in orange).

Figure 11-1 : Possible Route for RO concentrate Discharge from Byron Based AWTP

Nitrogen and phosphorus levels in the Belongil Creek Estuary are above guideline values from the ANZ Guidelines for Fresh and Marine Water Quality, 2018 [15]. For the purpose of developing the AWTP process train, is has been assumed that treatment to reduce total nitrogen and phosphorus levels in the RO concentrate would be required.

It is probable that modelling of the discharge of RO concentrate to the estuary will be required to demonstrate the impacts on the environment as a condition of environmental approvals, confirm the suitability of the discharge location, and establish the extent of nutrient removal required. It is also likely that substantial stakeholder/community engagement will be required to gain support of the community.

11.1.2 Lismore Schemes

Available salinity information for the Wilsons and Richmond River were reviewed to ascertain the location at which the prevailing salinity would be comparable to that in an AWTP RO concentrate stream. Monitoring results summarised in the *Richmond River Estuary Processes Study, Final Report* [16][18] indicate that even at Coraki, a full 15 km straight line distance from East Lismore STP, prevailing salinity levels are very low (typically less than 1,000 mg/L), and certainly much less than the expected AWTP RO concentrate salinity of 2,000 mg/L – 3,000 mg/L.

It may be feasible to dilute the RO concentrate within the Wilson River flow at Lismore. Determining the viability of this would require modelling of the flows and the impacts of that RO concentrate release under near-field modelling. Such modelling and analysis would be recommended should RCC wish to progress any of the Lismore-based schemes with an RO-based AWTP.

11.1.3 Ballina Schemes

While there are no Level 1 options based on source water from the Ballina WWTPs, two options are considered at Level 2. Given that both potential Ballina sources currently discharge effluent to saline or brackish waters (Lennox Head WWTP via Skennars Head to open coastal waters, Ballina WWTP via the North Creek Canal, a tidal tributary of the Richmond River (ebb-tide effluent discharge)), for the purpose of the Level 2 evaluation of options it is assumed that discharge of RO concentrate via existing WWTP outfalls will be acceptable.

11.2 Evaporation Ponds for RO concentrate Management

As an option to manage RO concentrate from RO-based AWTP operations, the feasibility of RO concentrate evaporation ponds was assessed under Northern Rivers climatic conditions.

Long-term daily data available from the Bureau of Meteorology (BOM) on evaporation and precipitation covered a 40-year period from 1971 to 2011. These data were collected from the Alstonville Tropical Fruit Research Station, to simulate evaporation pond dynamics in the area. Evaporation data past 2011 were not available at this station.

Evaporation normally exceeded precipitation on most days during this period. However, on a long-term basis, the occurrence of large rain events outpaced cumulative evaporation for extended durations. This led to a higher rate of precipitation, compared to evaporation, on an annual basis during most years. This is demonstrated via annual totals in Figure 11-2, where 27 out of 40 years showed annual precipitation exceeding annual evaporation.

[18] Key references within the document are Figure 6-4 (p 6-9), with locations shown on Figure 6-1 (p 6-4).

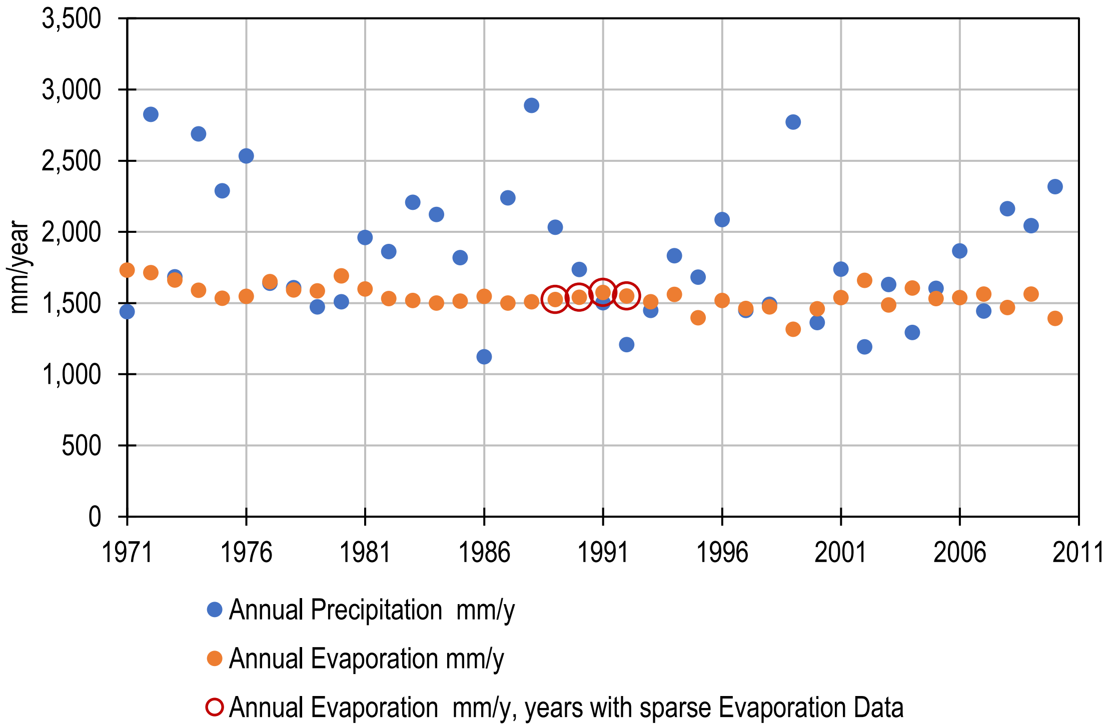

Figure 11-2: Comparison of Annual Evaporation and Precipitation Note 1

Note 1: There are periods of missing evaporation data between 1989 and 1993. Average evaporation rates from the same months, from all other years where data were available, were used to fill in the gaps. Data points for years with large data gaps are denoted by red circles.

A reasonably sized RO concentrate evaporation pond would receive daily inputs of RO concentrate from the AWTP during its functioning periods, in addition to incident rainfall over its exposed surface. Evaporation from this surface would also occur on a daily basis, but would be reduced (compared to the evaporation pan data received from BOM) due to the elevated salinity of the pond due to RO concentrate input. The balance between these three factors would ideally be assessed over a long-term basis to adequately size an evaporation pond. However, the balance between precipitation and evaporation data alone (shown cumulatively over the 40-year period during which data were available) indicates that, even without the impact of elevated salinity on evaporation potential, cumulative increases in the volume held within the ponds is to be expected. This occurs regardless of pond size, as precipitation volume rises linearly with exposed water surface area. This is shown in Figure 11-3. **The dominance of precipitation over baseline evaporation over the 40-year analysis period indicates, therefore, that RO concentrate evaporation from open ponds is not feasible in the Northern Rivers area.**

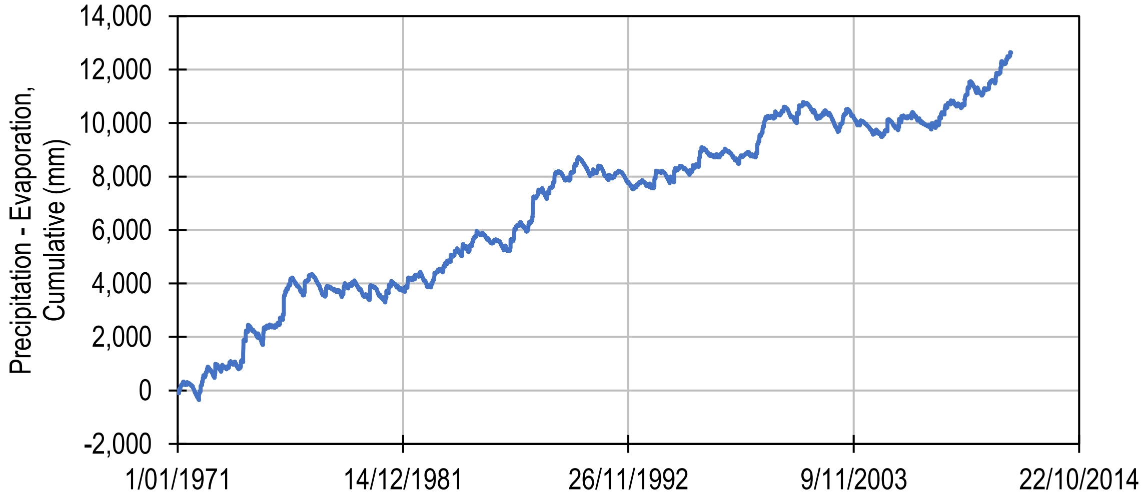

Figure 11-3: Cumulative daily precipitation (corrected for daily evaporation)

11.3 Zero Liquid Discharge

Zero liquid discharge (ZLD) involves mechanically treating RO concentrate (brine[19]) to reduce the volume and prevent discharge to the environment. Brine concentration (such as by a falling film evaporator), heats the brine to remove water, such that the TDS in the brine is increased to a concentration just prior to the point where solid salt begins to precipitate (on the order of 250,000 mg/L TDS). This reduces the volume the brine by around 95% to 97%. This means that an RO plant producing 2 ML/d of brine could reduce the volume of waste to be managed to about 50 kL/d to 80 kL/d by brine concentration.

This concentrated brine can then be further treated by a forced circulation crystalliser to produce a solid waste product. This is achieved by heating to further concentrate the brine beyond the solubility of the dissolved solids to create crystals, resulting in formation of crystals.

ZLD processes have a high energy demand and impose high capital and operating costs. Section 11.3.1 provides an example of a system with brine concentration only, to demonstrate the capital and operating (electricity) costs.

11.3.1 Brine Concentrator Example

As an example, consider an RO plant with a feed flow of 8 ML/d and operating at 80% recovery. The RO concentrate flow from such a plant would be 1.6 ML/d. For illustrative purposes, a mechanical vapour recompression falling film evaporator has been assumed for concentration of this brine stream, due to its high efficiency compared to other potential thermal technologies.

The high efficiency is due to the use of a rotary blower or steam compressor, which increases its latent heat by the mechanical action of volumetric compression, and the operation of the system under vacuum conditions.

11.3.2 Overview of Operating Principles

Vertical tubes inside the evaporator provide the heat exchange surface to evaporate water from brine. Pre-heated feed (RO brine) enters the evaporator sump which contains concentrated brine produced by the process. This concentrated brine mixture is then pumped to the top of the unit where the mixture is discharged and is allowed to flow by gravity inside the long vertical tubes. As the water flows thin films develop on the inside of the tube heat exchanger.

Steam is introduced on the outside of the tubes, causing evaporation from the brine flowing inside the tubes and concentration of the brine. The water vapour produced is drawn from the inside of the tubes either to a distillate tank for

[19] For the purpose of consistency with the nomenclature used to describe the equipment in this section (i.e. this equipment is known in the industry as a brine concentrator), the RO concentrate produced by RO-based AWTPs is referred to as brine (even though the salinity is quite low compared to what is normally considered brine).

condensation or to the atmosphere (is the latter has been assumed in this example). Concentrated brine is withdrawn or 'blown down' to maintain the required brine concentration.

Mechanical vapour recompression utilises an electrically driven vapour compressor to draw vapour from the concentrator, compressing the vapour as required to return steam to the system at the desired temperature and pressure. Figure 11-4 provides a simplified schematic of a mechanical vapour recompression vacuum falling film evaporator.

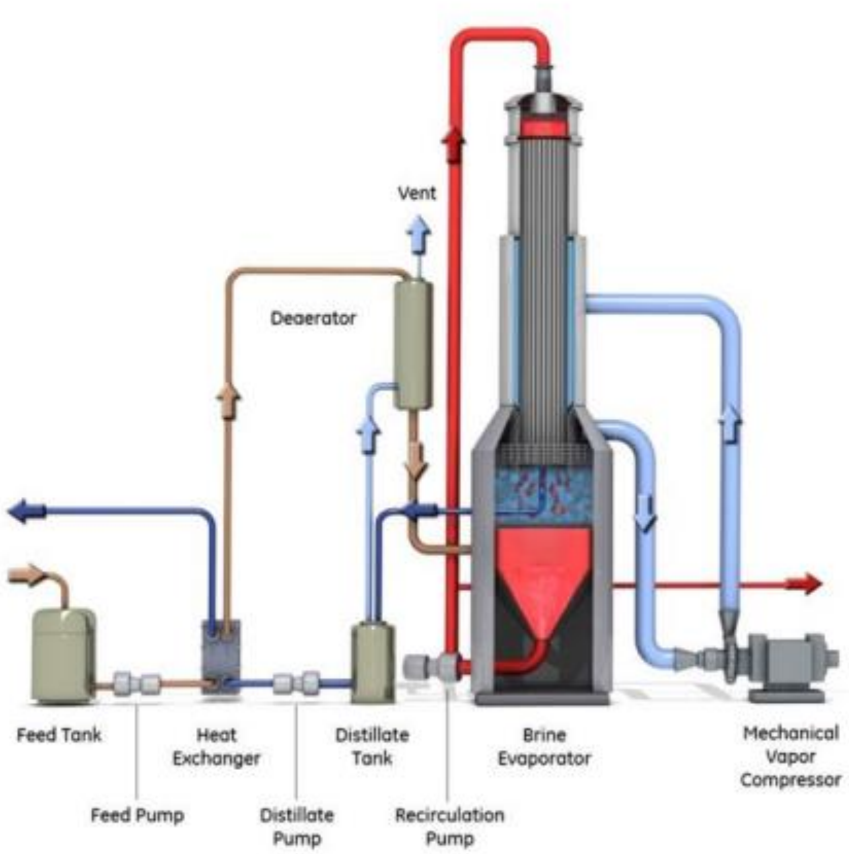

Figure 11-4: Falling Film Brine Concentrator Example (Veolia)

11.3.2.1 Application to Example Plant

Using brine concentration the 1.6 ML/d of RO brine from the example AWTP plant could be reduced to on the order of 50 kL/d to 80 kL/d.

A brine concentrator to treat this flow would cost on the order of $40m. The system would require 1,740 kW to operate, equating to approximately 15,250 MWh/year. Based on an electricity cost of $0.15/kWh, annual electricity cost to operate this system would be on the order of $2.2m. These costs do not include facilities to manage collection and trucking of the concentrated slurry, nor the transport and disposal costs.

Based on these capital and operating costs it is likely that any scheme requiring brine concentration would not be viable.

In addition:

- The brine concentrator system would require an area on the order of 26 m x 35 m;
- A suitable location to dispose of the concentrated slurry would need to be identified;
- Issues with transport and permitting would need to be investigated; and,
- Addition of brine concentration would significantly increase the operational complexity of the AWTP.

To bring the waste stream to a solid salt waste product, a crystallisation step could be added following the brine concentrator. This would significantly increase the capital cost and would add on the order to about $3m per annum in electricity cost.

11.3.2.2 Australian Example

In 2008, a demonstration project was considered in Canberra to investigate the viability of ZLD process based on mechanical vapour compression followed by a mechanical crystallisation stage. This project was developed by ACTEW and was branded as the *water2WATER* project. The project evaluated the design and estimated costs of a PRW plant located at Lower Molongolo Water Quality Control Centre. The AWTP was to incorporate a membrane filtration/RO/UV-AOP treatment train, and discharge of PRW to the Cotter Reservoir - an existing surface water reservoir supplying water to Stromlo WTP – essentially a surface water augmentation scheme.

Treatment of the concentrate generated by the RO stage in the AWTP was to be achieved through the ZLD process, with any remaining liquors being routed back to the inlet works of the Lower Molongolo WWTP and the underflow from the crystallisation stage being discharged to final evaporation ponds followed by mechanical harvesting.

The project was never developed as the overall project cost estimate was substantially higher than that developed for pumping water from the Murrumbidgee River to the Cotter Reservoir – the scheme that was finally adopted to augment Canberra's water supply.

11.4 High Recovery RO

RO recovery is typically constrained by the concentration of sparingly soluble salts, and the fouling potential of the feed water. While detailed water quality analysis and RO modelling would be required to confirm the recovery which could routinely be achieved for effluent from the Byron or Lismore STPs, a standard RO system would generally be expected to achieve up to about 85% recovery on water with those characteristics.

High recovery RO processes use different approaches (e.g. process configurations, chemical dosing, etc.) to manage scaling and/or fouling risks to enable higher recovery rates to be achieved.

While utilising a high recovery RO system may significantly reduce the capital and operating cost of a brine concentrator; any such savings would be offset by increase in the capital and operating costs of the RO system. Further, high recovery RO systems are more operationally complex which imposes additional risks.

There are a number of high recovery (> 90%) RO processes currently available in the market, including the following:

11.4.1 Closed Circuit RO

Closed Circuit RO *(DesaliTec™ by DuPont)*[20] is a semi-batch RO process that operates in two modes - closed-circuit mode and plug-flow/flushing mode. In closed-circuit mode, a high-pressure pump feeds a closed loop comprising a single stage of membrane elements and a circulation pump. Multiple pressure vessels are operated in parallel with short membrane arrays. Permeate is produced at a rate equal to the flow rate of the high-pressure pump, while RO concentrate is recirculated without depressurisation.

When a desired recovery percentage is reached, RO concentrate is purged from the system (i.e. the system enters plug-flow/flushing mode) through displacement using feed water delivered by the high-pressure pump in a single plug-flow sweep.

[20] Refer to https://www.kansaswatertech.com/includes/newsletters/2019/05/CCRO_TheNewStandard.pdf for further information

RO concentrate displacement is executed without stopping the high-pressure pump or the production of permeate. The process then returns to closed-circuit operation, during which there is no RO concentrate reject stream.

The cycle time of the closed-circuit mode is much shorter than the induction time for precipitation of most sparingly soluble salts, enabling high recovery to be achieved without membrane scaling occurring.

11.4.2 Pulsed Flow Reverse Osmosis

Pulsed Flow Reverse Osmosis *(PFRO™* The PFRO™ (*by IDE)*[21] process operates in two cycles - a production cycle and a flushing cycle. During the production cycle, a RO concentrate valve (installed in the residual RO concentrate stream) is closed, resulting in no RO concentrate discharge. During this cycle, 100% of the feed flow passes to the permeate side, and the concentration of salts builds up on the feed membrane side.

During the flush cycle, the RO concentrate valve opens for a short period of time, and RO concentrate is discharged at high velocity (which means high shear forces).

Several activities take place during these cycles:

- RO concentrate is discharged in an intensive, short pulse.
- The most concentrated RO concentrate is discharged
- The drop pressure in the specific vessel increases during the flushing cycle
- The high RO concentrate flow creates a shear force that is several times higher than that in conventional RO.
- The fast opening and closing of the RO concentrate valve provides pressure strokes and related micro shaking of the free membrane portions.
- Forward Osmosis (FO) permeate back flush takes place on the last membranes of the pressure vessel at the beginning of each flush cycle.
- The synergetic membrane cleaning effect comes from a combination of shearing velocity; membrane shaking; FO backwash and changing osmotic and gauge pressures.

11.4.3 Flow-Reversal RO

Flow-Reversal RO *(by ROTEC)*[22] is a continuous process designed to inhibit mineral scaling and biofouling - two of the limiting factors for high-recovery. This is achieved using two unique functions:

- Flow Reversal - periodically reversing the direction of the feed stream through each one of the pressure vessels, which functions as a built-in flushing feature that reduces the adverse effects of scaling.
- Block Rotation - allowing each array of RO vessels ("block") to periodically function as the last stage in the process. Individual blocks are repositioned between each stage to help prevent fouling of colloids, biomaterials, and organics, while also helping to lower the concentration of salts on the membrane surface.

11.4.4 High Efficiency Reverse Osmosis

The HERO™ process (*by Aquatec International)*[23] increases recovery of conventional RO systems by pre-treating the feed water to remove hardness and raise the pH to prevent silica scaling). The process steps are as follows:

- Addition of chemicals to the feed water to raise the alkalinity to the same level as the feed water hardness concentration. This hardness/alkalinity balance increases the efficiency of the subsequent weak acid cation softening process.

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[21] Refer to [50] for further information
[22] Refer to https://files.chartindustries.com/FRRO.pdf for further information
[23] Refer to https://www.nrel.gov/docs/fy04osti/34721.pdf for further information

- Hydrogen ions from the weak acid cation resin are exchanged with hardness ions in the water. The addition of hydrogen ions reduces the pH of the feed water, which converts much of the feed alkalinity to carbonic acid and carbon dioxide.
- Additional acid may be added to this water to completely convert all the remaining alkalinity to free carbon dioxide gas, which then may be removed via degasification.
- The pH of the feed water is then raised to pH 10.5 to increase the solubility of the silica and destroy biological organisms in the feed water. The feed water then enters the RO system.

11.4.5 Brine Squeezer

The Brine Squeezer *(by Osmoflo)*[24] treats RO concentrate from a standard RO system to increase overall plant recovery. It operates at or above the scaling threshold of sparingly soluble salts, concentrating feedwater to a TDS of on the order of 100,000 mg/L. Concentrate is recirculated in the high-pressure circuit to increase cross-flow and lower flux. A thermally degradable coating is applied to the membranes in situ to prevent irreversible fouling. The membranes are fitted with spacers that are thicker than conventional RO systems to enhance removal of scaling compounds.

The system is constantly monitored, and when scaling reaches a predetermined level, the unit is taken off-line to undergo a high-temperature cleaning followed by reapplication of the membrane coating. This is usually undertaken every one to four days.

11.5 Other Technologies

Forward osmosis and membrane distillation are being investigated in the industry to maximise recovery and minimise the volume of concentrate requiring management. However, further advances in these technologies would be required before additional investigations would be warranted for any RCC potable reuse scheme.

Selective salt recovery can be an option for treatment of brines for inland plants, producing saleable products and minimising solid waste disposal. The SAL-PROC process is an example of this [17]. This process treats the brine through several steps, extracting useful products sequentially through the process as different compounds reach their saturation limit. The SAL-PROC process uses evaporation/crystallisation ponds to sequentially concentrate the brine. As discussed in Section 11.2, due to the climatic conditions in the RCC region the use of open evaporation ponds for management of brine is not feasible. On this basis, the SAL-PROC process is not likely to be applicable (unless mechanical concentration/crystallisation technologies (such as those discussed in Section 11.3.1) are employed.

Enviro Water Minerals installed a selective salt recovery plant to recover minerals in RO concentrate from the Kay Bailey Hutchison WTP in El Paso, Texas, USA. The plant design includes nanofiltration, degasification, electrodialysis and softening to produce calcium sulphate, sodium chloride, magnesium chloride and calcium chloride brine streams. These brine streams are then sent to specific mineral production systems to produce sodium hydroxide, hydrochloric acid, gypsum, and magnesium hydroxide. The process returns desalinated water to the El Paso Water Utility. The process claims to increase overall recovery of the source water to the EL Paso RO plant from 85% to 99%.

Due to equipment and other issues during the commissioning stage, the equity that Enviro Water Minerals had in the plant was transferred to another entity (understood to be Critical Minerals Corporation[25]).[26] The current status of the selective salt recovery plant is unclear. Due to the complexity of this solution, it is unlikely that it would be economically viable for any of the short-listed schemes. Further, this process does not have a sufficient track record to warrant further consideration at this time.

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[24] Refer to https://www.filtsep.com/content/news/osmoflo-develops-ro-brine-squeezer/
[25] https://www.epwater.org/our_water/plants/kay_bailey_hutchison_wtp
[26] https://envirowaterminerals.com/united-states

11.6 SUMMARY

As evaporation ponds for RO concentrate management are not feasible for the project area and ZLD technologies are anticipated to be cost prohibitive, this investigation had prioritised options that either do not produce a brine stream (carbon-based) or sites that have a potential avenue for brine disposal (i.e. Byron).

12 AWTP LOCATIONS

Based on the AWTP process trains described in Section 10, high-level layouts have been developed for the purpose of estimating the required site footprint for both the Lismore and Byron schemes. The layout sketches are provided in Section 12.4 (and Appendix F) for reference.

The following criteria have been applied to the selection of potentially suitable AWTP sites for the Lismore and Byron schemes:

- Close proximity to the source STP to achieve acceptable feed and return flow pipeline distances;
- Manageable flood risk;
- Sufficient area to support the estimated AWTP footprint;
- Reasonable access to sufficient power supply;
- For Byron, a reasonable pipeline route from the site to a suitable discharge location for RO concentrate; and,
- Suitable planning overlay / location constraints.

This section summarises the selection of the proposed AWTP location. Further information on transfer infrastructure is provided in Section 13.

A high-level review by RCC indicated that there is no RCC owned parcel of land of sufficient size within an acceptable distance to the source STPs. As the next best alternative, preference has been given to locating the AWTPs on land held by the relevant local council that satisfies the above selection criteria (e.g. adjacent to South Lismore STP).

For this investigation, the siting assessment was high-level, and was only suitable for preliminary identification of AWTP sites to support the assessment of for each short-listed option. Further investigation will be required to confirm the suitability of the proposed site for any short-listed option carried forward for further consideration.

12.1 LISMORE IPR VIA SURFACE WATER AUGMENTATION AND DPR VIA RAW WATER AUGMENTATION

For the Lismore IPR via surface water augmentation and Lismore DPR via raw water augmentation scheme options, the land to the east of the South Lismore STP site was adopted as the preliminary location for the AWTP. Figure 12-1 provides a sketch of this option.

The proposed site has sufficient space available for the AWTP, though the existing Animal Rights and Rescue Group facility will be impacted. This location minimises the length of the feed and return pipelines to South Lismore STP. This location also facilitates PRW pipeline alignments that minimise pipeline construction in highly developed areas of the Lismore township (see SK0101 and SK0102 in Appendix F). While there will be requirements to consider the environmental constraints and suitability of the proposed AWTP site, as the selected location is an existing STP site, this is expected to be less onerous than other short-listed options. It is noted that known environmental constraints are present.

Most of the selected site area is not designated as a flood risk, but there are portions located in areas designated low flood risk. For the locations shown in sketch Figure 12-1, about 2 m of fill would be required to raise these portions of the site out of the low flood risk area, corresponding to approximately 17,500 m^3 of fill in total. The estimated cost for these earthworks is included in Section 21.2.1/21.2.2).

Power supply to the AWTP is proposed to be provided by an underground connection from the existing mains power supply that feeds the transformer at South Lismore STP. The capability of the existing mains supply to provide the power required for the AWTP will need to be confirmed with Essential Energy after the AWTP power demand is further developed (initial calculations suggest a peak AWTP power demand around 1.8 MW[27]).

[27] Includes PRW transfer pump station

12.2 Lismore DPR via Treated Water Augmentation

For the Lismore DPR via treated water augmentation scheme option, the preliminary AWTP site selected for the purposes of this investigation is on Wyrallah Road, across the road from the Lismore Council Works Depot and south of the Norco Milk facility. This site is approximately 800 m to the north of the East Lismore STP. Figure 12-2 provides a sketch of this option.

The East Lismore STP site was considered as an option for the AWTP site, but was deemed unsuitable due to lack of available space outside of flood prone areas - particularly once the new wastewater treatment plant is constructed.

The proposed site has sufficient space available for the AWTP[28]. This location provides for reasonable pipeline lengths for the feed and return pipelines to East Lismore STP, while minimising PRW pipeline lengths for the feed to the four reservoirs intended to receive PRW under this scheme (refer to SK0103 in Appendix F). Given this land is not an existing STP site, there will be a requirement to consider the environmental constraints and suitability of the site more holistically. Known environmental constraints, such as flooding, are present.

About half of the selected site area is not designated as a flood risk, with the remaining half located in an area designated low flood risk. For the locations shown in Figure 12-2, depths of fill from about 1 m to about 4 m of fill would be required to raise these portions of the site out of the low flood risk area. This represents approximately 12,500 m^3 of fill in total. The estimated cost for these earthworks is included in is provided in Section 21.2.3).

Power supply to the AWTP is proposed to be provided by an overhead connection from the existing mains power supply directly across the road from the AWTP site. If this scheme option is to be progressed, the capability of the existing mains supply to provide the power required for the AWTP will need to be confirmed with Essential Energy after the AWTP power demand is further developed. Initial calculations suggest a peak AWTP power demand around 2.5 MW[18].

12.3 Byron DPR via Treated Water Augmentation

For the Byron DPR via treated water augmentation scheme option, the preliminary AWTP site selected for the purposes of this investigation is directly to the west of the Cavanbah Centre on Ewingsdale Road in Byron Bay. Figure 12-3 provides a sketch of this option.

Locations within and closer to the Byron STP were investigated, but were considered unsuitable due to lack of sufficient space.

The proposed site has sufficient space available for the AWTP. This location provides for reasonable pipeline lengths for the feed and return pipelines to Byron STP, while minimising PRW pipeline lengths for the feed to the new Blending Reservoir that would receive PRW under this scheme (refer to SK0050 in Appendix F).

Given this land is not an existing STP site, there will be a requirement to consider the environmental constraints and suitability of the site more holistically. Known environmental constraints, such as flooding, proximity to Coastal Wetlands and High Environment Value vegetation, are present. In this regard, this AWTP location presents a more complicated environmental assessment process compared to the other short-listed options.

The proposed AWTP site was selected to avoid designated coastal wetland areas but is partially located within designated coastal wetland buffer zone. The entire site is located in designated flood prone lands. For the locations shown in sketch Figure 12-3, depths of fill from about 1 m to about 3 m of fill would be required to raise these portions of the site out of the low flood risk area. This corresponds to a total fill volume of approximately 22,000 m^3. The estimated cost for these earthworks is included in Section 21.2.4).

[28] The current basis of a maximum blend ratio of 50% for this option limits the effluent sourced from East Lismore STP to 5.4 ML/d. The footprint allowed for the AWTP for this option is sufficient to allow for an AWTP capacity aligning with utilizing the entire 2040 ADWF from East Lismore STP of 6.5 ML/d. If this option is carried forward, consideration should be made for staging the AWTP capacity to potentially allow full utilization of East Lismore STP effluent if further investigation and/or operation of the AWTP demonstrate that a higher blend ratio is acceptable.

Power supply to the AWTP is proposed to be provided by a new overhead power supply from an existing Essential Energy substation approximately 4.5 km to the west of the proposed AWTP site along Ewingsdale Road. Power supply should be further investigated with Essential Energy if this scheme option is to be progressed. Initial calculations suggest a peak AWTP power demand around 2.6 kW[29].

The proposed AWTP site also facilitates the disposal of RO concentrate via a pipeline along Ewingsdale Road, discharging to the Belongil Creek Estuary (see Section 11.1.1).

12.4 AWTP Layout Sketches

Figure 12-1 through Figure 12-3 provide layout sketches for each of the proposed AWTP sites.

[29] Includes PRW transfer pump station

Figure 12-1: Lismore IPR via Surface Water Augmentation and DPR via Raw Water Augmentation AWTP Site

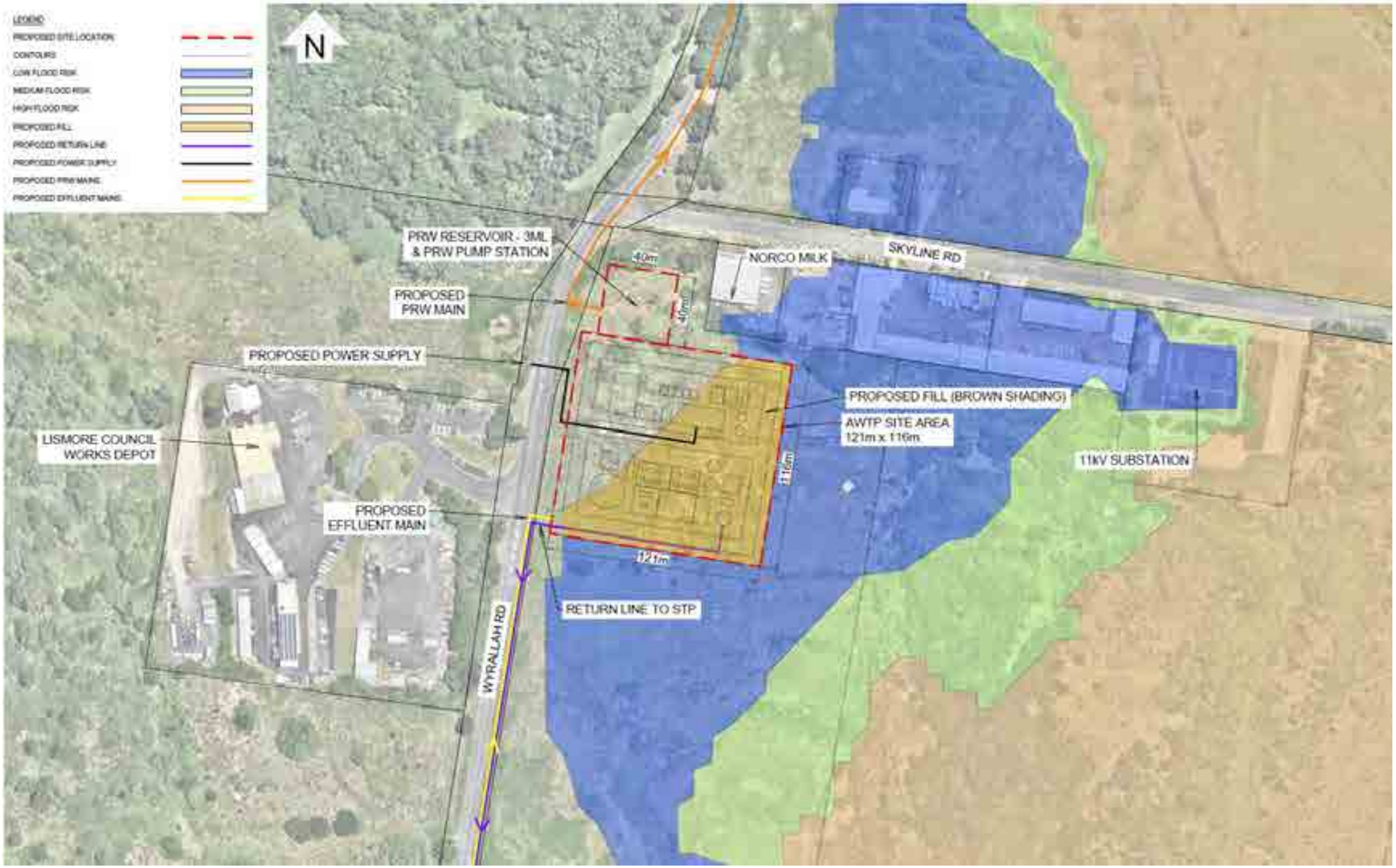

Figure 12-2: Lismore DPR via Treated Water Augmentation AWTP Site

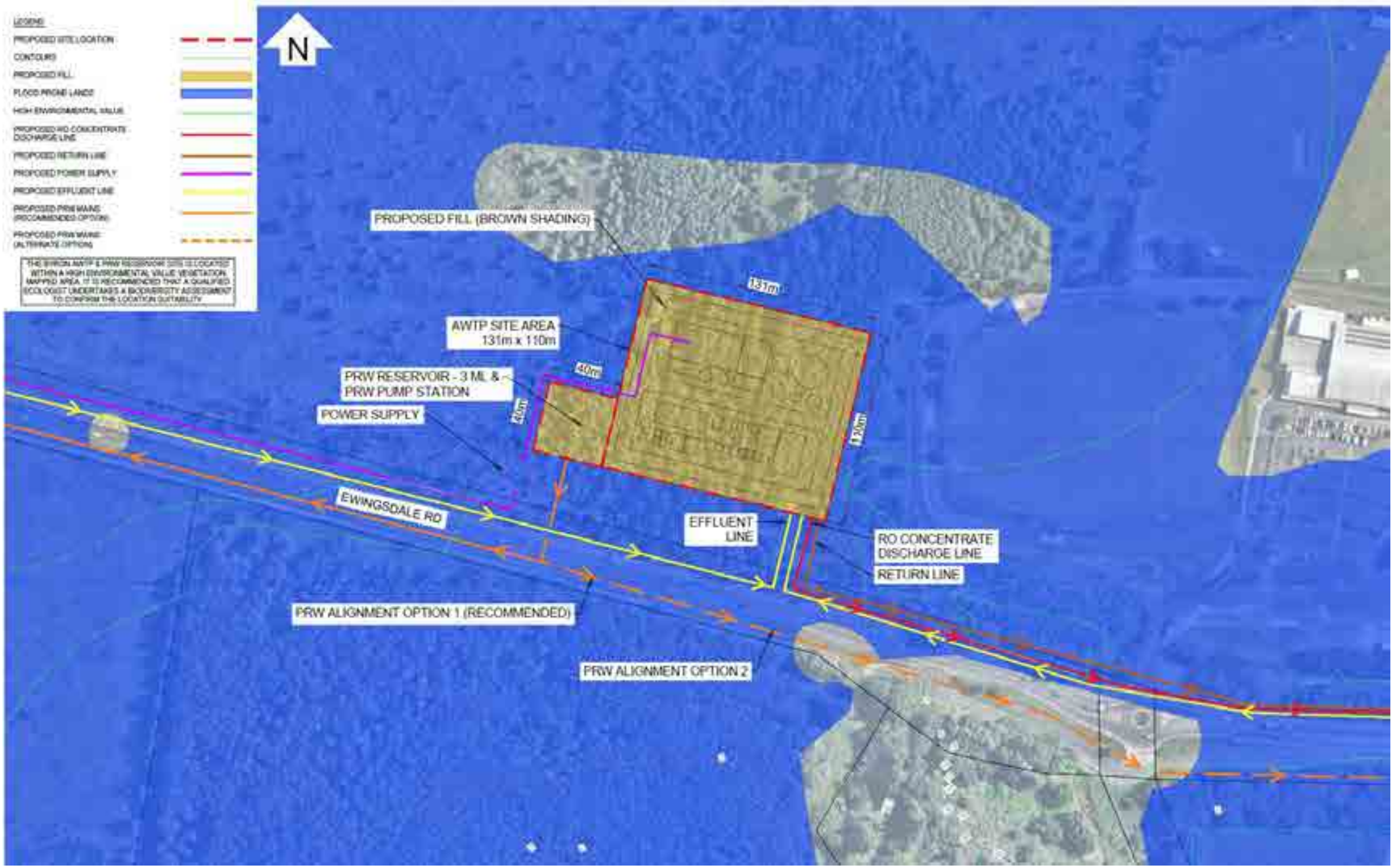

Figure 12-3: Byron DPR via Treated Water Augmentation AWTP Site

13 TRANSFER INFRASTRUCTURE REQUIREMENTS

This section describes and quantifies the high-level transfer infrastructure requirements and associated costs for the short-listed (Level 1) options.

13.1 Level 1 Short-Listed Options

For the short-listed options, pipe sizing has been based on providing a velocity of between 0.6 m/s and 2.0 m/s at the design flow, in accordance with the Northern Rivers Local Government Development Design Guidelines. Pipe diameters were increased where appropriate to reduce dynamic losses to reduce pump station power requirements.

Sketches of proposed infrastructure locations and pipeline alignments are provided in Section 12.4. Full resolution sketches are provided in and Appendix F.

13.1.1 Lismore IPR via Surface Water Augmentation

The Lismore IPR via surface water augmentation scheme transfers 9.1 ML/d of PRW to an Engineered Environmental Buffer Storage. Water from the Engineered Environmental Buffer Storage is pumped to the existing Wilsons River Source Pump Station for transfer to the head of Nightcap WTP via the existing pipeline.

The transfer infrastructure required for the Lismore IPR via surface water augmentation scheme is shown in Figure 13-1, and comprises:

- Pump station and pipeline to transfer STP effluent from South Lismore STP to the AWTP (located adjacent to South Lismore STP);
- Pump station and pipeline to transfer STP effluent from East Lismore STP to the AWTP (located adjacent to South Lismore STP);
- Pump Station at AWTP and pipeline to transfer PRW to a newly constructed Engineered Environmental Buffer Storage (location not defined at this time - assumed to be approximately 4.5 km east of the Wilsons River Source Pump Station for the purpose of developing a pipeline cost (see Section 21.2));
- Newly constructed Engineered Environmental Buffer Storage (required volume is not defined at this time, for costing purposes two volumes are considered, 0.6 GL and 1.2 GL (Section 21.2));
- Pump Station at newly constructed Engineered Environmental Buffer Storage and pipeline to transfer water from the newly constructed Engineered Environmental Buffer Storage to the existing Wilsons River Source Pump Station (from where it will be pumped to the head of Nightcap WTP); and,
- Pump station and pipeline to transfer return flows from the AWTP to the South Lismore STP.

Table 13-1 summarises the attributes of the pump stations, pipelines and other required infrastructure. Two options are shown in Figure 13-1 for PRW pipeline alignments. The information shown in Table 13-1 is for the preferred pipeline alignment option (Option 1).

Option 1 is preferred due to the proposed alignment being mostly in road reserves adjacent to undeveloped land, whereas the Option 2 alignment is mostly in road reserves adjacent to developed parcels of land (introducing potential issues with service clashes and public impacts during construction).

Option 1 utilises an existing pipe bridge for crossing the Wilsons River (noting that the pipe bridge will likely require upgrade to accommodate the new pipe).

A high-level assessment of planning constraints and overlays has been undertaken to understand planning approval requirements. Based on the project team's knowledge of the local area and delivering similar projects the pipeline routes appear feasible. However, a detailed environmental planning and cultural heritage assessment would be required if this option is carried forward.

The introduction of the Engineered Environmental Buffer Storage could facilitate improved utilisation of the Wilsons River Source. This would comprise pumping from the Wilsons River Source to the new buffer storage when licence conditions allow, and storing this water in the buffer storage combined with PRW. Significant additional investigation would be required to understand the economic, operational and environmental impacts of this approach. For the purposes of this investigation, no provision for pumping of Wilsons River Source water to the Engineered Environmental Buffer Storage has been included.

Table 13-1: Lismore IPR via Surface Water Augmentation Scheme Transfer Infrastructure

Asset	Asset Description	Length (m)/ Qty (No.)/Volume (m^3)	Pipe Size (DN)	Material	Flow (L/s) Note1	Velocity (m/s)	Total Pump Head (m)	Power Required (kW)	Standard Motor Size Note 2 (kW)	Installed Capacity (kW) Note 3
Pipeline 1	South Lismore STP to AWTP	50	200	PVC	56	1.6				
Pipeline 2	East Lismore STP outlet to AWTP at South Lismore	5,550	300	PVC	120	1.6				
Pipeline 3	Return stream from AWTP to South Lismore STP inlet works	50	100	PVC	19	2.0				
Pipeline 4	PRW to Engineered Environmental Buffer Storage	17,710	375	PVC	126	1.1				
Pipeline 5	Engineered Environmental Buffer Storage to Wilsons River Source Pump Station	4,250	500	DICL	405	1.8				
Pump Station 1	South Lismore STP to AWTP	1			56		9	6	7.5	15
Pump Station 2	East Lismore STP outlet to AWTP at South Lismore	1			120		52	76	90	180
	Return stream from AWTP to South Lismore STP inlet works	Included as part of the AWTP								
Pump Station 3	PRW to Engineered Environmental Buffer Storage	1			126		56	87	90	180
Pump Station 4	Engineered Environmental Buffer Storage to Wilsons River Source Pump Station	1			405		36	177	200	400
Fill	Volume of fill required for AWTP site area	18,000								

Asset	Asset Description	Volume (GL)
Environmental Buffer	Engineered Environmental Storage Buffer	0.6 to 1.2

Note 1. Basis for flow comprise:

- Pipeline 1/Pump Station 1 – 2040 ADWF for South Lismore STP of 2.6 ML/d (30 L/s). Assumes that on site effluent balance tank at South Lismore STP used to attenuate peak dry weather flow, therefore a peaking factor of 1.2 times ADWF has been applied. Return flows from the AWTP (1.4 ML/d, 16 L/s) are added to the peaked STP effluent flow, with a peaking factor of 1.2 applied to the AWTP return flow.

- Pipeline 2/Pump Station 2 – 2040 ADWF for East Lismore STP of 6.5 ML/d (75 L/s). A peaking factor of 1.6 times ADWF has been applied (details of new STP to be constructed at East Lismore are unknown).
- Pipeline 3/Pump Station 3 – 1.4 ML/d (16 L/s) of UF backwash and BAC backwash based on flow balance calculations, with a peaking factor of 1.2 applied.
- Pipeline 4/Pump Station 4 – 2040 combined ADWF for South Lismore STP and East Lismore STP (9.1 ML/d, 95 L/s) with a 1.2 peaking factor applied.
- Pipeline 5/Pump Station 5 – Flow rate set to match the capacity of the Wilsons River Source Pump Station (405 L/s)

Note 2. Power required is rounded up to next largest standard low voltage motor size.

Note 3. Includes redundancy. Assumes two pumps are provided in a duty/standby arrangement (consistent with costing approach (discussed in Section 21.2)).

13.1.2 Lismore DPR via Raw Water Augmentation

The Lismore DPR via raw water augmentation scheme transfers 9.1 ML/d of PRW to the existing Wilsons River Source Pump Station. The Wilsons River Source Pump Station then pumps this water to the head of Nightcap WTP via the existing pipeline.

The transfer infrastructure required for the Lismore DPR via raw water augmentation scheme is shown in Figure 13-2, and comprises:

- Pump station and pipeline to transfer STP effluent from South Lismore STP to the AWTP (located adjacent to South Lismore STP);
- Pump station and pipeline to transfer STP effluent from East Lismore STP to the AWTP (located adjacent to South Lismore STP);
- Pump Station at AWTP and pipeline to transfer PRW to the Wilsons River Source Pump Station (from where it will be pumped to the head of Nightcap WTP); and,
- Pump station and pipeline to transfer return flows from the AWTP to the South Lismore STP.

Table 13-2 provides information on pump stations, pipelines and other required infrastructure. Two options are shown in Figure 13-2 for PRW pipeline alignments. The information shown in Table 13-2 is for the preferred pipeline alignment option (Option 1).

Option 1 is preferred due to the proposed alignment being mostly in road reserves and adjacent to undeveloped land. By contrast, the Option 2 alignment is mostly in road reserves adjacent to developed parcels of land (introducing potential issues with service clashes and public impacts during construction).

Option 1 utilises an existing pipe bridge for crossing the Wilsons River (noting that the pipe bridge will likely require upgrade to accommodate the new pipe).

A high-level assessment of planning constraints and overlays has been undertaken to identify the potential planning approval requirements. Based on the project team's knowledge of the local area and delivering similar projects the pipeline routes appear feasible. However, if this option is progressed a detailed environmental planning and cultural heritage assessment will be required.

Table 13-2: Lismore DPR via Raw Water Augmentation Scheme Transfer Infrastructure

Asset	Asset Description	Length (m)/ Qty (No.)/Volume (m^3)	Pipe Size (DN)	Material	Flow (L/s) Note 1	Velocity (m/s)	Total Pump Head (m)	Power Required (kW)	Standard Motor Size Note 2 (kW)	Installed Capacity (kW) Note 3
Pipeline 1	South Lismore STP to AWTP	50	200	PVC	56	1.6				
Pipeline 2	East Lismore STP outlet to AWTP at South Lismore	5,550	300	PVC	120	1.6				
Pipeline 3	Return stream from AWTP to South Lismore STP inlet works	50	100	PVC	19	2.0				
Pipeline 4	PRW to Wilsons River Source Pump Station	6,250	375	PVC	126	1.1				
Pump Station 1	South Lismore STP to AWTP	1			56		9	6	7.5	15
Pump Station 2	East Lismore STP outlet to AWTP at South Lismore	1			120		52	76	90	180
	Return stream from AWTP to South Lismore STP inlet works	Included as part of the AWTP								
Pump Station 3	PRW to Wilsons River Source Pump Station	1			126		28	43	45	90
Fill	Volume of fill required for AWTP site area	18,000								

Note 1. Basis for flow comprise:

- Pipeline 1/Pump Station 1 – 2040 ADWF for South Lismore STP of 2.6 ML/d (30 L/s). Assumes that on site effluent balance tank at South Lismore STP used to attenuate peak dry weather flow, therefore a peaking factor of 1.2 times ADWF has been applied. Return flows from the AWTP (1.4 ML/d, 16 L/s) are added to the peaked STP effluent flow, with a peaking factor of 1.2 applied to the AWTP return flow.
- Pipeline 2/Pump Station 2 – 2040 ADWF for East Lismore STP of 6.5 ML/d (75 L/s). A peaking factor of 1.6 times ADWF has been applied (details of new STP to be constructed at East Lismore are unknown).
- Pipeline 3/Pump Station 3 – 1.4 ML/d (16 L/s) of UF backwash and BAC backwash based on flow balance calculations, with a peaking factor of 1.2 applied.
- Pipeline 4/Pump Station 4 – 2040 combined ADWF for South Lismore STP and East Lismore STP (9.1 ML/d, 95 L/s) with a 1.2 peaking factor applied.

Note 2. Power required is rounded up to next largest standard low voltage motor size.

Note 3. Includes redundancy. Assumes two pumps are provided in a duty/standby arrangement (consistent with costing approach (discussed in Section 21.2)).

13.1.3 Lismore DPR via Treated Water Augmentation

The Lismore DPR via treated water augmentation scheme transfers 5.4 ML/d of PRW to City View Reservoir, Belvedere Drive Reservoir, High Street Reservoir and Ross Street Reservoir. To allow for up to a 50% blend ratio, the transfer infrastructure is sized to deliver PRW at 50% of the current peak inflow rate to all four reservoirs simultaneously. To accomplish this a PRW reservoir is required at the AWTP site.

The transfer infrastructure required for the Lismore DPR via treated water augmentation scheme is shown in Figure 13-3, and comprises:

- Pump station and pipeline to transfer STP effluent from East Lismore STP to the AWTP, located ~800 m to the north of East Lismore STP (pump station and pipeline are sized for combined flow from South Lismore STP and East Lismore STP in the event that flow from South Lismore STP might be utilised in future);
- Pump Station at AWTP and pipeline to transfer PRW to the City View Reservoir offtake, including a 3 ML reservoir at the AWTP site to allow for pumping PRW at a rate corresponding to the target blend ratio at the peak fill rates of the existing reservoirs;
- Pipeline to deliver PRW into City View Reservoir (including flow control valves and flow meters to control the blend ratio into the reservoir);
- Pipeline from City View Reservoir to Belvedere Drive Reservoir offtake;
- Pipeline to deliver PRW into Belvedere Drive Reservoir (including flow control valves and flow meters to control the blend ratio into the reservoir);
- Pipeline to location of split between High Street Reservoir and Ross Street Reservoir;
- Booster pump station and pipeline to deliver PRW into Ross Street Reservoir (including flow control valves and flow meters to control the blend ratio into the reservoir);
- Pipeline to deliver PRW into High Street Reservoir (including flow control valves and flow meters to control the blend ratio into the reservoir);
- Pump station and pipeline to transfer return flows from the AWTP to the East Lismore STP.

Note that Figure 13-3 also includes a pump station and pipeline from South Lismore STP to East Lismore STP that is shown for information only. At the proposed 50% blend ratio effluent will not need to be sourced from South Lismore STP.

Two options are shown in Figure 13-3 for PRW pipeline alignments supplying PRW to Ross Street Reservoir.

Option 1 is preferred as the proposed alignment utilises Ross Street road reserve to minimise works within Ballina Road, whereas the Option 2 alignment requires construction along Ballina Road. The Option 2 alignment is also more heavily vegetated than the Option 1 alignment.

Table 13-3 provides information on pump stations, pipelines and other required infrastructure for the preferred pipeline alignment option (Option 1).

Constraints for the Option 1 alignment include 1) it is partially aligned along main roads, and 2) there is limited space to locate the required booster pump station at the intersection of Dibbs Street and McKenzie Street.

A high-level assessment of planning constraints and overlays has been undertaken to understand planning approval requirements. Based on the project team's knowledge of the local area and delivering similar projects the pipeline routes appear feasible. However, if this option is progressed a detailed environmental planning and cultural heritage assessment will be required.

Table 13-3: Lismore DPR via Treated Water Augmentation Scheme Transfer Infrastructure

Asset	Asset Description	Length (m)/ Qty (No.)/Volume (m^3)	Pipe Size (DN)	Material	Flow (L/s) Note 1	Velocity (m/s)	Total Pump Head (m)	Power Required (kW)	Standard Motor Size Note 2 (kW)	Installed Capacity (kW) Note 3
Pipeline 1	East Lismore STP outlet to AWTP at East Lismore	1,530	300	PVC	160	2.1				
Pipeline 2	Return stream from AWTP to East Lismore STP inlet works	1,530	100	PVC	17	1.8				
Pipeline 3	PRW to City View Reservoir offtake	810	600	DICL	430	1.4				
Pipeline 4	PRW into City View Reservoir	10	300	PVC	100	1.3				
Pipeline 5	PRW from City View Reservoir offtake to Belvedere Drive Reservoir offtake	350	500	DICL	330	1.5				
Pipeline 6	PRW into Belvedere Drive Reservoir	250	300	PVC	85	1.1				
Pipeline 7	PRW from Belvedere Drive Reservoir offtake to location of split between High Street Reservoir and Ross Street Reservoir	1,750	450	DICL	245	1.4				
Pipeline 8	PRW into Ross Street Reservoir	1,250	200	PVC	45	1.3				
Pipeline 9	PRW into High Street Reservoir	1,750	375	PVC	100	0.9				
Pump Station1	East Lismore STP outlet to AWTP at East Lismore	1			160		29	56	75	150
	Return stream from AWTP to East Lismore STP inlet works	Included as part of the AWTP								
Pump Station 2	PRW to City View Reservoir offtake	1			430		109	574	700	1,400
	PRW into City View Reservoir									
	PRW from City View Reservoir offtake to Belvedere Drive Reservoir offtake									
	PRW into Belvedere Drive Reservoir									
	PRW from Belvedere Drive Reservoir offtake to Ross Street/High Street split									
	PRW into High Street Reservoir (from split)									
Pump Station 3	PRW into Ross Street Reservoir (from split)	1			45		81	45	45	90
PRW Storage	3 ML PRW Reservoir at AWTP Site	1		Steel						
Fill	Volume of fill required for AWTP site area	12,500								
Flow Control	Allowance for flow meters and flow control valves at each PRW discharge to existing reservoirs	4								

Note 1. Basis for flow is as follows:

- Pipe 1/Pump 1 – The current basis for blend ratio of PRW to network water is 50%, which requires supply from East Lismore STP of 5.4 ML/d (63 L/s) only (as compared to the available 2040 ADWF from East Lismore of 6.5 ML/d (75 L/s)). The pipe/pump sizing is designed to accommodate the full 2040 ADWF from East Lismore STP to allow for potential higher blend ratio if this is found to be acceptable based on future investigation and/or through operation of the AWTP. Flow from South Lismore STP is not included in the sizing of Pipe 1/Pump 1. Pipe 1/Pump 1 are sized based on 6.5 ML/d (75 L/s) of effluent from East Lismore STP, with a peaking factor of 1.6 times ADWF applied, plus 1.2 ML/d (14 L/s) of return flow from the AWTP with a peaking factor of 1.2 applied to the AWTP return flow. At the 50% blend ratio case the flow rate would be 116 L/s (63 L/s East Lismore effluent times a 1.6 peaking factor, plus 13 L/s of AWTP return flow times a 1.2 peaking factor).
- Pipe2/Pump2 – 1.2 ML/d (14 L/s) of UF backwash and BAC backwash based on flow balance calculations for an AWTP sized based on 6.5 ML/d of available source water from East Lismore STP, with a peaking factor of 1.2 applied. At the 50% blend ratio the return flow would be 1.1 ML/d (13 L/s, 15 L/s with 1.2 peaking factor).
- Pipe 3/Pump 3 – This value is 50% of the combined peak inflow rates to each of the network reservoirs (City View, Belvedere Drive, High Street and Ross Street), to achieve a 50% blend ratio at the inlet to each reservoir simultaneously. If a higher blend ratio is found to be acceptable through further investigation and/or through operation of the AWTP, it may be possible to meet that blend ratio at the inlet to each reservoir by staggering the filling of the reservoirs (this would need further investigation to confirm – a higher blend ratio may require a higher PRW flow than assumed here). Alternative operation of the network, if possible, may enable reduction in the size of this pump station. An alternative approach may be to pump from the AWTP at the average daily PRW production rate to a suitably sized PRW reservoir located somewhere in reasonable proximity to the existing reservoirs. Both alternatives should be further investigated if this option is to be carried forward.
- Pipe 4 – This value is 50% of the peak inflow rate to City View Reservoir.
- Pipe 5 – This value is 50% of the peak inflow rate to each of the network reservoirs less the peak inflow rate to City View Reservoir.
- Pipe 6 – This value is 50% of the peak inflow rate to Belvedere Drive Reservoir.
- Pipe 7 – This value is 50% of the combined peak inflow rate to High Street Reservoir and Ross Street Reservoir.
- Pipe 8 – This value is 50% of the combined peak inflow rate to High Street Reservoir.
- Pipe 9/Pump 4 - This value is 50% of the combined peak inflow rate to Ross Street Reservoir.

Note 2. Power required is rounded up to next largest standard low voltage motor size.

Note 3. Includes redundancy. Assumes two pumps are provided in a duty/standby arrangement (consistent with costing approach (discussed in Section 21.2)).

13.1.4 Byron DPR via Treated Water Augmentation

The Byron DPR via treated water augmentation scheme transfers 6.7 ML/d of PRW to St Helena Reservoir and Knockrow Reservoir. To allow for up to a 50% blend ratio, the transfer infrastructure is sized to deliver PRW at 50% of the current peak inflow rate to both reservoirs simultaneously. To accomplish this a PRW reservoir is required at the AWTP site. PRW to be delivered to Knockrow Reservoir is pumped to a new Blending Reservoir (notionally located in the general vicinity of the split in the existing pipeline from Nightcap WTP to St Helena Reservoir and Knockrow Reservoir (i.e. where the pipeline branches to Knockrow Reservoir)). The PRW is blended with Nightcap WTP treated water and pumped to Knockrow Reservoir via a new pump station.

This configuration for transfer of PRW to Knockrow has been adopted to manage risks to customers drawing flow directly from the transfer main, but substantially increases the electricity consumption of this scheme option (see Section 21.3.1.4). On this basis, alternative approaches (e.g. an additional blending reservoir or blending at Knockrow, in combination with alternative supply to customers drawing directly from the main) should be considered if this option is progressed.

The transfer infrastructure required for the Byron DPR via treated water augmentation scheme is shown in Figure 13-5 through Figure 13-6, and comprises:

- Pump station and pipeline to transfer STP effluent from Brunswick Valley STP to the AWTP (including two booster pump stations and reservoirs along the pipeline);

- Pump stations and pipeline to transfer STP effluent from Byron STP to the AWTP (pump stations provided to allow drawing effluent from the STP and from the wetland);
- Pump Station at AWTP and pipeline to transfer PRW to the St Helena Reservoir offtake, including a 3 ML reservoir at the AWTP site to allow for pumping PRW at a rate corresponding to the target blend ratio at the peak fill rates of the existing reservoirs;
- Pipeline to deliver PRW into St Helena Reservoir (including flow control valves and flow meters to control the blend ratio into the reservoir);
- Pipeline from St Helena Reservoir offtake to new Blending Reservoir;
- New Blending Reservoir and pump station to direct blended water to Knockrow Reservoir in existing rising main;
- Pump station and pipeline to transfer RO concentrate to the discharge location in the Belongil Creek Estuary; and,
- Pump station and pipeline to transfer return flows from the AWTP to the Byron STP.

Table 13-4 provides information on pump stations, pipelines and other required infrastructure. Two options are shown in Figure 13-4 and Figure 13-5 for PRW pipeline alignments supplying PRW to St Helena Reservoir and two options to supply effluent from Brunswick Valley STP to the AWTP. The information shown in Table 13-4 is for the preferred PRW pipeline alignment option (Option 1) and the preferred effluent pipeline alignment (Option 1).

STP effluent Option 1 is preferred as:

1. The proposed alignment only traverses Coastal Wetlands in existing road reserves or where there are existing pipelines, whereas Options 2 has two additional water body crossings and additional traversing of Coastal Wetland; and,
2. This alignment has a shorter pipe length. Both options require works adjacent to a busy highway.

PRW Option 1 is preferred as:

1. The proposed alignment does not impact vegetation and Coastal Wetlands; and,
2. This alignment has a shorter pipe length. Both options require works adjacent to a busy highway.

A high-level assessment of planning constraints and overlays has been undertaken to understand planning approval requirements. Based on the project team's knowledge of the local area and delivering similar projects the pipeline routes appear feasible. However, if this option is progressed a detailed environmental planning and cultural heritage assessment will be required.

Table 13-4: Byron DPR via Treated Water Augmentation Scheme Transfer Infrastructure

Asset	Asset Description	Length (m)/ Qty (No.)/Volume (m^3)	Pipe Size (DN)	Material	Flow (L/s) Note 1	Velocity (m/s)	Total Pump Head (m)	Power Required (kW)	Standard Motor Size Note 2 (kW)	Installed Capacity (kW) Note 3
Pipeline 1	Brunswick Valley STP outlet to AWTP	17,405	200	PVC	30	0.9				
Pipeline 2	Bryon STP and wetlands to AWTP	1,500	300	PVC	158	2.1				
Pipeline 3	Return stream from AWTP to East Lismore STP inlet works	1,800	100	PVC	14	1.5				
Pipeline 4	RO Concentrate to Belongil Creek Estuary (along Ewingsdale Road)	1,800	150	PVC	19	0.9				
Pipeline 5	PRW to St Helena Reservoir offtake	4,725	450	DICL	200	1.1				
Pipeline 6	PRW into St Helena Reservoir	10	300	PVC	100	1.3				
Pipeline 7	PRW from St Helena Reservoir offtake to the new Blending Reservoir	4,500	375	PVC	100	0.9				
Pump Station 1	Brunswick Valley STP outlet to AWTP	3			30		80	30	30	60
Pump Station 2	Bryon STP and wetlands to AWTP	2			158		25	48	55	110
	Return stream from AWTP to East Lismore STP inlet works	Included as part of the AWTP								
Pump Station 3	RO Concentrate to Belongil Creek Estuary	1			19		17	4	5.5	11
Pump Station 4	PRW to St Helena Reservoir offtake PRW into St Helena Reservoir PRW from St Helena Reservoir offtake to the new Blending Reservoir	1			200		131	320	335	670
Pump Station 5	Blended water from new Blending Reservoir	1			200		88	215	215	430
Effluent Storage	0.5 ML for Transfer Stations	2		Steel						
PRW Storage	750 kL PRW Reservoir at AWTP Site	1		Steel						
PRW Storage	3 ML PRW Reservoir at AWTP Site	1		Steel						
Fill	Volume of fill required for AWTP site area	22,000								
Flow Control	Allowance for flow meters and flow control valves at the PRW discharge to St Helena Reservoir and to the new Blending Reservoir	2								

Note 1. Basis for flow is as follows:

- Pipe 1/Pump 1 – 2040 ADWF for Brunswick Valley STP of 2.16 ML/d (25 L/s). Assumes that on site effluent balance tank at Brunswick Valley STP used to attenuate peak dry weather flow, therefore a peaking factor of 1.2 times ADWF has been applied.

- Pipe2/Pump2 – 2040 ADWF for Byron STP of 6.6 ML/d (76 L/s). Assumes flow is taken directly from the STP effluent, hence a peaking factor of 2 times ADWF is applied. Return flows from the AWTP (1 ML/d, 12 L/s) are added to the peaked STP effluent flow, with a peaking factor of 1.2 applied to the AWTP return flow.
- Pipe 3/Pump 3 – 1 ML/d (12 L/s) of UF backwash and BAC backwash based on flow balance calculations, with a peaking factor of 1.2 applied.
- Pipe 4/Pump 4 – Based on RO recovery of 80%, refer to flow balance (Appendix E).
- Pipe 5/Pump 5 – This value is 50% of the combined peak inflow rates to St Helena Reservoir and Knockrow Reservoir to allow for a blending ratio of up to 50% at the reservoir. Alternative operation of the network, if possible, may enable reduction in the size of this pump station. An alternative approach may be to pump from the AWTP at the average daily PRW production rate to a suitably sized PRW reservoir located somewhere in reasonable proximity to the existing reservoir(s). Both alternatives should be further investigated if this option is to be carried forward.
- Pipe 6 – This value is 50% of the peak inflow rate to St Helena Reservoir.
- Pipe 7 – This value is 50% of the peak inflow rate to Knockrow Reservoir.
- Pump 6 – This value is 100% of the peak inflow rate to Knockrow Reservoir (existing pipeline to Knockrow Reservoir is used to transport blended water)

Note 2. Power required is rounded up to next largest standard low voltage motor size.

Note 3. Includes redundancy. Assumes two pumps are provided in a duty/standby arrangement (consistent with costing approach (discussed in Section 21.2)).

13.1.5 Infrastructure Locations Pipeline Alignments

Sketches of proposed infrastructure locations and pipeline alignments are provided in Figure 13-1 through Figure 13-6. Full resolution versions of the sketches are provided in Appendix F.

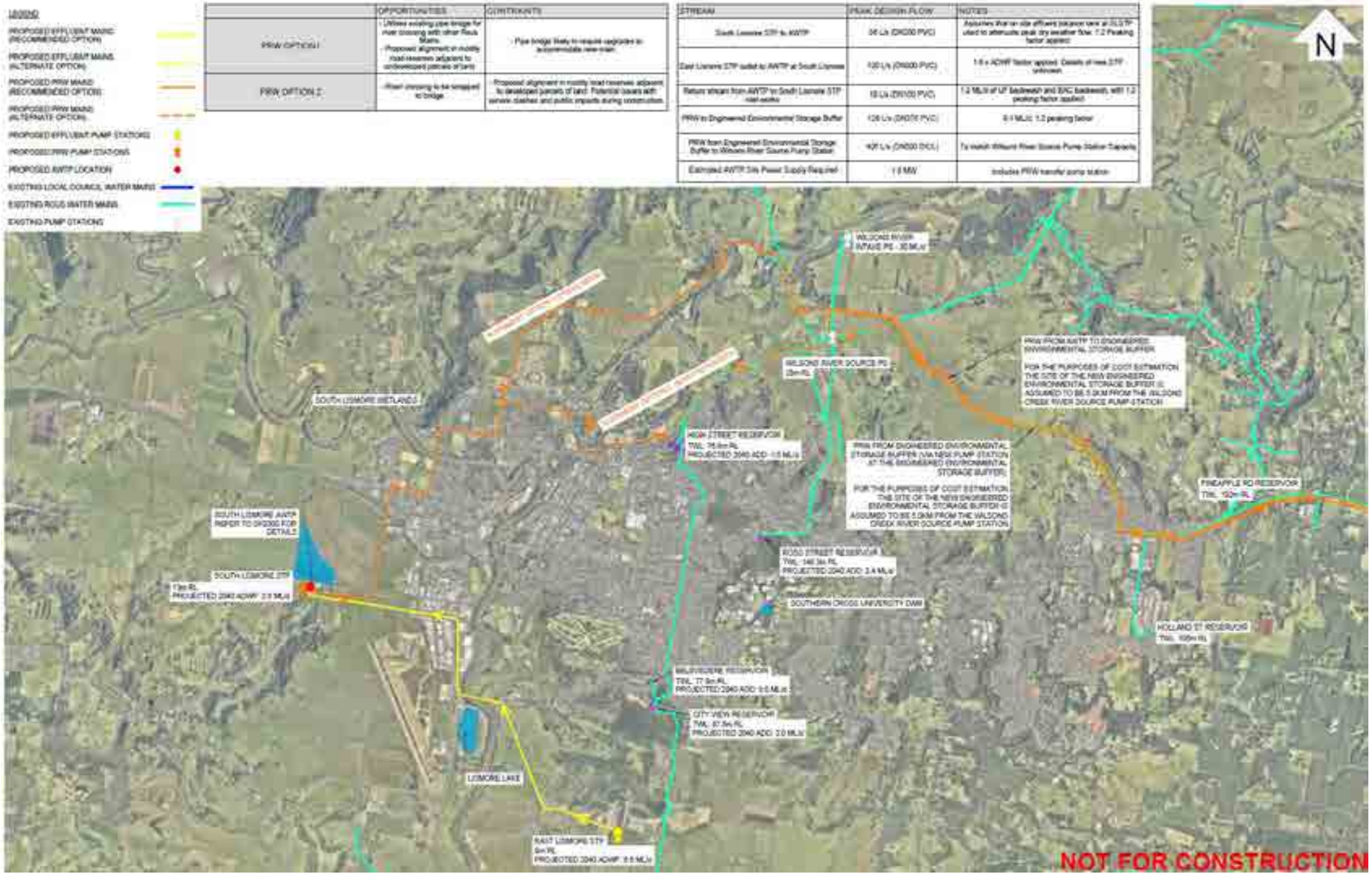

Figure 13-1: Lismore IPR via Surface Water Augmentation Proposed Infrastructure Locations and Pipeline Alignments

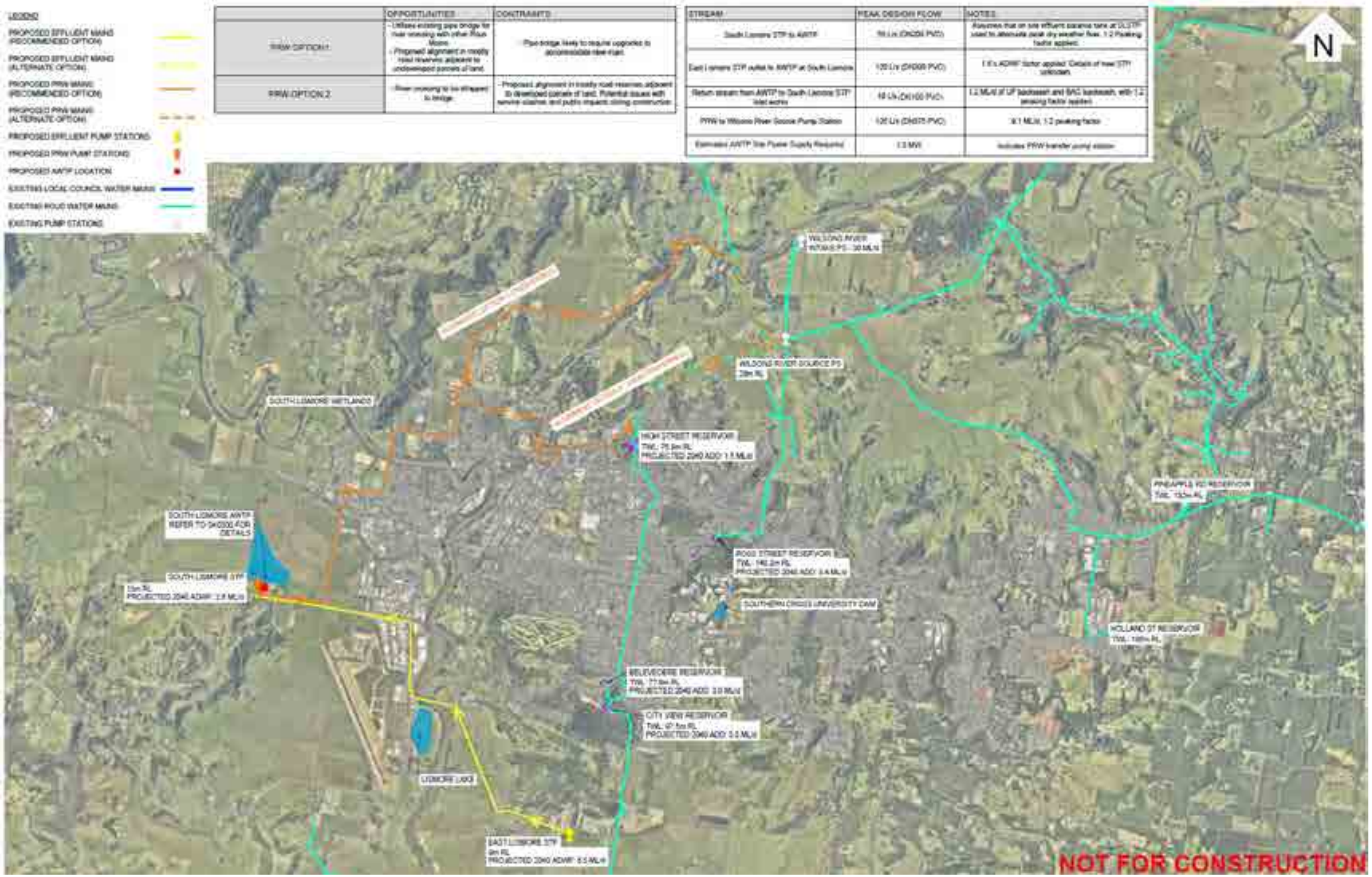

Figure 13-2: Lismore DPR via Raw Water Augmentation Proposed Infrastructure Locations and Pipeline Alignments

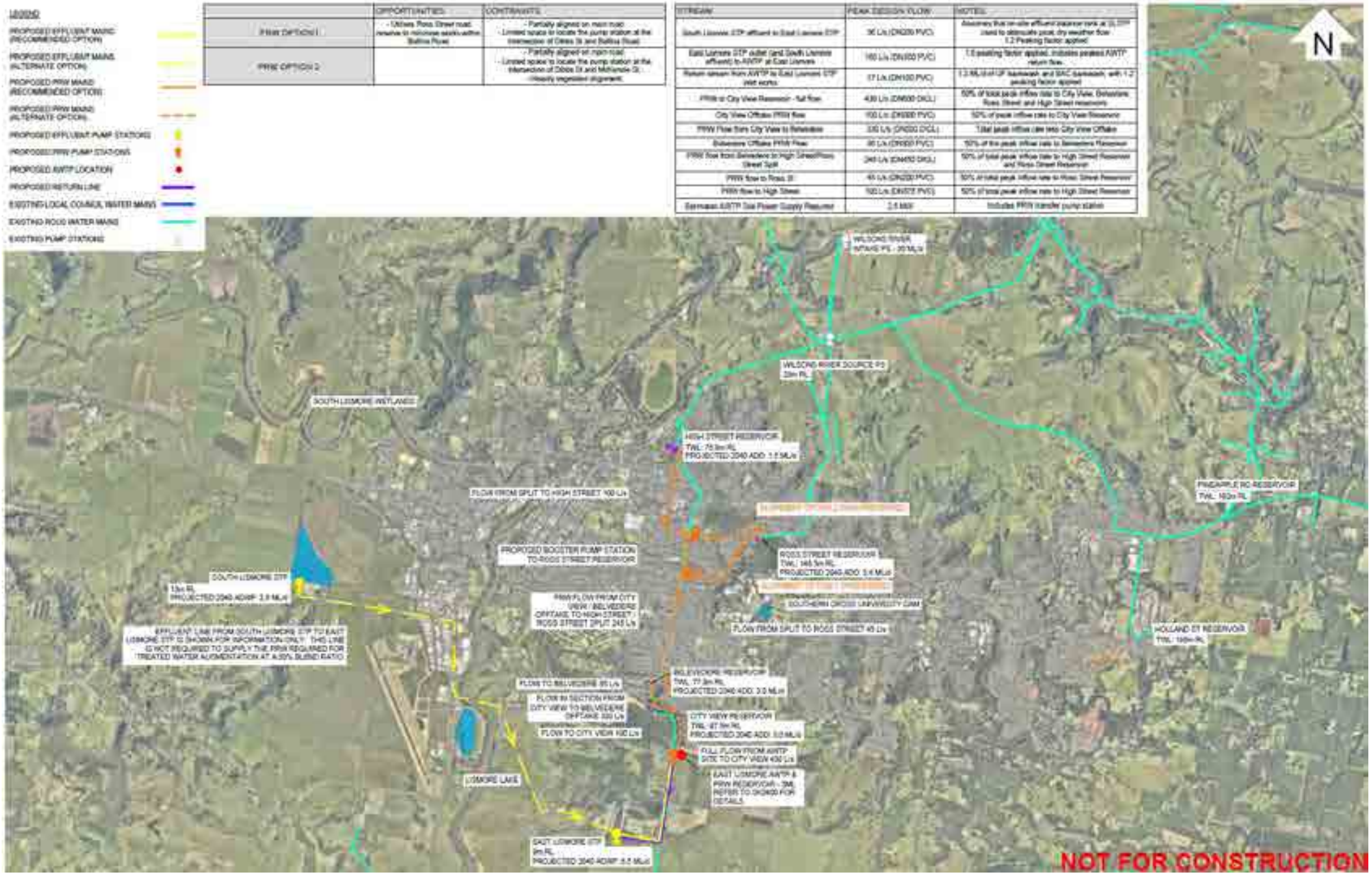

Figure 13-3: Lismore DPR via Treated Water Augmentation Proposed Infrastructure Locations and Pipeline Alignments

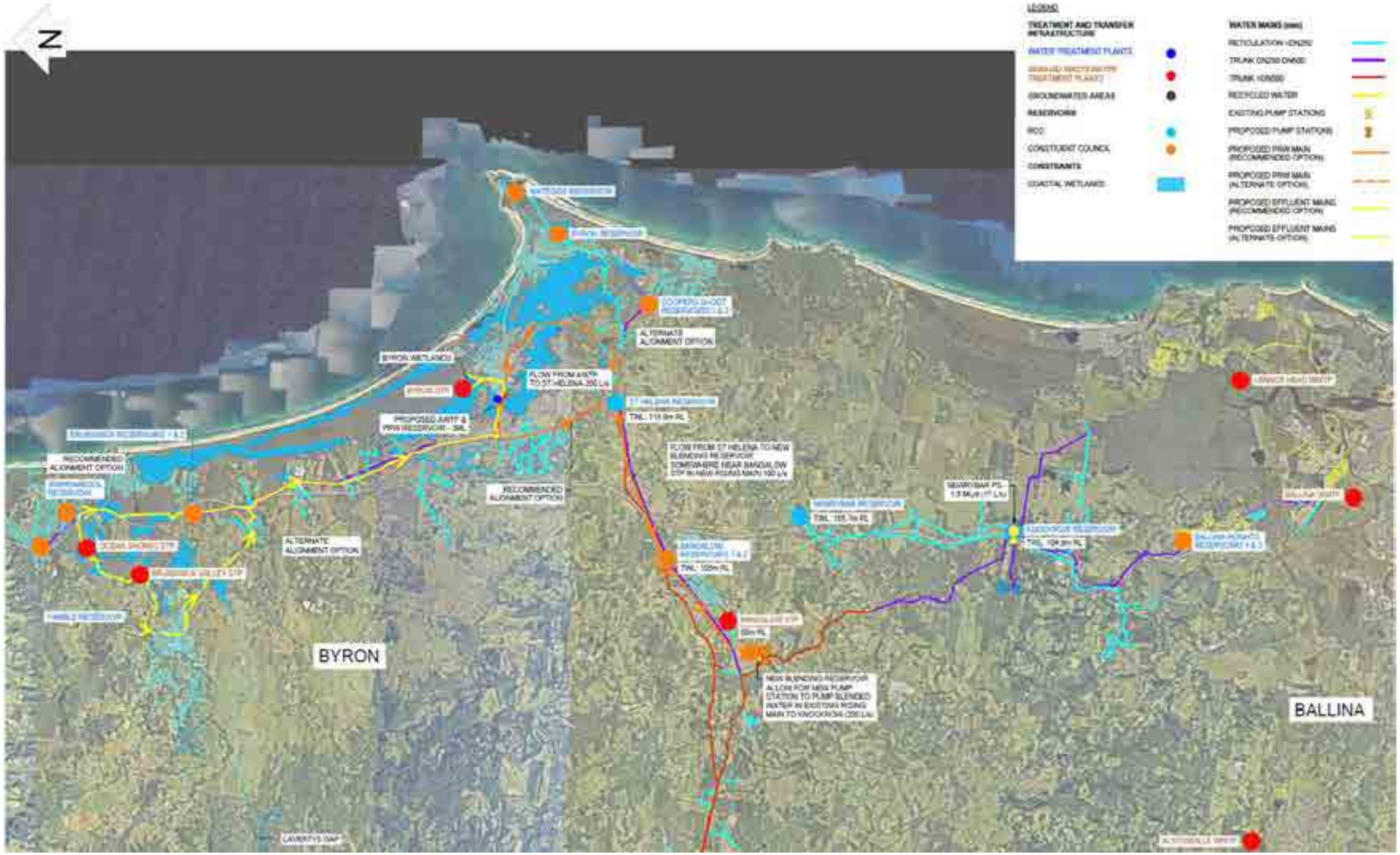

Figure 13-4: Byron DPR via Treated Water Augmentation Proposed Infrastructure Locations and Pipeline Alignments (Sketch 1 of 3)

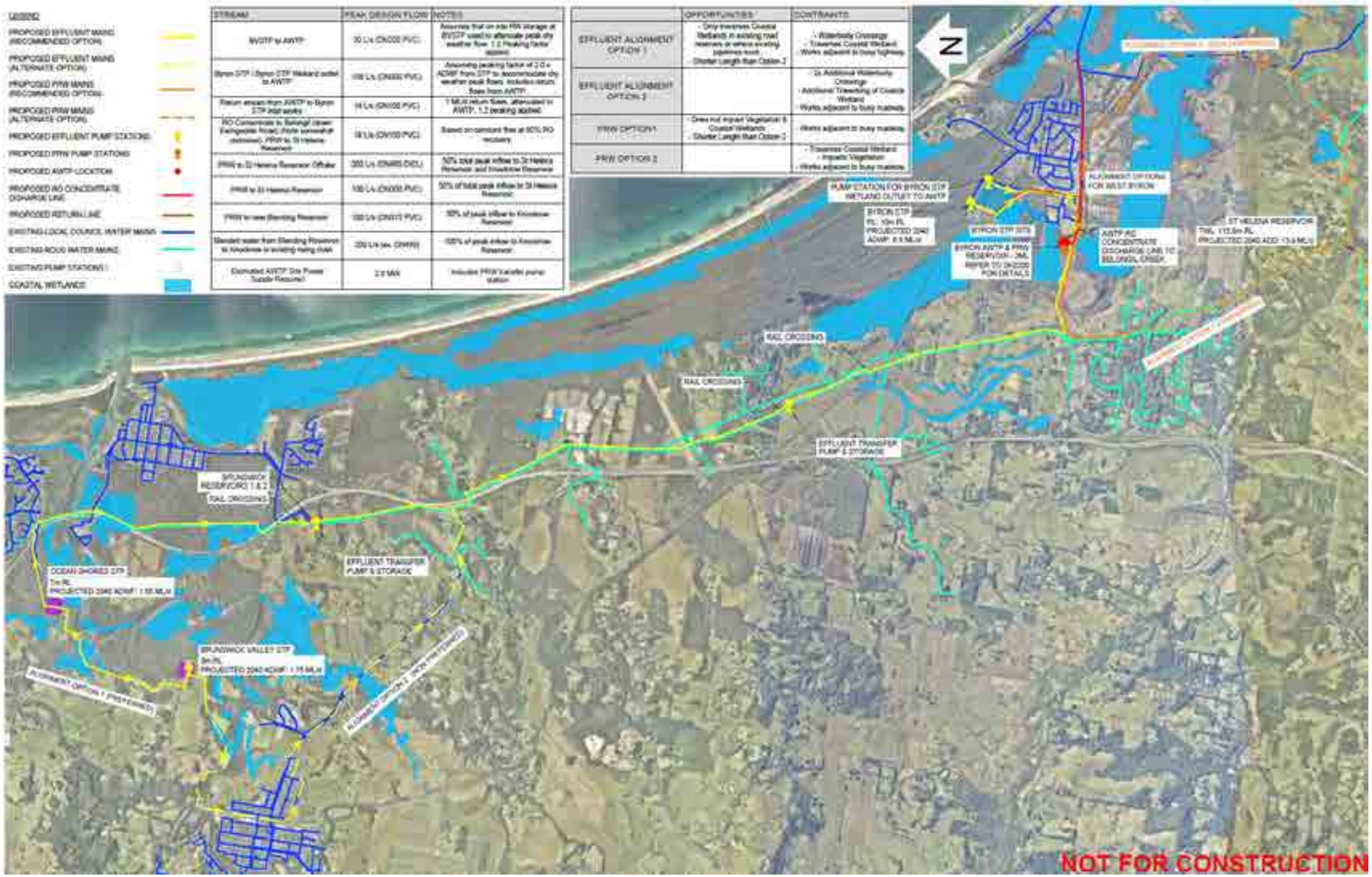

Figure 13-5: Byron DPR via Treated Water Augmentation Proposed Infrastructure Locations and Pipeline Alignments (Sketch 2 of 3)

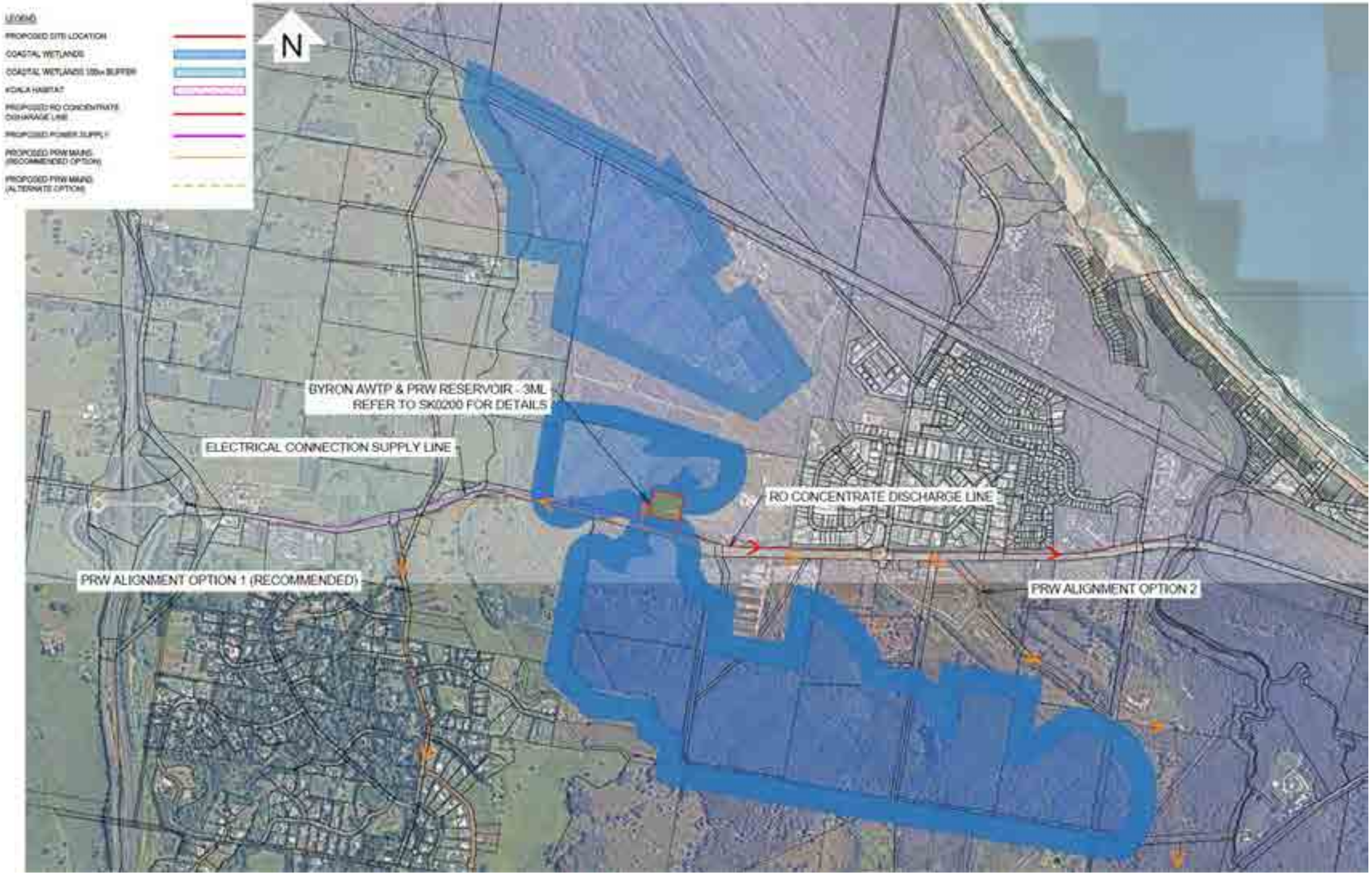

Figure 13-6: Byron DPR via Treated Water Augmentation Proposed Infrastructure Locations and Pipeline Alignments (Sketch 3 of 3)

14 SOURCE WATER CHARACTERISATION AND CONTROL

14.1 ENHANCED SOURCE CONTROL

An enhanced source control program would need to be developed as part of implementation of any PRW scheme by RCC. The enhanced source control program is generally considered to be the first barrier in the multiple-barrier approach to PRW quality assurance – primarily by minimising risk of problematic compounds entering the sewer system providing source water for the PRW production scheme. Problematic substances could include:

- Treatment interference chemicals - substances that cause process upsets in the WWTP and/or AWTP which could impact the production ability of the advanced treatment system and/or reduce biological degradation of some constituents; and,
- Pass through chemicals – substances that are anticipated to not be well removed by the planned multiple barrier process, such as volatile organic compounds (e.g. acetone, toluene, etc.).

An effective enhanced source control program is essential to any PRW scheme for reduction of chemical hazards – both to understanding and enable mitigation of risks, and to support regulation of the occurrence and load of compounds of concern in the source water.

Key elements of the enhanced source control program would be expected to include [18]:

- Establishment of legal authority to develop and implement source control measures to regulate industries and their waste. As all trade waste dischargers are customers of the constituent councils (rather than RCC), this key step has an additional complication which will need to be addressed for the schemes considered in this investigation;
- Establishment of discharge permits to regulate and reduce discharge of compounds of concern into the sewer system;
- Development of monitoring and enforcement response program to identify and respond to discharges of compounds of concern;
- Development of a joint WWTP-AWTP response plan including a flow chart showing key responsibilities and decision points to either investigate or mitigate compounds of concern being discharged into the collection system. This would be anticipated to require a memorandum of understanding or other contractual agreement between RCC and the relevant constituent Council(s) as strong interagency cooperation will be required for the enhanced source control program to be successful);
- Source water characterisation (prior to scheme implementation, refer to Section 14.2);
- Identification and short-listing of compounds of concern based on experience gathered from other Source Control Programmes associated with PRW production within Australia and internationally;
- Evaluation of the compounds of concern for their potential to cause interference, pass through the AWTP processes, and/or adversely affect human health and/or the environment within the sewer system;
- Development and maintenance of a frequently updated, comprehensive inventory of commercial and industrial dischargers that may use products containing the compounds of concern;
- Development and maintenance of a database of chemicals stored on-site and volumes used by all industrial and commercial dischargers;
- Development of a process for identifying new industrial sources/new businesses, and/or the use of new compounds or changed processes in established businesses, and a means of approving and documenting these;

- Communication with and education of industrial and commercial dischargers, as well as the general public, of the importance of what they dispose of via the sewer;
- Development of an overarching regulation governing illegal discharges to the sewer system – particularly ensuring capture of waste liquid haulers;
- Development of a program to require waste haulers to be permitted to discharge and required to provide details of the waste being discharged (e.g. volume, chemicals in the waste and their amounts, etc.) prior to being allowed to discharge;
- Development and maintenance of a database of fact sheets for compounds of concern within the service area; and,
- Development of an action plan for responding to water quality deviations.

Depending on compounds of concern identified, and evaluation of the risks they present to PRW quality, addition of water quality analysers at key locations or nodal points within the wastewater collection system or within the WWTP (e.g., screened or primary effluent) are often considered as a cost-effective means of detecting illegal discharges.

Additional resources to be used in development of an enhanced source control program include the *Australian Wastewater Quality Management Guidelines 2022* [19] and *Enhanced Source Control Recommendations for DPR in California* [20]

14.2 Source Water Characterisation

A wide variety of chemicals may be present in source wastewater used to produce PRW. The AGWR suggest the following could be present [2]:

- Inorganic chemicals;
- Nutrients;
- Pesticides;
- Water treatment chemicals, disinfection byproducts and advanced oxidation byproducts[30];
- Industrial chemicals;
- Household and garden chemicals;
- Surfactants;
- Flame retardants;
- Human and veterinary pharmaceutical products;
- Radiological contrast media;
- Naturally occurring radionuclides;
- Radionuclides from medical, industrial and research wastes and discharges;
- Personal-care products (e.g. fragrances, cosmetics, antiperspirants, moisturisers, soaps, creams, whitening agents, dyes and shampoos);
- Natural hormones; and,

[30] Water treatment chemicals, disinfection byproducts and advanced oxidation byproducts need to be considered as a whole treatment process chemical risk and managed as such through proper design, operation and maintenance of the whole treatment system (i.e. source WWTPs and AWTP). These compounds are much more likely to be added/formed as part of the treatment process than to be introduced by industrial and commercial users.

- General organic chemicals, such as aliphatics, chlorobenzenes, monocyclic hydrocarbons, nitrosamines, organotins, phenols, phthalates, plasticisers, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), sterols and stanols.

Since the publication of the AGWR [2] was published there has also been a major focus on PFAS in drinking water. Any source characterisation should include PFAS.

Both the Byron and Lismore sources include medical dischargers (including a hospital located in each LGA). These facilities could introduce risks through discharge of a wide variety of compounds[31]. Current discharges to sewers from medical facilities, including hospitals and cancer treatment clinics, are understood to already be the subject of trade waste controls. However, due to the requirements for PRW production, the risks associated with hospital waste streams should be the subject of consultation with all such dischargers, including the suitability of the current regulations governing what wastes can be discharged, and if required or practical, the development of additional appropriate discharge standards and controls.

The AGWR [2] provides a list of chemicals that have been detected in secondary treated effluent. This list has been compared to source characterisation performed for an urban southeast Queensland catchment, and additionally to source characterisation performed in Western Australia "to determine the feasibility of augmenting drinking water supplies through groundwater replenishment" [21]. Appendix G compares the two source characterisation programs to the AGWR list of chemicals. Between the chemicals listed in the AGWR and the chemicals sampled during the two source characterisations, plus the addition of PFAS compounds, there are over 650 compounds to consider.

Some items listed in the table in Appendix G under the "general" and "metals" categories (e.g. alkalinity, calcium) are associated with AWTP design and operation as opposed to chemical risk. These are included as this information will be easy to collect while sampling for other parameters.

For the purposes of estimating costs and assessing availability of suitable laboratories, the full list of compounds included in Appendix G has been considered. It is likely that a detailed assessment of catchment risks would provide justification for removing some of the listed compounds from a source characterisation program specific to RCC's potable reuse project, which could reduce cost and complexity of the source characterisation sampling program. The final source characterisation sampling program should prioritise targeting health and environmental risks, and should be designed to assist in the development of surrogates for routine PRW quality monitoring (refer to Section 15.1 for more information on routine PRW quality monitoring).

A potential approach to develop a source characterisation sampling program, to ensure that health and environmental risk are prioritised, could include:

- Development of a full list of chemicals that can be discharged into the sewer system (based on detailed assessment of dischargers to the relevant catchment(s)), and from which industrial/commercial sources they may be discharged;
- Sampling source WWTP effluents for all identified parameters. Repeat sampling several times (e.g. monthly over one to two years to capture seasonal variation), considering:
    - For chemicals that continuously come back at non-detect levels (and these levels are below the health-based guideline value), reduce sample frequency (to say quarterly as opposed to monthly);
    - Conduct a desktop study to evaluate how the advanced treatment processes remove the chemicals that have been detected at significant levels (e.g. 50% or higher than health-based

[31] These wastes could include drugs and their metabolites such as antibiotics, lipid regulators, analgesics, antidepressants, antiepileptics, antineoplastic, antipyretics, antiphlogistic, antirheumatics, estrogens, organic matter, radionuclides, solvents, metals, disinfectants, cytostatic agents, anaesthetics and sterilization products, specific detergents for endoscopes and other instruments, radioactive markers, and iodinated contrast media. Metals present could include platinum, mercury, rare earth elements (gadolinium, indium, osmium), and iodinated X-ray contrast media [52].

or environmental risk-based level – subject to approval by the Regulator). Removal efficiency can be verified by testing during operation of the demonstration plant.

- For chemicals that are found at significant levels (e.g. 50% or higher than health-based or environmental risk-based level – subject to approval by the Regulator), continue sampling and search for the source.
  - If advanced treatment is sufficiently robust in removing these chemicals, continue monitoring them only.
  - If advanced treatment is not robust in removing these chemicals, then investigate opportunities to more tightly regulate discharge of these chemicals at the source.

Bioanalytical tools are an emerging area for providing better understanding of source water characteristics. See Section 15.1.3 for information on these techniques and the application.

14.2.1 Potential Source Characterisation Programme

Table 14-1 summarises the classes of analytes that may form part of a potential source characterisation sampling programme. The full list of analytes is provided for reference in Appendix G. This list is based on the master list provided by the AGWR [2], as well as comparable programmes implemented in southeast Queensland and Western Australia.

Table 14-1: Classes of Analytes in a Potential Source Water Characterisation Sampling Programme

Class of Analyte	No. of Analytes
General	29
Metals	31
Disinfection Byproducts	35
Chelating Agents	6
Surfactants	1
Pharmaceuticals	121
Endocrine Disrupting Compounds/Estrogenic and Androgenic Hormones	19
Monocyclic Aromatic Hydrocarbons	14
Oxygenated Compounds	5
Sulfonated Compounds	1
Fumigants	5
Halogenated Aliphatic Compounds	29
Halogenated Aromatic Compounds	10
Aliphatic Hydrocarbons	2
Phthalate Esters	6
Chlorinated Hydrocarbons	10
Organotin Compounds	7
Phenolic Compounds	20
Polynuclear Aromatic Hydrocarbons	24
Chlorinated Naphthalene Compounds	4
Organophosphorus Pesticides	48
Organochlorine Pesticides	44
Carbamate Pesticides	9
Glyphosate and AMPA	2
Quaternary Ammonium Herbicides	2
Phenoxyacid Herbicides	11
Other Herbicides (by LC/MS)	15
Other Herbicides (by GC/MS)	25
Other Herbicides/Pesticides/Fungicides	52
Radiological Analytes	21
Other Chemicals	18

Table 14-1: Classes of Analytes in a Potential Source Water Characterisation Sampling Programme (continued)

Class of Analyte	No. of Analytes
Fire Retardants	2
Dioxins and Dioxin-like Compounds	8
Fragrances	7
PFAS Compounds	6
Total	**649** Note 1

Note 1: This total accounts for repeated compounds in the original list shown in Appendix G. On the other hand, Appendix G maintains the full list of compounds, including repetitions (highlighted). For this reason, the total shown in this table is less than the raw count of number of compounds in Appendix G.

14.2.2 Estimated Costs of Source Characterisation Programme

Based on high-level discussions with multiple local labs (public and private), it has been determined that the vast majority of the more than 600 analytes identified in Table 14-1 can be analysed (see Appendix H). However, if a sampling programme is implemented, the appropriate levels of detection required for each analyte or class of analytes should be compared with the proposed method detection limits, to ensure they are at or below the relevant health/environmental-based targets, as agreed with the Regulator.

Seven labs were consulted in all, with six labs providing responses on the entire suite of analytes, and a seventh (research) lab responding to the analyte set that none of the other six labs stated they were able to process. Table 14-2 lists the estimated capability of each of the initial six labs to address the entire analyte list, as well as the estimated annual cost thereof, assuming one monthly sample over a one-year period. The methods targeting the majority of compounds are Liquid Chromatography (LC) or Gas Chromatography (GC) in combination with Mass Spectroscopy (MS) or tandem Mass Spectroscopy (MS/MS). Since these methods can be tailored to analyse entire suites of similar compounds, it is possible that additional compounds on the list can be analysed by a given lab in the future, but may require method development against appropriate standards for quantitation.

As of the drafting of this report, Queensland Health labs have been identified as having the capability to measure the most analytes of all labs consulted. It should also be noted that Queensland Health labs have been involved in potable reuse-related monitoring for the Western Corridor Recycled Water Scheme in South East Queensland.

The responses of each of these labs with respect to the analyte list, as well as the subset of analytes that Queensland Health are currently unable to process, are identified in Appendix H.

Note that the estimated prices shown in Table 14-2 only reflect lab processing costs, for the subset of analytes that each lab identified it can process. The costs shown in Table 14-2 do not include the costs of sampling, personnel, associated sample preparation, storage and transport. These logistical considerations are detailed in Section 14.2.3.

Table 14-2: Estimated Capability and Cost of Contacted Labs

Lab	Percent of Total Analytes Lab can Process	Estimated Cost per Sample Event	Estimated Annual Cost Note 1
Envirolab Group	71%	$20,000 Note 2	$240,000 Note 2
ALS Global	69% Note 3	$6,200	$75,000
Eurofins Environmental Testing	44%	$5,000	$60,000
Queensland Health Forensic and Scientific Services	73%	$6,000	$72,000
Tweed Laboratory Centre, Tweed Shire Council	19%	Price not requested Note 5	
Environmental Analysis Laboratory, Southern Cross University	9% Note 4	Price not requested Note 5	

Note 1: Estimated annual costs based on approximate per-sample pricing provided by each lab, assuming one monthly sample over a year in 2024 dollars.

Note 2: These costs are likely overestimated, since this lab only provided an overall estimated cost, rather than a breakdown of costs based on the methods to be used.

Note 3: ALS Global have identified that the analysis of pharmaceuticals and endocrine disrupting compounds is likely to be subcontracted to Queensland Health Forensic and Scientific Services, who have provided a separate direct quote and capability statement.

Note 4: This lab identified a large number of analytes to be subcontracted to others. Including subcontract analytes would bring their total to 54% of all analytes. However, only the in-house capabilities of the above labs have been compared, to ensure even comparison.

Note 5: Since these labs have a lower level of capability than the other labs shown in Table 14-2, costs were not requested from these labs.

The subset of analytes that none of the six contacted labs were able to process amounted to about 89 compounds in all, of which 66 were pharmaceuticals, including antibiotics. A seventh lab, Queensland Alliance for Environmental Health Sciences (QAEHS), was contacted regarding this subset of 89 compounds. QAEHS is a part of the University of Queensland and, as a research-centred lab, has the capability to process a larger range of compounds and also to engage in method development for additional compounds.

QAEHS identified that 22 of the 89 remaining analytes could be readily processed and quantified by their lab, all of which were pharmaceuticals. The remaining compounds may be analysable via method development with the procurement of appropriate standards.

If any of the short-listed schemes are further progressed, additional labs could be consulted to determine where the remaining compounds could be analysed, and the costs and logistics associated with utilising these labs.

14.2.3 Source Characterisation Programme Logistics

In planning a successful source characterisation programme, the following logistical considerations will need to be taken into account:

- **Sampling:** STP or Council staff (or perhaps personnel supplied by RCC or the PRW scheme operator) will be required to coordinate sampling of effluent of the relevant STP(s). Sampling of the influent flow to the STP may additionally be required if chemical removal within the STP is to be examined. The frequency of sampling is currently assumed to be monthly, but may be amended based on several factors, including the practical feasibility of conducting a monthly sampling programme, the number of analytes in the original list that consistently return non-detects, and the potential application of surrogate compounds to test as the programme matures.

  Samples taken will generally be grab samples, but composite samples will likely be required for some parameters. A detailed assessment of the sample type required for each analyte should be conducted when developing a plan for the source characterisation program. Planning should also include detailing how samples will be collected, equipment required (bottles, automatic sampler, etc.), chain of custody requirements, etc.

- **Contract with Lab:** It is likely that RCC (or the PRW scheme operator) would have to develop a long-term monitoring contract with the appropriate lab that will conduct and coordinate the majority of sample analysis. This includes any subcontract labs that may be required to perform a subset of analyses. The cost of all work to be performed will need to be negotiated, well as for changes to the programme over time. Responsibilities around sample collection, preparation, storage, delivery and turnaround times for data will also need to be agreed.

- **Sample Preparation:** It is likely that multiple samples will need to be collected on a given sample date to account for multiple preparation methods. As indicated from a preliminary review by ALS Global, the vast majority of analytes identified in Table 14-1 will require refrigeration after collection at a minimum, with a subset potentially requiring pre-filtration or acidification onsite. The appropriate containers for each level of onsite sample preparation will likely be supplied by the contract lab, along with advice on the required volumes of sample needed. However, the actual preparation will likely need to be performed by the personnel conducting sampling immediately after sample collection.

- **Sample Storage:** Samples collected will require storage until either collection by the contract lab, or delivery to the lab, as agreed. The vast majority of analytes will require refrigeration at 4 ^{o}C with maximum holding times varying from 2 days to 180 days.
- **Collection/Delivery of Samples:** Sample collection by the contract lab or delivery to the lab by RCC or other staff will need to be agreed and coordinated such that holding times for analytes are not exceeded. Similarly, the sample collection dates will need to be assessed regularly to ensure that public holidays or other facility closures do not impact holding times.
- **Analysis of Results:** The contract lab is expected to provide all results within a specified turnaround time in a format that is easily readable for further analysis by RCC and its associates.
- **Amendments to Programme:** The programme and the associated agreement with the contract lab should be amendable such that the list of analytes, frequency of sampling and other aspects of the programme can be modified as needed. For example, analytes that are consistently below the method levels of detection should either be examined using a method with a lower level of detection as appropriate, or sampled at a lower frequency if deemed no longer relevant or necessary to sample at the default monthly frequency.

14.3 Emerging Issues to be Monitored

As more knowledge is gained globally with respect to source water risks, additional issues that will need to be considered in the context of any RCC potable reuse scheme will be identified. As these issues are identified in the industry, they should be added to a project risk register, and the status of these issues monitored over time to determine if or when RCC needs to take action.

Three examples of currently emerging issues for which there is not yet sufficient information to allow the project team to provide clear direction with respect to source characterisation, are provided in Section 14.3.1 through 14.3.3. Each of these items should be included on the project risk register and monitored to determine what actions are required.

14.3.1 Antibiotic Resistance

California's Expert Panel on potable reuse has addressed the topic of antibiotic resistance. The Expert Panel's findings were [22]:

- "Antibiotic resistance is a valid and serious worldwide public health concern.
- Risk levels associated with antibiotic resistant bacteria (ARB) and antibiotic resistance genes (ARG) in water have not been determined; however, concentrations of ARB/ARG in waters subjected to DPR treatment processes would likely be lower than that from current water sources entering drinking water treatment facilities, suggesting that risk levels would be comparable to, or less than, those associated with current source waters.
- ARB and ARG are found in wastewater and in other environments, such as soils and other source waters (not necessarily impacted by wastewater).

- There are currently no standardized tests for ARB/ARG/mobile genetic elements in environmental samples[32].
- The determination of ARB/ARG concentrations in water can be helpful in assessing treatment process efficiencies to remove antibiotic resistance determinants.
- Current wastewater treatment technologies (e.g., activated sludge, tertiary filtration, and chlorine disinfection) reduce ARB and ARG concentrations.
- The current knowledge base regarding urgent and serious potentially waterborne drug-resistant bacteria is limited for known antibiotic resistance determinants and their fate during treatment.
- Information about the performance of advanced water treatment processes related to ARG removal is limited. Disinfection and oxidation (e.g., chlorine, ozone, UV) differ in their effectiveness of removing ARG in treated wastewater. There is limited information regarding the efficiency of membrane processes (e.g., UF, RO) at pilot-scale and full-scale on the removal of ARG.
- Considering all the available information, a combination of secondary wastewater treatment and advanced water treatment processes (i.e., a sequence of treatment train processes such as microfiltration/UF, RO, and ultraviolet disinfection/advanced oxidation processes) leading to a finished potable water is likely to reduce ARB and ARG concentrations in recycled water to levels well below those found in conventional treated drinking water.
- Ongoing research in the U.S., Europe, and Asia is examining wastewater and other sources (e.g., hospitals, agriculture) for ARG and ARB and their removal by different treatment processes.
- Antibiotic resistance is a valid and serious worldwide public health concern; and,
- Concentrations of ARB and ARG in waters subjected to DPR treatment processes would likely be lower than that from current water sources entering drinking water treatment facilities, suggesting that risk levels would be comparable to, or less than, those associated with current source waters."

The Expert Panel recommended the following with respect to antibiotic resistance [22]:

- "Additional research is needed to determine the risk to humans associated with ARB and ARG in water relative to other sources of exposure. In particular, research is needed on defining dose-response relationships between ARB and ARG concentrations in water and their ability to be acquired by human pathogens and transferred to environmental microbiota and the gut microbiome.
- Standardized tests to determine ARB and/or ARG concentrations in potable water and wastewater should be developed. These tests should be financially and technologically accessible to a majority of water and wastewater treatment agencies. Ideally, the tests would quantify ARB and ARG that are relevant to humans. Methodology should be developed that also provides an assessment of ARG transferability within water matrices (including biofilms).
- Characterize and evaluate ARB and ARG removal using advanced water treatment processes. Projects practicing DPR should quantitatively determine the removal of ARB and/or ARG and identify the most promising and robust technologies within their treatment trains to reduce antibiotic resistance determinants for potable reuse."

[32] Culture-based approaches test the susceptibility of a bacterium or specific group of bacteria, which can be propagated in liquid or on solid media, to one or more antibiotics. There are three basic variations: disk-diffusion, limiting diffusion and selective media augmentation. The first two have been standardized for use in clinical laboratories. Variations of all three methods have been applied to different waters; however, at present, standardised protocols have not been validated for water-based matrices. In addition, some reports have used culture-based techniques to evaluate horizontal gene transfer between bacteria. Culture-based analyses are confined to detecting antibiotic resistance only in bacteria that can grow on the particular media used and will not detect antibiotic resistance determinants from other sources, such as viable but non-culturable bacteria, injured organisms, and extracellular DNA. It is estimated that over 90 percent of environmental bacteria cannot currently be cultured; thus, culture-based assays may lead to an underrepresentation of antibiotic resistance. [22]

As information is developed based on the Expert Panel's recommendations, means to understand risk to human health and standardised methods for quantification of ARB/ARG should become available. When this occurs RCC can evaluate the risk and determine what further work will be required (e.g. characterisation of ARB/ARG removal through the AWTP processes).

14.3.2 Engineered Nanomaterials

A nanomaterial is defined by the International Standards Organization as a "material with any external dimension in the nanoscale [approx. 1-100 nm] or having internal structure or surface structure in the nanoscale"[33]. Due to their small size and/or structures, nanomaterials often exhibit unusual or exotic properties, making them of particular interest to industry — nanomaterials such as carbon nanotubes and graphene have already been investigated for application in the electronics, medical, and energy sectors [23]. Engineered nanomaterials (ENM) are also widely used in cosmetics, coatings, pigments, personal care products, food packaging, and nanotechnology [24].

ENMs are manufactured using various materials, including [25]:

- Silver;
- Iron;
- Titanium dioxide;
- Aluminium oxide
- Ceramic oxide;
- Zinc oxide;
- Silicon dioxide; and,
- Gold.

In Australia, the National Industrial Chemicals Notification and Assessment Scheme is the Federal Government body responsible for assessing the risks of industrial chemicals and providing information to promote their safe use.

A workshop on "ENMs in Drinking Water & Potable Reuse" that was held in November 2016 at the University of New South Wales (Law I & Davison A, paper presented at OzWater 2018) concluded that there was still much work to be done to be able to reliably monitor for the range of ENMs that are currently in our everyday life. Currently, single particle ICP-MS is the favoured means of analysis but this system is limited to ENMs >20 nm in size.

ENMs do not currently have health-based guidelines listed in the ADWG, nor health-based standards in the USA for drinking water. However, Abbott Chalew et.al. noted [26]:

- The ingestion of ENMs via drinking water may pose a potential direct human health threat or an indirect risk due to release of metal ions from the ENMs. Exposure to metal ENMs or metal ENM ions via ingestion can result in adverse effects.
- Exposure to ENM via the ingestion of drinking water, tested using in-vivo animal studies, revealed adverse effects in terms of elevated metal concentrations in livers, kidneys, brains and blood.

The project team are not aware of availability of a standard analytical approach to ENM enumeration in water or wastewater.

Given the currently undefined status of health risks associated with ENMs and the lack of standardised methods for quantification, RCC should monitor the status of research in this area and when sufficient information is available to determine and assess risks, develop a plan to do so.

[33] International Standards Organisation. (2015). TS 80004-1:2015: Nanotechnologies — Vocabulary — Part 1: Core terms. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:ts:80004:-1:ed-2:v1:en.

14.3.3 Microplastics/Nanoplastics

Microplastics are generally characterised as water-insoluble, solid polymer particles that are ≤ 5 mm in size. A formal definition for the lower size boundary does not exist, but particles below 1 µm are usually referred to as nanoplastics rather than microplastics. Although microplastics are often detected in the environment, the risks they pose are debated and largely unknown. One key challenge in assessing the risks of microplastics to humans and the environment relates to the variability of the physical and chemical properties, composition and concentration of the particles. Further, microplastics in the environment are difficult to identify, and standardised methods do not exist. While the dominant source of microplastics often is the fragmentation of larger plastics or product wear, the rate of fragmentation under natural conditions is unknown. These challenges and unknowns hamper the prospective assessment of exposure and risk. [27]

Humans are exposed to microplastics through various routes, and the associated health effects are complex and variable. Little is known regarding the impact of microplastics on human health and the toxic effects that may vary depending on the type, size, shape, and concentration of microplastics, as well as other factors. Therefore, further research is needed to understand the cellular and molecular mechanisms of microplastic toxicity and related pathologies [28].

The current WRF project 5088[34] (*Defining Exposures of Microplastics/Fibers in Treated Waters and Wastewaters: Occurrence, Monitoring, and Management Strategies*) has the goals of [29]:

- Critically reviewing microplastic occurrence data in all waters, facilitating calculation of mass balance and identification of data gaps;
- Providing guidance on media-specific sampling and monitoring guidelines; and,
- Using water cycle-scale mass balance to inform a decision-making framework for reduction strategies.

Given the currently undefined status of health risks associated with microplastics/nanoplastics and the lack of standardised methods for quantification, RCC should monitor the status of research in this area and when sufficient information is available to determine and assess risks, develop a plan to do so.

[34] Project completion expected in 2024

15 ADVANCED TREATMENT MONITORING AND OPERATION

This section discusses key operational and monitoring considerations for successful implementation of potable reuse schemes.

15.1 ROUTINE MONITORING

Routine monitoring will be required to:

- Ensure water quality requirements are met;
- Ensure treatment barriers are intact; and,
- Monitor the process to ensure smooth, efficient operation of the plant and/or to identify trends that could indicate reduction in plant performance that could require intervention (e.g. monitoring increase in RO permeate conductivity can help predict when membranes will need to be replaced so that membranes can be ordered in time).

15.1.1 PRW Quality Monitoring

Routine sampling and analysis of the PRW produced by any scheme will be required to verify that water quality requirements are met (both pathogen and chemical) and to identify potential issues related to chronic chemical risks. The frequency of sampling will be agreed with the Regulator, however monthly monitoring is typical.

As discussed in Section 14.2, the number of potential chemicals that could be present in the source water is extensive.

Routine monitoring for all parameters identified as present in the source water at significant levels through the source water characterisation program, over the life of the potable reuse scheme operation, may be impractical and cost prohibitive for an RCC scheme (depending on the number of parameters and frequency of sampling).

To ensure the treatment barriers intended to remove compounds identified as chemical risks are intact, indicator (surrogate) chemicals are typically used to monitor treatment performance for a group of chemicals having similar characteristics. The specific indicators used in an RCC scheme will depend on the specific chemical risks identified. Suitable treatment performance indicator chemicals should [21] :

- Have characteristics that can be linked to a predominant removal mechanism (e.g. filtration, adsorption or oxidation), because different treatment processes target different properties;
- Be present in concentrations that are representative of the broader class of compounds, and are sufficiently high to determine a meaningful degree of reduction through a unit process or a sequence of processes; and
- Be quantifiable using an established, and preferably accredited, analytical method.

The final source characterisation sampling program (refer to Section 14.2) should be designed to assist in the development of surrogates for routine PRW quality for a wide range of analytes. Surrogates would be determined through discussion with and evaluation by the Regulators – much as was achieved in Perth by Water Corporation where a list of 18 surrogates was developed to represent 18 different chemical groups, as summarised in the following section. Developing a list of surrogates will have a significant cost benefit to RCC.

15.1.1.1 Beenyup Advanced Water Recycling Plant

Table 15-1 provides an example of PRW routine monitoring parameters used for the Beenyup Advanced Water Recycling Plant (AWRP) in Western Australia, including both chemical and pathogen parameters[35] [30].

[35] 2,4,6-trichlorophenol was previously included but has been removed as agreed with Western Australia Department of Public Health due to consistent results below the level of reporting (personal communication with Stacey Hamilton, Team Leader –Treatment Performance and Review, Water Quality Business Unit, Water Corporation)

Table 15-1: Recycled Water Quality Indicators for Beenyup AWRP

Indicator	Group Represented	Sampling Frequency	Units	Limit of Reporting
MS2 Coliphage	Microorganisms (pathogens including viruses)	Monthly	pfu/100 mL	1
Boron	Inorganic compounds, metals and metalloids	Monthly	mg/L	0.02
Nitrate		Monthly	mg/L as N	0.01
N-nitrosodimethylamine (NDMA)	Nitrosamine disinfection by-products	Monthly	ng/L	2
Chlorate	Inorganic disinfection by-products	Quarterly	mg/L	0.01
Chloroform	Other disinfection by-products	Monthly	µg/L	0.05
Carbamazepine	Pharmaceuticals and personal care products	Monthly	µg/L	0.1
Diclofenac		Monthly	µg/L	0.1
Estrone	Hormones	Quarterly	µg/L	1
Trifluralin	Pesticides and herbicides	Quarterly	µg/L	1
1,4-Dioxane	Other organic chemicals	Monthly	µg/L	0.1
1,4-dichlorobenzene		Monthly	µg/L	1
Ethylenediamine tetraacetic acid (EDTA)		Monthly	µg/L	10
Fluorene		Biannually	µg/L	0.001
Octadioxin		Biannually	pg/L	2
Alpha particle activity	Radioactivity	Quarterly	mBq/L	10
Beta particle activity (- K40)		Quarterly	mBq/L	10

The surrogates were selected to monitor the performance of the AWRP process chemical barriers, with parameters selected to represent groups of chemicals with similar characteristics (e.g. mechanism(s) of rejection by RO membranes).

15.1.1.2 California

Project team experience in California suggests that routine monitoring for IPR schemes in California can be expected to sample for compounds including:

- Primary maximum contaminant level (MCL) parameters;
- Secondary MCL parameters;
- Notification level parameters;
- Priority toxic pollutant parameters; and,
- Constituents of Emerging Concern (CEC)[36].

A sampling programme for a representative project in California consisting of over 240 compounds is included in Appendix I as an example. For this example project, sampling frequency during the first year of operation is monthly for primary and secondary MCLs and notification level parameters, and quarterly for priority toxic pollutant parameters.

15.1.1.3 Luggage Point AWTP

The Western Corridor Recycled Water Scheme in southeast Queensland includes three AWTPs, located at Bundamba, Gibson Island and Luggage Point. Only the Luggage Point AWTP is currently in operation, and only for the supply of PRW for industrial use (e.g. power generation) at this time.

[36] CEC's to be monitored are classified as "Performance" CECs, which serve as indicators of plant performance, and "health-based" CECs, which serve as indicators of public health risk.

The current situation notwithstanding (i.e. the system is not producing water for augmenting drinking water supplies), Seqwater (who owns the Luggage Point AWTP), has reported on sample results for over 700 parameters in the water produced by Luggage Point AWTP in their 2021-2022 Recycled Water Management Plan Annual Report (as well as close to 600 parameters for the Luggage Point WWTP secondary effluent) with sampling for many of the parameters occurring almost on a weekly basis (i.e. on the order of 50 samples collected for certain parameters during the year) [31]. A copy of this report is included in Appendix J.

The Queensland Public Health Regulation 2018[37] indicates that "Recycled water that is intended to augment a supply of drinking water must be tested for the presence of each required parameter at the frequency required under the management plan for the water." The "required parameters" referred to in the regulation include all ADWG parameters for which a guideline value for health is stated in the physical and chemical guideline table (ADWG Table 10.6 [3], 212 parameters) plus four microorganisms, and 148 chemical parameters specified in Schedule 6 of the Regulation (364 parameters in total).

15.1.1.4 Singapore

The NEWater AWTPs in Singapore sample PRW for about 300 compounds. The frequency of sampling is variable, from as low as three or four times per year to as frequently as twice per week, depending on the compound. The list of compounds and their sampling frequency is included in Appendix K.

15.1.1.5 PRW Quality Monitoring Approach for Cost Estimating

As discussed in Section 15.1.1.1 through 15.1.1.4, the approach to PRW quality monitoring varies widely depending on the jurisdiction and particular project risks. The PRW quality monitoring required for any RCC potable reuse scheme would require discussion and agreement with the Regulator.

While the project team supports the approach taken by Water Corporation and the Western Australia Department of Health (i.e. the use of surrogates to represent the removal performance of the plant for groups of parameters having similar characteristics), for the purpose of providing a conservative operating cost estimate, the PRW sampling is assumed to include the 241 parameters specified for the example California IPR (referenced in Section 15.1.1.2) sampled on a monthly basis.

Table 15-2 summarises a high-level cost estimate for PRW water quality monitoring developed on this basis using rates provided by Queensland Health Forensic and Scientific Services (QHFSS).

The following considerations were made in developing this cost estimate:

- Approximately a third of the constituents on the California IPR list were not identified directly on QHFSS' methods list; however, it is likely that several of these are able to be analysed via existing methods subject to method development and availability of standards. To account for this uncertainty, and allow for a small subset of the parameters which are not immediately analysable, a 20% surcharge has been added to the calculated costs shown in Table 15-2.
- California's IPR monitoring list identifies the need to monitor representative analytes for CECs. These are classified as "Performance" CECs, which serve as indicators of plant performance, and "health-based" CECs, which serve as indicators of public health risk. The specific compounds in each of these classes are listed in Appendix I [32]. As some of these compounds are already included in the MCL, Priority, and Notification lists, their recurrence have been accounted for in the cost estimate.
- The Performance CECs described above are associated with performance surrogates as identified by the California State Water Resources Control Board [32]. However, the measurement of the actual compounds is conservatively costed instead in the below estimate.

[37] https://www.legislation.qld.gov.au/view/pdf/inforce/current/sl-2018-0117

Table 15-2: Summary of Estimated Costs for PRW Monitoring based on Example California IPR Project

Frequency	Baseline Year			Subsequent Years		
	No. of Samples	No. of Analyses	Approx. Cost Note 4	No. of Samples	No. of Analyses	Approx. Cost Note 4
Weekly Note 1	2 Note 2	5	$2,100	2 Note 2	5	$2,100
Monthly (additional to weekly)	0	16	$3,000	0	0	$0
Quarterly (additional to weekly and monthly)	0	0	$0 Note 3	0	14	$1,300
Annual (additional to weekly, monthly and quarterly)	0	0	$0	0	1	$110
Total Estimated Annual Cost			**$145,200**			**$114,500**

Note 1: Analytes identified for bi-weekly (i.e. twice weekly) sampling are conservatively assumed to be sampled weekly.

Note 2: One sample of AWTP influent and one sample of PRW.

Note 3: Even though additional analytes are to be monitored quarterly, no additional cost for the additional suite of analytes to be sampled quarterly because the analyses involved are all already performed during monthly sampling, and costs are provided per analysis.

Note 4: Includes an estimated 20% surcharge for analytes on the California IPR list that were not directly identified on QHFSS' list of analytes.

15.1.2 Process Monitoring

Process monitoring will include monitoring of the plant CCPs to ensure treatment barriers are intact and general monitoring of process performance.

15.1.2.1 Critical Control Points

Table 15-3 summarises the CCPs expected to be required for the various treatment barriers. CCPs would include both "alert" and "critical" limits, where critical limits are set at the point where the claimed LRV would be breached and alert limits are set sufficiently below the critical limit to allow operations personnel to respond before the critical limit is reached. CCPs and actions to breach of alert and/or critical alarms would be determined through a Hazard Analysis and Critical Control Point (HACPP) process[38].

In addition to the CCPs listed in Table 15-3, as South Lismore STP has no wet weather bypass an additional CCP will likely be required based on indication from the STP that the plant has entered its wet weather mode of operation.[39]

15.1.2.2 General Process Monitoring

Monitoring of various process parameters, in addition to those monitored via the CCP instruments discussed in Table 15-3, will be vital to ensuring smooth and efficient operation of the plant. Table 15-4 summarises key parameters to be monitored in addition to the CCPs. Note that this list is not intended to be exhaustive, and the full process monitoring requirements will need to be determined through development of the scheme and AWTP designs for any scheme options which is carried forward.

[38] HACCP was developed in the food industry to identify process disruptions with the potential to impact the quality of the product to ensure food safety. HACCP principles provide the basis for the water safety plan approach in the WHO Guidelines for Drinking-water Quality [50].

[39] For any of the short-listed schemes, design of the AWTP and its associated CCPs will need to consider the location of the offtake of STP effluent and whether additional controls will be required to address water quality risks associated with wet weather events (e.g. if the offtake to the AWTP is taken at a point where treated effluent and bypass flows combine an additional CCP may be required based on the STP going into bypass).

Table 15-3: Critical Control Points

Treatment Process	Critical Control	AWTP Type (Carbon, RO or both)	Comments
Secondary Wastewater Treatment	Ammonia Turbidity TOC Nitrate pH Conductivity	Both	• Ammonia analyser with results returned every 15 minutes to verify the integrity of the biological treatment system • Turbidity analyser continuously reporting results to verify clarifier performance • TOC analyser with results returned every ten minutes to prevent chemical spikes (e.g. from illegal dumping into the sewer) from entering the AWTP • Nitrate analyser with results returned every 15 minutes to address acute chemical risk presented by nitrate • pH analyser continuously reporting results analyser to prevent chemical spikes (e.g. from illegal dumping into the sewer) from entering the AWTP • Conductivity analyser continuously reporting results analyser to prevent chemical spikes (e.g. from illegal dumping into the sewer) from entering the AWTP • Results greater than an alert level would result in cessation of intake of feed water to the AWTP
Ultrafiltration	Filtrate turbidity PDT	Both	• Turbidity analyser continuously reporting results for filtrate of each UF unit as an online verification of membrane integrity • Daily PDT performed on each UF unit as a physical test of membrane integrity
Ozone	Ozone:TOC ratio	Carbon-based	• Ozone analyser continuously reporting results to confirm ozone concentration applied • TOC analyser on ozone system feed, with results returned every 10 minutes to verify the required ozone dose based on ozone to TOC ratio • Nitrite analyser with results returned every 15 minutes to account for nitrite in the applied ozone dose
BAC	BAC effluent turbidity	Carbon-based	• Turbidity analyser continuously reporting results for effluent of each BAC unit as an online verification of filter pathogen reduction performance
RO	Permeate conductivity	RO-based	• Conductivity analysers continuously reporting results for the common RO feed and the permeate of each stage of each RO unit as online verification of pathogen reduction performance (up to LRV of 1.5)
Ultraviolet Light Disinfection	Flow UV transmittance UV intensity	Both	• Flow meter continuously reporting flow through each UV unit (to allow calculation of dose and to ensure the unit is not operated outside its validated flow range) • UV transmittance analyser continuously reporting feed water UV transmittance for the common feed to all UV units • UV intensity analyser continuously reporting intensity of UV applied to the water within each UV unit
UV/Advanced Oxidation Process	Flow UV transmittance UV intensity	RO-based	• Flow meter continuously reporting flow through each UV unit (to allow calculation of dose and to ensure the unit is not operated outside its validated flow range) • UV transmittance analyser continuously reporting feed water UV transmittance for the common feed to all UV units • UV intensity analyser continuously reporting intensity of UV applied to the water within each UV unit • Free chlorine analyser with results returned every 3 to 5 minutes to verify free chlorine dose to UV units
Chlorine Disinfection	Feed flow Free chlorine residual Free chlorine C.t.	Both	• Feed flow meter continuously reporting flow to allow calculation of contact time • Free chlorine analyser with results returned every 3 to 5 minutes to verify free chlorine residual • C.t. calculated based on contact time and free chlorine residual
Treated Water	TOC Nitrate	Both	• TOC analyser with results returned every ten minutes as a secondary means (in addition to monitoring of the feed to the AWTP) to prevent chemical spikes (e.g. from illegal dumping into the sewer) from impacting PRW quality • Nitrate analyser with results returned every 15 minutes as a secondary means (in addition to monitoring the feed to the AWTP) to address acute chemical risk presented by nitrate • Results greater than an alert level would result in diversion of PRW and/or shutdown of the AWTP

Table 15-4: Key Additional Process Parameters to be Monitored

Unit Process/Area	Parameter	Comment
AWTP Feed Water	ORP	• Monitored to indicate potential change to feed water that may require further investigation
Ultrafiltration	PDT results Transmembrane pressure (TMP) Flow Temperature Monochloramine/free chlorine	• PDT trends monitored to allow planning of membrane pinning • TMP trends monitored to determine when membrane clean in place (CIP) is required and effectiveness of cleaning functions (i.e. backwash, maintenance clean, CIP) • Flow, TMP and temperature are used to calculate temperature corrected specific flux, which is used to assess the condition of the membranes (when compared to baseline following CIP provides an indication of irreversible fouling) • Online analysis of monochloramine/free chlorine used to ensure appropriate dose is applied to control biofouling (analyser as appropriate for the chemical dosing utilised for a given AWTP type)
Ozone	Flow UV Transmittance	• Flow meter continuously reporting flow to confirm residence time • UV transmittance analysers on the feed to and effluent from the ozonation system as an indicator of chemical oxidation
BAC	Flow Pressure DOC	• Flow to each filter used to confirm hydraulic loading rate/empty bed contact time • Pressure monitored on feed and effluent to determine differential pressure across the filters (one trigger for backwash) • DOC analyser on the BAC effluent to monitor overall removal of organics
GAC	Contaminant concentration at different bed levels Flow UV Transmittance DOC	• Routine manual sampling conducted using sample taps at 25%, 50% and 75% of the GAC media bed depth to monitor progression of the contaminant(s) through the bed – allows for estimating time until change out of the media will be required • Flow to each filter used to confirm hydraulic loading rate/empty bed contact time • UV transmittance analysers on the feed to and effluent from the ozonation system as an indicator of GAC performance over time • DOC analyser on the GAC effluent to monitor GAC performance over time

Reverse Osmosis	Flow
	Pressure
	Conductivity
	Temperature
	pH
	ORP
	TOC
		• Flow, pressure and conductivity measured on the feed, permeate and concentrate for each stage, as well as feed temperature, to allow calculation of:
		  ○ normalised salt passage,
		  ○ normalised permeate flow,
		  ○ normalised differential pressure,
		  ○ temperature-corrected specific flux
		• Monitoring increase in RO permeate conductivity can help predict when membranes will need to be replaced
		• Feed pH monitored to ensure pH is appropriate to minimise scaling risk
		• ORP is monitored to detect presence of free chlorine that would damage the RO membranes
		• Feed and permeate TOC used to monitor chemical removal performance (and potentially pathogen LRV online verification (if higher pathogen LRV is claimed for the RO))

UV/AOP	Chlorine dose Feed pH	• Online free chlorine analyser to verify chlorine dose applied to the AOP system • pH analyser to confirm feed water pH to the AOP system is at the target level

Table 15-4: Key Additional Process Parameters to be Monitored (continued)

Unit Process/Area	Parameter	Comment
Treated Water	pH TOC Nitrate	• pH is monitored to verify it is within an appropriate range • TOC in the feed to the Engineered Storage Buffer to ensure chemical peak not identified by upstream analysers does not enter PRW distribution • Nitrate in the feed to the Engineered Storage Buffer to ensure nitrate not identified by upstream analyser does not enter PRW distribution
RO Concentrate	Total chlorine/ORP	• Total chlorine and/or ORP monitored to ensure feed to downstream treatment has been dechlorinated
RO Concentrate Nitrification MBBR	DO Effluent ammonia	• DO is monitored to ensure aeration system supplies sufficient DO for biological process • Ammonia is monitored to confirm removal and ensure compliance with discharge requirements
RO Concentrate Denitrification MBBR	Effluent nitrate	• Nitrate is monitored to confirm removal and ensure compliance with discharge requirements
RO Concentrate Lamella Clarifier	Effluent phosphate Effluent turbidity	• Phosphate is monitored to confirm removal and ensure compliance with discharge requirements • Turbidity is monitored to confirm solids removal performance of clarifier

15.1.3 Effect-Based Methods (Bioanalytical Tools)

While targeted chemical analysis of priority substances is typically used for water quality monitoring; such an approach may not capture all chemical risks associated with the water. Some chemicals may be present below the analytical limit of detection but may still contribute to a biological effect resulting from exposure to complex mixtures of chemicals at low concentrations via different exposure routes. Effect-based methods (EBM) are emerging methods for water quality assessment which overcome the limitations of applying targeted chemical analyses alone. Two relevant types of EBM for this purpose include high-throughput in vitro bioassays (primarily mammalian cell models) and well plate-based in vivo assays (small organisms). [33]

EBM are complementary to existing chemical analysis methods, and overcome some limitations of the current chemical-by-chemical approach by:

- Detecting unknown or potent chemicals present at concentrations below analytical detection limits, and,
- Accounting for mixture effects, enabling better assessment of water quality for complex mixtures of organic micropollutants, and providing a sum parameter for all active chemicals with the same mode of action.

EBM does not identify the individual chemicals causing the effect.

While EBM has advanced greatly in the past decade, there are still some knowledge gaps that need to be addressed, including:

- Systematic assessment of the validity of sample preparation methods, which is challenging for EBM as internal standards cannot be added to correct for any losses.
- A lack of comprehensive in vitro models for some relevant endpoints, such as reproduction and developmental toxicity.
- Restriction to offline testing most EBM are offline (i.e., water samples are collected and then taken to a laboratory for processing and analysis). However, there is also potential for the development of online EBM for surveillance monitoring.

While there has so far been only tentative uptake of EBM by regulatory bodies to date, there may be potential for greater acceptance of EBM in regulatory contexts to address the ever-increasing universe of potential chemical contaminants, as supported by:

- Recent progress in establishing effect-based trigger values (EBT) for a wide range of bioassays;
- The development of frameworks to respond to EBT exceedances, and,
- Extensive experience with the systematic application of EBM to water quality monitoring.

The use of bioanalytical tools, combined with chemical analysis, for routine water quality monitoring, as well as source water characterisation, is likely to become more widespread as the knowledge gaps are addressed and as regulatory agencies develop an understanding of what the test results mean with respect to protection of public health.

Neale et. al. [33] provides a good summary of the basis for using EBM as well as practical considerations. Detailed information on this topic can be found in the book *Bioanalytical Tools for Water Quality Assessment* (see reference [34]).

California's Policy for Water Quality Control for Recycled Water [35] requires the recycled water producer to conduct quarterly monitoring using two bioassay tools (estrogen receptor-α and aryl hydrocarbon receptor) and evaluate the results by comparing the measured bioanalytical equivalent concentrations[40] to their respective monitoring trigger level[41] (concentration). The policy then specifies response actions based on the ratio of bioanalytical equivalent concentrations to monitoring trigger level. Currently there are no specific response actions defined when this ratio is above 10, with the requirements being to resample and perform another bioassay and contact the State Water Board to discuss additional actions.

Based on the current direction with bioanalytical tools it is likely that their use will become more widespread within the water industry. As such, it is recommended that RCC:

- Plan for inclusion of the quarterly bioassays as per the California policy (i.e. quarterly monitoring using two bioassay tools (estrogen receptor-α and aryl hydrocarbon receptor)), and,
- Monitor developments in this area and consider including additional EBM in routine PRW quality monitoring (as well as potentially for investigating chemical performance of individual treatment processes) if sufficient benefit in doing so is expected.

It should be noted that Griffith University have the appropriate expertise and capabilities to perform the recommended quarterly bioassays, and indicated that costs to perform estrogen receptor-α testing would be about $5,000 per quarterly sample and cost to perform aryl hydrocarbon receptor testing would be about $3,000 per quarterly sample.

15.1.4 Excitation Emission Matrix Fluorescence

Excitation emission matrix fluorescence, and other fluorescence methods, can be used to analyse the type and concentration of dissolved organic matter in water, and the conversion of dissolved organic matter through the AWTP process train. They can also be used to evaluate the treatment efficiency, such as the removal rate of trace organic pollutants, and indicate toxicity changes and disinfection by-product variations in water [36].

However, there are still many uncertainties about the process of fluorescence data analysis. High sample concentrations can exceed the analytical range, and extraction of useful information from complex multi-dimensional fluorescence data is difficult. In addition, water quality parameters and interactions between different components in the samples can affect fluorescence analysis [36].

As there is currently no standardised approach for use of fluorescence methods for monitoring potable reuse systems, there is no recommendation for inclusion of this in the routine monitoring of the proposed schemes. However, developments in this area should be monitored and further consideration given to this topic in the future if appropriate.

15.2 Laboratory

The sampling and laboratory requirements associated with PRW monitoring are similar to those required for source characterisation, as detailed in Section 14.2. The lab(s) that may be contracted for routine PRW

[40] Bioanalytical equivalent concentration (BEQ): The outputs from bioanalytical screening tools are referenced to a substance that initiates a physiological response from the receptor (strong agonist) to generate BEQs. A BEQ is generated from a standard curve of a strong agonist for the receptor and is expressed in mass (ng/L) or molar concentration units. A BEQ is typically derived by comparing the 50th percentile effect concentration (EC50) or 10th percentile effect concentration (EC10) responses of the test sample with the same effect concentration (EC) level of the standard curve. The BEQ is compared to the Monitoring Trigger Level in water for the strong agonist for the receptor used to generate the BEQ. [35]

[41] Monitoring trigger level (MTL): CEC concentrations above which response actions may be required. MTLs were established by the Science Advisory Panel for CECs in Recycled Water in their final report "Monitoring Strategies for Constituents of Emerging Concern (CECs) in Recycled Water – Recommendations of a Science Advisory Panel," dated April 2018. [35]

monitoring will likely be the same as that/those contracted for source water monitoring, noting that the former will likely involve fewer analytes as agreed with the regulator.

In addition to monitoring of PRW quality, laboratory analysis would also play a role in monitoring of operational performance. This could include:

- Sample analysis to verify online analysers;
- Sample analysis for verification of chemical dose (e.g. mg ozone/mg DOC);
- Samples analysis for process troubleshooting;
- EBM in addition to those recommended in Section 15.1.3 (based on outcomes of monitoring developments in this area); and,
- EEM fluorescence analysis (based on outcomes of monitoring developments in this area).

Membrane autopsy is another form of off-site laboratory analysis that may be used for membrane processes as a means to troubleshoot performance issues, particularly if the plant experiences fouling or scaling events.

15.3 PERSONNEL

The AWTPs proposed for the potable reuse schemes are complex, requiring a highly skilled team to properly operate and maintain the plant.

15.3.1 Operators

Operators of the AWTP will need to be amongst the most highly skilled in the industry as they will need to:

- Operate multiple complex treatment process units;
- Be able to identify potential issues in feed water quality that will require further investigation (by others);
- Understand why the plant needs to be operated in accordance with the design and the importance of protection of public health;
- Be able to identify issues with the plant that require further investigation by process engineers or maintenance staff; and,
- Be able to communicate effectively with maintenance staff, process engineers, management and external stakeholders.

Operator training will be critical to successful operation of any PRW scheme and will need to start well before commissioning of the full scale AWTP. The required approach will depend on whether RCC intends to utilise its own operations staff, for which RCC would need to develop a training program, or if RCC intend to engage a contract operator with experience operating this type of scheme (e.g. Veolia).

Key elements of the Operator training would be expected to include:

- Participating in the operation of a demonstration plant, enabling the Operators to gain experience with the specific process units;
- Engagement in design reviews and workshops (e.g. HACCP, Hazards and Operability (HAZOP), etc.) which will support the Operators understanding of the AWTP;
- Completion of plant and process specific training modules delivered by the design team (including the equipment suppliers). Within the personnel delivering the training would be tasked with ensuring Operator understanding (i.e. just attending the training would not be sufficient, a means to validate and confirm the Operators' knowledge following the training would be required); and,
- Potentially visiting other operating AWTP facilities (e.g. including multiple weeks working directly with Operators of these facilities).

Training would also need to continue beyond the initial training to ensure the operators' skills are up to date.

Appropriately skilled/trained operators must be available prior to the start-up of the AWTP.

The level of operator attendance at the AWTP would need to be agreed with the Regulator. The DPR regulation recently passed in California[42] requires an operator to be on-site at all times[43]. For this investigation it is assumed that the AWTP will need to have an operator on site at all times, with the chief operator and a second operator on the day shift and a single operator on for the other two shifts per day (assuming eight hours per shift). Based on this, at a minimum it should be expected the one chief operator/superintendent and five operators would be required.

15.3.2 Process Engineers

Process engineers will be required to review and analyse the plant operating data to:

- Understand the performance of the plant at any given time;
- Review and analyse trends that could indicate decline in performance;
- Identify when critical media renewal of items such as GAC media, RO membranes, etc. will be required;
- Identify opportunities for optimisation or improvement (these could include operational and/or, maintenance changes, control system updates, physical changes to improve performance, etc.); and,
- Communicate all of the above to relevant stakeholders.

Based on the complexity of the AWTP it can be expected that at least two process engineers will be required to analyse the plant operating data in the timeframes required.

15.3.3 Maintenance

Similar to the operators, maintenance staff will also need to be highly skilled as they will need to:

- Maintain multiple complex treatment processes;
- Understand the criticality of protecting public health;
- Understand the risk to water quality that could eventuate as a result of maintenance activities;
- Understand the criticality of ensuring proper functioning of all CCP analysers at all times;
- Ensure that an appropriate inventory of spare parts is maintained at all times and that all perishable items (e.g. analyser reagents) are managed such that they always within safe use by dates; and,
- Ensure predictive, preventative and reactive maintenance is performed in accordance with an approved maintenance system.

As with Operators, training of maintenance personnel will be critical to successful operation of the AWTP. Training will need to start well before commissioning of the full scale AWTP. If RCC intends to utilise its own maintenance staff RCC would need to develop a training program. Alternatively, if RCC intend to engage a contract operator with experience maintaining this type of scheme (e.g. Veolia), these elements of the training would need to be driven by the contractor (with suitable oversight from RCC).

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[42] California Code of Regulations, Title 22, Division 4, Chapter 14, Article 10

[43] There is a provision in the regulations that allows the public water authority responsible for the AWTP to request a waiver from this staffing requirement after twelve months of operation if it can be demonstrated that "an equivalent degree of operational oversight and treatment reliability with either unmanned operation or operation under reduced operator oversight". If the waiver is granted, the operator is not required to be on-site at all times but shall be able to monitor operations and exert physical control over the AWTP within the period specified in the operations plan, or one hour, whichever is shorter.

Training would likely include maintenance staff:

- Gaining experience by participating in maintenance of a demonstration plant;
- Developing an understanding of the design of the AWTP by taking part in design reviews and workshops (e.g. HACCP, HAZOP, etc.);
- Attending training delivered by equipment suppliers of for the specific equipment used in the AWTP; and,
- Potentially visiting other operating AWTP facilities (e.g. including multiple weeks working directly with maintenance staff at these facilities).

Training would also need to continue beyond the initial phase to ensure skills are up to date.

Appropriately skilled/trained maintenance staff must be available prior to the start-up of the AWTP.

For the purposes of this investigation, it is assumed managing maintenance of the AWTP will require at a minimum a maintenance supervisor, two fitters, one electrician and one analyser specialist. Aside from the analyser specialist, who will likely be required full time, it is assumed that the other maintenance staff would be required for AWTP maintenance 50% of the time (i.e. 20 hours per week). RCC will need to evaluate existing maintenance capabilities to determine how much of the maintenance burden could be accommodated by existing maintenance staff and how many new resources may be required.

15.3.4 Management

The management team will need to understand the importance of protection of public health and the role of all staff in ensuring that outcome. The management team must ensure that operations and maintenance functions are adequately resourced so that public health is always protected.

Management must also ensure plans and procedures are in place and updated as required. These could include, among others, the following:

- Risk management plan;
- Continual improvement plan;
- Management of change plan;
- Reporting procedures;
- Training plans;
- Staffing plans (including plans for staff retention); and,
- Operations and maintenance plans and procedures.

It is also critical that management ensure plant operation and maintenance documentation, including manuals, standard operating procedures, unit process guidelines, and response plans adequately document the requirements for operating and maintaining the plant and are suitable for use. Further, management must ensure that these documents are frequently reviewed and updated as required to ensure the information remains current.

There may be some equipment, analysers, etc. that require a service contract for maintenance and repairs. Management must ensure these service contracts are in place and fully meet the needs of operations.

For the purposes of this investigation, it is assumed that three full time staff (one overall project manager and two support staff) will be required to perform the required management functions.

15.3.5 Auditing

There will be a need to audit the operation, maintenance and management of the AWTP on a regular basis to demonstrate that the plant is being operated and maintained appropriately to RCC management, the Regulator and other stakeholders. The auditor would need to be independent from the resources that carry out these functions, and have sufficient knowledge and experience to:

- Assess the operation and maintenance of the plant against agreed metrics (e.g. PRW quality meets requirements, operation is performed in accordance with approved plans and procedures, maintenance being performed to an approved schedule, etc.);
- Review any incidents and the responses thereto, and identify shortcomings/risks;
- Review the effectiveness of operations and maintenance systems;
- Review competence and training needs for operations and maintenance staff;
- Review changes to plant operation, control, maintenance, etc. to determine if the change management plan is being followed appropriately;
- Review documents (e.g. operating procedures) to determine if they reflect current plant operation;
- Identify areas where improvement is needed (as part of a commitment from RCC for continuous improvement); and,
- Identify risks as they emerge.

The audit could be conducted by RCC personnel – provided there are RCC staff with the relevant experience and availability and this is confirmed to be acceptable to the Regulator. Otherwise, a third party would need to be engaged to perform the audits. Examples of this include:

- The Memorandum of Understanding between Water Corporation and the Western Australia Department of Health requiring a third party to review operation of the Beenyup AWRP. WaterCorp has engaged Stantec to perform biannual reviews of the Beenyup AWRP to meet this requirement.
- The Singapore Public Utility Board commissioned an Independent Audit Panel in 2012 to conduct six-monthly audits, including:
    - Operation and performance of its labs;
    - Sampling and monitoring programs for all waters; and
    - Operation and performance of its WWTPs, NEWater Plants (AWTPs), seawater desalination plants and WTPs.

For the purposes of this investigation, it is assumed that biannual reviews will be conducted by an appropriately qualified consultant.

15.3.6 Community Engagement

The need for effective community engagement, and the various aspects associated with gaining community acceptance and support are discussed in Section 17.1.2. RCC will need to employ or engage personnel with skills in the area of community engagement to develop and run the community engagement program.

For the purposes of this investigation, it is assumed that one full time equivalent community engagement specialist will be required (supported by management staff described in Section 15.3.4).

15.3.7 Source Control

Section 14.1 describes the requirements of an enhanced source control program. For this purpose of this investigation, it is assumed that one full time staff will be required to manage the enhanced source control program over the life of the project, with a second full time resource required during the first two years to establish the program.

15.3.8 Water Quality

An appropriately qualified water quality specialist will be required to:

- Oversee sampling activities;
- Review laboratory analysis methods and reporting levels;
- Analyse laboratory results and coordinate with laboratory regarding any spurious results;
- Preparing data for reporting purposes; and,
- Communicating results and issues with the Regulator.

For the purposes of this investigation, it is assumed that one full time resource will be required to satisfy these requirements.

15.3.9 Institutional Capabilities

It is anticipated that RCC does not currently have suitable in-house resources with the appropriate skills to provide the functions described in Section 15.3.1 through 15.3.4 (and possibly Section 15.3.5).

If these functions cannot be supplied by current staff, RCC could consider recruiting personnel with the appropriate skills and/or training existing staff. A plan would need to be developed to demonstrate if this approach would be feasible and affordable, and if so, how it would be executed.

RCC should also consider contracting the operation and maintenance of the AWTP[44] to a contract operator with the appropriate experience and resources (e.g. Veolia). If this approach is taken, to manage such a contract, RCC would need capabilities including, but not limited to:

- Preparation of tender documents to facilitate procurement of the services;
- Preparation of a contract that details roles and responsibilities of all parties and other contractual terms (e.g. payment, minimum staffing levels, etc.);
- Project management, including confirmation of key performance indicators and performance audits, to ensure contract conditions are being met (by both the contract operator and RCC); and,
- Regulatory engagement/interface – the Regulator will likely require routine ongoing updates on plant operations and maintenance, as well as notification of any incidents that occur. RCC should consider employing an individual dedicated to interface with the regulator to ensure accurate information is provided within the timing specified by the Regulator. This critical engagement should not be left to the contract operator (the contract operator would be involved, but RCC would drive this).

15.4 Redundancy and Plant Availability

Redundancy requirements for unit processes (i.e. number of individual process units, in excess of those required to treat the design flow and load, included as standby units) will depend on RCC's approach to required uptime for the AWTP. For example:

- Three RO units could be provided in a two duty, one standby arrangement to ensure the ability for the plant to produce as capacity is maximised; or,
- Two duty units could be provided (with no standby) with the AWTP operating at lower production rate when one of the RO units is offline (e.g. for CIP or membrane replacement).

[44] It is assumed that RCC has in-house capabilities required for operation and maintenance of the transfer infrastructure associated with the potable reuse schemes. The operation and maintenance of the transfer infrastructure could also be outsourced to a contract operator if required.

For cost estimating purposes it will be assumed that all systems are provided with N + 1[45] redundancy to provide a high availability for the plant at its full design capacity. Based on this redundancy approach, the availability of the AWTPs to produce PRW at full capacity would be expected to have availability on the order of 95% based on typical equipment failures. Given the higher pathogen LRV targets assumed for the DPR schemes for this investigation, it would be reasonable to assume that the DPR schemes would have marginally lower availability based on higher likelihood of diversion of part or all of the AWTP process flow[46]. For further assessments RCC may undertake it is suggested that:

- The Lismore IPR via surface water augmentation scheme be assumed to have an availability of 95%;
- The Lismore DPR via raw water augmentation scheme be assumed to have an availability of 92.5%; and,
- Each of the DPR via treated water augmentation schemes be assumed to have availability of 90%.[47]

Redundancy for critical instruments, which can have a strong influence on availability, is discussed in Section 15.5.

To maximise plant availability, it is also important that an appropriate inventory of critical spare parts is maintained at all times. To this end, maintenance staff, plans and procedures, as well as a spare parts inventory, must be in place prior to AWTP start up.

15.5 Critical Analysers and Instruments

Section 15.1.2 summarises the analysers and instruments included in the AWTP process trains for monitoring plant operation (including CCPs and general process monitoring). The instruments and analysers that are considered critical to protection of public health and overall plant operation are summarised in Table 15-5 overleaf, along with comments on the proposed approaches to redundancy.

[45] Where N is the number of process units required to treat the design flow/load
[46] With respect to redundancy and availability, the AWTP design for each short-listed option would need to consider the minimum LRV targets that are agreed with the regulator, the means of managing water quality risks (based on the HACCP process) and RCC's intended use of PRW.
[47] These availabilities are not intended to represent targets for each of the short-listed options, but rather are provided for RCC's information with respect to further assessments they may wish to undertake.

Table 15-5: Critical Analysers and Instruments

Unit Process/Area	Analyser/Instrument	Redundancy
AWTP Feed Water	Ammonia analyser Turbidity analyser	Consider N + 1 redundancy for each analyser, possibly on two separate analyser panels fed by two separate sampling systems, as these analysers confirm the integrity of the WWTP as a pathogen barrier
	TOC analyser Nitrate analyser pH analyser Conductivity analyser	No redundancy required for TOC at this location (as downstream TOC analysers may be used as back-up). No redundancy required for nitrate at this location (as downstream nitrate analysers may be used to provide back-up). Online redundancy not considered necessary for pH or conductivity analysers, but spare probes should be considered for each (as part of the plant's spare parts inventory)
Ultrafiltration	Filtrate turbidity analyser Pressure transmitters Flow transmitters	Each UF unit should be equipped with feed and filtrate flow meters, pressure transmitters and a filtrate turbidity analyser. While the UF units are a pathogen barrier, it is considered that the provision of UF units would be provided in an N + 1 arrangement eliminates the need for redundancy on these items.
	Monochloramine (RO-based train)/free chlorine (carbon-based train)	While dosing of the given chemical is important to control biofouling, redundancy of the analyser is not considered required. If the analyser fails, the chemical dose could be set based on historic plant operation. If the dose is insufficient, the frequency of maintenance cleans could be increased (triggered based on increased backwash frequency).
Ozone	Feed TOC analyser Feed flow transmitter Ozone analyser Nitrite analyser UV Transmittance	The ozone system is claiming LRV credits for virus and bacteria, based on ozone:TOC ratio, to minimise risk of bromate formation. In the event of a TOC analyser failure, a backup control could be in place to operate based on ozone Ct. This would require an online ozone analyser to be available to confirm ozone residual at a defined location within the contactor. Alternatively, if the AWTP feed is also equipped with a TOC analyser this could serve as a back-up to the ozone system feed TOC analyser. As such, it is considered that no redundant TOC analyser will be required on the feed to the ozone contactor. It is likely that a service contract would be required for the TOC analyser. As extended operation without the TOC analyser would likely be unacceptable coordination with the service provider will be required to ensure prompt response to analyser issues. Redundancy for the feed flow analyser is not considered to be required as flow from individual feed flow meters on the downstream BAC filters could be summed (when the filter is in not in backwash). Redundancy should be considered for the ozone and nitrite analysers. It is considered that no redundancy would be required for the UV transmittance analysers – primarily as these are intended to monitor chemical removal performance related to chronic health risks (rather than acute risks). There should however be a plan in place to ensure any failure of these analysers is addressed as quickly as possible. This could include ensuring appropriate spare parts are held in inventory (potentially even complete spare analyser(s) given the number of these intended to be used in the plant), and ensuring appropriate service contracts in place, etc.
Biologically Active Carbon	BAC effluent turbidity analyser Feed flow meters Pressure transmitters	Each BAC unit should be equipped with an effluent turbidity analyser. Online redundancy for each effluent turbidity analyser is not recommended. Feed flow meters would be provided on each BAC filter to confirm hydraulic loading rate/empty bed contact time. Differential pressure transmitters would be provided on each BAC filter to measure headloss across the filter. Online redundancy for each flow meter/pressure transmitter is not recommended. There should be a plan in place to ensure any failure of these items is addressed as quickly as possible. This could include ensuring appropriate spare parts are held in inventory (potentially including complete spare units given the number of these intended to be used in the plant), and ensuring appropriate service contracts are in place, etc. In the event of failure of these items the associated BAC filter could be taken offline and the plant flow rate reduced accordingly.
	DOC analyser	No redundancy is considered required for the BAC filter effluent DOC analyser as this is intended to monitor chemical removal performance related to chronic health risks (rather than acute risks). There should however be a plan in place to ensure any failure of these analysers is addressed as quickly as possible. This could include ensuring appropriate spare parts are held in inventory, ensuring appropriate service contracts are in place, etc. The additional TOC analysers provided on the AWTP feed and on the feed to the Engineered Storage Buffer Tanks would be expected to provide adequate protection against chemical peaks in the event of failure of this TOC analyser.

Table 15-5: Critical Analysers and Instruments (continued)

Unit Process/Area	Analyser/Instrument	Redundancy
Granular Activated Carbon	Feed flow meters Pressure transmitters	Feed flow meters would be provided on each GAC filter to confirm hydraulic loading rate/empty bed contact time. Differential pressure transmitters would be provided on each GAC filter to measure headloss across filter. Online redundancy for each flow meter/pressure transmitter is not recommended. There should be a plan in place to ensure any failure of these items is addressed as quickly as possible. This could include ensuring appropriate spare parts are held in inventory (potentially even complete spare units given the number of these units intended to be used in the plant), having appropriate service contracts in place, etc. In the event of failure of these items the associated GAC filter could be taken offline and the plant flow rate reduced accordingly.
	UV Transmittance DOC analyser	No redundancy is considered required for the GAC filter effluent DOC analyser nor for the UV transmittance analysers, as these are all intended to monitor chemical removal performance related to chronic health risks (rather than acutes). There should however be a plan in place to ensure any failure of these analysers is addressed as quickly as possible, including ensuring appropriate spare parts are held in inventory, having appropriate service contracts in place, etc. The additional TOC analysers provided on the AWTP feed and on the feed to the Engineered Storage Buffer Tanks would be expected to provide adequate protection against chemical peaks in the event of failure of this TOC analyser.
Reverse Osmosis	Flow meters, pressure transmitters and conductivity analysers	Each stage of each RO unit should be equipped with flow meters, pressure transmitters and conductivity analysers on the feed, permeate and concentrate of each stage. While the RO units are a pathogen barrier, the provision of the RO units in an N + 1 arrangement would eliminate the need for redundancy on any of these individual items.
	pH analyser	The pH analyser is important for controlling scaling of the RO membranes. Redundancy for the analyser is not considered necessary as the scale being controlled is most likely calcium sulphate which is readily cleaned from the membranes by acid cleaning.
	ORP analyser	The ORP analyser provides protection of the RO membranes from the unlikely event of exposure to free chlorine. However, a redundant online ORP analyser is not recommended as once the monochloramine dosing system is commissioned the likelihood of free chlorine being present is very low. Provision of a spare ORP analyser in the spares inventory could be considered.
	TOC analyser	No redundancy is considered necessary for the RO TOC analysers as these are primarily intended to monitor chemical removal performance related to chronic health risks (rather than acute risks). There should however be a plan in place to ensure any failure of these analysers is addressed as quickly as possible, including ensuring appropriate spare parts are held in inventory, having appropriate service contracts in place, etc. The additional TOC analysers provided on the AWTP feed and on the feed to the Engineered Storage Buffer Tanks would be expected to provide adequate protection against chemical peaks in the event of failure of the TOC analysers associated with the RO.
UV Disinfection	Flow meter UV intensity analyser	Each UV unit should be equipped with a flow meter and a UV intensity analyser. While the UV units are a pathogen barrier, the provision of UV units in an N + 1 arrangement would eliminate the no need for redundancy on either of these individual items.
	UV transmittance analyser	The UV transmittance analyser would be installed on the common feed to all UV units. While the UV transmittance reading is used in the control system to determine the dose of UV required, redundancy is not required for this analyser as if there is a fault the system can be operated with control based on the UV intensity analyser.
UV Advanced Oxidation	Flow meter UV intensity analyser	Each UV unit should be equipped with a flow meter and a UV intensity analyser. While the UV units are a pathogen barrier, the provision of UV units in an N + 1 arrangement would eliminate the need for redundancy on either of these items.
	UV transmittance analyser	The UV transmittance analyser would be installed on the common feed to all UV units. While the UV transmittance reading is used in the control system to determine the dose of UV required, redundancy is not required for this analyser as if there is a fault the system can be operated with control based on the UV intensity analyser.
	Free chlorine analyser	The free chlorine analyser would be used to confirm the dose applied to the AOP system. In the case of the AOP, the pathogen PRV credits are based on the high UV dose applied rather than the level of chlorine. The function of the chlorine applied is the reduction of chemicals of concern (which are a chronic risk rather than acute). As such, there is no need for redundancy of the free chlorine analyser. In the short-term dose could be based on historic chlorine dose (perhaps checked with daily grab sample to confirm free chlorine concentration), as chlorine demand in the RO permeate would not be expected to be highly variable.
Chlorine Disinfecti on	Free chlorine analyser Flow meter	The flow measurement and free chlorine analyser reading would be used to confirm the claimed LRV for the chlorine disinfection system through continuous measurement of the chlorine Ct value. No redundancy would be needed for the CCT feed flow meter, as in the case of failure upstream flow meters (i.e. on the UV) could be summed. Given the criticality of the chlorine disinfection step a redundant free chlorine analyser (and sample system) would be recommended. Additionally, there should however be a plan in place to ensure any failure of these analysers is addressed as quickly as possible. This could include ensuring appropriate spare parts are held in inventory, having appropriate service contracts in place, etc.
Treated Water	TOC	The additional TOC analyser provided on the AWTP feed, and others elsewhere in the process train, would be considered likely to provide adequate protection against chemical peaks in the event of failure of this TOC analyser.
	Nitrate	The additional nitrate analyser provided on the AWTP feed would be considered likely to provide adequate protection against nitrate in the event of failure of this analyser.

16 DEMONSTRATION PLANT

Development and operation of an onsite demonstration plant is highly recommended. Benefits of operating the demonstration plant include:

- Verifying the Claimed LRVs for pathogens assumed for the conceptual design can be achieved;
- Testing alternative process configurations and/or different vendor equipment (e.g. UF membranes) to optimise performance and/or costs;
- Verifying chemical occurrence and removal performance;
- Providing an opportunity to review performance data with stakeholders, including the Regulator in particular;
- Ability to establish initial setpoints for plant control and in particular CCPs (noting that the applicability of these setpoint to the full scale AWTP would need to be verified);
- Providing and opportunity for hands on training for all personnel expected to be involved in operation, maintenance and management of the scheme (with particular importance for operations staff); and,
- Providing an opportunity for community engagement and education (e.g. the demonstration plant could also include a visitor centre). As an example, this was undertaken using a demonstration plant that preceded the Beenyup AWRP for WaterCorp's Groundwater Replenishment project, for Singapore's NEWater scheme and more recently through Sydney Water's Visitor Centre at its Quakers Hill WWTP site.

The demonstration plant should be designed to adequately simulate the intended full-scale design and be designed with sufficient flexibility to trial different configurations of the process units (where appropriate), different flow rates, and/or different operating and chemical regimes.

A demonstration plant plan should be developed in conjunction with the design, to ensure the design incorporates the features required to execute the plan. The demonstration plant plan and design should be reviewed with relevant stakeholders, and operations staff and the Regulator in particular.

Demonstration plants are typically designed to treat around 500 kL/d to 600 kL/d[48]. Key benefits of operating a demonstration plant at this scale include:

- Generation of the required engineering information, with confidence as to its validity with respect to design and operation of the full-scale AWTP;
- Allowing for realistic training opportunities for operators; and,
- Providing the Regulator with confidence in the results.

Given the very early stage of the project and the associated unknowns, a cost estimate for a demonstration plant cannot be provided with confidence. A very basic system, with skid mounted equipment mounted outside on a slab at grade under a carport type roof with pipes floor mounted (as opposed to buried or overhead) might be on the order of about $3m. A system housed in a building with a community education centre could be on the order of $8m to $10m.

[48] While this is the typically recommended flow range, it is possible to design a demonstration facility based on lower flow rates. Regardless of the design flow, the system design and demonstration plant operating plan need to consider what information is required to be generated from the demonstration plant, how this is going to be achieved and how the quality of the data with respect to project requirements will be assured.

As an example, the Las Virgenes Pure Water Demonstration Facility cost about $4.5m in 2019[49]. Given the escalation in construction costs since 2019 a similar facility constructed in Australia may fall into the $8m to $10m range.

Sydney Water indicates that $25m has been invested into their Purified Recycled Water Discovery Centre located at Quaker's Hill[50], it is unclear however what is included in the $25m and what percentage of that is associated with capital costs for the Discovery Centre.

49 https://www.lvmwd.com/Home/Components/News/News/5910/22

50 https://www.sydneywater.com.au/education/drinking-water/purified-recycled-water.html

17 REGULATORY APPROVAL

Gaining approval for introduction of PRW to a drinking water supply will require significant work and communication with the Regulator (NSW Department of Health). The AGWR [2] describes the key principles that are fundamental to safe augmentation of drinking water supplies and outlines a twelve-element risk management framework. These items will need to be addressed to the Regulator's satisfaction in order to gain their approval.

The key principles and the risk management framework relate to the potable reuse scheme as a whole, not just the AWTP. There must be clear recognition of the importance of the multiple barriers proposed to produce the PRW, starting with enhanced source control as the first barrier.

This section discusses items that RCC will need to demonstrate to the Regulator, as a minimum, for any potable reuse scheme that RCC wishes to pursue in accordance with the current AGWR [2].

The AGWR [2] has been applied for IPR schemes in Australia (e.g. Western Corridor, Beenyup). While there is precedent and a prescribed pathway for IPR, the AGWR [2] notes the following with respect to DPR:

"Direct options should not proceed unless sufficient mechanisms and controls are established to prevent substandard water from being supplied. Implementation of direct augmentation presents substantial technical and management challenges. The need for reliability of processes, vigilance of monitoring and highly skilled operators — already high for indirect use — is magnified for direct augmentation. Knowledge and understanding of system reliability and control of variability is essential before direct augmentation can proceed."

Hence, it can be expected that the scrutiny the Regulator applies to the approval process, which would already be high for IPR, would be even higher for DPR schemes.

Hamilton [37] and Altavilla[51] both recommend combining the ADWG and AGWR (inclusive of DPR) into a single national framework. This approach would provide clarity to both regulators and water utilities wishing to pursue potable reuse schemes.

Those wishing to pursue DPR schemes have two options, these being:

- Following the existing AGWR framework and attempt to demonstrate to the regulator that sufficient mechanisms and controls are provided such that public health is protected; or,
- Waiting for update of the AGWR framework to incorporate DPR, and development of NSW specific guidance on how the AGWR will be applied in NSW for potable reuse.

RCC have indicated that seeking approval under the first approach would not be considered without explicit support and endorsement from NSW Health and NSW Department of Climate Change, Energy, the Environment and Water. Acknowledging that development of national DPR guidelines is largely outside of RCC's sphere of influence, RCC's preferred approach would be to not seek approval of a potable reuse scheme until such time as a clear regulatory framework (for DPR) and NSW specific guidance is in place.

The information provided in this section relates to the first approach, as national guidelines providing a prescribed approval pathway for DPR schemes are not yet available.

As part of the PRW Investigations, the NSW Department of Health and NSW Department of Planning and Environment were engaged through a series of update meetings and technical discussions on the progress of the project. Continued engagement with the Regulator will be critical to the success of any potable reuse

[51] Presentation given by Nanda Altavilla (NSW Department of Climate Change Energy and the Environment) at OzWater 2024 in the WaterVal session "Purified Recycled Water in Focus"

scheme RCC wishes to pursue, including eliciting comments from the Regulator on RCC's proposed means of addressing the key principles and risk management framework.

In the absence of an updated AGWR framework incorporating DPR and specific guidance on how the AGWR would be applied in NSW for potable reuse, there is a level of uncertainty with respect to the exact requirements to achieve regulatory approval. The remainder of this section provides an example of likely minimum requirements, timelines and costs associated with approval of a potable reuse scheme following the AGWR framework. The actual requirements, timelines and costs would be dependent on the specifics of the AGWR update, and guidance from the NSW Regulator. While any national guidelines incorporating DPR may be similar to the current AGWR framework, there is risk that some additional work, or rework may be required if the actions identified herein are progressed prior to finalisation of updated national guidelines and/or NSW specific guidance.

17.1 Key Principles

AGWR [2] defines the following eight key principles as fundamental to safe augmentation of drinking water supplies:

- **Protection of public health** – protection of public health is of paramount importance and should never be compromised;
- **Community acceptance and support** – drinking water augmentation requires community acceptance and support;
- **Institutional capability** – institutional capacity is required;
- **Multiple barriers** – recycled water systems need to include and continuously maintain robust and reliable multiple barriers;
- **Skills and training**:
  - Designers, operators and managers of schemes must have appropriate skills and training;
  - System operators must be able to respond quickly and effectively to adverse monitoring signals;
  - System operators must maintain a personal sense of responsibility and be dedicated to providing consumers with safe water;
- **Management of industrial waste** – industrial waste management programs need to be established and maintained;
- **Regulatory surveillance** – all schemes must be subject to regulatory surveillance;
- **Additional principles**:
  - 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; and,
  - Any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) needs to arouse suspicion that drinking water might become contaminated.

17.1.1 Protection of Public Health

For any potable reuse scheme, there are multiple facets to protection of public health. These include, but are not limited to:

- Source characterization to develop understanding of chemical risks (refer to Section 14.2);
- Implementation of enhanced source control (industrial waste management) to control chemical risks (refer to Section 14.1);

- Developing minimum pathogen LRV targets consistent with protection of public health. The AGWR [2] clearly defines these requirements for IPR schemes, and these requirements also apply to DPR schemes as a minimum for protection of public health. While the AGWR does not include a proscriptive pathway for approval of DPR schemes, the final pathogen LRV targets will likely be dependent on the final design of the system and pathogen barrier failure modelling (refer to Section 6), with targets to be agreed with the Regulator;
- Robust treatment process design – this includes:
  - Developing a conceptual process design to meet the minimum pathogen LRV targets and to remove chemicals to address chemical risk (refer to Section 10):
    - Using established treatment unit processes configured in a multiple barrier approach (with respect to both pathogens and chemicals);
    - Selecting Claimed LRVs consistent with expected performance of these unit processes;
    - Ensuring that the Claimed LRVs can be adequately monitored via CCPs;
  - Testing the process design through operation of an onsite demonstration plant using the STP effluent that is intended for use in the full-scale system;
  - Modifying the system design as required based on the outcomes of the demonstration plant operation;
  - Considering the likelihood and potential impact of sudden or extreme changes in source water quality and how risks to PRW quality would be mitigated;
  - For items which are “pre-validated” (e.g. UV disinfection systems), ensuring the mechanical/hydraulic design is consistent with the conditions under which the unit was validated;
  - Developing HACCP plan that describes the pathogen and chemical hazards, establishes CCPs and describes the responses to be taken by the control system and/or operator to a breach of an alert or critical CCP level;
  - Reviewing CCPs to establish if redundancy is required in analyser systems;
  - For DPR schemes, consideration of engineered storage buffer tanks to capture PRW produced between CCP analyser readings in the event of a CCP breach;
  - For the IPR scheme, design of an engineered storage buffer, including development of operating strategies (e.g. amount of Wilsons River water to be stored and the timing of withdrawal(s)) and appropriate hydrodynamic modelling so that an understanding of the impact of the engineered storage buffer (e.g. retention time, blend ratio) can be gained;
- Developing commissioning and testing plans to ensure all plant systems are thoroughly checked prior to validation and verification;
- Development of operation and maintenance manuals as soon as practical prior to commissioning;
- During commissioning of the system validation and verification activities will need to be completed. Validation could include challenge testing of a given until process. Verification would include an intensive period of sampling to confirm the PRW meets all water quality requirements. Demonstration of proper functioning of the plant control system, and in particular the function of the CCP system and any automated response, would also occur during commissioning.

- Ensuring operators, maintenance staff and any other personnel involved with the operation, maintenance, management and oversight of the potable reuse system are adequately trained[52]. It is imperative that everyone involved with the potable reuse scheme understands the importance of the protection of public health and their role in achieving this (refer to Section 15.3 for skills anticipated to be required for different personnel).
- Developing a plan for predictive, preventative and reactive maintenance to ensure the plant can continue to operate as intended.
- Developing a clear communication plan for interaction between operations and maintenance activities, generally including a permit to work type of system where Operations has to sign off on maintenance activities before they commence. This plan must ensure maintenance activities do not introduce risk to public health (e.g. an analyser being taken offline for maintenance without the operator's knowledge).
- Developing a change management system to prevent unexpected/unknown changes from occurring (e.g. changes to the coding of the plant control system);
- Ongoing assessment of plant performance to ensure deterioration in performance is identified as early as possible and responded to (e.g. increasing RO permeate conductivity as membranes age can provide an indication of the expected end of life for the membranes and therefore also identify when new membranes need to be ordered);
- Ongoing auditing of scheme operation, maintenance and management (As an example, the Memorandum of Understanding between Water Corporation and the Western Australia Department of Health requires a third party to review operation of the Beenyup AWRP. WaterCorp has engaged Stantec to perform biannual reviews of the Beenyup AWRP to meet this requirement.);
- Ongoing regulatory oversight and surveillance as independent verification that the potable reuse system is being managed and operated correctly and at a high standard, and that public health is being protected;
- Ensuring a continuous improvement process is established and followed to ensure any shortcomings identified by the above activities are appropriately considered and identified response actions are implemented.

17.1.2 Community Acceptance and Support

Educating the community in order to gain acceptance and support for the potable reuse scheme is critical to the project's success. Community education would include the describing the process of producing and introducing PRW to a drinking water supply, but also describing the water cycle, the need for climate independent water sources, what the risks are, and how those risks are managed.

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[52] Operator understanding of how to operate the plant and why the plant needs to be operated in accordance with the design is critical to success. Hence operator training needs appropriate consideration in the overall development of any potable reuse scheme. Operator training will need to start well before commissioning of the full scale AWTP. If RCC intends to utilise its own operations staff, RCC would need to develop a training program. Alternatively, if RCC intend to hire a contract operator with experience operating this type of scheme (e.g. Veolia), specification and oversight of performance against the specification will be the focus for RCC. Training would generally be expected to include operators:

- Gaining experience with the process units by participating in operation of a demonstration plant;
- Developing an understanding of the design of the AWTP by taking part in design reviews and workshops (e.g. HACCP, HAZOP, etc.);
- Attending training delivered by the design team (including the equipment suppliers) with the design team tasked with ensuring operator understanding. Attendance at the training alone would not be sufficient. Rather, a means to test the operator's knowledge following the training would be required, and,
- Potentially visiting other operating AWTP facilities (e.g. multiple weeks working directly with operators of these facilities).

The first step in attaining community acceptance and support would be the development of a community engagement program, with the program being launched in the early stages of planning and continuing through the life of the project. *Framework for Direct Potable Reuse* (WateReuse Research Foundation, 2015 [18]) provides detailed discussion on community engagement programs. WSAA [38] also provides information on the importance of community engagement with respect to the success of potable reuse schemes. Key activities for developing a community engagement program from this reference include:

- Providing a rationale for the need for the potable reuse scheme proposed;
- Identifying public perception challenges;
- Developing a communication plan;
- Developing and disseminating communications material on the project; and,
- Connecting with community engagement staff at other AWTPs to gain practical information and lessons learned.

Clear and transparent communication is needed to gain the trust of the community. Examples of community communications tools/materials are provided in Table 17-1 [18].

Table 17-1: Community Communication Tools and Materials

Tool/Material	Purpose/Example
Printed materials	Fact sheets, frequently asked questions, brochures, bill inserts, posters and banners, materials for youth and children, white papers.
Digital materials Note 1	Project website; slide presentations; e-newsletters; videos.
Mailing lists	To communicate to different groups for different purposes; mailing lists can be electronic or physical.
Centralised internal information system	To catalogue and store materials.
Media engagement	To provide timely information and ensure media are informed, as well as to address misinformation. Examples: spokespeople, media training, contacts, articles, tours, and responding to media requests.
Social media	To reach certain segments of the population and provide information on a real-time basis.
Speakers' bureau	To facilitate opportunities to speak at group meetings, including business leaders, civic groups, and environmental, multicultural, and other community groups.
Stakeholder groups	To provide a process for input and feedback from interested parties within a community. Stakeholder group members can become important supporters of the project.
Demonstration facility/visitor centre[1]	To provide a positive learning experience for participants. Visitor centres involve educational displays and materials; demonstration facilities show treatment processes and treated water for examination.
Independent advisory panels	To provide credibility and validation of a project. Local physicians and national experts in health, water quality, and technology can provide an independent viewpoint and make recommendations for improvement.
Rapid response plan	To swiftly address unexpected events related to the project.
Monitoring and evaluation	To provide measurable community engagement objectives that can be reviewed periodically. Results of review will provide feedback for adapting or changing communications plan, tools, and materials.

Note 1: Examples include the web site for the Las Virgenes Pure Water Demonstration Facility (https://www.ourpureh2o.com/learn-more/demonstration-project#ad-image-23) and the Sydney Water Purified Recycled Water web site (https://www.sydneywater.com.au/education/drinking-water/purified-recycled-water.html)

The extended period of time required to deliver a successful potable reuse scheme makes it likely that the project will likely extend over climatic cycles and political cycles, and have to contend with staff turnover within the client, consultant and regulatory organizations. Ensuring that there are at least a few strong advocates from the community to help drive the project through these cycles will be important.

17.1.3 Institutional Capacity

As described in the AGWR [2], to undertake any of the short-listed potable reuse schemes RCC would require:

- Sufficient resources;
- Appropriate levels of expertise and personnel; and,
- A commitment to high levels of management and monitoring throughout the life of the scheme.

Section 15.3 discusses the personnel skills and levels anticipated to be required. In addition to personnel requirements, RCC will need to have appropriate infrastructure and systems, as well as access to suitable laboratories (refer to Section 14.1 and 15.1) in place to support the project (e.g. I.T., management systems, maintenance systems, etc.).

As noted in Section 15.3, RCC could consider contracting the operation and maintenance of the AWTP to a contract operator with the appropriate experience and resources (e.g. Veolia) if sufficient in-house capability cannot be developed efficiently. Section 15.3.9 describes the skills RCC would need if contract operations were to be pursued.

AGWR [2] notes there is also a need for the Regulator to "have the expertise understand the complexities and challenges of managing and monitoring recycling schemes, and the ability to either audit schemes themselves or critically assess audits undertaken by third parties".

17.1.4 Multiple Barriers

The AGWR [2] indicates that "recycled water systems need to include and continuously maintain robust and reliable multiple barriers". Providing multiple robust barriers is the fundamental basis on which the process trains presented in Section 10 have been developed. The personnels' skills described in Section 15.3 (e.g. operations, maintenance, process engineers) will be required to monitor and maintain the barriers. The CCPs described in Section 15.1.2 and the PRW monitoring described in Section 15.1.1 would be used to ensure integrity of the barriers is maintained and that PRW quality is never compromised.

17.1.5 Skills and Training

As discussed in Section 15.3, high skill levels will be required for operators, maintenance staff and managers of any of the short-listed schemes. In addition, RCC must ensure that the system designer(s) and auditors of the scheme have the appropriate knowledge, experience and skills for their respective roles.

The AGRW [2] also indicate that:

- Operators and managers must have the knowledge and appropriate responsibility to respond as necessary to adverse monitoring signals (e.g. sudden changes in process performance); and,
- System operators must maintain a personal sense of responsibility and be dedicated to providing consumers with safe water.

17.1.6 Management of Industrial Waste

Industrial waste management programs (enhanced source control) need to be established and maintained. Refer to Section 14.1 for further information and recommendations in relation to enhanced source control.

17.1.7 Regulatory Surveillance

It is anticipated, and would be a reasonable expectation from the public, that any potable reuse scheme would be subject to rigorous regulatory oversight. This would include the process to attain approval from the Regulator for introduction of PRW to the drinking water supply, as well as ongoing regulatory oversight to ensure that the scheme is being operated and managed correctly to a high standard, and that public health is being protected [2]

17.1.8 Additional Principles

The AGWR [2] includes two additional principles identified in the ADWG [3] that are applicable to augmentation of drinking water supplies.

The first additional principle is that the greatest risks to consumers of drinking water are pathogenic microorganisms. Hence, protection of water sources and treatment are of paramount importance and must never be compromised. Protection of sources could include:

- For the short-listed IPR scheme, any sources additional to PRW entering the Engineered Environmental Buffer Storage should be protected from livestock and human waste; and,
- For all short-listed schemes, while enhanced source control will not impact the pathogen load to the STP, the control of industrial chemicals provided by such a program can help protect the integrity of the first treatment barrier in the system (i.e. by preventing discharges of compounds that could negatively impact on overall STP performance (and more specifically on pathogen removal performance of the STP)).

The second additional principle is that any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) needs to arouse suspicion that drinking water might become contaminated. This principle would be addressed by:

1. Consideration of the range of operating conditions and associated performance of the STP (which will be impacted by wet weather); and,
2. Application of appropriate CCPs to monitor performance of the STPs.

17.2 AGWR Risk Management Framework

The twelve elements of the AGWR [2] risk management framework are summarised as:

- Commitment to responsible use and management of recycled water quality;
- Assessment of the recycled water system;
- Preventive measures for recycled water management;
- Operational procedures and process control;
- Verification of recycled water quality and environmental performance;
- Management of incidents and emergencies;
- Operator and contractor awareness and training;
- Community involvement and awareness;
- Validation, research and development;
- Documentation and reporting;
- Evaluation and audit; and,
- Review and continual improvement.

Extensive detail is provided in the AGWR [2] with respect to the twelve elements of the risk management framework summarised above. RCC would need to develop and document a risk management plan that addresses each of the elements described in the AGWR [2]. The Regulator should be involved in the development of the risk management plan from the start of the project to ensure their concerns are appropriately considered and included in the plan.

17.3 Monitoring

AGWR Phase 1 (2006, [39]) and Phase 2 (2008, [2]) provide an overview of monitoring requirements for recycled water schemes, with topics including:

- General principles;
- Validation monitoring;
- Operational monitoring;
- Verification monitoring; and,
- A summary of monitoring requirements (indicative monitoring requirements covering public health aspects are provided, noting that the monitoring requirements listed are indicative rather than prescriptive – hence project specific risks will need to be considered when referencing these monitoring requirements).

The approach to monitoring should be summarised in a format that will assist in discussions with the Regulator, with proposed monitoring for each of the multiple barriers clearly identified. Suggested initial approaches to PRW quality monitoring and process monitoring are provided in Section 15.1.

17.4 Suggested Key Actions

The process of gaining regulatory approval will consist of ongoing interaction and communication with the Regulator to provide sufficient evidence that the AGWR [2] key principles have been addressed and the risk management framework has been followed. Ultimately this is required to provide the Regulator with sufficient confidence to approve the potable reuse scheme.

Table 17-2 summarises suggested key actions that RCC will likely need to complete to provide information to the Regulator (not necessarily listed in order and not exhaustive). The Regulator may not need to approve each item in Table 17-2, but will likely want to review documentation associated with each action understand how risks are being managed, and the robustness of the processes being used to develop the scheme. As project specific risks are identified during the development of the project, the Regulator may require additional information to understand these risks and how RCC intent to mitigate them.

Table 17-2: Suggested Key Actions

Action	Description
Project risk assessment	An initial analysis of project risks should be conducted and documented in a risk register. The risk register would be a live document that would be maintained and updated throughout the life of the project (including through the ongoing operation of the scheme). Risks would need to encompass all aspects of the scheme (i.e. not just water quality or process risks).
Community engagement program	Development of a community engagement program is needed to allow engagement with the community to gain support and acceptance for the project and develop community advocates for the project. This program would continue throughout the life of the project.
Source characterisation	To understand the chemical risks presented by the source catchments, a source characterisation program needs to be completed. This would include: • Conducting a review of the Trade Waste dischargers in the source catchment to documents the nature, quantity and quality of each discharge and • Conducting a sampling programme on the effluent of the source STPs to identify chemicals that would need to be removed by a downstream AWTP and their concentration. Additional sampling could also be conducted on the influent of the STPs to determine the removal of chemicals of concern within the STP process. Refer to Section 14.2 for further information.
Enhanced source control program	To manage risks from Trade Waste discharges, an enhanced source control program would need to be developed. Section 14.1 describes what would need to be included in such a program.
Confirmation of source pathogen concentration	To set pathogen LRV requirement and confirm STP pathogen reduction, concentrations of reference virus, protozoa and bacteria in the raw wastewater to each of the source STPs need to be established and agreed with the Regulator. AGWR [2] provides default values, but it is recommended that RCC sample the raw wastewater to each of the source STPs to confirm. This sampling could be combined with the source characterisation sampling discussed above. The microorganisms to be monitored need to be confirmed with the Regulator – particularly for enteric viruses (i.e. Rotavirus/Adenovirus amalgam or Norovirus).
Confirmation of STP pathogen LRV	Sampling of the STPs' effluent in conjunction with the raw wastewater sampling discussed above is recommended to confirm pathogen LRVs that would be claimable for the source STPs. As noted in Section 9, this investigation has conservatively assigned 0.5 LRV for each pathogen type to the STPs.
Confirmation of pathogen LRV targets/Development of conceptual AWTP process train	Based on the outcomes of the above actions: • Confirm pathogen LRV targets; and, • Update the conceptual AWTP process train for the selected scheme, documenting the basis for selection and key design criteria for each unit process. There will likely be multiple steps in confirming the final required minimum pathogen LRV to be delivered by the AWTP, as the Regulator may want "excess LRVs" to be included for the DPR schemes. As noted in Section 6, the final minimum pathogen LRV requirement to be agreed with the Regulator should be based on pathogen barrier failure modelling, which will be specific to the AWTP design. As part of confirming the final required minimum pathogen LRV the quantitative microbial risk assessment should be updated.
Demonstration plant	With the above actions completed, a demonstration plant design and a demonstration plant operational plan can be developed and agreed with the Regulator. Then the demonstration plant can be constructed and operated. Refer to Section 16 for more information on the demonstration plant.
Chemical risk assessment	Based on the information developed in the above actions, develop a site specific QCRA (based on the example summarised in Section 7).
Design AWTP	Based on the information gathered in the above actions, update the design of the AWTP, including confirmation of CCPs (and the associated alert and critical levels for the CCPs) and what equipment will be supplied pre-validated (and what design requirements need to be included for the pre-validated equipment). Also included in this action would be the finalisation of the minimum pathogen LRV targets in conjunction with the Regulator. Refer to the discussion on design included in Section 17.1.1.
Establish validation and verification plan	Prior to commissioning the AWTP, the methods that will be used to validate (e.g. challenge testing) and verify (e.g. PRW sampling) will need to be documented in a plan and agreed with the Regulator. This is separate to the ongoing sampling and monitoring program discussed below.
Sampling and monitoring plan	A plan for ongoing monitoring of PRW quality, the integrity of all barriers/unit processes and the overall performance of the system, which would act as ongoing verification of the project, will need to be developed and agreed with the Regulator prior to introduction of PRW to the drinking water supply. Section 15.1 provides initial information on routine monitoring. This information would need to be verified and expanded on as part of development of the sampling and monitoring plan. As noted in Section 15.1.3, it is recommended that PRW monitoring include bioassay testing.
Commissioning and testing plan	To ensure all plant systems are thoroughly checked prior to validation and verification, in particular the function of the CCP system and any automated response, a commissioning and testing plan would need to be developed well prior to commissioning of the AWTP.

Table 17-2: Suggested Key Actions (continued)

Action	Description
Operation and maintenance manuals	To ensure the plant is properly operated and maintained from the start of commissioning, development of draft operation and maintenance manuals should occur as far in advance of commissioning as practical. The operation and maintenance manuals would be finalised following commissioning based on any pertinent findings/learnings through the commissioning process.
Institutional capacity	As discussed in Section 17.1.3, RCC will need to document that it has the institutional capacity, or has a plan for developing this capacity, required to execute the proposed potable reuse scheme. This would include development of a staffing plan for the scheme and consideration as to whether contracting operation and maintenance of the scheme to a contract operator with the appropriate experience and resources is preferrable to RCC.
Operational and management communication plan	Given that the functions required to manage some aspects of the potable reuse scheme will be split between RCC and the relevant constituent council, having a clear communication plan in place will be vital to risk minimisation (e.g. communication between the STP operator and the AWTP operator over a known issue occurring at the STP that could impact on the feed water quality to the AWTP). The operational and management communication plan will need to ensure ready and seamless communication between staff responsible for the wastewater collection system, Trade Waste management, STP operations, AWTP operations and drinking water treatment and distribution operations.
Training plan	A training plan would need to be developed to ensure operators, maintenance staff and any other personnel involved with the operation, maintenance, management and oversight of the potable reuse system are adequately trained. It is imperative that everyone involved with the potable reuse scheme understands the importance of the protection of public health and their role in achieving this, and the Regulator will want to confirm that this has been adequately considered. The plan would need to describe the proposed training methods, locations and durations for training the various staff.
Maintenance plan	A plan would need to be developed that considers predictive, preventative and reactive maintenance to ensure the plant is maintained such that it can continue to operate as intended. This would need to include consideration of spare parts inventory (including how and where the spares would be stored), special tools, maintainer qualifications, maintenance contracts, etc.
Management plan	A plan describing the management structure, policies and procedures that will be required to appropriately manage the scheme and how RCC intent to implement these (or if these are already in place) would be required.
Operations and maintenance communication plan	Developing a clear communication plan for interaction between operations and maintenance activities (generally including a permit to work type of system where Operations has to sign off on maintenance activities before they commence) to ensure maintenance activities do not introduce risk to public health (e.g. an analyser being taken offline for maintenance without the operator's knowledge) will be an important risk mitigation action.
Auditing plan	The Regulator will likely want to see a clear plan for routine auditing of the scheme operations, maintenance and management.
Change management system	A change management system should be developed to minimise the risk of unexpected/unknown changes from occurring (e.g. changes to the coding of the plant control system).
Continuous improvement plan	To ensure any shortcomings identified are appropriately considered and identified response actions are implemented a continuous improvement plan should be developed.

17.5 TIMELINE

As shown in Figure 17-1, the time between starting the project and completing the actions required to gain Regulatory approval could be on the order of about nine years (noting that, in the absence of specific NSW guidance, this timeline reflects approval of an IPR scheme following the AGWR framework in a general sense).

While it is difficult to differentiate between the different short-listed schemes due to the various complexities and current unknowns associated with each, it could be expected that the IPR would have a shorter approval timeline than the DPR options. This may change if a clear pathway for DPR options is defined by the Regulator in the meantime. It is conceivable that approval of a DPR scheme could take significantly longer than the timeline suggested in Figure 17-1.

17.6 COSTS

At this early stage of the project, given the level of unknowns and lack of definition of all the requirements of the key actions, only order of magnitude estimates of costs likely to be incurred from the start of the project to the point of attaining Regulator approval can be provided. Table 17-3 provides high-level, order of magnitude costs for the suggested key actions identified in Table 17-2 in relation to approval of an IPR scheme following the AGWR framework in a general sense. Actual costs could be higher than the costs suggested in Table 17-3 depending on the outcomes of the update of the AGWR framework to incorporate DPR and development of NSW specific guidance on how the AGWR will be applied in NSW for potable reuse.

Capital costs for the scheme options are not included in Table 17-3 (see Section 21 for scheme option capital costs).

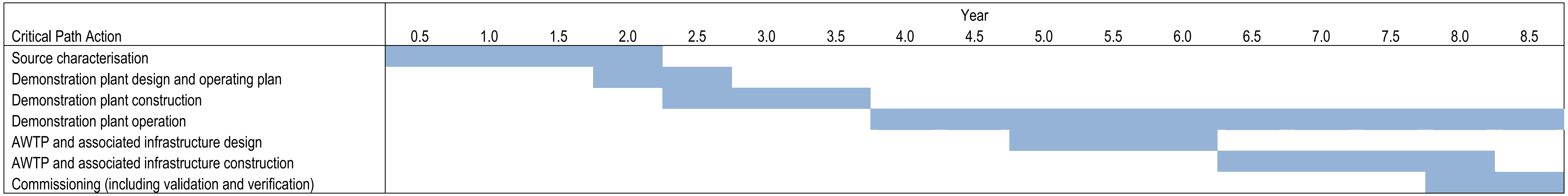

Figure 17-1: High-Level Timeline

Table 17-3: High-Level Estimate of Costs

Action	Cost	Comments
Community engagement program	$2.9m	Assumes one full time community engagement specialist at $200,000 per year, one 50% support staff at $75,000 per year and $50,000 per year in expenses. Assumes these annual costs are incurred every year from the beginning of the project to achieving Regulatory approval (9 years as per Figure 17-1).
Source characterisation	$800k to $1.6m	Assumed to include confirmation of source pathogen concentration, STP pathogen LRV and STP chemical removal. Annual sample costs presented in Table 14-2 have been increased by 100% to account for microbiological analysis. This value is then doubled to account for sampling of both STP influent and effluent. $100,000 per year has been included to account for the cost of labour, couriers, miscellaneous items required for sampling, etc. Cost based on a two-year program. Range provided depends on whether one or two source STPs are characterised.
Enhanced source control program	$2.2m	Assumes one full time staff for duration of regulatory approval period (9 years as per Figure 17-1) at $150,000 per year, one full time staff during first two years at $150,000 per year to assist in establishing program and an allowance of $500,000 to cover legal advice and other expenses.
Demonstration plant capital cost	$3m to $10m	Cost range depending on the approach to demonstration plant, as discussed in Section 16. Does not include operating costs for demonstration plant.
Demonstration plant operating cost	$5.5m	Assumes operation of the demonstration plant for five years (as per Figure 17-1) and that the plant is RO-based. Annual operating costs estimated to be $1.1m, broken down as follows: • Power - $50,000 per annum (based on specific power use of 1.4 kWh/kL (based on Gibson Island specific power use) and an electricity cost of $0.15/kWh) • Chemicals - $30,000 per annum • Labour - $460,000 per annum (one full-time operator at $100,000 per annum, one full time process engineer at $150,000 per annum, one half time process engineer at $75,000 per annum and oversight by a principal process consulting engineer at quarter time (say $135,000 based on charge rate of $280/h) • Sampling – allowance of $400,000 per annum to allow for expected intensive sampling during demonstration plant operation • Maintenance - $150,000 per annum based on 3% of an assumed demonstration plant capital cost of $5m (not including visitor centre)

Table 17-3: High-Level Estimate of Costs (continued)

Action	Cost	Comments
Items assumed to be completed by management team and process engineers during the Regulatory approval period, including: • Project risk assessment • Confirmation of pathogen LRV targets/Development of conceptual AWTP process train • Chemical risk assessment • Sampling and monitoring plan • Institutional capacity • Operational and management communication plan • Training plan • Maintenance plan • Management plan • Operations and maintenance communication plan • Auditing plan • Change management system • Continuous improvement plan	$7.2m	Assumes one overall project manager at $200,00 per year, two project management support staff at $150,00 per year each and two process engineers at $150,000 per year each. Assumes these annual costs are incurred every year from the beginning of the project to achieving Regulatory approval (nine years as per Figure 17-1).
Design AWTP	-	Cost included in AWTP capital cost
Establish validation and verification plan	-	Cost included in AWTP capital cost
Commissioning and testing plan	-	Cost included in AWTP capital cost
Operation and maintenance manuals	-	Cost included in AWTP capital cost

18 SEWAGE TREATMENT PLANT IMPLICATIONS FOR EACH SCHEME

The sewage treatment plants impacted under each of the four shortlisted schemes are listed in Table 18-1.

Table 18-1: Summary of Sewage Treatment Plants in Proposed Potable Reuse Schemes

Parameter	Brunswick Valley STP	Byron STP	Lismore East STP	Lismore South STP
Projected 2040 ADWF (ML/d)	1.75	6.6	6.5	2.6
Treatment Processes	3 Stage Phoredox (Oxidation Ditch) Biological Nitrogen Removal with Selector Chemical Phosphorus Removal UV Disinfection	Oxidation Ditch Biological Nitrogen Removal Chemical Phosphorus Removal UV Disinfection	New plant to be constructed in the next 2-3 years	Intermittent Decant Extended Aeration Biological Nitrogen Removal Biological Phosphorus Removal UV Disinfection
Effluent Discharge Location	Brunswick River	Byron Bay Urban Recycled Water Scheme, Byron Bay Integrated Water Management Reserve, and the Union Drain to Belongil Creek Estuary	Monaltrie Creek	Yeurabar Creek
Effluent Flow applied to Potable Reuse Scheme (ML/d)	1.75	6.6	6.5 (IPR-SWA, DPR-RWA) 5.4 (DPR-TWA) Note 1	2.6 (IPR-SWA, DPR-RWA)

Note 1: Targeted at producing a 50% blend of Nightcap WTP water and PRW. No contribution from South Lismore STP is required for this scenario.

18.1 BRUNSWICK VALLEY STP

Brunswick Valley STP primarily discharges effluent to the Brunswick River, with some non-potable reuse via the Mullumbimby Recycled Water Facility. The potable reuse scheme involving Byron STP and Brunswick Valley STP would see most of this effluent redirected to an AWTP, in combination with effluent from Byron STP. Redirecting effluent from Brunswick Valley STP for potable reuse would reduce the organic, solids and nutrient loads to the Brunswick River, as well as minimising or eliminating dry weather flow discharges to the river.

The implementation of a potable reuse scheme would shift all dry weather effluent away from discharge or reuse <u>during operation of the AWTP at full capacity</u>. This would result in:

1. Eliminating flows available to the local recycled water scheme (which is understood to not have been in operation for several years): and,
2. Elimination (or near elimination) of dry weather discharges to the Brunswick River should be investigated to ensure impacts are understood, reducing pollutant loads to the environment.

As the waste streams from the AWTP would be returned to Byron STP, there are no expected impacts to the Brunswick Valley STP related to return flows.

18.2 BYRON STP

Effluent from Byron STP is currently divided between non-potable reuse, flow augmentation to adjacent wetlands and Melaleuca Forest, and discharge to the Belongil Creek Estuary. The potable reuse scheme proposed for the Byron area would see most of this effluent used for potable reuse, reducing flow to discharge[53]. Should this scheme option be progressed, the preferred methodology for maintaining supply to the existing non-potable reuse would need to be investigated further, such that impacts on existing customers are eliminated or otherwise managed.

The flows discharged from the STP to the Belongil Creek Estuary via the Union Drain would be largely reduced (or eliminated under dry weather conditions). There would be a flow contribution to the Belongil Creek Estuary in the form of treated RO concentrate from the AWTP. At a typical flow of 9.1 ML/d delivered to the AWTP, the projected flow of treated RO concentrate is expected to be about 1.7 ML/d. For this investigation, this stream is expected to undergo additional treatment then be discharged to the Belongil Creek Estuary (nominally adjacent to the Ewingsdale Road bridge, see Section 11.1.1).

The RO process would increase the TDS concentration in the discharge compared to that of current Byron STP discharge, however the mass load of TDS related to the Byron STP contribution to the AWTP would be comparable. There would be an overall increase in the TDS mass load due to the transfer of Brunswick Valley STP effluent to the AWTP, and the chemical dosing within the AWTP itself (upstream of RO).

To minimise the impact of nutrient loads transferred from the Brunswick Valley STP, as well as the additional ammonia load that would result from chloramination within an RO-based AWTP for biofouling control, nutrient treatment is included in the AWTP process train for the Byron DPR scheme. This treatment would be expected to maintain or reduce the mass load of ammonia, nitrate and phosphorus.

Recalcitrant dissolved organic nitrogen present in the feed to the AWTP would be highly rejected by the RO and would not be removed by the RO concentrate treatment processes. With the transfer of Brunswick Valley STP effluent to the AWTP there would potentially be an increase in mass load of recalcitrant dissolved organic nitrogen discharged to the Belongil Creek Estuary.

If the Byron DPR scheme were to be progressed, it is anticipated that process modelling would be required to verify the nutrient mass loads expected in the RO concentrate discharge and water quality modelling for the Belongil Creek Estuary would need to be completed to qualify its impacts.

The existing discharge from Byron STP to the Union Drain has been raised as a concern in flooding of neighbouring farmland. The utilisation of dry-weather flows for potable reuse may have some positive impact on this flooding potential, any such benefits may be limited, as wet weather flows will generally be discharged via the existing locations during wet weather, and operation of the AWTP may be limited during periods of sustained higher rainfall.

Waste flows from the AWTP and RO concentrate treatment process would be returned to the inlet works of Byron STP. These flows are estimated to total about 1 ML/d under 2040 conditions. These flows are comprised of backwash waste from UF and calcite filters, strainer wash water waste, and the underflow from lamella clarifiers treating the RO concentrate. These flows are expected to increase the mass suspended (including some particulate nutrient load) in the STP influent to a small degree. Modelling of the AWTP and STP would be required to determine the impact of the return flows on the STP, but any impacts on the plant capacity or effluent quality would be expected to be minor.

18.3 SOUTH LISMORE STP

The South Lismore STP discharges effluent to the Yeurabar Creek. The Lismore IPR via surface water augmentation scheme or Lismore DPR via raw water augmentation scheme would be fed effluent from both

[53] The proposed scheme in this investigation includes allowance of facilities to draw effluent either directly from Byron STP or from the wetlands downstream of the STP (i.e. flow to the wetlands could continue with wetland effluent directed to the AWTP).

South Lismore STP and East Lismore STP. During periods where the potable reuse scheme is in operation, the dry weather effluent discharged to Yeurabar Creek is expected to be negligible, with most of the plant's dry weather effluent flow diverted to the AWTP. This would reduce pollutant loads to Yeurabar Creek.

Waste streams from the AWTP for the Lismore IPR via surface water augmentation scheme or Lismore DPR via raw water augmentation scheme would be directed to South Lismore STP. These waste streams would include strainer washwater, backwash waste flows from the BAC, GAC and UF filters, as well as waste from clean-in-place of the UF filters. These streams are expected to total about 1.6 ML/d when the entirety of available effluent flow from both South Lismore and East Lismore STPs (9.1 ML/d in total; 2.6 ML/d from South Lismore STP) is fed to the AWTP.

The waste flows are expected to increase the mass suspended (including some particulate nutrient load) in the STP influent to a small degree. Modelling of the AWTP and STP would be required to determine the impact of the return flows on the STP, but any impacts on the plant capacity or effluent quality would be expected to be minor.

Modelling of the AWTP and STP would be required to determine the impact of the return flow on the STP. Additionally, the impact of the return flow on the hydraulic capacity of the STP would need to be investigated. The reductions and increased variability in flows to the Yeurabar Creek would likely also need to be considered and potentially subjected to environmental assessment.

Since South Lismore STP does not form part of the Lismore DPR via treated water augmentation scheme, the plant would remain unaffected if that scheme option is progressed.

18.4 EAST LISMORE STP

The East Lismore STP is undergoing a full upgrade after flood damage incurred in 2022 (detailed in Section 3.1.3.2). The upgraded plant is expected to continue discharging to Monaltrie Creek.

18.4.1 Lismore IPR via Surface Water Augmentation/DPR via Raw Water Augmentation

Under the Lismore IPR via surface water augmentation scheme and Lismore DPR via raw water augmentation scheme, the projected 2040 ADWF of 6.5 ML/d would be directed to the AWTP. Under these schemes there would be no return flow from the AWTP to East Lismore STP. Hence, the only impact that would need to be investigated is the decrease in flow to Monaltrie Creek that would result from the implementation of either of these schemes.

18.4.2 Lismore DPR via Treated Water Augmentation

Under the Lismore DPR via treated water augmentation scheme, about 5.4 ML/d of the 6.5 ML/d ADWF projected to be available in 2040 would be directed to the AWTP. The reductions and increased variability in flows to the Monaltrie Creek would likely need to be considered and potentially subjected to environmental assessment.

Waste streams from the AWTP under this scheme would be directed to East Lismore STP. These waste streams would include strainer washwater, backwash waste flows from the BAC, GAC and UF filters, as well as waste from clean-in-place of the UF filters. These streams are expected to total about 1 ML/d (based on a feed of 5.4 ML/d to the AWTP).

The waste flow is expected to result in a minor increase in the influent solids load to East Lismore STP. Modelling of the AWTP and STP would be required to determine the impact of the return flow on the STP, but any impacts on the plant capacity or effluent quality would be expected to be minor.

19 ANTICIPATED SCOPE OF FUTURE INVESTIGATIONS

This section provides high-level descriptions of the further investigations likely to be required for the short-listed potable reuse schemes, or that have been recommended as part of the PRW Investigations.

19.1 Preferred Water Supply Option Assessment

RCC are investigating other potential water sources (e.g. groundwater, desalination) in addition to the *PRW Investigation*. On completion of the various investigations, RCC will need to compare the various options to determine which of the future water source options are optimal for meeting their water supply commitments and will be further investigated.

This would include consideration of cost and non-cost aspects, likely including:

- Secure yield modelling for each option, and comparison to projected demand under the critical scenarios;
- Documentation of risks for each option;
- Analysis of strengths, weaknesses, opportunities and threats;
- Comparison of capital, operating and whole of life costs; and,
- Multiple criteria assessment.

19.2 Community Engagement Program

See Section 17.1.2 for details of the needs, anticipated goals, and outline scope for a community engagement program.

19.3 Source Characterisation

If potable reuse is the preferred future water source option, one of the first investigations that should be conducted is source characterisation. This will provide the basis for understanding the prevailing chemical risks and the impacts of these risks on AWTP design and enhanced source control requirements. Source characterisation, and the associated sampling program, is described in Section 14.2.

19.4 Institutional Capacity

As discussed in Section 17.1.3, RCC will need to review the capacity within the organisation to provide the additional skills, resources, etc. would be required to adequately, operate, maintain, monitor, manage and audit the potable reuse scheme.

Once the gaps in existing institutional capacity are identified, RCC will need to determine the best methods for filling any gaps, along with the associated costs and risks. Based on the outcomes of this activity, RCC can then compare the approaches of operating and maintaining the potable reuse scheme in-house to contracting out these activities to an appropriately qualified contract operations business.

The decision to utilise contract operations/maintenance may also depend on the procurement strategy used for the project (e.g. a review of procurement options may indicate that a design-build-operate-maintain model is preferred over other options).

Critically, even if RCC elect to contract out the operations and maintenance, they will still require a level of oversight, auditing and other skills to be procured or held in house to ensure the contracts are suitably administered and their responsibilities met.

19.5 Enhanced Source Control

The need for an enhanced source control program and associated items requiring further investigation are discussed in Section 14.1. The STPs for the short-listed schemes are not owned nor controlled by RCC, and that RCC currently has no management or controls in place for trade waste discharges. A key to understanding how the risks associated with trade waste discharges could be controlled, from a legal and administrative viewpoint, would be investigation into how legal authority to develop and implement source control measures to regulate industries and their waste could be established.

It is important to note that the LGA has control over the discharge of trade waste to their sewer network. Developing a means to implement management and control of trade waste discharge as required for an enhanced source control program will require a collaborative effort between RCC and the relevant LGA.

19.6 Land Acquisition, Easements, Cultural Heritage, Native Title and Environmental

As discussed in Section 12, none of the AWTP sites selected for the short-listed schemes are currently owned by RCC. For the Lismore IPR via surface water augmentation and Lismore DPR via raw water augmentation scheme options, the AWTP is proposed to be located at the South Lismore STP site (owned by Lismore City Council). For the Byron DPR via treated water augmentation scheme option, the AWTP is proposed to be located on land adjacent to the Cavanbah Centre owned by Byron Shire Council. For the Lismore DPR via treated water augmentation scheme option, the AWTP is proposed to be located on a privately held parcel.

For any of the potable reuse scheme which are progressed, RCC will need to investigate acquisition of the relevant land with the owner, and potentially investigate other suitable parcels in the area should there be barriers to acquisition of the desired land.

The transfer infrastructure systems for the different short-listed schemes (discussed in Section 13.1) include various pump stations and reservoirs. Further investigation will be required to select specific sites for the transfer infrastructure including investigation of land acquisition requirements. This is of particular relevance with relation to the Engineered Environmental Buffer Storage that would be included as part of the Lismore IPR via surface water augmentation scheme if this option is carried forward.

Additionally, investigation of easement requirements associated with the transfer infrastructure would need to be carried out as part of the concept design of the system.

Critically, investigation into possible cultural heritage, native title and environmental impacts will need to be conducted for all infrastructure to be constructed as part of the development of the concept design.

19.7 Procurement and Funding

There are many different procurement models for delivery of the AWTP and the transfer infrastructure. These could include (among others):

- Design-bid-construct;
- Design-construct;
- Design development-construct;
- Progressive design-construct;
- Alliance;
- Design-construct-operate-maintain; and,
- Public private partnership

RCC will need to review these options in relation to the preferred short-listed potable reuse option and develop a procurement strategy for the project (if potable reuse is carried forward).

Sources of funding, and RCC's preferred approach to funding the project, will have an impact on the selection of the preferred procurement strategy.

Depending on the procurement strategy selected, RCC may wish to hire a program manager/owner's engineer to oversee the development of the project (e.g. if a design-build model is selected, RCC would likely want to have an owner's engineer with relevant expertise provide input into the design process to ensure RCC's project goals are achieved and the right amount of rigour is included in the design).

19.8 Electrical Supply

This investigation has located potential sources of electrical supply the AWTPs for each short-listed scheme option. For any scheme which is being progressed, further investigations into electricity supply, for both the AWTP and the transfer infrastructure, will be needed to identify what upgrades to the supply Essential Energy would need to complete, if any, and what costs would be the responsibility of RCC. This investigation should occur as soon as practical to gain an understanding of potential cost impact, but will need to be revisited when the electrical loads associated with the project have been determined with sufficient confidence.

19.9 Engineered Environmental Buffer Storage

If the Lismore IPR via surface water augmentation scheme is carried forward several investigations related to the associated Engineered Environmental Buffer Storage would need to be conducted, including:

- Confirmation of minimum theoretical retention time – in order to size the Engineered Environmental Buffer Storage a minimum theoretical retention time for the PRW would need to be agreed with the Regulator. A high-level basis for this was presented in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* included in Appendix A;
- Sizing – determination of the required volume for the reservoir. This would be impacted by the amount of PRW (i.e. the size of the system to be developed), and the amount of Wilsons River Source water, if any, to be directed to the Engineered Environmental Buffer Storage;
- Siting – as noted in Section 13.1, a location for the Engineered Environmental Buffer Storage has not been selected as part of this investigation. Once the size requirement has been established, investigation of suitable sites to provide that storage volume could be undertaken - this would need to include consideration of planning and approval requirements. This investigation may result in a need to resize the Engineered Environmental Buffer Storage if a suitable location to provide the initial size requirement cannot be identified;
- Hydrodynamic modelling – modelling of the Engineered Environmental Buffer Storage would be required to establish the level of short circuiting that would be expected, the impact on retention time and determine what measures would need to be taken to provide the required minimum retention time; and,
- Water quality modelling – required to understand nutrient loads within the Engineered Environmental Buffer Storage, the associated risk of algal blooms and potential means to mitigate these risks.

19.10 RO Concentrate Discharge

As discussed in Section 11.1.1, this investigation assumes discharge of RO concentrate to a location in the Belongil Creek Estuary where existing salinity levels are sufficient to accept this discharge without an expected significant impact. If the Byron DPR via treated water augmentation scheme is carried forward and remains based on an RO treatment train, modelling of the impacts of the discharge of RO concentrate to the Belongil Creek Estuary would likely be required.

In addition to understanding any cultural or native title issues associated with the proposed RO concentrate discharge, approvals from relevant authorities (e.g. fisheries, marine parks, etc.) would likely be required. Further investigation would be required to determine which approvals from which authorities would be required and the information required to attain them.

19.11 EXISTING INFRASTRUCTURE IMPACTS

Each of the short-listed schemes interacts with various existing infrastructure. The impacts on the existing infrastructure would need to be further examined to determine what upgrades or operational changes may be required. This would include:

- STP impacts – all of the schemes source effluent from either Lismore City Council or Byron Shire Council STPs, and return flows to the STPs. A high-level discussion of the impacts to the STPs is provided in Section 18. This would need to be further expanded to identify environmental impacts of the change in use of the STP effluent, the upgrades that may be required to accommodate the return flows, and/or the impact of limitations in the existing system on the proposed scheme. This may require process and/or hydraulic capacity assessment of the STPs.
- Nightcap WTP impacts – the Lismore IPR via surface water augmentation and Lismore DPR via raw water augmentation schemes would direct PRW (possibly combined with Wilsons River Source water) to Nightcap WTP for further treatment. The impact of the introduction of the source on the operation of Nightcap WTP would need to be assessed in detail, including modelling the water chemistry through the plant, to determine what upgrades and/or operational changes would be required (if any).
- Drinking water reservoir impacts – the two DPR via treated water augmentation schemes direct PRW to existing drinking water reservoirs. While significant impacts are not expected, a detailed water quality analysis should be performed to confirm this and to determine if any operational changes would be required and/or beneficial. As one example, changing the method of reservoir filling may allow for reduction in the size of new infrastructure required to deliver PRW to the reservoirs.

19.12 TREATED WATER BLENDING

For the Lismore DPR via treated water augmentation scheme, a high-level TDS mass balance (refer to *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E)) has indicated that the blend ratio (i.e. the amount of PRW divided by the total drinking water supplied by the reservoirs) needs to be 50% or less to maintain TDS in the drinking water supplied to Lismore at levels that are expected to be acceptable to customers. Detailed analysis would be required to confirm the appropriate blend ratio to use if this scheme is carried forward.

Based on the available supply of STP effluent and the projected demand for St Helena Reservoir and Knockrow Reservoir, the blend ratio is expected to be 38%. Even if a carbon-based AWTP is adopted, this level of blending in combination with the division of the PRW between Byron and Ballina, is (not expected to introduce issues with respect to unacceptable TDS increase. However, detailed analysis would be required to confirm this.

The approach for blending assumed in this investigation for the purpose of sizing pipelines and pump stations was to pump from the AWTP to the reservoir at 50% of the peak inflow rate to the reservoir. Due to the distances and elevation involved, this imposes a large pump station capacity. Alternative reservoir filling operation and/or the possibility of pumping at the AWTP average production rate to a new reservoir in reasonable proximity to the existing reservoirs where PRW is to be introduced should be further investigated if either TWA option is carried forward. This alternative approach would likely require another pump station at this new reservoir location to transfer the PRW at the required flow rate to achieve the blend ratio.

19.13 DEMONSTRATION PLANT

As indicated in Section 16, the use of a demonstration plant is highly recommended to gather information required to develop the design and operating strategy of the potable reuse system, as well as to train staff and support community engagement.

In order to execute this, both a design and demonstration plan would need to be developed based on meeting all of the goals for the facility. The design would need to ensure that all of the processes expected to be utilised in the full scale AWTP are included and that appropriate features are included to allow for sampling, testing, operation and control are included. The design should also include allowance for flexibility (e.g. operation at different flow rates, operation of GAC vessels in both parallel and series (i.e. lead/lag) configurations, etc.) to account for known or expected variations within the trial, as well as to try to allow for unexpected variations. For example, extra valving and connection points may need to be included to allow changing the order of unit processes, such as trialling operating the system with the UF upstream of the ozone/BAC/GAC and vice versa).

Details included in the demonstration plan should include, but would not be limited to:

- Clear goals and exclusions in relation to the expectations for the demonstration plant in terms of process unit testing selection, and optimization, training of operations and maintenance personnel, and engagement and education of the community;
- All tests expected to be conducted during the operation of the demonstration plant and the associated procedures, methods, etc. for carrying out those tests;
- The anticipated testing schedule;
- The sampling plan, including procedures and logistics;
- The quality control/quality assurance measures to be implemented;
- The staffing plant for the demonstration;
- The operating plan, in particular the intended means of demonstrating the CCPs and the response actions to these;
- Maintenance requirements for the demonstration plant and how these will be met (including required servicing and calibration of water quality analysers to allow for confidence in the system to be developed); and,
- Safety plan, including safety data sheets for chemicals, personal protective equipment required, identification of safety risk (i.e. a detailed risk assessment documenting identified hazards);

Detailing all tests that would be performed as part of the demonstration plant is not included in the scope of this investigation. Below are some potential items to be considered for inclusion of the demonstration plan, as identified through the course of the PRW Investigations:

- Optimisation of the ozone/BAC arrangement and operating parameters;
- Trialling different vendor equipment (e.g. allow for trialling different UF membrane modules side by side);
- Trailing both the direct filtration (ozone-coagulation-flocculation-BAC) and conventional filtration (coagulation-flocculation-sedimentation-ozone-BAC), as discussed in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E);
- Validation of pathogen LRVs and chemical removal for given units processes (e.g. processes that are not pre-validated for pathogen LRV);
- Investigation into the characteristics of the waste streams and if there is potential for removal of the neutralisation system from the design;
- Confirmation of flux rates for membrane systems, loading rates for BAC, GAC, RO recovery, etc.
- Comparison of ozone:TOC control to ozone C.t. control;
- Jar testing to develop understanding of coagulant dose rates;

- If the Lismore DPR via raw water augmentation scheme is carried forward, performing bench scale testing to investigate the impacts of ozone dosing at both the AWTP and WTP with respect to bromate formation;
- Confirmation of appropriate media (e.g. GAC type(s) for BAC and GAC systems);
- Confirmation of chemical dose rates;
- Confirmation of initial setpoints for CCP alert and critical levels for the full-scale plant;
- Trailing GAC vessels in both parallel and series (i.e. lead/lag) configurations;
- Confirmation of expected cleaning frequency and types for membrane systems; and,
- Potentially trialling ozone/BAC as a pretreatment in an RO-based train (if an RO-based scheme is the preferred option), to allow for a cost/benefit assessment of ozone/BAC pretreatment (as discussed in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E)).

19.14 Design

The conceptual designs developed for the PRW Investigations are high-level and have been developed only to facilitate the comparison of options and development of order of magnitude costs. For any scheme option which is progressed, the conceptual process design presented herein would need to be reviewed, refined and updated to produce a Concept Design that:

- Reflects additional information gathered;
- Provides more detail to allow for development of a more accurate cost estimate; and,
- Defines the future phases of design (in line with the selected procurement strategy).

The Concept Design would generally be anticipated to include:

- Development of the basis of design;
- Development of the process design (e.g. process and instrumentation diagrams, process schedule, preliminary control philosophy, process flow diagram with flow and mass balances, process modelling (e.g. membrane system projections, water chemistry, etc.));
- Development of a mechanical equipment list and electrical load list;
- Development of a hydraulic model/hydraulic grade line for the plant;
- Initial mechanical general arrangement drawings (with plans and section showing basic dimensions of all major process units);
- Initial site layout drawings;
- Initial single line electrical drawings and electrical layouts;
- Initial Safety in Design considerations (e.g. hazard identification); and,
- Update of the project risk register (the project risk register should be developed at the initiation of the project).

Verification of key elements of the process design would be required prior to initial operation of the demonstration plant. The Concept Design would then be informed from the outcomes of the initial operation of the demonstration plant (say the first two years of operation).

During the Concept Design phase geotechnical investigations and site survey (including location of existing services if applicable) would likely be initiated.

On approval of the Concept Design by RCC, the designed would then develop the Detailed Design for the scheme. RCC would likely want the Detailed Design to be delivered in stages (e.g. 50%, 75%, 100%, etc.) to allow for review and input as the design develops and possibly allow for interim updates to the project cost estimate.

Regardless of the procurement strategy selected, the end result of the design process would be a set of drawings, specification and other documentation that would allow a contractor to construct the scheme. Key documents would likely include:

- Design report;
- Process flow diagrams;
- Process and instrumentation diagrams;
- Site layout drawings (for AWTP and transfer infrastructure sites (e.g. pump stations));
- General layout plans;
- General arrangement drawings;
- Hydraulic profiles;
- Piping plans and sections;
- Civil drawings (e.g. earthworks, roads, yard piping, drainage, flood levels, civil details, etc.);
- Structural drawings;
- Electrical drawings (e.g. single line diagrams, layouts, cable schedule, etc.);
- Instrumentation and control drawings (e.g. system architecture, termination diagrams, loop diagrams, etc.);
- Building layouts and architectural drawings;
- Specifications (for all disciplines and all project requirements);
- Schedules (e.g. equipment list, valve schedule, piping schedule, instrument schedule, etc.)
- Plain English functional description;
- Functional specification;
- Safety in Design documentation (e.g. HAZOP report, Construction Hazard Assessment Implication Review (CHAIR) report);
- HACCP report;
- Commissioning and testing plan;
- Verification and validation plan;
- Operations and maintenance documentation (e.g. manuals, unit operating procedures, etc.), this would likely be developed during the construction phase and finalised after commissioning.

During the design phase, barrier failure modelling should be conducted to allow for update of the QMRA and agreement with the Regulator on the minimum pathogen LRV requirements for the project, with the design updated as required to reflect the outcome. The chemical risk assessment should also be updated based on the findings of the source characterisation, demonstration plant operational data and evidence from projects elsewhere, with the design updated as required to reflect the outcomes.

During the course of the PRW Investigations, specific items for consideration during design were identified, including:

- The option of directing water diverted within the process due to not meeting quality specifications back to the Raw Water Balance Tank rather than to the source STP;

- The impact of limitations of the source STP to accept return flows (if any);
- The size required for the Engineered Storage Buffer Tanks;
- The potential for removing the Neutralisation System from the design;
- Consideration of the updates to the chemical risk assessment and if additional unit processes are required (e.g. addition of GAC in the RO-based process train);
- The use of concrete tanks rather than pressure vessels for BAC, GAC and Calcite Filters and/or the use of horizontal pressure vessels instead of vertical pressure vessels;
- Review of developments in areas including online verification of RO units and online monitoring of pathogens;
- Cost/benefit assessment of ozone/BAC pretreatment for an RO-based system (if this is the preferred option);
- If the Byron DPR via treated water augmentation option is preferred, hydraulic analysis/modelling to determine if the pump station included in the conceptual transfer infrastructure design to pump blended water from the blending reservoir to Knockrow Reservoir is required; and,
- Cost/benefit assessment of providing GAC in a lead/lag arrangement rather than parallel.

19.15 Cost

The high-level costings presenting in Section 21 are presented to provide an order of magnitude of the potential costs of developing the short-listed schemes and to allow comparison of options. Further investigations into the project costs would be required as a part of progressing a scheme option.

These investigations would include, but not be limited to:

- Updates to the transfer infrastructure and AWTP capital costs as the design progresses;
- Updates to operating costs based on learnings from the demonstration plant operation and based on design development;
- Costings for the various investigations outlined in this section;
- Updates to costings presented in Section 17.5 related to Regulatory approval items; and,
- Confirmation of costings for sampling programs based on sampling parameters and frequencies to be agreed with the Regulator.

20 AWTP UTILISATION

As potable water demand fluctuates RCC may need to choose between shutting down the AWTP in a preservation mode ("mothballing") or operating the AWTP at a low, continuous flow.

Depending on the unit processes within the AWTP, even short shutdowns can introduce risks. For example, in a plant utilising RO in a reuse application, each RO unit must be flushed with permeate on shutdown. Further, it is considered good practice to flush each shutdown unit once every 24 hours. This is to minimise biofouling risks.

DuPont [40] indicate the following with regard to management of RO membranes:

- The membrane plant can be stopped for 24 hours without preservation or precautions for microbiological fouling. If water for flushing every 24 hours is not available, preservation with chemicals is necessary for longer stops than 48 hours.
- Membrane elements must be preserved any time the plant is shut down for more than 48 hours to prevent biological growth. Depending on the operational history of the plant, it will be necessary in almost all cases to clean the membranes prior to shutdown and preservation.
- After cleaning, the preservation should follow within the next 10 hours as follows:
    1. Fully immerse the elements in the pressure vessels in a solution of 1 – 1.5% SMBS, venting the air outside of the pressure vessels. Circulate the sodium bisulphite solution in such a way that the remaining air in the system is minimised after the recirculation is completed. After the pressure vessel is filled, the sodium bisulphite solution should be allowed to overflow through an opening located higher than the upper end of the highest pressure vessel being filled.
    2. Separate the preservation solution from the air outside by closing all valves. Any contact with oxygen will oxidise the sodium bisulphite.
    3. Check the pH once a week. When the pH becomes 3 or lower, change the preservation solution.
    4. Change the preservation solution at least once a month.

The information from DuPont provided above indicates the level of effort required to place an AWTP into a preservation mode, and then maintain the plant while in preservation. Dupont indicate a similar procedure is required for UF membranes for shutdowns of greater than seven days.

In the case of extended shutdown membranes may need to be discarded. This was the case for AWTPs in the Western Corridor Recycled Water Scheme. It has been estimated that it would take up to two years to bring the scheme back on-line [41].

All other components of the AWTP would need to be considered with respect to maintaining their condition during any shutdown period. This would include rotating equipment (e.g. pumps), analysers, tanks, pipelines, and the like.

The alternative to shutting down and preserving the AWTP is to continue operating the plant at a minimum flow. The plant would need to be designed to provide the turndown and operational flexibility required to achieve this. The main benefit of operating at a minimum flow is the ability to cycle through operation of process units so they are not offline for extended periods, enabling the intensive works required for preservation to be avoided.

Continuing to operate the plant, and to maintain the operating plant, would provide the benefit of maintaining institutional capacity with respect to operating and maintaining the plant. There is a risk that some of this institutional capacity could be lost (by RCC and/or the contract operators if applicable) if the AWTP were to be shutdown for extended period.

RCC have indicated:

- Due to the need to maintain institutional capacity, mothballing the AWTP would not be likely to be acceptable;
- Based on operational requirements of the system, it is anticipated that if the AWTP were to be taken offline, it would need to be back online within six months; and,
- As a point of reference, Emigrant Creek WTP needs to be run at least once per week to prevent degradation of plant equipment.

If any of the short-listed options are carried forward, it is recommended that further investigations into mothballing and operation at minimum flow be undertaken to ensure the plant is equipped to meet RCC's requirements.

21 COST ESTIMATION

21.1 MARKET ENGAGEMENT

To support development of capital cost estimates for the short-listed schemes, specialist suppliers to the Australian market were requested to provide support in equipment model selection, configuration and budget pricing for key process equipment included in the AWTP conceptual process designs. Data sheets (included in Appendix L) were developed and sent to suppliers for the following items:

- Ozone generators;
- UF systems
- RO systems; and,
- UV and UV/AOP systems.

The suppliers were asked to provide cost information for units of varying capacities, ranging from 0.5 ML/d to 50 ML/d AWTP capacity, to allow for generation of cost curves.

21.1.1 Ozone Generator

Table 21-1 summarises the capital costs provided by the vendor for supply of the ozone generators. In Table 21-1 AWTP flow rate refers to the STP effluent supplied to the AWTP (i.e. inclusive of return streams from the AWTP to the STP).

Table 21-1: Ozone Generator Estimated Equipment Supply Costs

AWTP Flow Rate (ML/d)	Ozone Demand (kg/h)	Estimated Equipment Supply Capital Cost ($AUD 2024) per Ozone Generator Note 1
0.5	0.3	$45,700
2	1.0	$68,100
5	2.5	$159,600
8	4.0	$238,700
20	9.9	$318,200
50	24.8	$488,000

Note 1: Cost provided in US dollars. Converted to AUD using an exchange rate of $1.00 USD = $1.50 AUD. All assume generator is supplied with pure oxygen.

The costs and generator capacities shown in Table 21-1 result in the cost curve provided in Figure 21-1.

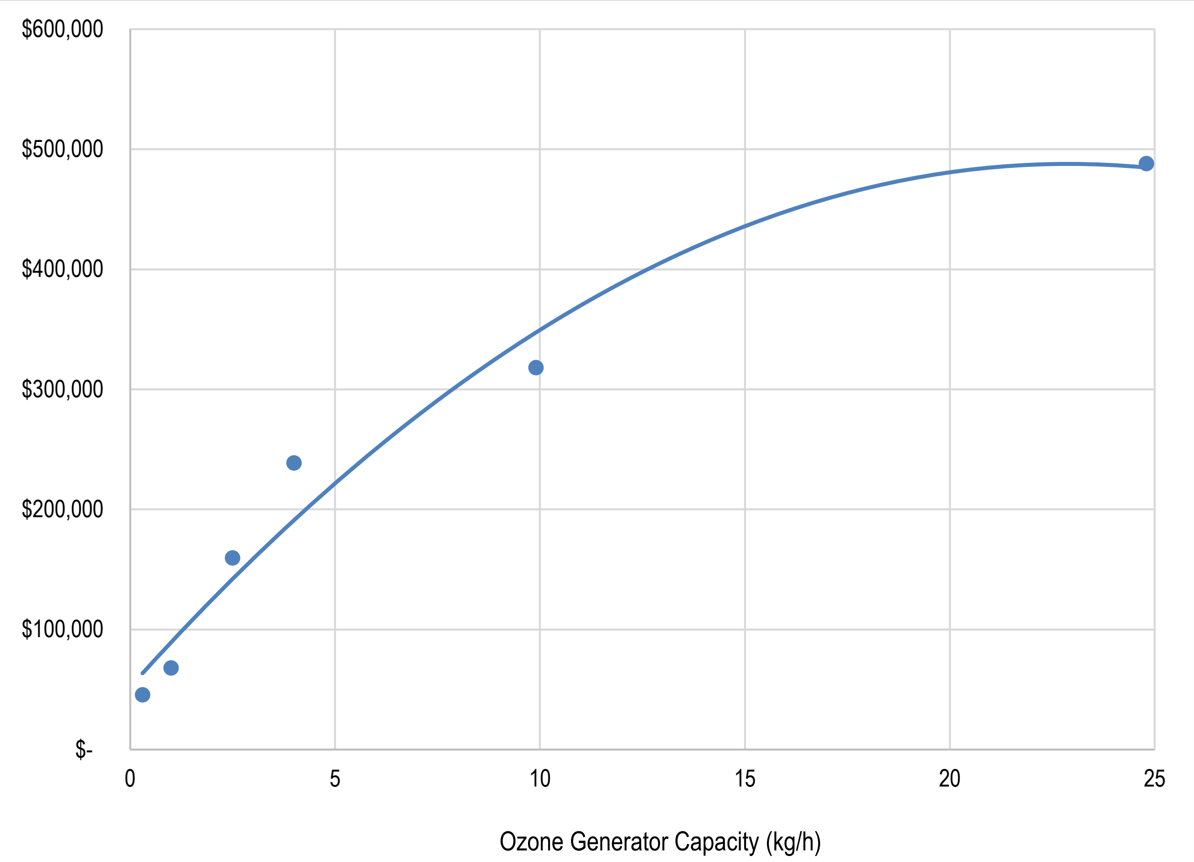

Figure 21-1: Ozone Generator Cost Curve

21.1.2 UF System

Cost information was provided for UF systems for direct treatment of STP effluent (for the RO-based process train) and for treatment of effluent from ozone/BAC/GAC (for the carbon-based process train). The flux used for sizing the UF units was 50 LMH for the RO-based process train and 70 LMH for the carbon-based process train.

Table 21-2 presents the UF system costs. These costs include the membrane skids and all ancillary equipment (e.g. CIP systems, blowers, etc.). The following are not included in these costs:

- Installation;
- Interconnect piping;
- Feed and filtrate storage;
- Chemical storages; and,
- Waste handling.

Table 21-2: UF System Estimated Equipment Supply Costs

AWTP Flow Rate (ML/d)	UF System Equipment Supply Capital Cost ($AUD 2024) RO-based AWTP	UF System Equipment Supply Capital Cost ($AUD 2024) Carbon-based AWTP	Number of Membrane Skids and Capacity
0.5	$831,000	$804,000	2 x 100%
2	$1,339,000	$1,268,000	3 x 50%
5	$2,477,000	$2,300,000	3 x 50%
8	$3,575,000	$3,298,000	3 x 50%
20	$6,009,000	$5,326,000	5 x 25%
50	$10,797,000	$9,453,000	6 x 20%

Figure 21-2 and Figure 21-3 provide cost curves for UF systems for the RO-based process train and for the carbon-based process train, based on the costs presented in Table 21-2. In Figure 21-2, Figure 21-3 and Table 21-2 AWTP flow rate refers to the STP effluent supplied to the AWTP (i.e. inclusive of return streams from the AWTP to the STP).

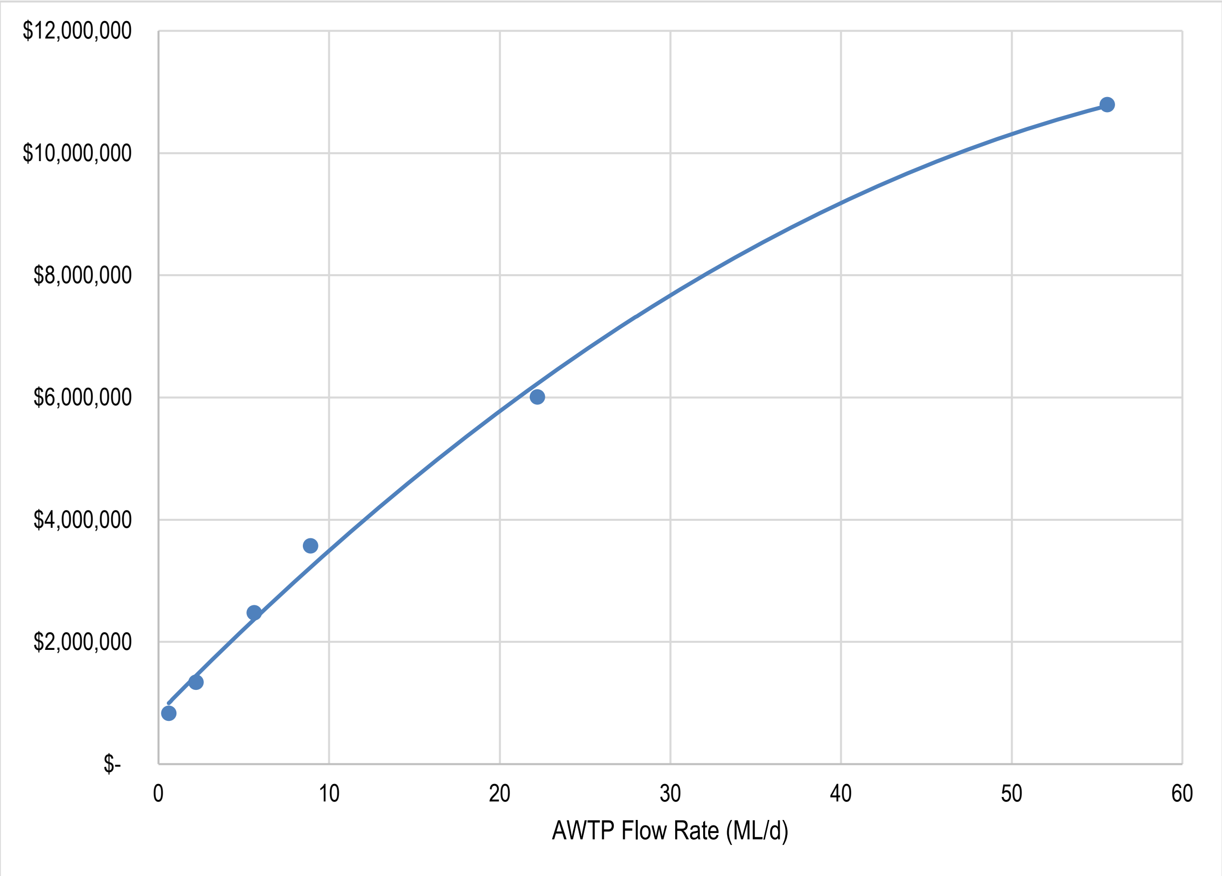

Figure 21-2: UF System Cost Curve for RO-based Process Train

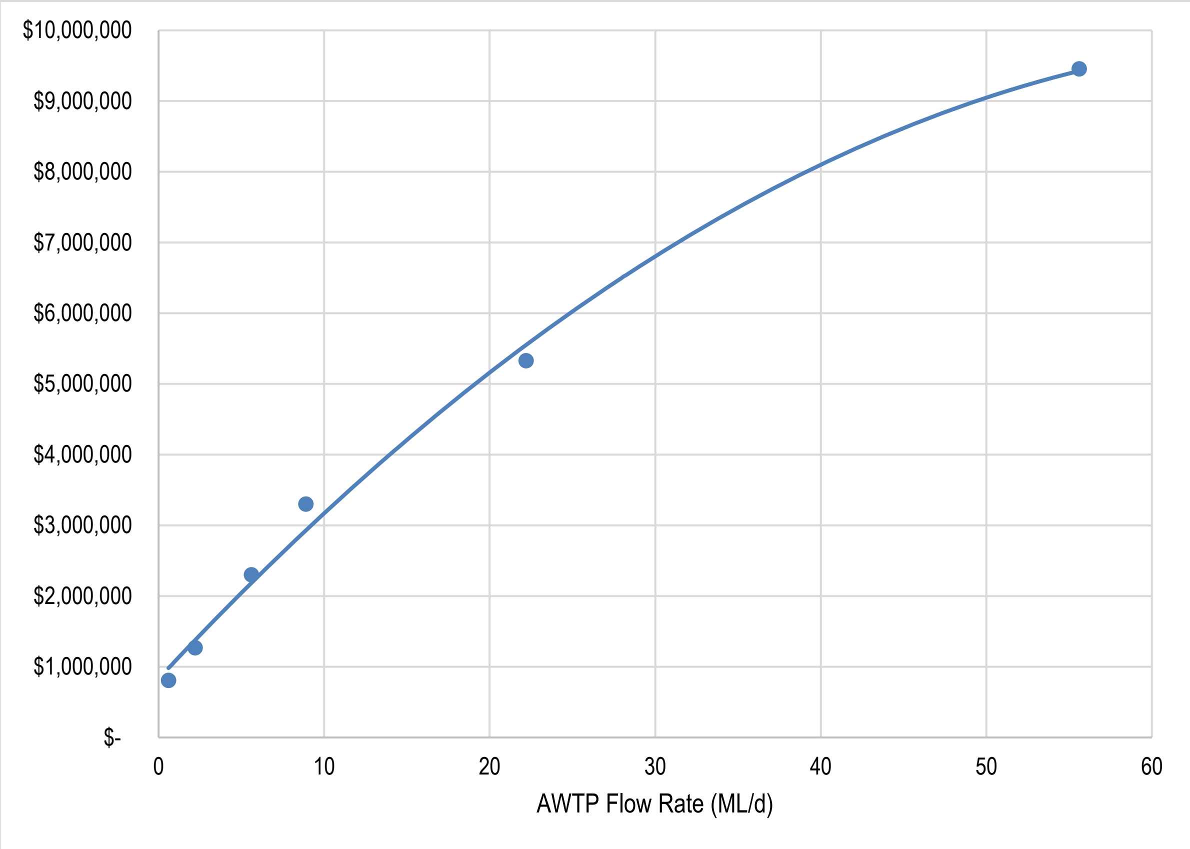

Figure 21-3: UF System Cost Curve for Carbon-based Process Train

21.1.3 RO System

Cost information was provided for RO systems based on a flux of 20 LMH.

Table 21-3 presents the RO system costs. These costs include the membrane skids and all ancillary equipment (e.g. CIP systems, flush pumps, etc.). The following are not included in these costs:

- Installation;
- Interconnect piping;
- Feed, permeate and flush water storage;
- Chemical storages; and,
- Waste handling.

Table 21-3: RO System Estimated Equipment Supply Costs

AWTP Flow Rate (ML/d)	RO System Cost Equipment Supply Capital Cost ($AUD 2024)	Number of Membrane Skids and Capacity
0.5	$613,000	2 x 100%
2	$1,192,000	3 x 50%
5	$2,104,000	3 x 50%
8	$2,722,000	3 x 50%
20	$5,393,000	3 x 50%
50	$10,594,000	6 x 20%

Figure 21-4 provides a cost curve for RO systems based on the costs presented in Table 21-3. In Figure 21-4 and Table 21-3 AWTP flow rate refers to the STP effluent supplied to the AWTP (i.e. inclusive of return streams from the AWTP to the STP).

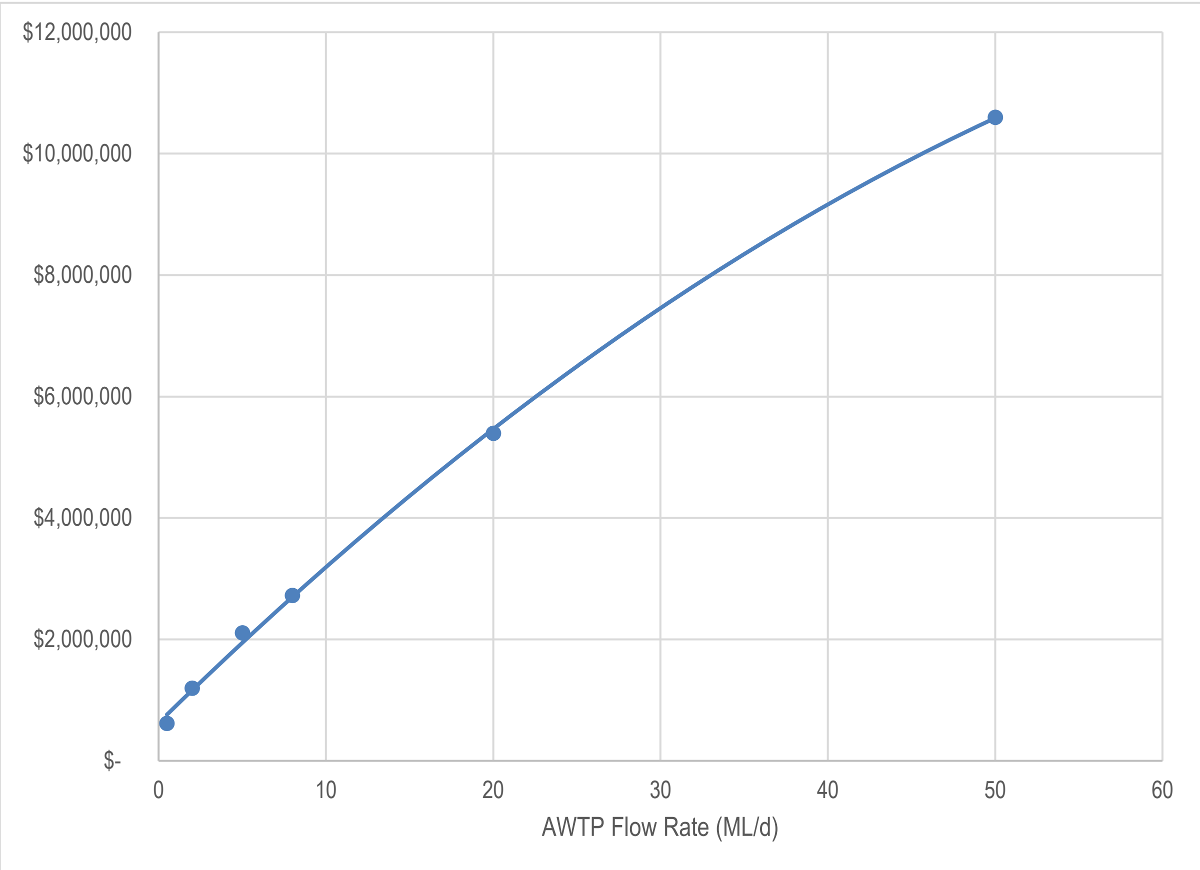

Figure 21-4: RO System Cost Curve

21.1.4 UV Systems

Costs for UV and UV/AOP systems were provided, but due to discrepancies in the information reliable cost curves could not be developed. Table 21-4 UV system cost estimates for the flow rates and minimum UV transmittance for the short-listed AWTP conceptual designs.

Table 21-4: UV System Estimated Equipment Supply Costs

Option	Application	UV Feed Flow (ML/d)	Minimum UV Transmittance	UV Dose (mJ/cm2)	Equipment Supply Capital Cost ($AUD 2024)
Lismore IPR via SWA	Primary UV Disinfection	9.3	80%	186	$720,000
Lismore DPR via RWA	Primary UV Disinfection	9.3	80%	186	$720,000
Lismore DPR via TWA	Primary UV Disinfection	5.6	80%	186	$300,000
	Secondary UV Disinfection	5.6	80%	186	$300,000
Byron DPR via TWA	UV/AOP	6.7	95%	>500	$820,000
	Secondary UV Disinfection	6.7	95%	186	$300,000

21.2 CAPITAL COSTS[54]

This section presents capital cost estimates for the AWTPs and associated transfer infrastructure for each of the four short-listed potable reuse schemes. The level of project definition associated with this investigation, with the exception of the Engineered Environmental Buffer Storage associated with the Lismore IPR via surface water augmentation scheme, is considered to be in the range of 1% to 15%. This aligns with an AACE International[55] Class 4 cost estimate [42], which has an expected accuracy range from -30% to +50%. The level of definition for the Engineered Environmental Buffer Storage (0% to 2%) aligns with an AACE International Class 5 cost estimate, which has an expected accuracy range from -50% to +100%.

The following sub-sections present summaries of the estimated capital costs. Full details regarding the derivation and build-up of the cost estimates are provided in Appendix M.

For the purposes of this investigation, no provision for generators has been included in the AWTP or pump station conceptual designs, or in the capital cost estimates. For any option which is progressed, RCC will need to evaluate the criticality of the assets with respect to the operation of the drinking water system, as it relates to supply of PRW from the AWTP, to determine if electricity generation capacity would be required.

21.2.1 Lismore IPR via Surface Water Augmentation

Table 21-5 provides a summary of the estimated costs for the transfer infrastructure for the Lismore IPR via surface water augmentation scheme.

[54] The capital cost estimates presented in this report have been developed based on the information available to Tyr Group (and its subconsultants, henceforth included in references to Tyr Group in this footnote) and on the basis of Tyr Group's experience and qualifications, and represents Tyr Group's judgement as experienced and qualified professional engineers. As Tyr Group has no control over the cost of labour, materials, equipment or services provided by others, nor over the contractor's methods of determining prices or the competitive bidding or market conditions, Tyr Group does not guarantee that actual project costs will not vary from the cost estimate ranges provided.
[55] AACE International is the Association for the Advancement of Cost Engineering

Table 21-5: Lismore IPR via Surface Water Augmentation Transfer Infrastructure Estimated Costs

Asset	Asset Description	Length (m)/ Qty (No.)	Pipe Size (DN)	Material	Installed Pump Station Capacity (kW)	Estimated Capital Cost ($AUD 2024)
Pipeline 1	South Lismore STP to AWTP	50	200	PVC		$18,000
Pipeline 2	East Lismore STP outlet to AWTP at South Lismore	5,550	300	PVC		$3,184,000
Pipeline 3	Return stream from AWTP to South Lismore STP inlet works	50	100	PVC		$10,000
Pipeline 4	PRW to Engineered Environmental Buffer Storage	17,710	375	PVC		$15,041,000
Pipeline 5	Engineered Environmental Buffer Storage to Wilsons River Source Pump Station	4,250	525	DICL		$6,155,000
Pump Station 1	South Lismore STP to AWTP	1			22	$209,000
Pump Station 2	East Lismore STP outlet to AWTP at South Lismore	1			180	$1,136,000
Pump Station 3	PRW to Engineered Environmental Buffer Storage	1			220	$1,136,000
Pump Station 4	Engineered Environmental Buffer Storage to Wilsons River Source Pump Station	1			400	$2,073,000
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit excl. contingency)						**$29,000,000**
Total Contract Cost plus contingency (40%)						**$40,600,000**
RCC costs - survey, investigation, design, construction supervision, contact administration (20%)						**$8,100,000**
Total						**$48,700,000**
Estimated Cost Range						
Estimate Range Low End (Total Cost -30%)						$34,000,000
Estimate Range High End (Total Cost +50%)						$73,000,000

Table 21-6 summarises the estimated costs for AWTP included in the Lismore IPR via surface water augmentation scheme, including the contractor's direct costs, contractor's indirect costs, contractor's overhead and profit and RCC's costs (e.g. design, contract management, etc.). The contractor's direct costs shown in Table 21-6 include a 40% contingency.

Table 21-6: Lismore IPR via Surface Water Augmentation AWTP Estimated Costs Note 1

Item	Estimated Capital Cost ($AUD 2024)
Contractor's Direct Costs	
Preliminaries Note 2 (10% of sum of Direct Costs below)	$6,372,000
Raw Water Balance Tank	$2,510,000
Ozone Contactor Feed Pump Station	$469,000
Ozone Contactor	$581,000
Ozone Generators and Destruction Units	$1,246,000
Ozone Sidestream Pumps	$69,000
Floc Tank	$904,000
BAC and GAC	$12,587,000
UF Feed Tank	$651,000
UF System	$6,079,000
UF Backwash Supply Tank	$651,000
UV System	$960,000
Chlorine Contact Tank	$372,000
Treated Water Tank	$509,000
Waste Buffer Tank	$541,000
Neutralisation Tank	$535,000
Chemical Storage and Dosing	$3,873,000
Buildings	$11,637,000
Electrical and Controls (15% of Direct Costs excluding Preliminaries)	$8,311,000
General Civil (Earthworks, Roads, Landscaping, Fencing, etc.)	$3,513,000
Mechanical Installation (15% of equipment costs)	$3,307,000
Piping (20% of equipment costs)	$4,409,000
Contractor's Direct Costs Subtotal	**$70,086,000**
Contractor's Indirect Costs	
Contractor's Project and Construction Management (9% of Contractor's Direct Costs)	$6,308,000
Construction Staff (13% of Contractor's Direct Costs)	$9,111,000
Defect Attendance (0.5% of Contractor's Direct Costs)	$350,000
Risk and Contingency (10% of Contractor's Direct Costs)	$7,009,000
Contractor's Indirect Costs Subtotal	**$22,778,000**
Contractor Overhead and Profit	
Overhead and Profit (15% of Contractor's Direct plus Indirect Costs)	$13,900,000
Contractor Overhead and Profit Subtotal	**$13,900,000**
Contract Cost	
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit)	**$106,800,000**
RCC Costs	
Design plus Commissioning and Construction Support (13% of Total Contract Cost)	$13,900,000
Project/Contract Management (8% of Total Contract Cost)	$8,500,000
Total Cost	
Total	**$129,200,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$91,000,000
Estimate Range High End (Total Cost +50%)	$194,000,000

Note 1: Renewals costs are not included in the NPC calculations provided in Section 22. If RCC wish to include renewal costs in longer term economic assessments the following are reasonable assumptions:

- Mechanical – 35% of Total Contractor's Direct Cost
- Electrical – 12% of Total Contractor's Direct Cost

- Civil – 45% of Total Contractor's Direct Cost

Note 2: Preliminaries include items such as site establishment and maintenance, project plans, handover documentation, environmental management, erosion and sediment control, gates and fencing, traffic management, etc.

As discussed in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E), cost sensitivity to addition of a second GAC system has been considered in the event that future investigations determine that additional chemical removal capability is required. Addition of a second GAC system would increase the Contractor's Direct Cost Subtotal listed in Table 21-6 by about $8,900,000 and the Total Contract Price by about $16,300,000 (with corresponding increases to the Estimate Range).

RCC have developed a very high-level cost model to provide an indication of potential costs for construction of an environmental buffer storage in the region. As the required size for an Engineered Environmental Buffer Storage cannot be accurately determined at this time, Table 21-7 provides cost estimates, based on RCC's cost model, for two potential storage volumes (0.6 GL and 1.2 GL). As the level of project development with respect to the Engineered Environmental Buffer Storage aligns with an AACE Class 5 cost estimate, the range of costs provided for each option in Table 21-7 represent an expected accuracy range from -50% to +100%.

Table 21-7: Engineered Environmental Buffer Storage Estimated Cost – Based on RCC Cost Model

Option	Volume (GL)	Estimated Capital Cost ($AUD 2024)
Engineered Environmental Buffer Storage Option 1	0.6	**$40,000,000**
Estimate Range Low End (Total Cost -50%)		$20,000,000
Estimate Range High End (Total Cost +100%)		$80,000,000
Engineered Environmental Buffer Storage Option 2	1.2	**$54,000,000**
Estimate Range Low End (Total Cost -50%)		$27,000,000
Estimate Range High End (Total Cost +100%)		$108,000,000

RCC note the following with respect to the estimated costs shown in Table 21-7:

- The costs produced by RCC's cost model can at best be considered as an unreliable Class 5 estimate in terms of the AACE methodology;
- The costs have a baseline assumption of generally favourable conditions for construction;
- The costs do not consider any site-specific factors beyond the general relations associated with capacity, catchment area and surface area (for the specific area examined, which may differ from an actual location determined in the future through further investigation);
- Wall length, construction method, wall height and other key factors are not taken into account in this cost model; and,
- The cost model was developed based on Petheram et.al. [43]. After escalating costs from 2016 dollars to current dollars, a contingency of 30% was applied to estimate the total contract cost. These values were then doubled to estimate the potential total project cost for the construction of the environmental buffer storage.

Table 21-8 summarises the estimated capital costs for the Lismore IPR via surface water augmentation scheme based on an Engineered Environmental Buffer Storage volume of 0.6 GL.

Table 21-8: Lismore IPR via Surface Water Augmentation Cost Estimate Summary – Engineered Environmental Buffer Storage Option 1 Note 1

Item	Estimated Capital Cost ($AUD 2024)
Transfer Infrastructure	$48,700,000
AWTP	$129,200,000
Engineered Environmental Buffer Storage	$40,000,000
Total	**$218,000,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$144,000,000
Estimate Range High End (Total Cost +50%)	$347,000,000

Note 1: Estimate does not include secondary GAC system priced for the cost sensitivity related to chemical risks. Inclusion of this system would increase the total cost to $234,000,000.

Table 21-9 summarises the estimated capital costs for the Lismore IPR via surface water augmentation scheme based on an Engineered Environmental Buffer Storage volume of 1.2 GL.

Table 21-9: Lismore IPR via Surface Water Augmentation Cost Estimate Summary – Engineered Environmental Buffer Storage Option 2 Note 1

Item	Estimated Capital Cost ($AUD 2024)
Transfer Infrastructure	$48,700,000
AWTP	$129,200,000
Engineered Environmental Buffer Storage	$54,000,000
Total	**$232,000,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$151,000,000
Estimate Range High End (Total Cost +50%)	$375,000,000

Note 1: Estimate does not include secondary GAC system priced for the cost sensitivity related to chemical risks. Inclusion of this system would increase the total cost to $248,000,000.

21.2.2 Lismore DPR via Raw Water Augmentation

Table 21-10 summarises the estimated costs for the transfer infrastructure for the Lismore DPR via raw water augmentation scheme.

Table 21-10: Lismore DPR via Raw Water Augmentation Transfer Infrastructure Estimated Costs

Asset	Asset Description	Length (m)/ Qty (No.)	Pipe Size (DN)	Material	Installed Pump Station Capacity (kW)	Estimated Capital Cost ($AUD 2024)
Pipeline 1	South Lismore STP to AWTP	50	200	PVC		$18,000
Pipeline 2	East Lismore STP outlet to AWTP at South Lismore	5,550	300	PVC		$3,184,000
Pipeline 3	Return stream from AWTP to South Lismore STP inlet works	50	150	PVC		$10,000
Pipeline 4	PRW to Wilsons River Source Pump Station	6,250	375	PVC		$5,308,000
Pump Station 1	South Lismore STP to AWTP	1			15	$209,000
Pump Sation 2	East Lismore STP outlet to AWTP at South Lismore	1			180	$1,136,000
Pump Station 3	PRW to Wilsons River Source Pump Station	1			90	$711,000
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit excl. contingency)						**$10,600,000**
Total Contract Cost plus contingency (40%)						**$14,800,000**
RCC costs - survey, investigation, design, construction supervision, contact administration (20%)						**$2,960,000**
Total						**$17,800,000**
Estimated Cost Range						
Estimate Range Low End (Total Cost -30%)						$12,000,000
Estimate Range High End (Total Cost +50%)						$27,000,000

Table 21-11 summarises the estimated costs for AWTP included in the Lismore DPR via raw water augmentation scheme, including the contractor's direct costs, contractor's indirect costs, contractor's overhead and profit and RCC's costs (e.g. design, contract management, etc.). The contractor's direct costs shown in Table 21-11 include a 40% contingency.

Table 21-11: Lismore DPR via Raw Water Augmentation AWTP Estimated Costs Note 1

Item	Estimated Capital Cost ($AUD 2024)
Contractor's Direct Costs	
Preliminaries Note 2 (10% of sum of Direct Costs below)	$6,430,000
Raw Water Balance Tank	$2,510,000
Ozone Contactor Feed Pump Station	$469,000
Ozone Contactor	$581,000
Ozone Generators and Destruction Units	$1,246,000
Ozone Sidestream Pumps	$69,000
Floc Tank	$904,000
BAC and GAC	$12,587,000
UF Feed Tank	$651,000
UF System	$6,079,000
UF Backwash Supply Tank	$651,000
UV System	$960,000
Chlorine Contact Tank	$372,000
Engineered Storage Buffer Tanks	$1,019,000
Waste Buffer Tank	$541,000
Neutralisation Tank	$535,000
Chemical Storage and Dosing	$3,873,000
Buildings	$11,637,000
Electrical and Controls (15% of Direct Costs excluding Preliminaries)	$8,387,000
General Civil (Earthworks, Roads, Landscaping, Fencing, etc.)	$3,513,000
Mechanical Installation (15% of equipment costs)	$3,307,000
Piping (20% of equipment costs)	$4,409,000
Contractor's Direct Costs Subtotal	**$70,730,000**
Contractor's Indirect Costs	
Contractor's Project and Construction Management (9% of Contractor's Direct Costs)	$6,366,000
Construction Staff (13% of Contractor's Direct Costs)	$9,195,000
Defect Attendance (0.5% of Contractor's Direct Costs)	$354,000
Risk and Contingency (10% of Contractor's Direct Costs)	$7,073,000
Contractor's Indirect Costs Subtotal	**$22,988,000**
Contractor Overhead and Profit	
Overhead and Profit (15% of Contractor's Direct plus Indirect Costs)	$14,100,000
Contractor Overhead and Profit Subtotal	**$14,100,000**
Contract Cost	
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit)	**$107,800,000**
RCC Costs	
Design plus Commissioning and Construction Support (13% of Total Contract Cost)	$14,000,000
Project/Contract Management (8% of Total Contract Cost)	$8,600,000
Total Cost	
Total	**$130,400,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$91,000,000
Estimate Range High End (Total Cost +50%)	$196,000,000

Note 1: Renewals costs are not included in the NPC calculations provided in Section 22. If RCC wish to include renewal costs in longer term economic assessments the following are reasonable assumptions:

- Mechanical – 35% of Total Contractor's Direct Cost
- Electrical – 12% of Total Contractor's Direct Cost
- Civil – 45% of Total Contractor's Direct Cost

Note 2: Preliminaries include items such as site establishment and maintenance, project plans, handover documentation, environmental management, erosion and sediment control, gates and fencing, traffic management, etc.

As discussed in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E), cost sensitivity to addition of a second GAC system has been considered in the event that future investigations determine that additional chemical removal capability is required. Addition of a second GAC system would increase the Contractor's Direct Cost Subtotal listed in Table 21-11 by about $8,900,000 and the Total Contract Price by about $16,300,000 (with corresponding increases to the Estimate Range).

Table 21-12 summarises the estimated capital costs for the Lismore DPR via raw water augmentation scheme.

Table 21-12: Lismore DPR via Raw Water Augmentation Cost Estimate Summary Note 1

Item	Estimated Capital Cost ($AUD 2024)
Transfer Infrastructure	$17,800,000
AWTP	$130,400,000
Total	**$148,000,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$103,000,000
Estimate Range High End (Total Cost +50%)	$223,000,000

Note 1: Estimate does not include secondary GAC system priced for the cost sensitivity related to chemical risks. Inclusion of this system would increase the total cost to $164,000,000.

21.2.3 Lismore DPR via Treated Water Augmentation

Table 21-13 summarises the estimated costs for the transfer infrastructure for the Lismore DPR via treated water augmentation scheme.

Table 21-13: Lismore DPR via Treated Water Augmentation Transfer Infrastructure Estimated Costs

Asset	Asset Description	Length (m)/ Qty (No.)	Pipe Size (DN)	Material	Installed Pump Station Capacity (kW)	Estimated Capital Cost ($AUD 2024)
Pipeline 1	East Lismore STP outlet to AWTP at East Lismore	1,530	300	PVC		$878,000
Pipeline 2	Return stream from AWTP to East Lismore STP inlet works	1,530	100	PVC		$406,000
Pipeline 3	PRW to City View Reservoir offtake	810	600	DICL		$1,396,000
Pipeline 4	PRW into City View Reservoir	10	300	PVC		$6,000
Pipeline 5	PRW from City View Reservoir offtake to Belvedere Drive Reservoir offtake	350	500	DICL		$507,000
Pipeline 6	PRW into Belvedere Drive Reservoir	250	300	PVC		$143,000
Pipeline 7	PRW from Belvedere Drive Reservoir offtake to location of split between High Street Reservoir and Ross Street Reservoir	1,750	450	DICL		$2,052,000
Pipeline 8	PRW into Ross Street Reservoir	1,250	200	PVC		$458,000

Table 21-13: Lismore DPR via Treated Water Augmentation Transfer Infrastructure Estimated Costs (continued)

Asset	Asset Description	Length (m)/ Qty (No.)	Pipe Size (DN)	Material	Installed Pump Station Capacity (kW)	Estimated Capital Cost ($AUD 2024)
Pipeline 9	PRW into High Street Reservoir	1,750	375	PVC		$1,486,000
Pump Station 1	East Lismore STP outlet to AWTP at East Lismore	1			150	$1,011,000
Pump Station 2	PRW to City View Reservoir offtake	1			1,400	$6,591,000
	PRW into City View Reservoir					
	PRW from City View Reservoir offtake to Belvedere Drive Reservoir offtake					
	PRW into Belvedere Drive Reservoir					
	PRW from Belvedere Drive Reservoir offtake to Ross Street/High Street split					
Pump Station 3	PRW into Ross Street Reservoir (from split)	1			180	$7,111,000
PRW Storage	3 ML PRW Reservoir at AWTP Site	1				$2,136,000
Flow Control	Allowance for flow meters and flow control valves at each PRW discharge to existing reservoirs	4				$800,000
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit excl. contingency)						**$18,600,000**
Total Contract Cost plus contingency (40%)						**$26,600,000**
RCC costs - survey, investigation, design, construction supervision, contact administration (20%)						**$5,200,000**
Total						**$31,200,000**
Estimated Cost Range						
Estimate Range Low End (Total Cost -30%)						$22,000,000
Estimate Range High End (Total Cost +50%)						$47,000,000

Table 21-14 summarises the estimated costs for AWTP included in the Lismore DPR via treated water augmentation scheme, including the contractor's direct costs, contractor's indirect costs, contractor's overhead and profit and RCC's costs (e.g. design, contract management, etc.). The contractor's direct costs shown in Table 21-14 include a 40% contingency.

Table 21-14: Lismore DPR via Treated Water Augmentation AWTP Estimated Costs Note 1

Item	Estimated Capital Cost ($AUD 2024)
Contractor's Direct Costs	
Preliminaries Note 2 (10% of sum of Direct Costs below)	$5,137,000
Raw Water Balance Tank	$1,726,000
Ozone Contactor Feed Pump Station	$374,000
Ozone Contactor	$401,000
Ozone Generators and Destruction Units	$1,022,000
Ozone Sidestream Pumps	$45,000
Floc Tank	$649,000
BAC and GAC	$8,014,000
UF Feed Tank	$465,000
UF System	$4,595,000
UF Backwash Supply Tank	$465,000
UV System	$960,000
Chlorine Contact Tank	$310,000
PRW Pumps	$66,000
Engineered Storage Buffer Tanks	$761,000
Waste Buffer Tank	$479,000
Neutralisation Tank	$535,000
Chemical Storage and Dosing	$3,873,000
Buildings	$11,637,000
Electrical and Controls (15% of Direct Costs excluding Preliminaries)	$6,700,000
General Civil (Earthworks, Roads, Landscaping, Fencing, etc.)	$2,813,000
Mechanical Installation (15% of equipment costs)	$2,348,000
Piping (20% of equipment costs)	$3,130,000
Contractor's Direct Costs Subtotal	**$56,507,000**
Contractor's Indirect Costs	
Contractor's Project and Construction Management (9% of Contractor's Direct Costs)	$5,086,000
Construction Staff (13% of Contractor's Direct Costs)	$7,346,000
Defect Attendance (0.5% of Contractor's Direct Costs)	$283,000
Risk and Contingency (10% of Contractor's Direct Costs)	$5,651,000
Contractor's Indirect Costs Subtotal	**$18,366,000**
Contractor Overhead and Profit	
Overhead and Profit (15% of Contractor's Direct plus Indirect Costs)	$11,200,000
Contractor Overhead and Profit Subtotal	**$11,200,000**
Contract Cost	
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit)	**$86,100,000**
RCC Costs	
Design plus Commissioning and Construction Support (13% of Total Contract Cost)	$11,200,000
Project/Contract Management (8% of Total Contract Cost)	$6,900,000
Total Cost	
Total	**$104,200,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$73,000,000
Estimate Range High End (Total Cost +50%)	$156,000,000

Note 1: Renewals costs are not included in the NPC calculations provided in Section 22. If RCC wish to include renewal costs in longer term economic assessments the following are reasonable assumptions:

- Mechanical – 32% of Total Contractor's Direct Cost
- Electrical – 12% of Total Contractor's Direct Cost

- Civil – 47% of Total Contractor's Direct Cost

Note 2: Preliminaries include items such as site establishment and maintenance, project plans, handover documentation, environmental management, erosion and sediment control, gates and fencing, traffic management, etc.

As discussed in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E), cost sensitivity to addition of a second GAC system has been considered in the event that future investigations determine that additional chemical removal capability is required. Addition of a second GAC system would increase the Contractor's Direct Cost Subtotal listed in Table 21-14 by about $4,400,000 and the Total Contract Price by about $8,100,000 (with corresponding increases to the Estimate Range).

As discussed in Section 10.3.2, a sensitivity case with respect to additional pathogen reduction has also been examined. A secondary UV system providing 4 LRV for all reference pathogens would increase the Contractor's Direct Cost Subtotal listed in Table 21-14 by about $1,600,000 and the Total Contract Price by about $3,000,000 (with corresponding increases to the Estimate Range).

Table 21-15 summarises the estimated capital costs for the Lismore DPR via treated water augmentation scheme.

Table 21-15: Lismore DPR via Treated Water Augmentation Cost Estimate Summary Note 1, 2

Item	Estimated Capital Cost ($AUD 2024)
Transfer Infrastructure	$31,200,000
AWTP	$103,300,000
Total	**$135,000,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$94,000,000
Estimate Range High End (Total Cost +50%)	$203,000,000

Note 1: Estimate does not include secondary GAC system priced for the cost sensitivity related to chemical risks. Inclusion of this system would increase the total cost to $143,000,000.

Note 2: Estimate does not include secondary UV system priced for the cost sensitivity related to pathogen reduction. Inclusion of this system would increase the total cost to $138,000,000.

21.2.4 Byron DPR via Treated Water Augmentation

Table 21-16 summarises the estimated costs for the transfer infrastructure for the Byron DPR via treated water augmentation scheme.

Table 21-16: Byron DPR via Treated Water Augmentation Transfer Infrastructure Estimated Costs

Asset	Asset Description	Length (m)/ Qty (No.)	Pipe Size (DN)	Material	Installed Pump Station Capacity (kW)	Estimated Capital Cost ($AUD 2024)
Pipeline 1	Brunswick Valley STP outlet to AWTP	17,405	200	PVC		$6,379,000
Pipeline 2	Bryon STP and wetlands to AWTP	1,500	300	PVC		$861,000
Pipeline 3	Return stream from AWTP to East Lismore STP inlet works	1,800	100	PVC		$350,000
Pipeline 4	RO Concentrate to Belongil Creek Estuary (along Ewingsdale Road)	1,800	150	PVC		$478,000
Pipeline 5	PRW to St Helena Reservoir offtake	4,725	450	DICL		$5,542,000

Table 21-16: Byron DPR via Treated Water Augmentation Transfer Infrastructure Estimated Costs (continued)

Asset	Asset Description	Length (m)/ Qty (No.)	Pipe Size (DN)	Material	Installed Pump Station Capacity (kW)	Estimated Capital Cost ($AUD 2024)
Pipeline 6	PRW into St Helena Reservoir	10	300	PVC		$6,000
Pipeline 7	PRW from St Helena Reservoir offtake to the new Blending Reservoir	4,500	375	PVC		$3,822,000
Pump Station 1	Brunswick Valley STP outlet to AWTP	3			60	$1,454,000
Pump Station 2	Bryon STP and wetlands to AWTP	2			110	$1,683,000
Pump Station 3	RO Concentrate to Belongil Creek Estuary	1			11	$188,000
Pump Station 4	PRW to St Helena Reservoir offtake PRW into St Helena Reservoir PRW from St Helena Reservoir offtake to the new Blending Reservoir	1			750	$3,251,000
Pump Station 5	Blended water from new Blending Reservoir	1			500	$2,202,000
Effluent Storage	0.5 ML for Transfer Stations	2				$1,694,000
PRW Storage	750 kL PRW Reservoir at AWTP Site	1				$1,057,000
PRW Storage	3 ML PRW Reservoir at AWTP Site	1				$2,136,000
Flow Control	Allowance for flow meters and flow control valves at the PRW discharge to St Helena Reservoir and to the new Blending Reservoir	2				$400,000
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit excl. contingency)						**$31,500,000**
Total Contract Cost plus contingency (40%)						**$44,100,000**
RCC costs - survey, investigation, design, construction supervision, contact administration (20%)						**$8,820,000**
Total						**$52,900,000**
Estimated Cost Range						
Estimate Range Low End (Total Cost -30%)						$37,000,000
Estimate Range High End (Total Cost +50%)						$79,000,000

Table 21-17 provides a summary of the estimated costs for AWTP included in the Byron DPR via treated water augmentation scheme, including the contractor's direct costs, contractor's indirect costs, contractor's overhead and profit and RCC's costs (e.g. design, contract management, etc.). The contractor's direct costs shown in Table 21-17 include a 40% contingency.

Table 21-17: Byron DPR via Treated Water Augmentation AWTP Estimated Costs Note 1

Item	Estimated Capital Cost ($AUD 2024)
Contractor's Direct Costs	
Preliminaries Note 2 (10% of sum of Direct Costs below)	$6,432,000
Raw Water Balance Tank	$2,272,000
UF System	$5,554,000
UF Backwash Supply Tank	$603,000
RO Feed Tank	$555,000
RO System	$5,340,000
RO Flush Tank	$555,000
UV/AOP System	$1,240,000
Secondary UV System	$540,000
Chlorine Contact Tank	$318,000
Calcite Filter Feed Pumps	$94,000
Calcite Filters	$3,960,000
Calcite Backwash Pumps	$94,000
PRW Pumps	$66,000
Engineered Buffer Storage Tank	$844,000
Waste Buffer Tank and Pumps	$543,000
Neutralisation Tank	$535,000
Nitrification MBBR	$664,000
Denitrification MBBR	$531,000
Lamella Clarifiers	$1,096,000
Lamella Flash Mixer	$46,000
Lamella Floc Tank	$221,000
Chemical Storage and Dosing	$4,564,000
Buildings	$15,204,000
Electrical and Controls (15% of Direct Costs excluding Preliminaries)	$8,390,000
General Civil (Earthworks, Roads, Landscaping, Fencing, etc.)	$4,177,000
Mechanical Installation (15% of equipment costs)	$2,708,000
Piping (20% of equipment costs)	$3,611,000
Contractor's Direct Costs Subtotal	**$70,758,000**
Contractor's Indirect Costs	
Contractor's Project and Construction Management (9% of Contractor's Direct Costs)	$6,368,000
Construction Staff (13% of Contractor's Direct Costs)	$9,199,000
Defect Attendance (0.5% of Contractor's Direct Costs)	$354,000
Risk and Contingency (10% of Contractor's Direct Costs)	$7,076,000
Contractor's Indirect Costs Subtotal	**$22,997,000**
Contractor Overhead and Profit	
Overhead and Profit (15% of Contractor's Direct plus Indirect Costs)	$14,100,000
Contractor Overhead and Profit Subtotal	**$14,100,000**
Contract Cost	
Total Contract Cost (Contractor Direct Cost, Indirect Cost and Overhead and Profit)	**$107,900,000**
RCC Costs	
Design plus Commissioning and Construction Support (13% of Total Contract Cost)	$14,000,000
Project/Contract Management (8% of Total Contract Cost)	$8,600,000

Table 21-17: Byron DPR via Treated Water Augmentation AWTP Estimated Costs Note 1 (continued)

Item	Estimated Capital Cost ($AUD 2024)
Total Cost	
Total	**$130,600,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$91,000,000
Estimate Range High End (Total Cost +50%)	$196,000,000

Note 1: Renewals costs are not included in the NPC calculations provided in Section 22. If RCC wish to include renewal costs in longer term economic assessments the following are reasonable assumptions:

- Mechanical – 30% of Total Contractor's Direct Cost
- Electrical – 12% of Total Contractor's Direct Cost
- Civil – 50% of Total Contractor's Direct Cost

Note 2: Preliminaries include items such as site establishment and maintenance, project plans, handover documentation, environmental management, erosion and sediment control, gates and fencing, traffic management, etc.

As discussed in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E), cost sensitivity to addition of a second GAC system has been considered in the event that future investigations determine that additional chemical removal capability is required. Addition of a second GAC system would increase the Contractor's Direct Cost Subtotal listed in Table 21-17 by about $5,400,000 and the Total Contract Price by about $9,800,000 (with corresponding increases to the Estimate Range).

Table 21-18 summarises the estimated capital costs for the Byron DPR via treated water augmentation scheme.

Table 21-18: Byron DPR via Treated Water Augmentation Cost Estimate Summary Note 1

Item	Estimated Capital Cost ($AUD 2024)
Transfer Infrastructure	$52,900,000
AWTP	$130,600,000
Total	**$184,000,000**
Estimated Cost Range	
Estimate Range Low End (Total Cost -30%)	$128,000,000
Estimate Range High End (Total Cost +50%)	$276,000,000

Note 1: Estimate does not include secondary GAC system priced for the cost sensitivity related to chemical risks. Inclusion of this system would increase the total cost to $195,000,000.

21.2.5 Summary of Estimated Capital Costs

Table 21-19 summarises the total cost estimates for each of the short-listed scheme options, as described in sections 21.2.1 through 21.2.4. The costs shown in Table 21-19 do not include any of the sensitivity cases. The additional costs required for the further investigations described in Section 19 (consideration for these costs is included in Section 22).

Table 21-19: Capital Cost Estimate Summary

Scheme	Transfer Estimated Capital Cost ($AUD 2024)	AWTP Estimated Capital Cost ($AUD 2024)	Engineered Environmental Buffer Storage Estimated Capital Cost ($AUD 2024)	Total Estimated Capital Cost ($AUD 2024)	Daily PRW Produced (ML)	Specific Estimated Capital Cost ($AUD 2024)
Lismore IPR via Surface Water Augmentation – 0.6 GL Buffer Storage	$48.7m	$129.2m	$40m	$218m	9.1	$24.0m per ML/d
Lismore IPR via Surface Water Augmentation – 1.2 GL Buffer Storage	$48.7m	$129.2m	$54m	$232m	9.1	$25.5m per ML/d
Lismore DPR via Raw Water Augmentation	$17.8m	$130.4m	N/A	$148m	9.1	**$16.3m per ML/d**
Lismore DPR via Treated Water Augmentation	$31.2m	$104.2m	N/A	**$135m**	5.4	$25.0m per ML/d
Byron DPR via Treated Water Augmentation	$52.9m	$130.6m	N/A	$184m	6.7	$27.5m per ML/d

Table 21-19 shows that the Lismore DPR via treated water augmentation scheme has the lowest estimated capital cost. However, this scheme provides about 60% of the PRW production capacity of the other Lismore scheme options. The Lismore DPR via raw water augmentation scheme appears to have the lowest specific capital cost of $16.3m per ML/d of PRW production capacity. The specific cost of the Lismore DPR via raw water augmentation scheme is about 35% lower than the other Lismore based schemes (on average) and about 40% lower than the Byron DPR scheme.

Table 21-20 summarises the capital cost impacts of the sensitivity cases considered for each short-listed option.

Table 21-20: Summary of Sensitivity Case Cost Impacts

Scheme	Item	Sensitivity	Estimated Capital Cost Increase ($AUD 2024)
Lismore IPR via Surface Water Augmentation	Secondary GAC	Chemical	$16.3m
Lismore DPR via Raw Water Augmentation	Secondary GAC	Chemical	$16.3m
Lismore DPR via Treated Water Augmentation	Secondary GAC	Chemical	$8.1m
	Secondary UV	Pathogen	$3.0m
Byron DPR via Treated Water Augmentation	GAC	Chemical	$9.8m

21.3 Estimated Operation and Maintenance Costs

Operation and maintenance costs are expected to include, but not be limited to:

- Electricity;
- Chemicals;
- Sampling;

- Maintenance; and,
- Labour (staff).

The sections 21.3.1 through 21.3.5 summarise the estimated costs for these items.

21.3.1 Electricity

Electricity use for transfer infrastructure for each short-listed option is summarised in sections 21.3.1.1 through 21.3.1.4. Electricity use related to each AWTP is summarised in sections 21.3.1.5 through 21.3.1.8. Electricity costs are based on a unit rate of $0.15/kWh.

21.3.1.1 Lismore IPR via Surface Water Augmentation – Transfer Infrastructure

Table 21-21 summarises the estimated electricity cost for the transfer infrastructure associated with the Lismore IPR via surface water augmentation scheme option. Operating flows shown in Table 21-21 are based on:

- Average daily STP effluent flow;
- Average return stream flows from the AWTP to South Lismore STP with the AWTP operating at its design production rate;
- PRW flow to and from the Engineered Environmental Buffer Storage at the AWTP daily production rate; and
- PRW flow from the Wilsons River Source Pump Station to Nightcap WTP at the AWTP daily production rate (actual flows in this line may be higher if Wilsons River water is pumped simultaneously – the approach used here is to account for only the portion of electricity used to pump the PRW to Nightcap WTP).

An efficiency of 80% has been assumed for all pump stations.

Table 21-21: Lismore IPR via Surface Water Augmentation – Transfer Infrastructure Electricity Cost

Asset	Description	Average Daily Operating Flow (L/s)	Total Head at Operating Flow (m)	Motor Power Required (kW)	Time at Operating Flow (h)	Average Electricity Use (kWh/d)	Estimated Annual Operating Cost ($AUD 2024 p.a.)
Pump Station 1 Note 1	South Lismore STP to AWTP	49	8	5	24	19	$6507
Pump Station 2	East Lismore STP to AWTP	75	23	21	24	504	$27,567
Pump Station 3	PRW to Engineered Environmental Buffer Storage	105	39	50	24	1,210	$66,264

Table 21-21: Lismore IPR via Surface Water Augmentation – Transfer Infrastructure Electricity Cost (continued)

Asset	Description	Average Daily Operating Flow (L/s)	Total Head at Operating Flow (m)	Motor Power Required (kW)	Time at Operating Flow (h)	Average Electricity Use (kWh/d)	Estimated Annual Operating Cost ($AUD 2024 p.a.)
Pump Station 4	Engineered Environmental Buffer Storage to Wilsons River Source Pump Station	105	15	19	24	465	$25,456
Existing	Wilsons River Pump Station to Nightcap WTP	105	212	273	24	6,547	$358,466
					Total	**8,845**	**$484,300**

Note 1: This flow is the sum of South Lismore STP 2040 ADWF (2.6 ML/d = 30 L/s) plus AWTP return flows (1.64 ML/d = 19 L/s)

The majority of the total cost in Table 21-21 is related to Wilsons River Source Pump Station, due to the high static head between the pump station and Nightcap WTP (~178 m).

21.3.1.2 Lismore DPR via Raw Water Augmentation – Transfer Infrastructure

Table 21-22 summarises the estimated electricity cost for the transfer infrastructure associated with the Lismore DPR via raw water augmentation scheme. Operating flows shown in Table 21-22 are based on:

- Average daily STP effluent flow;
- Average return stream flows from the AWTP to South Lismore STP with the AWTP operating at its design production rate;
- PRW flow to Wilsons River Source Pump Station at the AWTP daily production rate; and
- PRW flow from the Wilsons River Source Pump Station to Nightcap WTP at the AWTP daily production rate (actual flows in this line may be higher if Wilsons River water is pumped simultaneously – the approach used here is to account for only the portion of electricity used to pump the PRW to Nightcap WTP).

An efficiency of 80% has been assumed for all pump stations.

Table 21-22: Lismore DPR via Raw Water Augmentation – Transfer Infrastructure Electricity Cost

Asset	Description	Average Daily Operating Flow (L/s)	Total Head at Operating Flow (m)	Motor Power Required (kW)	Time at Operating Flow (h)	Average Electricity Use (kWh/d)	Estimated Annual Operating Cost ($AUD 2024 p.a.)
Pump Station 1 Note 1	South Lismore STP to AWTP	49	8	5	24	119	$6,507
Pump Station 2	East Lismore STP to AWTP	75	23	21	24	504	$27,567
Pump Station 3	PRW to Wilsons River Source Pump Station	105	19	25	24	597	$32,662
Existing	Wilsons River Pump Station to Nightcap WTP	105	212	273	24	6,547	$358,466
					Total	**7,766**	**$425,200**

Note 1: This flow is the sum of South Lismore STP 2040 ADWF (2.6 ML/d = 30 L/s) plus AWTP return flows (1.64 ML/d = 19 L/s)

As for the Lismore IPR via surface water augmentation scheme option, the majority of the total cost in Table 21-22 is related to Wilsons River Source Pump Station, due to the high static head between the pump station and Nightcap WTP (~178 m).

21.3.1.3 Lismore DPR via Treated Water Augmentation – Transfer Infrastructure

For the Lismore DPR via treated water augmentation scheme option, it is assumed that flow into the reservoirs:

- Would be undertaken with PRW contributing 50% of the current peak inflow rate to the reservoirs to match the blend ratio assumed in this investigation; and
- Commences with flow to for all four reservoirs simultaneously, with flow reducing when the total 2040 average day demand for each reservoir has been delivered.

Table 21-23 summarises the 2040 average daily demand, current peak inflow rates and time required to deliver the daily demand.

Table 21-23: 2040 Average Daily Demand, Reservoir Inflow Rates and Time to Deliver Required Volume

Reservoir	2040 Average Daily Demand (ML)	PRW Contribution to Daily Demand (ML)	Existing Network Contribution to Daily Demand (ML)	Reservoir Peak Inflow Rate (L/s)	PRW Rate (L/s)	Time Required to Deliver 2040 Average Daily Demand (h)
City View	2.98	1.49	1.49	200	100	4
Belvedere	2.98	1.49	1.49	165	83	5
High Street	1.47	0.74	0.74	400	200	1
Ross Street	3.40	1.70	1.70	90	45	10
Total	10.83	5.42	5.42	855	428	10

Table 21-24 summarises the sequence of PRW flows and the time required at each flow rate. Flows and times assume that flow to all reservoirs starts at the same time, with the PRW flowrate reducing in sequence as filling of each reservoir is completed.

Table 21-24: PRW Flow Sequence and Time

Case	PRW Flow (L/s)	Time (h)	Comment
1	428	1	Flow to High Street stops after this time elapses
2	228	3	Flow to City View stops after this time elapses
3	128	1	Flow to Belvedere stops after this time elapses
4	45	5	Flow to Ross Street stops after this time elapses

Table 21-25 summarises the estimated electricity cost for the transfer infrastructure associated with the Lismore DPR via treated water augmentation scheme option. Operating flows shown in Table 21-25 are based on:

- Average daily STP effluent flow;
- Average return stream flows from the AWTP to East Lismore STP with the AWTP operating at its design production rate; and,
- PRW flow rates and durations as per Table 21-24.

An efficiency of 80% has been assumed for all pump stations.

Table 21-25: Lismore DPR via Treated Water Augmentation – Transfer Infrastructure Electricity Cost

Asset	Description	Average Daily Operating Flow (L/s)	Total Head at Operating Flow (m)	Motor Power Required (kW)	Time at Operating Flow (h)	Average Electricity Use (kWh/d)	Estimated Annual Operating Cost ($AUD 2024 p.a.)
Pump Station 1 Note 1	East Lismore STP to AWTP	75	9	8	24	188	$10,302
Pump Station 2	PRW to all four reservoirs	428	109	571	1	583	$31,907
	PRW to City View, Belvedere and Ross Street reservoirs	228	89	249	3	776	$42,466
	PRW to Belvedere and Ross Street reservoirs	128	84	131	1	115	$6,306
	PRW to Ross Street reservoir	45	82	45	5	247	$13,535
Pump Station 3	PRW to Ross St (from split)	45	81	45	10	468	$25,617
					Total	**2,377**	**$130,100**

Note 1: This flow is the sum of East Lismore STP effluent (derived from raw sewage) plus AWTP return flows, limited to a total of 6.5 ML/d to maintain a PRW blend ratio of 50%.

21.3.1.4 Byron DPR via Treated Water Augmentation – Transfer Infrastructure

For the Byron DPR via treated water augmentation scheme option, it is assumed that flow into the reservoirs:

- Would be undertaken with PRW contributing 30% of the current peak inflow rate to the reservoirs to match the blend ratio determined in this investigation (based on available STP flow in 2040); and
- Commences flow to both reservoirs simultaneously, with flow reducing when the total 2040 average day demand for St Helena Reservoir has been delivered.

Table 21-26 summarises the 2040 average daily demand, current peak inflow rates and time required to deliver the daily demand.

Table 21-26: 2040 Average Daily Demand, Reservoir Inflow Rates and Time to Deliver Required Volume

Reservoir	2040 Average Daily Demand (ML)	PRW Contribution to Daily Demand (ML)	Existing Network Contribution to Daily Demand (ML)	Reservoir Peak Inflow Rate (L/s)	PRW Rate (L/s)	Time Required to Deliver 2040 Average Daily Demand (h)
St Helena	8.95	2.70	6.25	200	60	12
Knockrow	13.2	3.98	9.22	200	60	18
Total	22.2	6.7	15.5	400	121	18

Table 21-27 summarises the sequence of PRW flows and the time required at each flow rate. Flows and times assume that flow to all reservoirs starts at the same time.

Table 21-27: PRW Flow Sequence and Time

Case	PRW Flow (L/s)	Time (h)	Comment
1	400	12	Flow to St Helena stops after this time elapses
2	200	6	Flow to Knockrow (via new Blending Reservoir) stops after this time elapses

Table 21-28 summarises the estimated electricity cost for the transfer infrastructure associated with the Byron DPR via treated water augmentation scheme. Operating flows shown in Table 21-28 are based on:

- Average daily STP effluent flow;
- Average return stream flows from the AWTP to Byron STP with the AWTP operating at its design production rate; and,
- PRW flow rates and durations as per Table 21-27.

An efficiency of 80% has been assumed for all pump stations.

Table 21-28: Byron DPR via Treated Water Augmentation – Transfer Infrastructure Electricity Cost

Asset	Description	Average Daily Operating Flow (L/s)	Total Head at Operating Flow (m)	Motor Power Required (kW)	Time at Operating Flow (h)	Average Electricity Use (kWh/d)	Estimated Annual Operating Cost ($AUD 2024 p.a.)
Pump Station 1 Note 1	Brunswick Valley STP to AWTP	20	40	10	24	714	$39,079
Pump Station 2 Note 2	Byron STP to AWTP	88	8	8	24	200	$10,926
Pump Station 3	RO Concentrate to discharge at Belongil Creek Estuary	19	17	4	24	97	$5,327
Pump Station 4	PRW to St Helena Reservoir and Blending Reservoir – both filling	121	118	175	12.4	2,173	$118,963
	PRW to Blending Reservoir only	60	113	83	5.9	492	$26,961
Pump Station 5	Blended water from Blending Reservoir to Knockrow Reservoir	200 Note 3	88	216	18.3	3,957	$216,629
					Total	**7,633**	**$417,900**

Note 1: This power requirement is for the sum of the three pump stations along the pipeline at the Brunswick Valley STP 2040 ADWF of 1.75 ML/d.

Note 2: This flow is the sum of Byron STP 2040 ADWF (6.6 ML/d = 76 L/s) plus AWTP return flows (1.0 ML/d = 12 L/s)

Note 3: The conceptual design is based on blending PRW with Nightcap WTP treated water, then pumping to Knockrow Reservoir via a new pump station. This approach has been adopted to manage risks to customers drawing flow directly from the transfer main, but substantially increases the electricity consumption of this scheme option. On this basis, alternative approaches (e.g. an additional blending reservoir or blending at Knockrow, in combination with alternative supply to customers drawing directly from the main) should be considered if this option is progressed.

21.3.1.5 Lismore IPR via Surface Water Augmentation - AWTP

Table 21-29 shows the estimated AWTP electricity use and associated annual cost for the Lismore IPR via surface water augmentation scheme option.

Table 21-29: Lismore IPR via Surface Water Augmentation – AWTP Electricity Cost

Item	Power During Operation (kW)	Operation (h/d)	Average Daily Electricity Use (kWh/d)	Comments
Raw Water Balance Tank Mixing	11	24	264	Refer to process schedule
Ozone Contactor Feed Pump	6.9	24	166	Refer to process schedule
Strainer	1.1	1.2	1	Based on three strainers, each with 1/2 HP motor - backwash for 30 seconds every 30 minutes for each strainer
Ozone Generator	41	24	984	Refer to process schedule
Ozone Destruct Unit	5.1	24	122	Refer to process schedule
Ozone Sidestream Pump	6.3	24	151	Refer to process schedule
Flash Mixer	1.5	24	36	Refer to process schedule
BAC Feed Pump	7.8	24	188	Refer to process schedule
BAC Backwash Pump	18.7	2.68	50	Assumes each BAC filter backwashes once per week, backwash pump runs for 10 minutes per backwash
BAC Blower	15.9	1.14	18	Assumes each BAC filter backwashes once per week, blower pump runs for 5 minutes per backwash
GAC Backwash Pump	13.1	1.56	20	Assumes each GAC vessel backwashes once per month, backwash pump runs for 15 minutes per backwash
Strainer	1.1	1.2	1	Based on three strainers, each with 1/2 HP motor - backwash for 30 seconds every 30 minutes for each strainer
UF System			2,060	Based on 0.2 kWh/kL as advised by vendor
UV Disinfection	29.7	24	713	Based on advice from vendor
Ozone Cooling Water Pumps	0.1	24	3	Refer to process schedule
Waste Buffer Tank Pump	5.1	14.9	77	Based on transferring average daily waste flow (refer to flow balance) at a rate of required to empty tank in two hours

Table 21-29: Lismore IPR via Surface Water Augmentation – AWTP Electricity Cost (continued)

Item	Power During Operation (kW)	Operation (h/d)	Average Daily Electricity Use (kWh/d)	Comments
Neutralisation Pump	15	1.03	16	Assumes two duty UF units performing one maintenance wash per day and two CIP (one acid, one hypo) every 30 days - 30 minute neutralisation cycle assumed
Dosing pumps	2	24	48	Allowance
Polymer makeup system	2	24	48	Allowance
Equipment Load Subtotal				**4,966 kWh/d**
Base Load (Lighting, control system, security system, fire alarm, etc. - assumed to be 20% of the equipment load subtotal)				**993 kWh/d**
Total Estimated Electricity Consumption				**5,960 kWh/d**
Estimated Annual Operating Cost ($AUD 2024 p.a.)				**$326,300**
Specific Energy Use (based on production of 9.1 ML/d of PRW)				**0.65 kWh per kL PRW produced**
Specific Cost				**$0.10/kL**

21.3.1.6 Lismore DPR via Raw Water Augmentation – AWTP

The AWTP for the Lismore DPR via raw water augmentation is the same as the AWTP for the Lismore IPR via surface water augmentation scheme, with the exception of the use of Engineered Storage Buffer Tanks (instead of the single Treated Water Tank for the IPR AWTP). Hence, the electricity costs for the indirect potable reuse AWTP shown in Table 21-29 also apply to the DPR via raw water augmentation scheme.

21.3.1.7 Lismore DPR via Treated Water Augmentation – AWTP

Table 21-30 shows the estimated AWTP electricity use and associated annual cost for the Lismore DPR via treated water augmentation scheme option.

Table 21-30: Lismore DPR via Treated Water Augmentation – AWTP Electricity Cost

Item	Power During Operation (kW)	Operation (h/d)	Average Daily Electricity Use (kWh/d)	Comments
Raw Water Balance Tank Mixing	6	24	144	Refer to process schedule
Ozone Contactor Feed Pump	4.1	24	99	Refer to process schedule
Strainer	1.1	1.2	1	Based on three strainers, each with 1/2 HP motor - backwash for 30 seconds every 30 minutes for each strainer
Ozone Generator	25.8	24	619	Refer to process schedule
Ozone Destruct Unit	3.8	24	91	Refer to process schedule
Ozone Sidestream Pump	3.8	24	90	Refer to process schedule
Flash Mixer	1.1	24	26	Refer to process schedule
BAC Feed Pump	4.7	24	113	Refer to process schedule

Table 21-30: Lismore DPR via Treated Water Augmentation – AWTP Electricity Cost (continued)

Item	Power During Operation (kW)	Operation (h/d)	Average Daily Electricity Use (kWh/d)	Comments
BAC Backwash Pump	13.8	1.97	27	Assumes each BAC filter backwashes once per week, backwash pump runs for 10 minutes per backwash
BAC Blower	11.7	0.83	10	Assumes each BAC filter backwashes once per week, blower pump runs for 5 minutes per backwash
GAC Backwash Pump	9.6	1.15	11	Assumes each GAC vessel backwashes once per month, backwash pump runs for 15 minutes per backwash
Strainer	1.1	1.2	1	Based on three strainers, each with 1/2 HP motor - backwash for 30 seconds every 30 minutes for each strainer
UF System			1,237	Based on 0.2 kWh/kL as advised by vendor
UV Disinfection	17.8	24	428	Based on advice from vendor
Ozone Cooling Water Pumps	0.4	24	10	Refer to process schedule
PRW Pumps	4.6	24	110	Refer to process schedule
Waste Buffer Tank Pump	2.6	16.1	42	Based on transferring average daily waste flow (refer to flow balance) at a rate of required to empty tank in two hours
Neutralisation Pump	15	1.03	16	Assumes two duty UF units performing one maintenance wash per day and two CIP (one acid, one hypo) every 30 days - 30 minute neutralisation cycle assumed
Dosing pumps	2	24	48	Allowance
Polymer makeup system	2	24	48	Allowance
Equipment Load Subtotal				**3,165 kWh/d**
Base Load (Lighting, control system, security system, fire alarm, etc. - assumed to be 20% of the equipment load subtotal)				**633 kWh/d**
Total Estimated Electricity Consumption				**3,798 kWh/d**
Estimated Annual Operating Cost ($AUD 2024 p.a.)				**$207,900**
Specific Energy Use (based on production of 5.4 ML/d of PRW)				**0.70 kWh per kL PRW produced**
Specific Cost				**$0.11/kL**

21.3.1.8 Byron DPR via Treated Water Augmentation – AWTP

Table 21-31 shows the estimated AWTP electricity use and associated annual cost for the Byron DPR via treated water augmentation scheme option.

Table 21-31: Byron DPR via Treated Water Augmentation – AWTP Electricity Cost

Item	Power During Operation (kW)	Operation (h/d)	Average Daily Electricity Use (kWh/d)	Comments
Raw Water Balance Tank Mixing	8	24	192	Refer to process schedule
UF Feed Pump	4.1	24	99	Refer to process schedule
Strainer	1.1	1.2	1	Based on three strainers, each with ½ HP motor – backwash for 30 seconds every 30 minutes for each strainer
UF System			1,866	Based on 0.2 kWh/kL as advised by vendor
RO System			4,199	Based on 0.5 kWh/kL as advised by vendor
UV/AOP	42.7	24	1,025	Based on advice from vendor
Secondary UV	10.0	24	240	Based on advice from vendor
Calcite Filter Feed Pumps	7.8	24	188	Refer to process schedule
Calcite Filter Backwash Pumps	11.0	1.1	11	Assumes calcite filters each backwash once per week, backwash pump runs for 10 minutes per backwash
PRW Pumps	4.8	24	115	Refer to process schedule
Waste Buffer Tank Pump	14.9	2	156	Based on transferring average daily waste flow (refer to flow balance) at a rate of required to empty tank in two hours
Neutralisation Pump	15	10.4	16	Assumes two duty UF units performing one maintenance wash per day and two CIP (one acid, one hypo) every 30 days – 30 minute neutralisation cycle assumed
Dosing pumps	2	24	48	Allowance
Polymer makeup system	2	24	48	Allowance
Equipment Load Subtotal				**8,198 kWh/d**
Base Load (Lighting, control system, security system, fire alarm, etc. – assumed to be the same as the Lismore IPD/DPR via RWA AWTP)				**993 kWh/d**
Total Estimated Electricity Consumption				**9,183 kWh/d**
Estimated Annual Operating Cost ($AUD 2024 p.a.)				**$502,800**
Specific Energy Use (based on production of 6.7 ML/d of PRW)				**1.37 kWh per kL PRW produced**
Specific Cost				**$0.21/kL**

Table 21-31 shows the specific energy use for the RO-based AWTP is roughly double that of the carbon-based AWTPs. This is driven by the high demand of the RO and UV/AOP systems.

21.3.1.9 Electricity Cost Summary

Table 21-32 summarises the estimated transfer infrastructure and AWTP electricity use and annual cost.

Table 21-32: Electricity Consumption and Cost Summary

Scheme	Transfer Electricity Use (kWh/d)	AWTP Electricity Use (kWh/d)	Total Use (kWh/d)	Transfer Annual Operating Cost ($AUD 2024 p.a.)	AWTP Annual Operating Cost ($AUD 2024 p.a.)	Total Annual Electricity Cost ($AUD 2024 p.a.)	Specific Energy Use (kWh/kL)	Specific Total Electricity Cost ($AUD 2024 /kL)
Lismore IPR via Surface Water Augmentation	8,845	5,960	14,805	$484,300	$326,300	$810,600	1.6	$0.24/kL
Lismore DPR via Raw Water Augmentation	7,766	5,960	13,726	$425,200	$326,300	$751,500	1.5	$0.23/kL
Lismore DPR via Treated Water Augmentation	2,377	3,798	6,175	$130,100	$207,900	**$338,000**	1.1	**$0.17/kL**
Byron DPR via Treated Water Augmentation	7,633	9,193	16,816	$417,900	$502,800	$920,700	2.5	$0.38/kL

Table 21-32 shows that the Lismore DPR via treated water augmentation scheme has the lowest total annual cost and lowest specific cost. This scheme option outperforms the other Lismore based schemes due to the significantly lower electricity cost for transfer of flows, and outperforms the Byron DPR via treated water augmentation scheme option in terms of the electricity demand for both the AWTP and the transfer of flows.

21.3.2 Chemicals

The estimated chemical consumption and costs for each short-listed option are summarised in sections 21.3.2.1 through 21.3.2.4. Except as noted otherwise, unit costs for chemicals are based on information provided by RCC[56].

21.3.2.1 Lismore IPR via Surface Water Augmentation

Table 21-33 shows the estimated AWTP chemical consumption and associated annual cost for the Lismore IPR via surface water augmentation scheme option.

Table 21-33: Lismore IPR via Surface Water Augmentation – Chemical Consumption and Cost

Item	Use (L/d)	Use (kg/d)	Unit cost ($/tonne)	Annual Operating Cost ($AUD 2024 p.a.)	Comments
Sodium Hypochlorite	373	425	$440	$68,212	Dose as per unit process sizing, plus allowance of 1.2 L/ML per vendor advice
Aluminium Chlorohydrate	52	69	$969	$24,571	Dose as per unit process sizing
Liquid Oxygen		88	$1,400	$45,007	Assumed to be double the cost of CO_2 in the RCC spreadsheet
Liquid Oxygen Equipment Rental				$20,000	Allowance - based on RCC spreadsheet costs for CO2 equipment rental for Emigrant Creek WTP (similar mass of gas used)
Polyelectrolyte	10	11	$9,100	$35,677	Dose as per unit process sizing
Sodium Hydroxide	11.9	16.2	$555	$3,277	Allowance of 0.3 L/ML of 30% NaOH per vendor advice, plus mass needed to neutralise citric acid cleans
Citric Acid	9.3	11.5	$1,110	$4,658	Allowance of 0.9 L/ML of 50% citric acid per vendor advice, assumes unit cost is double NaOH
Sulphuric Acid	14.7	18.4	$555	$3,731	Assumes same unit cost as NaOH
Sodium Bisulphite	5.1	6.0	$660	$1,444	Assumes 1.5 times mass of hypo used for UF cleaning and cost of sodium bisulphite is 1.5 times cost of sodium hypochlorite
Total Estimated Annual Operating Cost ($AUD 2024 p.a.)					**$206,600**
Specific Cost (based on production of 9.1 ML/d of PRW)					**$0.06/kL**

21.3.2.2 Lismore DPR via Raw Water Augmentation

The AWTP for the Lismore DPR via raw water augmentation scheme option is the same as the AWTP for the Lismore IPR via surface water augmentation scheme, with the exception of the use of Engineered Storage Buffer Tanks (instead of the single Treated Water Tank for the IPR AWTP). Hence, the chemical costs for the IPR AWTP shown in Table 21-33 also apply to the DPR via raw water augmentation scheme.

[56] In the spreadsheet provided by RCC called “RCC Bulk Chemical Budgeting 2022.xlsx”

21.3.2.3 Lismore DPR via Treated Water Augmentation

Table 21-34 shows the estimated AWTP chemical consumption and associated annual cost for the Lismore DPR via treated water augmentation scheme option.

Table 21-34: Lismore DPR via Treated Water Augmentation – Chemical Consumption and Cost

Item	Use (L/d)	Use (kg/d)	Unit cost ($/tonne)	Annual Operating Cost ($AUD 2024 p.a.)	Comments
Sodium Hypochlorite	224	256	$440	$41,095	Dose as per unit process sizing, plus allowance of 1.2 L/ML per vendor advice
Aluminium Chlorohydrate	31	42	$969	$14,754	Dose as per unit process sizing
Liquid Oxygen		53	$1,400	$27,308	Assumed to be double the cost of CO2 in the RCC spreadsheet
Liquid Oxygen Equipment Rental				$20,000	Allowance - based on RCC spreadsheet costs for CO_2 equipment rental for Emigrant Creek WTP (similar mass of gas used)
Polyelectrolyte	6.1	6.4	$9,100	$21,423	Dose as per unit process sizing
Sodium Hydroxide	7.1	9.7	$555	$1,968	Allowance of 0.3 L/ML of 30% NaOH per vendor advice, plus mass needed to neutralise citric acid cleans
Citric Acid	5.6	6.9	$1,110	$2,797	Allowance of 0.9 L/ML of 50% citric acid per vendor advice, assumes unit cost is double NaOH
Sulphuric Acid	8.8	11.1	$555	$2,240	Assumes same unit cost as NaOH
Sodium Bisulphite	3.3	3.8	$660	$927	Assumes 1.5 times mass of hypo used for UF cleaning and cost of sodium bisulphite is 1.5 times cost of sodium hypochlorite
Total Estimated Annual Operating Cost ($AUD 2024 p.a.)					**$136,200**
Specific Cost (based on production of 5.4 ML/d of PRW)					**$0.07/kL**

21.3.2.4 Byron DPR via Treated Water Augmentation

Table 21-35 shows the estimated chemical consumption and associated annual cost for the Byron DPR via treated water augmentation AWTP.

Table 21-35: Byron DPR via Treated Water Augmentation – Chemical Consumption and Cost

Item	Use (L/d)	Use (kg/d)	Unit cost ($/tonne)	Annual Operating Cost ($AUD 2024 p.a.)	Comments
Sodium Hypochlorite	780	889	$440	$142,801	Dose as per unit process sizing, plus allowance of 1.2 L/ML per vendor advice
Ammonia	40	50	$2,500	$45,236	Unit cost based on 2021 cost of $2,200/tonne based on IBCs (increased to account for escalation and site location)
Antiscalant	25	30	$9,200	$102,372	Based on an assumed cost of $8.50/kg + $770 per IBC for delivery (based on quote from vendor)
Sulphuric Acid	126	233	$555	$47,113	RO feed dose plus neutralisation of caustic cleans, assumes same unit cost as NaOH
Sodium Bisulphite	18	21	$660	$5,076	Assumes 1.5 times mass of hypo used for UF cleaning and cost of sodium bisulphite is 1.5 times the cost of sodium hypochlorite (plus bisulphite for dechlorinating RO concentrate)
Citric Acid	12	15	$1,110	$6,071	Allowance of 1.44 L/ML of 50% citric acid (converted from vendor advice based on HCl), assumes unit cost is double NaOH
Sodium Hydroxide	18	24	$555	$4,854	Allowance of 0.3 L/ML for UF and 0.39 L/ML for RO of 30% NaOH per vendor advice, plus mass needed to neutralise citric acid cleans
Aluminium Chlorohydrate	16	21	$969	$7,389	Dose as per unit process sizing
Methanol	42	34	$791	$9,699	Based on 2018 cost of $0.82/L, increased to $1.00/L to account for escalation and site location
Polyelectrolyte	6	6	$9,100	$21,423	Dose as per unit process sizing
Total Estimated Annual Operating Cost ($AUD 2024 p.a.)					**$329,000**
Specific Cost (based on production of 6.7 ML/d of PRW)					**$0.16/kL**

21.3.2.5 Chemical Cost Summary

Table 21-36 provides a summary of the estimated annual chemical costs, as well as the specific chemical costs.

Table 21-36: Chemical Consumption and Cost Summary

Scheme	Total Annual Chemical Cost ($AUD 2024 p.a.)	Specific Cost ($AUD 2024/kL)
Lismore IPR via Surface Water Augmentation	$206,600	$0.06/kL
Lismore DPR via Raw Water Augmentation	$206,600	$0.06/kL
Lismore DPR via Treated Water Augmentation	$136,200	$0.07/kL
Byron DPR via Treated Water Augmentation	$329,000	$0.16/kL

Table 21-36 shows the specific chemical cost for the RO-based treatment system (Byron DPR via treated water augmentation) is more than double the specific costs for the carbon-based treatment systems (Lismore).

21.3.3 Sampling

As discussed in Section 15.1.1.5, costs have been estimated for sampling required during operation of the AWTP. The California IPR approach applied to estimation of the sampling ang testing requirements includes more frequent analysis of some compounds during the first year of operation, making the analysis costs during the first year are higher than in subsequent years. Year one costs have been estimated at $145,200 and subsequent year costs at $114,500.

These costs are assumed to be the same for each short-listed scheme. These costs do not include full source characterisation sampling (which occurs prior to design and construction of the AWTP) but do include AWTP influent sampling corresponding to each PRW sample.

21.3.4 Maintenance

Two categories have been used to estimate maintenance costs, these being consumables (e.g. membranes, UV lamps, etc.) and general maintenance.

21.3.4.1 Consumables

Table 21-37 summarises the unit costs and replacement frequency for UF membrane, RO membrane and UV lamps, lamp drivers (ballasts) and wipers.

Table 21-37: Consumable Unit Cost and Replacement Frequency

Item	Unit Cost ($AUD 2024)	Replacement Frequency
UF Membrane Module	$4,800 per membrane module	10 years
RO Membrane Module	$1,000 per membrane module	5 years
UV Lamps	$1,650 per lamp	15,000 hours
UV Lamp Drivers	$2,500 per driver	10 years
UV Wipers	$150 per lamp	2 years

Table 21-38 summarises UF membrane replacement costs for each short-listed scheme. The Byron scheme is based on a maximum instantaneous flux of 50 LMH. All other schemes are based on 70 LMH. Membrane area is assumed to be 51 m^2 (based on Dow SFP-2860 modules). For each scheme, the conceptual design is based on two duty plus one standby UF unit.

Table 21-38: UF Membrane Replacement Costs

Item	Number of Modules	Cost per Replacement	Annualised Cost ($AUD 2024 p.a.)
Lismore IPR via Surface Water Augmentation	180	$865,500	$86,500
Lismore DPR via Raw Water Augmentation	180	$865,500	$86,500
Lismore DPR via Treated Water Augmentation	109	$521,000	$52,100
Byron DPR via Treated Water Augmentation	228	$1,094,100	$109,400

Table 21-39 summarises RO membrane replacement costs for the Byron DPR via treated water augmentation scheme. The key assumptions for this estimate comprise:

- Maximum instantaneous flux of 20 LMH;
- Membrane area of 37.1 m^2 (based on Toray TML20D-400 modules); and,
- Two duty plus one standby RO units.

Table 21-39: RO Membrane Replacement Costs

Item	Number of Modules	Cost per Replacement	Annualised Cost ($AUD 2024 p.a.)
Byron DPR via Treated Water Augmentation	708	$707,500	$141,500

Table 21-40 summarises the costs for UV lamp, driver and wiper replacement for each of the short-listed schemes. Duty/standby UV units are assumed.

Table 21-40: UV Lamp, Driver and Wiper Replacement Costs

Scheme	Number of Lamps	Lamp Cost per Replacement	Ballast Cost per Replacement	Wiper Cost per Replacement	Total Annualised Cost ($AUD 2024 p.a.)
Lismore IPR via Surface Water Augmentation	128	$211,200	$320,000	$19,200	$164,900
Lismore DPR via Raw Water Augmentation	128	$211,200	$320,000	$19,200	$164,900
Lismore DPR via Treated Water Augmentation	80	$132,000	$200,000	$12,000	$103,100
Byron DPR via Treated Water Augmentation Note 1	180	$297,000	$450,000	$27,000	$231,900

Note 1: Includes both the UV/AOP system (80 lamps per unit) and the secondary UV system (10 lamps per unit).

21.3.4.2 General Maintenance

General maintenance has been estimated based on 3% of the total direct equipment cost per annum. Table 21-41 summarises the direct equipment costs and the associated annual maintenance costs.

Table 21-41: Direct Equipment Costs and Annual Maintenance Costs

Scheme	Direct Equipment Cost ($AUD 2024)	Annual Maintenance Cost ($AUD 2024 p.a.)
Lismore IPR via Surface Water Augmentation	$15,746,000	$472,400
Lismore DPR via Raw Water Augmentation	$15,746,000	$472,400
Lismore DPR via Treated Water Augmentation	$11,194,000	$335,800
Byron DPR via Treated Water Augmentation	$12,895,000	$386,900

21.3.4.3 Maintenance Summary

The annual maintenance costs for consumables and general maintenance for each short-listed scheme is summarised in Table 21-42.

Table 21-42: Annual Maintenance Costs

Scheme	Annual Consumable Cost Note 1 ($AUD 2024 p.a.)	Annual General Maintenance Cost ($AUD 2024 p.a.)	Total Annual Maintenance Cost ($AUD 2024 p.a.)
Lismore IPR via Surface Water Augmentation	$251,500	$472,400	$723,900
Lismore DPR via Raw Water Augmentation	$251,500	$472,400	$723,900
Lismore DPR via Treated Water Augmentation	$155,200	$335,800	$491,000
Byron DPR via Treated Water Augmentation	$482,900	$386,900	$869,800

Note 1: Assumes an annual contribution is made to cover costs of consumables.

21.3.5 Labour

Costs associated with labour are based on the staffing estimates provided in Section 15.3. These cost estimates are summarised in Table 21-43, and have been assumed to be the same across all of the short-listed scheme options.

Labour costs shown here are for ongoing operation and maintenance of the scheme and do not include costs associated with the regulatory approval process described in Section 17.

Table 21-43: Labour Costs

Position	Full Time Equivalents (No.)	Cost per Person ($AUD 2024 p.a.)	Total Annual Cost ($AUD 2024 p.a.)
Chief Operator/Superintendent	1	$120,000	$120,000
Operator	5	$100,000	$500,000
Process Engineer	2	$150,000	$300,000
Maintenance Supervisor	0.5	$120,000	$60 000
Fitter	1 (2 x 0.5)	$150,000	$150,000
Electrician	0.5	$150,000	$75,000
Analyser Specialist	1	$150,000	$150,000
Project Manager	1	$200,000	$200,000
Management Support	2	$150,000	$300,000
Auditor Note 1			$200,000
Community Engagement	1	$200,000	$200,000
Source Control	1	$150,000	$150,000
Water Quality Specialist	1	$150,000	$150,000
		Total	$2,555,000

Note 1: Assumes auditing is performed by an appropriately qualified consultant

21.3.6 Operation and Maintenance Cost Summary

The estimated operation and maintenance costs for each short-listed scheme option are summarised in Table 21-44 . The figures listed are based on continuous operation of the scheme option at the design production rate. For intermittent PRW production, the variable operating costs would be lower, but the specific O&M costs (i.e. $/kL) would likely be increased by any fixed cost elements which persist when the scheme is not producing water.

Table 21-44: Summary of Estimated Annual Operation and Maintenance Costs

Item	Total Estimated Annual Cost ($AUD 2024 p.a.)						
	Electricity	Chemicals	Sampling	Labour	Maintenance	Total (Year 2 onwards)	
Lismore IPR via SWA	$810,600	$206,600	Year one: $145,200 Subsequent years: $114,500.	$2,555,000	$723,900	$4.41m p.a.	$1.33 /kL
Lismore DPR via RWA	$751,500	$206,600			$723,900	$4.35m p.a.	$1.31 /kL
Lismore DPR via TWA	$338,000	$136,200			$491,000	$3.63m p.a.	$1.84 /kL
Byron DPR via TWA	$920,700	$329,000			$869,800	$4.79m p.a.	$1.92 /kL

It is noteworthy that the specific highest operating cost (per kL) occurs for the Byron DRP via treated water augmentation and Lismore DPR via treated water augmentation options. This is due the lower PRW production rates for these scheme options in combination with the dominance of fixed labour costs on overall operating and maintenance costs.

22 NET PRESENT COST

Net present costs have been calculated for each short-listed scheme based on the following criteria provided by RCC:

- 40-year term;
- 5% discount (interest) rate (with sensitivity at 3% and 7%);
- 0% inflation; and,
- Continuous operation of the scheme option at the design production rate. For intermittent PRW production, the specific NPC would be higher.

Table 22-1 summarises the cost inputs and timing of incurred costs used in the NPC calculation.

Table 22-1: Net Present Value Input Costs and Timing

Item	Scheme				Comment
	Lismore IPR via SWA Note 1	Lismore DPR via RWA	Lismore DPR via TWA	Byron DPR via TWA	
Project Development and Capital Costs					
Source Characterisation	$1,600,000	$1,600,000	$800,000	$1,600,000	Annual cost as per Table 17-3. Lismore DPR via TWA assumes one STP is characterised, all others assume two STP. Costs split evenly over year one and year two as per Figure 17-1
Community Engagement	$325,000	$325,000	$325,000	$325,000	Annual cost as per Table 17-3. Costs assume to be incurred each year from the start of the project to attainment of regulatory approval (estimated to be nine years as per Figure 17-1)
Enhanced Source Control - 1	$550,000	$550,000	$550,000	$550,000	Annual cost as per Table 17-3. Costs assumed to be incurred during first two years of the project to establish the program
Enhanced Source Control - 2	$150,000	$150,000	$150,000	$150,000	Annual cost as per Table 17-3. Costs assumed to be incurred from year three through nine of the project (after year nine costs for this item are included in the "Ongoing Labour Costs" category)
Management team and process engineers during Regulatory approval period	$800,000	$800,000	$800,000	$800,000	Annual cost as per Table 17-3. Costs assumed to be incurred from the start of the project through year nine (after year nine costs for this item are included in the "Ongoing Labour Costs" category)
Demonstration Plant Capital Cost	$6,500,000	$6,500,000	$6,500,000	$6,500,000	Lump sum as per Table 17-3. Costs are assumed to be incurred as follows (as per Figure 17-1): - 10% split evenly between in years 2 and 3 of the project for design - Remaining 90% split such that 60% is in year three of the project and 30% is in year 4
Demonstration Plant Operating Cost	$1,100,000	$1,100,000	$1,100,000	$1,100,000	Annual cost as per Table 17-3. Costs assumed to be incurred at 50% in year four and 100% per year in years five through nine of the project (as per Figure 17-1)
Capital Costs	$218,000,000	$148,000,000	$135,000,000	$184,000,000	Lump sum as per Table 21-19. Costs are assumed to be incurred as follows (as per Figure 17-1): - 10% of total assumed for design – split such that 1/3 of this value is incurred in year 5 of the project and 2/3 of this value is incurred in year 6 - 85% of total for delivery of AWTP and transfer infrastructure – split evenly over year 7and year 8 - Remaining 5% allocated to commissioning – split evenly over year eight and year nine

Table 22-1: Net Present Value Input Costs and Timing (continued)

Item	Scheme				Comment
	Lismore IPR via SWA Note 1	Lismore DPR via RWA	Lismore DPR via TWA	Byron DPR via TWA	
Operation and Maintenance Costs					
Electricity Costs	$810,600	$751,500	$338,000	$920,700	Annual cost as per Table 21-32. Assumed to be incurred starting in year nine of the project and continuing through year 40
Chemical Costs	$206,600	$206,600	$136,200	$329,000	Annual cost as per Table 21-36. Assumed to be incurred starting in year nine of the project and continuing through year 40
Year One Sampling Costs	$145,200	$145,200	$145,200	$145,200	Single annual cost as per Section 21.3.3. Assumed to be incurred in year nine of the project
Ongoing Sampling Costs	$114,500	$114,500	$114,500	$114,500	Ongoing annual cost as per Section 21.3.3. Assumed to be incurred starting in year ten of the project and continuing through year 40
Maintenance Costs	$723,900	$723,900	$491,000	$869,800	Annual cost as per Table 21-42. Assumed to be incurred starting in year nine of the project and continuing through year 40
Ongoing Labour Costs	$2,555,000	$2,555,000	$2,555,000	$2,555,000	Annual cost as per Table 21-43. Assumed to be incurred starting in year nine of the project and continuing through year 40

Note 1: Based on provision of 0.6 GL Engineered Environmental Buffer Storage. NPC has been calculated for the 1.2 GL Engineered Environmental Buffer Storage option by substituting a capital cost of $232m (as per Table 21-19).

Table 22-2 summarises the NPCs for all of the short-listed options calculated using a 5% discount rate. Full calculations are provided in Appendix N.

Table 22-2: NPC Summary – Based on 5% Discount Rate

Item	NPC	PRW Produced (ML/d)	Specific NPC Note 1
Lismore IPR via Surface Water Augmentation – 0.6 GL Buffer Storage	$231.2m	9.1	$25.4m per ML/d
Lismore IPR via Surface Water Augmentation – 1.2 GL Buffer Storage	$241.5m	9.1	$26.5m per ML/d
Lismore DPR via Raw Water Augmentation	$179.8m	9.1	**$19.8m per ML/d**
Lismore DPR via Treated Water Augmentation	**$169.0m**	5.4	$31.3m per ML/d
Byron DPR via Treated Water Augmentation	$206.5m	6.7	$30.8m per ML/d

Note 1: The figures listed are based on continuous operation of the scheme option at the design production rate. For intermittent PRW production, the specific NPC would be higher.

Table 22-2 shows that the Lismore DPR via treated water augmentation option has the lowest NPC by around 6%, but this option also provides the least amount of PRW of the short-listed schemes. The Lismore DPR via raw water augmentation has the lowest specific NPC (NPC per ML of PRW produced) – approximately 20% less than the next highest specific NPC.

Table 22-3 shows the NPC sensitivity to discount rates of 3% and 7%. See Appendix N for full calculations.

Table 22-3: NPC Sensitivity at Discount Rates of 3% and 7%

Item	NPC at 3% Discount Rate	Specific NPC at 3% Discount Rate	NPC at 7% Discount Rate	Specific NPC at 7% Discount Rate
Lismore IPR via Surface Water Augmentation – 0.6 GL Buffer Storage	$277.0m	$30.4m per ML/d	$197.0m	$21.7m per ML/d
Lismore IPR via Surface Water Augmentation – 1.2 GL Buffer Storage	$288.6m	$31.7m per ML/d	$206.2m	$22.7m per ML/d
Lismore DPR via Raw Water Augmentation	$219.0m	**$24.0m per ML/d**	$151.5m	**$16.6m per ML/d**
Lismore DPR via Treated Water Augmentation	**$206.9m**	$38.3m per ML/d	**$141.8m**	$26.3m per ML/d
Byron DPR via Treated Water Augmentation	$249.1m	$37.2m per ML/d	$175.1m	$26.1m per ML/d

Table 22-3 shows similar results to Table 22-2, with:

- The Lismore DPR via treated water augmentation scheme having the lowest NPC -around 5% less than the next highest NPC for both sensitivity scenarios; and,
- The Lismore DPR via raw water augmentation scheme having the lowest specific NPC around 24% less than the next highest specific NPC for both sensitivity scenarios.

23 MULTIPLE CRITERIA ASSESSMENT

The four short-listed schemes have been subjected to multiple criteria assessment to indicate RCC's likely relative preference of each scheme. The methodology used for the MCA is described in Section 23.1, with MCA results are provided in Section 23.2.

23.1 METHODOLOGY

The four shortlisted schemes were assessed for cost and non-cost criteria via an MCA as described in this section. The assessment criteria were classed into three major categories, which are broadly intended to line up with overarching project outcomes. Each category was further classified into criteria, with each intended to address a specific area of potential differentiation among the four schemes. Some of the criteria were further subclassified into sub-criteria, which were specific, generally quantifiable and differentiable metrics on which to score each scheme. Weightings were assigned to each category and the sub-criteria within each category.

In the application of an MCA to evaluation of the schemes, it is implicit that each of the options are technically viable, and meet all relevant hurdle criteria. This is generally true for the short-listed schemes with one key exception – the absence of a prescribed regulatory pathway for approval for the three DPR scheme options. Hence, in comparing IPR option to the DPR option as part of an MCA, there is an implicit presumption that the regulatory requirements for DPR emerge (see Section 17).

Table 23-1 summarises the three categories and their corresponding weightings. Note that the "Financial" category, which relates to the estimated project costs, carries about half the entire weighting of the MCA, accounting for the largest single share. The other half of weightings are assigned to the two non-cost categories, which are further divided into criteria and sub-criteria, as described below. All sub-criteria were developed based on consultation with RCC based on their understanding of the most important factors on a technical basis, in the context of the region, and within the specific goals and requirements of RCC.

Table 23-1: Summary of Categories Used in MCA and Weights Assigned

Category	Description	Weight Assigned
A	**Technical** – Considers the appropriate use of technology, infrastructure and resources to deliver a potable reuse solution to the region.	30%
B	**Financial –** Considers the financial implications of a given potable reuse scheme in terms of capital and operating cost, as well as the need for future investigations, represented in the form of a Net Present Cost.	50%
C	**Social/Environmental –** Considers the social, ecological and cultural implications of a given potable reuse scheme and its impacts thereof on local communities and the region as a whole.	20%
Total		100%

23.1.1 Technical Criteria

A total of four technical criteria were developed and further divided where suitable, leading to a total of eight technical sub-criteria. Table 23-2 details the major technical criteria and sub-criteria applied to the MCA.

Table 23-2: Description of Technical Criteria and Sub-criteria Applied to the MCA

Criterion	Criteria Description	Sub-criterion	Description	Weighting (within Technical category)
A1	**Scheme Configuration Type**	i	Regulatory Risk associated with Health Approvals	20%
		ii	Operational Complexity	20%
A2	**Quantity of Water Produced**	iii	Quantity of PRW produced	10%
		iv	Pre-existing non-potable reuse schemes	10%
A3	**Catchment Hazards and Risk**	v	Share of flow from commercial/industrial sources	10%
A4	**Land Availability/ Location**	vi	Construction Complexity	10%
		vii	Expandability for Future	10%
		viii	Flood Risk	10%
Total				100%

The sub-criteria under Criterion A1 (Scheme Configuration Type) are primarily geared toward the architecture of each scheme and the implications thereof. The time and effort potentially associated with regulatory pathway approvals are captured in sub-criterion A1(i). Operational complexity is captured in subcriterion A1(ii) in non-cost terms (noting that cost implications are captured under the Financial category). This includes, among other factors, the number of process streams within each scheme's AWTP, chemical use levels, process unit operability, and RCC's familiarity with the unit processes in each scheme.

Sub-criterion A2(iii)captures the quantity of PRW that can be generated and utilised, and sub-criterion A2(iv) considers the potential impacts of a potable reuse scheme to existing non-potable reuse schemes or flow augmentation to existing water bodies. Criterion A3(v) considers the level of risk to water quality due to the share of industrial or commercial trade waste input into the source STPs under each scheme.

The land used for the construction of the AWTP and other major new assets under each scheme is considered in Criterion A4. Construction complexity in terms of site access, utilities connection, greenfield vs brownfield construction and zoning/ownership considerations are captured in sub-criterion A4(vi). Considerations around future expandability of a given scheme, while considered low in priority, is nevertheless captured in sub-criterion A4(vii). Finally, the flood risk around all major sites, particularly of selected AWTP sites, is considered in sub-criterion A4(vii).

In terms of weightings assigned, the regulatory and operations-related sub-criteria received the highest priorities.

23.1.2 Financial Criteria

The financial category was the most heavily weighted to aid decision-making, and as the only cost parameter applied, consisted of a single criterion and sub-criterion, B5(ix), based on project NPC under each scheme option.

Two MCAs have been completed, on based on NPC and the other based on Specific NPC. The MCA based on NPC considered total costs incurred over the 40-year term with no consideration of the benefit in terms of PRW provided. The MCA based on Specific NPC considers the value of the costs incurred, in terms of dollars per ML/d of PRW produced (assuming continuous operation of each scheme at the nameplate PRW production rate).

Derivation of NPC and Specific NPC is discussed in Section 22.

23.1.3 Social and Environmental Criteria

The social/environmental category comprised two criteria, divided into three sub-criteria as detailed in Table 23-3.

Table 23-3: Description of Social and Environmental Criteria and Sub-criteria Applied to the MCA

Social/ Environmental Criteria	Criteria Description	Sub-criteria	Sub-criteria Description	Sub-criteria Weight (within Social and Environmental category)
C6	**Residuals Management**	x	Risk and impacts associated with residuals handling	20%
C7	**Greenhouse Gas Emissions Potential**	xi	Overall Power Estimate relative to Greenhouse Gas emissions potential	30%
C8	**Other Considerations**	xii	Social and community impacts across each scheme	30%
		xiii	Constituent Council Considerations	20%
Total				100%

The risks associated with residuals handling from both a regulatory perspective and a community perspective are captured in criterion C6. The community perspectives are associated with local levels of acceptance around proposed disposal options for RO concentrate.

The potential for greenhouse gas emissions is captured in sub-criterion C7(xi), but this was assessed on a **relative** basis. The overall power use, as applied to operating cost, was factored here, but compared to the potential for using renewable sources under each scheme. A score was assigned to each scheme under this sub-criterion such that the estimated power use was weighed against the availability of solar or other renewable power sources.

The major social and community impacts, as currently perceived or understood, were scored under sub-criterion C8(xii). For example, the site identified for an AWTP in the Lismore area is a plot of available land directly to the east of South Lismore STP. However, an Animal Rights and Rescue Group facility that serves the community is located directly to the east of this plot of land and may be impacted by the AWTP. Impacts of this nature, as currently understood, resulted in lower scores for the relevant schemes under this sub-criterion.

Considerations around the various constituent councils involved in a potable reuse scheme were captured under sub-criterion C8(xiii). This sub-criterion considered, for example, the potential for equitable distribution of PRW across councils, to distribute any perceived inequity.

23.2 MCA RESULTS

The MCA was completed by assigning scores to each of the sub-criteria for each short-listed scheme. Scores are based on a scale of 1 to 5, with 1 being least favourable 5 being most favourable and. Ranking of the short-listed scheme options is based on the total MCA score.

Table 23-4 shows the MCA results based on NPC. Table 23-5 shows the MCA results based on Specific NPC.

Table 23-4: MCA Results Based on NPC

Category	Category Weight	Criteria	Criteria Description	Sub-criteria	Sub-criteria Description	Sub-criteria Weight within Category	Overall Sub-criteria Weight	Lismore SWA (IPR)	Lismore RWA (DPR)	Lismore TWA (DPR)	Byron TWA (DPR)	Comments
Technical	30%	A1	Scheme Configuration Type	i	Regulatory Risk associated with Health Approvals	20%	6%	5	4	3	3	IPR has prescribed pathway and is familiar to regulators, hence highest score. RWA is expected have more difficult regulatory approval process, but also have a lower perceived risk than TWA, hence RWA is scored 1 less than IPR and TWA is scored 1 less than RWA
				ii	Operational Complexity	20%	6%	5	5	5	3	Byron TWA has is expected to have higher operational complexity as there are more unit processes (nine versus seven for the carbon- based AWTPs) and more chemical systems (with higher quantities of chemical use, including methanol). In addition, RCC has familiarity with most of the unit processes in the carbon-based scheme (e.g. coagulation, ozone/BAC, UF, chlorine disinfection) but would be unfamiliar with the RO system and MBBRs used in the Byron TWA scheme.
		A2	Quantity of Water Produced	iii	Quantity of PRW produced	10%	3%	5	5	3	4	Lismore SWA and RWA each provide 9.1 ML/d, Byron TWA provides 6.7 ML/d and Lismore TWA provides 5.4 ML/d
				iv	Pre-existing non-potable reuse schemes	10%	3%	5	5	5	3	No off-site non-potable reuse for Lismore. Byron effluent is reused for irrigation of sporting fields and nurseries, parks and gardens, and in dual reticulation for toilet flushing in public and private bathrooms, as well as providing environmental benefit through the Byron Bay Integrated Water Management Reserve.
		A3	Catchment Hazards and Risk	v	Share of flow from commercial/industrial sources	10%	3%	3	3	3	3	Similar percentage and types of trade waste for all schemes
		A4	Land Availability/ Location	vi	Construction Complexity	10%	3%	4.5	4.5	5	5	Minor brownfield issues associated with AWTP located at South Lismore STP (Lismore SWA and RWA), otherwise all sites similar.
				vii	Expandability for Future	10%	3%	4	4	5	4	South Lismore STP site is more constrained than other sites. Byron AWTP site has potential environmental constraints depending on the level of expansion.
				vii	Flood Risk	10%	3%	4	4	4	3	Byron AWTP site is on "flood prone" land. Both Lismore AWTP sites are partially in low flood risk areas. All sites will need some level of fill to elevate above flood level (with Byron having the highest level of fill)
Financial	50%	B5	Initial Economic Assessment	ix	NPC	100%	50%	2	4	5	3	Refer to Section 22
Social and Environmental	20%	C6	Residuals Management	x	Risk associated with residuals handling	20%	4%	5	5	5	3	Byron TWA is the only scheme with a discharge stream (other than return stream to STPs)
		C7	GHG Emissions Potential	xi	Overall Power Estimate relative to Greenhouse Gas emissions potential	30%	6%	4	4	5	3	Lismore TWA has lowest power use and high likelihood of land availability for solar. Lismore SWA/RWA has mid-level power consumption but limited land availability for solar. Byron TWA has significantly higher power use than other options - solar may be possible but all adjacent land is flood prone so implementation of solar may be challenging
		C8	Other Considerations	xii	Social and community impacts across each scheme	30%	6%	3	3	5	4	Lismore SWA/RWA likely to impact animal rescue facility. Byron TWA is located adjacent to coastal wetlands, which may result in community perception issues.
				xiii	Constituent Council Considerations	20%	4%	5	5	3	4	Lismore SWA and RWA distribute across all three LGAs. Byron TWA distributes across two LGAs (Byron and Ballina). Lismore TWA only provides PRW within Lismore.
Total	100%						100%	**3.2**	**4.1**	**4.7**	**3.2**	

Table 23-5: MCA Results Based on Specific NPC

Category	Category Weight	Criteria	Criteria Description	Sub-criteria	Sub-criteria Description	Sub-criteria Weight within Category	Overall Sub-criteria Weight	Lismore SWA (IPR)	Lismore RWA (DPR)	Lismore TWA (DPR)	Byron TWA (DPR)	Comments
Technical	30%	A1	**Scheme Configuration Type**	i	Regulatory Risk associated with Health Approvals	20%	6%	5	4	3	3	IPR has prescribed pathway and is familiar to regulators, hence highest score. RWA is expected have more difficult regulatory approval process, but also have a lower perceived risk than TWA, hence RWA is scored 1 less than IPR and TWA is scored 1 less than RWA
				ii	Operational Complexity	20%	6%	5	5	5	3	Byron TWA has is expected to have higher operational complexity as there are more unit processes (nine versus seven for the carbon- based AWTPs) and more chemical systems (with higher quantities of chemical use, including methanol). In addition, RCC has familiarity with most of the unit processes in the carbon-based scheme (e.g. coagulation, ozone/BAC, UF, chlorine disinfection) but would be unfamiliar with the RO system and MBBRs used in the Byron TWA scheme.
		A2	**Quantity of Water Produced**	iii	Quantity of PRW produced	10%	3%	5	5	3	4	Lismore SWA and RWA each provide 9.1 ML/d, Byron TWA provides 6.7 ML/d and Lismore TWA provides 5.4 ML/d
				iv	Pre-existing non-potable reuse schemes	10%	3%	5	5	5	3	No off-site non-potable reuse for Lismore. Byron effluent is reused for irrigation of sporting fields and nurseries, parks and gardens, and in dual reticulation for toilet flushing in public and private bathrooms, as well as providing environmental benefit through the Byron Bay Integrated Water Management Reserve.
		A3	**Catchment Hazards and Risk**	v	Share of flow from commercial/industrial sources	10%	3%	3	3	3	3	Similar percentage and types of trade waste for all schemes
		A4	**Land Availability/ Location**	vi	Construction Complexity	10%	3%	4.5	4.5	5	5	Minor brownfield issues associated with AWTP located at South Lismore STP (Lismore SWA and RWA), otherwise all sites similar.
				vii	Expandability for Future	10%	3%	4	4	5	4	South Lismore STP site is more constrained than other sites. Byron AWTP site has potential environmental constraints depending on the level of expansion.
				viii	Flood Risk	10%	3%	4	4	4	3	Byron AWTP site is on "flood prone" land. Both Lismore AWTP sites are partially in low flood risk areas. All sites will need some level of fill to elevate above flood level (with Byron having the highest level of fill)
Financial	50%	B5	**Initial Economic Assessment**	ix	Specific NPC	100%	50%	4	5	3	3	Refer to Section 22
Social and Environmental	20%	C6	**Residuals Management**	x	Risk associated with residuals handling	20%	4%	5	5	5	3	Byron TWA is the only scheme with a discharge stream (other than return stream to STPs)
		C7	**GHG Emissions Potential**	xi	Overall Power Estimate relative to Greenhouse Gas emissions potential	30%	6%	4	4	5	3	Lismore TWA has lowest power use and high likelihood of land availability for solar. Lismore SWA/RWA has mid-level power consumption but limited land availability for solar. Byron TWA has significantly higher power use than other options - solar may be possible but all adjacent land is flood prone so implementation of solar may be challenging
		C8	**Other Considerations**	xii	Social and community impacts across each scheme	30%	6%	3	3	5	4	Lismore SWA/RWA likely to impact animal rescue facility. Byron TWA is located adjacent to coastal wetlands, which may result in community perception issues.
				xiii	Constituent Council Considerations	20%	4%	5	5	3	4	Lismore SWA and RWA distribute across all three LGAs. Byron TWA distributes across two LGAs (Byron and Ballina). Lismore TWA only provides PRW within Lismore.
Total	100%						100%	**4.2**	**4.6**	**3.7**	**3.2**	

Table 23-6 summarises the total MCA scores and the associated preference ranking for each short-listed scheme for both the NPC and Specific NPC cases.

Table 23-6: MCA Total Score Summary and Ranking of Scheme Preference

Scheme	NPC MCA Score	NPC MCA Ranking	Specific NPC Score	Specific NPC Ranking
Lismore IPR via Surface Water Augmentation	3.2	3	4.2	2
Lismore DPR via Raw Water Augmentation	4.1	2	4.6	1
Lismore DPR via Treated Water Augmentation	4.7	1	3.7	3
Byron DPR via Treated Water Augmentation	3.2	3	3.2	4

Table 23-6 shows:

- The Lismore DPR via treated water augmentation scheme is ranked highest based on NPC; and,
- The Lismore DPR via raw water augmentation scheme is ranked highest based on Specific NPC.

With respect to selecting a preferred option, the following should be taken into consideration:

- The NPC for the Lismore DPR via raw water augmentation scheme is about 5% greater than the NPC for the Lismore DPR via treated water augmentation scheme;
- The capital cost for the Lismore DPR via raw water augmentation scheme is about 10% greater than the capital cost for the Lismore DPR via treated water augmentation scheme; and,
- The Lismore DPR via raw water augmentation scheme provides almost 70% more PRW than the Lismore DPR via treated water augmentation scheme.

To test the sensitivity of the MCA scores and rankings, category weights were changed so that all three categories were equally weighted (i.e. each category was weighted at 33.3%). Table 23-7 shows the scores and rankings based on the equal category weighting.

Table 23-7: MCA Total Score Summary and Ranking of Scheme Preference with Equal Category Weights

Scheme	NPC MCA Score	NPC MCA Ranking	Specific NPC Score	Specific NPC Ranking
Lismore IPR via Surface Water Augmentation	3.6	3	4.2	2
Lismore DPR via Raw Water Augmentation	4.2	2	4.5	1
Lismore DPR via Treated Water Augmentation	4.6	1	3.9	3
Byron DPR via Treated Water Augmentation	3.3	4	3.3	4

Table 23-7 shows that while equalising the category weights changes the total MCA scores for both the NPC based and Specific NPC based assessments, the rankings do not change for the Specific NPC based assessment. Only the ranking of the Byron DPR via treated water augmentation scheme changes for the NPC based assessment.

24 SHORT-LISTED OPTIONS SUMMARY

Table 24-1 summarises the outcomes of the cost estimation (i.e. capital cost, operating cost, NPC), and the results of the and MCA results.

Table 24-1: Summary of Short-listed Options

Scheme	Lismore IPR via Surface Water Augmentation Note 4, 5	Lismore DPR via Raw Water Augmentation Note 6	Lismore DPR via Treated Water Augmentation Note 7	Byron DPR via Treated Water Augmentation Note 8
2040 Available STP Effluent (ML/d) Note 1	9.1	9.1	9.1	8.35
AWTP PRW Capacity (ML/d)	9.1	9.1	5.4	6.7
2040 Potable Water Demand (ML/d) Note 2	32.95	32.95	10.8	22.15
Blend Ratio[3]	28%	28%	50%	30%
Number of LGAs Receiving PRW	3	3	1	2
AWTP Capital Cost	$129m	$130m	$104m	$131m
Transfer Infrastructure Capital Cost	$48.7m	$17.8m	$31.2m	$52.9m
Total Capital Cost	$218m	$148m	$135m	$184m
Specific Capital Cost	$24.0m per ML/d	$16.3m per ML/d	$25.0m per ML/d	$27.5m per ML/d
AWTP Electricity Cost	$326,300 p.a.	$326,300 p.a.	$207,900 p.a.	$502,800 p.a.
Transfer Electricity Cost	$484,300 p.a.	$425,200 p.a.	$130,100 p.a.	$417,900 p.a.
Specific Electricity Cost (including transfer)	$0.24/kL	$0.23/kL	$0.17/kL	$0.38/kL
Chemical Cost	$206,600 p.a.	$206,600 p.a.	$136,200 p.a.	$329,000 p.a.
Specific Chemical Cost	$0.06/kL	$0.06/kL	$0.07/kL	$0.16/kL
NPC	$231m	$180m	$169m	$206m
Specific NPC	$25.4m per ML/d	$19.8m per ML/d	$31.3m per ML/d	$30.8m per ML/d
NPC MCA Score	3.2	4.1	4.7	3.2
NPC MCA Ranking	3	2	1	3
Specific NPC MCA Score	4.2	4.6	3.7	3.2
Specific NPC MCA Ranking	2	1	3	4

Note1: For Lismore DPR via treated water augmentation scheme value shown is total of East Lismore and South Lismore. South Lismore STP effluent would not be utilised unless further investigation demonstrated that acceptable drinking water TDS could be attained at blend ratio above 60%.

Note 2: For Lismore IPR via surface water augmentation and Lismore DPR via raw water augmentation schemes, based on 2040 demand of St Helena, Knockrow, City View, Belvedere Drive, High Street and Ross Street reservoirs. For Lismore DPR via treated water augmentation scheme, based on 2040 demand of City View, Belvedere Drive, High Street and Ross Street reservoirs. For Byron DPR via treated water augmentation scheme, based on 2040 demand of St Helena and Knockrow reservoirs.

Note 3: Blend ratio is the PRW supplied (AWTP capacity) divided by the 2040 potable water demand. For Byron DPR via treated water augmentation scheme a carbon-based scheme would allow blend ratio up to 38%.

Note 4: Carbon-based AWTP located adjacent to the South Lismore STP. PRW is transferred to new Engineered Environmental Buffer Storage (location tbd – assumed to be ~ 4.5 km west of the Wilsons River Source Pump Station. Water from Engineered Environmental Buffer Storage (which may include Wilsons River water) is pumped to the Wilsons River Source Pump Station. The Wilsons River Source Pump Station pumps this water to the head of Nightcap WTP where it is blended with Rocky Creek Dam water. Effluent sourced from South Lismore STP and East Lismore STP.

Note 5: Costs shown for the Lismore IPR via surface water augmentation scheme are based on the 0.6 GL Engineered Environmental Buffer Storage. Total capital cost includes $40M for the 0.6 GL buffer storage. Total capital cost for the 1.2 GL buffer storage would be $232m.

Note 6: Carbon-based AWTP located adjacent to the South Lismore STP. PRW is transferred to the Wilsons River Source Pump Station. The Wilsons River Source Pump Station pumps this water to the head of Nightcap WTP where it is blended with Rocky Creek Dam water. Effluent sourced from South Lismore STP and East Lismore STP.

Note 7: Carbon-based AWTP located approximately 800 m to the north of the East Lismore STP along Wyrallah Road. PRW is pumped to City View, Belvedere Drive, High Street and Ross Street reservoirs to achieve a blend ratio of up to 50% based on peak instantaneous inflow to all four reservoirs simultaneously. Effluent sourced from East Lismore STP.

Note 8: RO-based AWTP located directly to the west of the Cavanbah Centre on Ewingsdale Road in Byron Bay. PRW is pumped to St Helena and Knockrow reservoirs to achieve a blend ratio of up to 50% based on peak instantaneous inflow to both reservoirs simultaneously. A new Blending Reservoir is provided in the general vicinity of the split in the existing pipeline from Nightcap WTP to St Helena Reservoir and Knockrow Reservoir (i.e. where the pipeline branches to Knockrow Reservoir)). The PRW is blended with Nightcap WTP treated water and pumped to Knockrow Reservoir via a new pump station. Effluent sourced from Byron STP and Brunswick Valley STP.

Note 9: All costs reported in terms of AUD, 2024.

25 LEVEL 2 OPTIONS

As discussed in Section 4, the following options were carried forward for high level consideration (Level 2):

- Lismore IPR via Surface Water Augmentation – PRW derived from effluent sourced from East Lismore STP and South Lismore STP directed to Rocky Creek Dam via Wilson River Source Pump Station, co-treatment with Wilson River water;
- Byron IPR via Groundwater Augmentation – PRW derived from effluent sourced from Byron STP and Brunswick Valley STP directed to Tyagarah aquifer for managed aquifer recharge;
- Byron IPR via Surface Water Augmentation – PRW derived from effluent sourced from Byron STP and Brunswick Valley STP directed to Rocky Creek Dam;
- Ballina DPR via Raw Water Augmentation – PRW derived from effluent sourced from Ballina WWTP and Lennox Head WWTP directed to Emigrant Creek WTP; and,
- Ballina DPR via Treated Water Augmentation – PRW derived from effluent sourced from Ballina WWTP and Lennox Head WWTP directed to Knockrow Reservoir.

These options are considered have potential to meet the main aims of a potable reuse scheme for RCC, but with substantial barriers reducing likely viability compared to Level 1 options, including approximation of pipelines and AWTP process train requirements and costs, qualitative discussion of opportunities and risks, and considerations of infrastructure costs, complexities and risks relative to Level 1 options.

This section provides a high-level discussion of potential infrastructure requirements for the scheme options that were classified as Level 2 during the short-listing process.

Pipeline routes and other information presented in the following sections are indicative only and for the purpose of providing a level of understanding of potential infrastructure requirements. Where pipeline routes have been developed for Level 1 options that coincide with the general requirements of a given Level 2 option the applicable sections of these alignments have been used. Where no Level 1 alignment exists, pipeline routes have been considered based on the shortest route along existing roadways as determined from Google Maps/Google Earth. Pipeline routes have not been analysed for constraints. Significant additional work would be required to develop conceptual pipeline routes, layouts, etc. if any of the Level 2 options are to be further investigated in future.

For the Level 2 options, pipe sizing has been based on maintaining velocity at or below 1.5 m/s. Pipe materials have been selected based on:

- Where meeting the velocity sizing basis requires DN375 or less, the pipe material is assumed to be PVC (except where total head exceeds 160 m); and,
- For all other pipes DICL is assumed.

If any of the Level 2 options were to be progressed, alternative pipe materials and/or sizes should be considered.

25.1.1 Lismore IPR via Surface Water Augmentation

This option is similar to the Level 1 Lismore IPR via surface water augmentation scheme, with two significant differences:

- PRW would be combined with pre-treated river water from the Wilsons River and pumped to Rocky Creek Dam, which would act as an Environmental Buffer. The PRW/river water would be directed to the northwest end of the dam to provide as much theoretical hydraulic residence time as possible (refer to Figure 25-1); and,
- Water from the Wilsons River would be pre-treated prior to combining with PRW at the Wilsons River Source Water Pump Station.

The AWTP for this option would be the same as described in Section 10.1, delivering 9.1 ML/d of PRW to the Wilsons River Source Pump Station. The transfer infrastructure to direct PRW to the Wilsons River Source Pump Station would be the same as described in Section 13.1.2 for the Lismore DPR via Raw Water Augmentation option (as shown on sketch SK0102 (Appendix F)).

Flow from the Wilsons River Source Pump Station currently discharges to the head of Nightcap WTP. For this option the flow (consisting of a combination of PRW and pre-treated Wilsons River water) would be disconnected from the feed to Nightcap WTP, but be piped to the northwest end of Rocky Creek Dam (as shown in Figure 25-1). This would require approximately 3 km of DN600 pipe (based on the 35 ML/d capacity of the Wilsons River Source Pump Station) to be installed within Rocky Creek Dam[57].

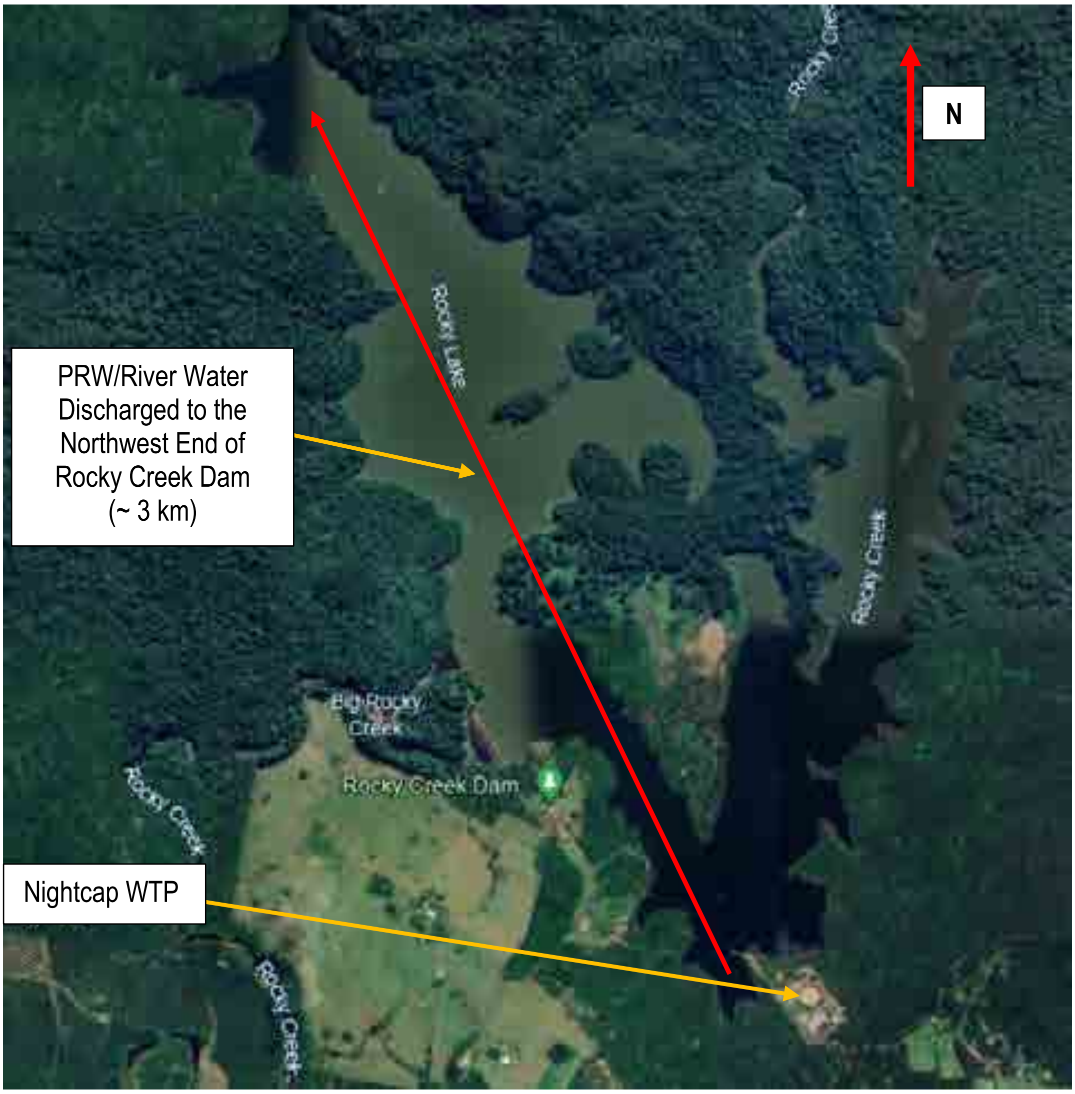

Figure 25-1: PRW/River Water Discharge to Rocky Creek Dam

Table 25-1 compares water quality for Rocky Creek Dam, the Wilsons River Source and PRW.

[57] Velocity in the pipe would be about 1.3 m/s.

Table 25-1: Water Quality Comparison (Rocky Creek Dam, Wilsons River Source and PRW)

Source		Parameter						
		pH	Turbidity	Total Alkalinity	Total Hardness	Total Dissolved Solids	Total Nitrogen	Total Phosphorus
		pH Units	NTU	mg/L as $CaCO_3$	mg/L as $CaCO_3$	mg/L	mg/L	mg/L
Rocky Creek Dam [10]	Minimum	5.7	0.7	10	4	20	0.24	0.05
	5th %ile	6.2	1.3	20	5	27	0.25	0.05
	Median	6.6	2.3	20	6	33	0.33	0.05
	Average	6.7	2.4	20	6	33	0.34	0.05
	95%ile	7.3	3.6	20	7	39	0.49	0.08
	Max	8.7	8.7	21	19	92	0.56	0.18
Wilsons River Source [10]	Minimum	6.1	1	20	10	38	0.15	0.05
	5th %ile	6.6	6.1	20	15	54	0.2	0.05
	Median	7.1	12	26	20	66	0.37	0.06
	Average	7.2	15	27	21	69	0.38	0.09
	95%ile	7.7	34	42	32	95	0.69	0.22
	Max	8.5	174	61	49	120	0.72	0.68
PRW Note 1	Average	7	< 1	110	90	425	3.4	0.5
	95th %ile	-	-	125	100	515	6.1	2.0

Note 1: Values for alkalinity and total hardness are based on sampling programme data shown in Table 5-1 and Table 5-2. Values for TDS are based on historic effluent data shown in Table 5-1 and Table 5-2. Values for total nitrogen and total phosphorus are based on historic effluent data shown in Table 5-2 (it is assumed that new East Lismore STP will have nutrient removal performance at least equal to the performance to the South Lismore STP). PRW pH will be adjusted to a target to be determined (assumed to be 7.0 for the purposes of this investigation). PRW turbidity should always be low due to treatment with ultrafiltration.

Table 25-1 shows that:

- pH in the Wilsons River Source water and PRW is generally higher than in Rocky Creek Dam;
- Turbidity in the Wilsons River Source water is higher than in Rocky Creek Dam and in the PRW is expected to be lower than in Rocky Creek Dam;
- Total alkalinity is, in general, slightly higher in the Wilsons River Source water than in Rocky Creek Dam and is expected to be much higher in the PRW than in Rocky Creek Dam;
- Total hardness is slightly higher in the Wilsons River Source water than in Rocky Creek Dam and is expected to be much higher in the PRW than in Rocky Creek Dam;
- Total dissolved solids are higher in the Wilsons River Source water than in Rocky Creek Dam and are expected to be much higher in the PRW than in Rocky Creek Dam; and
- Median concentration of total nitrogen and total phosphorus are similar in the Wilsons River Source water and in Rocky Creek Dam, but in PRW are expected to be significantly higher.

Detailed modelling of the introduction of Wilsons River Source water and PRW to Rocky Creek Dam would be required to determine the impact and any additional treatment requirements. For the purposes of this investigation, it is assumed that pre-treatment of Wilsons River water would likely include a process to remove suspended solids (e.g. Lamella clarifiers, DAF, high-rate clarification (e.g. Actiflo), etc.).

The allowable extraction rate from Wilsons River ranges from 0 to 30 ML/d depending on the season and the flow conditions in the river. For the purposes of this assessment, it is assumed that the Wilsons River Source pre-treatment system would be designed to treat 25.9 ML/d (the Wilsons River Source Pump Station capacity (35 ML/d), less the amount of PRW supplied by the AWTP (9.1 ML/d)).

Reducing total nitrogen in the PRW to a concentration around 1.5 mg/L is likely achievable with conventional wastewater treatment technology (e.g. nitrification/denitrification moving bed biofilm reactors (MBBRs)) but reducing the total nitrogen to levels similar to that in Rocky Creek Dam would require advanced treatment (e.g. RO). As use of RO for Lismore based schemes has been discounted due to the difficulties related to management of the RO concentrate, this assessment assumes that PRW total nitrogen would be reduced by addition of nitrification and denitrification MBBRs in the AWTP process train (installed upstream of pathogen barriers within the AWTP). As noted above, detailed modelling would be required to determine the impact of this level of total nitrogen entering Rocky Creek Dam.

Reduction of total phosphorus in the PRW could be achieved by addition of a metal salt (e.g. alum) followed by sedimentation. For the purposes of this investigation, it is assumed that a lamella clarifier would be included in the AWTP process train for this purpose, and to remove solids generated by the MBBRs. While it is likely possible to reduce total phosphorus concentration in the PRW to levels similar to that in Rocky Creek Dam, an assessment would need to be conducted to determine the need to meet this concentration and the impact of doing so (e.g. chemical costs, impacts on PRW pH, etc.).

Table 25-2 summarises the potential infrastructure required downstream of the AWTP for this option.

Table 25-2: Level 2 Lismore IPR via Surface Water Augmentation Potential Infrastructure

Item	Description
PRW Transfer to Wilsons River Source Pump Station	Approximately 6.3 km of DN375 PVC pipe and a 90 kW pump station (same systems as for the Level 1 Lismore DPR via raw water augmentation option – refer to SK0102 in Appendix F)
Wilsons River Water Pre-treatment	Solids removal process (e.g. DAF, Actiflo) and likely nitrogen removal via MBBRs – sized for 25.9 ML/d. Would need to be located between Wilsons River Source Low Lift (Intake) Pump Station and the Wilsons River Source High Lift Pump Station. It is anticipated that either upgrade to the Low Lift Pump Station or a new pump station would be required to accommodate the pre-treatment system
Additional PRW Treatment	Treatment for total nitrogen and total phosphorus reduction. Assumed to consist of a nitrification MBBR (including aeration), denitrification MBBR (including mixing and carbon dosing (e.g. methanol), metal salt and polyelectrolyte dosing and a Lamella clarifier (refer to Section 5.4.3 of the *AWTP Process Trains* memorandum (Appendix E) for a description of these processes.
Transfer of PRW/River Water to South End of Rocky Creek Dam	Existing Wilsons River Source Pump Station and pipeline to Nightcap WTP would be utilised to transfer PRW/pre-treated river water to the southern end of Rocky Creek Dam. Existing connection to Nightcap WTP would be disconnected and the pipeline extended to the far northwest end of the dam (as described below).
Transfer of PRW/River Water to Northwest End of Rocky Creek Dam	Approximately 3 km of DN600 DICL pipe installed within Rocky Creek Dam. DICL pipe is assumed for cost approximation. Further investigation would be required to determine the preferred pipe material. The impact of this extra piping on the capacity of the Wilsons RiverSource Pump Station would need to be evaluated.

Table 25-3 summarises provides a high-level approximation of capital costs for this option.

Table 25-3: Level 2 Lismore IPR via Surface Water Augmentation Capital Cost Approximation

Item	Cost	Comments
AWTP	$149m	The AWTP for this option is the same as the AWTP for the Level 1 Lismore IPR via surface water augmentation scheme, with the exception of the addition of MBBRs for nitrogen removal and Lamella clarifiers for phosphorus removal. The additional cost of these unit processes is estimated to be on the order of $20m (estimated from costs developed for these items for the Level 1 Byron scheme using a power factor of 0.6, inclusive of contractor indirect costs, 40% contingency and RCC costs (20%)).
Wilsons River Water Pre-treatment	$20m	The additional cost of a Lamella clarifier for the Wilsons River Source is estimated to be on the order of $20m (estimated from costs developed for these items for the Level 1 Byron scheme using a power factor of 0.6, inclusive of contractor indirect costs, 40% contingency and RCC costs (20%)).
Transfer Infrastructure (to Wilsons River Source Pump Station)	$18m	The infrastructure to transfer PRW from the AWTP to the Wilsons River Source Pump Station would be the same for this option as for the Lismore DPR via raw water augmentation scheme.
Pipe within Rocky Creek Dam	$26m	At a unit cost of $1,724/m for DN600 DICL, the cost of this 3 km pipeline under normal construction conditions would be about $5m. As construction within Rocky Creek Dam would introduce more complexities and associated costs, for the purposes of this investigation the pipeline cost is assumed to be three times this value. Cost includes contract price plus 40% contingency and RCC costs (20%).
Total	$213m	The approximated costs for the additional nitrogen and phosphorus removal, the lamella clarifier for the Wilsons River water and the pipeline within Rocky Creek Dam would align with an AACE Class 5 cost estimate, with an accuracy range of -50% to +100%. Based on this, the range of possible cost for this option would be on the order of $136m to $353m

The main opportunities associated with this option are the utilisation of the existing Wilsons River Source Pump Station and pipeline to Nightcap WTP and the use of Rocky Creek Dam as the environmental buffer storage in lieu of construction of a new buffer storage for the Level 1 Lismore IPR via surface water augmentation option.

However, utilising Rocky Creek Dam for surface water augmentation of PRW produced in Lismore would be complicated by:

- The very high water quality in the dam, which would require detailed analysis and modelling to ascertain the impacts on the prevailing ecology of adding PRW at different temperature, salinity, and nutrient levels.
- The need to mitigate co-mingling of PRW and the Wilsons River Source water, which would impose water quality risks to any proposed surface water augmentation scheme. The Wilsons River Source is not a protected catchment, and therefore any transfer Wilsons River Source water into Rocky Creek Dam would likely be unacceptable.
- The cost and complexity of additional treatment to improve the water quality of the Wilsons River Source water to a level required to make it acceptable for discharge to the Rocky Creek Dam.
- The ownership of the land surrounding the dam, and the associated difficulties in placing new pipework through areas with such high environmental values.
- The potential for additional challenges in discharge of PRW from a carbon-based AWTP to the dam (in the absence of detailed modelling and analysis). The Lismore schemes do not have a clear avenue for brine disposal, making RO-based treatment less viable. For carbon-based treatment there will less ability to mitigate the salt content and nutrient levels of the produced PRW water, and

therefore limited ability to adjust the baseline water quality should the modelling identify it as problematic in terms of the prevailing ecology.

This option was categorised as Level 2 based on the items highlighted above.

25.1.2 Byron IPR via Groundwater Augmentation

This option would direct PRW from a Byron based AWTP to the coastal sand aquifer at Tyagarah. For the purposes of this investigation, it is assumed that the AWTP would be the same as described in Section 10.4 for the Level 1 Byron DPR via treated water augmentation scheme, producing approximately 6.7 ML/d of PRW (utilising the full 2040 ADWF available from Brunswick Valley STP and Byron STP). The infrastructure required to transfer effluent from Brunswick Valley STP to Byron STP would be included in this option.

Rather than being directed to the drinking water network reservoirs, as in the Level 1 Byron DPR via treated water augmentation option, the PRW would be directed to the coastal groundwater aquifer at Tyagarah. This would require approximately 7 km (refer to Figure 25-2) of DN250 PVC pipe[58] and at least two injection wells as a minimum to provide redundancy. More injection wells may be required depending on the hydrogeology of the aquifer. In addition, it is likely that several sampling wells would be required to allow impacts of the PRW on the aquifer (and vice-versa) to be monitored.

Figure 25-2 provides an example of a possible PRW pipeline alignment to convey PRW from the AWTP, proposed to be located adjacent to the Cavanbah Centre in Byron Bay, to the Tyagarah coastal sand aquifer. This pipeline would follow the same alignment for delivery of effluent from Brunswick Valley STP to the Byron based AWTP included in the Level 1 Byron DPR via treated water augmentation scheme (see SK0050 (Appendix F)). From the AWTP, this route follows Ewingsdale Road to Quarry Lane, then runs cross country in a generally north westerly direction towards Tyagarah Airfield, then turns to the north, ending notionally at the Byron Bay Bluesfest venue.

Figure 25-2: Possible Pipeline Alignment to Deliver PRW to Tyagarah Aquifer

A pump station would be required to pump PRW from the AWTP through the pipeline to the injection well site(s). However, the 3 ML PRW reservoir required for the Level 1 Byron DPR via treated water augmentation

[58] Velocity in the pipe would be about 1.5 m/s.

option will not be required for delivery of PRW to the aquifer. It is likely that small reservoirs will be required at the injection well locations to facilitate smooth operation of the system.

The pump station would be required to lift the PRW from the proposed AWTP site (~ 5 m AHD) through the high point of the proposed alignment (~ 35 m AHD), with a total head of about 68 m. The power demand of the pump station size would be on the order of about 65 kW to provide the required lift[59].

New extraction wells and a new drinking water treatment plant would be required to extract and treat groundwater from the aquifer and treat it to required standards prior to discharge to the drinking water network. The level of treatment required would be expected to be low, however this would be dependent on the characteristics of the aquifer and the quality of the natural occurring water therein. The number of extraction wells would need to be determined from detailed hydrogeological modelling.

To deliver the treated groundwater to the drinking water network a pipeline and pump station from the WTP site to St Helena Reservoir would be required. Figure 25-3 shows a potential route for the pipeline.

Figure 25-3: Possible Pipeline Alignment to Deliver Treated Groundwater from Tyagarah Aquifer to St Helena Reservoir

The pipeline route shown in Figure 25-3 follows the same route as shown in Figure 25-2 (in the opposite direction) from Tyagarah to the intersection of Quarry Lane and Ewingsdale Road. From this point the alignment follows the alignment used for delivery of PRW from the Byron based AWTP to St Helena Reservoir included in the Level 1 Byron DPR via treated water augmentation scheme (see SK0050 (Appendix F)), comprising:

- Continuing on Quarry Lane to the intersection with Mcgettigans Lane;
- Then following Mcgettigans Lane to Scenic Vista;
- Then following Scenic Vista and travelling a short distance cross country to Bay Vista Lane; and,
- Then running along Bay Vista Lane before turning in a northeasterly direction and running cross country to the St Helena Reservoir site.

The pipeline to deliver treated groundwater to St Helena Reservoir would be about 10 km in length. To accommodate the high inflow rate to St Helena Reservoir (150 L/s to 200 L/s), effective blending would require a new reservoir to supply the new high lift pump station feeding St Helena Reservoir[60]. For the purposes of

[59] Based on frictional loss of 0.6 m per 100 m of pipe length and pump efficiency of 80%
[60] For the purposes of this investigation a 3 ML reservoir is assumed for storage of treated groundwater prior to pumping to St Helena Reservoir (same assumption as for Level 1 treated water augmentation options).

this assessment, it is assumed that the system would be designed to deliver 150 L/s to St Helena Reservoir [61] Resulting in a DN375[62] pipe size being required.

A total head of approximately 170 m would be required to lift the treated groundwater to St Helena Reservoir (top water level 115.8 m AHD, pump station level assumed to be 5 m AHD), resulting in a pump station power demand of about 311 kW[63]. This total head would require at least a portion of the pipeline to be DICL.

Table 25-4 summarises the potential infrastructure required downstream of the AWTP for this option.

Table 25-4: Level 2 Byron IPR via Groundwater Augmentation Potential Infrastructure

Item	Description
PRW Transfer to Tyagarah coastal sands aquifer	Approximately 7 km of DN300 PVC pipe and a 150 kW pump station (65 kW demand, next largest standard motor size is 75 kW (two pump assumed for redundancy))
Injection Wells	At least two injection wells (to provide redundancy). Actual number would be dependent on detailed hydrogeological modelling.
Sampling Wells	Number of sampling wells (in excess of any existing) would need to be based on detailed hydrogeological modelling and agreed with the appropriate regulatory agencies.
Extraction Wells	Number of extraction wells would need to be based on detailed hydrogeological modelling
Groundwater Treatment Plant	Sized to treat 6.7 ML/d (or potentially higher based on detailed hydrogeological modelling and RCC's needs). Treatment process will be dependent on the characteristics of the aquifer and the quality of the natural occurring water therein, but could be reasonably expected to include some form disinfection.
Transfer of Treated Groundwater to St Helena Reservoir	Approximately 10 km of DN375 pipe (assumed to be DICL for cost approximation) and a 630 kW pump station (311 kW demand, next largest standard motor size is 315 kW (two pump assumed for redundancy)). A reservoir (notionally 3 ML) would be required to store the treated groundwater for pumping to St Helena Reservoir at the designated inflow rate of 150 L/s.

Table 25-5 summarises provides a high-level approximation of capital costs for this option.

[61] Changes to the filling strategy for the reservoir should be investigated in an effort to reduce the size and energy requirement of the pump station if this option is considered further.
[62] Velocity in the pipe would be about 1.2 m/s.
[63] Based on frictional loss of 0.6 m per 100 m of pipe length and pump efficiency of 80%

Table 25-5: Level 2 Byron IPR via Groundwater Augmentation Capital Cost Approximation

Item	Cost	Comments
Brunswick Valley Effluent Transfer Infrastructure	$16m	Based on 17.4 km of DN200 PVC pipe at $366/m, three 60 kW pump stations at $484k each and two 0.5 ML steel reservoirs at $850k each. Cost includes contract price plus 40% contingency and RCC costs (20%).
AWTP	$131m	The AWTP for this option is the same as the AWTP for the Level 1 Byron DPR via treated water augmentation scheme.
Transfer Infrastructure – PRW to Injection Wells	$8m	Based on 7 km of DN300 PVC pipe at $574/m plus 150 kW pump station at $1m. Cost includes contract price plus 40% contingency and RCC costs (20%).
Injection, Sampling and Extraction Wells	$2m	Allowance assuming two injection wells at $300,000 each (well construction and pump), five monitoring wells at $30,000 each and two injection wells at $300,000 each (well construction and pump) plus 50% contingency [44]
Groundwater Treatment Plant	$13m	Assumes media filters and chlorination for a flow of 6.7 ML/d. Based on Byron Level 1 DPR via treated water augmentation pressure vessels and chlorine contact tank (with allowances for building, switchroom and general civil works (roads, fencing, etc.). Cost includes contract price plus 40% contingency and RCC costs (20%).
Transfer Infrastructure – Treated Groundwater to St Helena Reservoir	$24m	Based on a 3 ML reservoir ($2.1m), a 630 kW pump station ($3.1m) and 10 km of DN375 DICL pipe at $920/m. Cost includes contract price plus 40% contingency and RCC costs (20%).
Total	$194m	The approximated costs for all items other than the AWTP would align with an AACE Class 5 cost estimate, with an accuracy range of -50% to +100%. Based on this, the range of possible cost for this option would be on the order of $126m to $314m

None of the groundwater augmentation schemes were considered suitable given the currently available information, hence no groundwater augmentation options were categorised as Level 1. However, as RCC continues its groundwater investigations, the value and feasibility of groundwater replenishment may change.

The use of groundwater is highly regulated by the NSW Government to ensure there is no material impact to the environment. RCC would only consider a groundwater augmentation scheme at Tyagarah if:

- RCC develops a groundwater scheme utilizing the aquifer (i.e. extraction wells and a WTP are constructed to supply the network); and,
- Usage of that groundwater becomes limited by availability of groundwater and/or impact on the environment such that a benefit can be achieved by augmenting supply with PRW.

RCC have indicated that a groundwater scheme at Tyagarah would only proceed if all the assessments and available evidence indicate that groundwater extraction would be sustainable at the flowrate equivalent to expected local demand.

If groundwater extraction from the Tyagarah aquifer becomes a significant source of water for the region, and it is found that there is insufficient allocation available within the aquifer for the future water supply required and/or the required extraction rate introduces impacts on the environment, benefit may be achieved through replenishment of the aquifer with PRW.

25.1.3 Byron IPR via Surface Water Augmentation

This option would direct approximately 6.7 ML/d (78 L/s) of PRW from a Byron based AWTP to Rocky Creek Dam. For the purposes of this investigation, it is assumed that the AWTP would be the same as described in

Section 10.4 for the Level 1 Byron DPR via treated water augmentation scheme. The infrastructure required to transfer effluent from Brunswick Valley STP to Byron STP would be included in this option.

Similar to the option described in Section 25.1.1, PRW would be directed to the northwest end of Rocky Creek Dam via a pipeline installed within the dam. This option would not change the current supply arrangement of Wilsons River water to Nightcap WTP.

Figure 25-4 shows a potential pipeline alignment for transfer to PRW from the AWTP.

The alignment shown in Figure 25-4 is approximately 37 km in length and traverses the following roads:

- Ewingsdale Road;
- Myocum Road;
- Possum Shoot Road;
- Coorabell Road;
- Binna Burra Drive;
- Federal Drive;
- Whian Road;
- Eureka Road;
- Repentance Creek Road;
- Dunoon Road; and,
- Rocky Creek Dam Road.

Figure 25-4: Potential Pipeline Alignment for Level 2 Byron IPR via Surface Water Augmentation Scheme

The pipeline would continue within Rocky Creek Dam to the northwest end, as shown in Figure 25-5.

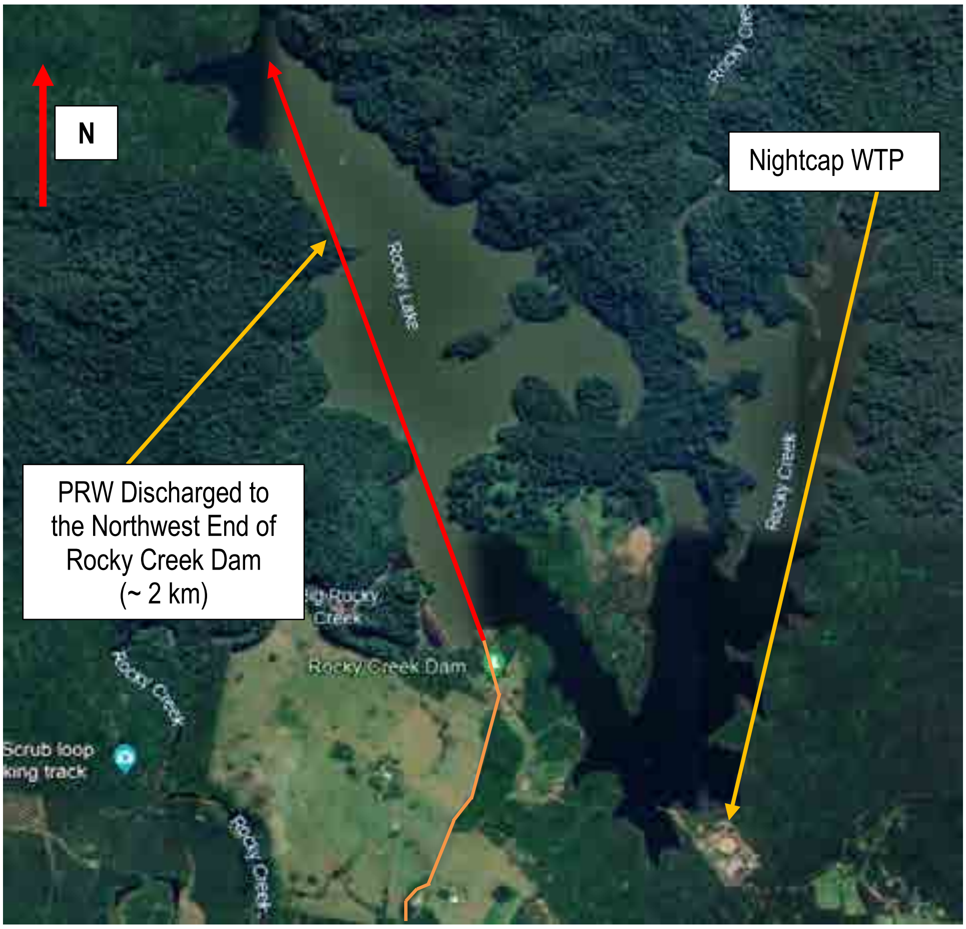

Figure 25-5: PRW River Water Discharge to Rocky Creek Dam

A pump station would be required to lift the PRW from the proposed AWTP site (~ 5 m AHD) to Rocky Creek Dam (~ 187 m AHD, based on water level of 95% in the dam). The pump station power demand would be about 400 kW to provide the required lift[64], based on a total head of approximately 416 m[65]. The pipe would be DN300[66], with the high head necessitating the use of DICL (or other appropriately pressure rated pipe).

Table 25-6 compares average water quality in Rocky Creek Dam to typical PRW quality for an RO-based AWTP (based on data from Luggage Pont AWTP [45]).

[64] Based on frictional loss of 0.6 m per 100 m of pipe length and pump efficiency of 80%.
[65] It is likely that more detailed analysis and further consideration of design basis could reduce the total head and pump station size.
[66] Velocity in the pipe would be about 0.9 m/s.

Table 25-6: Comparison of Average Rocky Creek Dam Water to Typical RO-Based PRW

Source	Parameter						
	pH	Turbidity	Total Alkalinity	Total Hardness	Total Dissolved Solids	Total Nitrogen	Total Phosphorus
	pH Units	NTU	mg/L as $CaCO_3$	mg/L as $CaCO_3$	mg/L	mg/L	mg/L
Rocky Creek Dam [10]	6.7	2.4	20	6	33	0.34	0.05
PRW Note 1	7.9	0.5	66	67	114	0.33	0.006

Note 1: Based on average PRW quality from Luggage Point AWTP [45]

Table 25-6 shows:

- pH, total alkalinity, total hardness and total dissolved solids could be expected to be higher in the PRW than in Rocky Creek Dam
- Total nitrogen levels could be expected to be similar in Rocky Creek Dam and in the PRW; and,
- Total phosphorus in the PRW could be expected to be lower than the level in Rocky Creek Dam.

Detailed modelling would be required to confirm the expected PRW quality, noting that pH, total alkalinity, total hardness and total dissolved solids in the PRW would be significantly impacted by the approach to stabilization of the PRW post RO treatment.

Additionally, detailed modelling would be required to determine the impact of the introduction of PRW to Rocky Creek Dam.

Table 25-7 summarises the potential infrastructure required downstream of the AWTP for this option.

Table 25-7: Level 2 Byron IPR via Surface Water Augmentation Potential Infrastructure

Item	Description
PRW Transfer to Rocky Creek Dam	Approximately 37 km of DN300 pipe (likely DICL in the lower sections and PVC where total head reduces below 160 m) and an 800 kW pump station (396 kW demand, next largest standard motor size is 400 kW (two pump assumed for redundancy)).
Transfer of PRW/River Water to Northwest End of Rocky Creek Dam	Approximately 2 km of DN300 pipe installed within Rocky Creek Dam. DICL pipe is assumed for cost approximation. Further investigation would be required to determine the preferred pipe material.

Table 25-8 summarises provides a high-level approximation of capital costs for this option.

Table 25-8: Level 2 Byron IPR via Surface Water Augmentation Capital Cost Approximation

Item	Cost	Comments
Brunswick Valley Effluent Transfer Infrastructure	$16m	Based on 17.4 km of DN200 PVC pipe at $366/m, three 60 kW pump stations at $484k each and two 0.5 ML steel reservoirs at $850k each. Cost includes contract price plus 40% contingency and RCC costs (20%).
AWTP	$131m	The AWTP for this option is the same as the AWTP for the Level 1 Byron DPR via treated water augmentation scheme.
Transfer Infrastructure – PRW to Rocky Creek Dam	$48m	Based on an 800 kW pump station ($3.8m) and 37 km of DN300 DICL pipe at $667/m. Cost includes contract price plus 40% contingency and RCC costs (20%).
Pipe within Rocky Creek Dam	$7m	At a unit cost of $667/m for DN300 DICL, the cost of this 2 km pipeline under normal construction conditions would be about $1.3m. As construction within Rocky Creek Dam would introduce more complexities and associated costs, for the purposes of this investigation the pipeline cost is assumed to be three times this value. Cost includes contract price plus 40% contingency and RCC costs (20%).
Total	$201m	The approximated costs for all items other than the AWTP would align with an AACE Class 5 cost estimate, with an accuracy range of -50% to +100%. Based on this, the range of possible cost for this option would be on the order of $129m to $329m

As indicated in Section 25.1.1, there are several challenges associated with introduction of PRW to Rocky Creek Dam that led to no options utilising this approach to be short-listed. This option has an advantage over the Lismore Level 2 IPR via surface water augmentation scheme with respect to the water quality characteristics of the PRW (i.e. lower TDS, likely lower nutrients, etc.).

However, the main disadvantage of this option as compared to the Lismore Level 2 IPR via surface water augmentation scheme is the need to construct 37 km of pipeline and an 800 kW pump station (where the infrastructure to lift flow to Rocky Creek Dam is already in place for the Lismore option by utilizing the Wilsons River Source pump Station and associated pipeline to Nightcap WTP).

25.1.4 Ballina DPR via Raw Water Augmentation

This option would direct PRW from a Ballina based AWTP to the head of Emigrant Creek WTP. Effluent would be sourced from Lennox Head WWTP and Ballina WWTP. The 2040 ADWF for Lennox Head WWTP is estimated to be 5.3 ML/d and for Ballina WWTP 8.1 ML/d.

The current Emigrant Creek WTP actual capacity is 6.5 ML/d, delivering drinking water to Knockrow Reservoir. The 2040 Knockrow Reservoir demand is estimated to be 13.2 ML/d.

Lennox Head WWTP effluent has relatively low TDS, on the order of 250 mg/L to 450 mg/L and therefore either a carbon-based or RO-based AWTP could be used if only Lennox Head WWTP effluent is used. Ballina WWTP has higher TDS, on the order of 1,000 mg/L to 2,000 mg/L, which would require an RO-based AWTP to provide the TDS reduction necessary to achieve the aesthetic drinking water target of 600 mg/L.

A Ballina RO-based plant could produce up to 10.7 ML/d, based on an 80% RO recovery. The actual size of the AWTP would depend on the blend ratio adopted by RCC. If 10.7 ML/d of PRW were supplied the blend ratio would be about 80% (based on the 2040 Knockrow Reservoir demand, assuming no supply to Knockrow Reservoir from Nightcap WTP). If the blend ratio were limited to say 50%, the amount of PRW supplied would be about 6.6 ML/d.

To supply the 2040 Knockrow Reservoir demand from Emigrant Creek WTP, the capacity of the plant would need to be doubled. The Emigrant Creek WTP site is very constrained, making any upgrade to the plant complex and expensive.

For the purposes of this investigation, the blend ratio is assumed to be 50%. This would result in an AWTP of about the same capacity as the Byron DPR via treated water augmentation Level 1 scheme.

Effluent from Ballia WWTP would be pumped to an AWTP located at Lennox Heads. Assuming a peaking factor of 1.2 times ADWF (based on drawing from the Ballina WWTP effluent lagoon), the pump station and pipeline would need to be sized for 9.7 ML/d (113 L/s). Figure 25-6 shows a possible pipeline route.

Figure 25-6: Possible Pipeline Alignment to Deliver Effluent from Ballina WWTP to an AWTP Located at Lennox Head WWTP

The alignment shown in Figure 25-6 is approximately 12 km in length, with general pipeline route being:

- Exiting the Ballina WWTP site, travelling northeast to Ferngrove Drive;
- Following Ferngrove Drive to Tamarind Drive;
- Turning onto Tamarind Drive and travelling in a southeasterly direction to Angels Beach Drive;
- Following Angels Beach Drive to The Coast Road;
- Running in a generally northerly direction to Skennars Head Road;
- Following Skennars Head Road to North Creek Road;
- Travelling in a generally southerly direction to the access road to Lennox Head WWTP; and,
- Following the access road to a notional stopping point at the mid-point of the largest effluent lagoon.

A pump station would be required to lift the effluent from the Ballina WWTP site (~ 2 m AHD) to the proposed AWTP site at Lennox Head WWTP, passing through a high point on The Coast Road of about 42 m AHD). The pump station size power demand would be about 124 kW to provide the required lift[67], based on a total head of approximately 113 m. The piping would be DN300 PVC[68].

[67] Based on frictional loss of 0.6 m per 100 m of pipe length and pump efficiency of 80%
[68] Velocity in the pipe would be about 1.5 m/s.

PRW from an AWTP located at Lennox Head would be pumped to the head of Emigrant Creek WTP. The pump station and pipeline would need be sized for 6.6 ML/d (76 L/s)[69]. Figure 25-7 shows a possible pipeline route.

Figure 25-7: Possible PRW Pipeline Route from Lennox Head Based AWTP to Emigrant Creek WTP

The alignment shown in Figure 25-7 is approximately 18 km in length, with general pipeline route being:

- Exiting the Lennox Head site via the WTP Access Road to North Creek Road;
- Travelling north on North Creek Road to Byron Bay Road;
- Following Byron Bay Road in a northerly direction to Ross Lane;
- Travelling west on Ross Lane to Tamarind Drive;
- Following a generally southerly on Tamarind Drive to Tintenbar Road;
- Turning west on Tintenbar Road to Friday Hut Road: and,
- Following Friday Hut Road to the north to the access road to Emigrant Creek WTP.

A pump station would be required to lift the PRW from the proposed AWTP site (~ 2 m AHD) to Emigrant Creek WTP (~ 70 m AHD). The pump station size power demand would be about 133 kW to provide the

[69] Based on a 50% blend ratio, 6.6 ML/d of PRW would be required to meet the 2040 Knockrow Reservoir demand. The RO-based AWTP developed for the Level 1 Byron DPR via treated water augmentation option is designed to produce 6.7 ML/d of PRW, hence the layout and design information developed for the Level 1 Byron DPR via treated water augmentation option could be reference here if this option we to be considered further.

required lift[70], based on a total head of approximately 177 m[71]. The high head would necessitate the use of DICL (or other appropriately pressure rated pipe) for at least some portion of the pipeline. The pipe diameter would be DN250[72].

Table 25-9 compares average water quality in the feed to Emigrant Creek WTP to typical PRW quality for an RO-based AWTP (based on data from Luggage Pont AWTP [45]).

Table 25-9: Comparison of Average Feed Water to Emigrant Creek Dam Typical RO-Based PRW

Source	Parameter				
	pH	Turbidity	Total Alkalinity	Total Hardness	Total Dissolved Solids
	pH Units	NTU	mg/L as $CaCO_3$	mg/L as $CaCO_3$	mg/L
Emigrant Creek Dam	6.8	5.0	22	19	65
PRW Note 1	7.9	0.5	66	67	114

Note 1: Based on average PRW quality from Luggage Point AWTP [45]

Table 25-9 shows that pH, total alkalinity, total hardness and total dissolved solids could be expected to be higher in the PRW than in feed to the WTP from Emigrant Creek Dam, while turbidity in the PRW could be expected to be lower.

Detailed modelling would be required to confirm the expected PRW quality, noting that pH, total alkalinity, total hardness and total dissolved solids in the PRW would be significantly impacted by the approach to stabilization of the PRW post RO treatment.

Detailed modelling would be required to determine the impact of the introduction of PRW to Emigrant Creek WTP and any process changes or upgrades that would be required for the WTP.

As the AWTP needs to be RO-based for treatment of effluent from Ballina, a means of managing RO concentrate would be required. For the purposes of this investigation, it is assumed that the RO concentrate would be discharged at the current Lennox Head WWTP discharge point. Further investigation, detailed modelling and consultation with the Regulator would be required to determine an approvable location for discharge of RO concentrate and any design features (e.g. diffusers) that may be required.

Table 25-10 summarises the potential infrastructure required for this option.

Table 25-10: Level 2 Ballina DPR via Raw Water Augmentation Potential Infrastructure

Item	Description
Effluent Transfer from Ballina WWTP to AWTP Located at Lennox Head WWTP	Approximately 12 km of DN250 PVC pipe and a 264 kW pump station (124 kW demand, next largest standard motor size is 132 kW (two pump assumed for redundancy)).
RO-based AWTP	Assume same RO plant as for Level 1 Byron DPR via treated water augmentation scheme (producing 6.6 ML/d of PRW)
PRW Transfer from AWTP to Emigrant Creek WTP	Approximately 18 km of DN250 DICL pipe and a 264 kW pump station (133 kW demand, assumes 132 kW motor will be sufficient (two pump assumed for redundancy)).
Emigrant Creek WTP Upgrades	An upgrade to double the capacity of Emigrant Creek WTP would be required. Further upgrades and/or process modifications may be required based on differences in feed water quality with introduction of PRW (detailed modelling would be required to determine).

Table 25-11 summarises provides a high-level approximation of capital costs for this option.

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70 Based on frictional loss of 0.6 m per 100 m of pipe length and pump efficiency of 80%.
71 It is likely that more detailed analysis and further consideration of design basis could reduce the total head and pump station size.
72 Velocity in the pipe would be about 1.4 m/s.

Table 25-11: Level 2 Ballina DPR via Raw Water Augmentation Capital Cost Approximation

Item	Cost	Comments
Transfer Infrastructure – Effluent from Ballina WWTP to Lennox Head WWTP	$12m	Based on a 264 kW pump station ($1.5m) and 12 km of DN250 PVC pipe at $460/m. Cost includes contract price plus 40% contingency and RCC costs (20%).
AWTP	$131m	The AWTP for this option is the same as the AWTP for the Level 1 Byron DPR via treated water augmentation scheme.
Transfer Infrastructure – PRW from AWTP (located at Lennox Head WWTP) to Emigrant Creek WTP	$19m	Based on a 264 kW pump station ($1.5m) and 18 km of DN250 DICL pipe at $552/m. Cost includes contract price plus 40% contingency and RCC costs (20%).
Total	$162m	The approximated costs for all items other than the AWTP would align with an AACE Class 5 cost estimate, with an accuracy range of -50% to +100%. Based on this, the range of possible cost for this option would be on the order of $107m to $258m. **This total does not include costs for upgrades that would be required at Emigrant Creek WTP.**

This option was not included in the short-listed options based on:

- The high target for utilisation of source water for non-potable reuse by Ballina Shire Council; and
- Limited site area at existing Emigrant Creek WTP making significant upgrades to the plant complex and expensive. Augmentation to the WTP as required to maintain existing secure yield from Emigrant Creek Dam would likely challenging.

It is not possible to provide a reasonable estimate for upgrades to Emigrant Creek WTP without further investigations. Therefore, the **costs shown in Table 25-11 do not include costs associated with upgrading Emigrant Creek WTP**.

25.1.5 Ballina DPR via Treated Water Augmentation

This option would direct PRW from a Ballina based AWTP to the Knockrow Reservoir. The effluent sources and AWTP would be the same as described in Section 25.1.4 for the Ballina DPR via raw water augmentation option, hence Section 25.1.4 can be referred to for descriptions of these items.

PRW from an AWTP located at Lennox Head would be pumped to the Knockrow Reservoir to achieve a 50% blend ratio (matching the assumption for the Ballina DPR via raw water augmentation option). The inflow rate to Knockrow Reservoir is either 135 L/s or 200 L/s, depending on which of the two inlet lines (DN150 and DN300) is used. Based on the selected blend ratio of 50%, for the purposes of this investigation, the pump station and pipeline design flow is assumed to be 100 L/s (50% of the peak inflow to Knockrow Reservoir). Figure 25-8 shows a possible pipeline route.

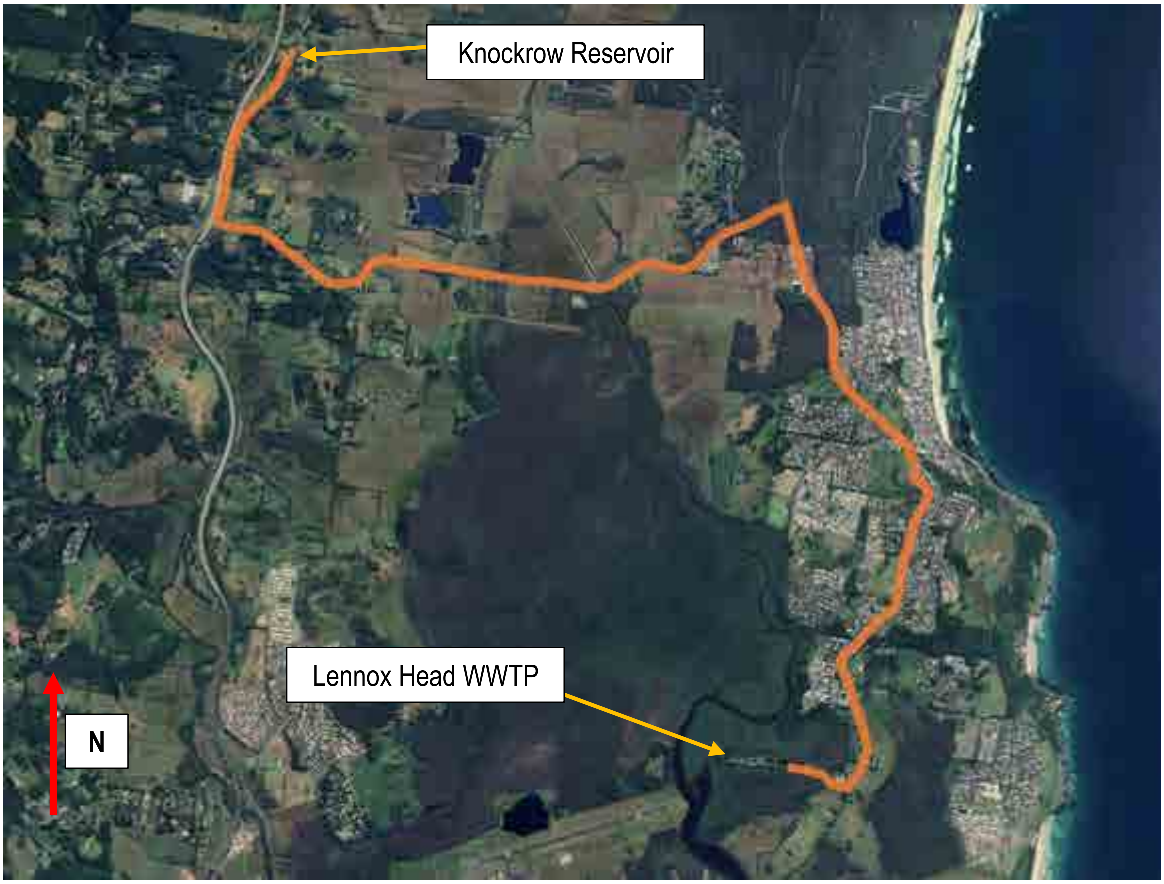

Figure 25-8: Possible PRW Pipeline Route from Lennox Head Based AWTP to Knockrow Reservoir

The alignment shown in Figure 25-8 is approximately 14 km in length, with general pipeline route being:

- Exiting the Lennox Head site via the WTP Access Road to North Creek Road;
- Travelling north on North Creek Road to Byron Bay Road;
- Following Byron Bay Road in a northerly direction to Ross Lane;
- Travelling west on Ross Lane to Hinterland Drive; and,
- Travelling north on Hinterland Drive to Knockrow Reservoir.

To accommodate the high inflow rate to Knockrow Reservoir (100 L/s) a reservoir would be required to supply the new high lift pump station feeding Knockrow Reservoir[73].

A total head of approximately 187 m would be required to lift the PRW to Knockrow Reservoir (top water level 104.8 m AHD, pump station level assumed to be 2 m AHD), resulting in a pump station power demand of about 185 kW[74]. Based on delivery of 100 L/s, the pipe would need to be DN300[75], with the pipe material being DICL in the lower section and potentially transitioning to PVC where total head drops below the 160 m threshold.

As the AWTP needs to be RO-based for treatment of effluent from Ballina, a means of managing RO concentrate would be required. For the purposes of this investigation, it is assumed that the RO concentrate would be discharged at the current Lennox Head WWTP discharge point. Further investigation, detailed

[73] Changes to the filling strategy for the reservoir should be investigated in an effort to reduce the size and energy requirement of the pump station if this option is considered further.
[74] Based on frictional loss of 0.6 m per 100 m of pipe length and pump efficiency of 80%.
[75] Velocity in the pipe would be about 1.1 m/s.

modelling and consultation with the Regulator would be required to determine an approvable location for discharge of RO concentrate and any design features (e.g. diffusers) that may be required.

Flow meters and control valves will need to be installed in the new PRW line and the existing drinking water supply line to allow for control of blend ratio at the inlet to Knockrow Reservoir.

Table 25-12 summarises the potential infrastructure required downstream of the AWTP for this option.

Table 25-12: Level 2 Ballina DPR via Treated Water Augmentation Potential Infrastructure

Item	Description
Effluent Transfer from Ballina WWTP to AWTP Located at Lennox Head WWTP	Approximately 12 km of DN250 PVC pipe and a 264 kW pump station (124 kW demand, next largest standard motor size is 132 kW (two pump assumed for redundancy)).
RO-based AWTP	Assume same RO plant as for Level 1 Byron DPR via treated water augmentation scheme (producing 6.6 ML/d of PRW)
PRW Transfer from AWTP to Knockrow Reservoir	Approximately 14 km of DN300 DICL and a 400 kW pump station (183 kW demand, next largest standard motor size is 200 kW (two pump assumed for redundancy)). A reservoir (notionally 3 ML) would be required to store PRW for pumping to Knockrow Reservoir at the designated inflow rate of 100 L/s.

Table 25-13 summarises provides a high-level approximation of capital costs for this option.

Table 25-13: Level 2 Ballina DPR via Treated Water Augmentation Capital Cost Approximation

Item	Cost	Comments
Transfer Infrastructure – Effluent from Ballina WWTP to Lennox Head WWTP	$12m	Based on a 264 kW pump station ($1.5m) and 12 km of DN250 PVC pipe at $460/m. Cost includes contract price plus 40% contingency and RCC costs (20%).
AWTP	$131m	The AWTP for this option is the same as the AWTP for the Level 1 Byron DPR via treated water augmentation scheme.
Transfer Infrastructure – PRW from AWTP (located at Lennox Head WWTP) to Emigrant Creek WTP	$23mM	Based on a 400 kW pump station ($1.5m), 14 km of DN300 DICL pipe at $552/m and a 3 ML steel reservoir. Cost includes contract price plus 40% contingency and RCC costs (20%).
Total	$165m	The approximated costs for all items other than the AWTP would align with an AACE Class 5 cost estimate, with an accuracy range of -50% to +100%. Based on this, the range of possible cost for this option would be on the order of $108m to $265m.

This option was not included in the short-listed options – primarily due to the high target for utilisation of source water for non-potable reuse by Ballina Shire Council. Another disadvantage of this option is that PRW is only distributed to one LGA.

26 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendation can be drawn from the PRW Investigations:

1. Of forty potential potable reuse scheme options initially identified, the short-listing process:
    - Identified four scheme options, for full quantitative and qualitative development (Level 1 assessment); and,
    - Carried forward a further five scheme options to be partially developed for consideration at a high level (Level 2 assessment)

   The four Level 1 scheme options comprised one IPR option (including an Engineered Environmental Buffer Storage), and three DPR options based on Raw Water Augmentation and Treated Water Augmentation.
2. Minimum pathogen LRV requirements were derived in detail to support conceptual AWTP design and sensitivity analyses. While the actual minimum pathogen LRV requirements applied to any scheme which is progressed would need to be the subject of consultation and agreement with the Regulator the values derived are considered well supported and suitable for the purposes of option development, assessment and evaluation in line with the goals of the PRW Investigations.
3. All process trains presented meet minimum pathogen LRV requirements to meet the drinking water target of 10^{-6} DALY;
4. “Excess LRVs” have been included in the pathogen reduction requirements exclusively for the purpose of considering “worst case” scenarios in AWTP scope and costs. These are not considered necessary for the management of pathogen risks in the opinion of the project team. The final minimum pathogen LRV requirements used in design of the AWTP (which will be subject to consultation and agreement with regulators) should be based on pathogen barrier failure modelling with consideration of:
    - The LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere);
    - The failure mode of each unit process (i.e. instantaneous, such as disinfectant dosing system failure, or gradual such as loss of UF membrane integrity which normally occurs slowly and can be observed through monitoring PDT trends;
    - The response time of online analysers used for CCPs;
    - The reliability and redundancy provided for these analysers (including consideration of the maintenance strategy for the analysers and the frequency of calibration);
    - The use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk; and,
    - Other design features used to mitigate risk (e.g. use of “off spec” diversions at CCP alert levels, use of Engineered Storage Buffer Tanks to allow for capture and diversion of water produced between analyser readings, etc.).
5. The process trains developed for each of the short-listed options provide a reasonable basis on which to develop costs and site area requirements. Significant additional work will be required to verify the Claimed LRVs for pathogens, including confirming validated LRVs for equipment selected during design (e.g. UV disinfection) and confirming Claimed LRVs by testing in a demonstration AWTP (e.g. LRVs claimed for direct filtration via BAC). The claimed pathogen LRVs would also likely be subject to onsite validation (e.g. challenge testing) and verification testing (e.g. water quality sampling) during commissioning of the plant prior to regulatory approval to add PRW to the drinking water supply.
6. A high-level chemical risk assessment indicated that, each of the proposed scheme options can generally be expected to provide good control of chemical risk in the proposed catchments. The high-level chemical risk assessment did not identify any issues that would drive inclusion of additional chemical barriers in the conceptual process trains discussed in Section 10.

7. If any scheme option is progressed, further assessment of chemical risk will need to be conducted using catchment specific source sampling and monitoring data. The approach described in the *Chemical Risk Assessment Memorandum* (Appendix D) can be used to guide the future detailed QCRA. Further investigations required to support a future detailed chemical risk assessment would include, but not be limited to:
   - Source characterisation;
   - Development of an enhanced source water control program (including a detailed study of all dischargers and the chemicals they use that could end up in the sewer);
   - Demonstration plant testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water and their removal through the various unit processes within the demonstration plant; and
   - Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available.
8. Based on the high-level chemical risk assessment, PFAS appears to be a broad concern for all proposed treatment trains. This concern is driven almost solely by the risk to human health posed by these compounds (rather than the capability of the AWTP process trains to remove PFAS). A further concern is the origin of PFAS. While landfill leachate may contribute a significant load, it is equally possible that a substantial PFAS load originates from households. If any scheme option is progressed, it is recommended that chemical characterisation of leachate be compared to raw wastewater to determine the potential extent of contamination for this source for any schemes carried forward for further consideration. If leachate is shown to be a significant contributor of chemical load, then segregation from a potable reuse scheme or enhanced point source treatment may be more effective than addition of further unit operations to the potable reuse treatment train.
9. An assessment of chemicals of industrial concern in the raw wastewater should be conducted for any schemes carried forward for further consideration to better understand if these industries contribute significantly to chemical load. While chemical risk is highly specific to individual catchments, the high-level analysis of the catchments (i.e. lower percentage trade waste, limited heavy industry) gives some indication that risks could be similar to or lower than a typical catchment.
10. The source characterisation sampling program, to be developed if any scheme option is progressed, should prioritise targeting health and environmental risks, and should be designed to assist in the development of surrogates for routine PRW quality monitoring.
11. Based on the information in hand, RO-based treatment is not recommended for the Lismore based scheme options as:
    - Lismore is remote from saline waterways which likely to be able to receive discharges of RO concentrate;
    - Evaporation ponds are not a feasible means of managing RO concentrate for a Lismore based scheme based on climatic conditions;
    - Alternative forms of RO concentrate treatment (e.g. zero liquid discharge) would impose substantial additional costs, complexity, and resource demands on any scheme; and,
    - The TDS in South and East Lismore STP effluent is low enough to enable carbon-based treatment for the Lismore scheme options. However, under this approach, the blend ratio of PRW generated under a Lismore DPR via treated water augmentation scheme with bulk potable water from Nightcap WTP needs to be limited to 50% to maintain drinking water TDS at acceptable levels.

    This conclusion may be reconsidered if local discharge of RO concentrate to the Wilson River were investigated and found to be acceptable.

12. The Byron DPR via treated water augmentation scheme is RO-based owing to the ability to discharge brine to sufficiently saline waters. However, the Byron and Brunswick Valley STP effluent is low enough in TDS for either RO-based or carbon-based treatment to be considered for this scheme option.
13. If any scheme option is progressed, it is strongly recommended that a demonstration plant be developed and utilised for the following (as appropriate for the specific project needs):
    - Verification that the Claimed LRVs for pathogens can be achieved;
    - Testing of alternative process configurations and/or different vendor equipment (e.g. UF membranes) to optimise performance and/or costs;
    - Verification of chemical occurrence and removal performance;
    - Providing an opportunity to review performance data with stakeholders – Regulators in particular;
    - Establishing initial setpoints for plant control – in particular CCPs (noting that the applicability of these setpoint to the full scale AWTP would need to be verified);
    - Enabling hands on training for all personnel expected to be involved in operation, maintenance and management of the scheme (with particular importance for operations staff);
    - Providing an opportunity for community engagement and education (e.g. the demonstration plant could also include a visitor centre).

    The demonstration plant should be designed to adequately simulate the intended full-scale design and be designed with sufficient flexibility to trial different configuration of the process units (where appropriate), different flow rates, etc.

    A demonstration plant plan should be developed in conjunction with the design, to ensure the design incorporates the features required to execute the plan. The demonstration plant plan and design should be reviewed with relevant stakeholders, in particular operations staff and the Regulator.
14. If any scheme option is progressed, future investigations likely to be required include:
    - Source characterisation;
    - Assessment of Rous County Council institutional capacity;
    - Enhanced source control;
    - Land acquisition, easements, cultural heritage, native title and environmental issues;
    - Procurement and funding options;
    - Electrical supply;
    - Engineered Environmental Buffer Storage options (for Lismore IPR via surface water augmentation option);
    - RO concentrate discharge (for Byron DPR via treated water augmentation option);
    - Impacts on existing infrastructure;
    - Treated water blending (for treated water augmentation options);
    - Design, construction and operation of a demonstration plant;
    - AWTP and transfer infrastructure design; and
    - Refinement of cost estimates.

    Additional investigations may become required as the planning develops.

15. If a potable reuse scheme option is progressed, there are currently two options in relation to achieving regulatory approval:
    - Following the existing AGWR framework and demonstrating to the regulator that sufficient mechanisms and controls are provided such that public health is protected; or,
    - Waiting for update of the AGWR framework (or other relevant guidelines) to incorporate DPR, and development of NSW specific guidance on how the requirements will be applied in NSW for potable reuse.

    RCC have indicated that seeking approval under the first approach would not be considered without explicit support and endorsement from NSW Health and NSW Department of Climate Change, Energy, the Environment and Water. It is noted that development of national DPR guidelines is largely outside of RCC's sphere of influence.

    Gaining regulatory approval by following the existing AGWR framework is estimated to have a minimum timeline on the order of nine years.

16. Cost estimation and analysis of the four short-listed schemes indicated that the Lismore DPR via raw water augmentation scheme option represents the best value on a commercial basis, with:
    - Lowest specific capital cost ($16.3m per ML/d of PRW production capacity) estimate indicates the Lismore DPR via raw water augmentation scheme provides the highest value;
    - Second lowest absolute capital cost ($148m). The Lismore DPR via treated water augmentation scheme option has the lowest estimated capital cost ($135m), with the estimated capital cost of the Lismore DPR via raw water augmentation scheme option approximately 10% higher;
    - Lowest estimated specific whole of life cost (NPC[76] of $19.8m per ML/d of PRW produced at design production rate).
    - Second lowest absolute whole-of life cost (NPC of $180m). The Lismore DPR via treated water augmentation scheme option has the lowest estimated NPC ($169m), with the estimated NPC of the Lismore DPR via raw water augmentation scheme option approximately 6% higher.
    - Lowest specific operations and maintenance cost ($1.31 per kL). The Lismore IPR via surface water augmentation scheme option had similar specific operations and maintenance cost ($1.33 per kL).

17. Multiple criteria assessment was applied to the four short-listed options based on the assumption that approval of DPR can be viably achieved in the required timeframe. The assessment indicated that the Lismore DPR via raw water augmentation scheme would have the highest preference. With the short-listed scheme options broadly similar in terms of non-cost criteria, this preferred status is largely the result of the favourable whole-of-life cost.

Overall, it is recommended that the Purified Recycled Water for Drinking Water Investigations be used to inform the following ongoing and future work as applicable:

- **Utilisation in Future Water Project:** The study has identified and developed suitable scheme options to facilitate comparison of PRW to other potential sources of bulk water as a part of RCC's Future Water Project. To support this comparison, the secure yield offered by the PRW scheme options should be determined by water balance modelling, then compared in terms of overall value to alternative approaches to meeting the region's projected bulk water demand.
- **Utilisation in development of one or more PRW schemes:** If PRW is to be progressed as a source, the findings and outputs of this study should be used as a reference and guide to inform future work.

[76] NPC based on 40 years, 5% discount rate and 0% inflation

The validity of the assumptions applied need to be confirmed, including ongoing developments in potable reuse.

- **Utilisation as a model for other regional areas as applicable:** While this study is highly specific to the requirements and attributes of the RCC service area, the *Purified Recycled Water for Drinking Water Investigations* may provide insights to inform the identification, development and assessment of PRW options at a planning-level in the context of other areas of regional Australia.

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APPENDIX A: POTABLE REUSE SCHEME IDENTIFICATION AND SHORT-LISTING MEMORANDUM

Rous County Council
Purified Recycled Water for Drinking Investigations
Memorandum - Potable Reuse Scheme Identification and Short-Listing

Revision	Date	Description	Prepared by	Reviewed by
A	July 4, 2023	Draft for Discussion (Workshop Briefing)	Ryan Schwartz, David Fligelman	David Fligelman
B	November 20, 2023	Draft for Review	Ryan Schwartz, David Fligelman, Andrew Findlay	David Fligelman
C	February 13, 2024	Updated with Client Comments	Ryan Schwartz, David Fligelman, Andrew Findlay	David Fligelman

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ABBREVIATIONS

AADD	Annual Average Daily Demand
AAL	Average Annual Load
ADD	Average Daily Demand
ADWF	Average Dry Weather Flow
ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AWTP	Advanced Water Treatment Plant
BNR	Biological Nutrient Removal
BOD	Biological Oxygen Demand
CCPs	Critical Control Points
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DPR	Direct Potable Reuse
EFS	Environmental Flow Substitution
EP	Equivalent Population
GWA	Groundwater Augmentation
ICOLLs	Intermittently Closed and Open Lakes and Lagoons
IPR	Indirect Potable Reuse
IWCM	Integrated Water Cycle Management
LGA	Local Government Area
MBR	Membrane Bioreactor
PDD	Peak Daily Demand
PRW	Purified Recycled Water
PST	Primary Sedimentation Tank
PWWF	Peak Wet Weather Flow
SRT	Sludge Retention Time (Sludge Age)
RCC	Rous County Council
RO	Reverse Osmosis
RWA	Raw Water Augmentation
STP	Sewage Treatment Plant
SWA	Surface Water Augmentation
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TWA	Treated Water Augmentation
WRSPS	Wilsons River Source Pump Station
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

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1 BACKGROUND

Rous County Council (RCC) is responsible for the bulk supply of potable water to the Lismore, Ballina, Byron, and Richmond Valley Local Government Areas (LGAs). RCC has undertaken extensive assessment through the Future Water Project 2060 to identify additional water supplies to provide long-term water security to the region.

RCC's Integrated Water Cycle Management Strategy (IWCM, 2022) collated the findings of the investigations undertaken to date, including consideration of a range of configurations for utilising recycled water as undertaken in a preliminary feasibility investigation. RCC identified that this preliminary feasibility study (and hence the IWCM strategy) did not consider methods for implementation of all potential configurations for utilising recycled water, including the omission of options based on groundwater augmentation and direct potable reuse, and utilisation of options using effluent from Byron Shire Council's effluent streams.

On the basis of this review, RCC identified that purified recycled water (PRW) should be further investigated as a potential source of bulk water. As the initial task of the PRW investigations, a comprehensive approach has been pursued to identify all potential options potable reuse options, including:

- Indirect Potable Reuse via Surface Water Augmentation (IPR via SWA)
- Indirect Potable Reuse via Ground Water Augmentation (IPR via GWA)
- Direct Potable Reuse via Raw Water Augmentation (DPR via RWA)
- Direct Potable Reuse via Treated Water Augmentation (DPR via TWA), and,
- Environmental Flow Substitution (EFS) opportunities.

These and additional options were then considered through a workshop held with the project team and RCC on July 11, 2023. Using feedback from the workshop, and additional information and analysis undertaken subsequent to the workshop, the options to be carried forward for further consideration as a part of the investigation were identified.

2 PURPOSE

This memo outlines the key information utilised by participants in the *Scheme Option Identification, Review and Short-Listing Workshop*, *provides* an overview of the options short-listed through the workshop process, and summarises the key drivers for the classification adopted. More specifically, this memo:

1. Collates the available information on the effluent sources available for recycling, the wastewater treatment plant and potable water infrastructure, surface water storages and environmental buffers, existing and planned groundwater schemes, and environmental flow substitution opportunities in the RCC region;

2. Presents the collated information in a summarised form to explain the key considerations applied to the identification of potential potable reuse schemes, and;

3. Provides high level assessment and short-listing of the potable reuse scheme options based on the *Scheme Option Identification, Review and Short-Listing Workshop* and close out of comments and observations during the workshop.

3 ROUS COUNTY COUNCIL REGION MAPPING

Figure 3-1 through Figure 3-5 provide overview mapping of the RCC region to provide context of the region's topography and existing water and wastewater infrastructure for use in identification of potential schemes. Specific items included comprise:

- Municipal wastewater treatment plants (including elevation and projected 2040 Average Dry Weather Flow (ADWF));
- Surface water locations, water treatment plants ((WTPs) including elevation and capacity), water mains and water pump stations;
- Constituent Council local government area boundaries, and
- Areas identified by RCC with potential for groundwater extraction.

Full resolution versions of the maps are provided in Appendix B.

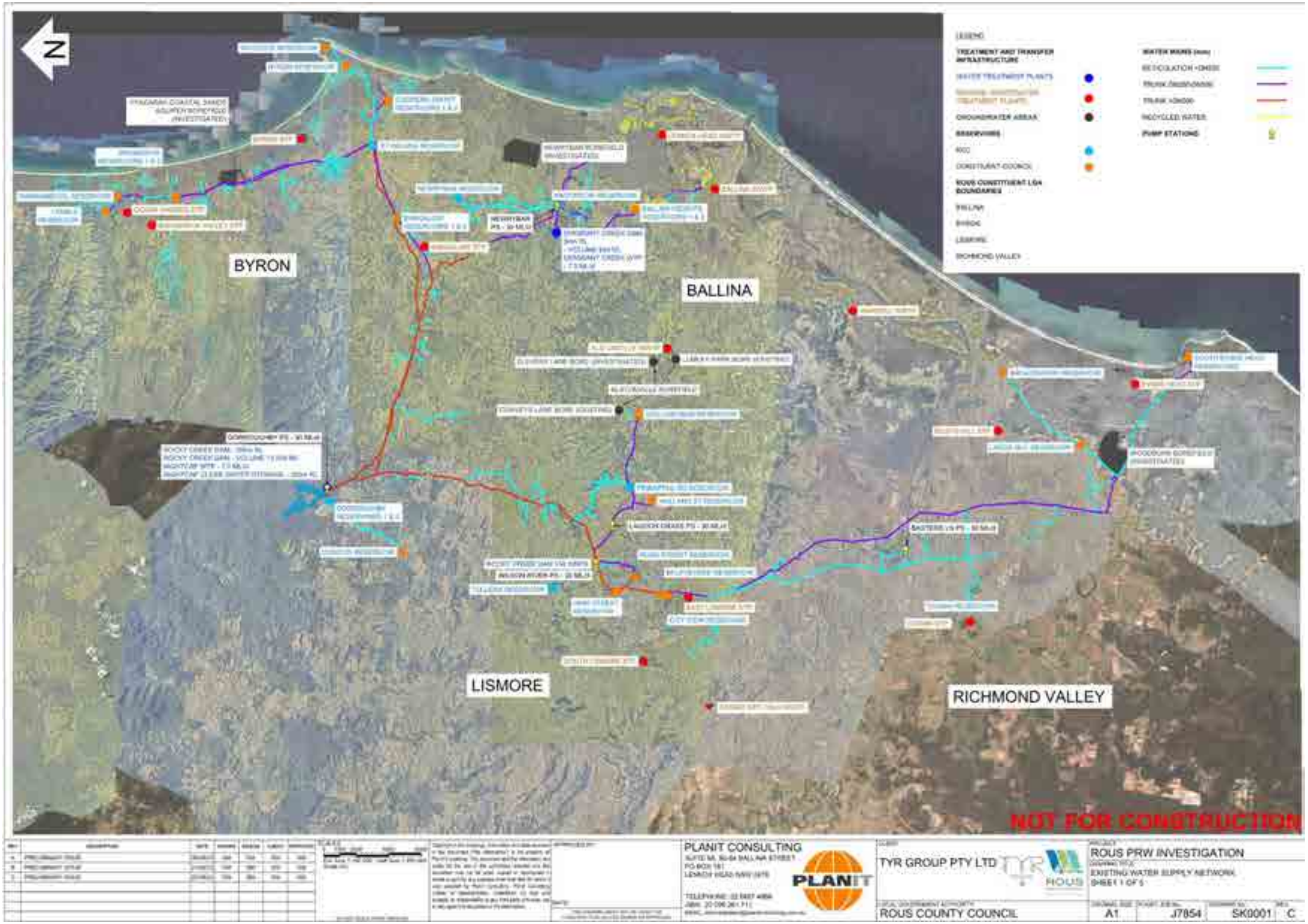

Figure 3-1: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 1 of 5

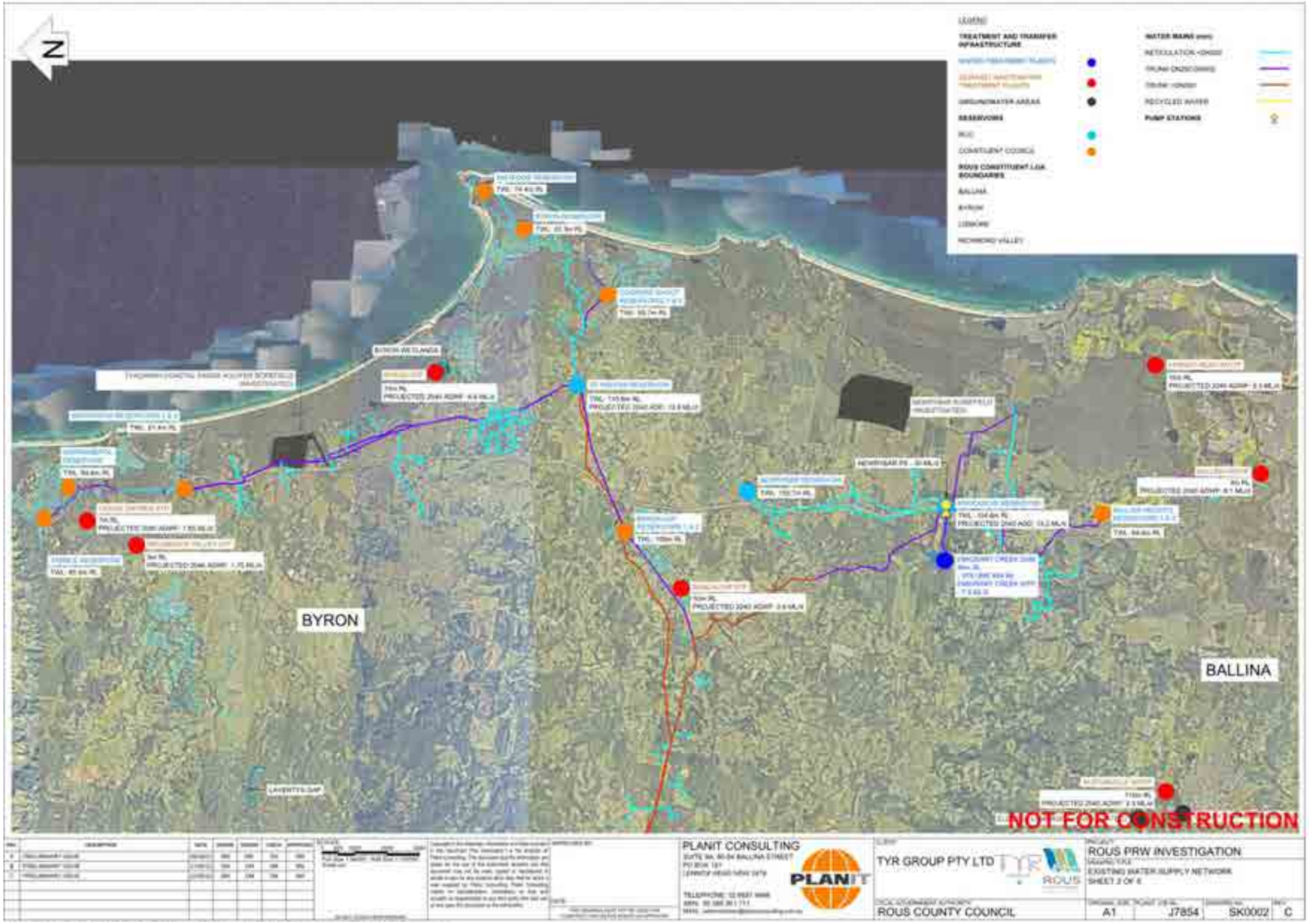

Figure 3-2: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 2 of 5

Figure 3-3: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 3 of 5

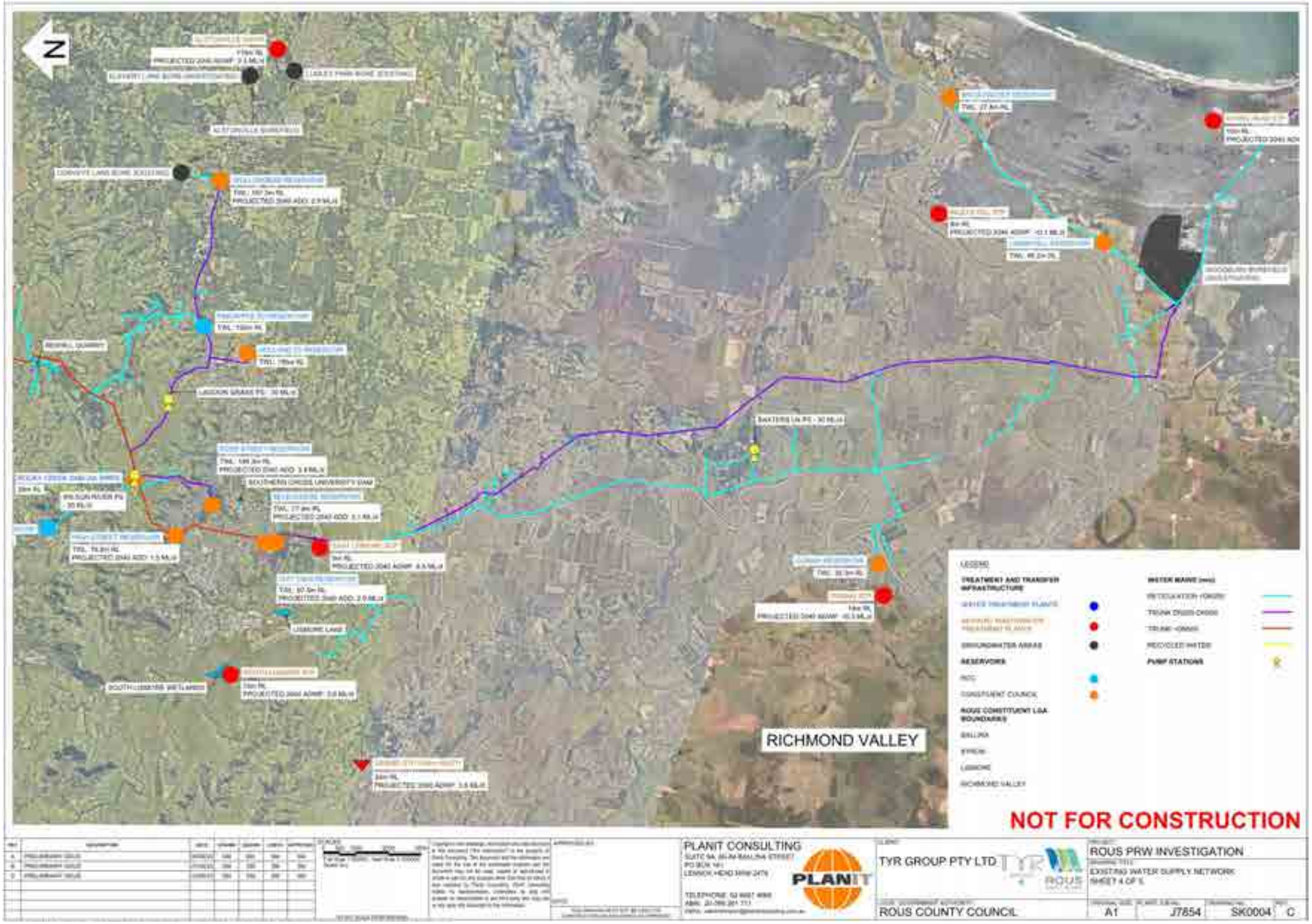

Figure 3-4: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 4 of 5

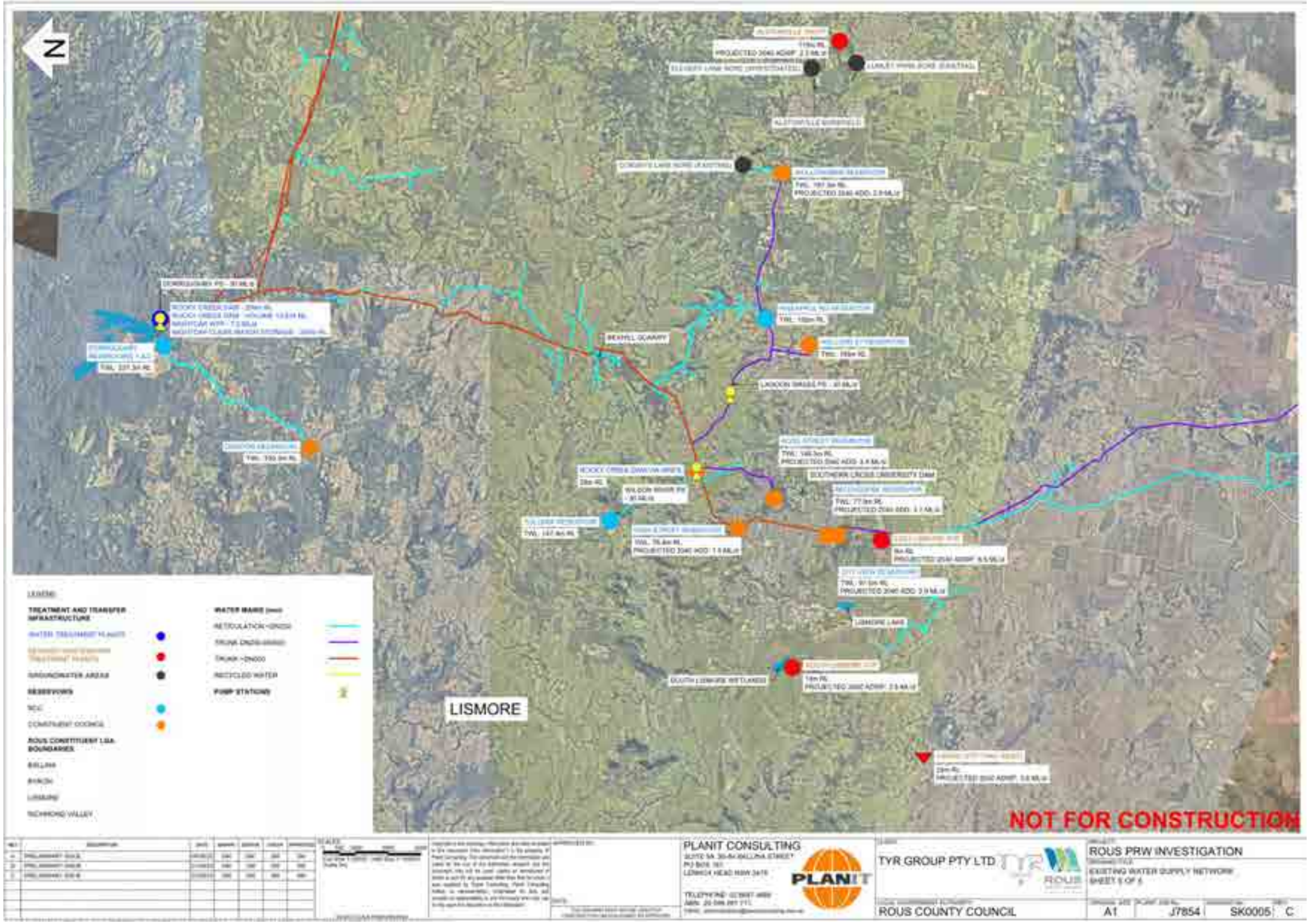

Figure 3-5: Rous County Council Supply Region – Relevant Existing Assets and Features – Sheet 5 of 5

4 ESTIMATED AVAILABLE EFFLUENT FLOWS AVAILABLE FOR POTABLE REUSE

Rous County Council provides the bulk water supply for the local government areas of Ballina, Byron, Lismore and Richmond Valley. The constituent councils for each of these LGAs own and operate multiple wastewater treatment plants with current flows ranging from 0.1 ML/day to 6.4 ML/day ADWF. Sections 4.2 through 4.5 summarise the key attributes of each wastewater treatment plant and identifies their likely suitability to supply source water for a potable reuse scheme, including:

- The current and projected effluent flow available for potable reuse;
- The nominal capacity of the existing plant relative to current and future projected loads;
- The typical effluent quality achieved for relevant monitored parameters including suspended solids, nitrogen and phosphorus, and the plant's current discharge location;
- The salinity or total dissolved solids in the effluent stream where available, and,
- An overview of each plant's treatment process and impacts the process type has on the quality and variability in the effluent stream;

This information has been drawn or derived directly from information supplied by the constituent councils. Where the available information was insufficient to enable direct estimation of the available effluent flows and composition, the key assumptions and methodology applied have been explained in this section.

4.1 Impact of Water Restrictions on Available Effluent Flows

While potable reuse primarily represents a "climate independent" water source, reductions in the effluent flow available for production of PRW due to drought and severe water restrictions are anticipated, and will influence the secure yield delivered by the scheme options.

To estimate the impact of sustained dry weather on sewage flows, the minimum wastewater flows for each substantial plant have been estimated from the data provided by the constituent councils. In particular, the minimum monthly flows have been estimated (including during the severe drought period of 2019), and compared to the annual ADWFs over the longer term.

Additionally, the available data was reviewed in an effort to estimate the impact of water restrictions on sewage flows. Table 4-1 summarises the indoor water saving measures for each level of water restrictions, and the impact on the available measured sewage flows during previous restriction periods. While the data available to support this analysis for the RCC service area are limited, the following key observations have been applied for this assessment:

- Level 1 and 2 Water Restrictions have a negligible impact on sewage flows. Review of the influent sewage flow data from the Ballina, Lennox Head, Byron and Brunswick Valley plants indicated higher dry weather flows during the Level 1 and Level 2 restriction periods of December 2019 through February 2022 than during the same months in the 2018-2019 and 2021-22 years. This is consistent with:
    - Level 1 and 2 Water Restrictions primarily targeting outdoor water use (which is expected to impact water demand without impacting sewer flows) rather than indoor water use, and,
    - The prevailing dry weather flow being much more strongly impacted by sustained infiltration than these water restriction measures.
- As water restrictions beyond Level 2 have not been applied in the RCC area since 2003, it was not possible to correlate the impact of water restrictions beyond Level 2 to measured influent flow data for STPs in the RCC service area. However, as Level 3 does remains primarily focussed on outdoor water use, it is not expected to result in substantial reductions in sewage flows (relative to changes in sustained sewer infiltration).
- Published data has been used to support estimates of the impact of water saving measures on sewage flows at each restriction level, including:

- Flow records from Melbourne Water's two major wastewater treatment plants (Western Treatment Plant and Eastern Treatment Plant) for the period 2001-2009. Data from this period, as collated and reported in [1], included the sustained "Millenium Drought".
- Data from six Californian (Bay Area) Wastewater Treatment Plants for the period 2000-2017, as collated and reported in [3]. This period included two droughts which extended over multiple years.
- Data from the Inland Empire Utilities Agency's Regional Water Recycling Plant #1 (southern California) for the period 2011-2016, as collated and reported in [4]. This period showed a decline of 14% in wastewater flows to the plant associated with a Drought State of Emergency proclamation in January 2014.

Table 4-1: High-Level Estimate of Impact of Water Restrictions on Sewage Flows

Restriction Level Note 1	Target Demand Reduction [1].	Residential and Non-Residential - Indoor Use [1].	Additional measures for Non-Residential Uses [1].	Previous Application Periods	Estimated reduction in wastewater flow from Baseline
Level 1: Moderate	2016: 5% Draft 2025: 7.5%	All users are requested to conserve water wherever possible.	Nil	Dec 4 to 19 2019	Negligible (flow higher in restriction period than same period in unrestricted years)
Level 2: High	2016: 15% Draft 2025: 15%		Water Management Plan to be prepared.	Dec 20, 2019 – mid-Feb 2020	
Level 3: Very High	2016: 25% Draft 2025: 22.5%		Consumption in accordance with approved Water Management Plan only.	Sep-Oct 2002	Assumed Negligible based on restrictions focussing on outdoor water use
Level 4: Severe	2016: 35% Draft 2025: 30%	Essential uses only.		Nov 2002 to Jan 2003	14% Assumed from Literature Data
Emergency	2016: 45% Draft 2025: 37.5%		Not Permitted	Feb-Mar 2003	18% Assumed from Literature Data

Note 1: Water restrictions primarily targets outdoor water use at Levels 1-3, only water saving measures pertaining to indoor use listed – see [2] for full list of water saving measures at each level.

Appendix C: provides additional details on the analysis of the impact of water restrictions on wastewater flows in the literature.

4.2 Ballina Shire Council

4.2.1 Alstonville Wastewater Treatment Plant

Alstonville WWTP services the townships of Alstonville and Wollongbar. The plant effluent is directed to on-site storage from where it is gravity fed to storages for irrigation of playing fields, and nurseries.

Table 4-2 provides a summary of Alstonville WWTP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-2: Alstonville WWTP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	2 ML/day[1]		Plant Average Dry Weather Flow – November 2022 – April 2023
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	1.5 ML/d [2]		Plant Average Dry Weather Flow – April 2022 – April 2023
Projected 2040 ADWF	2.5 ML/day[3]		[1]
Non-potable reuse (Dry Weather Periods)	70-90% of plant effluent		Plant Historical Recycled Water Production June 2018 – April 2023
Effluent Discharge Location	Maguires Creek – Freshwater Creek (Median electrical conductivity 120 µS/cm)		NSW Office of Water Surface Water Quality Extract (2013) [2]. Dataset from 1976-1995, measured at Teven (Station 203039 and 20310076)
Treatment Type	Intermittently Decanted Extended Aeration Biological Nitrogen Removal Chemical Phosphorous Removal UV Disinfection		[3]
Effluent Quality	**Median**	**90th Percentile**	
Biological Oxygen Demand	4 mg/L	5 mg/L	Environmental Protection Licence Report Version 199 – April 2022 to April 2023
Total Nitrogen	5 mg/L	14.2 mg/L	
Total Phosphorus	0.2 mg/L	0.3 mg/L	
Total Suspended Solids	2.5 mg/L	11 mg/L	
Fats, Oil and Grease	2.5 mg/L	5.7 mg/L	
Thermotolerant Coliforms	<1 cfu/100 mL	5 cfu/100 mL	
pH	7 – 7.7		

As an intermittently decanted extended aeration plant, Alstonville STP generally produces effluent with low total nitrogen, BOD and phosphorus, and limited total suspended solids. The plant however appears to produce inferior effluent quality in wet weather periods, as is typical of this treatment type. This is evident in the 90th percentile effluent quality from the plant.

Effluent from the plant is chlorinated, then stored in an on-site balancing pond. Effluent to be reused is directed to UV treatment prior to storage. The non-potable recycled water is then gravity fed from the reservoir to on-farm storages and used for both agricultural reuse (cattle, avocado, macadamia, custard apples) and nursery irrigation [3].

Overall, effluent from Alstonville WWTP is not considered to be a likely candidate for use in a potable reuse scheme based on:

- **Low dry weather flow.** The current and projected flows are less than a third of Ballina WWTP's ADWF, and will not be sufficient to deliver a substantial proportion of the secure yield required in 2040.

[1] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalie s.
[2] Minimum of 30 day rolling average of dry weather flow.
[3] Projected 2040 flow estimated from extrapolation of 2025-2030 Ballina Shire Total Population Growth Rate presented in Table 2 of Ballina Shire Council, "Development Servicing Plan for Wastewater and Recycled Water Supply Infrastructure," 2015 [5].

- **High utilisation of effluent in non-potable reuse.** The majority of Alstonville WWTP's dry weather effluent flows are currently reused for irrigation on farmland in dry weather periods, leaving just 200-600 kL/d of the effluent being discharged to the environment.
- **Relatively remote from other effluent sources, the most prospective environmental buffers and major potable water demands.** Transfer of the Alstonville WWTP effluent to another facility for combined advanced water treatment is not considered likely to be efficient given its distance to other population centres, and small flows generated.
- **Variability in effluent quality.** The available effluent monitoring data shows a substantial degradation in quality during wet weather, which is consistent with the process type. This suggests substantial upgrades to the WWTP would be required to facilitate utilisation of wet weather flows as an input to an advanced water treatment plant (AWTP).

Based on these attributes, effluent from Alstonville WWTP has not been carried forward in any of the identified scheme options.

4.2.2 Wardell Wastewater Treatment Plant

Wardell WWTP services a population of approximately 1,750 people in Wardell and Cabbage Tree Island. Table 4-3 provides a brief summary of Wardell WWTP's current and projected sewage flows, treatment type, and typical reuse applications.

Table 4-3: Wardell WWTP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	0.5 ML/day [4]		Plant Average Dry Weather Flow – April 2022 – April 2023
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	0.3 ML/day [5]		Plant Average Dry Weather Flow – April 2022 – April 2023
Projected 2040 ADWF	0.65 ML/day [6]		[1]
Non-potable reuse (Dry Weather Periods)	Reuse for local sports fields and farming use (turf farm), up to 0.3 ML/day		Ballina Shire Council Fact Sheet – 2014 and Environmental Protection Licence Report Version 5785 – April 2022 to April 2023
Effluent Discharge Location	Richmond River		Saline / Tidal
Treatment Type	Extended Aeration BOD Removal		Ballina Shire Council Fact Sheet - 2014
Effluent Quality	**Median**	**90th Percentile**	
Biological Oxygen Demand	3 mg/L	4 mg/L	Environmental Protection Licence Report Version 5785 – April 2022 to April 2023
Total Nitrogen	2.1 mg/L	5.0 mg/L	
Total Phosphorus	0.2 mg/L	0.4 mg/L	
Total Suspended Solids	2.5 mg/L	6.6 mg/L	
Fats, Oil and Grease	2.5 mg/L	2.5 mg/L	
Thermotolerant Coliforms	175 cfu/100 mL	3500 cfu/100 mL	
pH	7 – 7.9		

Given its small scale (~8% of Ballina WWTP's ADWF) and the prevailing non-potable reuse of the plant effluent, Wardell WWTP would not be expected to be of sufficient scale to warrant investigation as a standalone option for potable reuse. Further, given its distance to other population centres, it is not anticipated that the plant would be suitable to transfer to another facility for combined advanced water treatment.

Based on these attributes, use of effluent from Wardell WWTP has not been carried forward in any of the identified scheme options.

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4 Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalie s.

5 Minimum of 30-day rolling average of dry weather flow

6 Projected 2040 flow estimated from extrapolation of 2025-2030 Ballina Shire Total Population Growth Rate presented in Table 2 of Ballina Shire Council, "Development Servicing Plan for Wastewater and Recycled Water Supply Infrastructure," 2015 [5].

4.2.3 Ballina Wastewater Treatment Plant

Ballina WWTP services Ballina Island, North Ballina and West Ballina. The plant is located approximately 4.3 km from the mouth of the Richmond River. All effluent generated by the plant is currently discharged to the tidal waters of the North Creek Canal - a constructed waterway which connects the Richmond River and North Creek. Effluent discharge to the canal is limited to ebb tide to minimise any impacts of the nutrient loads on the receiving waters [4].

Table 4-4 provides a summary of Ballina WWTP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-4: Ballina WWTP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	6.4 ML/day [7]		Plant Average Dry Weather Flow – November 2022 – April 2023
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	5.6 ML/day [8]		Plant Average Dry Weather Flow – April 2022 – April 2023
Projected 2040 ADWF	8.1 ML/day [9]		[1]
Non-potable reuse (Dry Weather Periods) 2023	Nil [9]		[5]
Effluent Discharge Location	North Creek Canal, a tidal tributary of the Richmond River. Ebb-tide effluent discharge.		Environmental Protection Licence 588
Treatment Type	Continuous Flow Activated Sludge with Biological Nitrogen Removal Chemical Phosphorus Removal Flat Sheet Membrane Bioreactor (MBR)		Environmental Protection Licence Report Version 588
Effluent Quality	**Median**	**90th Percentile**	
Biological Oxygen Demand	1 mg/L	2 mg/L	Environmental Protection Licence Report Version 588 – April 2022 to April 2023
Ammonia Nitrogen	0.06 mg/L	0.16 mg/L	
Total Nitrogen	4.8 mg/L	7.5 mg/L	
Total Phosphorus	0.1 mg/L	0.3 mg/L	
Total Suspended Solids	2.5 mg/L	6 mg/L	
Fats, Oil and Grease	2.5 mg/L	6 mg/L	
Thermotolerant Coliforms	10 cfu/100 mL	35 cfu/100 mL	
pH	7.6 – 8.2		
Total Organic Carbon, Total Dissolved Solids and Electrical Conductivity [10]	Total Organic Carbon: 7.52-19.11 mg/L Total Dissolved Solids: 1035 – 2054 mg/L Electrical Conductivity: 1893 – 3459 µS/cm [11]		[6]

Ballina WWTP's treatment process provides relatively consistent effluent quality, with minor variations in effluent total suspended solids and total nitrogen.

The membranes at the plant have presented issues since commissioning, with regulatory approval of the pathogen removal required for Class A non-potable reuse unable to be demonstrated. The installed flat sheet membranes are currently in poor condition which is consistent with the elevated effluent suspended solids concentrations (for an MBR) identified in Table 4-4. Ballina Shire Council is progressing with replacement of the existing membranes with flat sheet UF units which can be expected to alleviate this issue.

[7] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalie s.
[8] Minimum of 30 day rolling average of dry weather flow.
[9] Projected 2040 flow estimated from extrapolation of 2025-2030 Ballina Shire Total Population Growth Rate presented in Table 2 of Ballina Shire Council, "Development Servicing Plan for Wastewater and Recycled Water Supply Infrastructure," 2015 [5].
[10] Results from March to May 2016, "Ganden, "Ballina WWTP Desalination Options Investigation," 2017 [10].
[11] Electrical conductivity is reported as "Sm^-1". However the ratio to Total Dissolved Solids indicates that the units of the reported value are µS/cm (a typical unit for reporting of electrical conductivity).

While there is currently no reuse of effluent from Ballina WWTP, the peak day demand (PDD) for non-potable recycled water is projected to exceed the effluent available from Lennox Head from around 2028 (see Section 4.2.5 for additional details).

The high concentrations of total dissolved solids (TDS) in the plant effluent are likely a result of significant inflow and infiltration in the sewerage network from the tidal estuary of the Richmond River. While the Ballina WWTP was designed to provide recycled water for dual reticulation, previous attempts to reduce inflow and infiltration have not successfully reduced the effluent TDS below Ballina Shire Council's aesthetic target value of 600 mg/L target for recycled water to be supplied for dual reticulation [10]. As a consequence, the feasibility and costs of desalination of the plant effluent to enable its use in its existing and future dual reticulation recycled water networks have been investigated [10]. Based on this analysis, Ballina Shire Council indicated an intention to provide the treatment required to allow Ballina WWTP to supply Class A recycled water to the dual reticulation system (i.e. reverse osmosis (RO) based treatment).

Should the planned non-potable reuse of effluent from Ballina WWTP not proceed (which is considered unlikely – see Section 4.2.5), or be suspended during extreme drought conditions there would be potential for the effluent generated by the plant to be utilised in a potable reuse scheme based on:

- **Substantial scale and dry weather flow.** Ballina WWTP is the largest individual WWTP in the RCC service area in terms of current and projected ADWF.
- **No current utilisation in non-potable reuse.** Due to the elevated salinity in the effluent stream, the plant effluent is not currently utilised for non-potable reuse. This elevated salinity would be removed within an RO-based AWTP, and would not represent an impediment to utilisation of the effluent in a potable reuse scheme.
- **Coastal location suitable for brine discharge.** As the plant effluent is currently discharged to tidally influenced saline waters, the discharge of brine stream from an RO-based AWTP is considered likely to be acceptable.
- **Proximity to Lennox Head WWTP to combine effluent streams.** Ballina WWTP is approximately 4.5 km from Lennox Head WWTP, and non-potable recycled water is currently supplied from Lennox Head WWTP to a storage reservoir at Ballina WWTP to facilitate supply to customers. In the event that the current and planned non-potable usage of recycled water Lennox Head WWTP were reduced or stopped), the available effluent from the two plants could be utilised within a single potable reuse scheme to maximise scale.
- **Proximity to Emigrant Creek Dam.** The potential existing environmental buffer at Emigrant Creek Dam is ~10 km from Ballina WWTP on a straight line basis, and 81 m higher in elevation.
- **Proximity to substantial potable water demand.** Ballina WWTP is close to the population centres of Lennox Head and Ballina and the supply reservoir for the region, Knockrow reservoir (~10 km on a straight line basis, and ~102 m higher in elevation) creating potential for efficient direct augmentation schemes (subject to regulatory constraints).
- **Suitable effluent quality.** The available effluent monitoring data suggests the existing plant can consistently achieve low concentrations of pollutants. The replacement of the existing membranes, which is currently in progress, can be expected to further improve the effluent quality in terms of effluent suspended solids and bacterial pathogens.

Based on these attributes, effluent from Ballina WWTP has been considered in a number of the identified scheme options to account for scenarios where the plant effluent would be reprioritised to potable reuse. However, as detailed in Section 4.2.5, the viability of directing Ballina WWTP effluent to potable reuse is complicated by the non-potable reuse of this flow anticipated under Ballina Shire Council's current planning.

4.2.4 Lennox Head Wastewater Treatment Plant

Lennox Head WWTP services East Ballina, Skennars Head and Lennox Head. On average, approximately 18% of the prevailing plant ADWF undergoes additional treatment via ultrafiltration and UV disinfection prior to use in non-potable applications (see Section 4.2.5). Effluent flows in excess of the prevailing recycled water demand are discharged to open coastal waters via an outfall at Skennars Head.

Table 4-5 summarises Lennox Head WWTP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-5: Lennox Head WWTP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	4.2 ML/day [12]		Plant Average Dry Weather Flow – November 2022 – April 2023
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	3.5 ML/day [13]		Plant Average Dry Weather Flow – April 2022 – April 2023
Projected 2040 ADWF	5.3 ML/day [14]		[1]
Non-potable reuse – April 2022 to April 2023	280 ML/annum ~18% of ADWF flow Maximum - 3.6 ML/d[15] Peak Monthly Average Daily Usage: ~1.8 ML/d		Environmental Protection Licence Report Version 590 – April 2022 to April 2023
Effluent Discharge Location	Skennars Head – Open coastal waters		Environmental Protection Licence 590
Treatment Type	Intermittent Decant Extended Aeration (IDEA) Biological Nitrogen Removal Chemical Phosphorus Removal		
Existing Advanced Water Treatment Process	Ultrafiltration (1 skid) UV Disinfection (1 reactor-type) Chlorination		Ballina Shire Council Recycled Water Fact Sheet [8], site visit
Effluent Quality	**Median**	**90th Percentile**	
Biological Oxygen Demand	3 mg/L	4 mg/L	Environmental Protection Licence Report Version 590 – April 2022 to April 2023
Total Nitrogen	6.6 mg/L	9.9 mg/L	
Ammonia (as Nitrogen)	0.5 mg/L	0.8 mg/L	
Total Phosphorus	0.2 mg/L	0.4 mg/L	
Total Suspended Solids	2.5 mg/L	2.5 mg/L	
Fats, Oil and Grease	2.5 mg/L	2.5 mg/L	
Thermotolerant Coliforms	4 cfu/100 mL	1050 cfu/100 mL	
pH	6.8 – 9.6 (90th Percentile – 7.7)		
Ammonia	0.52 mg/L	0.78 mg/L	Plant Effluent Results (Pre UV) – April 2022 to April 2023 [16]
Nitrate	4.9 mg/L	8.2 mg/L	
Total Organic Carbon and Total Dissolved Solids	Total Organic Carbon: 4 – 7 mg/L Total Dissolved Solids: 240 – 461 mg/L		

While the monitoring results show the plant complies with its discharge consent, the plant effluent has elevated concentrations of nitrogen and suspended solids relative to the other candidate plants in the region. This is consistent with the configuration and prevailing loading of the plant's secondary treatment process, which can also be expected to suffer further reductions in treatment performance during sustained wet weather events. This somewhat inferior nitrogen and solids removal performance is not expected to generate substantial treatment issues in a typical RO-based AWTP process

12 Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalie s.
13 Minimum of 30 day rolling average of dry weather flow.
14 Projected 2040 flow estimated from extrapolation of 2025-2030 Ballina Shire Total Population Growth Rate presented in Table 2 of Ballina Shire Council, "Development Servicing Plan for Wastewater and Recycled Water Supply Infrastructure," 2015.
15 The maximum reported daily use of non-potable water (3.6 ML/d) is much higher than the nominal current peak daily demand of 1.69 ML/d. It is anticipated that this discrepancy is the result of short-term operational challenges (such as filling of a storage in the network or maintenance activities).
16 The sampling results provided do not indicate the method of sampling (i.e. grab or composite sampling)

train for potable reuse. Additionally, it appears the existing plant configuration includes substantial scope to reduce effluent nitrogen through minor modification and augmentation works.

The available data indicates the effluent is consistently low in phosphorus, which is in line with the chemical dosing applied for phosphorus precipitation. The relatively large secondary effluent storage lagoons at the STP site are subject to substantial algal and weed growth, which in turn causes periods of elevated effluent pH.

Lennox Head WWTP produces Class A recycled water for:

- Irrigation of open spaces including golf courses, playing fields and Council parks;
- Industrial and commercial use, and,
- Utilisation within a dual reticulation network for residential customers for toilet flushing, clothes washing, and outdoor use. As discussed in Section 4.2.5, the Lennox Head WWTP minimum month flow is projected to be insufficient to meet the recycled water PDD from 2028, and the ADWF is projected to be insufficient to meet the recycled water PDD from about 2035.

Should the additional non-potable reuse of effluent from Lennox Head WWTP not proceed (which is considered unlikely – see Section 4.2.5), or be suspended during extreme drought conditions, there would be potential for the effluent generated by the plant to be utilised in a potable reuse scheme based on:

- **Substantial scale and dry weather flow.** Lennox Head WWTP is the fourth largest WWTP in the RCC service area in terms of current and projected ADWF.
- **Proximity to Ballina WWTP to combine effluent streams.** As noted in the previous section, Lennox Head and Ballina WWTP are approximately 4.5 km apart. There is possibly an existing pipeline between the two sites.
- **Coastal location suitable for brine discharge.** The low TDS in the current Lennox Head WWTP effluent indicates that a Carbon-based AWTP (that does not generate a brine stream) may be an option. Regardless, as the plant effluent is current discharged to tidally influenced saline waters, the discharge of brine stream from an RO-based AWTP treating effluent from Lennox Head (and Ballina if preferred) is considered likely to be acceptable.
- **Proximity to Emigrant Creek Dam.** The potential existing environmental buffer at Emigrant Creek Dam is 8.5 km from Lennox Head WWTP on a straight line basis, and 74 m higher in elevation.
- **Proximity to substantial potable water demand.** Lennox Head WWTP is close to the population centres of Lennox Head and Ballina and the key supply reservoir for the region, Knockrow reservoir (~8 km on a straight line basis, and ~95 m higher in elevation), creating potential for efficient direct augmentation schemes (subject to regulatory constraints).
- **Suitable effluent quality.** The available information indicates that the current effluent quality is generally viable for treatment in a typical AWTP process train, and further, that there is scope to improve the secondary effluent quality through relatively minor works.

Based on these attributes, effluent from Lennox Head WWTP has been considered in a number of the identified scheme options to account for scenarios where the plant effluent would be reprioritised to potable reuse. However, as detailed in Section 4.2.5, the viability of directing Lennox Head WWTP effluent to potable reuse is complicated by the current non-potable reuse of this flow, and the anticipated increases in the non-potable recycled water demand under Ballina Shire Council's current planning.

4.2.5 Ballina Shire Council's Existing and Planned Dual Reticulation Non-Potable Reuse

The intent of Ballina Shire Council's recycled water planning is to provide sustainable management of urban water resources [13]. To this end, Ballina Shire Council has developed a significant dual-reticulation network in the Lennox Head and Ballina regions, in addition to the recycled water supply provided for open space irrigation.

As of 2020, Ballina Shire Council's recycled water network comprised:

- 31.1 km of transfer and reticulation mains to service 1,960 residential customers (household connections) and 74 non-residential customers [13].
- Recycled water storages at Ballina WWTP (anticipated to be disused), Lennox Head WWTP, and two reservoirs in the dual-reticulation network.
- A reported average daily demand (ADD) of 0.63 ML/d, and a PDD of 1.69 ML/d [14].

Ballina Shire Council's Recycled Water Modelling Report indicates a PDD in 2040 of 5.9 ML/d. Based on the current ADD to PDD ratio, this equates to an ADD in 2040 of about 2.3 ML/d.

The projected wastewater ADWF to Lennox Head WWTP in 2040 is 5.3 ML/d, while the projected recycled water PDD in 2035 is about 5.2 ML/d.

Based on the current minimum month flow to ADWF ratio and the available projections, the PDD can be expected to exceed the minimum monthly flow from Lennox Head WWTP from around 2028 (PDD = min month flow = 3.75 ML/d (based on linear interpolation of Lennox Head flows))[17]. This suggests additional recycled water from the Ballina WWTP would be required to supply the PDD under minimum monthly flow conditions by this time.

The projections indicate that approximately 1.6 ML/d of Ballina WWTP's minimum month flow would be required to meet the PDD by 2040, leaving about 6.6 ML/d of available for other uses or to be discharged.

In the context of overall water security for the region, and sustainable management of urban water resources, it is important to consider the best value to be gleaned from utilisation of the available Ballina and Lennox Head WWTP's effluent in peak drought events. Extensive discussions between RCC and Ballina Shire Council would be required to determine the conditions under which the effluent resource might become available for potable reuse. However, to inform this discussion, Ballina Shire Council staff have indicated that any diversion of effluent to a potable reuse scheme which constrains the availability of non-potable recycled water to their existing and future customers may be challenging due to:

- The long-standing commitment of Ballina Shire to non-potable reuse in recognition of community preferences to minimize the discharge or effluent to the environment, and,
- The substantial investment by the Ballina Shire Council and developers into infrastructure and systems for the treatment and reticulation of non-potable recycled water.

Additionally, outside periods of severe water restrictions, any substantial limitations on the availability of non-potable recycled water within the Ballina system could potentially increase the potable water demand. Such an outcome would partially reduce the benefit to the overall system yield of diversion of effluent to potable reuse at the expense of non-potable reuse.

On this basis, the extent of non-potable reuse in Ballina has direct implications on the sustainable yield that may be achieved through reuse from the Ballina and Lennox Head WWTPs.

Based on Ballina Shire Council's extensive current and planned non-potable reuse scheme, options which utilise effluent from the Ballina and Lennox Head WWTPs as source water for a potable reuse scheme have not been short-listed for further quantitative development as part of this PRW investigation.

[17] The projected years at which Ballina effluent may be required to augment the non-potable recycled water supply have been derived from a simple comparison of the sewage flow and recycled water demand projections. These estimates should be considered approximate as they do not consider system dynamics, including the additional variations in ADWF and recycled water demands associated with seasonal conditions, the operation and control of the recycled water storages, and/or the network constraints and redundancy requirements.

4.3 BYRON SHIRE COUNCIL

4.3.1 Byron Sewage Treatment Plant

Byron STP is a coastal plant that services Byron Bay and surrounds.

Table 4-6 provides a summary of Byron STP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-6: Byron STP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	4.6 ML/day [18]		Plant Average Dry Weather Flow – November 2022 – April 2023 provided by Byron Shire Council
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	3.2 ML/day [19]		Plant Average Dry Weather Flow – January 2019 – April 2023 provided by Byron Shire Council
Projected 2040 ADWF	6.6 ML/day [20]		[15]
Byron STP – Design Capacity	6.95 ML/day		
Non-Potable Reuse – Byron Bay Urban Recycled Water Scheme	2020 – 1.1 ML/day Average, 1.8 ML/day Peak Daily Demand 2021 – 1.1 ML/day Average, 1.9 ML/day Peak Daily Demand 2022 – 0.6 ML/day Average, 2.2 ML/day Peak Daily Demand		Plant data provided by Byron Shire Council
Effluent Discharge Location	Byron Bay Urban Recycled Water Scheme, Byron Bay Integrated Water Management Reserve, and the Union Drain to Belongil Estuary		[16]
Treatment Type	Oxidation Ditch Biological Nitrogen Removal Chemical Phosphorus Removal UV Disinfection		
Non-Potable Reuse Treatment	Chlorination and Sand Filtration		
Effluent Quality – Discharge to Wetlands	**Mean**	**Maximum**	
Biological Oxygen Demand	1.3 mg/L	3 mg/L	NSW EPA Annual Return – Licence 3404 – April 2021 to April 2022
Total Nitrogen	1.5 mg/L	3.9 mg/L	
Total Phosphorus	0.1 mg/L	0.25 mg/L	
Total Suspended Solids	5.6 mg/L	14 mg/L	
Fats, Oil and Grease	1.1 mg/L	2 mg/L	
Thermotolerant Coliforms	12 cfu/100 mL	113 cfu/100 mL	
pH	7.0 – 7.3		
Influent Quality			
Influent Conductivity	830 – 872 µS/cm		March to April 2023 Influent Composite Sampling[21]

Byron STW consistently produces effluent with low total nitrogen and phosphorus. However, it appears to intermittently produce effluent with high suspended solids concentrations. This is consistent with the oxidation ditch process adopted,

[18] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalie s.
[19] Minimum of 30 day rolling average of dry weather flow, manually filtered to remove anomalies. Minimum in data set observed in September/October 2021.
[20] Projected 2040 flows derived from sewerage equivalent tenement growth from Table 9 of Hydrosphere Consulting, "Byron Shire Co uncil Water Supply and Sewerage Strategic Plan: 2017 Review," 2017.
[21] Results from six days of influent composite sampling from March 25, 2023, to April 11, 2023

which is generally an effective design for consistent nutrient removal, but can be susceptible to poor settling characteristics in the mixed liquor of the plant at high flows.

Recycled effluent from Byron STW is reused for irrigation of sporting fields and nurseries, parks and gardens, and in dual reticulation for toilet flushing in public and private bathrooms. Additionally, up to 400 ML/annum of plant effluent is reused through the Byron Bay Integrated Water Management Reserve, a combination of wetlands and Melaleuca Forest, and is utilised to mitigate acid sulphate solids, and wetland and catchment degradation [17].

The wetlands downstream of the plant have been found to generally improve water quality in terms of nitrogen (with an average reduction of 78% measured in February to April 2023) and a minor adverse impact on total phosphorus concentration (with an average increase of 26% measured in February to April 2023) [18].

While a portion of Byron STW's effluent is directed to urban reuse and the Byron Bay Integrated Water Management Reserve, the outflow from the wetland cells on the treatment plant site is directed to the Union Drain, a man-made drain to the Belongil Estuary. Long standing issues exist in the discharge from the plant to the Union Drain, with farmland adjacent to the Union Drain reported to be subject to significant flooding as a result of the additional flow directed to the Belongil Estuary from the plant, and the management of the intermittently closed and open lake and lagoon (ICOLL) discharging from the Belongil Estuary [15]. Given the suggested impacts of the plant's effluent flows on surrounding farmland, there may be benefit to the reduction of flow to the Union Drain in schemes where substantial reuse of plant effluent is applied on an ongoing basis, including in wet weather periods.

In the context of the RCC service area, effluent from Byron STW is considered to have substantial potential to be utilised in a potable reuse scheme based on:

- **Substantial scale and dry weather flow.** Byron STW is the second largest WWTP in the RCC service area in terms of current and projected ADWF.
- **Proximity to Brunswick Valley STP to combine effluent streams.** Byron and Brunswick Valley STP are approximately 11 km apart, providing potential for combined reuse of effluent from Byron and Brunswick Valley STPs (noting that Brunswick Valley STP is anticipated to treat flows from Ocean Shores and Brunswick Valley STP in future).
- **Limited utilisation in non-potable reuse.** While up to 33% of the dry weather effluent flow from Byron STW is currently reused, there remains substantial scope to combine the available effluent from the two plants within a combined potable reuse scheme to maximise scale.
- **Proximity to substantial potable water demand.** Byron STW is close to the population centre of Byron Bay and the key supply reservoir for the region, St. Helena reservoir (~4.5 km on a straight line basis, and ~105 m higher in elevation), creating potential for efficient direct augmentation schemes (subject to regulatory constraints).
- **Suitable effluent quality.** The available information indicates that the current effluent quality is likely to be generally viable for treatment in a typical AWTP process train.

Based on these attributes, a number of the identified scheme options are based on utilising effluent from Byron STW and combining effluent from Byron and Brunswick Valley STPs.

4.3.2 Ocean Shores Sewage Treatment Plant

The Ocean Shores STP is a coastal plant that services Ocean Shores and South Golden Beach.

Table 4-7 provides a summary of Ocean Shores STP's current sewage flows, treatment type, and effluent quality.

Table 4-7: Ocean Shores STP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	1.45 ML/day [22]		Plant Average Dry Weather Flow – November 2022 – April 2023 provided by Byron Shire Council
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	1.2 ML/day [23]		Plant Average Dry Weather Flow – January 2019 – April 2023 provided by Byron Shire Council
Ocean Shores STP – Assessed Capacity	1.1 ML/day		[16]
Treatment Type	IDEA ('Hybrid BNR') Biological Nutrient Removal		[16]
Effluent Quality	**Mean**	**Maximum**	
Biological Oxygen Demand	2.3 mg/L	13 mg/L	NSW EPA Annual Return – Licence 784 – April 2021 to April 2022
Total Nitrogen	4.0 mg/L	14.1 mg/L	
Total Phosphorus	0.1 mg/L	0.6 mg/L	
Total Suspended Solids	3.2 mg/L	14 mg/L	
Fats, Oil and Grease	<2 mg/L	<2 mg/L	
Faecal Coliforms	19,201 cfu/100 mL	440,000 cfu/100 mL	
pH	6.7 – 7.2		

The Ocean Shores STP is currently operating close to capacity. Byron Shire Council is currently investigating the transfer of a portion of the wastewater loads currently received at Ocean Shores to Brunswick Valley STP for combined treatment [21]. This approach will reduce the loading on Ocean Shores STP, and in combination with renewal and minor upgrade works, enable it to reliably comply with its effluent quality criteria. Under this adaptive planning approach, Ocean Shores STP may eventually be decommissioned, and the remainder of the sewage loads currently diverted to Brunswick Valley STP. However, the current projections suggest that this final decommissioning and transfer (or major plant upgrade) to Ocean Shores STP would not occur until around 2055.

Ocean Shores STP has not been carried forward for consideration as a source of effluent for a PRW scheme based on:

- The relatively small dry weather flows to Ocean Shores STP (1.45 ML/d ADWF, expected to reduce to 1.15 ML/d through transfer to Brunswick Valley STP), and,
- The relatively poor effluent quality reported at times from the plant.

Rather, consideration has been applied to schemes which utilise Brunswick Valley STP effluent flows (which will incorporate a portion of Ocean Shores current sewage loads in the future).

[22] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalies.
[23] Minimum of 30 day rolling average of dry weather flow, manually filtered to remove anomalies.

4.3.3 Brunswick Valley Sewage Treatment Plant

The Brunswick Valley STP is an inland plant that services Brunswick Heads and Mullumbimby.

Table 4-8 provides a summary of Brunswick Valley STP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-8: Brunswick Valley STP – Plant Summary

Parameter	Value		Reference/Comment
Estimated ADWF	1.5 ML/day [24]		Plant Average Dry Weather Flow – November 2022 – April 2023 provided by Byron Shire Council
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	1 ML/day [25]		Plant Average Dry Weather Flow – January 2019 – April 2023 provided by Byron Shire Council
Projected 2040 ADWF (Brunswick Valley, current catchment)	1.75 ML/day [26]		[11]
Projected 2040 ADWF (Brunswick Valley with partial Ocean Shores load transfer)	2.16 ML/day [27]		Estimated based on 25% sewage transfer [21].
Brunswick Valley STP Design Capacity	3.8 ML/day		[15]
Non-Potable Reuse – Main Arm Recycled Water Scheme	2020 – 0.26 ML/day Average, 1.9 ML/day Maximum 2021 – 0.05 ML/day Average, 1.2 ML/day Maximum 2022 – 0.05 ML/day Average, 0.5 ML/day Maximum		Plant Data provided by Byron Shire Council
Effluent Discharge Location	Brunswick River		[22]
Treatment Type	3 Stage Phoredox (Oxidation Ditch) Biological Nitrogen Removal with Selector Chemical Phosphorus Removal UV Disinfection		
Effluent Quality	**Mean**	**Maximum**	
Biological Oxygen Demand	0.9 mg/L	2.7 mg/L	NSW EPA Annual Return – Licence 13266 – April 2021 to April 2022
Total Nitrogen	1.3 mg/L	3.4 mg/L	
Total Phosphorus	0.1 mg/L	0.14 mg/L	
Total Suspended Solids	2.8 mg/L	8.4 mg/L	
Fats, Oil and Grease	1.1 mg/L	3 mg/L	
Faecal Coliforms	500 cfu/100 mL[28]	55 cfu/100 mL	
pH	6.8 – 7.8		

Brunswick Valley STP is significantly underloaded in dry weather conditions, however it is subject to extreme peaks of wet weather flow due to very high inflow and infiltration in the sewerage network, receiving more than 15 x ADWF in peak wet

[24] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalies. Note that there is a significant discrepancy between the measured influent and effluent flow from the Brunswick Valley STP, with the average effluent flow from the plant in the same period estimated at 2.2 ML/d.

[25] Minimum of 30 day rolling average of dry weather flow, manually filtered to remove anomalies.

[26] Projected 2040 flows derived from sewerage equivalent tenement growth from Table 9 of Hydrosphere Consulting, "Byron Shire Council Water Supply and Sewerage Strategic Plan: 2017 Review," 2017.

[27] 25% of Projected 2040 flows derived from sewerage equivalent tenement growth from Table 9 of Hydrosphere Consulting, "Byron Shire Council Water Supply and Sewerage Strategic Plan: 2017 Review," 2017 times average of 20-30% diversion reported in GHD " Ocean Shores – Brunswick Valley Sewage Transfer and Treatment Study", 2023.

[28] Reported as per EPA Annual Return – 500 cfu/100mL (reported mean) and 55 cfu/100 mL (reported maximum) appear to be listed in error.

weather flow events [17]. Despite this, the plant effluent is typically of a very high quality, with low total nitrogen and total suspended solids.

Recycled effluent produced at the plant is supplied to the Main Arm Recycle Water Scheme (MARWS) via the Mullumbimby Recycled Water Facility storage lagoon for pasture and fodder irrigation. Two local farms currently utilise the recycled effluent, with the remainder discharged to the Brunswick River [13], but the usage has waned to very low levels in recent years.

With Byron Shire Council's planned transfer of sewage from Ocean Shores STP to Brunswick Valley STP, the volume of treated effluent available from Brunswick Valley STP for potable reuse is expected to increase in the future. As no results for salinity or electrical conductivity are available for either Ocean Shores or Brunswick Valley STP at this point, further assessment is required to determine the suitability of the combined plant effluent for a carbon-based AWTP.

In the context of the RCC service area, effluent from Brunswick Valley STP is considered to have some potential to be utilised in a potable reuse scheme based on:

- **Some scale and dry weather flow.** With the combined flow from Brunswick Valley and Ocean Shores STPs, Brunswick Valley STP is the fifth largest STP in the RCC service area in terms of projected ADWF.
- **Proximity to Byron STW to combine effluent streams.** As noted in the previous section, Byron and Brunswick Valley STP are approximately 11 km apart, providing potential for combined reuse of effluent from Byron and Brunswick Valley STPs.
- **Limited utilisation in non-potable reuse.** While peak reuse from Brunswick Valley STP can be substantial, the average daily reuse has dropped to very low levels (0.05 ML/day from 2021 and 2022). While reuse would be expected to increase in dry periods, there remains substantial scope to combine the available effluent from Byron and Brunswick Valley within a combined potable reuse scheme to maximise scale.
- **Suitable effluent quality.** The available information indicates that the current effluent quality is generally viable for treatment in a typical AWTP process train, however further investigation of effluent conductivity and/or TDS is required.

Based on these attributes, a number of the identified scheme options are based on directing effluent from Brunswick Valley to Byron STW to increase the available water production from a Byron-based AWTP.

4.3.4 Bangalow Sewage Treatment Plant

The Bangalow STP is an inland plant that services the hinterland town of Bangalow.

Table 4-8 provides a summary of Bangalow STP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-9: Bangalow STP – Plant Summary

Parameter	Value		Reference/Comment
Bangalow STP - Estimated ADWF	0.38 ML/day [29]		Plant Average Dry Weather Flow – November 2022 – April 2023 provided by Byron Shire Council
Bangalow STP – Projected 2040 ADWF	0.6 ML/day [30]		[11]
Non-Potable Reuse – Bamboo Plantation Irrigation	2020 – 70 kL/day Average, 0.5 ML/day Maximum 2021 – 40 kL/day Average, 0.35 ML/day Maximum 2022 – 0 kL/day Average, 0 ML/day Maximum		Plant Data provided by Byron Shire Council
Effluent Discharge Location	Maori Creek, a tributary of Byron Creek		[24]
Treatment Type	Membrane Bioreactor Biological Nitrogen Removal Chemical Phosphorus Removal		
Effluent Quality	**Mean**	**Maximum**	
Biological Oxygen Demand	0.6 mg/L	2.4 mg/L	NSW EPA Annual Return – Licence 2522 – April 2021 to April 2022
Total Nitrogen	3.2 mg/L	5.6 mg/L	
Total Phosphorus	0.03 mg/L	0.04 mg/L	
Total Suspended Solids	0.6 mg/L	1.6 mg/L	
Fats, Oil and Grease	1.3 mg/L	3 mg/L	
Faecal Coliforms	1 cfu/100 mL	5 cfu/100 mL	
pH	6.8 – 7.1		

Given its small scale (~8% of Byron STW's ADWF) Bangalow STP would not be expected to be of sufficient scale to warrant investigation as a standalone option for potable reuse. Further, given its remote location (10 km from Byron STW), it is not anticipated that the plant would be suitable to transfer for combined advanced water treatment.

Given these considerations, Bangalow STP has not been carried forward for further assessment.

[29] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalies.
[30] Projected 2040 flows derived from sewerage equivalent tenement growth from Table 9 of Hydrosphere Consulting, "Byron Shire Council Water Supply and Sewerage Strategic Plan: 2017 Review," 2017.

4.4 Lismore City Council

4.4.1 South Lismore Sewage Treatment Plant

The South Lismore STP is an inland plant that services South Lismore and the North Lismore Plateau [20].

Table 4-10 provides a summary of South Lismore STP's current and projected sewage flows, treatment type, reuse, and effluent quality.

Table 4-10: South Lismore STP – Plant Summary

Parameter	Value		Reference/Comment
South Lismore STP - Estimated ADWF	2.1 ML/day [31]		Lismore City Council flow data from September 2022 to May 2023
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	1.7 ML/day [32]		Lismore City Council flow data from April 2021 to May 2023
South Lismore STP – Projected 2040 ADWF	2.6 ML/day [33]		[26]
South Lismore STP – Design Capacity	5.4 ML/day		[27]
Non-Potable Reuse	Reuse limited to onsite service water		
Effluent Discharge Location	Yeurabar Creek		
Treatment Type	Intermittent Decant Extended Aeration Biological Nitrogen Removal Biological Phosphorus Removal UV Disinfection		
Effluent Quality	**Median**	**90th Percentile**	
Biological Oxygen Demand	1.0 mg/L	2.5 mg/L	Lismore City Council Wastewater Lab Results – South Lismore – June 2019 to August 2021 (Ammonia results are from November 2018 to May 2023)
Total Nitrogen	3.5 mg/L	5.0 mg/L	
Ammonia (as Nitrogen)	0.13 mg/L	3.1 mg/L	
Total Phosphorus	0.2 mg/L	0.7 mg/L	
Total Suspended Solids	0.9 mg/L	4.8 mg/L	
Fats, Oil and Grease	1.8 mg/L	4 mg/L	
Faecal Coliforms	45 cfu/100 mL	1,200 cfu/100 mL	
pH	6.8 – 7.6		
Electrical Conductivity	660 µS/cm	720 µS/cm	
Total Dissolved Solids	450 mg/L	490 mg/L	

In the context of the RCC service area, effluent from South Lismore STP is considered to have substantial potential to be utilised in a potable reuse scheme based on:

- **Proximity to East Lismore STP to combine effluent streams.** East and South Lismore STPs are approximately 5 km apart on a straight line basis, providing potential for combined reuse of their effluent in schemes.
- **Reasonable scale and dry weather flow.** South Lismore's proximity to East Lismore STP, and reasonable effluent flow is considered suitable for retention as an option for reuse in combined schemes.
- **Limited utilisation in non-potable reuse.** As South Lismore's current reuse is limited to onsite service water production, and Lismore City Council's planning does not currently include large scale non-potable reuse, there is a substantial opportunity to reuse the vast majority of the plant's effluent in potable reuse schemes.
- **Proximity to substantial potable water demand.** South Lismore STP is close to the population centres of Lismore City and Goonellabah, and the key supply reservoirs for the region (City View, High Street, Belvedere and Ross St)

[31] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalies.
[32] Minimum of 30 day rolling average of dry weather flow, manually filtered to remove anomalies.
[33] In the absence of projected sewage flows from Lismore City Council, projected 2040 flows have been derived from equivalent tenement growth for water supply to Ross Street, High Street, Belvedere, Holland Street, Wollongbar and Pineapple Road Reservoirs, with linearised annual growth applied between 2021 and 2030, and 2030 and 2060 provided in Table 4.7 of Engeny Water Management, "Rous County Council Bulk Water Network - Milestone 1 - Model Update and Existing System Performance Assessment," 2021.

(~5 km on a straight line basis, and ~65-135 m higher in elevation), creating potential for efficient direct augmentation schemes (subject to regulatory constraints).

- **Potential to utilise the Wilsons River Source Pump Station (WRSPS).** The WRSPS is approximately 10 m higher in elevation and 7 km from South Lismore STP on a straight line basis, which may provide opportunities for schemes directing flow via the WRSPS to Rocky Creek Dam.
- **Suitable effluent quality.** The available information indicates that the current effluent quality is generally viable for treatment in a typical AWTP process train. While it is also anticipated that the effluent TDS will be suitable for treatment in a carbon-based AWTP train, further monitoring of effluent conductivity and/or total dissolved solids is required.

Based on these attributes, a number of the identified scheme options are based on combining effluent from South Lismore and East Lismore STPs.

4.4.2 East Lismore Wastewater Treatment Plant

The East Lismore STP is an inland plant that was fully inundated during a flood event in February and March of 2022. This event resulted in a series of temporary works being undertaken to temporarily re-establish the plant during 2022. As a result of the significant damage to the plant, it is understood that East Lismore STP is likely to be upgraded, with a new treatment train providing sewage treatment on an elevated area of the existing site.

As the future treatment process to be adopted is unknown, Table 4-11 provides a summary of East Lismore STP's current and projected sewage flows and the current effluent quality.

Table 4-11: East Lismore STP – Plant Summary

Parameter	Value		Reference/Comment
East Lismore STP - Estimated ADWF	5.4 ML/day [34]		Lismore City Council flow data from September 2022 to May 2023
Estimated Minimum Month ADWF (at Level 0 Water Restrictions)	4.8 ML/day [35]		
East Lismore STP – Projected 2040 ADWF	6.5 ML/day [36]		[21]
Non-Potable Reuse	Reuse limited to onsite service water		Lismore City Council
Effluent Discharge Location	Monaltrie Creek		[28]
Treatment Type	Intermittent Decant Extended Aeration with Biological P removal (Plant to be replaced in next 2-3 years)		
Effluent Quality	**50th Percentile**	**95th Percentile**	
Biological Oxygen Demand	1.8 mg/L	5.4 mg/L	Lismore City Council Wastewater Lab Results – East Lismore - December 2011 - March 2022. Plant to be replaced in next 2-3 years.
Nitrogen (Ammonia)	0.68 mg/L	2.64 mg/L	
Total Nitrogen	6.3 mg/L	10.3 mg/L	
Total Phosphorus	0.4 mg/L	1.2 mg/L	
Total Suspended Solids	2.5 mg/L	10.4 mg/L	
Fats, Oil and Grease	1.8	5.8 mg/L	

The existing plant's effluent is substantially higher in quality than required under its environment protection licence. The upgraded plant would generally be expected to deliver effluent as good (or better) than the existing plant. Additionally, while the plant's licence does not require disinfection, the plant operated a UV disinfection system prior to the 2022 flood, and the temporary works undertaken to recommence treatment after the flood included provision of facilities for chlorine dosing for

[34] Inflow when rainfall for preceding 3 days is less than 7mm, and rainfall on day is 0 mm, manually filtered to remove anomalie s.
[35] Minimum of 30 day rolling average of dry weather flow, manually filtered to remove anomalies.
[36] In the absence of projected sewage flows from Lismore City Council, projected 2040 flows have been derived from equivalent te nement growth for water supply to Ross Street, High Street, Belvedere, Holland Street, Wollongbar and Pineapple Road Reservoirs, with linearised annual growth applied between 2021 and 2030, and 2030 and 2060 provided in Table 4.7 of Engeny Water Management, "Rous County Council Bulk Water Network - Milestone 1 - Model Update and Existing System Performance Assessment," 2021.

disinfection. UV disinfection (or an alternative form or non-chemical disinfection) is anticipated to be retained in the upgraded plant.

In the context of the RCC service area, effluent from East Lismore STP is considered to have substantial potential to be utilised in a potable reuse scheme based on:

- **Substantial scale and dry weather flow.** East Lismore STP is the third largest WWTP in the RCC service area in terms of current and projected ADWF.
- **Proximity to South Lismore STP to combine effluent streams.** East and South Lismore STPs are approximately 5 km apart on a straight line basis, providing potential for combined reuse of their effluent in schemes.
- **Limited utilisation in non-potable reuse.** As East Lismore's current reuse is limited to onsite service water production, and there are no plans in place to increase non-potable reuse in Lismore, there is a substantial opportunity to reuse the vast majority of the plant's effluent in potable reuse schemes.
- **Proximity to substantial potable water demand.** East Lismore STP is close to the population centres of Lismore City and Goonellabah, and the key supply reservoirs for the region (City View, High Street, Belvedere and Ross St) (~4 km on a straight line basis, and ~70-140 m higher in elevation), creating potential for efficient direct augmentation schemes (subject to regulatory constraints).
- **Potential to Utilise Wilsons River Pump Station.** The Wilsons River Pump Station (WRSPS) is approximately 15 m higher in elevation and 6 km from East Lismore STP on a straight line basis, which may provide opportunities for schemes directing flow via the WRSPS to Rocky Creek Dam.
- **Likely suitable effluent quality.** The available information suggests that the both the current and future effluent quality is generally viable for treatment in a typical AWTP process train. However further investigation of effluent conductivity and/or total dissolved solids is required.

Based on these attributes, a number of the identified scheme options are based on combining effluent from South Lismore and East Lismore STPs. Use of effluent from East Lismore alone may be an option for a smaller scheme (or an initial stage of a larger scheme).

4.5 Richmond Valley Council

Richmond Valley Council operates four sewage treatment plants in their region. The plants are generally remote from the region's key water supplies (Rocky Creek Dam and Emigrant Creek Dam). Note that while Casino STP is not supplied with potable water by RCC, Coraki, Evans Head, Broadwater, Woodburn and Rileys Hill are supplied via the City View Reservoir in Lismore, with additional supply provided by groundwater from a bore located in Woodburn when Rocky Creek Dam is below 60% of its storage capacity under RCC's bulk water supply operating rules [24].

4.5.1 Casino Sewage Treatment Plant

Casino STP services the inland community of Casino, located on the upper reaches of the Richmond River.

Table 4-12 provides a summary of Casino STP's projected sewage flows and treatment type.

Table 4-12: Casino STP – Plant Summary

Parameter	Value	Reference/Comment
Casino STP – Projected 2040 ADWF	3.6 ML/day [37]	
Current Reuse	Blue Dog Agriculture – Irrigation of 140 Ha of tea tree plantation, maize and soybean crops Peak Reuse of up to 95% in dry periods Golf Course Irrigation Wetlands	[25]
Effluent Discharge Location	Barlings Creek via Wetlands	
Treatment Type	Trickling Filter and Extended Aeration Tank Biological Nitrogen Removal	

While Casino STP is of a substantial scale, the plant's remote location (~18 km to the closest STP, and ~22 km to the nearest RCC managed reservoir), coupled with the substantial non-potable reuse of the plant effluent in dry periods, makes it unsuitable for consideration in potable reuse schemes. On this basis, Casino STP has not been carried forward for further assessment.

4.5.2 Coraki Sewage Treatment Plant

Coraki STP services the inland community of Coraki, located on the Richmond River.

Table 4-12 provides a summary of Coraki STP's current sewage flows and treatment type.

Table 4-13: Coraki STP – Plant Summary

Parameter	Value	Reference/Comment
Coraki STP – Estimated ADWF	<0.5 ML/day [38]	[25]
Effluent Discharge Location	Barlings Creek via Wetlands	
Treatment Type	Trickling Filter Biological Nitrogen Removal	

Given its small scale Coraki STP has not been carried forward for further assessment.

[37] Assumes a 1% annual growth from the 2032 forecasted 1.283 ML/d provided in Hydrosphere Consulting, "Richmond Valley Council Water Supply and Sewerage Strategic Plan," 2018.
[38] Estimated from flow to 2017 provided in Hydrosphere Consulting, "Richmond Valley Council Water Supply and Sewerage Strategic Plan," 2018.

4.5.3 Evans Head Sewage Treatment Plant

The Evans Head STP is a coastal plant that services Evans Head, Woodburn and Broadwater.

Table 4-14 provides a summary of Evans Head STP's projected sewage flows, reuse, and treatment type.

Table 4-14: Evans Head STP – Plant Summary

Parameter	Value	Reference/Comment
Evans Head STP – Projected 2040 ADWF	1.35 ML/day [39]	[25]
Current Reuse	On-site reuse	
Effluent Discharge Location	Wetlands to Salty Lagoon	
Treatment Type	Intermittent Decant Extended Aeration Biological Nitrogen Removal Chemical Phosphorus Removal UV Disinfection	

Given its small scale (~15% of Ballina STP's ADWF) and remote location (~34 km from Lismore and ~30 km from Ballina), Evans Head STP would not be expected to be of sufficient scale to warrant investigation as a standalone or combined option for potable reuse.

Given these considerations, Evans Head STP has not been carried forward for further assessment.

4.5.4 Rileys Hill Sewage Treatment Plant

The Rileys Hill STP is an extremely small plant servicing only Rileys Hill through a single pump station.

Table 4-14 provides a summary of Rileys Hill STP's projected sewage flows, reuse, and treatment type.

Table 4-15: Rileys Hill STP – Plant Summary

Parameter	Value	Reference/Comment
Rileys Hill STP - Estimated ADWF	<20 kL/day	[25]
Effluent Discharge Location	Richmond River (Saline / Tidal)	
Treatment Type	Biological Nitrogen Removal Chemical Phosphorus Removal UV Disinfection	

Given its small scale, Rileys Hill STP has not been carried forward for further assessment.

[39] Assumes a 1% annual growth from the 2032 forecasted 3.3 ML/d provided in Hydrosphere Consulting, "Richmond Valley Council Water Supply and Sewerage Strategic Plan," 2018.

4.6 Summary of Estimated Maximum Purified Recycled Water Available

Due to the relatively small scale of the sewage treatment plants within the region (relative to the additional secure yield required from 2035-40), utilisation of flows from the two treatment plants in each of the three major population centres is likely to result in the most promising schemes. To this end, the option identification has initially considered these larger capacity schemes. Estimated maximum PRW production rates for these schemes are summarised in Table 4-16. Schemes utilising a single plant's effluent stream may be considered as sub-options where relevant for the most promising options in subsequent considerations, or as a part of staging a larger system for the ultimate demands.

Table 4-16: Combined Treatment Plant Effluent Schemes Estimated Maximum PRW Production Rates

Local Government Area		Lismore	Ballina	Byron	
Effluent Sources		East Lismore STP (6.5 ML/d) + South Lismore STP (2.6 ML/d)	Lennox Head WWTP (5.3 ML/d) + Ballina WWTP (8.1 ML/d)	Brunswick Valley STP (2.2 ML/d) + Byron STW (6.6 ML/d)	
Projected 2040 ADWF		9.1 ML/d	13.4 ML/d	8.8 ML/d ADWF	
Non-potable reuse		Nil	Actual recent: 0.77 ML/d Est. 2040 Target: 2.35 ML/d 2040 PDD: 5.9 ML/d	Actual recent: ~1.15 ML/d	
AWTP Type		Carbon based	RO based (at 80% recovery)	RO based (at 80% recovery)	Carbon based
Estimated Maximum Dry Weather PRW Production	With no non-potable reuse	9.1 ML/d	10.7 ML/d	7.0 ML/d	8.8 ML/d
	With recent non-potable reuse		10.1 ML/d	6.1 ML/d	7.6 ML/d
	With target non-potable reuse		6.0 ML/d		

For all AWTP options there will be return streams to the nearest WWTP (e.g. filter backwash flows). This does not affect the maximum production rates shown in Table 4-16, but will need to be considered in the overall flow balance between the WWTPs and the AWTP.

4.7 Trade Waste

Initial review of trade waste in the relevant WWTP catchments indicates that trade waste primarily consists of hospitality (i.e. cafes and restaurants) and medical facilities (including hospitals in Byron, Ballina and Lismore). It is worth noting that the plants identified as potential sources for potable reuse scheme options (Ballina, Lennox Head, Byron, Brunswick Valley, South Lismore and East Lismore) all operate activated sludge processes at sufficient sludge age to achieve biological nitrogen removal. As a consequence, it is anticipated that a substantial proportion of hormones and pharmaceutical byproducts received at the plant from medical facilities and other sources will be degraded through the treatment process [11].

While even small trade waste sources can have a substantial impact on chemical risk, it is our current understanding that there is very little heavy industry in the relevant catchment areas. The available trade waste data will be further reviewed as part of the input into the high level quantitative chemical risk assessment (QCRA) to be performed in the next phase of the investigation. At a general level, it is noted that heavy industry and other significant chemical risk contributors are expected to have a much lower presence in the RCC service area compared to major urban centres, which may serve to reduce the chemical risks for the scheme options.

5 SURFACE WATER ENVIRONMENTAL BUFFERS

To support the identification of surface water augmentation (SWA) options, consideration has been given to:

- Existing surface water storages utilised in the RCC potable water network (for SWA);
- Additional existing surface water storages in the RCC region, and;
- The potential for engineered surface water storages in the RCC region.

Relevant information in regard to each of these surface water buffers is summarised in the following sections.

5.1 Existing Surface Water Storages and Surface Water Supply in RCC Potable Water Network

The Rous County Council potable water supply system includes two significant existing surface water storages - Rocky Creek Dam and Emigrant Creek Dam. Each of these dams form a key component of the Rous County Region's water supply and include a water treatment plants for supply to the potable water network.

5.1.1 Rocky Creek Dam and Nightcap Water Treatment Plant

The Rocky Creek Dam is the main supply source for the RCC's potable water system, with the associated Nightcap Water Treatment Plant (WTP) positioned to supply the entirety of RCC's potable water network.

Located inland, and at a higher elevation than all supply reservoirs in the region, the dam and its associated WTP comprise the only source in the region that are able to provide supply to all reservoirs in the bulk water supply network (excl. Casino).

Table 5-1 provides brief details of the Rocky Creek Dam and Nightcap WTP.

Table 5-1: Rocky Creek Dam and Nightcap WTP [31]

Surface Water Storage	Rocky Creek Dam
Full Supply Volume	13,524 ML
Dead Storage Volume	150 ML
Location	Whian Whian State Forest
Indicative Elevation	187.1 mAHD at spillway
Operating Principle	Always in use
Environmental Release	Not Required
Water Treatment Plant	**Nightcap WTP**
Treatment Type	pH correction→Dissolved Air Flotation in-Filter (DAFF)→Ozone→Biological Activated Carbon→Chlorine Disinfection
Capacity	70 ML/d

Table 5-2 summarises the typical raw water quality supplied to Nightcap WTP from Rocky Creek Dam. The TDS in Rocky Creek Dam is particularly low.

Table 5-2: Rocky Creek Dam Water Quality– January 2010 to March 2021 [27]

Parameter	pH	Turbidity	Alkalinity	Total Hardness	TDS	Conductivity	TN	TP
Units	pH Units	NTU	mg/L as $CaCO_3$	mg/L as $CaCO_3$	mg/L	µs/cm	mg/L	mg/L
Minimum	5.7	0.7	10	4	20	32	0.24	0.05
5^{th} Percentile	6.2	1.3	20	5	27.4	43	0.25	0.05
Median	6.6	2.3	20	6	33	51	0.33	0.05
Average	6.7	2.4	20	6	33	52	0.34	0.05
95%ile	7.3	3.6	20	7	39	61	0.49	0.08
Max	8.7	8.7	21	19	92	144	0.56	0.18
Count	559	565	132	298	308	311	65	65

As Rocky Creek Dam represents the primary water source for the vast majority of the region's water supply, RCC would be concerned by any PRW scheme that could potentially require cessation of supply from the dam as a corrective action. While surface water augmentation to primary water sources occurs in a number of large-scale IPR schemes, RCC has elected to not carry this forward for detailed consideration on a risk basis,.

The most promising schemes for SWA of Rocky Creek Dam are from the Lismore WWTPs due to the shorter transfer distances, and large-scale savings in transfer infrastructure through utilisation of the existing Wilson River Source pipeline and pump station (refer to Section 9).

However, utilising Rocky Creek Dam for surface water augmentation of PRW produced in Lismore would be complicated by:

- The very high water quality in the dam, which would require detailed analysis and modelling to ascertain the impacts on the prevailing ecology of adding PRW at different temperature, salinity, and nutrient levels;

- The need to mitigate co-mingling of PRW and the Wilsons River Source water, which would impose water quality risks to any proposed SWA augmentation scheme. The Wilsons River Source is not a protected catchment, and therefore any transfer Wilsons River Source water into Rocky Creek Dam would likely be unacceptable.

- The cost and complexity of additional treatment to improve the water quality of the Wilsons River Source water to a level required to make it acceptable for discharge to the Rocky Creek Dam.

- The ownership of the land surrounding the dam, and the associated difficulties in placing new pipework through areas with such high environmental values, and,

- The potential for additional challenges in discharge of PRW from a carbon-based AWTP to the dam (in the absence of detailed modelling and analysis). The Lismore schemes do not have a clear avenue for brine disposal, making RO-based treatment less viable. For carbon-based treatment there will less ability to mitigate the salt content and nutrient levels of the produced PRW water, and therefore limited ability to adjust the baseline water quality should the modelling identify it as problematic in terms of the prevailing ecology.

On this basis, RCC's position is that RWA schemes (rather than SWA) are likely to be more prudent based on the project specific issues identified, assuming it is possible to demonstrate similar levels of public health protection through appropriate management of chemical and pathogen risks.

While surface water augmentation to Rocky Creek Dam has not been short-listed for detailed consideration as part of this investigation, surface water augmentation to the dam from PRW produced in the Byron STPs has been carried forward for higher level consideration (see Section 9.2).

5.1.2 Emigrant Creek Dam and Emigrant Creek Water Treatment Plant

Emigrant Creek Dam acts as a secondary source of potable water in the RCC Region, providing potable water supply to the Ballina Shire Region through the Emigrant Creek WTP via Knockrow Reservoir when Rocky Creek Dam is below 95% of its storage capacity. The attributes of the dam and its associated Water Treatment Plant are summarised in Table 5-3.

Table 5-3: Emigrant Creek Dam and Water Treatment Plant [26]

Surface Water Storage	Emigrant Creek Dam
Full Supply Volume	854 ML
Dead Storage Volume	50 ML
Location	Knockrow
Indicative Elevation	62.3 mAHD at spillway
Associated WTP	Emigrant Creek WTP (Existing Nominal Capacity 7.5 ML/d, Existing Actual Capacity 6.5 ML/d)
Operating Principle	WTP brought online when Rocky Creek Dam reaches 95% storage
Environmental Release	10 L/s
Water Treatment Plant	**Emigrant Creek WTP**
Treatment Type	Iron and Manganese Removal→pH Correction→Ultrafiltration Membrane→Ozone→Biological Activated Carbon→Chlorine Disinfection
Capacity	7.5 ML/d

The Australian Guidelines for Water Recycling (AGWR) do not provide definitive direction of sizing requirements for environmental buffers, but provides the following general direction [32]:

Indirect augmentation schemes should be designed so that the time in receiving waters is sufficient to enable operators and regulators to assess recycled water treatment and recycled water quality and, where necessary, to intervene before water is supplied to consumers.

Assuming routine sampling of the PRW occurs monthly, a minimum retention time of 70 days has been applied for preliminary consideration of the minimum residence time in environmental buffers based on:

- 30 days between sampling events;
- 14 days to obtain laboratory results;
- 7 days to organise resampling if required;
- 14 days to obtain laboratory results for second sample event; and,
- 5 days contingency;

Based on a PRW production rate of 8 ML/d, the current capacity of Emigrant Creek WTP of 6.5 ML/d, and a minimum required environmental flow of 0.8 ML/d (see Section 8.2), the maximum sustained total outflow from the dam could be up to 15.3 ML/d. At this throughflow, the dam were 100% full, the theoretical retention time would be 55 days. Hence, at this maximum throughput, the dam would be insufficient to provide the minimum 70 day theoretical retention time under this scenario.

An alternative approach could include using PRW to replenish the dam when natural inflow is low. For this scenario, assuming the outflow is equivalent to the current WTP capacity plus the minimum environmental flow, and the inflow is only PRW, the dam would provide 70 days of theoretical retention time until dam levels drop to 70% full. At less than 70%, the dam would need to be operated in a batch mode to ensure the minimum 70 day criteria is met. This has potential to negatively impact yield from the dam.

As an additional constraint, it is noted that the Emigrant Creek WTP site is very constrained, making any upgrade to the plant complex and expensive.

Based on the issues with minimum theoretical retention time and potential impact on yield, as well as the complexity and cost associated with upgrade of Emigrant Creek WTP, the use of this infrastructure for an IPR scheme presents substantial challenges.

5.1.3 Wilsons River Source

The Wilsons River Source comprises:

- The Low Lift (Intake) Wilsons River Source Pump Station on the bank of the upper reaches of the Wilsons River tidal pool at Howards Grass;
- A small buffer tank and the High Lift (Intake) Wilsons River Source Pump Station, and,
- A 19.6 km pressure main from High Lift Pump Station to the inlet chamber of Nightcap WTP.

RCC's current licence entitlement for the Wilson River Source is 5,400 ML/annum (14.8 ML/d annual average).

The extraction of water from the Wilsons River Source occurs when the Rocky Creek Dam is below 95% storage volume.

Rous County Council's licence to extract flow from the Wilsons River Source is limited based on the measured flow in the river, with differing volumes available to use in summer and winter periods. The peak extraction rate is capped at 30 ML/d. Table 5-4 summarises the permissible daily extraction volume from the Wilsons River based on the observed flow recorded at the Eltham Gauge under these scenarios.

Table 5-4: Wilsons River Source – Allowable Daily Extraction Volume [26]

Summer (September to February)		Winter (March – August)	
River Flow (ML/d)	Maximum Extraction to Nightcap WTP (ML/d)	River Flow (ML/d)	Maximum Extraction to Nightcap WTP (ML/d)
<29	0	<33	0
29-42	5	33-41	5
42-54	10	41-50	10
54-66	15	50-58	15
66 – 78	20	58-67	20
78-90	25	67-75	25
>= 90	30	>=75	30

The Wilsons River Source Pump Station (WRSPS) comprises four pumps, with two pumps configured as single stage units (600 kW each) and two smaller pumps operating in series (375 kW each). With a standby pump available, the pump station can deliver up to 405 L/s (35 ML/d). Under test, the peak output of the pump station with all pumps operating was reported as 580 L/s (50 ML/d). However it is understood that this peak flow rate can be realised in practice or sustained without an electrical upgrade at the site.

Table 5-5 summarises the typical water quality supplied to Nightcap WTP from the Wilsons River Source:

Table 5-5: Wilsons River Water Quality – January 2010 to March 2021 [27]

Parameter	pH	Turbidity	Alkalinity	Total Hardness	TDS	Conductivity	TN	TP
Units	pH Units	NTU	mg/L as $CaCO_3$	mg/L as $CaCO_3$	mg/L	µs/cm	mg/L	mg/L
Minimum	6.1	1	20	10	38	81	0.15	0.05
5th Percentile	6.6	6.1	20	15	54.2	94	0.2	0.05
Median	7.1	12	25.5	20	66	116	0.37	0.06
Average	7.2	15	27	21	69	122	0.38	0.09
95%ile	7.7	34	42	32	94.6	162	0.69	0.22
Max	8.5	174	61	49	120	295	0.72	0.68
Count	521	521	126	285	163	143	50	50

5.2 OTHER EXISTING SURFACE WATERS

Consideration has also been given to alternative locations for surface water's potential to provide benefit in purified recycled water schemes in the RCC region. By conducting a broad sweep of the RCC region, several alternative water bodies were considered as potential environmental buffers within PRW schemes, including:

- The Lismore Lake, an engineered lake constructed beside the Wilsons River on the southern side of Lismore as a potential surface water storage;
- The Bexhill Quarry, a disused clay shale quarry approximately 7.5 km north east of Lismore as a potential surface water storage;
- The South Lismore Wetlands, located downstream of the South Lismore STP as a potential environmental buffer;
- The Byron Wetlands, located downstream of the Byron STW as a potential environmental buffer; and,
- The Byron Creek located between St Helena and the Wilsons River as a potential environmental buffer.

A brief summary of each storage, including its potential role and key attributes, is provided in Sections 5.2.1 through 5.2.5. As limited little detail is available for each of the water bodies at this stage, they have only been considered on a qualitative level.

5.2.1 Lismore Lake

The Lismore Lake is an engineered lake that was constructed beside the Wilsons River in the 1970's, which was historically periodically provided with water from the Wilsons River through a pumped flow [28].

The lake is relatively large, covering an area of ~10 hectares. Although there is potential that a substantial storage volume may be provided by the lake, its proximity to the Wilsons River raises concerns regarding flow exchange between the river and the lake.

5.2.2 Bexhill Quarry

The Bexhill quarry located to the North-East of Lismore and is a disused brickworks quarry. While the quarry may provide a suitable volume for surface water storage there is little information available on the water quality in the quarry. Given the potential for substantial complexities in its water quality, and the local community demand for the area to be transformed into a parkland for public use, the quarry has not been carried forward as an option for environmental buffering.

5.2.3 South Lismore Wetlands

The South Lismore wetlands are located adjacent to the South Lismore STP and formerly received effluent from the South Lismore STP, with flow from the STP diverted around the wetlands directly to the creek at the commissioning of the upgraded sewage treatment plant in 2017.

The wetlands cover an extensive area (~9 hectares), but are very shallow, and are only likely to provide a substantial storage volume if specifically modified to form an engineered buffer. It should also be noted that the wetlands are subject to flooding. Given the extended period of receival of treated sewage from the prior stage of the South Lismore STP, substantial evaluation of the soil quality at the site, as well as its environmental sensitivity would be required prior to any consideration of its use as an engineered storage.

5.2.4 Byron Wetlands

The Byron Wetlands are located adjacent to the Byron STW, and receive treated effluent from the plant prior to discharge to Union Drain. While the wetlands cover a large area (~15 hectares), and hence may provide some benefit as an environmental buffer, they are indicated as being only 0.5 m deep, hence providing 75 ML of environmental buffering at most. Consideration may be given to the additional benefit provided by the wetlands as a minor environmental buffer and/or effluent polishing step prior to an AWTP.

5.2.5 Byron Creek

Extending from the St Helena reservoir to the Wilsons River (upstream of the WRSPS), Byron Creek was considered as a potential environmental flow path to provide PRW from schemes in the Byron region to the Wilsons River – specifically with the potential to enable additional extraction from the Wilsons River source under a modification to the licence.

While considered a potentially viable low cost transfer option for treated effluent from the Byron region to the WRSPS, a number of barriers have been identified for this approach at this stage, including:

- The extensive assessment required to determine the environmental impacts of the scheme in its modification of the Byron Creek through the addition of substantial additional daily flow.
- The limited residence supplied by the creek system prior to withdrawal at the WRSPS (anticipated to be only a few days), which reduces its potential as an environmental buffer.
- The potential for uncontrolled withdrawal of water from the creek by other users, limiting the ability to claim additional supply at the WRSPS.

Critically, discussion with Rous County Council indicated that it is unlikely additional secure yield from the WRSPS could be achieved through implementation of this additional flow in Byron Creek, with significant challenges anticipated in amendment to the licence for Wilsons River source (regardless of additional input flow added).

Given these considerations, use of the Byron Creek within a potable reuse scheme is considered unlikely to be viable.

5.3 Engineered Off-Stream Storages

As noted in Sections 5.1.1 and 5.1.2, the criticality of Rocky Creek Dam and the small scale of Emigrant Creek Dam means there is limited scope to use existing dams to provide an extended failure response time without placing imposing risks on the existing secure yield from those systems. Where an extended failure response time is required (i.e. under traditional indirect potable reuse), then off-stream storages could be specifically engineered to provide an extended delay between supply of PRW to the storage system and subsequent supply to customers.

Given the regional nature of the Rous County, there are expected to be multiple locations of limited ecological value (such as cleared grazing land) where an engineered dam could be constructed. For example, high level review of contours of rural land in vicinity of Lagoon Grass suggests a dam providing storage on the order of 0.6 GL to 1.2 GL could be implemented. Noting the constraints on Wilsons River source discussed in Section 5.1.3, such a storage could additionally be used to increase take from Wilsons River when available (with or without PRW) to supply Nightcap WTP.

While not relevant to this study, comparable examples of this approach were considered in the Mullumbimby Water Supply Strategy, with potential locations for storages with volumes of up to 689 ML were identified [29] .

RCC has completed high-level investigations to estimate costs for an engineered off-stream storage in the general vicinity of the Wilsons River source. These estimates suggest costs for an engineered off-stream storage in the range of 0.6 GL to 1.2 GL would likely cost on the order of $40M to $50M. RCC has determined that, based on the rudimentary cost estimates, it can be inferred that the business case for this kind of environmental buffer would not be supportable if utilised exclusively as part of a PRW scheme. However, an engineered storage which can be used for both indirect potable reuse and to enhance the yield of the Wilsons River Source may have better viability.

The construction of large off-stream storages has been specifically considered in one of the options at this stage – primarily to retain an IPR option with potential to align with the expectations of the existing AGWR. Despite this, it is important to note that:

- Practices in potable reuse internationally are moving towards the somewhat increased robustness in treatment design in combination with small engineered storages (i.e. T_{10} of 30-60 minutes), and,
- The additional approvals and construction works associated with a large new storages may impose significant additional challenges and costs.

6 EXISTING AND PLANNED GROUNDWATER SCHEMES

Under the current planning, the groundwater sources in the RCC region are not going to be used for routine supply for the RCC potable water network until the Rocky Creek Dam storage falls below 60% [10]. At this level, two borefields will be brought into operation in Alstonville and Woodburn, providing alternative supply for the regions. Given the sustainable yield shortfall anticipated to 2060, RCC has undertaken extensive analysis of opportunities to utilise groundwater through the Future Water Project.

Within the studies undertaken, it has been noted that several of the groundwater sources indicated by RCC have not been extensively utilised by RCC to this point, and the understanding of the impacts of severe drought on sustainable yields from a number of these sources do not appear to be well understood at this time.

Sections 6.1 through 6.4 provide a summary of the attributes of the four key groundwater supplies that have been considered in investigations of future groundwater sources for the region, and considers their potential suitability to schemes for indirect potable reuse via GWA in further detail.

6.1 ALSTONVILLE

6.1.1 Existing and Planned Groundwater Schemes

RCC's assessment of groundwater in its service region has identified two key aquifers that are accessible in the inland region of Alstonville, close to the major population centre of Lismore:

- The Alstonville basalt aquifer (currently accessed by RCC through the Lumley Park and Converys Lane bores), and
- The Clarence Moreton basin.

The Alstonville basalt aquifer is heavily utilised. There are a large number of bores on freehold land throughout the region, with the available supply from the aquifer fully allocated. RCC currently accesses this aquifer through its Lumley Park and Converys Lane bores, with an allocation of 680 ML/year. RCC has low expectations of accessing additional allocations of groundwater from this source.

The Clarence Moreton basin is a significantly larger aquifer that underlies the Alstonville basalt aquifer, and is currently underexploited, with an estimated 2% of the available 300,000 ML/year assigned to licenses [30].

Both aquifers are considered good groundwater sources, and provide water with electrical conductivity ranging from 180 µS/cm to 500 µS/cm [31].

As an element of the Future Water Project [32], RCC has developed options for an upgraded Alstonville borefield, designed to target the projected 2060 average daily demand of the Wollongbar reservoir, an estimated 4 ML/d, including:

- Retention of the Lumley Park bore, re-equipped to supply 22 L/s, accessing the Alstonville Basalt Aquifer;
- Replacement of the Converys Lane bore, which was found to be unable to achieve its sustainable yield of ~16 L/s when last used in a drought period with a new bore producing an estimated 35 L/s – accessing both the Clarence Moreton Aquifer, and Alstonville Basalt aquifer.
- Construction of a new standby bore at Elvery Lane, with the capacity to supply 35 L/s.
- Construction of a new groundwater treatment plant, clear water storage and transfer pump station and pipeline to Wollongbar Reservoir. Note that consideration has also been given to the upgrade and use of the existing Marom Creek WTP (which supplies the small community of Wardell) as a groundwater treatment plant in place of developing a new groundwater treatment plant.

Based on the assessment undertaken, RCC anticipates that ongoing development of the Alstonville borefield is likely, with an estimated combined yield of ~4.5 ML/d.

6.1.2 Aquifer Suitability to Groundwater Augmentation

While it appears that the Alstonville basalt aquifer is stressed during drought, there is a significant risk that RCC will be unable to control access to any purified recycled water directed to the aquifer due to:

- The large number of existing access licenses and bores throughout the aquifer, and;
- The spatially diverse nature of the fractured basalt aquifer (with little current understanding of the correlation between injection and re-extraction).

In this case, it should be noted that the only example of indirect potable reuse through groundwater augmentation in Australia (currently undertaken in the in the Beenyup Groundwater Replenishment Scheme in Western Australia) implemented a recharge management zone with a distance of ~10 km to the closest private bore from the recharge site.

In the case of the Clarence Moreton Aquifer, while there may be opportunities to undertake groundwater recharge of the aquifer, the large extent and volume of available allocations from this water source make it unlikely to be of value at this stage. As the aquifer becomes further utilised, the value of recharging this aquifer may change, however recharge of the aquifer would only be of value to RCC at this stage if a one-for-one allocation is able to be obtained (as has been achieved in the Beenyup Groundwater Replenishment Scheme in Western Australia).

When considered in the context of the potential for groundwater recharge, the two aquifers in the Alstonville borefield are expected to be unlikely to be suitable at this stage, and hence have not been carried forward for further assessment.

6.2 WOODBURN

6.2.1 Existing and Planned Groundwater Schemes

The Woodburn coastal sand aquifer is shallow (at a depth of ~17 to 19 m), and is located approximately 6 km from the coast, and ~30 km to the south of the major population centre of Ballina. The aquifer is moderately utilised with a number of bores on freehold land throughout the region. The aquifer is located close to the smaller population centres of Woodburn, Evans Head, Broadwater and Coraki. Currently, RCC may provide some additional water supply to the Lower Richmond regions of Woodburn, Broadwater, Evans Head and Coraki from the aquifer as an emergency supply when Rocky Creek Dam falls below 60% via one of three existing bores and the use of a package water treatment plant. The remaining two existing bores in the Woodburn aquifer owned by RCC are unable to accessed due to re-routing of the major highway in the region [24]. Based on the current understanding developed from preliminary aquifer modelling, RCC expects that there may be some potential for future allocations of the water from this aquifer [33].

Assessment of the shallow coastal sand aquifer identified would have the capacity to provide a total borefield yield of 3.87 – 4.98 ML/d based on implementation of four bores. A concept design for a borefield and associated groundwater treatment plant was developed to satisfy the average day demands of the region in 2060 that includes:

- Construction of four bores, each designed to extract 16 L/s, for 22 hours per day (borefield capacity of 5 ML/d)
- Construction of a 4.0 ML/d groundwater treatment plant, greater than the 2060 average day demand of the region of Woodburn, Evans Head, Broadwater and Coraki intended to be supplied by the groundwater scheme.

6.2.2 Aquifer Suitability to Groundwater Augmentation

Two key aspects of the Woodburn aquifer have been considered in assessing its suitability to groundwater recharge:

1. Its remote location relative to other major population centres including Lismore and Ballina (approximately 30 km from the identified borefield respectively), and;
2. The suitable capacity of the borefield to local demands for potable water.

While studies to date of the Woodburn aquifer indicate that the yield from the aquifer could be substantially increased, the remote location of the aquifer from major demand centres and trunk mains makes it unlikely to be utilised as a groundwater source for locations outside of its local region [34].

Further, given the borefields capacity for expansion and suitability to local demands to 2060, it is not expected that groundwater augmentation would be of substantial value in this aquifer at this stage. While increased utilisation of the aquifer may increase the viability of GWA (especially in drought conditions), there do not appear to be good drivers for its augmentation with PRW at this stage. As a result, schemes adopting GWA at Woodburn have not been carried forward for further assessment.

6.3 NEWRYBAR

The Newrybar aquifer is another shallow, coastal sands aquifer located approximately 3.5 km from the coast. RCC's assessment of the region investigated two distinct regions of the aquifer, and identified that:

- The southern region, with a capacity of up to 6 ML/d, has been identified to be saline, with TDS in excess of 5,000 mg/L identified in initial testing. Initial options assessment for groundwater treatment indicates the need for brackish groundwater RO to treat the extracted groundwater to drinking water standards.
- The Northern region, with a capacity of up to 2.0 ML/d and low TDS.

Concept designs for a borefield and groundwater treatment plant in the region have been developed, however given the poor water quality in the main water source in this aquifer, and the small volume of groundwater of a viable water quality, RCC has indicated that this aquifer is unlikely to be developed. On this basis, the aquifer has not been carried forward for further assessment.

6.4 TYAGARAH

The Tyagarah coastal sand aquifer is located approximately 1.5 km from the coast, 5.5 km to the North-East of the Byron STW. The aquifer is expected to have minimal existing bores, and is located in close proximity to the Tyagarah Nature Reserve - a 7km stretch of coastline National Park [35]. RCC has undertaken extensive assessment of the aquifer to determine the possibility of utilising the aquifer as a potable water supply for the regions of Ocean Shores, Brunswick Heads and Byron Bay. Initial assessments indicate good groundwater quality, with electrical conductivity from 100-200 µS/cm .

RCC has developed a scheme considering the use of an extensive borefield in the aquifer, with a staged implementation of up to 12 bores in the aquifer and a groundwater treatment plant to provide up to 12.5 ML/d to Ocean Shores, Brunswick Heads and Byron Bay via the St Helena Reservoir. While total volume able to be provided by the borefield is anticipated to be up to 22 ML/d, the methodology for utilising flow in excess of RCC's Average Daily Demand in the local region via the St Helena Reservoir has not been developed [32].

The viability of the Tyagarah coastal sands aquifer borefield is under ongoing assessment. The borefield has been identified as having a potential fatal flaw in the possible impact of the borefield on groundwater dependent ecosystems in the region, including in the National Park. On this basis, it is currently unclear whether the borefield will be further developed at this stage, with further assessment required to determine the potential impact of the borefield on locally sensitive environments.

Given the current uncertainty in the ongoing development of this groundwater scheme, and its potential fatal flaw in environmental impacts, groundwater augmentation of this source with PRW has not been carried forward for further assessment at this stage. If the Tyagarah groundwater scheme is further developed and found to be viable, consideration may be given to the potential benefit of GWA depending on sustainable yields from the aquifer.

6.5 Groundwater Schemes for Groundwater Augmentation

As outlined in Sections 6.1 through 6.4, none of the existing and planned groundwater schemes in the region appear suitable for consideration of groundwater augmentation at this stage. However, as the groundwater investigations continue (under their respective projects), the value and feasibility of groundwater replenishment may change. If groundwater extraction becomes a significant source of water for the region, and it is found that there are insufficient allocation's available within the existing aquifers for the future water supply required, benefit may be achieved through replenishment of the aquifers with PRW. However, in each case, the viability of groundwater augmentation would need to be considered against options associated with expansion of an existing or planned borefield, and the ability to undertake aquifer recharge without risking inadvertent offtake of PRW by other users.

> Based on the information in hand, none of the existing and planned groundwater schemes in the region appear suitable for consideration of groundwater augmentation. As a consequence, no GWA schemes have been short-listed for further quantitative development as part of the PRW Investigation Project.
>
> To this end, it is recommended that an ongoing watching brief for groundwater replenishment with PRW be considered as additional information on the groundwater resources and their utilisation becomes available.

7 EXISTING AND PLANNED BULK SUPPLY NETWORK

The major existing potable water distribution infrastructure in the region, is shown in the figures presented in Section 3.

In considering options based on Treated Water Augmentation (TWA), the size, throughflow and connectivity of the existing reservoirs are of key interest, with the key issues being:

- The capacity of any scheme based on TWA will be limited to the potable water demand through the augmented reservoirs, and,

- The proportion of water supplied through the reservoirs which is purified recycled water (known as the “blend ratio”).

A low “blend ratio” provides only minimal benefits in terms of dilution of pathogens or chemicals, and these benefits can be efficiently matched or exceeded by designing the AWTP with suitable safety factors. High blend ratios also have the potential to result in increased potable water salinity, but only in specific cases where:

- The STPs used supply the AWTP do not receive substantial wastewater flows from outside the catchment being supplied with PRW, and,

- A carbon-based AWTP process is in use (i.e. no RO).

While the salinity impacts of a high blend ratio will need to be assessed in detail where relevant, the low salinity of the Rocky Creek Dam and Wilsons River raw water sources will increase the blend ratio which can be tolerated without causing salinity build-up.

In determining the most suitable reservoirs for TWA, consideration was given to all reservoirs within the network, however only those listed in Table 7-1 have the capacity and throughflow to be considered viable (with the major four parallel reservoirs in Lismore considered on a combined basis). In this assessment, consideration was given to the 2040 average day demand from each reservoir, as well as its volume, effectively providing an indication of the suitability of the reservoir to both provide substantial enough scale to supply a significant demand (matching the PRW supplied) and a significant enough storage volume to enable effective blending where applied.

Table 7-1: Major Reservoirs considered for Treated Water Augmentation

LGA	Lismore				Ballina	Byron
Reservoirs	Ross St	City View	High St	Belvedere Dr.	Knockrow	St Helena Reservoir
Volume	6.56 ML	9.05 ML	4.36 ML	3.4 ML	10.4 ML	9.05 ML
	23.4 ML (combined)				19.45 ML (for St Helena with Knockrow backfeed)	
Elevation (TWL)	RL 145.3m	RL 97.5m	RL 76.8m	RL 77.9m	RL 104.8m	RL 115.8m
Projected 2040 Average Daily Demand	3.4 ML/d	2.98 ML/d	1.47 ML/d	2.98 ML/d	13.2 ML/d	8.95 ML/d
	10.8 ML/d with all four main reservoirs 7.4 ML/d without Ross St				22.15 ML (for St Helena with Knockrow backfeed)	

For each of these regions, the reservoirs identified in Table 7-1 form the key supply points for the major demand points of the Rous County Council region, servicing Lismore, Ballina and Byron respectively.

The Lismore reservoirs have the additional benefit of servicing Woodburn, Evans Head, Broadwater and Coraki via the City View reservoir.

Additional features of RCC's potable water network, including opportunities to provide additional supply in locations that service multiple demand areas, have been considered. The key opportunities identified to provide this broader supply was backfeed of Knockrow Reservoir from Saint Helena reservoir. This was indicated as worthy of further investigation by RCC, noting that detailed consideration will be required relation to:

- Blending requirements;
- The risks and modifications required to any direct residential connections;
- Gravity flow limitations, and,
- Pipeline condition (in relation to any increase in operating pressures).

8 ENVIRONMENTAL FLOW SUBSTITUTION OPPORTUNITIES

Environmental flow substitution opportunities have been assessed for the existing major supplies within the RCC Region, including:

- Rocky Creek Dam;
- Emigrant Creek Dam, and;
- The Wilsons River Pump Station.

For each of these supplies, the feasibility of providing purified recycled water as an alternative to the required environmental flows downstream of the water source to enable increased utilisation of the water source has been considered (discussed in Section 8.1 through 8.3).

Based on the information provided in Section 8.1 through 8.3, no environmental flow substitution options have been carried forward for further development.

8.1 Rocky Creek Dam Environmental Flow Substitution

Rocky Creek Dam has no specific requirement for environmental flow releases under its current water access licence, with downstream flow occurring only as a result of dam overflows and seepage through the dam wall. The lack of environmental flow releases from Rocky Creek Dam is acknowledged to have an ecological impact on downstream environments [36]. On the basis of this understanding, no additional sustainable yield would be able to be provided from Rocky Creek Dam via environmental flow substitution. Hence, environmental flow substitution has not been carried forward for further assessment for this location.

8.2 Emigrant Creek Dam Environmental Flow Substitution

Emigrant Creek Dam's existing water access licence requires that when flow is entering Emigrant Creek Dam the flow in the downstream watercourse should be equivalent to the lesser of the flow entering the dam, or that required to see visible flow at Tintenbar downstream of the dam. Effectively, the only environmental flow release from the Emigrant Creek Dam in dry weather periods is through the release of ~0.8 ML/d (a constant flow of 10 L/s) from an outlet pipe at the base of the dam [36]. RCC operations have also indicated that there are ongoing losses through the dam wall. The inability to stop these flows would inhibit the ability to use PRW in place of these releases.

Given the impacts of the limited flow release from the dam in dry weather periods, it is not expected that any substantial additional sustainable yield would be able to be provided from Emigrant Creek Dam via environmental flow substitution, and hence this has not been carried forward for further assessment at this stage.

8.3 Wilson River Source Environmental Flow Substitution

As indicated in Section 0, the volume that may extracted from the Wilsons River Source for use in the potable water network is governed by the flow in the river system as measured at the Eltham Gauge. As the two sewage treatment plants in close proximity to the Wilsons River Source Pump Station (South and East Lismore STPs) are currently discharging their treated effluent to the Wilsons River downstream of the abstraction point (effectively providing environmental flows to the river) RCC does not expect that access licences for additional sustainable yield from the WRSPS would be granted for Environmental Flow Substitution to the Wilsons River.

On the basis of this understanding, environmental flow substitution to the Wilsons River has not been carried forward for further assessment at this stage.

9 IDENTIFICATION AND ASSESSMENT OF REUSE SCHEMES

9.1 COARSE-LEVEL OPTION ASSESSMENT

Given the range of treated effluent sources and augmentation types available in the Rous County Council service area, a systematic approach was applied to the identification of the potable reuse scheme options based on the three major areas where substantial effluent flows are generated, and the potential uses of those flows in each key type of potable reuse.

While the coarse level assessment included options based on surface water augmentation to Rocky Creek Dam, RCC subsequently excluded these options from further consideration under this investigation due to the criticality of the dam to their current system. Additionally, large engineered water storages were not considered in the coarse-level option assessment, but were considered in the options to ensure that an IPR-based option was carried forward.

An initial coarse-level assessment was undertaken for the full range of schemes using a spreadsheet tool. The spreadsheet tool was developed by Rous Water to systematically consider utilisation of effluent from the six substantial source STPs in groundwater augmentation (GWA), surface water augmentation (SWA), raw water augmentation (RWA) and treated water augmentation (TWA), and identify the most promising schemes based on quantitative and semi-quantitative assessment of:

- Purified recycled water (PRW) which can be generated;
- Capacity of downstream system to accommodate and utilise the PRW, and,
- New pipeline and pump stations requirements for transfer of PRW.

Additionally, coarse assessment considered the following potential challenges for each scheme on a non-cost basis:

- Proximity to the ocean for discharge RO concentrate from an RO-based AWTP;
- Potential suitability of a carbon-based AWTP process train (specifically based on the TDS and pollutant levels in the STP effluent stream).

The coarse assessment rated the scheme options based on the rules summarised in Table 9-1. The following two criteria were applied to the capacity considerations:

1. A target capacity of 8 ML/d with no constraints in regard to the blend ratio in the receiving stream, and,
2. A target capacity of 5 ML/d with a maximum blend ratio of 50% in the receiving stream.

The results show the strong influence that the assessment criteria applied have on the ratings of scheme options.

As detailed in the table, where key information was unknown around salinity or groundwater replenishment viability, the coarse assessment applied optimistic assumptions. This approach was designed to keep more options (rather than fewer) in consideration for the subsequent analyses.

Additionally, the coarse level assessment considered both indirect and direct potable reuse scheme types. On this basis, and given the timeframe of the project, the assessment did not exclude options based on the absence of a proscriptive methodology for approval of direct potable reuse schemes in the current Australian Guidelines for Water Recycling (2008) [37].

Table 9-1: Summary of Rules and Assumptions Applied to Coarse-level Scheme Option Assessment

Scheme Attribute	Limits	Comments
Salinity	Of the STPs under consideration, the limited available data suggests that the effluent TDS likely acceptable for carbon-based treatment (without salt capture) for South Lismore STP, Lennox Head STP and Byron STW. Ballina STP effluent will require RO-based treatment due to its high salinity. Lennox Head based effluent was assumed to require RO-based treatment based on its effluent nutrient concentrations and variability in composition. For East Lismore and Brunswick Valley STPs, there is no monitoring data available. However, based on the water supply and attributes of the adjacent plants, there is strong potential that salt removal in the AWTP will not be strictly required, so carbon based treatment can be considered.	
Aquifers	As detailed in Section 6, the limited information available regarding the key attributes of the aquifers in the region makes the scope for their replenishment unclear at this time. Of the aquifers identified, Tyagarah appears to have the highest potential for use in a groundwater augmentation scheme based on its location, scale and existing water quality.	
PRW Production and Utilisation Capacity	**Criterion 1:** No Max Blend Ratio Good: ≥8 ML/d Marginal / Unsure: <8, ≥5 ML/d Poor: <5 ML/d **Criterion 2:** ≤50% Blend Ratio Good: ≥5 ML/d Marginal / Unsure: <5, ≥4 ML/d Poor: <4 ML/d	A minimum blend ratio has not been applied to the coarse analysis for Criterion 1. For carbon-based AWTPs and treated water augmentation, a suitable blend ratio will need to be applied for TWA to manage salinity, and may be required to manage expectations. Additionally, blend ratios will be a consideration in the assessment of surface water augmentation and raw water augmentation schemes. For Criterion 2, a 50% blend ratio was applied. Schemes where RO based treatment is required (i.e. where Ballina STP effluent is utilised) were assessed assuming a recovery of 80%.
PRW Pipeline Length	Good: ≤25 km Marginal / Unsure: >25 km, ≤40 km Poor: ≥ 40 km	The road travel length between the two GPS locations, as reported by Google Maps, was used to estimate the likely pipeline length. Secondary effluent transfer pipelines from plants to AWTP were not considered in the coarse-level assessment.
Non-Potable Reuse	Non-potable reuse has been assumed to be maintained at recent levels (rather than the 2040 targets) for the coarse level assessment.	
Environmental Flow Substitution	Substitution of environmental flows has not been considered in the coarse level assessment.	
Avenues for Residuals (Concentrate) Disposal	RO concentrate (brine) disposal typically requires access to the coast. The lack of a clear disposal option in inland areas lowers the feasibility of RO-based advanced treatment schemes, and favours carbon-based treatment trains.	

The full inputs and out outputs of this analysis are provided in Appendix A, with the outputs of the coarse option analysis summarised in Table 9-2.

Table 9-2: Coarse Potable Reuse Scheme Assessment – Summary of Outputs

No.	General Scheme Information			Overall Promise					
	Source WWTPs	Scheme Type	Transfer Point	Criterion 1: 8 ML/d Target 100% blend		Criterion 2: 5 ML/d Target 50% blend		PRW Pipeline Length	AWTP Type
1	South Lismore STP	SWA	Rocky Ck Dam	Poor	X, 2.6	Poor	X, 2.6	??, 31.5 km	Carbon
2	South Lismore STP	GWA	Tyagarah	Poor	X, 2.6	Poor	X, 2.6	X, 51.5 km	Carbon
3	South Lismore STP	RWA	Nightcap WTP via WRSPS	Poor	X, 2.6	Poor	X, 2.6	✓, 8.6 km	Carbon
4	South Lismore STP	TWA	Main Lismore Res	Poor	X, 2.6	Poor	X, 2.6	✓, 6.3 km	Carbon
5	East Lismore STP	SWA	Rocky Ck Dam	Unsure	N/A	Unsure	N/A	??, 31.5 km	Carbon[1]
6	East Lismore STP	GWA	Tyagarah	Poor	X, 6.5	Poor	X, 6.5	X, 56.7 km	Carbon[1]
7	East Lismore STP	RWA	Nightcap WTP via WRSPS	Unsure	??, 6.5	Good	✓, 6.5	✓, 8.6 km	Carbon[1]
8	East Lismore STP	TWA	Main Lismore Res	Unsure	??,6.5	Good	✓, 5.5	✓, 1.8 km	Carbon[1]
9	Lismore Combined	SWA	Rocky Ck Dam	Unsure	N/A	Unsure	N/A	??, 31.5 km	Carbon[1]
10	Lismore Combined	SWA	Rocky Ck Dam via WRSPS	Good	✓, 9.1	Good	✓, 9.1	✓, 8.6 km	Carbon[1]
11	Lismore Combined	GWA	Tyagarah	Poor	✓, 9.1	Poor	✓, 9.1	X, 53.3 km	Carbon[1]
12	Lismore Combined	RWA	Nightcap WTP via WRSPS	Good	✓, 9.1	Good	✓, 9.1	✓, 8.6 km	Carbon[1]
13	Lismore Combined	TWA	Main Lismore Res	Good	✓, 9.1	Good	✓5.5	✓, 6.3 km	Carbon[1]
14	Ballina WWTP	SWA	Emigrant Ck Dam	Unsure	N/A	Good	✓, 6.5	✓, 13.4 km	RO
15	Ballina WWTP	GWA	Tyagarah	Unsure	✓, 6.5	Unsure	??, 6.5	??, 35.5 km	RO
16	Ballina WWTP	RWA	Emigrant Ck WTP	Unsure	✓, 6.5	Good	✓, 6.5	✓, 13.4 km	RO
17	Ballina WWTP	TWA	Knockrow Res	Unsure	✓, 6.5	Good	✓, 6.5	✓, 12.5 km	RO
18	Lennox Head WWTP	SWA	Emigrant Ck Dam	Poor	X, 3.6	Poor	X, 3.6	✓, 20.4 km	RO
19	Lennox Head WWTP	GWA	Tyagarah	Poor	X, 3.6	Poor	X, 3.6	??, 37.7 km	RO
20	Lennox Head WWTP	RWA	Emigrant Ck WTP	Poor	X, 3.6	Poor	X, 3.6	✓, 20.4 km	RO
21	Lennox Head WWTP	TWA	Knockrow Res	Poor	X, 3.6	Poor	X, 3.6	✓, 14.3 km	RO
22	Ballina Combined	SWA	Emigrant Ck Dam	Unsure	N/A	Good	✓, 7.5	✓, 20.4 km	RO
23	Ballina Combined	GWA	Tyagarah	Unsure	✓, 10.1	Unsure	✓, 10.1	??, 37.7 km	RO
24	Ballina Combined	RWA	Emigrant Ck WTP	Unsure	✓, 7.5	Good	✓, 7.5	✓, 20.4 km	RO
25	Ballina Combined	TWA	Knockrow Res	Good	✓, 10.1	Good	✓, 6.6	✓, 14.3 km	RO
26	Byron STW	SWA	Rocky Creek Dam	Unsure	N/A	Unsure	N/A	??, 35.3 km	Either
27	Byron STW	GWA	Tyagarah	Unsure	??, 5.5	Good	??, 5.5	✓, 13.2 km	Either
28	Byron STW	RWA	Nightcap WTP	Unsure	??, 5.5	Unsure	??, 4.8	??, 35.3 km	Either
29	Byron STW	TWA	St Helena Res	Unsure	??, 5.5	Unsure	??, 4.5	✓, 11.0 km	Either
30	Byron Combined	SWA	Rocky Ck Dam	Unsure	N/A	Unsure	N/A	??, 35.3 km	Either[2]
31	Byron Combined	GWA	Tyagarah	Good	✓, 8.8	Good	✓, 8.8	✓, 13.2 km	Either[2]
32	Byron Combined	RWA	Nightcap WTP	Unsure	✓, 8.8	Unsure	✓, 8.8	??, 35.3 km	Either[2]
33	Byron Combined	TWA	St Helena Res	Good	✓, 8.8	Unsure	??, 4.8	✓, 11.0 km	Either[2]
34	Byron Combined	TWA	St Helena + Knockrow Res	Good	✓, 8.8	Good	✓, 8.9	✓, 11.0 km	Either[2]

Note 1: Assumed based on new East Lismore STP performance and favourable salinity in East Lismore STP influent / effluent (no data in hand).
Note 2: Assumed favourable salinity in Brunswick Valley STP influent / effluent (no data in hand), with 25% of Ocean Shores STP flow diverted to Brunswick Valley for treatment.

The outputs of the coarse assessment provide a general guide to the selection and short-listing of options, but it is also clear that additional specific requirements and sub-options for each scheme will have a substantial bearing on the viability. Observations from the coarse assessment include:

- A scheme capacity of 8 ML/d (in 2040) can only be achieved by combining the effluent from the two STPs in each of the three major centres (Lismore, Byron and Ballina).
- Utilisation of the existing Wilsons River Source pipeline and pump station for transfer of PRW to Rocky Creek Dam (for SWA) or Nightcap WTP (for RWA) would eliminate the need to construct more than 20 km of new pipeline, and therefore would be a key element in any scheme delivering flow to these destinations.
- The use of Emigrant Creek Dam (for SWA) and Emigrant Creek WTP (for RWA) is currently limited by the capacity of the Emigrant Creek WTP. Additionally, as outlined in Section 5.1.2, there are complications in utilisation of Emigrant Creek Dam as an environmental buffer based on its small scale and limited inflows.
- The limited average day demand at Knockrow Reservoir (as projected for 2040) constrains the capacity of a Ballina TWA scheme if a low blend ratio is required. At a blend ratio of 50%, the estimated maximum scheme capacity is 6.6 ML/d. For a Byron TWA scheme utilizing St. Helena Reservoir alone, the constraint on capacity is even greater (4.8 ML/d for the 50% blend ratio). By contrast, a Byron TWA scheme capacity can be increased to 8.8 ML/d by directing flow to St. Helena Reservoir and additionally using the existing potable water network to discharge flow back down to Knockrow Reservoir.

9.2 BASELINE SCHEME OPTIONS DEVELOPMENT AND CATEGORISATION

9.2.1 Methodology and Key Assumptions

Using the outcomes of the investigations in earlier sections, and the Coarse-Level Option Assessment, the following key constraints were applied to the identification of baseline options for consideration during the Scheme Option Identification, Review and Short-Listing Workshop (“Short-listing Workshop”). The workshop was held on July 11, 2023, and was attended by RCC stakeholders and representatives from Tyr Group, Planit, IBL Solutions, BMT and Carollo. Minutes of the workshop are included in Appendix D.

The baseline scheme options were considered systematically through reference to each type of potable reuse (GWA, SWA, RWA and TWA) for the two major wastewater treatment plants in each population centre (Ballina / Lennox Head, Byron / Brunswick Valley, East Lismore / South Lismore). Adaptions were then applied where necessary (including prior to and as an output of the Shortlisting Workshop) to refine the baseline scheme options to increase their viability or value where relevant.

Further refinement of the baseline options was undertaken subsequent to the workshop based on issues identified of the workshop, and incorporating additional information obtained from the constituent councils.

The scheme options were then categorised into the following three groups:

- **Level 1** – Option carried forward and quantitatively and qualitatively developed as part of the PRW project.
- **Level 2** – Option carried forward at a high level – partial option development (approximation of pipelines and AWTP process train requirements and costs, qualitative discussion of opportunities and risks, including considerations of infrastructure costs, complexities and risks relative to Level 1 options). Option is considered potentially prospective, but with substantial barriers reducing likely viability compared to Level 1 options.
- **Level 3** – Option not carried forward for this investigation. Low or limited viability based on information in hand.

The following key assumptions were applied to the baseline option development (and their subsequent) categorisation based on the findings outlined in the previous sections.

Combining the effluent from source STPs: As commercial viability is expected to be best for larger scale schemes, the baseline options were based on combining the effluent from both main wastewater treatment plants is in each of the three major population centres (i.e. East and South Lismore, Lennox Head and Ballina, and Brunswick Valley and Byron STPs). Within this, sub-options to stage the development of the schemes can be considered where advantageous (i.e. where effluent from only one plant can meet the initial shortfall in secure yield, and effluent from the second plant is transferred to the AWTP only at a subsequent stage).

No short-listed Groundwater Replenishment Schemes: As detailed in Section 6.4, RCC has identified potential challenges around the environmental sensitivity of Tyagarah which may impact the viability of use of the aquifer in a groundwater scheme. In relation to development of a scheme based on augmentation of the aquifer with PRW, additional issues can be anticipated. Additionally, it is not clear that the Tyagarah aquifer, if it is used as a groundwater source, would require augmentation to deliver the required capacity. As investigations of the Tyagarah aquifer continue, the value and viability of groundwater augmentation with PRW should be reviewed in the event that the environmental concerns can be addressed and the capacity of the aquifer limits its use. As none of the existing or planned groundwater schemes in the region appear suitable for consideration of GWA, no GWA schemes were considered within the baseline scheme options.

GWA typically occurs where there are existing groundwater sources which are unable to be utilised or expanded based on availability of groundwater resources. At this stage, no such opportunities have been identified in the RCC regions. The aquifiers in the region which are stressed typically are accessed by multiple rural and agricultural users, meaning that RCC would not be able to control access to or usage of the PRW which poses challenges from a health/regulatory perspective. Additionally, it is not clear that RCC would have priority access to this water, hence it may not be contribute directly to increased secure yield/volume of bulk water supply.

Other potential ground water sources (i.e. Clarence Moreton Basin / Coastal Sands) which are yet to be developed, are not necessary limited by availability of groundwater, but rather by environmental, water quality, economic and other associated challenges which are not obviously resolved by augmentation with PRW.

Little or no impact on existing secure yield: In defining the options to be developed in subsequent stages of the project, a principal was applied to not consider schemes which substantially reduce the secure yield from an existing source for this study. Specific areas where this issue emerged for:

- **Emigrant Creek Dam and WTP:** The small volume of Emigrant Creek Dam (854 ML) creates complications in its use as an environmental buffer under an indirect potable reuse scheme. In the absence of measures to ensure the residence time in the dam under surface water augmentation (such as maintaining the dam at a high minimum level and/or suspending potable water production through Emigrant Creek WTP), surface water augmentation to the dam may not achieve the expectations of the AGWR in relation to indirect potable reuse. Similarly, the small scale of the WTP (6.5 ML/d) may limit the ability to draw water from this existing source simultaneously with purified recycled water under a SWA or RWA scheme. Schemes which do not resolve these constraints on the ability of RCC to utilise Emigrant Creek WTP have not been considered in the short-listing, but may be considered as sub-options in latter stages of the project.
- **Wilson River Source Pump Station and Pipeline:** Based on high-level modelling developed by Rous County Council, the Wilson River Source extends the duration to running out of potable water by approximately 7-9-months in an extreme drought. Hence, while utilisation of the pump station and pipeline of the Wilson River Source represents a very substantial capital saving for potable reuse schemes involving Rocky Creek Dam and Nightcap WTP, it is important that these schemes do not compromise the ability to draw the full allocation of flow from the Wilson River as permitted.

Criticality of Rocky Creek Dam: As Rocky Creek Dam and Nightcap Water Treatment Plant provide the vast majority of the bulk water supply to the region, it is essential that potable reuse scheme does not impact the security of this source. Based on the capabilities of typical AWTP process trains, it is anticipated that acute risks from pathogens or chemicals released to the dam under surface water augmentation could be mitigated to the point they are not substantial. For example, any scheme utilising Rocky Creek Dam would ideally have all Critical Control Points (CCPs) upstream of the release to the dam. As an exception, chemical indicator or surrogate testing of water could still be implemented downstream of the AWTP. This monitoring would specifically targeting chronic rather than acute risks and therefore would not be a CCP. It is RCC's position that for this to be acceptable from a regional water supply perspective, the monitoring program could not require corrective actions that include cessation of supply from Rocky Creek Dam based on project specific risks.

Similarly, modelling and analysis of the dam (and its ecology) could be undertaken to understand the risks (and mitigations) required for the release of PRW to the low salinity and low nutrient environment within the dam's waters. Additionally, the viability of installing the infrastructure to pipe the PRW to the dam (including via submerged pipeline) could be assessed.

However, given the criticality of Rocky Creek Dam to the regional water supply system, and the extent and nature of the additional analyses, barriers to implementation, and pipeline lengths required for SWA to the dam, RCC has elected to not carry forward any options that discharge PRW to the dam for detailed (Level 1) consideration. However, RCC opted to carry forward augmentation of Rocky Creek Dam with PRW produced from Byron Shire STP effluent for consideration at a Level 2 detail as:

- An AWTP located near the coast would provide avenues for brine disposal (enabling RO-based treatment). As a result, SWA from a Byron AWTP would have the best chance of minimising risks to prevailing ecology within Rocky Creek dam.
- Given the transfer distances required for a Byron SWA scheme would render this option costly in terms of both capital and energy consumption, detailed consideration (Level 1) is not warranted. However, consideration at Level 2 will enable this option to serve as a datum for RCC to compare this configuration to other water supply options (such as desalination or groundwater).

Other key considerations applied to the baseline option assessment and categorisation included:

- Technical and cost viability;
- Retention of at least one IPR option (i.e. with a proscribed pathway to approval under AGWR (2008));
- Diversity of approach where possible (GWA, SWA, RWA, TWA);
- Diversity of AWTP types, including seeking to include at least one Level 1 option with RO and carbon based AWTPs;
- High level of planned non-potable reuse for Ballina Shire Council, and,
- Reduction of blend ratio to minimum viable for the area.

Schematic diagrams of the key baseline options considered during and after the Short-Listing Workshop are summarised in Sections 9.2.2 through 9.2.4. Note that schematics have not been provided for all options, but are included for all scheme options which were identified as Level 1 (Carried Forward).

9.2.2 Ballina Based Schemes

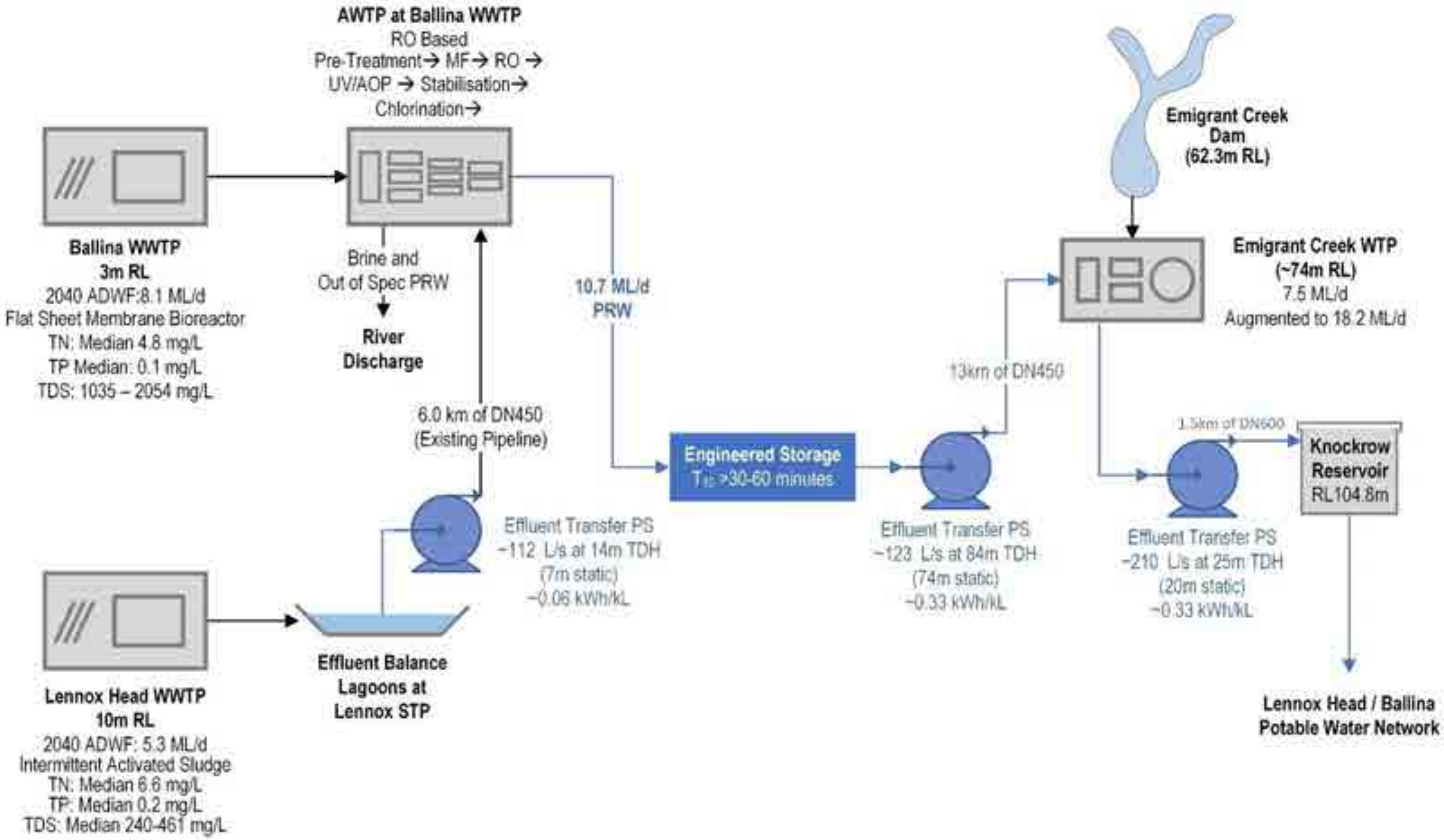

Figure 9-1: Baseline Scheme – Ballina / Lennox Head WWTPs Effluent to Raw Water Augmentation (Level 2 – High level consideration)

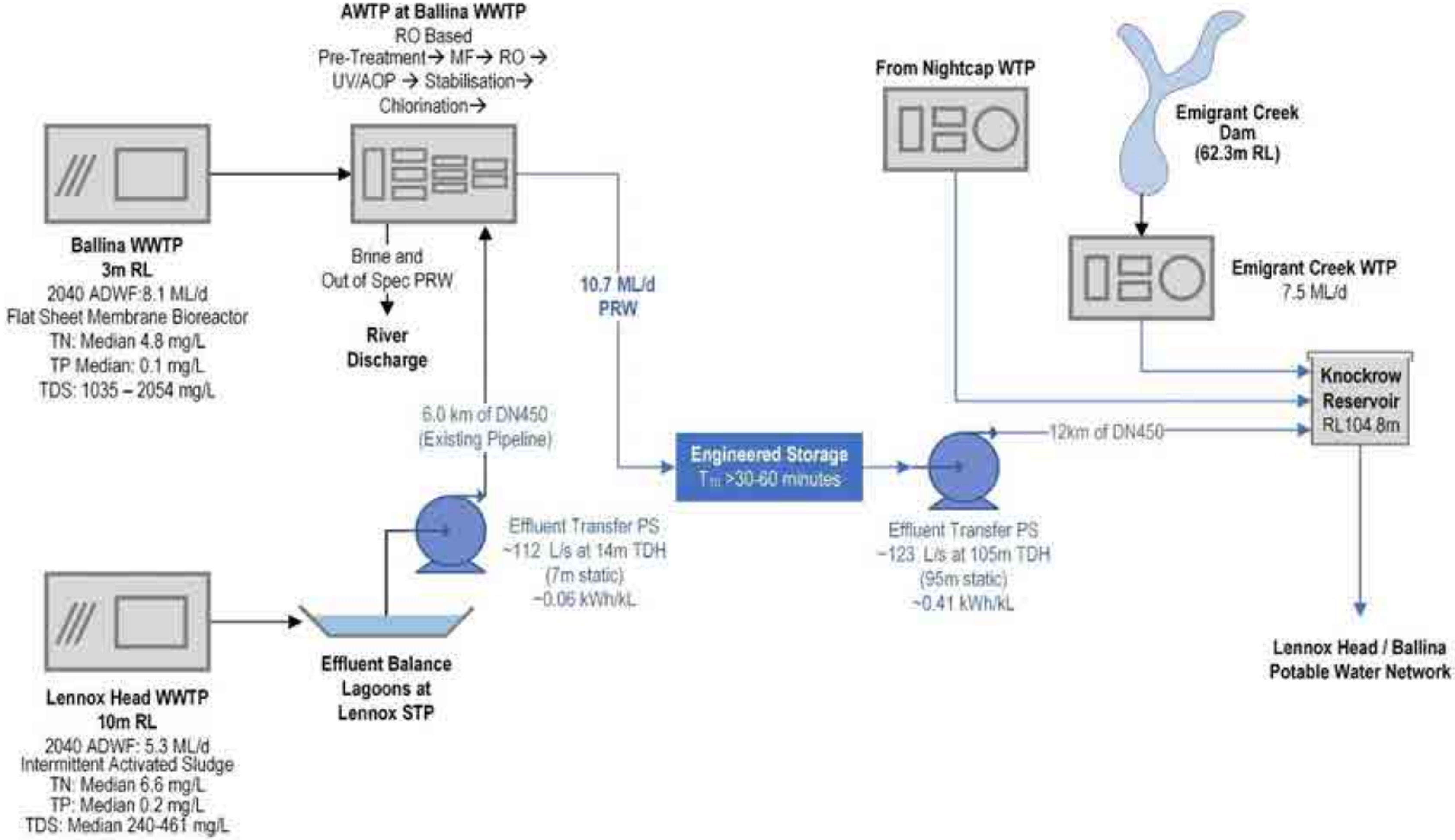

Figure 9-2: Baseline Scheme - Ballina / Lennox Head WWTPs Effluent to Treated Water Augmentation (Level 2 – High level consideration)

9.2.3 Byron Based Schemes

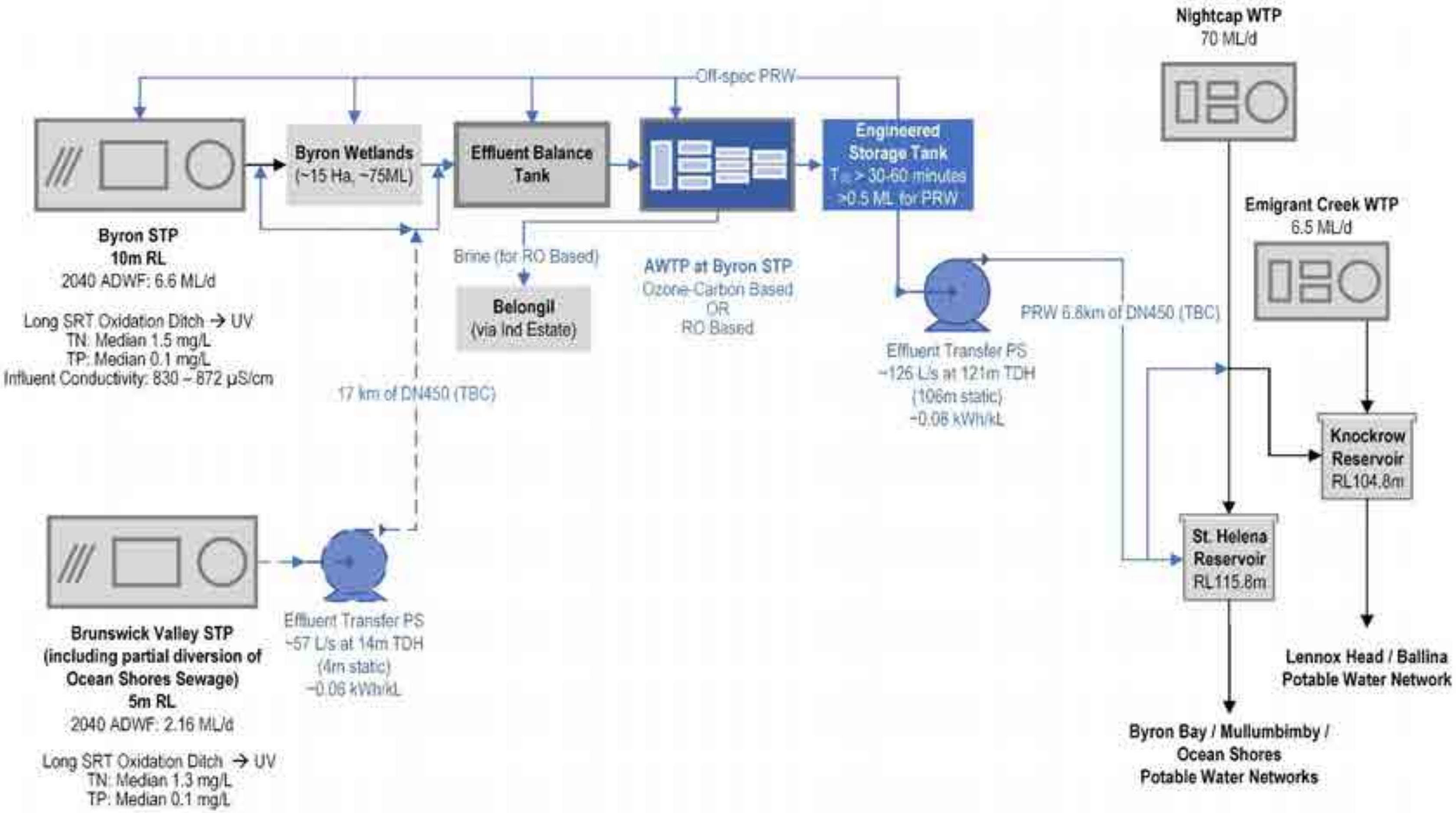

Figure 9-3: Baseline Scheme - Byron STP / Brunswick Valley STP Effluent to Treated Water Augmentation (Level 1 – Carried Forward)

9.2.4 Lismore Based Schemes

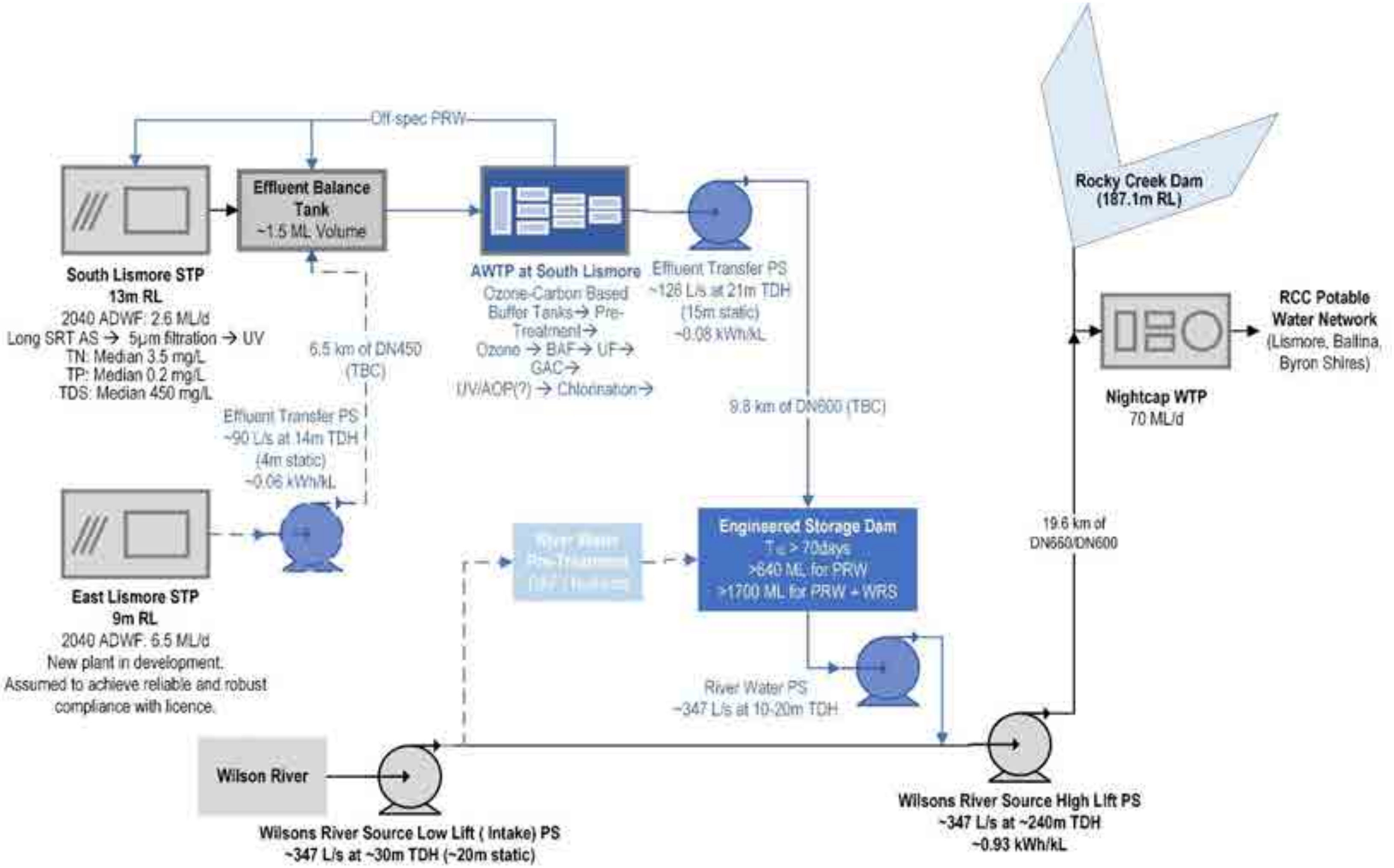

Figure 9-4: Baseline Scheme - Lismore STP Effluent to Surface Water Augmentation – Co-storage and co-transfer with Wilsons River Source (Level 1 – Carried Forward)

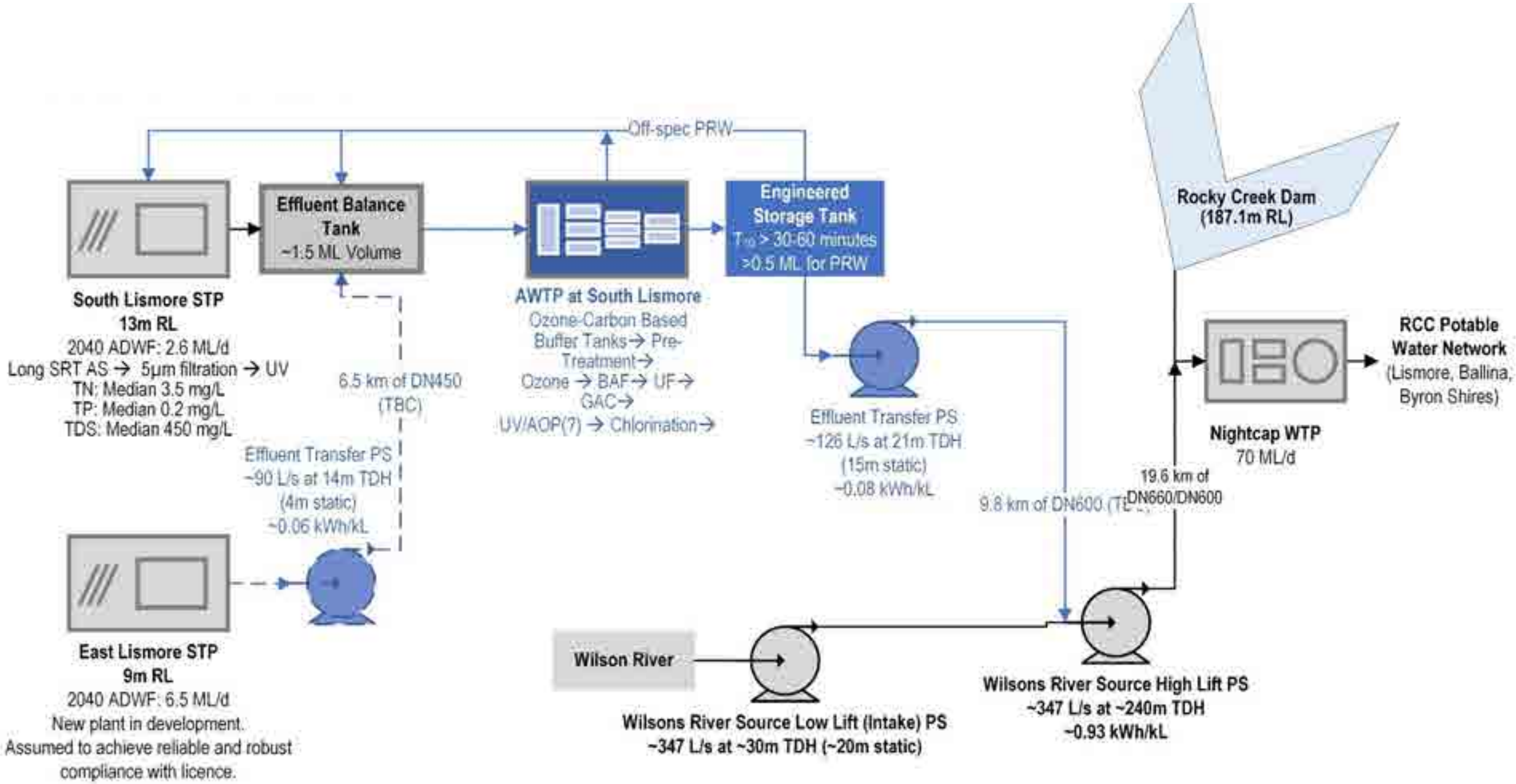

Figure 9-5: Baseline Scheme - Lismore STP Effluent to Raw Water Augmentation – Co-transfer to Nightcap WTP with Wilsons River Source (Level 1 – Carried Forward)

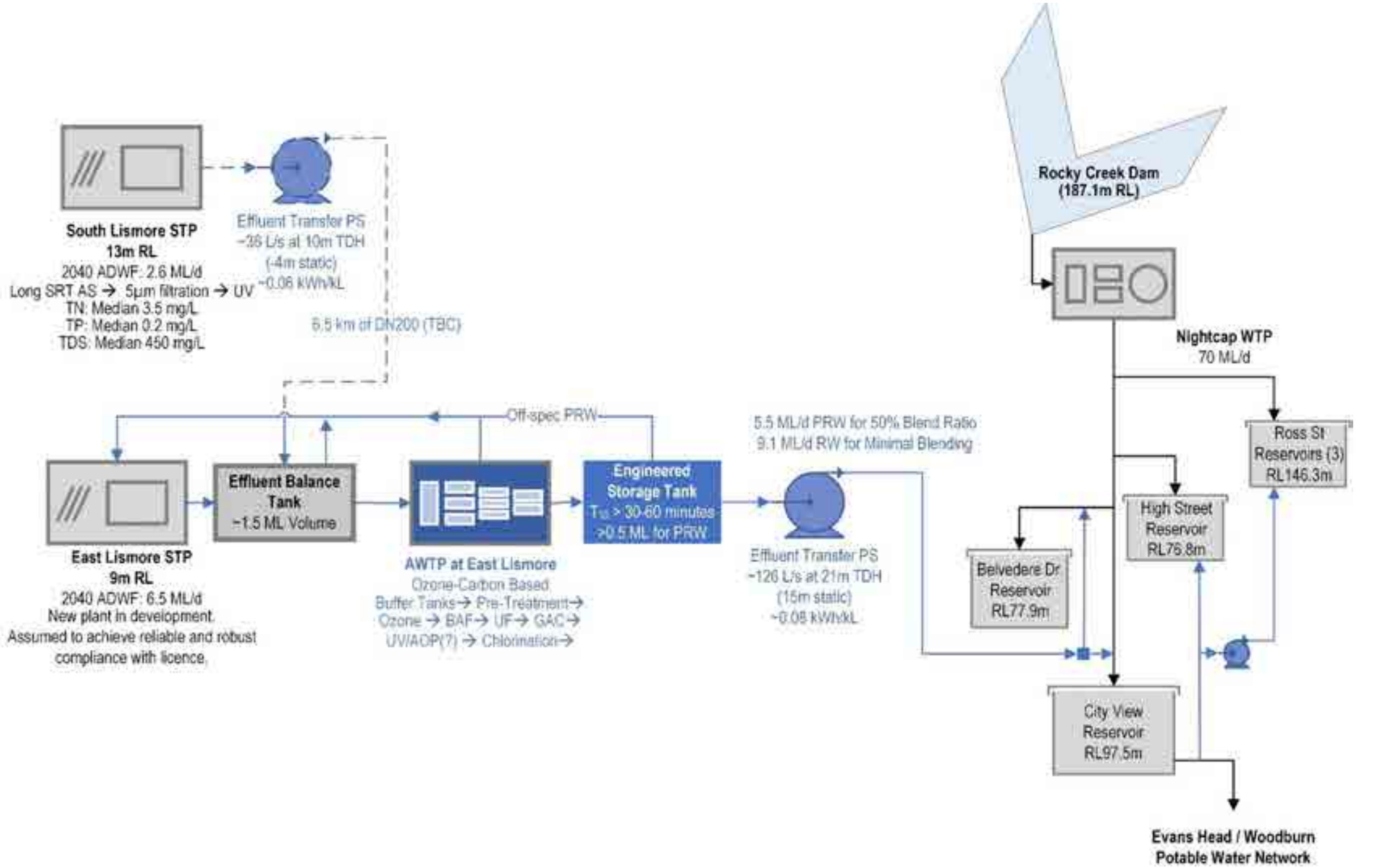

Figure 9-6: Baseline Scheme - Lismore STP Effluent to Treated Water Augmentation (Level 1 – Carried Forward)

9.2.5 Overview of Key Baseline Scheme Attributes

The key features of the key baseline schemes identified in Sections 9.2.2 through 9.2.4 are compared in Table 9-3. The relative importance of these attributes (and others identified at the workshop) was considered in evaluation of the scheme options, and then used to identify sub-options which may be of better value overall or otherwise better suited to carry forward for development in the context of the overall PRW investigations study.

Table 9-3: Overview of Advantages and Disadvantages for Key Baseline Scheme Options

Scheme	Advantages	Disadvantages
Ballina Based Schemes		
Ballina/Lennox Head WWTP Effluent to RWA (DPR via RWA)	• Lowest power consumption of RWA augmentation options for lift to Emigrant Creek WTP (~0.33 kWh/kL). • STP effluent transfer pipeline from Ballina to Lennox Head possibly existing (TBC).	• Projection of substantial increase in target non-potable recycled water use for the region. • The current AGWR (2008) do not provide a clear pathway for schemes of this form (i.e. DPR). • Augmentation of Emigrant Creek WTP potentially required to avoid compromising existing yield from Emigrant Creek Dam. • Substantial pipeline (~13 km) required to transfer to PRW to WTP.
Ballina / Lennox Head WWTP Effluent to TWA (DPR via TWA)	• STP effluent transfer pipeline from Ballina to Lennox Head possibly existing (TBC).	• Projection of substantial increase in target non-potable recycled water use for the region. • The current AGWR (2008) do not provide a clear pathway for schemes of this form (i.e. DPR). • Substantial pipeline (~12 km) required to transfer to PRW to Knockrow Reservoir.
Byron Based Schemes		
Byron STW Effluent to TWA (DPR via TWA)	• Very consistent and high quality source water (from Byron STW wetlands). • Highest potential use for TWA scheme based on discharge of PRW to reservoirs servicing Ballina and Byron. Best accommodation of blend ratio (32% at 8.8 ML/d PRW flow for carbon based AWTP). • Scope for staging with largest source (5.5 ML/d) available from 2040, with ~2.6 ML/d available to be added as a subsequent stage. • Under staged approach, least pipeline requirements of all schemes identified. • Possibly lowest electrical power consumption based on lower lift head for PRW to reservoirs and potential viability of carbon-based AWTP process train. • Possibility to utilise RO-based AWTP (if required) with local brine discharge.	• The current AGWR (2008) do not provide a clear pathway for schemes of this form (i.e. DPR). • Relatively long pipeline required to transfer flow from Brunswick Valley STP to Byron STW. • Relies on operation of existing main in reverse to transfer PRW to Knockrow Reservoir - needs to be confirmed as technically feasible.

Table 9-3: Overview of Advantages and Disadvantages for Key Baseline Scheme Options (continued)

Lismore Based Schemes		
Lismore STP Effluent to SWA - Co-storage and co-transfer with Wilsons River Source in large engineered storage (IPR via SWA)	• Potential pathway for regulatory approval under the current AGWR (2008) (i.e. IPR). • Minimal additional PRW pipework required through use of WRSPS. • Scope for staging with largest source (6.5 ML/d) available from 2040, with ~2.4+ ML/d available to be added as a subsequent stage. • Mitigates complications with operation of Nightcap WTP when Wilsons River Source is in use due to Wilsons River water quality. • Potential increase in the yield of the Wilsons River Source (by increasing withdrawals prior to low river flow conditions in extreme drought).	• High power consumption for lift to Rocky Creek Dam (~0.93 kWh/kL). • Additional engineering, approval, and costs imposed by large-engineered storage. • Need to ensure water quality in dam will remain suitable over time (with Wilson's River Water and PRW in storage for extended periods). • Several hectares of flood-free rural land required.
Lismore STP Effluent to RWA - Co-transfer with Wilsons River Source (DPR via RWA)	• Minimal additional PRW pipework required through use of WRSPS. • Scope for staging with largest source (6.5 ML/d) available from 2040, with ~2.4+ ML/d available to be added as a subsequent stage.	• The current AGWR (2008) do not provide a clear pathway for schemes of this form (i.e. DPR). • High power consumption for lift to Nightcap WTP (~0.93 kWh/kL).
Lismore STP Effluent to TWA (DPR via TWA)	• Low lift required for majority of reservoirs compared to other TWA schemes, reducing power consumption. • Limited additional pipework required due to proximity of East Lismore STP to	• The current AGWR (2008) do not provide a clear pathway for schemes of this form (i.e. DPR). • Limited scheme production where substantial blending is required.

9.3 Option Categorisation for PRW Investigation

Table 9-4 summarised the categorisation applied to the baseline scheme options to be carried forward for the remainder of the PRW Investigation Project, along with the key drivers behind the categorisation adopted.

Table 9-4: Scheme Option Overview and Categorisation

Local Government Area	Ballina	Byron	Lismore
Source Plants	Ballina WWTP / Lennox Head WWTP	Byron STW / Brunswick Valley STP	East Lismore STP / South Lismore WWTP
Ground Water Augmentation (IPR-GWA in line with AGWR 2008)	**Level 3: Not carried forward for this investigation** • Long distance or elevation to known aquifers. • Benefit or value of aquifer augmentation not clear or considered likely based on information in hand (see Section 6.5) • Limited effluent available for PRW production based on established Ballina planning and focus on non-potable reuse (see Section 4.2.5).	**Byron STW / Brunswick Valley STP To Tyagarah aquifer: Level 2: High level consideration** • Not clear whether Tyagarah aquifer will be developed as a source, or the value/need for augmentation. • Apply watching brief to Tyagarah aquifer. • Benefit or value of aquifer augmentation not clear or considered likely based on information in hand (see Section 6.5) • Consideration based on RO based AWTP option for biodegradable dissolved organic carbon reduction.	**Level 3: Not carried forward for this investigation** • Long distance or elevation to known aquifers. • Benefit or value of aquifer augmentation not clear or considered likely based on information in hand (refer to Section 6.5).
Surface Water Augmentation (IPR-SWA in line with AGWR 2008)	**Ballina / Lennox to Emigrant Creek Dam: Level 3: Not carried forward for this investigation** • Emigrant Creek Dam likely too small to meet the Regulatory expectations for "indirect augmentation" without relatively complex "batch operation" of the dam. Given the implications of this for existing Emigrant Creek Dam secure yield and utilisation of PRW infrastructure, not considered likely to be viable. • Large engineered storage to provide hydraulic residence time required for IPR under existing guidelines not likely to be cost effective compared to other areas. • Limited effluent available for PRW production based on established Ballina planning and focus on non-potable reuse (refer to Section 4.2.5).	**Byron / Brunswick Valley to RCD via pipeline: Level 2: High level consideration.** • Included as comparison point for RO-based AWTP with pipeline back to Rocky Creek Dam for nominal fit to requirements of AGWR 2008. • Note options utilising Rocky Creek Dam for SWA are considered unsuitable by RCC based on risk (refer to Section 5.1.1) **Byron / Brunswick Valley to Emigrant Creek Dam: Level 3: Not carried forward for this investigation** • Could be considered to Emigrant Creek Dam as element of scheme if Byron source otherwise viable. • Not carried forward based on Emigrant Creek constraints discussed in Section 9.2.1 **Byron / Brunswick Valley to Rocky Creek Dam via Byron Creek: Level 3: Not carried forward for this investigation** • Meaningful advantage to permitted take from the Wilsons River Source unlikely.	**To Rocky Creek Dam via Wilson River Source Pump Station, co-treatment with Wilson River water. Level 2: High level consideration.** • Considered unsuitable by RCC on risk to Rocky Creek Dam source. • Additional hurdles to implementation, including cost and operational challenges. **New engineered storage as environmental buffer. Level 1: Carry forward for consideration. See Figure 9-4.** • Nominal pathway to approval under AGWR 2008. • New large engineered storage additionally provides potential for improved utilisation of Wilson River Source, improving viability.

Local Government Area	Ballina	Byron	Lismore
Source Plants	Ballina WWTP / Lennox Head WWTP	Byron STW / Brunswick Valley STP	East Lismore STP / South Lismore WWTP
Raw Water Augmentation PRW from Augmentation (DPR-RWA)	**To Emigrant Creek WTP:** **Level 2: High level consideration.** **See Figure 9-1** • Augmentation to WTP as required to maintain existing source secure yield likely challenging. • Not adopted as Level 1 based on high target for utilisation of source water for non-potable reuse by Ballina Shire Council (refer to Section 4.2.5) and limited site area within existing Emigrant Creek WTP.	**Level 3: Not carried forward for this investigation** • Long distances to existing WTPs. • Could be considered if Tyagarah Aquifer WTP is developed. • Limited value over TWA option.	**To Nightcap WTP via Wilson River Source Pump Station and Pipeline, co-transfer with Wilson River water:** **Level 1: Carry forward for consideration.** **See Figure 9-5**
Treated Water Augmentation (DPR-TWA)	**To Knockrow Reservoir:** **Level 2 High level consideration.** **See Figure 9-2** • Not adopted as Level 1 based on high target for utilisation of source water for non-potable reuse by Ballina Shire Council (refer to Section 4.2.5) and lower blend ratio available than anticipated for Byron option.	**To St Helena Reservoir with reverse flow in existing main to Knockrow Reservoir:** **Level 1: Carry forward for consideration.** **See Figure 9-3** • High production with best blend ratio available for a TWA option. • Potential for RO-based or carbon-based AWTP.	**To main Lismore reservoirs:** **Level 1: Carry forward for consideration.** **See Figure 9-6** • New connection from AWTP at East Lismore Site to City View with feed from there to Belvedere, City View and Ross St.
Environmental Flow Substitution	**Level 3. Not carried forward for this investigation.** • Not viable for providing additional source water due to limited environmental flow requirements for Rocky Creek and Emigrant Creek (refer to Section 8).		

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APPENDIX A: COARSE-LEVEL SCHEME OPTION ASSESSMENT OUTPUTS

1. General Scheme Information				2. Prospective Screening					3. Capacity				4. Pipeline and Transfer				5. Treatment Train Fea		
#	WWTP	Scheme Type	Transfer Point	Overall Feasibility	WWTP Capacity	Transfer Capacity	Pipeline	Treatment Train	WWTP Capacity (ADWF)		Receiving Capacity (Transfer Point) *Includes Blending		Distance Via Google Maps		Pump Station Static Head	Total Static Head	RO-based Feasibility	Considerations	Carbon-based Feasibility
										ML/d		ML/d	km		m	m			
1	South Lismore STP	SWA	Rocky Creek Dam	Poor	X	✓	??	Carbon	X	2.6	✓	35.0	31.50	??	193	193	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
2	South Lismore STP	GWA	Tyagarah All Stages	Poor	X	✓	X	Carbon	X	2.6	✓	8.5	51.50	X	-8	-8	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
3	South Lismore STP	RWA	Nightcap WTP via WRPS	Poor	X	✓	✓	Carbon	X	2.6	✓	15.0	8.60	✓	15	195	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
4	South Lismore STP	TWA	All Main Lismore	Poor	X	✓	✓	Carbon	X	2.6	✓	5.4	6.30	✓	133.3	133.3	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
5	East Lismore STP	SWA	Rocky Creek Dam	Unsure	??	✓	??	Carbon	??	6.5	✓	35.0	31.50	??	197	197	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
6	East Lismore STP	GWA	Tyagarah All Stages	Poor	??	✓	X	Carbon	??	6.5	✓	8.5	56.70	X	-4	-4	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
7	East Lismore STP	RWA	Nightcap WTP via WRPS	Unsure	??	✓	✓	Carbon	??	6.5	✓	15.0	8.60	✓	19	199	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
8	East Lismore STP	TWA	All Main Lismore	Unsure	??	✓	✓	Carbon	??	6.5	✓	5.4	1.80	✓	137.3	137.3	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
9	Lismore Combined	SWA	Rocky Creek Dam	Unsure	✓	✓	??	Carbon	✓	9.1	✓	35.0	31.50	??	197	197	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
10	Lismore Combined	SWA	Rocky Creek Dam via WRPS	Good	✓	✓	✓	Carbon	✓	9.1	✓	15.0	8.60	✓	19	199	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
11	Lismore Combined	GWA	Tyagarah All Stages	Poor	✓	✓	X	Carbon	✓	9.1	✓	8.5	53.30	X	-4	-4	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
12	Lismore Combined	RWA	Nightcap WTP via WRPS	Good	✓	✓	✓	Carbon	✓	9.1	✓	15.0	8.60	✓	19	199	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
13	Lismore Combined	TWA	All Main Lismore	Good	✓	✓	✓	Carbon	✓	9.1	✓	5.4	6.30	✓	137.3	137.3	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
14	Lismore Combined	SWA	Off stream storage	Good	✓	✓	✓	Carbon	✓	9.1	✓	15.0	13.80	✓	41	41	Poor	Recovery may be limited by disposal options. - No existing ocean outfall for concentrate discharge. - Inland surface water discharge may result in recovery limitations to meet TDS (and or Nutrient) cocentrations in brine.	Good
15	Ballina STP	SWA	Emigrant Creek Dam	Poor	✓	X	✓	RO Based	✓	8.1	X	3.8	13.40	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
16	Ballina STP	GWA	Tyagarah All Stages	Unsure	✓	✓	??	RO Based	✓	8.1	✓	8.5	35.50	??	2	2	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
17	Ballina STP	RWA	Emigrant Creek Dam WTP	Poor	✓	X	✓	RO Based	✓	8.1	X	3.8	13.40	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
18	Ballina STP	TWA	Knockrow Reservoir	Good	✓	✓	✓	RO Based	✓	8.1	✓	6.6	12.50	✓	101.8	101.8	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
19	Lennox Head STP	SWA	Emigrant Creek Dam	Poor	??	X	✓	RO Based	??	5.3	X	3.8	18.30	✓	74	74	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge. - Poor wastewater quality may result in the need for additional treatment of concentrate or residuals to allow for discharge.	Poor
20	Lennox Head STP	GWA	Tyagarah All Stages	Unsure	??	✓	??	RO Based	??	5.3	✓	8.5	37.70	??	-5	-5	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge. - Poor wastewater quality may result in the need for additional treatment of concentrate or residuals to allow for discharge.	Poor
21	Lennox Head STP	RWA	Emigrant Creek Dam WTP	Poor	??	X	✓	RO Based	??	5.3	X	3.8	18.30	✓	74	74	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge. - Poor wastewater quality may result in the need for additional treatment of concentrate or residuals to allow for discharge.	Poor
22	Lennox Head STP	TWA	Knockrow Reservoir	Unsure	??	✓	✓	RO Based	??	5.3	✓	6.6	14.30	✓	94.8	94.8	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge. - Poor wastewater quality may result in the need for additional treatment of concentrate or residuals to allow for discharge.	Poor

#	WWTP	Scheme Type	Transfer Point	Overall Feasibility	WWTP Capacity	Transfer Capacity	Pipeline	Treatment Train
1. General Scheme Information				2. Prospective Screening				
23	Ballina Combined	SWA	Emigrant Creek Dam	Poor	✓	X	✓	RO Based
24	Ballina Combined	GWA	Tyagarah All Stages	Unsure	✓	✓	??	RO Based
25	Ballina Combined	RWA	Emigrant Creek Dam WTP	Poor	✓	X	✓	RO Based
26	Ballina Combined	TWA	Knockrow Reservoir	Good	✓	✓	✓	RO Based
27	Byron STP	SWA	Rocky Creek Dam	Unsure	??	✓	??	Either
28	Byron STP	GWA	Tyagarah All Stages	Unsure	??	✓	✓	Either
29	Byron STP	RWA	Nightcap WTP	Unsure	??	✓	??	Either
30	Byron STP	TWA	St Helena Reservoir	Unsure	??	??	✓	Either
31	Byron Combined	SWA	Rocky Creek Dam	Unsure	✓	✓	??	Either
32	Byron Combined	GWA	Tyagarah All Stages	Good	✓	✓	✓	Either
33	Byron Combined	RWA	Nightcap WTP	Unsure	✓	✓	??	Either
34	Byron Combined	TWA	St Helena Reservoir	Unsure	✓	??	✓	Either
35	Byron Combined	TWA	St Helena Reservoir + Knockrow Backfeed	Good	✓	✓	✓	Either
36	Ballina Combined	RWA	Emigrant Creek Dam WTP (Upgrade)	Good	✓	✓	✓	RO Based
37	Ballina STP	RWA	Emigrant Creek Dam WTP (Upgrade)	Good	✓	✓	✓	RO Based
38	Ballina Combined	SWA	Emigrant Creek Dam (Upgrade)	Good	✓	✓	✓	RO Based
39	Ballina STP	SWA	Emigrant Creek Dam (Upgrade)	Good	✓	✓	✓	RO Based
40	Ballina Combined	SWA	Rocky Creek Dam	Poor	✓	✓	X	RO Based

#	WWTP Capacity (ADWF)		Receiving Capacity (Transfer Point) *Includes Blending		Distance Via Google Maps		Pump Station Static Head	Total Static Head	RO-based Feasibility	Considerations	Carbon-based Feasibility
	3. Capacity				4. Pipeline and Transfer				5. Treatment Train Fe		
		ML/d		ML/d	km		m	m			
23	✓	13.4	X	3.8	18.30	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
24	✓	13.4	✓	8.5	37.70	??	2	2	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
25	✓	13.4	X	3.8	18.30	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
26	✓	13.4	✓	6.6	14.30	✓	101.8	101.8	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
27	??	6.6	✓	35.0	35.30	??	196	196	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
28	??	6.6	✓	8.5	13.20	✓	-5	-5	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
29	??	6.6	✓	35.0	35.30	??	196	196	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
30	??	6.6	??	4.5	11.00	✓	105.8	105.8	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
31	✓	10.0	✓	35.0	35.30	??	196	196	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
32	✓	10.0	✓	8.5	13.20	✓	-5	-5	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
33	✓	10.0	✓	35.0	35.30	??	196	196	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
34	✓	10.0	??	4.5	11.00	✓	105.8	105.8	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
35	✓	10.0	✓	7.5	11.00	✓	105.8	105.8	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Good
36	✓	13.4	✓	7.5	18.30	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
37	✓	8.1	✓	7.5	13.40	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
38	✓	13.4	✓	7.5	18.30	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
39	✓	8.1	✓	7.5	13.40	✓	81	81	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor
40	✓	13.4	✓	35.0	54.50	X	203	203	Good	Recovery not likely to be limited by disposal options. - Existing ocean outfall may be suitable for concentrate discharge.	Poor

APPENDIX B: ROUS COUNTY COUNCIL REGION MAPPING

Provided separately due to large file size. See “Appendix B – Rous County Council Mapping for Potable Reuse Scheme Identification and Short-Listing”

APPENDIX C: SUMMARY OF REFERENCE DATA FOR IMPACT OF WATER RESTRICTIONS ON WASTEWATER FLOWS

The following sections provide additional detail on the reference data and methods used to support estimation of the reductions in wastewater treatment plant influent flows associated with water restrictions.

Melbourne, Victoria

Eastern Treatment Plant is one of the two major STPs servicing Melbourne, with an average dry weather flow of approximately 400 ML/d during the analysis period. Compiled sewage flow data for Eastern Treatment Plant for the millennium drought period was drawn from *Assessment of Potential Impacts on the Sewerage System by Advanced Water Efficiency* Measures [1], published in 2011. The water restriction measures and periods of their application during this period are summarised in Table 10-1.

Table 10-1: Overview of Water Restrictions Applied In Melbourne, 2002-2010
Adapted from [1, p. 18]

Restriction Level	Stage 1	Stage 2	Stage 3	Stage 3a
Period of Restrictions Applying	1/11/2002 to 31/7/2003 1/9/2006 to 31/10/2006	1/8/2003 to 28/2/2005 Note 1 1/11/2006 to 31/12/2007 1/9/2010 to ~30/11/2010	1/1/2007 to 31/3/2007 ¼/2010 to 31/8/2010	¼/2007 to ¼/2010 Note 2
Watering Lawns	Alternate days and restricted hours	Water lawns banned		
Reticulation watering days	Alternate days		Drippers only 2 days/week	
Automatic reticulation	Midnight – 4am			Midnight – 2am
Manual reticulation	6-8am and 8-10pm			6-8am
Hose watering / buckets / watering cans	Any time		2 days/week; 6-8am and 8-10pm	2 days/week; 6-8am
Hosing hard surfaces	Banned all times			
Car washing	Bucket / high pressure cleaner only; hose to rinse only	Bucket / high pressure cleaner only	Bucket only to clean windows, mirrors and lights	
Swimming pools	No filling without approval			No filling

Note 1: Permanent Water Saving Rules introduced from 1 Mar 2005
Note 2: T155 Campaign added from 1 Dec 2008

The sewage flow for each phase of water restrictions is compared to the average rainfall (as recorded at the Melbourne Botanic Gardens) in Figure 10-1.

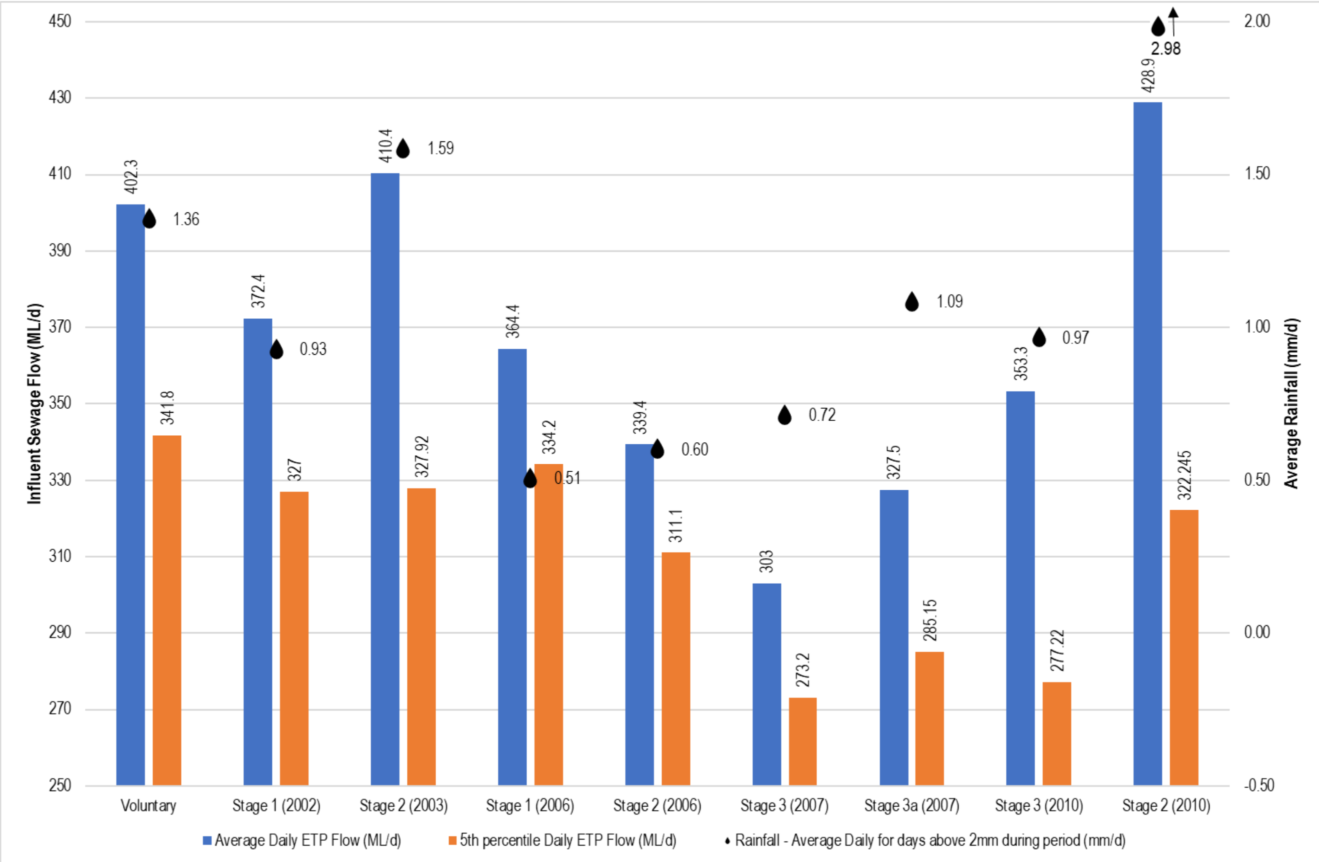

Figure 10-1: Influent Dry Weather Sewage Flow to Eastern Treatment Plant, 2001-10

Key observations from the reported restrictions and flows include:

- The restriction measures outlined in Table 10-1 are comparable to those for Rous County Council, and were primarily focused on external water use through to the maximum level reported (Stage 3a). However, public information campaigns (including the T155 campaign) were targeting reduced water consumption during the period, and likely impacted internal water use and flows to sewer – particularly during the three year period of Stage 3a restrictions. It is also understood that industrial water use was also being actively targeted during this period, and was likely reducing trade waste flows to the plant.
- For all water restriction levels up to and including Stage 3, the average daily sewage flow to ETP appears to have been more strongly correlated to the prevailing rainfall during the period than the level of water restrictions applied. Stage 3a restrictions, which were imposed for three years, did appear to reduce the average sewage flows by around 14%.
- By contrast to the average flows, the 5th percentile flow to the plant appears to have been more strongly influenced by water restrictions than prevailing rainfall for Stages 2, 3 and 3a. Overall, a reduction in the 5th percentile of sewer flows in the order of 13% was observed for Stage 3 and 3a restriction (compared to Stage 1 and Stage 2).

Bay Area, California

Sawyer et al [3] reported on the reductions in flow associated with water restrictions for eight municipal wastewater treatment plants in the Bay Area of California. All eight plants are larger in scale than those in the RCC service area, and as shown in Figure 10-2, showed proportional reductions in summer flows in the order of 10-25% between 2011 and 2015. The larger all showed similar reductions in flow on a proportional basis. The two smallest plants reported (G and H with a capacity of <10 mgd (<45 ML/d)) are the most comparable in scale to the largest wastewater plants in the RCC service area.

The data presented [3, p. 10] that summer flows to Plant G reduced by approximately 18% between 2011 and 2015, and reduced by an additional 3-4% through to 2017.

For Plant H. the collated data indicated a 24% (Plant H) reduction in summer flows between 2011 and 2015, and a 6-7% increase in flows between 2015 and 2017. It should additionally, be noted that composition data from Plant H indicates that the overall loading of the plant (in terms of both flow and pollutants) reduced by around 20% over the period of analysis [3, p. 15]. This suggests that part of the reduction in flows may have been partially due to a reduction in connected population or industry rather than the water conservation measures.

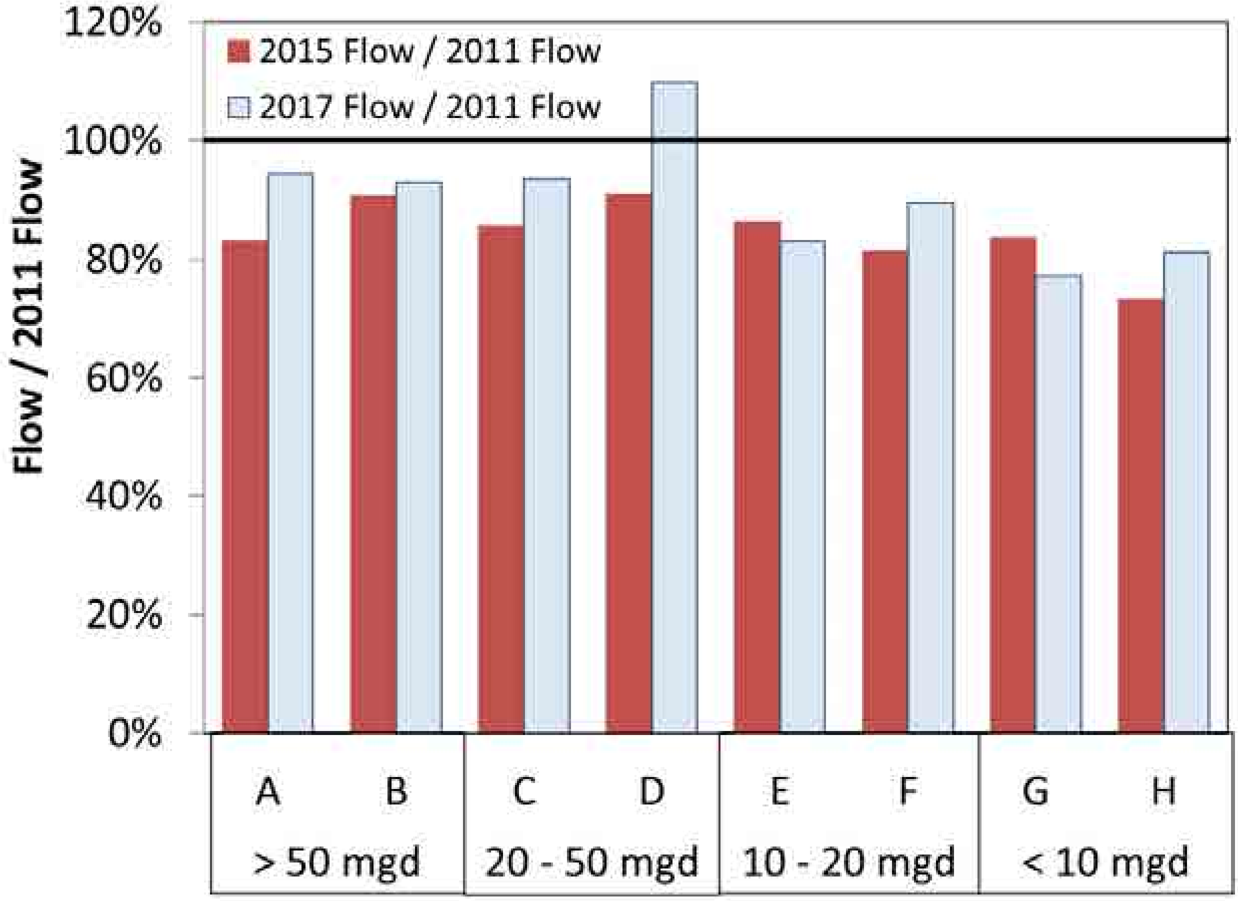

Figure 10-2: Ratio of Summer Flows to Eight Californian Wastewater Treatment Plants in California during and after 2012-16 Drought
(Source: [3, p. 10])

Southern California

Tran et al [4, p. 12] reported a reduction of 14% in wastewater flows to the Inland Empire Utilities Agency's Regional Water Recycling Plant #1 between 2011 and 2015. As shown in Figure 10-3, the steepest reduction in per capita flows appears to have been subsequent to the proclamation of a Drought State of Emergency Proclamation in January2014.

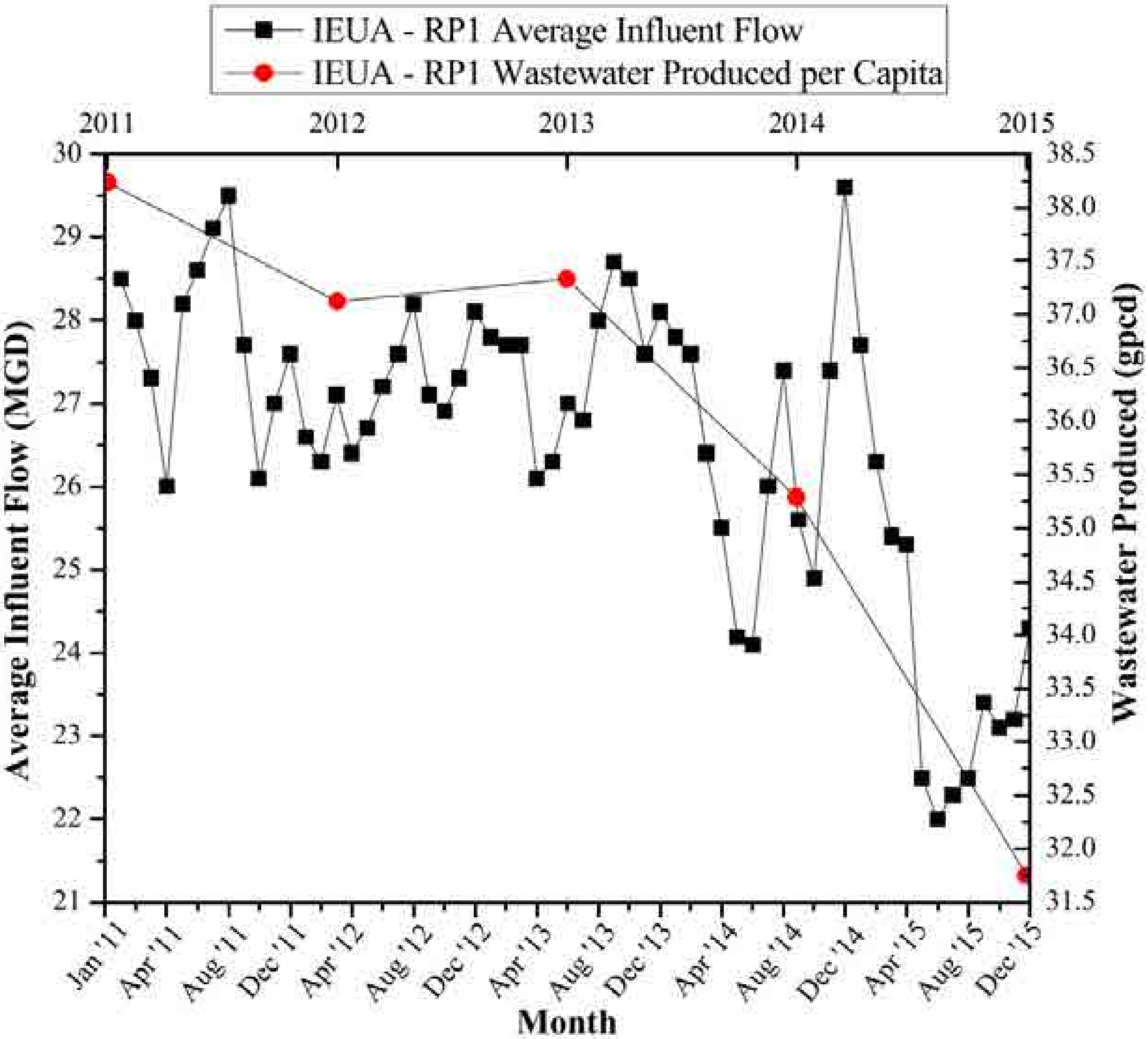

Figure 10-3: Inland Empire Utilities Agency's Regional Water Recycling Plant #1 – Wastewater Production, 2011-15
(Source: [4, p. 1 of Corregium]

APPENDIX D: SCHEME OPTION IDENTIFICATION, REVIEW AND SHORT-LISTING WORKSHOP MINUTES

MEETING AGENDA

Chaired By: David Fligelman	Minutes by: Judy Scott	Distribution Date: August 1, 2023

Attendees (in person):
Michael McKenzie (MM) (Rous – Future Water Planning Manager)
Jeremy Wilson (JW) (Rous -Project Manager)
Tania Burls (TB) (Rous – Future Water Program Manager)
Tom Lloyd (TL) (Rous – Dams & Treatment Engineer)
Griffin Kilpatrick (GK) (Rous)
David Fligelman (DF) (Tyr Group - Project Director)
Judy Scott (JS) (Tyr Group – Project Manager)
Ryan Schwartz (Tyr Group – Process Engineer)
Andrew Wells (AW) (Planit – Planning Engineer)

Attendees (via Teams):
James Sun (JaS) (Rous – Process Engineer)
Ian Law (IL) (IBL Solutions – Potable Reuse Specialist)
Damion Cavanaugh (DC) (BMT – Environmental Specialist)
Simon Millichamp (SM) (Planit – Infrastructure Engineer)
Eva Steinle-Darling (ES) (Carollo – Water Reuse Specialist)
Andy Salveson (AS)(Carollo – Water Reuse Treatment Specialist)
Amos Branch (AB)(Carollo – Water Reuse Technologist)

Distribution:
Attendees

Agenda:

1. Purpose
2. Background
   a) Estimated Available Effluent Flows
   b) Surface Water Environmental Buffers
   c) Existing and Planned Groundwater Schemes
   d) Existing and Planned Bulk Water Supply Network
   e) Environmental Flow Substitution
3. Identification of Potential Reuse Schemes
   a) Coarse Assessment
   b) Baseline Schemes for Consideration
4. Discussion and Miro Board

See presentation (attached) for details of information presented and briefing memo (also attached) for additional details.

Meeting Minutes

Slide #	Specific Comments	Follow Up	By When
10	**Ballina and Lennox Head WWTPs** AS – Is there any pressure to reduce salts at Ballina plant (for environmental discharge)? DF – Understood not to be any pressure as effluent discharges to saline water body	N/A	
11	**Byron and Brunswick Valley STPs** DC – Belongil catchment has too much water; therefore exporting some of it may provide some benefit from flooding farm lands. SM – Flows to catchment are split depending on wet or dry season AS – How much nitrogen treatment do wetlands provide? **Post Meeting Note:** As an example, for the period February 2023 through April 2023, the nitrogen removal in the wetlands was 78% (2.77 mg/L at inlet reduced to 0.61 mg/L average at outlet). DC – Better to balance by taking some water before wetlands and some after DF – More of a water balance issue than a nitrogen issue.	N/A Consider withdrawal point to AWTP in scheme definition	In Task 1-7B
12	**East and South Lismore STPs** MM – There is no appetite for re-use in S. Lismore IL – Are TDS high at South Lismore? **Post Meeting Note:** TDS is normally reasonably low at South Lismore (450 mg/L at median. Not anticipated that TDS would increase with wet weather events at South Lismore, but more likely reduce, so that is not considered the likely reason for no reuse. Tyr Group to check TDS data for wet weather events at South Lismore to confirm.	Check wet weather TDS	In Task 7B
14	**STP/WWTP Summary** MM – Are there issues with wet weather? Should the available flow from South Lismore be downrated to account for wet weather events. DF – South Lismore does contact stabilisation under extreme wet weather inflows events (that is, the plant does not include a sewage bypass); wet weather would be anticipated to provide a net gain in water available for reuse through increase in treated effluent flows.	N/A	
15	**Surface Water Storages and Supply** TL – Not all elevations shown on slide are correct; Actual capacity at Emigrant Creek is 6.5 ML/d (not 7.5 ML/d)	Tyr Group to check and revise elevations and capacities accordingly.	In memo finalisation, then through Task 1-6.
16	**Additional Surface Water Storages** MM – In considering Byron Creek as an environmental flow path to WRPS, stream loss is very difficult to quantify; MM- Wilsons River Source license limit is a theoretical max - it is not reality that this full extraction can be practically achieved. TL – Question to MM - How will Rous operate re-use system? From when Rocky Creek is below 95% full as for existing sources?	N/A	

	MM – (response) Need to look at cost, water security, operations. Rous hasn't done optimisation.		
17	**Engineered Off-Stream Storages** MM – Could consider engineered storage at Lagoon Grass for storage of Wilsons Creek source water to increase yield, with PRW. This storage could be an alternate to discharge to Rocky Creek to provide environmental buffer. Historical study of Lagoon Grass showed cost too high for Wilsons Creek Source alone. MM - Rous staff have identified that a engineered off-stream storage/ "turkey's nest" in lagoons grass might be worth consideration as an environmental buffer for use in a Lismore Scheme. A key consideration for feasibilty is that it must not have adverse flood impacts, and therefore would need to be located outside of the flood plain.	Additional options considering engineered storage at Lagoon Grass to be considered for Task 3.	In memo finalisation, then through Task 1-7.
18	**Existing and Planned Groundwater** MM – Groundwater schemes probably not viable due to environmental and social concerns; Recharge rates unknown for Tyagarah aquifer. IL – Does slide show existing or potential? DF – Aquifers investigated previously for utilisation as potable water sources. JW – Rous only looking at Alstonville but have there are multiple users. Not clear if it is beneficial to recharge for any schemes. MM – Model applied to aquifers does not represent reality for groundwater flows. Alstonville has multiple users in 4 km radius (primarily stock and domestic). SM – Would extraction from coastal aquifers cause salt water intrusion? MM – No, Tyagarah is at higher elevation so low chance of intrusion; Woodburn looks like it doesn't have significant risk. DF – Tyagarah groundwater system is largely unknown at this time.	N/A	
19	**Existing and Planned Bulk Supply** MM – Confirming St Helena elevation of 116 is correct MM - Ross St may need to be excluded due to pumping.	Review ability to direct PRW to Ross St. Reservoir	SP2 as required.
20	**Environmental Flow Substitution** MM – Emigrant Creek has visible flow requirements; ? has to be equal to inflow. When no inflow, no requirements downstream. There is about 10-15 L/s of seepage around and through (concrete) wall; there are no return flow requirements. No source/reference/documentation at this point, but this would further limit ability for EFS. Wilson Creek – there is a reluctance for return flow credits		
21	**Shortlisting Criteria – Key Considerations** IL – Suggest not to hold onto "Compliant with 2008 for SWA Options". There are movements/ developments internationally. IL – note there is discussion of updating the Australian Drinking Water Guidelines (ADWG) to include PRW. JW – Suggest rewording to state "At least one option compliant with 2008"	Delete "for SWA options", and change to "at least one option compliant to 2008 AGWR.	

	AS – Suggest to set thresholds for Level 2 so there won't be a need to explain in the future why those options weren't looked at further. (In US West Coast, several potential projects were considered too difficult/not viable and now they are being considered.) AS - Regarding GW injection being too close to extraction; if direct use is done, this concern goes away. MM – There are no active bores in Tyagarah.	Set clear thresholds for options placed under Level 2.	
23	**Coarse Level Scheme Identification – see spreadsheet** JM – Explanation of spreadsheet; all files in Sharepoint. JM- Possible flow requirement to Belongil In relation to Ballina sources: ES – Disspell notion that high BOD precludes CBAT DF – CBAT ruled out due to high TDS for Ballina WWTP effluent for these schemes.	N/A	
24	**Baseline Option Considerations** MM – Rocky Creek Dam currently the lowest cost water source as no pumping required, also huge recharge AS – If Rocky Creek must be protected at all cost, might as well go with treated water augmentation.	N/A	
25	**Baseline Schemes – see Miro** MM – Must not allow Wilson Creek water enter Rocky Creek due to aquatic weed concern; flushing would be complicated; could do as a one off. IL – What is the technology at Night Cap MM – Ozone? since 2007	N/A	
28-30	**Ballina Schemes** TL – Emigrant Creek WTP site has a lot of constraints due to area. Augmentation of the WTP not viable within existing WTP site. Capacity is closer to 6.5 ML/day.	Note for options finalisation; update Table 5-3 in Memo	Task 1-7
34	**Byron Schemes** SM – Has the option of upgrading Mullumbimby plant been considered? The plant will be upgraded with a UV filter and operated for the next few years. DF – Mullum is a confined site, on steep ground and at high elevation. While new AWTP or WTP could be located at lower elevation (where more land is available), haven't considered this option because it could only feed Mullum; no network to feed other populations.	N/A	
35-45 And Main Map	**Backflow from St. Helena to Knockrow** MM – Line from Buttery to Knockrow is DN525; may need to put in a duplicate line. It's technically possible to backfeed. May consider duplication at St. Helena. Lots of rural customers in that area so may be better to put all back into St. Helena. New pipe is usually put into next to old pipe leaving old pipe in operation as long as possible. DF – May need to add operational considerations **Rocky Creek Dam Constraints** MM – Regarding Lismore, Rous only owns small area of dam; the remainder is a National Park thus very difficult to get approval. DC – Must look at buoyancy and hardness of input flows.	Further refinement of backfeed scope of works and operational regime to be considered in options development. Consider South Lismore location for	Task 1-7

	Lismore Scheme AWTP Location AS – (In relation to AWTP location for Lismore Schemes) When the treatment facility is not near source, what is done with off spec water? DF – Significant issue with locating near WRSPS. Will consider putting in different location, close to S. Lismore as preferred for these schemes.	AWTP for Lismore schemes.	
46 & 47	**Baseline Schemes** IL – Are the GW schemes considered very valid (on a value basis)? DF – For Tyagarah, much is unknown – it may not be viable for a GW scheme due to environmental constraints. MM – There is plenty of GW (Alstonville) just a question of how many bores; bores very expensive. There are overall viability concerns at Tyagarah. IF – (Regarding SW Augmentation) – Is there a ranking of risk for off spec water? Is it prudent to put re-use water in Rocky Creek if it is considered sacrosanct DF – All CCP's would need to be upstream of discharge to Rocky Creek. Off-spec water would need to be diverted to South Lismore plant influent or (or wetlands). TB – Why pump back to Rocky Creek DF – Due to requirements regarding AGWR (2008) for environmental buffer. MM – Lagoon Grass could have as much capacity as Emigrant Creek Dam and is not flood liable; An evaporation system could be used to reduce losses. MM - Energy draw at Lagoon Grass has been a previous issue. Can only run 2 pumps (30 ML/d) at Lagoon Grass with current electrical storage. Running all pump units at 580 L/s (50 ML/d) would necessitate an electrical upgrade Add Part 2 to Lismore options. Turkey Nests are a concern because they are flood liable. DF – Will look into options which could make use of a storage at Lagoon Grass further to see where they might provide value.	Consider options which make use of a storage at Lagoon Grass (for WRS and PRW combined as appropriate).	For Tasks 1.5, 1-7.
	Engineered Storage Solution comments: DC – Dual benefit, large upstream storage for flood mitigation MM – Storage would have to be much larger to help mitigate flooding DF – Will add engineered storage solutions to options	N/A	
	Additional Comments: MM – Ballina was very optimistic in estimating 80% recovery; a lot of money spent on their reuse system and it will only handle a small fraction of WWTP output; suggest that Ballina gets reuse water first. AB – Regarding Ballina operations, new membranes could improve operations and 2040 is fully 2 membrane replacements away DF – Good point, but noting Ballina has had ongoing issues with membrane integrity.	Consider potential for improved effluent TSS from Ballina in future (post-membrane replacement)	For Task 1-7.
	Miro Board Comments: Link to Miro Board: (https://miro.com/app/board/uXjVM4X7h6A=/) WHITEBOARD 4 (CARRIED FORWARD SCHEMES) Ballina Scheme: *General (Further Investigation)* • Bromide concentration risk due to seawater ingress into sewer network may limit viability of implementing ozone in California style DPR treatment	Note Consider potential	For Task 1-6

	• Capacity of existing pipeline between Ballina and Lennox WWTPs unknown (via retic - not dedicated pipe) <u>Byron Scheme:</u> *General (Further Investigation)* • Bromide concentration risk due to seawater ingress into sewer network may limit viability of implementing ozone in California style DPR treatment *Treated Water Augmentation (Further Investigation)*: • Viability and scope of works to facilitate back-feed to Knockrow Reservoir from St Helena Reservoir <u>Lismore Scheme:</u> *General (Further Investigation)* • East Lismore design, location, etc. largely unknown • Salt mass balance considerations • AWTP location with respect to out of spec water *Surface Water Augmentation (Concerns)* • Wilson's River source too dirty to be sent to RCD; may need to separate pipeline *Surface Water Augmentation (Further Investigation)* • Impacts on receiving water bodies (i.e. nutrients) *Treated Water Augmentation (Opportunities)* • May consider East Lismore Only scheme • East Lismore site closer to reservoirs so different AWTP site should be considered WHITEBOARD 5 (OUTCOME CAPTURE) <u>Lismore Scheme:</u> *Surface Water Augmentation* • Land ownership (i.e. National Park) may complicate placement of PRW outfall into RCD • Are we suggesting to build a 24.1 ML/d AWTP to Treat 9.1 ML/d? **Post-meeting note**: Wilsons River sourced water would only receive the required level of treatment (e.g. DAF or DAFF). • Water quality targets / nutrient and salt mass loadings on receiving body needs careful consideration. Particularly eutrophication risk.	transfer capacity between plants Note Scope works and operational constraints Seek latest information from LCC. Consider risk item. Identify analysis / modelling required Noted – will consider AWTP location options for South or East Lismore Consider risk item. Identify analysis / modelling required	For Task 1-6 For Task 1-7 For Task 1-5 1-10 For Task 1-6 For Task 1-5
	NEXT STEPS • Revised and develop memo to: ○ Provide suitable capture of information for report; ○ Close out of Task 2, and, ○ Provide suitable update to Regulators • Consider meeting with regulators to discuss status and direction.		

Attachments:

1. Presentation from Scheme Identification and Shortlisting Workshop

2. J2212 - Rous PRW - Workshop Briefing Memo for Scheme Identification and Short-Listing - Revision A
Workshop Briefing Memo for Potable Reuse Scheme Identification and Shortlisting

Logos: TYR Group, ROUS County Council, FutureWater Project

Rous County Council

Purified Recycled Water for Drinking

Workshop: Scheme Identification and Shortlisting

July 11th, 2021

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Agenda

1. Purpose
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Slide 2

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The Rous County Council Region

Slide 3

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Byron and Ballina

Slide 4

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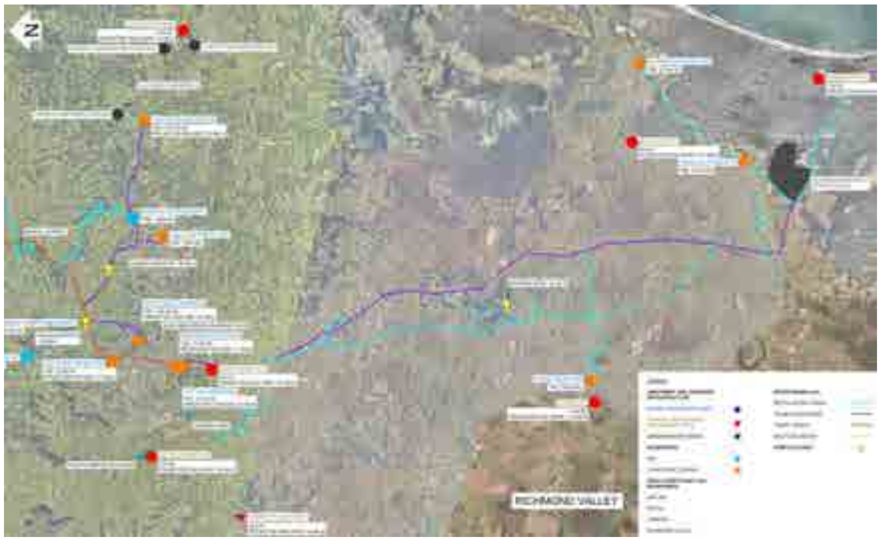
Richmond Valley and Lismore



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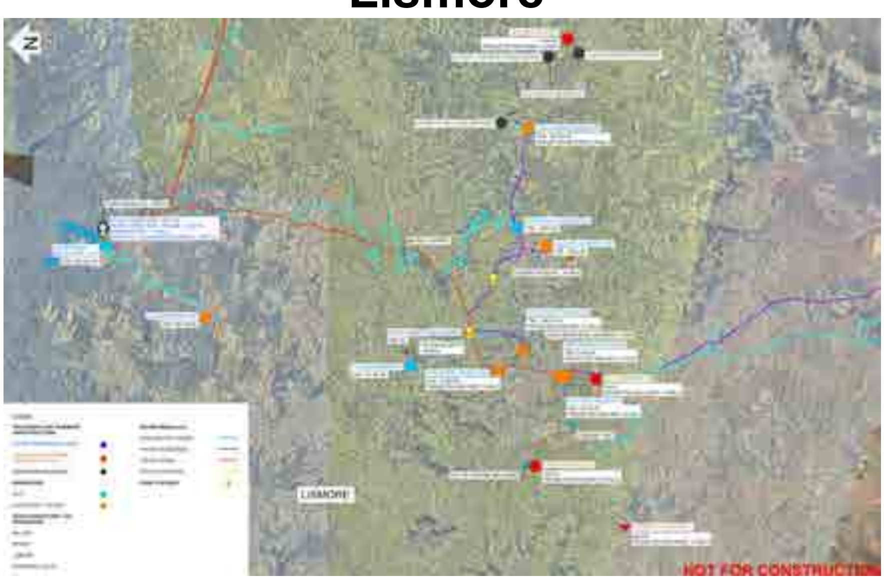
Lismore



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Estimated Available Effluent Flows

- 14 Wastewater Treatment Plants considered
- Flows projected to 2040 – 0.1 ML/day to 8.1 ML/day
- Consideration given to current and projected non-potable reuse
- Effluent quality generally suitable for potable reuse
- Range of treatment types throughout region
  (Oxidation Ditch, MBR, Trickling Filter, IDEA)

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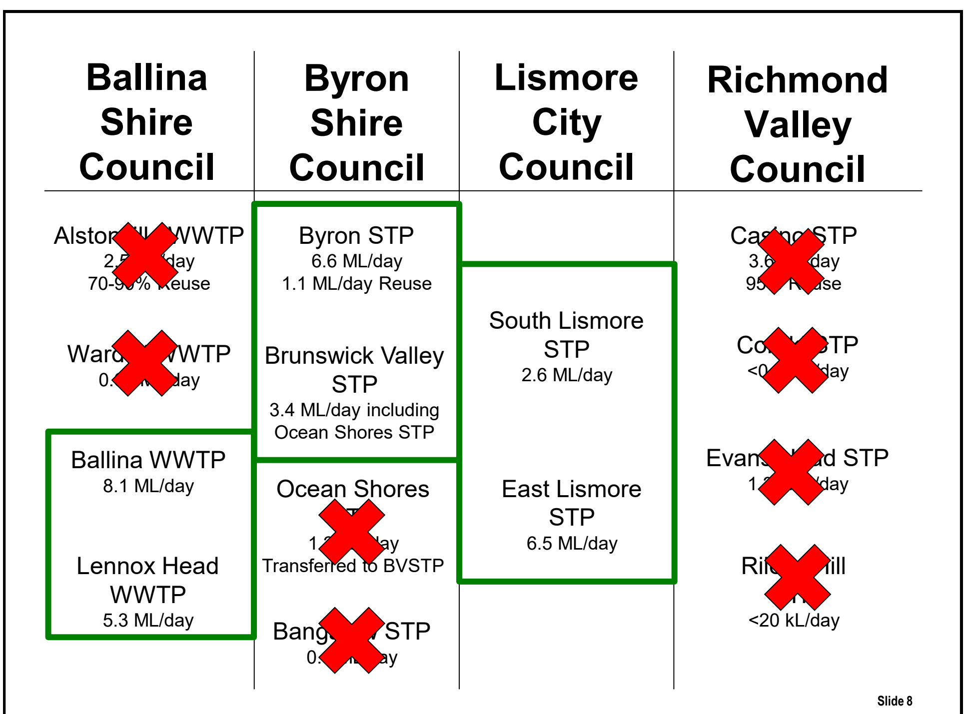

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Excluded Plants

- Alstonville STP → Small, Significant Reuse
- Wardell → Small
- Ocean Shores → Transferred to Brunswick Valley STP
- Casino → Remote
- Coraki → Small
- Evans Head → Remote
- Rileys Hill → Small

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Ballina and Lennox Head WWTP

Ballina WWTP

- 8.1 ML/day
- TDS - 1035 to 2054 mg/L
- River discharge
- No current reuse
- TN 5 median, 7 90th %ile
- TP 0.1 median, 0.3 90th %ile

Lennox Head WWTP

- 5.3 ML/day
- TDS – 240 to 461 mg/L
- Ocean outfall discharge
- 0.77 ML/d reuse (ADD)
- TN 6.6 median, 9.9 90th %ile
- TP 0.2 median, 0.4 90th %ile

Projected 2040 Reuse ADD - ~2.35 ML/day

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Byron and Brunswick Valley STP

Byron STP

- 6.6 ML/day
- Conductivity – 830 to 872 µS/cm
- Wetland/River Discharge
- 0.6-1.1 ML/d reuse (ADD)
- TN 1.5 mean, 3.9 max
- TP 0.1 mean, 0.25 max

Brunswick Valley STP

- 3.4 ML/day (BV STP + OS STP)
- Conductivity/TDS - Unknown
- River Discharge
- 0.05 ML/d reuse (ADD)
- TN 1.3 mean, 3.4 max
- TP 0.1 mean, 0.14 max

Projected 2040 Reuse ADD – to be determined

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East and South Lismore STP

East Lismore STP

- 6.5 ML/day
- Conductivity/TDS - Unknown
- River Discharge
- No current reuse
- Licence TN 15 50th %ile, 25 100th
- Licence TP 1 50th %ile, 3 100th

South Lismore STP

- 2.6 ML/day
- TDS – 450 to 490 mg/L
- River Discharge
- No current reuse
- TN 3.5 median, 5 90th %ile
- TP 0.2 median, 0.7 90th %ile

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East and South Lismore STP

East Lismore STP

- 6.5 ML/day
- Conductivity/TDS - Unknown
- River Discharge
- No current reuse
- Licence TN 15 50^{th} %ile, 25 100^{th}
- Licence TP 1 50^{th} %ile, 3 100^{th}

South Lismore STP

- 2.6 ML/day
- TDS – 450 to 490 mg/L
- River Discharge
- No current reuse
- TN 3.5 median, 5 90^{th} %ile
- TP 0.2 median, 0.7 90^{th} %ile

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STP/WWTP Summary

Local Government Area		Lismore	Ballina	Byron	
Effluent Sources		East Lismore + South Lismore STPs	Lennox Head + Ballina WWTPs	Brunswick Valley + Byron STPs	
Projected 2040 ADWF		9.1 ML/d	13.4 ML/d	10.0 ML/d ADWF	
Non-potable reuse		Nil	Actual recent: 0.77 ML/d Est. 2040 Target 2.35 ML/d	Actual recent: ~1.15 ML/d	
AWTP Type		Carbon based	RO based	RO based	Carbon based
Estimated Maximum Dry Weather PRW Production	With no non-potable reuse	9.1 ML/d	10.7 ML/d	8.0 ML/d	10.0 ML/d
	With recent non-potable reuse		10.1 ML/d	7.1 ML/d	8.8 ML/d
	With target non-potable reuse		8.8 ML/d		

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Surface Water Storages and Supply

Rocky Creek Dam
13,500 ML
206m RL

Wilsons River Source
30 ML/day (15 ML/day Annual Average)
River level dependent
19.5 km pipeline to Nightcap WWTP,
240m head

→ **Nightcap WTP**
70 ML/day

Emigrant Creek Dam
854 ML
84m RL

→ **Emigrant Creek WTP**
7.5 ML/day

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Additional Surface Water Storages

- Lismore Lake → Adjacent to river
- Bexhill Quarry → Public use
- South Lismore Wetlands → Treated effluent
- Byron Wetlands → ~15 Ha, 75 ML
- Byron Creek→ Environmental flow path to WRPS?

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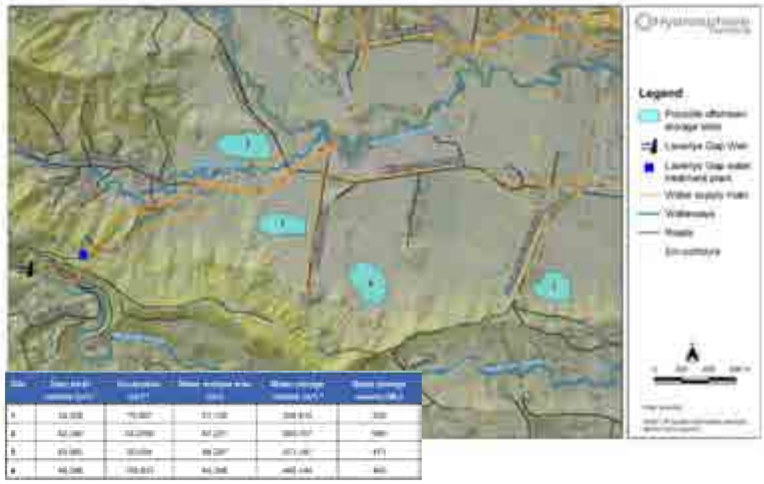
Engineered Off-Stream Storages



Reference: Hydrosphere Consulting, "Mullumbimby Water Supply Strategy," Byron Shire Council, Byron Bay, 2023.

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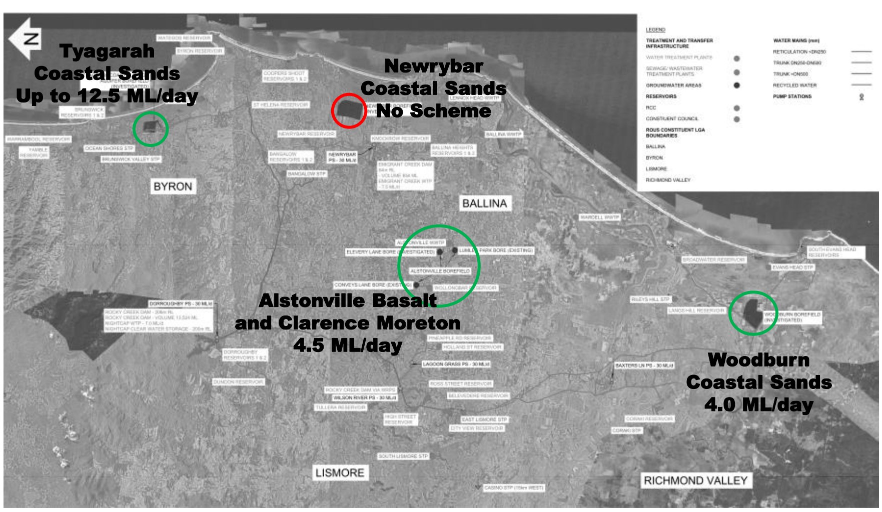
Existing and Planned Groundwater



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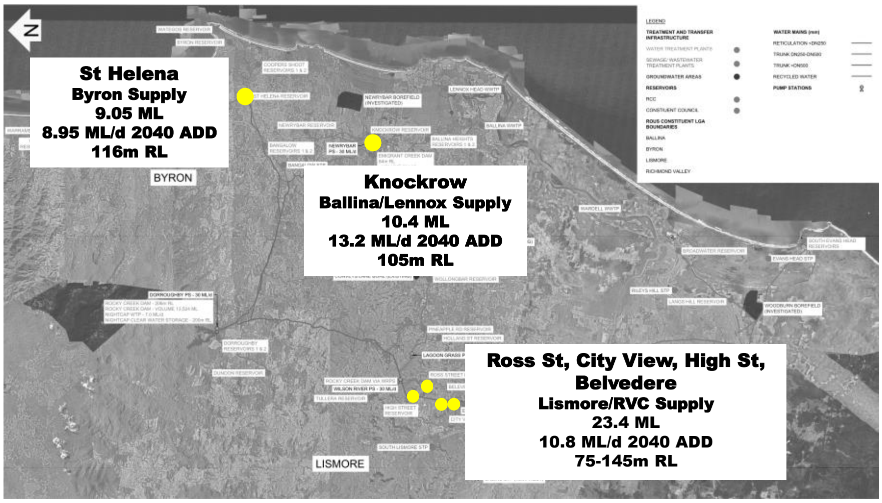
Existing and Planned Bulk Supply



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Environmental Flow Substitution

- Rocky Creek Dam → No environmental flow required
- Emigrant Creek Dam → 0.8 ML/day
- Wilsons River Pump Station → Unlikely to yield additional provision if we treat Lismore effluent to a higher level.

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Shortlisting Criteria –Key Considerations

- Technical and cost viability
- At least one option compliant with 2008 AGWR ~~(for SWA options)~~
- Diversity of approach (GWA, SWA, TWA, RWA)
- Diversity of AWTP types (RO and Carbon Based)
- Spread of geographical location?

Level 1 – Full option development

Full Pipeline Alignments, AWTP process train, All infrastructure for level 5 cost estimate

Level 2 – Partial option development

Approximated pipeline and AWTP details. Discussion of issues.

Level 3 – Not carried forward

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Coarse Level Scheme Identification

- Optimistic Initial Assumptions
  - Intent to keep more options live
  - E.g. Water quality, Blending, Groundwater, Non-potable reuse
- Considered all options for GWA, SWA, RWA and TWA
- Target capacity - 8 ML/d with no constraints
- Target capacity - 5 ML/d with a max 50% blend
- Indirect and direct reuse schemes considered

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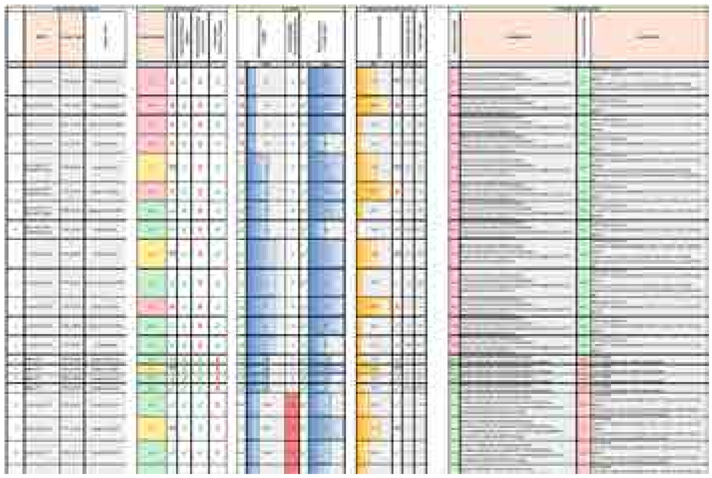
Coarse Level Scheme Identification - see spreadsheet



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Baseline Options Considerations

- Opportunities to combine effluent streams
- Groundwater not carried forward
- Avoid options that may impact existing secure yield
- Consider criticality of Rocky Creek Dam

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Baseline Schemes – see Miro

Local Government Area	Ballina	Byron	Lismore
Ground Water Augmentation	Nil	Nil (Watching brief)	Nil
Surface Water Augmentation	Not in baseline options. Unlikely without engineered storage.	Not in baseline options. Unlikely without engineered storage.	**To Rocky Creek Dam via WRPS (co-treatment) Engineered Storage (IPR with T_{10} of 30-60 minutes)**
Raw Water Augmentation	**Emigrant Creek WTP (augmented)**	Not in baseline options. Emigrant Creek could be considered.	**To Nightcap WTP via Wilson River Source Pump Station, co-transfer with Wilson River water.**
Treated Water Augmentation	**To Knockrow Reservoir**	**To St Helena Reservoir with reverse flow in existing main to Knockrow Reservoir**	**Discharge to main Lismore reservoirs (two options)**
Environmental Flows	Not viable for providing additional source water.		

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Scheme Overviews

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Scheme Overviews

Ballina

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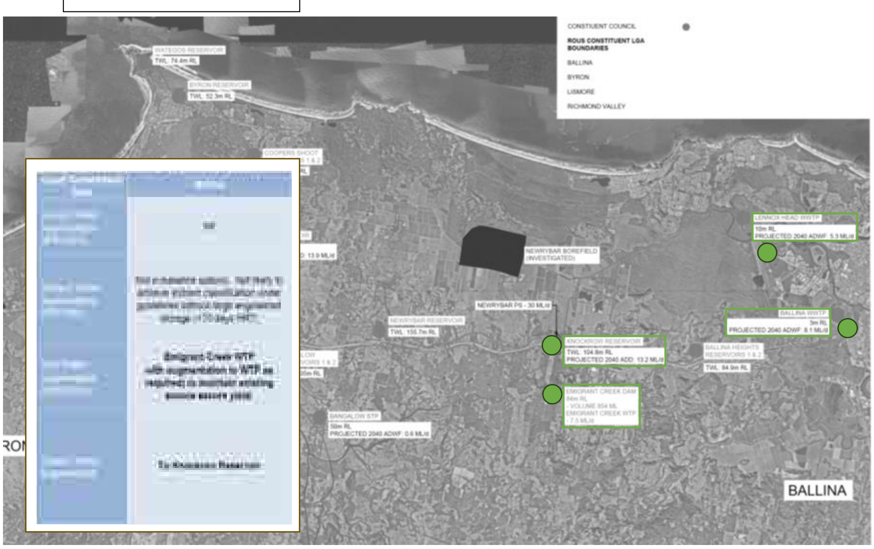
BALLINA SCHEMES



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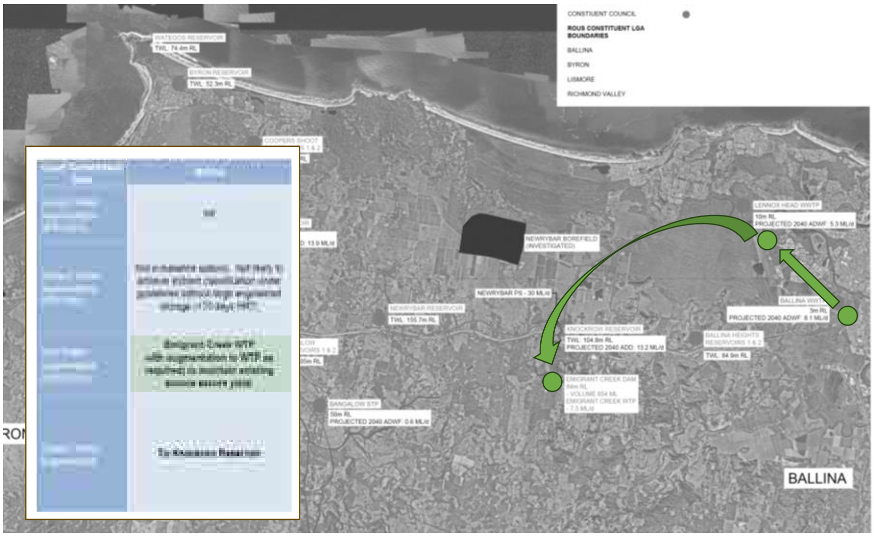
DPR via RWA: BALLINA COMBINED TO ECD WTP



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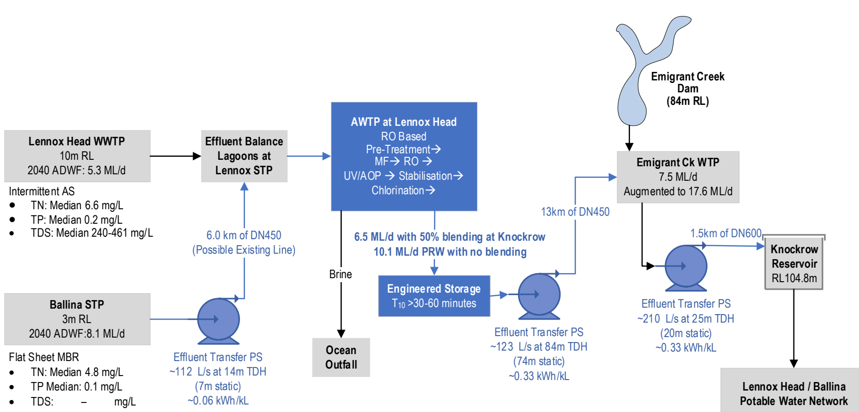
DPR via RWA: BALLINA COMBINED TO ECD WTP



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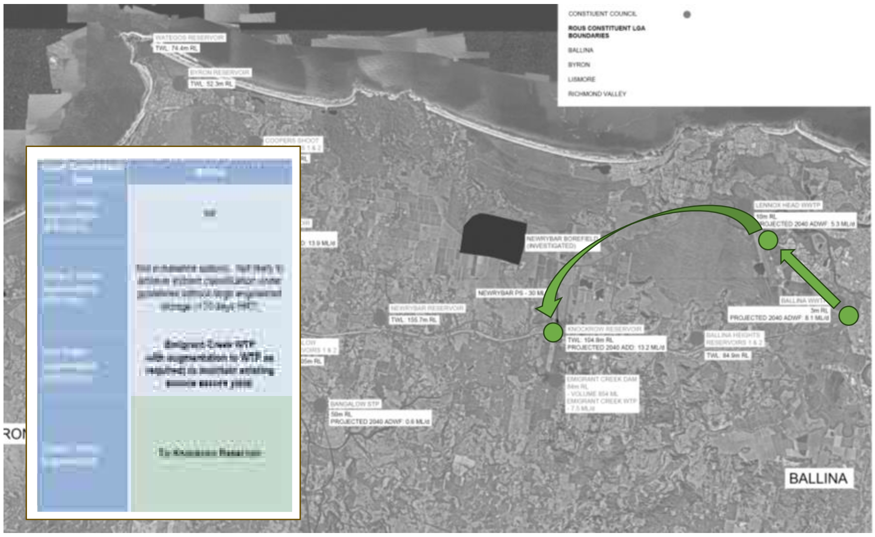
DPR via TWA: BALLINA COMBINED TO KNOCKROW



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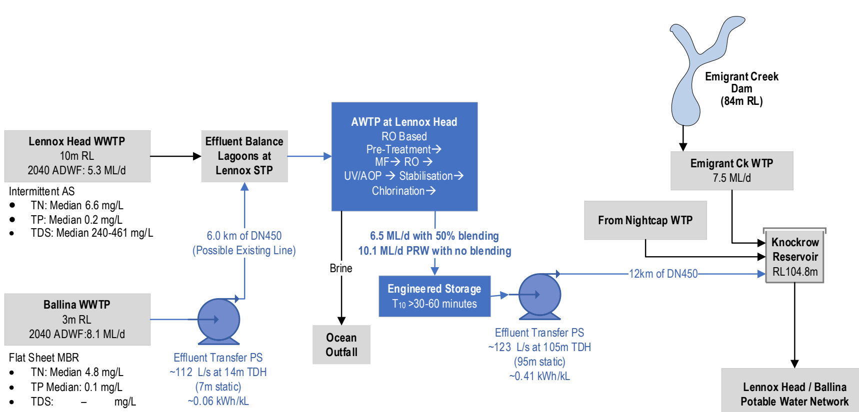
DPR via TWA: BALLINA COMBINED TO KNOCKROW



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Scheme Overviews

Byron

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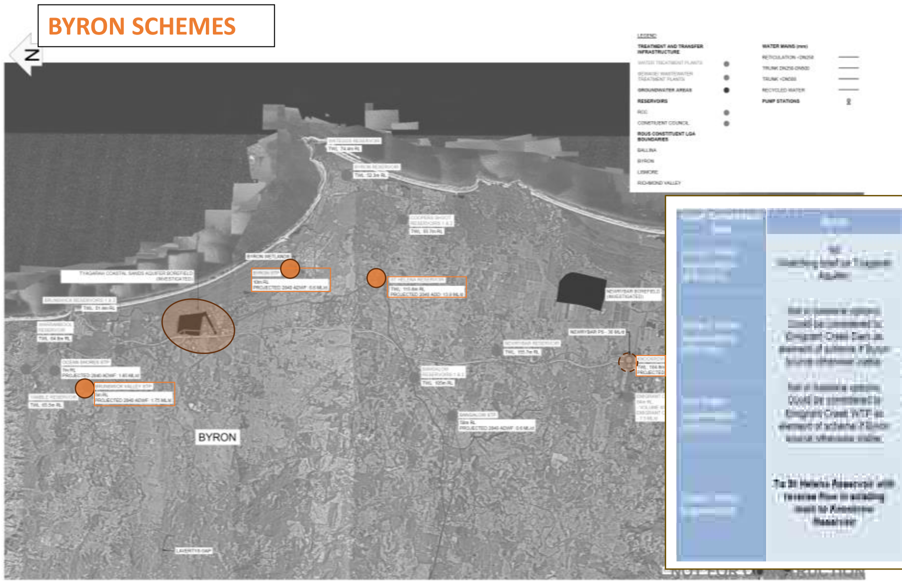
BYRON SCHEMES



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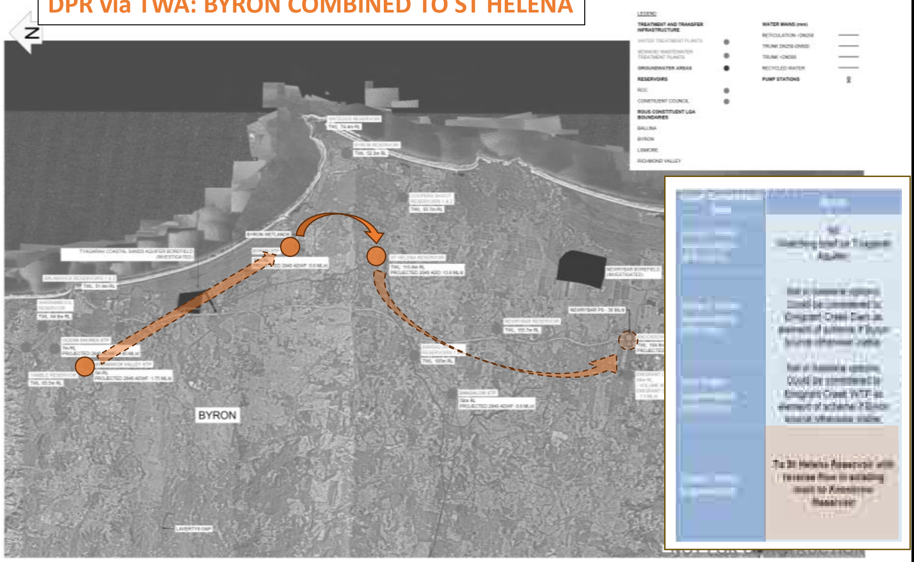
DPR via TWA: BYRON COMBINED TO ST HELENA



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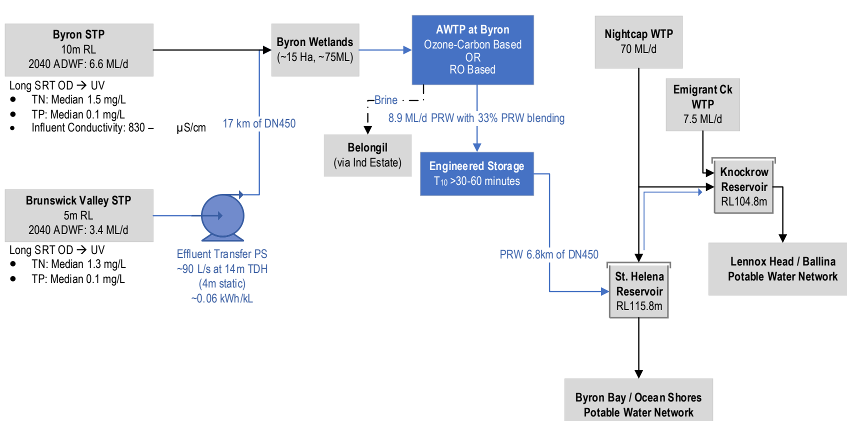
DPR via TWA: BYRON COMBINED TO ST HELENA



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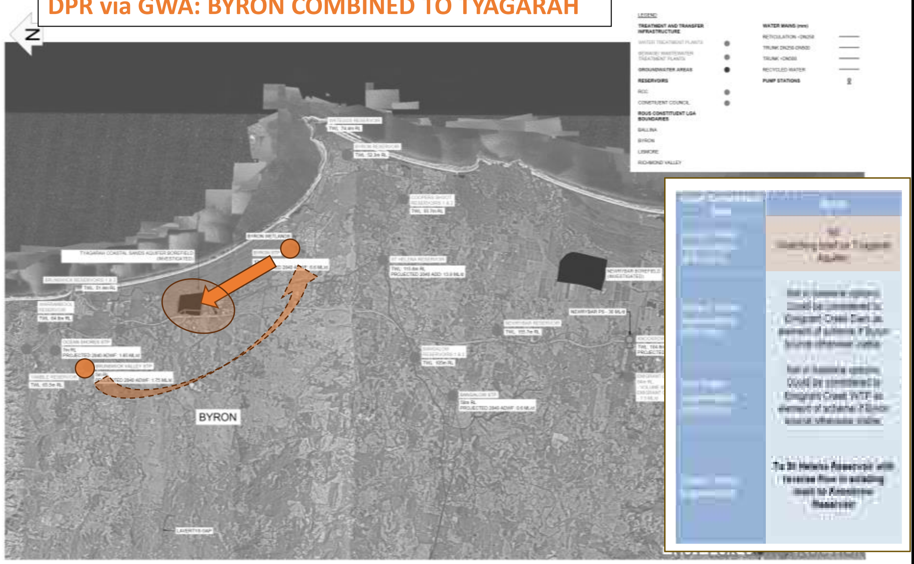
DPR via GWA: BYRON COMBINED TO TYAGARAH



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Scheme Overviews

Lismore

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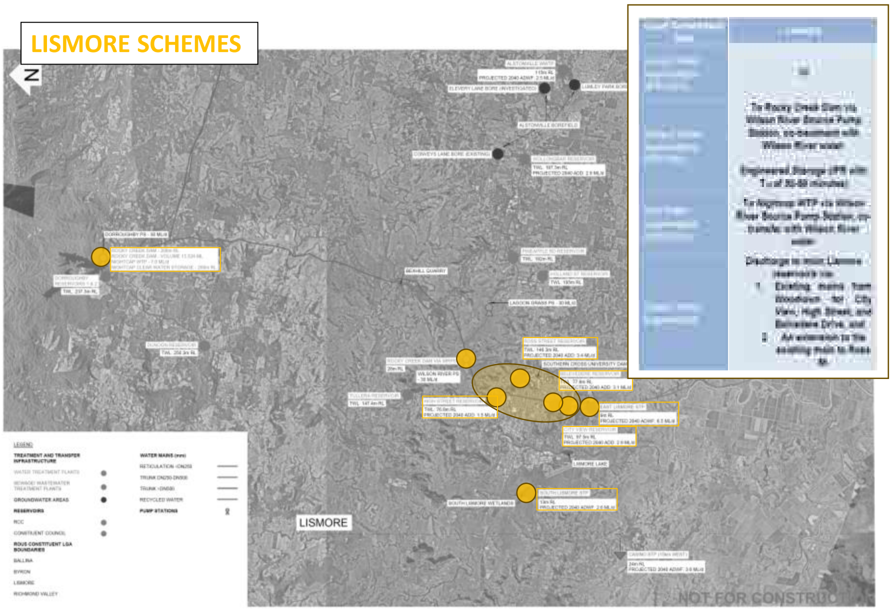
LISMORE SCHEMES



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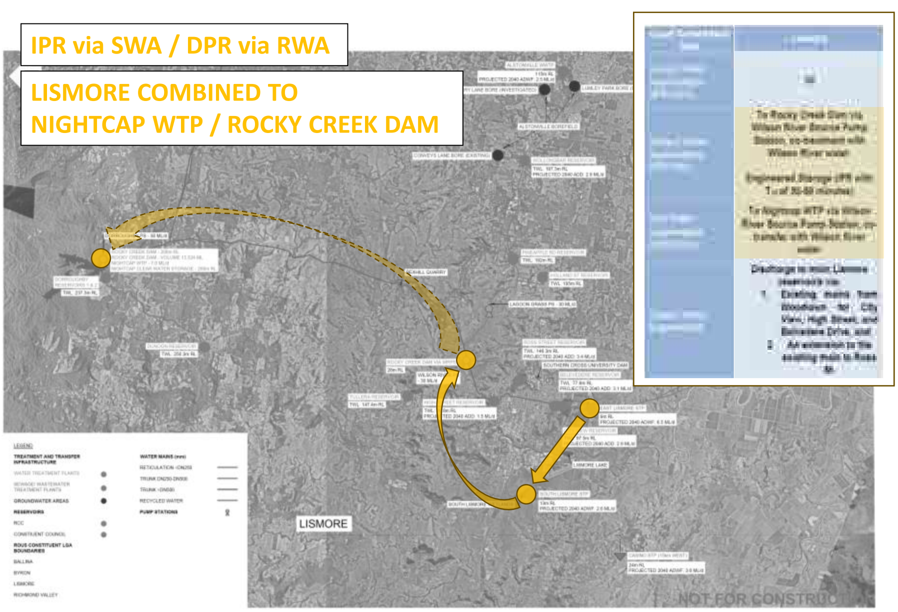
IPR via SWA / DPR via RWA

LISMORE COMBINED TO NIGHTCAP WTP / ROCKY CREEK DAM



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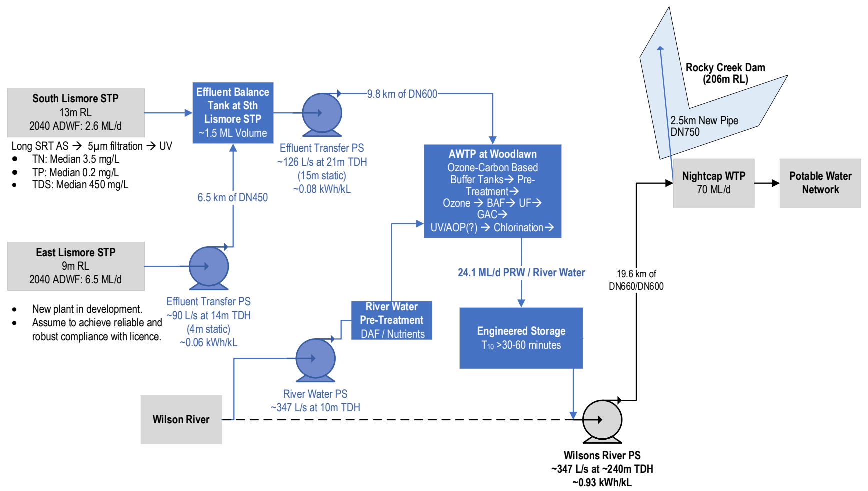
IPR via SWA: LISMORE COMBINED TO ROCKY CREEK DAM



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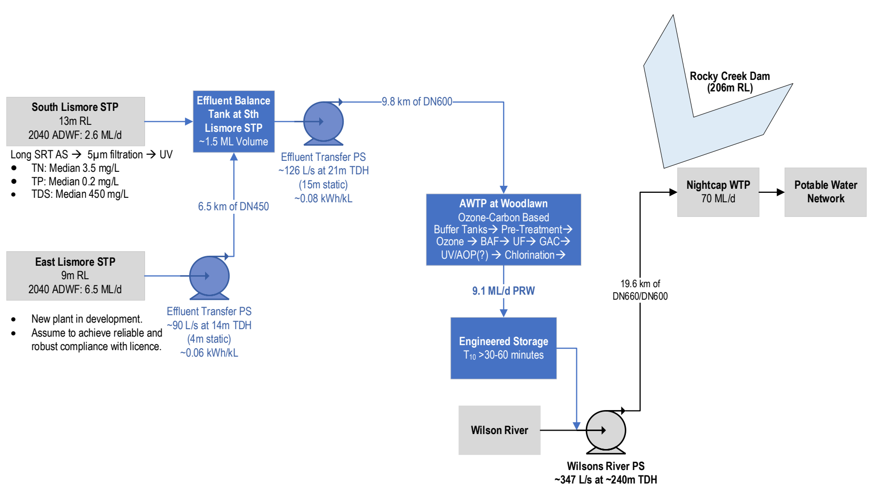
DPR via RWA : LISMORE COMBINED TO NIGHTCAP WTP



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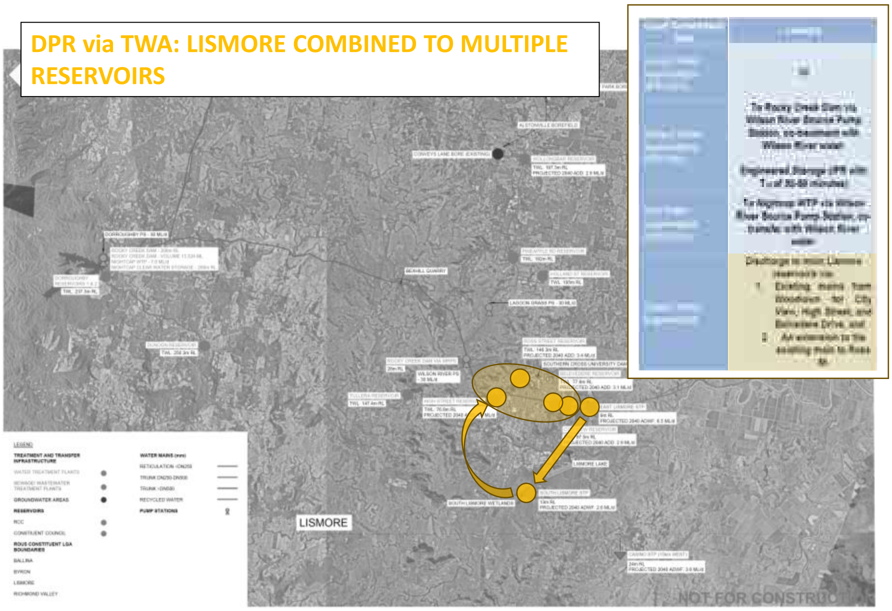
DPR via TWA: LISMORE COMBINED TO MULTIPLE RESERVOIRS



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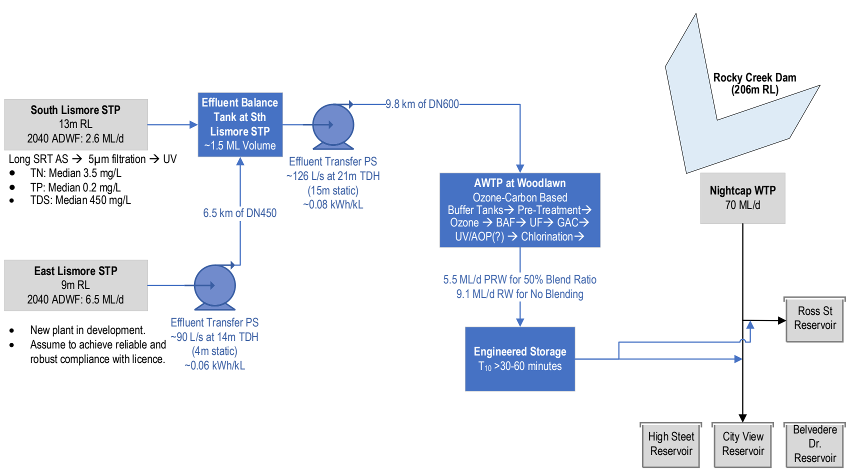
DPR via TWA: LISMORE COMBINED TO MULTIPLE RESERVOIRS



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Baseline Schemes

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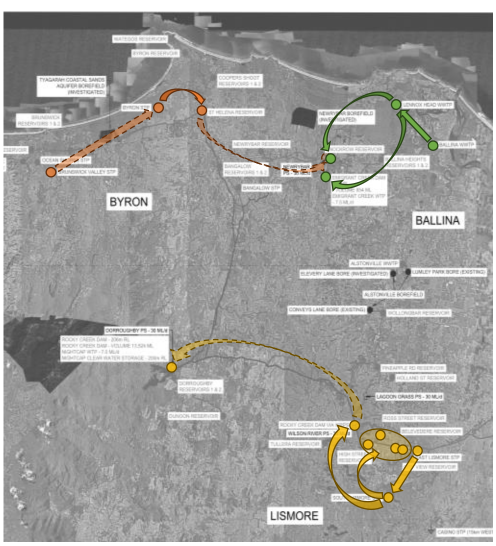
Baseline Schemes



Local Government Area	Ballina	Byron	Lismore
Ground Water Augmentation	Nil	Nil (Watching brief)	Nil
Surface Water Augmentation	Not in baseline options. Unlikely without engineered storage (>70 days HRT)	Not in baseline options. Emigrant Creek could be considered.	**To Rocky Creek Dam via WRPS (co-treatment) Engineered Storage (IPR with T_{10} of 30-60 minutes)**
Raw Water Augmentation	**Emigrant Creek WTP (augmented)**	Not in baseline options. Emigrant Creek could be considered.	**To Nightcap WTP via Wilson River Source Pump Station, co-transfer with Wilson River water.**
Treated Water Augmentation	**To Knockrow Reservoir**	**To St Helena Reservoir with reverse flow in existing main to Knockrow Reservoir**	**Discharge to main Lismore reservoirs (two options)**
Environmental Flows	Not viable for providing additional source water.		

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Baseline Schemes - Attributes

Scheme	Advantages	Disadvantages
Ballina Based Schemes		
Ballina/Lennox Head WWTP Effluent to RWA (DPR via RWA)	Lowest power consumption of RWA ~0.33 kWh/kL to ECD WTP Effluent transfer pipeline possibly existing	AGWR (2008) – no clear pathway for DPR Augmentation of ECD WTP may be required ~13 km of pipeline required Projected increase in non-potable reuse
Ballina / Lennox Head WWTP Effluent to TWA (DPR via TWA)	Effluent transfer pipeline possibly existing	AGWR (2008) – no clear pathway for DPR ~12 km of pipeline required Projected increase in non-potable reuse
Byron Based Schemes		
Byron STP Effluent to TWA (DPR via TWA)	Consistent and high water quality (Wetlands) Potential to distribute TWA to Ballina and Byron (33% blend at 8.9 ML/d) Staging potential Carbon based - Low power consumption, Possible RO	AGWR (2008) – no clear pathway for DPR Long pipeline from BV STP to Byron STP Requires operation of existing main in reverse
Lismore Based Schemes		
Lismore STP Effluent to SWA - Co-treatment and co-transfer with WRS (IPR via SWA)	Potential pathway for regulatory approval under the current Australian Guidelines for Water Recycling (2008) (i.e. IPR) Minimal additional pipework – using WRPS Staging potential	High power consumption to lift to RCD (~0.93 kWh/kL) Additional treatment required Pipeline and diffuser required TDS/temperature impacts on dam Additional conservatism in AWTP – critical infrastructure
Lismore STP Effluent to RWA - Co-transfer with WRS (DPR via RWA)	Minimal additional pipework – using WRPS Staging potential	AGWR (2008) – no clear pathway for DPR High power consumption to lift to Nightcap WTP (~0.93 kWh/kL)
Lismore STP Effluent to TWA (DPR via TWA)	Lower lift required for majority of reservoirs compared to other TWA schemes, reducing power consumption.	AGWR (2008) – no clear pathway for DPR Limited scheme production where substantial blending is required.

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Discussion and Miro Board

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The Rous County Council Region

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Byron and Ballina

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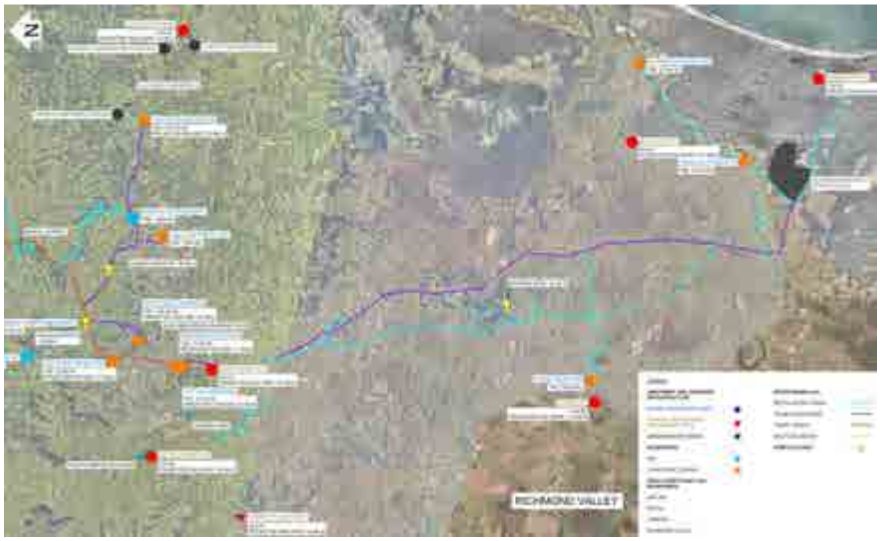
Richmond Valley and Lismore



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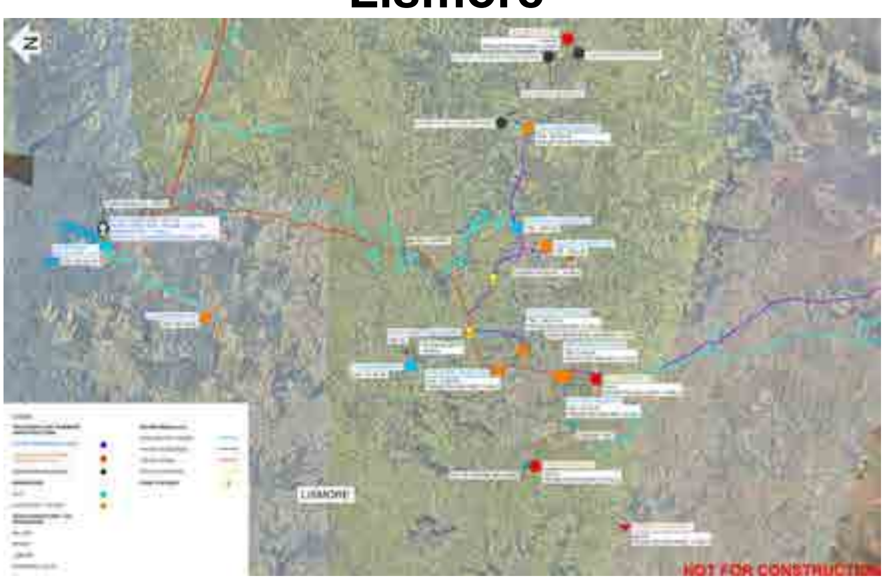
Lismore



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APPENDIX B: SAMPLING RESULTS

South Lismore STP - Effluent Stream Monitoring Programme Results

Parameter	Units	Week 1	Week 2	Week 3
		2/11/2023	9/11/2023	15/11/2023
Total Suspended Solids	mg/L	2	1	1
Algal Biomass	mg/L	1.5	0.3	0.1
TSS corrected for algal biomass	*mg/L*	0.5	0.7	0.9
BOD_5	mg/L	2.2	1.6	<1
COD	mg/L	26	16.0	18.0
Oil and Grease	mg/L	10	<2	<2
Total Phosphorus	mg/L	0.42	0.23	0.06
Orthophosphate	mg/L	0.339	0.091	0.030
Total Nitrogen	mg/L	1.228	1.325	2.050
Total Kjeldahl Nitrogen	mg/L	0.961	0.928	0.890
Organic Nitrogen (calculated)	*mg/L calculated*	*0.885*	*0.872*	*0.846*
Nitrate (as N)	mg/L	0.258	0.383	1.120
Nitrite (as N)	mg/L	0.009	0.014	0.041
Ammonia (as N)	mg/L	0.076	0.056	0.044
pH	mg/L	7.65	7.41	7.57
Conductivity	µS/cm	656	465	703
Total Dissolved Solids	mg/L	428	334	411
Turbidity	NTU	1.2	0.7	0.8
UV Transmissivity	%	55.0	66.6	68.1
Total Organic Carbon	mg/L	9.31	7.0	8.4
Dissolved Organic Carbon	mg/L	8.97	6.4	6.8
Alkalinity (Total)	mg/L CaCO3	134	90	115
Aluminium	mg/L	0.044	0.051	0.054
Boron	mg/L	0.03	0.033	0.05

South Lismore STP - Effluent Stream Monitoring Programme Results (continued)

Parameter	Units	Week 1	Week 2	Week 3
		2/11/2023	9/11/2023	15/11/2023
Bromide	mg/L	0.3	0.150	0.2
Calcium	mg/L	31.0	27.3	29.2
Chloride	mg/L	73	72.1	88
Ferric Iron	mg/L	0.731	0.315	0.454
Ferrous Iron	mg/L	0.040	0.030	0.030
Fluoride	mg/L	0.24	<0.1	0.1
Magnesium	mg/L	7.73	6.22	7.23
Manganese	mg/L	0.080	0.059	0.057
Potassium	mg/L	12.5	9.23	14.4
Sodium	mg/L	104	70.3	93.0
Sulphur	mg/L	21	17.2	22

East Lismore STP - Effluent Stream Monitoring Programme Results

Parameter	Units	Week 1	Week 2	Week 3	Week 4
		23/10/2023	2/11/2023	9/11/2023	15/11/2023
Total Suspended Solids	mg/L	8	1	20	75
Algal Biomass	mg/L	0.3	1.3	1.4	1.0
TSS corrected for algal biomass	mg/L	7.7	0.0	18.6	73.5
BOD5	mg/L	7.7	5.7	15.4	43.6
COD	mg/L	37.0	23	27.0	85.0
Oil and Grease	mg/L	<2	<2	<2	<2
Total Phosphorus	mg/L	0.661	0.278	0.931	2.210
Orthophosphate	mg/L	0.457	0.231	0.382	0.274
Total Nitrogen	mg/L	3.98	5.37	5.38	7.23
Total Kjeldahl Nitrogen	mg/L	0.98	4.97	4.96	6.97
Organic Nitrogen	mg/L calculated	0.56	4.49	4.70	6.85
Nitrate (as N)	mg/L		3.77	2.980	2.400
Nitrite (as N)	mg/L	0.218	0.402	0.415	0.257
Ammonia (as N)	mg/L	0.423	0.476	0.260	0.127
pH	mg/L	7.75	7.50	7.49	7.22
Conductivity	µS/cm	0.553	0.831	0.710	0.538
Total Dissolved Solids	mg/L	376	565	483	366
Turbidity	NTU	3.0	1.2	9.8	34.5
UV Transmissivity	%	66.8	74.6	70.1	57.2
Total Organic Carbon	mg/L	8.07	5.98	7.0	15.5
Dissolved Organic Carbon	mg/L	7.83	5.59	5.4	5.8
Alkalinity (Total)	mg/L CaCO3	109	110	123	99
Aluminium	mg/L	0.171	0.047	0.427	4.65
Boron	mg/L	0.046	0.04	0.039	0.06

East Lismore STP - Effluent Stream Monitoring Programme Results (continued)

Parameter	Units	Week 1	Week 2	Week 3	Week 4
		23/10/2023	2/11/2023	9/11/2023	15/11/2023
Bromide	mg/L	0.1	0.1	0.130	0.1
Calcium	mg/L	25.4	24.2	23.0	30.1
Chloride	mg/L	61	81	67.7	81
Ferric Iron	mg/L	0.01	<0.02	<0.02	0.05
Ferrous Iron	mg/L	0.01	<0.02	<0.02	0.06
Fluoride	mg/L	0.73	0.19	<0.1	0.1
Magnesium	mg/L	4.19	5.07	4.19	5.87
Manganese	mg/L	0.029	0.036	0.030	0.052
Potassium	mg/L	16.7	14.1	11.6	19.4
Sodium	mg/L	73.2	76.9	55.6	79.3
Sulphur	mg/L	10	8	8.77	11

Brunswick Valley STP - Effluent Stream Monitoring Programme Results

Parameter	Units	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
		15/11/2023	22/11/2023	29/11/2023	6/12/2023	13/12/2023	20/12/2023
Total Suspended Solids	mg/L	3.4	5	4.2	2	1.2	3
BOD_5	mg/L	2.1	1.2	<1	3.3	<1	<1
COD	mg/L	21	24	18	12	19	13
Oil and Grease	mg/L	<2	<2	<2	<2	<2	<2
Total Phosphorus	mg/L	0.15	0.15	0.08	0.07	0.15	0.07
Orthophosphate	mg/L	0.06	<0.02	<0.02	<0.02	0.07	0.02
Total Nitrogen	mg/L	1.2	9.1	2.08	0.68	1.08	0.83
Total Kjeldahl Nitrogen (CALC)	mg/L	0.9	8.83	1.81	0.65	0.98	0.65
Nitrate (as N)	mg/L	0.3	0.23	0.25	0.03	0.1	0.18
Nitrite (as N)	mg/L	<0.02	0.04	0.02	<0.02	<0.02	<0.02
Ammonia (as N)	mg/L	0.03	8.83	1.16	<0.02	0.15	0.04
pH (*measured onsite*)	mg/L	7.3	7.0	6.9	7.0	7.7	7.6
Conductivity	µS/cm	679	828	714	830	921	980
Total Dissolved Solids	mg/L	410	470	410	510	570	550
Turbidity	NTU	2	3.1	2	1.8	1.4	1.4
UV Transmissivity (filtered sample)	%	71.5	71.5	73.1	73.3	66.5	68.4
Total Organic Carbon	mg/L	7.2	6.4	5.9	5.3	8.5	6.2
Dissolved Organic Carbon	mg/L	6.6	6.1	5.3	5.1	7.7	6
Alkalinity	mg/L as $CaCO_3$	83	102	76	82	97	104
Aluminium (total)	mg/L	0.12	0.21	0.15	0.14	0.097	0.14
Arsenic (III & V)	mg/L	ND	ND	ND	ND	ND	ND
Barium (total)	mg/L	0.012	0.017	0.017	0.017	0.019	0.017
Boron (total)	mg/L	<0.01	<0.01	0.06	0.07	0.09	0.091
Bromide	mg/L	0.27	0.3	0.25	0.275	0.375	0.335

Brunswick Valley STP - Effluent Stream Monitoring Programme Results (continued)

Parameter	Units	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
		15/11/2023	22/11/2023	29/11/2023	6/12/2023	13/12/2023	20/12/2023
Calcium	mg/L	14	16	14	15	19	20
Chloride	mg/L	100	120	100	120	140	140
Chromium (VI)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ferric Iron	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ferrous Iron	mg/L	<0.05	0.07	<0.05	<0.05	0.05	0.06
Fluoride	mg/L	0.05	0.06	0.04	0.05	0.03	0.05
Magnesium	mg/L	7.1	7.7	6.9	7.6	9.2	9.4
Manganese (total)	mg/L	0.127	0.138	0.141	0.154	0.161	0.123
Potassium	mg/L	15	17	16	19	21	23
Silica as SiO_2	mg/L	14	13	13	14	14	14
Sodium	mg/L	102	110	101	118	147	150
Strontium (total)	mg/L	0.082	0.088	0.087	0.093	0.093	0.098
Sulphate	mg/L	94	111	97	115	139	144

Byron STP - Effluent Stream Monitoring Programme Results – Constructed Wetland Outlet

Parameter	Units	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
		15/11/2023	22/11/2023	29/11/2023	6/12/2023	13/12/2023	20/12/2023
Total Suspended Solids	mg/L	<1	<1	4.2	<1	<1	2
Algal Biomass (chlorophyll - a)	µg/L	<1	<1	3	3	2	1
Total Suspended Solids corrected for algae (NFR from TSS and chlorophyll-a acceptable)	mg/L	<1	<1	<1	<1	<1	1.9
BOD_5	mg/L	<1	<1	<1	3.3	1.2	<1
COD	mg/L	22	26	32	30	26	26
Oil and Grease	mg/L	<2	<2	<2	<2	2	<2
Total Phosphorus	mg/L	0.14	0.11	0.2	0.21	0.12	0.13
Orthophosphate	mg/L	0.11	0.09	0.17	0.18	0.08	0.09
Total Nitrogen	mg/L	0.62	0.6	0.81	0.79	0.81	0.75
Total Kjeldahl Nitrogen (CALC)	mg/L	0.62	0.6	0.81	0.79	0.81	0.75
Nitrate (as N)	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrite (as N)	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ammonia (as N)	mg/L	0.02	0.02	0.1	0.1	0.06	0.04
pH *(measured onsite)*	mg/L	7.1	7.1	6.9	6.9	7	7
Conductivity	µS/cm	804	691	704	812	883	906
Total Dissolved Solids	mg/L	450	400	370	490	520	500
Turbidity	NTU	0.7	1.1	2	1.6	1.7	1.6
UV Transmissivity (filtered sample)	%	45	49.1	40.2	35.8	41.1	41.1
Total Organic Carbon	mg/L	9.1	8.3	11	11	12	11
Dissolved Organic Carbon	mg/L	8.5	8.3	10	11	11	10
Alkalinity	mg/L as $CaCO_3$	91	89	88	97	98	109
Aluminium (total)	mg/L	<0.01	0.01	0.01	<0.01	0.01	0.03

Byron STP - Effluent Stream Monitoring Programme Results – Constructed Wetland Outlet (continued)

Parameter	Units	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
		15/11/2023	22/11/2023	29/11/2023	6/12/2023	13/12/2023	20/12/2023
Arsenic (III & V)	mg/L	ND	ND	ND	ND	ND	ND
Barium (total)	mg/L	0.007	0.008	0.007	0.008	0.008	0.008
Boron (total)	mg/L	<0.01	<0.01	0.05	0.06	0.06	0.07
Bromide	mg/L	0.34	0.265	0.28	0.355	0.355	0.38
Calcium	mg/L	23	20	20	21	25	24
Chloride	mg/L	150	140	120	160	170	180
Chromium (VI)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ferric Iron	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ferrous Iron	mg/L	<0.05	0.08	0.13	0.19	<0.05	0.08
Fluoride	mg/L	0.05	0.05	0.05	0.06	0.03	0.05
Magnesium	mg/L	7.6	6.4	6.2	7	8.4	8.4
Manganese (total)	mg/L	0.094	0.063	0.105	0.141	0.049	0.065
Potassium	mg/L	15	16	16	19	20	21
Silica as SiO_2	mg/L	6.7	7.7	8.9	12	12	13
Sodium	mg/L	111	94	92	106	132	133
Strontium (total)	mg/L	0.091	0.082	0.082	0.092	0.089	0.096
Sulphate	mg/L	42	41	38	40	52	54

Byron STP - Effluent Stream Monitoring Programme Results – STP Discharge to Wetland

Parameter	Units	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
		15/11/2023	22/11/2023	29/11/2023	6/12/2023	13/12/2023	20/12/2023
Total Dissolved Solids	mg/L	400	420	390	490	480	480
UV Transmissivity (filtered sample)	%	65.6	69.1	68.1	69.3	62.6	70.2
Total Organic Carbon	mg/L	8.6	6.6	8	6.4	9	6.6
Dissolved Organic Carbon	mg/L	8.4	6.4	7	6.1	8.3	6.5

APPENDIX C: MINIMUM PATHOGEN REDUCTIONS FOR POTABLE REUSE SCHEME DEVELOPMENT DISCUSSION PAPER

Rous County Council
Purified Recycled Water Investigations
Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development

Revision	Date	Description	Prepared by	Reviewed by
A	November 30, 2023	Draft for Internal Consultation	Andy Findlay	David Fligelman
B	December 19, 2023	Draft for Client Review	Andy Findlay	David Fligelman
C	February 20, 2024	Final incorporating Client comments	Andy Findlay	David Fligelman
D	March 25, 2024	Minor edit	Andy Findlay	David Fligelman

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ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AOP	Advance Oxidation Process
AWTP	Advanced Water Treatment Plant
BAC	Biological Activated Carbon
CCPs	Critical Control Points
CIP	Clean-In-Place
Ct	Concentration x Contact Time
DALY	Disability Adjusted Life Year
DPR	Direct Potable Reuse
ESB	Engineered Storage Buffer
HACCP	Hazard Analysis and Critical Control Point
IPR	Indirect Potable Reuse
LRV	Log Reduction Value
MBR	Membrane Bioreactor
NWRI	National Water Research Institute
NSW	New South Wales
PDT	Pressure Decay Test
PRW	Purified Recycled Water
QMRA	Quantitative Microbial Risk Assessment
RCC	Rous County Council
RO	Reverse Osmosis
UV	Ultraviolet Light Disinfection
WHO	World Health Organization
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

ACKNOWLEDGEMENTS

Tyr Group would like to acknowledge the outstanding support provided by staff from Rous County Council. In particular, Rous County Council's Recycled Water Project Manager, Jeremy Wilson, has provided information used in development of excess log reduction values.

1 BACKGROUND

Rous County Council (RCC) is investigating the potential to utilise purified recycled water (PRW) as a climate resilient source of water for supply of potable water. As part of the *Purified Recycled Water for Drinking Investigations* project it is necessary to establish minimum pathogen log reduction values (LRV) to allow development of conceptual advanced water treatment plant (AWTP) process trains. The investigation has short-listed various scheme options for use of PRW, including:

- Indirect potable reuse (IPR) via surface water augmentation – PRW is discharged to an environmental buffer (e.g. dam or other large surface water storage) where it is blended with other water sources. The environmental buffer provides a minimum detention time for the water prior it being fed to a drinking water treatment plant (WTP);
- Direct potable reuse (DPR) via raw water augmentation – PRW is blended with other water sources and fed directly to the start of the WTP process without an environmental buffer; and,
- DPR via treated water augmentation – PRW is blended with treated water from the WTP in the drinking water distribution system.

At the time of writing, New South Wales (NSW) does not have any guidelines or regulations for potable reuse. However, the NSW Water Strategy does include actions associated with development of a *Recycled Water Roadmap* to identify policy and regulatory options.

The Greater Sydney Water Strategy [1] references the use of PRW as follows:

"Purified recycled water involves releasing highly purified wastewater into an 'environmental buffer', such as a river or underground aquifer before re-extracting and treating the water for drinking. Currently there are no indirect potable schemes in NSW." [1, p. 69]

Notably, the Draft Regional Water Strategy for the Far North Coast [2, p. 111] identified both indirect and direct potable reuse as long list options to improve town water security, and to protect and enhance the environment.

The current regulatory approach adopted by NSW regulatory agencies toward DPR is guided by the *Australian Guidelines for Water Recycling: Phase 2 Augmentation of Drinking Water (2008)*.

The current Australian Guidelines for Water Recycling (AGWR) [3] detail an approach for determining the minimum LRV requirements for schemes based on indirect augmentation. The approach adopted by NSW regulatory agencies toward DPR is guided by this document. While the AGWR [3] do not exclude direct augmentation schemes, they do not provide a prescribed pathway for approval. More specifically, the AGWR [3] indicate that[1]:

- *"Direct augmentation will require higher levels of treatment to provide sufficient assurance that water-quality targets can be met and maintained."* [3, p. 45], and,
- *"The need for reliability of processes, vigilance of monitoring and highly skilled operators — already high for indirect use — is magnified for direct augmentation. Knowledge and understanding of system reliability and control of variability is essential before direct augmentation can proceed. Further research is required in this area."* [3, p. 4].

The feed water to the AWTP comprises treated effluent from wastewater treatment plants (WWTPs) under each of the short-listed schemes. In considering the pathogen load that needs to be treated, the AGWR [3] considers the minimum log removal values (LRVs) from raw wastewater (rather than WWTP effluent).

[1] Significant work has been undertaken with respect to DPR since the AGWR was published in 2008. Section 5 discusses the current approach to address these concerns raised in the AGWR.

Pathogen reduction is achieved by treatment through the WWTP and AWTP, and in the case of surface water augmentation and raw water augmentation also through treatment through the downstream WTP. For surface augmentation, some level of pathogen reduction may also be possible through the environmental buffer.

In addition to pathogen risks, the risks associated with chemicals in the raw wastewater also need to be considered. Chemical risks are being considered as a separate task within the investigation.

Minimum LRV targets presented in this report have been developed based on high-level quantitative microbial risk assessment (QMRA). The high-level QMRAs provide a broad overview to specifically highlight or eliminate concerns. In the absence of substantial scheme-specific data, the QMRAs have:

- Applied documented typical and literature values, assessment methodology and data (as sourced from the AGWR [3], Australian Drinking Water Guidelines (ADWG) [4] and World Health Organization (WHO) guidance [5]);
- Developed minimum pathogen LRV targets based on the AGWR methodology using typical pathogen densities and DALY values, and,
- Included limited modelling of failure scenarios.

2 PURPOSE

This discussion paper describes the derivation of the minimum pathogen LRV requirements proposed to be applied to development of the conceptual AWTP process trains for each of the short-listed schemes**, for the purpose of providing cost estimates for RCC's forward planning (this document is not intended to establish pathogen LRV criteria with which a future design would be based as additional work (e.g. site-specific testing/demonstration, engagement with the regulator, etc.) will be required to establish these criteria)**. In combination with the chemical removal requirements, the minimum pathogen removal will have a strong bearing on the key attributes of the schemes, including:

- The process units to be utilised in the process trains, and their configuration;
- Operational and maintenance requirements (e.g. critical control points (CCPs), operator skills, sampling/monitoring, etc.) required to verify the required water quality is delivered at all times;
- High level estimates of the capital costs for each scheme; and,
- High level estimates of the operating costs for each scheme.

A key aim of this discussion paper is to establish the proposed pathogen removal requirements for each scheme type (for costing purposes) that:

1. Are consistent with robust protection of public health, while,
2. Not imposing excessive treatment requirements that increase costs or complexity without providing meaningful improvements to public health protection.

3 PATHOGEN REDUCTION

Pathogen reduction is achieved by treating the source water with various treatment processes, referred to as "barriers". Similar to the methodology prescribed by the ADWG [4], the AGWR [3] requires a multiple barrier approach. The AGWR [3] states:

"Multiple barriers protect against variations in performance of individual barriers. Variations in different barriers are unlikely to align to the extent that all perform poorly at the same time; nevertheless, every effort should be taken to ensure that barriers operate within acceptable ranges." [3, p. 8]

There is a distinction between the "Achievable LRV" for a given barrier (as demonstrated in field investigations, challenge tests and laboratory trials), and the "Validated LRV" (which can be confirmed through validation in the design and commissioning of the plant, and then verified by monitoring ongoing operation). The Validated LRV is limited by practical limitations on the operational monitoring and quality of evidence available regarding the minimum pathogen removal.

For the purposes of establishing conceptual treatment process trains for which "Claimed LRVs" meet or exceed the minimum LRV requirement, it is proposed that Claimed LRVs consider Validated LRVs that are based on short term verification (e.g. online analysers reporting results in minutes) and longer-term verification (e.g. daily pressure decay tests (PDTs) on membrane filtration units). Using membrane filtration as an example:

1. Failures in membrane integrity would be detected in real time by turbidity;
2. Spikes in turbidity would be used to trigger an out of schedule/immediate PDT which can verify if there is an actual integrity issue;
3. The act of triggering a PDT is a corrective action in itself, as the suspect unit is no longer producing water;
4. There are no known reports of membrane systems that have failed significantly (e.g. more than 2 log) within 24 hours and not shown other symptoms.
5. It is assumed the system would be well designed and have multiple trains. Each train would have a scheduled PDT performed every day. The PDTs would not occur at the same time, but be scheduled across the day. In this way, the whole treatment process is incrementally checked multiple times a day.

There is currently no national guidance on the maximum LRV that can be claimed per treatment process. A maximum of 4 LRV per treatment process has generally been applied for recycled water applications in Australia (both potable and non-potable), including in:

- Victoria's *Guidelines for validating processes for pathogen reduction* [6] (for non-potable reuse applications);
- The NSW Department of Primary Industries Office of Water's *Recycled Water Guidance Document* [7], and,
- The Australian Drinking Water Guidelines (ADWG) [4].

For the purpose of developing the conceptual AWTP treatment process trains, <u>a maximum 4 LRV per unit process has been assumed</u> for this investigation, noting that other jurisdictions (e.g. California) permit up to 6 LRV to be claimed for certain processes (e.g. ozonation, UV disinfection, chlorination).

With respect to operation of a potable reuse scheme, the pathogen removal requirements have been considered based on the expectation that the system would be managed and operated in accordance with prevailing best practice, including:

- Operation in accordance with comprehensive and appropriate management systems and documentation (e.g. Hazard Analysis and Critical Control Point (HACCP) Plan, standard operating procedures, incident response procedures, etc.);
- The AWTP treatment process utilises a multiple barrier approach, with no one barrier claiming more than 4 LRV for a given pathogen type;

- Treatment process units utilised have been demonstrated to provide the required performance, reliability and robustness to ensure protection of public health and can be validated to achieve the Claimed LRV;
- Operations personnel have suitable qualifications, training[2] and experience, and the team is adequately resourced;
- The plant design and configuration are consistent with the comprehensive HACCP Plan, with:
  - CCPs with both “alert” and “critical” limits, where:
    - Critical limits set at the point where the claimed LRV would be breached; and,
    - Alert limits set sufficiently below the critical limit to allow operations personnel to respond before the critical limit is reached;
  - Automated shutdown of the relevant process unit and/or diversion of product water or if the critical limit is reached;
  - Robust control system design and testing (initial and ongoing) to ensure all CCPs function as intended;
  - Redundancy for CCP analyser systems, where appropriate;
  - For DPR via treated water augmentation: Product water tankage sized and configured with a minimum residence time in excess of the duration between the longest consecutive monitoring events for any CCP analyser. This will ensure any water produced prior to any CCP critical level breach being recorded is captured prior to discharge from the AWTP. The tankage would be equipped with an automated diversion system to allow the contents of the tank to be returned to the WWTP and/or AWTP for retreatment.
- Maintenance personnel have suitable qualifications, training and experience, and the team is adequately resourced. Additionally, it is the expectation that maintenance staff are trained such that they understand the potential impacts of their actions on operation of the plant;
- Predictive, preventative and reactive maintenance is performed in accordance with an approved maintenance system to ensure optimal plant performance;
- A clear communication plan is in place for interaction between operations and maintenance activities (generally including a permit to work type of system where Operations has to sign off on maintenance activities before they commence); and,
- A change management system is in place and followed to prevent unexpected/unknown changes from occurring (e.g. changes to the coding of the plant control system).

3.1 Source Control

Source control can be used as a means of reducing chemical risk in the source water (e.g. stringent discharge limits on trade waste users and the ability to stop their discharge to sewer if they are not meeting their discharge condition). However, source control is not considered as a means to directly reduce pathogen concentrations.

Another aspect of source control is its role as the first barrier in the treatment process. While source control directly reduces the chemical risk within the treated water from the AWTP, the control of adverse chemicals also helps prevent upsets at the WWTP which helps ensure the AWTP process units operate optimally and as intended. An example of this would be an enhanced source control program removing chemicals that are fouling to membrane systems, resulting in extension of the time interval between chemical clean-in-place (CIPs) events and prolonging the life of the membranes.

[2] Operator understanding of how to operate the plant and why the plant needs to be operated in accordance with the design is critical to success, hence operator training needs appropriate consideration in the overall development of any PRW scheme. Operator training will need to start well before commissioning of the full scale AWTP and will depend on whether RCC intends to utilize its own operations staff, for which RCC would need to develop a training program, or if RCC intend to hire a contract operator with experience operating this type of scheme (e.g. Veolia). Training would likely include operators gaining experience with the process units by participating in operation of a demonstration plant, developing an understanding of the design of the AWTP by taking part in design reviews and workshops (e.g. HACCP, HAZOP, etc.), attending training delivered by the design team (including the equipment suppliers) with the design team tasked with ensuring operator understanding (i.e. just attending the training would not be sufficient, a means to test the operators knowledge following the training would be needed), and could also include visits to other operating AWTP facilities (e.g. multiple weeks working directly with operators of these facilities).

3.2 WASTEWATER TREATMENT[3]

The secondary wastewater treatment process provides a level of pathogen removal and hence can be considered as a barrier. Table 3-1 provides indicative achievable and validated pathogen LRV for secondary treatment [6].

Table 3-1: Indicative Pathogen LRV for Secondary Treatment of Wastewater

Treatment Process	Achievable LRVs			Validated LRVs			Online analysers for verification
	Virus	Protozoa	Bacteria	Virus	Protozoa	Bacteria	
Secondary Treatment[1]	2	2	2	0.5 - 1	0.5 - 1	1 - 2	Ammonia – analysis results returned every 15 to 30 minutes Turbidity – continuously reporting analyser results[2]

1. Ballina WWTP utilises membrane bioreactor (MBR) technology. MBRs have higher validated LRVs based on the membrane process, but Ballina has historically had issues with the membranes at this plant. Hence, no consideration is given to the potential higher MBR LRVs in this work. The existing membranes are being replaced with new membranes from a different manufacturer. Should any schemes be developed in future that utilise Ballina WWTP effluent, the LRV claimed for this plant should be considered further.
2. CCP would require analyser reading to be above the critical limit for a defined time (e.g. > 10 NTU for more than 5 minutes) before the CCP would be considered breached.

For the purpose of this investigation, a conservative validated LRV of 0.5 is proposed to be claimed for each pathogen type for the WWTP. For reference, the Beenyup WWTP is credited with an LRV of 1.0 for each of virus and bacteria and of 0.5 for protozoa as part of Water Corporation's groundwater replenishment scheme [5].

It is likely additional LRV could be claimed for the WWTP, but further site-specific study would be required to justify. This would include collecting an extensive data set over the biological treatment operational range, which would mean defining the nutrient removal values, effluent BOD, effluent UV transmittance, and effluent turbidity.

3.3 ADVANCED WATER TREATMENT PLANT

A variety of treatment processes can be used in an AWTP for pathogen reduction. Table 3-2 provides indicative achievable and validated pathogen LRV for various treatment processes that could be included in the conceptual AWTP design (validated LRVs are from the ADWG[4] [4]).

[3] Reference to protozoa in Section 3.2 through 3.4 means *Cryptosporidium.*
[4] With some modification as described in the table notes.

Table 3-2: Indicative Pathogen LRV for Potential AWTP Treatment Processes

Treatment Process	Achievable LRVs			Validated LRVs			Online analysers for verification of CCP
	Virus	Protozoa	Bacteria	Virus	Protozoa	Bacteria	
Microfiltration/Ultrafiltration[1]	3	6	6	0	4	4	Turbidity – continuously reporting analyser results[2] PDT – daily
Ozone[3]	4	3	4	4	0	4	Ozone residual – continuously reporting analyser results Flow – continuously reporting (to allow determination of Ct)
Biological Activated Carbon (BAC)[4]	-	-	-	1	0.5	1	BAC effluent turbidity – continuously reporting analyser results
Reverse Osmosis (RO)[5]	6	6	6	1.5 – 2			Conductivity – continuously reporting analyser results TOC - analysis results returned every 10 minutes
				2.5 – 4			Sulphate/fluorescent dye testing
Ultraviolet Light Disinfection (UV) [6]	6	6	6	4			Flow – continuously reporting results UV transmittance – continuously reporting analyser results UV Intensity – continuously reporting analyser results
UV/Advanced Oxidation Process (AOP)	6	6	6	4			Flow – continuously reporting results UV dose – continuously reporting results UV transmissivity – continuously reporting analyser results
Chlorine	6	0	6	4	0	4	Free chlorine – analysis results returned every 3 to 5 minutes

Notes:

1. Ultrafiltration systems can obtain 3+ LRV of virus, whereas microfiltration systems can obtain 1+ LRV of virus. The UF system at Beenyup AWRP claims 3 log virus removal [5]. There is current work studying real time measurement of virus with online analysers that would allow for frequent (e.g. daily) challenge testing of UF systems to allow for claiming higher virus LRVs. The ADWG [4] currently allocates no virus LRV credit for microfiltration or ultrafiltration.
2. CCP would require analyser reading to be above the critical limit for a defined time (e.g. > 0.15 NTU for more than 5 minutes) before the CCP would be considered breached.
3. Control of the ozone system could be based on Ozone/TOC ratio (for control of Bromate formation) or Ozone C.t. Where Ozone C.t is utilised, the US EPA Long Term 2 Enhanced Surface Water Treatment Rule: Toolbox Guidance Manual [8] indicates claimable *Cryptosporidium* LRV of 0.25 to 3 (based on increasing ozone C.t). The WaterVal Ozone Disinfection Validation Protocol [9] (and ADWG [4]), include the same *Cryptosporidium* LRV information as US EPA [8], and supports up to 4 LRV for virus. US Water Research Foundation Project 5129 demonstrated that using the ozone/TOC ratio is a much more accurate and controllable method to demonstrate up to 5 LRV of virus. As ozone dose increases the risk of bromate formation increases.
4. RCC currently claim separate LRV for ozonation and the BAC filters at Nightcap WTP. This approach is proposed to be considered in the development of the AWTP process trains where/if appropriate, noting that the indicative pathogen LRV attributable to media filtration (as described in Table 5.6 of the ADWG [4]) currently relies on coagulation upstream of the filtration to be credited for virus removal (there is currently a WaterVal project underway to investigate validation of granular media filters) .
5. The approach to AWTP process train development will be to limit claimed LRV to that which can be validated LRV based on online conductivity/TOC only. The WaterVal Reverse Osmosis and Nanofiltration Validation Protocol supports RO LRV of up to 4 [10]. The RO system at Beenyup AWRP claims 3 log virus, protozoa and bacteria removal [5] (understood to be based on weekly sulphate testing).
6. While disinfection via hydroxyl radical chemistry has been demonstrated for ozone/peroxide systems, it is not currently possible to monitor and properly control at this time. For the purposes of establishing AWTP process trains, it is proposed that UV/AOP pathogen Claimed LRV is based entirely from UV standard monitoring methods. The WaterVal UV Disinfection Validation Protocol supports up to 4 LRV for all pathogen types [11].
7. The WaterVal Chlorine Disinfection Validation Protocol supports up to 4 LRV for virus and bacteria [12].

3.4 RCC Drinking Water Plants

Two short-listed scheme options direct the PRW to the inlet of Nightcap WTP (IPR via surface augmentation and DPR via raw water augmentation). Table 3-3 shows the LRVs claimed for Nightcap WTP within its Drinking Water Management System, and the basis applied to verification of those LRVs.

Table 3-3: Nightcap WTP LRVs

Treatment Process	Virus	Protozoa	Bacteria	Basis
Dissolved Air Flotation + Filtration	2	3.5	2	Effluent turbidity < 0.2 NTU 95% of the time and not > 0.5 NTU for > 15 min
Ozone	4	0.5	4	Ct value of 3.2 mg-min/L, based on achieving ozone residual of 0.135 mg/L
BAC	1	0.5	1	Effluent turbidity < 0.15 NTU 95% of the time and not > 0.3 NTU for > 15 min
Chlorine	4	0	4	Ct value of 16 mg-min/L, when > 1.2 mg/L free chlorine residual
Total	**11**	**4.5**	**11**	

Nightcap WTP has two different sets of treatment requirements to achieve the health-based targets in alignment with ADWG [4] – one for each of the Rocky Creek Dam and Wilsons River raw water sources. Table 3-4 compares the total claimed LRVs to the pathogen removal required for the two source waters. With improvements to control of the ozonation system it is likely that higher LRVs will be claimable.

Table 3-4: Nightcap WTP Required versus Claimed LRVs

Pathogen	Claimed LRV	Rocky Creek Dam		Wilsons River	
		Required LRV	Difference	Required LRV	Difference
Virus	11	4	+7	6	+5
Protozoa	4.5	3	+1.5	5	-0.5
Bacteria	11	4	+7	6	+5

Table 3-4 shows that the Nightcap WTP provides surplus LRV for virus and bacteria for both water sources and surplus for protozoa for the Rocky Creek Dam source. The plant has a shortfall of 0.5 LRV for protozoa for the Wilsons River source, however this is acceptable under the ADWG [4] as the microbial health outcome target of 10^{-6} disability adjusted life years (DALYs) per person per year is applied as an operational benchmark (rather than as a pass/fail criteria).

Traditionally in Australia, potable reuse schemes have not considered the LRVs in the WTP. While the WTP processes are not proposed to be claimed for the IPR or treated water augmentation options, they may be relevant to raw water augmentation options (particularly in relation to excess "LRV" requirements). For this investigation, it is proposed that LRVs achieved within the WTP be considered in the pathogen risk controls for the short-listed raw water augmentation scheme.

4 MINIMUM PATHOGEN LRV FOR PROTECTION OF PUBLIC HEALTH IN POTABLE REUSE SCHEMES

4.1 BASELINE PATHOGEN LRVS

The AGWR [3] uses DALYs to convert the likelihood of infection or illness into burdens of disease, and sets a tolerable risk as 10^{-6} DALYs per person per year. The latest version of the ADWG [4] sets the same DALY target as an operational benchmark (rather than a pass/fail criteria). Disability adjusted life years dose (DALYd) is the dose of pathogens equivalent to a DALY of 10^{-6}. DALYd includes consideration of dose response[5], ratios of infection to illness and severity weighting of the illness.

As it is impractical to set targets for all pathogens potentially present in a source of recycled water, the AGWR [3] specifies the use of the following reference pathogens:

- Virus – amalgam rotavirus and adenovirus (where the dose response relationship for rotavirus is used in conjunction with occurrence data for adenovirus)
- Protozoa and helminths – *Cryptosporidium*
- Bacteria – *Campylobacter*

The following equation is used to determine the minimum LRV for each reference pathogen to meet the target of 10^{-6} DALYs per person per year:

$$\text{Minimum LRV} = \log_{10} (\text{pathogen concentration in source water} \times \text{exposure} \times N \div \text{DALYd})$$

where:

- Pathogen concentration is the 95th percentile of reference pathogen concentration in source water. Default values are provided in AGWR [3] as follows:
  - Rotavirus – 8,000 per L
  - *Cryptosporidium* – 2,000 per L
  - *Campylobacter* – 7,000 per L
- Exposure can be defined as the amount of water consumed (2 L/d per AGWR [3])
- N is the number of exposures per year (assumed daily)
- DALYd is given by AGWR as:
  - Rotavirus – 2.5×10^{-3} per year
  - *Cryptosporidium* – 1.6×10^{-2} per year
  - *Campylobacter* – 3.8×10^{-2} per year

Table 4-1 summarises the QMRA based on the above parameters and the resulting minimum LRV for each reference pathogen based on this approach.

[5] Relationship between dose of organism and incidence or likelihood of illness.

Table 4-1: Minimum LRV Required Based on AGWR [3] based on 2 L/d Ingestion

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Rotavirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	8,000	2,000	7,000
DALYd	number per year	2.5×10^{-3}	1.6×10^{-2}	3.8×10^{-2}
Exposure	L/d	2	2	2
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	3.4×10^{-6}	2.2×10^{-5}	5.2×10^{-5}
Minimum Pathogen Removal	LRV	9.4	8.0	8.1
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**9.5**	**8.5**	**8.5**

The ADWG [4] suggest a reference exposure volume of 1 L unheated (unboiled) water per person per day. Table 4-2 shows the QMRA based on the above parameters and the resulting minimum LRV requirements based on this lower exposure volume.

Table 4-2: Minimum LRV Required Based on AGWR [3] based on 1 L/d Ingestion

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Rotavirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	8,000	2,000	7,000
DALYd	number per year	2.5×10^{-3}	1.6×10^{-2}	3.8×10^{-2}
Exposure	L/d	1	1	1
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	6.9×10^{-6}	4.4×10^{-5}	1.0×10^{-4}
Minimum Pathogen Removal	LRV	9.1	7.7	7.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**9.5**	**8.0**	**8.0**

Where the AGWR [3] considers Rotavirus, the ADWG [4] utilises the dose-response relationship of Norovirus in combination with the concentration of Adenovirus. As the ADWG does not have default concentrations for reference pathogens in raw wastewater, the concentrations for these pathogens in the WHO document *Potable Reuse Guidance for Producing Safe Drinking Water* [5] can be applied. Using the dose-response relationships, the relationships of infection to illness and the DALY per illness information provided in the ADWG [4] and the WHO pathogen concentration default values, there are differences in the calculated minimum pathogen removal requirements as compared to Table 4-1. Table 4-3 shows the revised DALYd values and the resultant minimum LRV that would need to be met under:

- The ADWG values for Norovirus dose-response;
- A raw wastewater concentration of Adenovirus based on WHO guidance, and,
- Ingestion of 2 L/d.

Table 4-3: Minimum LRV Required Based on ADWG [4] **combined with WHO** [5]

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus / Adenovirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	20,000	2,700	7,000
DALYd	number per year	3.6×10^{-3}	4.2×10^{-3}	7.5×10^{-3}
Exposure	L/d	2	2	2
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	5.0×10^{-6}	5.8×10^{-6}	1.0×10^{-5}
Minimum Pathogen Removal	LRV	9.6	8.7	8.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**10.0**	**9.0**	**9.0**

WHO uses 1 L/d ingestion of unboiled drinking water as per ADWG [4]. Table 4-4 summarises the QMRA that derives the WHO default LRV targets [5].

Table 4-4: WHO 2017 Default LRV Targets [5]

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus / Adenovirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	20,000	2,700	7,000
DALYd	number per year	4.2×10^{-3}	4.4×10^{-3}	7.3×10^{-3}
Exposure	L/d	1	1	1
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	1.1×10^{-5}	1.2×10^{-5}	2.0×10^{-5}
Minimum Pathogen Removal	LRV	9.3	8.4	8.5
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**9.5**	**8.5**	**8.5**

WHO [5] does not differentiate LRV targets for IPR and DPR (i.e. the same target applies for both). There is discussion in WHO [5] related to the use of engineered storage buffers (ESBs) for DPR, with much shorter detention times than that provided by environmental buffers in an IPR system. The following is an excerpt from WHO [5] related to the use of ESBs:

"*An ESB is a storage basin or system that provides sufficient time, termed the failure and response time, to interrogate and respond to any faults, including exceedances of critical limits in operational monitoring of the treatment train. Storage times in ESBs are likely to be of the order of hours to days. The failure and response time should take into account sampling intervals, time to complete analyses and time to respond. For example, for online parameters such as turbidity or disinfectant residuals, sampling intervals are very short, analyses are completed immediately and actions can be implemented within minutes. This can involve interrogating system performance by an operator or making a decision to stop the supply of water.*"

As the LRVs derived based on the ADWG (Table 4-3) are slightly more conservative for protozoa and bacteria than current AGWR [3], and slightly more conservative on bacteria than WHO [5], these values are the minimum LRV requirements proposed for this investigation.

The industry's knowledge of raw wastewater pathogen loads is evolving. For example, Gerrity et.al. [14] indicates a 95th percentile adenovirus (culture) concentration in raw wastewater of 2.5 x 10^4 per L. This is similar to the value listed in WHO guidance [5] of 2.0 x 10^4 per L. Using the slightly more conservative Gerrity et. al. value, and an assumed exposure of 2 L per person per day, the minimum virus LRV increases to 9.7 (which would result in a rounded value of 10). Potential increases in the minimum pathogen LRVs based on changes to the reference pathogen default values will be considered as part of a discussion of risks.[6]

4.2 Other Pathogen Removal Considerations

Given that there is not a prescribed pathway for DPR schemes in the current AGWR [3] (see Section 1), RCC has requested consideration of potential requirements for "excess LRVs" based on approaches in other jurisdictions - primarily in order to estimate the cost impacts should the regulator choose to require higher LRVs than those determined based on AGWR [3].

It is important to note that this study will not be able to identify or resolve all issues that may arise during the implementation of the risk-based framework as:

1. As noted in the NSW Office of Water Recycled Water Guidance Document (Recycled Water Management Systems, 2015), *Commercial and other considerations should be made ahead of the risk-based recycled water management system (RWMS) process and in the context of an Integrated Water Cycle Management (IWCM) Strategy and best practice.*" [7];
2. The RWMS is essentially the application of the AGWR, and,
3. The information required for application of the full AGWR methodology is not available for the current stage of scheme investigation.

IMPORTANT: It is important to note that it is not viable for the minimum LRVs required for DPR schemes in the Australian context to be derived or specified as a part of this investigation – the prevailing guidelines and lack of precedent within Australian (or NSW) regulations makes this impractical. To this end, the proposed considerations of minimum LRVs for DPR in this document are not intended to provide direction or guidance on what minimum LRV requirement may ultimately be required. Rather, the intent of this section is to develop reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes (and consider the sensitivity to higher, but still realistic in the Australian context, LRVs).

4.2.1 Indirect Potable Reuse via Surface Water Augmentation

The short-listed option utilising IPR via SWA assumes an engineered storage will be constructed to provide an environmental buffer between the AWTP discharge and the supply to the Nightcap WTP. For this scheme, PRW produced from the effluent of the South Lismore and East Lismore WWTPs would be discharged to an open surface water storage of at least 600-1,200 ML volume. The storage may also receive flow from the Wilsons River Source to improve the effective yield of this source, and the combined PRW / Wilsons River water transferred from the storage to the inlet of Nightcap WTP via the existing Wilsons River Source High Lift Pump Station.

As IPR schemes are covered by the AGWR, the minimum LRV requirements detailed in Table 4-3 are proposed to be adopted for the conceptual design of the AWTP for the surface water augmentation scheme option. On this basis, no sensitivity to higher LRVs is proposed for this option.

[6] QMRA conducted by RCC using the DPRisk tool and point estimates for influent pathogen concentration derived from probability distribution functions (which differ from the point estimates for pathogen load as used in AGWR/ADWG) suggest virus LRV would increase to 9.7 (rounded to 10) (matching the result by Gerrity et.al. [14], *Cryptosporidium* LRV would increase to 8.7 (rounded to 9.0) and *Campylobacter* LRV would increase to 10.3 (rounded to 10.5).

4.2.2 Direct Potable Reuse via Raw Water Augmentation

The three DPR options short-listed for assessment under the investigation comprise:

- Raw water augmentation – PRW produced from Lismore source waters transferred to inlet of Nightcap WTP (without an environmental buffer);
- Treated water augmentation:
    - PRW produced from Byron source waters delivered to St Helena Reservoir and blended with potable water from the distribution network; and,
    - PRW produced from Lismore sources delivered to the main Lismore reservoirs and blended with potable water from the distribution network.

For reference, three examples of regulatory approaches to DPR in the US are outlined in Section 4.2.2.1 through 4.2.2.3. Note that these examples are provided for information only. The approach to derivation of LRV requirements is vastly different between the approaches taken in these examples and the approach used in Australian and as endorsed by WHO [5] (i.e. used on DALYd taking into account dose response, ratios of infection to illness and severity weighting of the illness) and **therefore it is not reasonable to directly compare these examples to the Australian approach**.

4.2.2.1 Colorado

Colorado's approved *Direct Potable Reuse Policy* [15] sets the following default minimum LRV requirements for system lacking data on pathogen concentration in the treated wastewater effluent source water:

- Virus (Adenovirus) - 12
- *Cryptosporidium* – 10

The Colorado policy [15] provides flexibility for a DPR proponent to demonstrate alternative minimum LRV targets based a "dedicated sampling program", with the alternative minimum LRV targets not allowed to be lower than 8 LRV for virus and 5.5 log for *Cryptosporidium*.

Colorado's policy [15] states the definition of DPR as:

"using a series of processes that produce finished drinking water utilizing a source containing treated wastewater that has not passed through an environmental buffer."

Additionally, Colorado's approach would consider the unit processes in the drinking water treatment plant as part of the treatment system to achieve these minimum LRV requirements (for raw water augmentation).

4.2.2.2 Texas

The Texas Commission on Environmental Quality's approach to DPR [16] sets a minimum LRV of 8 for virus and 5.5 for *Cryptosporidium*. These minima are then potentially subject to increase based on:

1. Site-specific pathogen measurements, with the LRVs required for each pathogen calculated as the difference between the incoming WWTP effluent and the maximum permissible EPA finished water pathogen concentrations of 2.2×10^{-7} MPN/L for virus and 3.0×10^{-5} oocysts/L for *Cryptosporidium*, and,
2. A quantitative microbial risk assessment (QMRA).

While the Texas approach is efficient (in that each project need only provide pathogen reduction as required based on site specific conditions), it does not readily provide confirmation of the LRV requirements during the early investigation/planning stages due to the lack of site-specific information. The Texas approach is not considered further here.

4.2.2.3 California Indirect Potable Reuse

California has regulations for IPR by direct groundwater recharge[7] and by surface water augmentation[8]. Gerrity et. al. [14] describes the derivation of the California LRV requirements for IPR by direct groundwater recharge. This information is summarised in Table 4-5.

Table 4-5: California IPR LRV Requirements

Parameter	Units	Virus	Protozoa
Reference pathogen		Norovirus	*Cryptosporidium*
Pathogen concentration in source water	number per L	100,000	10,000
Exposure	L/d	2	2
Acceptable pathogen concentration in drinking water	number per L	2.5×10^{-7}	1.6×10^{-6}
Minimum Pathogen Removal	LRV	11.6	9.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**12**	**10**

California's regulations for IPR by surface water augmentation have lower LRV targets than the targets for direct groundwater discharge, due to the ability to utilize LRV credits from the surface water treatment plant[9]. Specifically[10]:

- 8 LRV are required for both virus and *Cryptosporidium* if the volume of water withdrawn from the augmented reservoir to be ultimately supplied for human consumption contains no more than one percent, by volume, of recycled municipal wastewater that was delivered to the surface water reservoir during any 24-hour period; or,
- 9 LRV are required for both virus and *Cryptosporidium* if the volume of water withdrawn from the augmented reservoir to be ultimately supplied for human consumption contains no more than ten percent, by volume, of recycled municipal wastewater that was delivered to the surface water reservoir during any 24-hour period.

For the purposes of this investigation, only the more conservative IPR by direct groundwater discharge LRV requirements are considered further (see Section 4.2.2.3).

The approach used in the California IPR regulation for protection of public health differs from that applied within the AGWR [3], ADWG [4] and WHO guidelines [5]. The California IPR approach is based on limiting infections to 1 in 10,000 per person per year [14], whereas AGWR/ADWG/WHO is based on achieving a disease burden of 10^{-6} DALYs per person per year.

The California IPR criteria lower the tolerable drinking water pathogen concentrations by 1 to 2 orders of magnitude compared to the AGWR/ADWG/WHO approach. The California IPR regulation also uses significantly higher source water pathogen concentrations than either AGWR [3] or WHO [5] (1 to 2 orders of magnitude difference for virus and 1 order of magnitude difference for *Cryptosporidium*). These differences have a direct impact on the significant differences in the LRV requirement.

[7] California Title 22, Division 4, Chapter 3, Article 5.2 (https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I735469B05B6111EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default))
[8] California Title 22, Division 4, Chapter 3, Article 5.3 (https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I73ECB2105B6111EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default))
[9] California's Surface Water Treatment Rule requires the surface water treatment plant to achieve a minimum LRV for virus of 4 and for Cryptosporidium of [20]
[10] https://www.law.cornell.edu/regulations/california/22-CCR-64668.30

4.2.2.3 California Direct Potable Reuse

Prior to enacting DPR regulations in November 2023[11], California published a *Proposed Framework for Regulating Direct Potable Reuse* [17].

The draft DPR criteria [17] modified the assumptions applied in the development of California's IPR criteria. These changes result in the following baseline LRV requirements:

- Virus (Norovirus) – 16 (increase from 12 for IPR)
- *Cryptosporidium* – 11 (increase from 10 for IPR)

In addition to the baseline LRV requirement, the draft California DPR criteria [17] include additional LRV requirements to account for failure of a unit process (6-log reduction in system LRV) once per year for 15 minutes. This provision further increases the LRV requirements to:

- Virus (Norovirus) – 20 (increase from 12 for IPR)
- *Cryptosporidium* – 15 (increase from 10 for IPR)

California has recently made available the *Notice of Public Availability of Changes to Proposed Direct Potable Reuse Regulations and Addition of Material to the Rulemaking Record* (SBDDW-23-001) [18]. This document does not change the pathogen LRV requirements from the previous values.

One of the changes California made in their assessment of baseline LRV requirements was shifting from an annual infection risk benchmark of 10^{-4} to a daily infection risk benchmark of 2.7×10^{-7}, related to decreased response time relative to IPR applications [14]. Gerrity et. al. analysed excess LRV requirement on the basis of a 10^{-4} to a daily infection risk [14] and determined that this change would result in the following LRV targets for a 6 LRV failure scenario:

- Virus (Norovirus) – 17
- *Cryptosporidium* – 12

An NWRI expert panel[12] review of California's draft DPR criteria [19] found that the "*draft pathogen control criteria are based on numerous conservative assumptions that result in an over-engineered treatment facility. Thus, the draft pathogen control criteria require additional treatment that does not contribute additional public health protection.*"

More specifically, with respect to the baseline LRV conditions, the NWRI expert panel indicated [19]:

[11] The draft LRV targets in the proposed criteria have been adopted in the enacted regulation.
[12] The NWRI expert panel consisted of:

- James Crook, PhD, PE, Panel Co-Chair • Environmental Engineering Consultant
- Adam Olivieri, DrPH, PE, Panel Co-Chair • EOA, Inc.
- Richard Bull, PhD • Washington State University (Emeritus)
- Jörg E. Drewes, PhD • Technical Univ of Munich
- Charles Gerba, PhD • University of Arizona
- Charles Haas, PhD • Drexel University
- Amy Pruden, PhD • Virginia Polytechnic Institute
- Joan B. Rose, PhD • Michigan State University
- Shane Snyder, PhD • Nanyang Technological University
- Jacqueline E. Taylor, REHS, MPA • Los Angeles County Department of Public Health (Retired)
- George Tchobanoglous, PhD, PE • University of California, Davis (Emeritus)
- Michael P. Wehner, MPA • Orange County Water District (Retired)

"*When the Panel reviewed the variables above, it appeared that DDW*[13] *chose the most conservative assumptions to protect public health. However, layering the most conservative assumptions upon each other results in unrealistic and impracticable processes that offer no additional significant positive effects on public health.*"

The NWRI expert panel note that two assumptions made (dose response and influent virus load), where the most conservative assumption was chosen by California, result in 7 orders of magnitude (i.e. 7 log) of uncertainty in LRV requirements (for virus) [19][11].

Based on their own analysis, the expert panel suggested minimum treatment for public health protection (without consideration of failure scenarios) of[14]:

- Norovirus – 13
- *Cryptosporidium* – 10

The expert panel analysis [19] indicated that a 5 LRV increase (i.e. virus – 18 LRV, *Cryptosporidium* – 15 LRV) would adequately protect public health in the event of an undetected 6 LRV failure 1% of the time and recommended California evaluate other alternatives.

4.2.2.4 Comparison of LRV Target Derivation

The purpose of this section is to highlight differences in the derivation of LRV targets for direct potable reuse as a caution against direct adoption of targets from other jurisdictions that have been derived by different methods. There are a number of different LRV targets specified for direct potable reuse. The targets from California, Colorado and the WHO are summarized in Table 4-6.

Table 4-6: Comparison of LRV Targets from Different Jurisdictions

Jurisdiction	Virus	Bacteria	Protozoa	
			Cryptosporidium	*Giardia*
California	20	-(1)	15	14
Colorado	12(3)	-(1)	10(3)	10(3)
WHO	9.5	8.5	8.5	-(2)

1. Bacteria LRV targets are not typically set for potable reuse in the US, as it is assumed that bacterial hazards are adequately controlled provided that protozoa and virus targets are met.
2. The WHO uses Cryptosporidium as a reference pathogen for protozoa and does not stipulate a target for Giardia.
3. Utilities may elect to perform a sanitary survey of the proposed source water for a potable reuse scheme. Upon completion of the sanitary survey, a revised log reduction target may be calculated using the 95th percentile concentration of reference pathogens and lower LRV targets can be proposed based on this provided that the revised targets exceed a minimum LRV target of 8.0, 5.5 and 6.0 for viruses, *Cryptosporidium* and *Giardia*, respectively.

The targets listed in Table 4-6 are notably different. However, each has been proposed within the jurisdiction as a suitable target to produce safe drinking water. There are important differences between each of the examples above, including:

- The WHO values utilize an acceptable risk metric of 1 x 10^{-6} DALY per person per year. A DALY dosage for a pathogen takes into account the risk of infection as well as the weighted severity of an infection. This is particularly important for Norovirus, which has a high infectivity, but will only in rare cases cause severe health impacts upon infection.
- The California and Colorado LRV targets use a risk level of 1 in 10,000 infections per person per year ([14], [15]). This does not consider the severity of infection (which can moderate the LRV requirements for particular pathogens).

[13] California State Water Resources Control Board, Division of Drinking Water
[14] Values taken from Appendix 6 of reference 11.

- The LRV targets for Colorado also differ from California as:
  - California elected to use Norovirus as the reference virus while Colorado elected to use adenovirus. The differences in dose response models and also typical wastewater abundance between these pathogens partially explain the different targets.
  - California DDW used the maximum point estimate for Norovirus that exceeded the wastewater occurrence data previously used and also exceeded the Norovirus concentrations reported in a study of California wastewaters. That is, an unrealistically conservative virus loading was assumed for wastewater.
  - California DDW included an arbitrary additional 4 log to the calculated treatment targets in an effort to increase pathogen control redundancy. The addition of 4 log was not related to pathogen infectivity or justified based on documented failure scenarios.

While the California DPR LRVs appear to be high compared to those based on WHO (and the AGWR and ADWG which use the same approach as WHO), there are differences in crediting approaches for treatment processes, including:

- In California, it is acceptable to claim a LRV up to a maximum of 6-log for a treatment process. For example, chlorine contact tables may be extrapolated and UV dose exceeding 6-log of a validated pathogen may be used to claim up to 6 log for UV.
- In California, multiple treatment processes in series using the same disinfection mechanism may be used to claim LRVs. For example, in recent California DPR planning efforts, it has been acceptable to propose UV disinfection by UV/AOP meeting 6 log reduction of all pathogen groups and then to claim further pathogen reduction, based on installation of a secondary UV system installed in the same treatment train. This would be achieved by installation of a UV reactor with a validated dose delivery exceeding 186 mJ/cm^2 downstream of the UV/AOP, which would be credited with 4 log additional adenovirus reduction and 6 log reduction of protozoa (i.e. in addition to any LRV claimed for the UV/AOP).

When compared to the Californian approach, current practices in Australia rely on substantially different methodologies to achieve treatment resilience, including:

1. Capping maximum LRVs at 4 log (as opposed to 6 log) per process, and,
2. Not allowing crediting of the same removal mechanism in the same treatment train (e.g. an additional UF membrane not receiving credit downstream of a membrane bioreactor).

In this way, the Australian approach encourages resilience by 1) diversifying mechanisms and 2) putting a maximum cap of 4 LRV on possible failures. However, this methodology makes it effectively impossible to meet excessive LRV targets (such as 20/14/15) with established AWTP process units – largely as there are simply not enough unit operations with different fundamental mechanisms.

To highlight these key differences, Table 4-7 summarises indicative LRVs for virus/*Giardia* and *Cryptosporidium* (v/g/c) for a hypothetical treatment train credited in California and Australia.

Table 4-7: Comparison of the total LRV for the same treatment train credited in California and Australia for Virus LRV/Giardia LRV and Cryptosporidium LRV (V/G/C)

Jurisdiction\Process (validation approach)	UF (pressure decay test)	RO (conductivity reduction)	UVAOP (1,000 mJ/cm^2)	UV (186 mJ/cm^2)	Free Chlorination (WaterVal CT equivalent to 6 log virus)	Total Scheme LRVs
California LRVs	0/4/4	1.5/1.5/1.5	6/6/6	4/6/6	6/0/0	18.5/17.5/17.5
Australia LRVs	0/4/4	1.5/1.5/1.5	4/4/4	0/0/0	4/0/0	9.5/9.5/9.5

Clearly, the same treatment train, operated the same way on the same wastewater will achieve the same pathogen reduction. However, the pathogen reduction accepted under the regulations is completely different in different jurisdictions such that the status quo in Australia would result in a credited LRV around half that credited in California (9.5 Australia vs 17.5 – 18.5 in California).

Based on the considerations above, LRV targets from other jurisdictions should not be directly applied unless the process crediting framework is also reconsidered. In addition, LRV targets from the US pertain to a substantially different metric for acceptable risk.

4.2.2.5 Excess LRV Analysis

Based on the information presented in Section 4.2.2.4, the project team believe the California DPR minimum LRV targets are excessively conservative for use as a basis for the purposes of this investigation, based on:

- The different raw wastewater pathogen loads (as compared to AGWR/WHO);
- Different tolerable drinking water pathogen concentration as compared to AGWR/ADWG/WHO (based on the difference between achieving 10^{-6} DALYs per person per year and limiting infections to 1 in 10,000 per person per year), and,
- Different assumptions for maximum claimable LRV per process unit (6 for California versus 4 assumed for the purposes of this investigation).

As a result, it is contended that application of the proposed California DPR regulations would result in excessive treatment requirements that increase costs and complexity without providing meaningful improvements to public health protection.

To better understand the potential impact of AWTP process unit failures on LRV requirements, RCC undertook preliminary analysis of possible failure scenarios using DPRisk - a calculation tool developed by Water Research Foundation for DPR systems[15]. Table 4-8 summarises the output of the preliminary QMRA investigations undertaken by RCC using DPRisk.

Table 4-8: Preliminary Assessment of Undetected Failure Scenarios

Scenario	Additional LRV Required			Conclusion
	Virus (Adenovirus)	Protozoa (*Cryptosporidium*)	Bacteria (Campylobacter)	
4 LRV undetected failure for four hours four times per year	2	2	2	A process train assumed to provide a total of 12 LRV for virus, 11.0 for *Cryptosporidium* and 12.5 for *Campylobacter* with no failure results in a 99th percentile annual risk with this failure scenario of less than 10^{-6} DALYs per person per year for each pathogen type.

In an effort to understand the absolute worst-case scenario for AWTP costs and complexity, a failure scenario of 4 LRV 100% of the time has been considered (correlating to an excess LRV of 4). This assumes that the AWTP is claiming a maximum of 4 LRV per unit process, and that treatment barrier is providing no pathogen removal. **Critically, it is not the opinion of the project team that this is necessary or suitable from a pathogen risk perspective. Rather, an excess**

[15] From the DPRisk web page (https://cawaterdatadive.shinyapps.io/DPRisk/): This tool is intended to facilitate quantitative microbial risk assessment (QMRA) and probabilistic assessment of treatment train performance (PATTP) for various direct potable reuse (DPR) scenarios. There are many possible analyses that you can conduct with this tool, including:

There are many possible analyses that you can conduct with this tool, including:
- Developing a distribution of treatment train performance for different potential DPR treatment trains.
- Evaluating daily and annual risks of infection for multiple microbial pathogens for different potential DPR treatment trains.
- Comparing different DPR treatment trains in terms of treatment performance and risk.
- Evaluating the impact of failures on treatment performance and risk.

LRV of 4 has been considered only to elucidate an extreme worst-case in terms of AWTP costing with respect to pathogen removal.

The final minimum pathogen LRV requirement applied to design of the AWTP (as ultimately agreed with the regulators) should be based on pathogen barrier failure modelling with consideration of:

- the LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere[16]);
- the failure mode of each unit process (i.e. instantaneous (e.g. disinfectant dosing system failure) or gradual (e.g. loss of UF membrane integrity which normally occurs slowly and can be seen by monitoring PDT trends);
- the response time of online analysers used for CCPs;
- the reliability of these analysers and any redundancy provided for these analysers;
- the use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk; and,
- other design features used to mitigate risk (e.g. use of "off spec" diversions at CCP alert levels, use of engineered storage buffer tank to allow for capture and diversion of water produced between analyser readings, etc.).

[16] Sylvestre et.al. [21] indicates that for a barrier with rapid loss in LRV performance credited with 6.0 LRV failure durations of 10 seconds per year need to be controlled, whereas for the same process claiming 4 LRV performance can be verified by controlling a failure of 15 minutes per year.

5 PROPOSED LOG REMOVAL VALUES FOR AWTP CONCEPTUAL DESIGNS

Based on the information presented in Section 4, uncertainties in regard to future regulatory requirements, and that this project represents an early investigation stage, the baseline and sensitivity analysis scenarios summarised in Table 5-1 are proposed to be applied to the conceptual AWTP designs for the short-listed scheme options.

Table 5-1: Proposed Approach for Conceptual AWTP Designs and Sensitivity Analyses

Scheme	Baseline AWTP LRV Basis	Sensitivity Analyses
IPR via Surface Water Augmentation	Apply values from Table 4-3: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0	None
DPR via Raw Water Augmentation	Apply values from Table 4-3: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0 Assume blending of source water to and treatment in the downstream WTP is sufficient to manage the risk of barrier failure	Consider a worst case as aligning with an excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0
DPR via Treated Water Augmentation	Consider a case of excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0	Consider ***an absolute worst case*** as aligning with an excess LRV of 4 for all pathogen types (i.e. 100% redundancy) – i.e. the process would provide: Virus LRV – 14.0 Protozoa LRV – 13.0 Bacteria LRV – 13.0 **It is not the opinion of the project team that this is suitable from a public health risk perspective, and is only presented to represent an extreme worst-case scenario for AWTP costing (with respect to pathogen removal).**

The conceptual AWTP process trains will be developed based on process technologies that have been proven for potable reuse applications elsewhere. The assumptions for Claimed LRV used in the design of the process trains would be subject to significant additional work, including, but not limited to:

- Site specific bench scale testing of source water (e.g. ozone decay);
- On site demonstration of treatment processes using intended source water;
- Review of performance of operating full scale system;
- Review of advancements in technology over time (e.g. ability for real time monitoring of virus for UF LRV verification);
- Engagement with regulators; and,
- Potentially, expert panel review.

This additional work would address the concerns raised in the AGWR with respect to DPR, as described in Section 1.

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APPENDIX D: CHEMICAL RISK ASSESSMENT MEMORANDUM

Rous County Council
Purified Recycled Water Investigations
Memorandum – Chemical Risk Assessment

This report has been prepared solely for the benefit of Rous County Council for the Purified Recycled Water Investigations. No liability is accepted by Tyr Group or any employee or sub-consultant of Tyr Group with respect to its use by any other person or in relation to any other project.

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ABBREVIATIONS

ADWF	Average Dry Weather Flow
ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AOP	Advanced Oxidation Process
AWTP	Advanced Water Treatment Plant
BAC	Biological Activated Carbon
BOM	Bureau of Meteorology
CBAT	Carbon-Based Advanced Treatment
CEC	Constituents of Emerging Concern
DBP	Disinfection Byproduct
DPR	Direct Potable Reuse
GAC	Granular Activated Carbon
HAA	Halo Acetic Acid
ICCS	Industrial Contaminant Screening Score
ICRQ	Industrial Contaminant Risk Quotient
IPR	Indirect Potable Reuse
LRV	Log Reduction Value
MCL	Maximum Contaminant Level
NHMRC	National Health and Medical Research Council
PFAS	Per- and Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic Acid
PRW	Purified Recycled Water
RBAT	Reverse Osmosis Based Treatment
RCC	Rous County Council
RfD	Oral Reference Dose
RO	Reverse Osmosis
RSD	Risk Specific Dose
STP	Sewage Treatment Plant
THM	Trihalomethane
TOC	Total Organic Carbon
UF	Ultrafiltration
US EPA	United States Environmental Protection Agency
UV	Ultraviolet Light Disinfection
WRF	Water Research Foundation
WTP	Water Treatment Plant

1 INTRODUCTION

1.1 BACKGROUND

Rous County Council (RCC) is investigating the potential to utilise purified recycled water (PRW) as a climate resilient source of potable water. This study, *Purified Recycled Water for Drinking Investigations* (PRW Investigations), has short-listed various scheme options for use of PRW, including configurations based on:

- Indirect potable reuse (IPR) via surface water augmentation – PRW is discharged to an environmental buffer (e.g. dam or other large surface water storage) where it is blended with other water sources. The environmental buffer provides a minimum detention time for the water prior it being fed to a drinking water treatment plant (WTP);
- Direct potable reuse (DPR) via raw water augmentation – PRW is blended with other water sources and fed directly to the start of the WTP process without an environmental buffer; and,
- DPR via treated water augmentation – PRW is blended with treated water from the WTP in the drinking water distribution system.

The Australian Guidelines for Water Recycling (AGWR) highlight the need for chemical risk assessment and source control to ensure production of water that is safe for use in drinking water augmentation [1]. Correspondingly, the *Purified Recycled Water for Drinking Investigations* includes a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW - a first step in understanding potential chemical risks in the absence of detailed scheme-specific source water information. Should one or more scheme be carried forward for development, these risks, and the methods by which they will be controlled, will need to be further defined through future investigations including:

- Source characterisation;
- Development of an enhanced source control program (including detailed study of all dischargers and the chemicals they use that could potentially emerge in the sewage stream);
- Pilot/demonstration advanced water treatment plant (AWTP) testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water, and their removal through the various unit processes required for the production of the PRW;
- Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available; and,
- Detailed quantitative chemical risk assessment based on the information gathered as described above.

Any future detailed chemical risk assessment should incorporate consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1]. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, such as the Australian Drinking Water Guidelines, World Health Organization guidelines, etc. should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP. The detailed risk assessment would be a "live" document and updated over the operational life of the AWTP based on changes in the source water characteristics and/or changes or additions to the guideline values.

1.2 SCOPE

Due to the very early phase of the project and corresponding lack of project specific data, the chemical risk assessment described herein is very high level in nature. As such, this chemical risk assessment is presented to provide a general understanding of the chemical risk assessment process and provide an example, as a starting point for RCC, should any of the short-listed PRW schemes be carried forward.

As defined in the *AWTP Process Trains Memorandum* produced for the PRW Investigations, conceptual AWTP process trains have been developed based on achieving the minimum pathogen log reduction value (LRV) targets set in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development*. The chemical risk assessment documented in this memorandum is based on these conceptual process trains (refer to Section 3 for descriptions of the process trains).

As there is currently no catchment specific data available defining chemicals of concern in the source water and their concentration, this memorandum presents a high-level assessment of chemical risks based on:

- The 262 chemicals examined in the Water Research Foundation (WRF) Project No. 4960 (*An Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse*) for which there were available health risk metrics and/or removal data [2]; and,
- Publicly available occurrence data for chemicals in the feed to the Luggage Point AWTP (owned by Seqwater) [3], where compounds found in this source water overlap with the chemicals examined within WRF Project No. 4960.

Should one or more PRW schemes be carried forward for development, catchment specific data will need to be collected and analysed to support further assessment of chemical risk, and supported with appropriate removal performance data. The approach described in this memorandum can be used to guide this programme of monitoring and investigation, and the subsequent future detailed chemical risk assessment.

More specifically, the chemicals included in this risk assessment may or may not be relevant to any RCC potable reuse scheme, based on occurrence, or the risk of occurrence, of specific chemicals in the catchments providing source water for a given scheme. Further investigation would be a key first step to defining the occurrence (or risk of occurrence) of chemicals within the relevant catchment(s).

It should also be noted that Table 4.4 of the AGWR [1] also includes a list of 221 chemicals detected in secondary treated sewage, and health based guideline values for those chemicals in PRW. Any future source characterisation and/or chemical risk assessment should incorporate consideration of those specific chemicals. While the example application of the WRF Project No. 4960 methodology applied in this investigation could have included the chemicals listed in the AGWR, this has not been undertaken as:

1. Health guideline values derived in the AGWR using a one-in-one-million risk target "is taken to mean that, if a population of one million people were to consume water at the guideline concentration for a lifetime, then one additional cancer might plausibly be expected to occur" [1]. By contrast, the risk specific dose used in WRF Project 4960 refers to one-in-ten thousand excess lifetime cancer risk. Application of the methodology to chemicals derived using different acceptable risk criteria would compromise the risk ranking and prioritisation.
2. 85 of the chemicals listed in the AGWR list are within the 262 chemicals examined in the WRF Project No. 4960. Hence, there is some cross-over. Further, given the AGWR was published around 16 years ago, the list of chemicals in WRF Project No. 4960 may be more contemporary (even in the Australian context).
3. Of the remaining 136 chemicals on the AGWR list which are not included in WRF project No. 4960, there is no removal data listed for the AWTP processes. On this basis, the screening level assessment conducted

herein would apply a zero removal (see next section), limiting its value in terms of identification of specific chemicals of concern.

4. As noted above, given the absence of source-specific chemical occurrence data, this investigation presents an example screening approach for chemical species. The specific chemicals analysed are used to illustrate the methodology. Until specific occurrence data is obtained for the source water for any schemes to be developed, the specific chemical species considered in the methodology applied to this study are not critical.

For this study, preliminary identification, screening and prioritisation of the high-level chemical risks was undertaken through:

- Project Definition:
  - High-level definition of the proposed potable reuse schemes in terms of treatment barriers that influence chemical risk.
- Source Water Assessment
  - Collation and summary of the available information on Trade Waste volumes received by the sewage treatment plants (STPs) which would provide source water to the AWTPs.
  - Benchmarking of the proportion and nature of the industrial (i.e. Trade Waste) loads against an existing potable reuse scheme in Australia (Luggage Point, for which a significant amount of chemical analysis had been reported for the secondary effluent).
- Industrial Chemical Risk Assessment:
  - Prioritisation of the chemical risks associated with Trade Waste discharges using the WRF Project No. 4960 framework [2], with reference to anticipated chemical removal performance for each proposed treatment train (as described within WRF Project No. 4960).
  - Where complementary data was available (approximately 26%, 68 chemicals of the 262 included for consideration in WRF Project No. 4960), a risk quotient was developed to provide an example of how to better understand and prioritize chemicals of concern (noting that site specific risk quotients can only be developed when catchment specific data is available).
- Process Related Chemical Risks:
  - Process related chemicals risks, i.e. risks that can be caused by, as well as controlled due to operation and design changes (such as disinfection by-products), were identified through review of recent literature on potable reuse treatment trains.
  - Absolute chemical risk assessment of these chemicals is site specific in nature and was therefore not quantitatively assessed.

Due to a number of conservative assumptions required in processing the data, the risk characterisation figures presented within do not represent an absolute risk. In the absence of occurrence data for chemicals of concern for the project area, risk quotients were developed based on Luggage Point data (a much larger and more urbanised catchment) to provide an indication of possible chemical risk. Consequently, the assessment outputs should be considered as:

1. Broadly indicative of the relative chemical risk control that is likely to be achieved with the shortlisted schemes, and,
2. Of value in targeting and developing the further investigations required to appropriately characterise the absolute, scheme-specific risk.

2 INDUSTRIAL CONTAMINANT SCREENING METHODOLOGY

WRF Project No. 4960 [4] compiled a list of representative removals of industrial chemicals and paired these with health risk factors. While the tool is not exhaustive, it allows for a rapid assessment and prioritisation based on a list of 262 chemicals that have either health risk metrics and/or removal data. In the development of the list of chemicals within WRF Project No. 4960, a further 228 chemicals were considered, but were omitted from detailed assessment – typically due to a contaminant being phased out of use and/or banned. Appendix A lists the omitted chemicals.

The WRF tool prioritises the chemicals based on an Industrial Contaminant Screening Score (ICSS). A high ICSS results from either a perceived high pass-through risk and/or high potential to impact human health, and is calculated as the normalised cumulative pass-through risk (1 – the rejection across cumulative processes) multiplied by a health risk factor (the inverse of the lower of the reference dose or risk specific dose) as shown in Equation 1.

$$\boldsymbol{ICSS = (1 - R_{overall})/\min(RfD, RSD)} \qquad \textbf{Equation 1}$$

Where:

- ICSS = Industrial Contaminant Screening Score (kg-d/mg)
- $R_{overall}$ = the rejection (as a decimal) of a compound through all chemical barriers in series that is being assessed (i.e. the product of rejection through each chemical barrier in the treatment process). Where known, WRF Project No. 4960 provides both average and conservative removals. For the purposes of this work, conservative removals of chemicals have been applied.
- Min (RfD, RSD) = the minimum of either:
  - The oral reference dose (RfD) – refers to non-cancer endpoints (mg/kg/d); or,
  - Risk specific dose (RSD) – refers to the 1 in 10,000 excess lifetime cancer risk[1], calculated by dividing 10^{-4} by the cancer slope factor (mg/kg-d).

Note that ICSS is not a metric of risk because it does not incorporate compound concentration or exposure. Rather, ICSS is a tool to prioritize contaminants for collecting occurrence data. [2]

[1] A cancer risk level of one-in-ten-thousand is applied by the US EPA when deciding whether cancer or non-cancer risk levels provide more meaningful scenario-specific risk reduction [4]. The AGWR uses a risk target on one-in-one-million for non-threshold chemicals whose carcinogenicity has been characterised by experimental determination of potency (i.e. by derivation of a ‘slope factor’) [1]. Health guideline values derived in the AGWR using the one-in-one-million risk target “is taken to mean that, if a population of one million people were to consume water at the guideline concentration for a lifetime, then one additional cancer might plausibly be expected to occur” [1]. Hence, the RSD used for this assessment is less conservative than if the RSD were developed based on the AGWR risk target. However, this is not important for this assessment as this screening process is used to demonstrate a methodology as to how chemicals could be prioritised for further investigation. Future detailed chemical risk assessment will need to include consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1] and ensure that the RSD used aligns with the one-in-one million AGWR risk target. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, including the Australian Drinking Water Guidelines, World Health Organization guidelines, etc should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP.

If concentration of a compound in the source water is known, the ICSS can be converted into an Industrial Contaminant Risk Quotient (ICRQ) by multiplying by typical conservative risk assessment assumptions of:

- Body weight: 70 kg;
- $Exposure_1$: 2 L per person per day; and,
- $Exposure_2$: 20% (i.e. water ingestion accounts for only 20% of broader exposure (e.g. inhalation or food ingestion)).

ICRQ calculation is defined as:

$$\boldsymbol{ICRQ = C \times Exposure_1 \times ICSS/(Exposure_2 \times Body\,Weight)} \qquad \textbf{Equation 2}$$

Where C = the concentration in the source water for which the ICSS was calculated (mg/L).

In WRF Project No. 4960, ICRQs of greater than 0.2 were elected as the cutoff to trigger concern and necessitate additional sampling and investigation, and values above 1.0 indicate compounds which "merit focused attention to identify potential sources and consider ways to eliminate the source or improve treatment"[2].

For this exercise, two ICSSs were calculated – one including and one excluding the contaminant removal achieved in the STP. The overall ICSS (i.e. including removal by the STP) was used to prioritise contaminants.

The WRF Project No. 4960 database includes an RfD or RSD for 65% of the listed chemicals. With the available RfDs or RSDs it is possible to calculate an ICSS, assuming a worst-case removal of zero through all treatment processes, to perform a risk rating for 171 chemicals in this database.

The ICSS excluding the STP removal was translated into an ICRQ using occurrence data for chemicals in secondary effluent, available from the Luggage Point water quality report [3], to provide indication of possible chemical risk and to provide an example of how to better understand and prioritize chemicals of concern. Of the 262 chemicals included in WRF Project No. 4960, the available Luggage Point secondary effluent concentration data included occurrence data for 121 of these chemicals.

Of the 121 chemicals with Luggage Point occurrence data, only 68 had human health impact data. This enabled ICRQs to be developed for 26% of the chemicals identified in WRF Project No. 4960 (i.e. 68 of 262), and 55% of chemicals where there was available occurrence data (i.e. 68 of 121).

The primarily focus of WRF Project No. 4960 is industrial chemicals, as these are anticipated to be key contributors to the STP catchment that could be effectively managed via source control practices (through an effective source control program in partnership with Trade Waste customers). Source control is anticipated to be less effective at controlling chemical emissions from municipal/residential customers - public education is a key part of minimising these specific risks.

In addition, with the exception of NDMA (which was shown to originate in a significant extent from industry as well as disinfection practices), most disinfection byproducts (DBP) were excluded from the scope of WRF Project No. 4960 as they are largely produced as a function of treatment practices. To this end, the perceived risks of DBPs relevant to the treatment schemes developed within this project are qualitatively reviewed in Section 5.5.

[2] ICRQ cutoff values would be two orders of magnitude lower (i.e. 0.002 and 0.01) when calculating ICSS and ICRQ based on the AGWR risk target of one-in-one-million. It is imperative that the approach used is consistent (i.e. the acceptable risk target must be consistent across calculations). As noted previously, the risk target selected does not effect the prioritisation of chemicals for further investigation. However, using the correct risk target is critical when establishing the guideline to be used for acceptable concentration of a given chemical in PRW.

3 PROJECT DEFINITION - TREATMENT SCHEMES CONSIDERED

Conceptual reverse osmosis-based advanced treatment (RBAT) and carbon-based advanced treatment (CBAT) trains have been developed, as described in the *AWTP Process Trains Memorandum* produced for the PRW Investigations, to achieve the minimum pathogen LRV targets set in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development*.

The conceptual RBAT train consists of ultrafiltration (UF), reverse osmosis (RO), ultraviolet light (UV) advanced oxidation (AOP), chlorine disinfection and stabilisation. The conceptual CBAT train consists of ozonation, coagulation, flocculation, biological active carbon (BAC), granular activated carbon (GAC), UF, UV disinfection and chlorine disinfection.

RBAT process trains similar to the conceptual RBAT train developed for the PRW Investigation have been used for many years in potable reuse applications due to their ability to effectively remove pathogens and compounds of concern, with examples including:

- Raw Water Production Facility – Big Spring, Texas, USA: a DPR via raw augmentation scheme that has been in operation since 2013, utilizing microfiltration, RO and UV/AOP to produce PRW that is blended with surface water from Moss Creek Lake prior to treatment in conventional drinking water plants. Sampling has shown lower concentrations of concern in the PRW than the concentrations found in the surface water source (Moss Creek Lake) [5];
- Groundwater Replenishment System – Orange County, California, USA: an IPR via groundwater augmentation scheme that has been in operation since 2008, utilizing microfiltration, RO and UV/AOP to produce PRW that is utilized aquifer injection. The plant produces PRW with:
    - "Concentrations of inorganic constituents in the purified recycled water, such as aluminum and chromium, were either non-detectable or if detectable, far below the permit limits. All potentially toxic organics, such as volatile organic compounds, pesticides, and other synthetic organic compounds, were also non-detectable or far below the permit limits. Analyses of purified recycled water for unregulated compounds and chemicals of emerging concern, such as endocrine disrupting chemicals and pharmaceuticals, were either non-detectable or if detectable, not found at levels thought to pose any significant public health risk." [6]

CBAT process trains similar to the conceptual CBAT train developed for the PRW Investigation are also serving as the basis for potable reuse treatment trains based on their ability to provide robust removal of both pathogens and compounds of concern. A notable example of this is the Hampton Roads Sanitation District's SWIFT program, which will be based on an ozone-BAC-GAC treatment train to produce PRW for managed aquifer recharge. Pilot testing has shown that the treatment train can remove the 96 compounds of concern measured in the trial to below the limit of quantification for up to 10,000 bed volumes, and provide 70% removal of these compounds up to 20,000 bed volumes [7].

Results from a study performed by Lau et.al (2022) indicate that PRW treatment trains, whether RBAT or CBAT produce waters of lower cytotoxicity than surface-water-derived conventional drinking waters [8].

California DPR regulations require the inclusion of ozone/BAC in an RBAT process train to provide treatment for compounds of concern. Based on the examples provided above, both the conceptual RBAT and CBAT process trains can reasonably be expected to provide robust treatment for compounds of concern, hence ozone/BAC has not been added to the conceptual RBAT process train. The potential need for further unit processes is considered in the *AWTP Process Trains Memorandum* but is not included in this high-level chemical risk assessment.

Figure 3-1 outlines the conceptual treatment process trains for the AWTPs[3] and highlights the treatment barriers relevant for the control of chemicals in the four advanced treatment schemes shortlisted for progression as part of this project (including the upstream STP and the downstream WTP (for the two scheme options where this is relevant)). The schemes are categorised as:

- CBAT with:
  - Scheme Chemical Risk Type A: Lismore IPR or Lismore DPR - Raw Water Augmentation
  - Scheme Chemical Risk Type B: Lismore DPR - Treated Water Augmentation OR
  - Scheme Chemical Risk Type B: Byron DPR - Treated Water Augmentation (CBAT option) (not listed further as AWTP process train equivalent to Lismore DPR - Treated Water Augmentation option) ; and,
- RBAT with Scheme Chemical Risk Type C: *Byron DPR - Treated Water Augmentation (RBAT option)*.

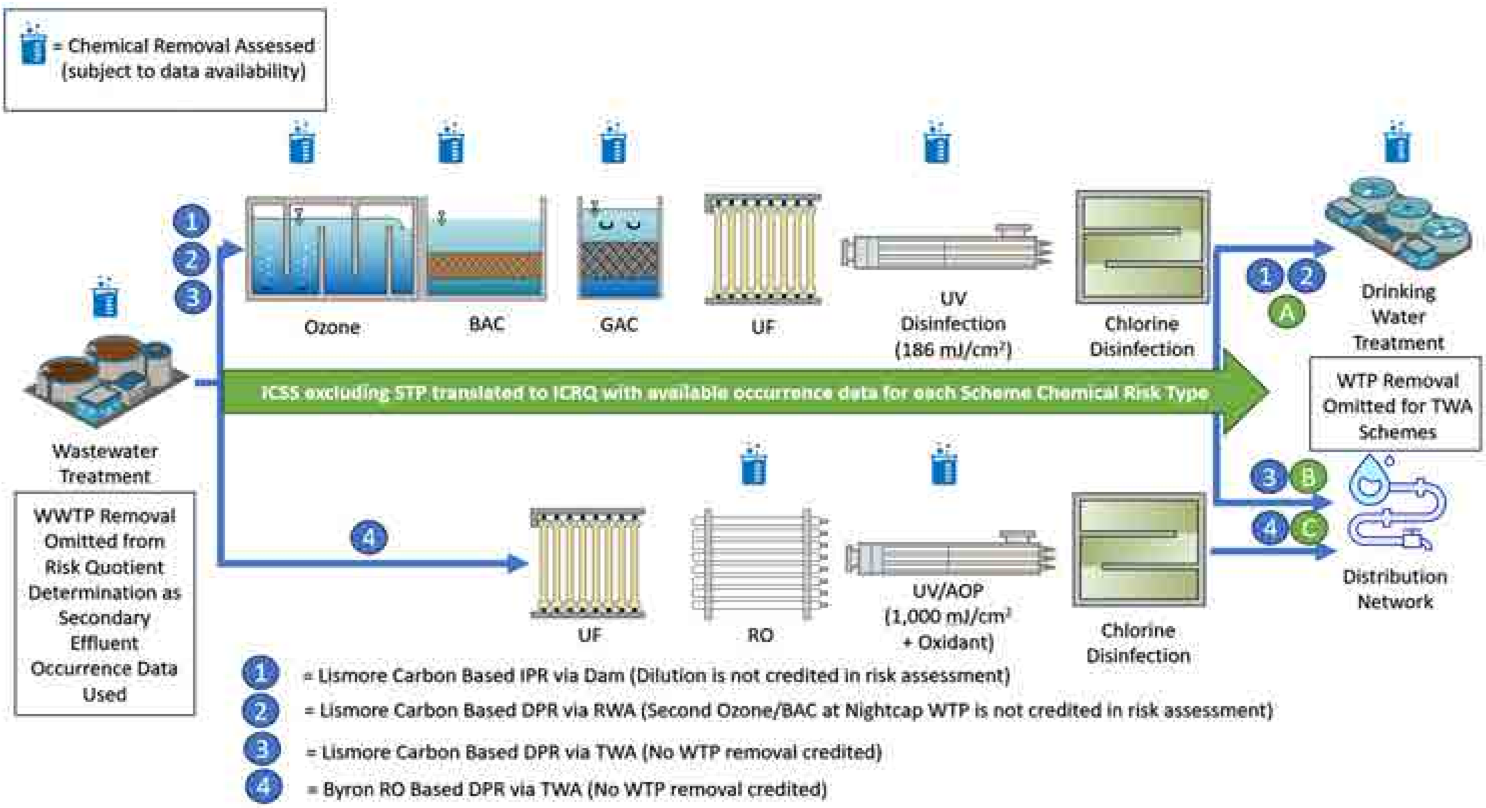

Figure 3-1: Simplified Process Flow Diagram Showing Chemical Barriers and Boundaries of Assessment for Shortlisted Schemes

[3] Scheme 3 and 4 in Figure 3-1 do not show a secondary UV process, that may be included for pathogen risk management, as no chemical removal credit is assumed for this process.

Table 3-1 summarises the scheme descriptions and the chemical risk classification outcomes for the ICSS and ICRQ development. Additionally, the table lists items that were not included in the chemical risk assessment that are likely to reduce risk.

Table 3-1: PRW Schemes and Chemical Barriers Considered for ICSS and ICRQ Development

Scheme ID	Scheme Name	Scheme Description	Scheme Chemical Barrier Omissions	Scheme Chemical Risk Type
1	Lismore IPR	Effluent from Lismore STP treated via ozone/BAC, GAC, UF, UV disinfection and chlorine disinfection prior to discharge to an engineered storage buffer (i.e. dam) and subsequent treatment via Nightcap WTP	Dilution and reservoir mixing in the Dam	A (CBAT + WTP)
2	Lismore DPR – Raw Water Augmentation	Effluent from Lismore STPs treated via ozone/BAC, GAC, UF, UV disinfection and chlorine disinfection prior to treatment via Nightcap WTP	Second ozone/BAC at Nightcap is not counted for chemical removal. Raw water blending and dilution is not counted.	A (CBAT + WTP)
3	Lismore DPR – Treated Water Augmentation	Effluent from Lismore STPs treated via ozone/BAC, GAC, UF, UV disinfection and chlorine disinfection (and potentially secondary UV disinfection) prior to discharge to the drinking water distribution system	In distribution blending is not counted. Secondary UV potential for chemical reduction is not counted.	B (CBAT)
4	Byron DPR – Treated Water Augmentation (RBAT Option considered for risk assessment)	Effluent from Byron STPs treated via UF, RO, UV advanced oxidation (AOP) and chlorine disinfection (and potentially secondary UV disinfection) prior to discharge to the drinking water distribution system	In distribution blending is not counted. Secondary UV potential for chemical reduction is not counted.	C (RBAT)

With the PRW Investigations at a strategy level, and corresponding available information, this risk assessment has been streamlined through adoption of the following conservative assumptions:

- Multiple chemical barriers of the same type were only claimed once in a scheme – even when employed as two separate treatment processes. Key implications of this assumption are expected to have included:
  - Likely overestimation of the chemical risk when a CBAT train is used to send water to the Nightcap WTP (which also uses ozone/BAC).
  - Low dose secondary UV disinfection systems, targeting additional removal of protozoa and virus, were not included. It is anticipated that the doses of these systems would not exceed 186 mJ/cm^2

required to treat for up to 4-log adenovirus. The potential contribution of these systems was not included as the level of chemical photolysis of these systems was presumed to be low[4].

    - Potential chemical removal via oxidation with chlorine was not included as there is no removal data on this within WRF Project No. 4960 (noting that disinfection has the potential to introduce is DBPs - the DBPs risks relevant to the treatment schemes are discussed in Section 5.5).

- Dilution credits were not claimed for raw water augmentation or IPR. This assumption results in overestimation of chemical risk for these options[5]. For this high-level screening level assessment, it was not considered appropriate to include reservoir dilution or dilution with a WTP inlet flow as:
    - The concentration of the chemical in the raw water was not known and could not reasonably be assigned a value of zero[6], and,
    - The exact minimum blending ratio was not known as this would require set limits and study of in reservoir mixing and raw water flows from other source waters relative to maximum wastewater contributions.
- WTP removal performance of chemicals and potential dilution and blending with existing source water were not applied for treated water augmentation schemes as:
    - For treated water augmentation, the WTP is not in the treatment train hence its contribution to removal was excluded, and,
    - During treated water augmentation, there will be some in-distribution dilution of PRW with existing treated surface water[7]. However, this dilution may change as a complex function of both distribution system location and relative flows of PRW versus treated surface water. Consideration of dilution impacts should be included in the detailed chemical risk assessment should any of the short-listed options be considered further.

Due to the conservatism associated with these assumptions and the non site-specific nature of the assessment (i.e. use of Luggage Point data), any exceedance of an ICRQ does not necessarily imply a risk. Rather, a high ICSS or ICRQ within this document should be managed through characterisation of occurrence and process removal performance (noting that site specific data may also highlight different risks to those developed in this assessment), and a full risk assessment.

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[4] Glover et.al. (2019) suggest that, as an example, a UV dose of 325 mJ/cm^2 is required for 90% removal of N-nitrosomorpholine (which is completely recalcitrant to ozonation and GAC [25]) as compared to the disinfection dose of 186 mJ/cm^2 [24].

[5] For an IPR scheme, both dilution benefits and short-circuiting risks within the environmental buffer storage would need to be considered based on water quality and hydrodynamic models.

[6] There is likely low risk of chemical contamination of Rocky Creek Dam due to the nature of the catchment. However, the Wilsons River Source is located downstream of the discharge from Bangalow STP and downstream of agricultural land (from which fertilizers, pesticides, etc. could run off).

[7] Initial high-level calculations suggest that the blend ratio (amount of PRW divided by the total amount of dinking water supplied) would be about 40% for the Byron DPR via treated water augmentation scheme and limited to 50% for the Lismore DPR via treated water augmentation scheme (to maintain acceptable total dissolved solids concentration in the drinking water). Refer to the *AWTP Process Trains Memorandum* prepared as part of this investigation for further information.

4 SOURCE WATER ASSESSMENT

The two catchments under consideration are operated by Lismore City Council (East and South Lismore STPs) and Byron Shire Council (Byron and Brunswick Valley STPs). While specific details of the trade waste management programmes operating in these Council areas have not been reviewed, it is understood that:

- Trade waste customers generally operate trade waste limits for bulk pollutants which are relevant to the sewage treatment processes (e.g. BOD, TSS, Nitrogen, Phosphorus, and Oil and Grease), and,
- Medical facilities within the catchment operate under medical waste management programmes.

The project team reviewed Trade Waste and landfill leachate volumetric data for these catchments, and categorised each source based on whether or not the industry identified in question had the potential to have substances posing risks to human health within their inventory. Additional information on Trade Waste discharges is located in Appendix B. In the following sections, reference to "Medical" as Trade Waste discharger type referees to all medical facilities (e.g. cancer treatment clinics, radiological services, etc.) not just hospitals.

If any of the short-listed schemes are considered further, the following should be investigated:

- Existing Trade Waste regulations in the relevant catchment(s), including conditions of acceptance for medical facilities;
- Chemicals included in the Trade Waste regulations and agreements;
- Information on any illegal discharges and if available:
    - The legacy of those events; and
    - Steps that were taken to control the discharges.

4.1 LISMORE

Lismore City Council maintains Trade Waste discharge permits with close to 300 permitted dischargers in the catchment of South Lismore STP and East Lismore STP. The permitted dischargers are summarized by business type and total permitted discharge volume in Table 4-1. Table 4-1 shows only dischargers holding permits with non-zero discharge volumes. No actual discharge data are available, and the permitted amount represents a maximum approved.

The estimated average dry weather flow (ADWF) influent to South Lismore STP is 2.1 ML/d, and the estimated ADWF to East Lismore STP is 5.4 ML/d. The total Trade Waste volume permitted for both plants amounts to about 271 kL/d, comprising a maximum of 4% of the combined ADWF flow into both plants. The total volume permitted of dischargers with a high presumptive risk (as per Table 4-1) is 90 kL/d, or 1% of the total ADWF flow into both Lismore STPs on a combined basis.

Table 4-1: Permitted Trade Waste Dischargers and Estimated Flows to South and East Lismore STPs

Discharger Type	Total Volume Permitted (kL/d)	High Presumptive Risk
Administration Office	1.8	
Auto-Related	2.5	Yes – May contain solvents or hydrocarbons
Club	9.7	
Food Processing	5.5	
Food-Related	126.8	
Function Centre	2.0	
Government Service	5.6	
Hotel/Accommodation	10.4	
Laboratory	1.6	Yes – May contain a range of chemicals
Laundry	5.2	Yes – Includes hospital laundry
Mechanical Repair Workshop	37.9	Yes – May contain solvents or hydrocarbons
Medical(1)	17.0	Yes – May contain a range of chemicals
Metal Finishing	2.2	Yes – May contain metals and solvents
Nursing Home	4.0	
Preschool	1.0	
Recycling	5.2	Yes – Leachate and other chemicals
Retail	7.4	
School	6.0	
Service Industry	16.2	Yes - Unknown
Service Station	2.4	Yes – May contain solvents or hydrocarbons
Swimming Pool	0.4	
Landfill Leachate(2)	Data Not Available	Yes – Leachate containing PFAS and other chemicals
Total	**271**	

1. Based on Kumari et. al. (2020, [9]), these wastes could include drugs and their metabolites such as antibiotics, lipid regulators, analgesics, antidepressants, antiepileptics, antineoplastic, antipyretics, antiphlogistic, antirheumatics, estrogens, organic matter, radionuclides, solvents, metals, disinfectants, cytostatic agents, anaesthetics and sterilization products, specific detergents for endoscopes and other instruments, radioactive markers, and iodinated contrast media. Metals present could include platinum, mercury, rare earth elements (gadolinium, indium, osmium), and iodinated X-ray contrast media. Depending on the waste management practices employed in the relevant facilities, a number of these components may be not present in the sewage stream.
2. Lismore City Council holds a license to discharge leachate to East Lismore STP after pre-treatment. However, the current license also allows discharge of the treated leachate to the environment without passing the flow to the STP. The leachate is pre-treated via a containerised plant (flocculation, pH adjustment, GAC and algal treatment to reduce PFAS). The Council are considering other options to divert/discharge leachate, and licencing for the STP may be revisited as part of an upcoming upgrade.

4.2 BYRON

Byron Shire Council accepts Trade Waste in the form of liquid tankered waste, as well as via the sewer network. All tankered waste goes to Byron STP, while network Trade Waste is accepted at both Byron STP and Brunswick Valley STP.

The breakdown of network waste by discharger and their estimated volumes discharged for calendar year 2022 are provided in Table 4-2. Table 4-2 also provides tankered waste volumes over the calendar year 2022.

Table 4-2: Estimated Volumetric Trade Waste to Byron and Brunswick Valley STPs by Discharger Type (2022)

Discharger Type	Total Volume Discharged to Byron STP (kL)(1)	Total Volume Discharged to Brunswick Valley STP (kL) (1)	High Presumptive Risk
Food-related/Hospitality(2)	6,696	6,126	
Medical(3), (4)	2,546	227	Yes – May contain a range of chemicals
Club	1,602	2,406	
Construction	30	0	Yes – May contain solvents
Mixed Industry	8,909	2,922	Yes - Unknown
Food Processing	639	947	
Hotel/Accommodation	15,170	2,333	
Laundry	245	0	
Mechanical/Auto	2,123	624	Yes – May contain solvents or hydrocarbons
Panel Beater	32	0	Yes – May contain solvents
School/Education Facility(5)	5,484	52	
Service Station	5,976	230	Yes – May contain solvents or hydrocarbons
Retail	8,641	748	
Total Network Volume, 2022	**58,093**	**16,613**	**Byron STP: 19,617 Brunswick Valley STP: 4,002**
Low-strength Domestic	840	0	
Low-strength Commercial	2,771	0	
Mullumbimby WTP Waste(6)	890	0	
Byron Resource Recovery Facility (Leachate)	12,500	0	Yes - Leachate containing PFAS and other chemicals
Total Tankered Volume, 2022	**17,000**	**0**	
Total Tankered + Network, 2022	**75,094**	**16,613**	**12,500 (Byron STP)**

1. Except where a flowmeter is used (as noted below), discharge volumes are estimated by Byron Shire Council as a percentage of metered water use, variable with type of business.
2. Related to restaurants, cafes, takeaways and other hospitality-related businesses.
3. The Byron Bay Hospital (categorised as a "Medical" discharger) uses an electromagnetic type flowmeter for more accurate readings of discharge volume. This hospital accounts for greater than 95% of the volume discharged under the "Medical" category.
4. Based on Kumari et. al. (2020, [9]), these wastes could include drugs and their metabolites such as antibiotics, lipid regulators, analgesics, antidepressants, antiepileptics, antineoplastic, antipyretics, antiphlogistic, antirheumatics, estrogens, organic matter, radionuclides, solvents, metals, disinfectants, cytostatic agents, anaesthetics and sterilization products, specific detergents for endoscopes and other instruments, radioactive markers, and iodinated contrast media. Metals present could include platinum, mercury, rare earth elements (gadolinium, indium, osmium), and iodinated X-ray contrast media. Depending on the waste management practices employed in the relevant facilities, a number of these components may be not present in the sewage stream.

5. The SAE College (categorised as a "School/Education Facility" discharger), uses an electromagnetic type flowmeter for more accurate readings of discharge volume. This facility accounts for roughly half the volume discharged under the "School/Education Facility" category.
6. Backwash waste from sand filters at the WTP, which are dosed with soda ash and alum.

The estimated ADWF influent to Byron STP is 4.6 ML/d and the estimated ADWF to Brunswick Valley STP is 1.5 ML/d.

Network Trade Waste constitutes about 3.5% of the ADWF to Byron STP and about 3% to Brunswick Valley STP. The network inputs deemed higher-risk (as per Table 4-2) constitute about 1.2% of the ADWF to Byron STP and about 0.7% to Brunswick Valley STP.

Among tankered Trade Waste, the only input deemed higher-risk is leachate from the Byron Resource Recovery Facility, at about 12,500 kL over calendar year 2022, which goes to Byron STP. The total tankered and network Trade Waste to Byron STP constitute about 4.5% of ADWF, while higher-risk inputs constitute 1.9% of ADWF.

The total Trade Waste volume to both plants amounts to about 251 kL/d, comprising about 4.1% of the combined ADWF into both plants. The total volume with a high presumptive risk is about 100 kL/d, or 1.6% of the combined ADWF into both plants.

The Bureau of Meteorology (BOM) collects summary statistics for public utilities. As part of these studies, the total volume of wastewater effluent (excluding Trade Waste) and also total volume of Trade Waste is reported annually. The reported total volume of effluent for Urban Utilities (for the 27 STPs in the Urban Utilities network), excluding Trade Waste, was 116,750 ML for the 2020 – 2021, and the reported total volume of Trade Waste was 10,205 ML[8]. The proportion of Trade Waste within the raw wastewater is in the order of 8.0 %.

Assuming the Trade Waste is distributed evenly to each plant in proportion to the raw wastewater flow, for the purposes of comparison, a Trade Waste contribution to the Luggage Point STP can be assumed to be 8%. This proportion of Trade Waste is:

- About double for which permits are in place at East Lismore STP and South Lismore STP; and,
- About double that received at Byron STP and Brunswick Valley STP.

Given the higher proportion of Trade Waste for Luggage Point, and the more urban nature of the catchment as compared to any of the short-listed schemes, benchmarking chemical contamination of Lismore or Byron sourced secondary effluent by use of Luggage Point effluent data is anticipated to be conservative[9].

[8] BOM, 2021, "Urban National Performance Report 2020 – 2021", Bureau of Meterology, Australian Government, URL: http://www.bom.gov.au/water/npr/npr_2020-21.shtm, Date Accessed: 2/19/2024

[9] The proportion of Trade Waste to Luggage Point could be higher than the assumed 8%, given the urban nature of the catchment (as compared to many of Urban Utilities smaller plants located in more rural areas). If this is the case, the use of Luggage Point data is even more conservative.

5 INDUSTRIAL CHEMICAL RISK ASSESSMENT

This section discusses:

- The ICSS values calculated based on the data available in WRF Project No. 4960;
- The ICRQ values calculated based on occurrence data for Luggage Point (i.e. contaminant concentrations measured in Luggage Point secondary effluent);
- Potential blending impact of ICRQ;
- The 20 compounds with the highest ICSS for each Scheme Chemical Risk Type;
- Chemicals which present a pass-through risk for each Scheme Chemical Risk Type;
- An assessment of chemicals that were present in Luggage Point secondary effluent at concentrations greater than the limit report which were excluded from consideration in WRF Project No. 4960; and,
- Risks associated with compounds that could be formed through the AWTP treatment process (i.e. DBPs).

This section presents a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW – as a first step in understanding potential chemical risks in the absence of detailed scheme specific source water information. Further assessment of chemical risk will need to be conducted when sufficient catchment specific data becomes available. The approach described in this memorandum can be used to guide the future detailed chemical risk assessment.

5.1 Relative Chemical Management of Proposed Treatment Trains

5.1.1 ICSS and ICRQ

In an effort to comment on the relative management barriers for industrial chemicals, the ICSS of industrial chemicals for which data was available within WRF Project No. 4960 were summed for each of the individual Scheme Chemical Risk types. The sensitivity or drivers of the ICSS total were also noted. A higher summed ICSS relative to a different option would imply a higher relative risk – provided the quality of input data (e.g. chemical removals for each unit process) is equal.

A similar approach has been applied to ranking the ICRQ, where this value was able to be developed for compounds with Luggage Point occurrence data that were able to be paired with risk and removal metrics from WRF Project No. 4960, to provide indication of possible chemical risk and to provide an example of how to better understand and prioritize chemicals of concern.

Table 5-1 summarises the relative risk assessment between the proposed process trains.

Table 5-1: Relative Risk Assessment Between Proposed Process Trains

Parameter	Scheme Chemical Risk Type A	Scheme Chemical Risk Type B	Scheme Chemical Risk Type C
Train Type	CBAT + WTP with IPR or raw water augmentation	CBAT DPR	RBAT DPR
Total Conservative ICSS	1.6 x 10^8	1.6 x 10^8	1.5 x 10^7
Total Conservative ICSS - PFOA	2.0 x 10^6	2.0 x 10^6	5.0 x 10^5
Total Conservative ICRQ	1.6 x 10^3	1.9 x 10^3	3.9 x 10^2
Total Conservative ICRQ – PFOA	7.3 x 10^2	9.7 x 10^2	3.1 x 10^2
Total Conservative ICRQ – Non detect contributors	4.1 x 10^1	5.1 x 10^1	2.0 x 10^0
Number of Chemicals with ICRQ > 0.2	17	21	11
Top 5 Chemicals Contributing to ICSS (% of Total ICSS)	1. PFOA (98.8%) 2. PFOS (0.9%) 3. PFHxS (0.1%) 4. Thallium (<0.1%) 5. NDMA (<0.1%)	1. PFOA (98.8%) 2. PFOS (0.9%) 3. PFHxS (0.1%) 4. Thallium (<0.1%) 5. NDMA (<0.1%)	1. PFOA (96.7%) 2. PFOS (2.0%) 3. NDMA (0.5%) 4. Hydrazine (0.2%) 5. 1,2,3-Trichloropropane
Top 20 Chemical Risks by ICRQ (ICRQ, %Total ICRQ)	PFOA (924, 55.8%) Cadmium (343, 20.7%) Thallium (286, 17.2%) Butylated Hydroxytoluene (64, 3.9%) PFOS (28, 1.7%) Chromium (2.5, 0.15%) Fluoride (2.3, 0.13%) PFHxS (2.0, 0.12%) Cobalt (1.0, 0.06%) Cyanide (1.0, 0.06%) Arsenic (0.9, 0.05%) NDMA (0.6, 0.04%) Nitrate (0.5, 0.03%) Boron (0.3, 0.02%) Manganese (0.3, 0.02%) NMOR (0.2, 0.01%) Nickel (0.2, 0.01%) Antimony (0.2, 0.01%) Iodide (0.14, <0.01%) Molybdenum (0.14, <0.01%)	PFOA (924, 48.8%) Cadmium (571, 30.1%) Thallium (286, 15.1%) Butylated Hydroxytoluene (64, 3.4%) PFOS (28, 1.5%) Fluoride (4.6, 0.3%) Arsenic (4.5, 0.2%) Chromium (4.1, 0.2%) PFHxS (2.0, 0.10%) Cyanide (1.7, 0.09%) Cobalt (1.0, 0.05%) NDMA (0.6, 0.03%) Nitrate (0.5, 0.03%) Bromide (0.4, 0.02%) Antimony (0.4, 0.02%) Boron (0.3, 0.02%) Manganese (0.3, 0.02%) Iron (0.3, 0.02%) NMOR (0.2, 0.01%) Molybdenum (0.2, 0.01%)	Butylated Hydroxytoluene (255, 65.3%) PFOA (84, 21.5%) Cadmium (29, 7.3%) Thallium (14, 3.7%) PFOS (5.6, 1.5%) NDMA (0.6, 0.2%) Iodide (0.6, 0.2%) Fluoride (0.2, 0.06%) Arsenic (0.2, 0.06%) Chromium (0.2, 0.05%) Boron (0.2, 0.05%) PFHxS (0.14, 0.04%) Nitrate (0.13, 0.03%) Cyanide (0.08, 0.02%) Bromide (0.08, 0.02% Beryllium (0.07, 0.02% Manganese (0.06, 0.02% Cobalt (0.05, 0.01% Nitrite (0.04, 0.01% Fipronil (0.04, <0.01%
Compounds in the top 20 contributing to the ICRQ below the detection limit at max concentration in Luggage Point secondary effluent	Cadmium, Thallium and Butylated Hydroxytoluene	Cadmium, Thallium and Butylated Hydroxytoluene	Butylated Hydroxytoluene, Cadmium, Thallium and Beryllium

For both Scheme Chemical Risk A and B, CBAT with and without a drinking water treatment plant, the total conservative ICSS was approximately ten times higher than Scheme Chemical Risk C (RBAT). The likely explanation for this differential is that RO is a well-studied and broad–spectrum barrier and may achieve much greater than 90% removal for a number of constituents of concern. When comparing based on summed metrics, a process that controls a larger number of compounds would likely result in a lower summed ICSS.

In general, when constructing the WRF Project No. 4960 framework, there were fewer compounds for which non–RO process removals were available and within this assessment, those compounds were assigned a removal of 0%. This likely leads to a far more conservative risk estimation for CBAT simply due to a lack of information on removals. This highlights the need for more research in this area, and specific to any RCC scheme, the need for demonstrating removals of the actual chemicals of concern through on site testing with the source water(s) intended to be used for the scheme.

A similar trend to ICSS was seen with the subset of data for ICRQ. Within the top 20 contributors for the total ICRQ, butylated hydroxytoluene, cadmium, thallium and beryllium were risk rated at the analytical detection limit as no samples in the Luggage Point effluent tested positive for these chemicals. Beryllium was only in the top 20 contributors for Scheme Chemical Risk Type C. Subtracting the ICRQ for these compounds reduced the ICRQ for Scheme Chemical Risk Types A, B and C to from 1,600, 1,900 and 390 to 41, 51 and 2.0 respectively. With more appropriate site-specific secondary effluent or raw wastewater data and less conservative process removal assumptions it is anticipated that the chemical risk would likely be lower than this.

When excluding the significant impact of Perfluorooctanoic Acid (PFOA), which accounts for more than 97% of the ICSS in each data set), the gap between the ICSS narrowed to less than a factor of four between the CBAT and RBAT trains, Similarly, the difference in ICRQ for the two train types narrowed to less than a factor of three. For the purpose of establishing conceptual process trains for the PRW Investigations, given the high level and conservative nature of the screening assessment conducted, the chemical control of all proposed treatment options should be considered equivalent. Further quantitative study, and potential chemical removal optimisation through AWTP design (based on data from demonstration plant operation), would be required to establish the absolute risk profile for any scheme/AWTP process train type that RCC chooses to pursue.

5.1.2 Potential Impact of Blending

The risk of Scheme Chemical Risk Type A could be anticipated to scale down linearly (assuming no presence of chemicals in surface water) based on the minimum volume of surface water in the environmental buffer storage (for IPR), or minimum blending ratio between PRW and surface water as part of raw water augmentation.

Similarly, assuming no presence of the same chemicals in the drinking water from Nightcap WTP, for Scheme Chemical Risk Types B and C the risk could be anticipated to scale down in relation to the blend ratio (amount of PRW delivered to the network (i.e. a given reservoir) divided by the total demand served by the network (i.e. the total combined flow of Nightcap WTP produced water plus PRW blended in the reservoir and sent out to the distribution system)).

Table 5-2 provides an example of blending impacts for a treated water augmentation scheme.

Table 5-2: Treated Water Augmentation Blending Example

	Lismore				Ballina	Byron
Reservoirs	Ross St	City View	High St	Belvedere Dr.	Knockrow	St Helena Reservoir
Projected 2040 Average Daily Demand	3.4 ML/d	2.98 ML/d	1.47 ML/d	2.98 ML/d	13.2 ML/d	8.95 ML/d
	10.8 ML/d with all four main reservoirs 7.4 ML/d without Ross St				22.15 ML (for St Helena with Knockrow backfeed)	
PRW Available[1]	9.1 ML/d				8.35 ML/d	
Blend Ratio[2]	84% (based on PRW blended across all four reservoirs)				38% (based on St Helena with Knockrow backfeed)	
Example Contaminant ICRQ without Blending	1				1	
Example Contaminant ICRQ with Blending[3]	0.84				0.38	

1. Assumes full projected 2040 ADWF from both STPs in scheme is used to create PRW. Note that the Lismore Treated Water Augmentation scheme option applied to the preliminary design and costing was reduced to meet a blend ratio of 50% at the projected 2040 flows to manage build-up of total dissolved solids within the system.
2. Volume of PRW supplied to the reservoir/total volume of water supplied from the reservoir.
3. Assumes the concentration of the example contaminant if the drinking water supplied to the reservoir from sources other than PRW is zero.

This highlights the need to develop an understanding of the water quality from other sources and the intended blending flows, and characteristics of the environmental buffer storage in the IPR scheme, for all foreseen operating conditions prior to conducting the detailed chemical risk assessment (with site specific chemical occurrence data and better-defined removal rates).

5.2 Highest Contributors to Summed ICSS

As discussed in Section 5.1.1, the ICSS of each individual industrial chemical for which data was available within WRF Project No. 4960 were summed to create a total ICSS for each Scheme Chemical Risk Type. This section summarises the chemicals that make up the top 20 individual contributors to the summed ICSS for each Scheme Chemical Risk Type (i.e. of the 171 chemicals for which ICSS could be calculated, the chemicals with the 20 highest individual ICSS, for each Scheme Chemical Risk Type), along with their chemical family and potential sources as grouped within WRF Project No. 4960. The full set of data is included in Appendix A.

Figure 5-1 presents, for each Scheme Chemical Risk Type, a breakdown of the top 20 individual contributors to the summed ICSS based on chemical family. Scheme Chemical Risk Type A and B, which predominantly rely on CBAT, have similar chemical families of concern. Relative to Scheme Chemical Risk Type B, the addition of assumed removals via the WTP shows marginally improved controls of metals and other inorganics. Scheme Chemical Risk Type C, using RBAT, shifts the focus of chemical control to solvents and industrial precursors, likely as a result of a large proportion of this family having lower molecular weights and some being neutrally charged thus contributing a challenge to removal by RO.

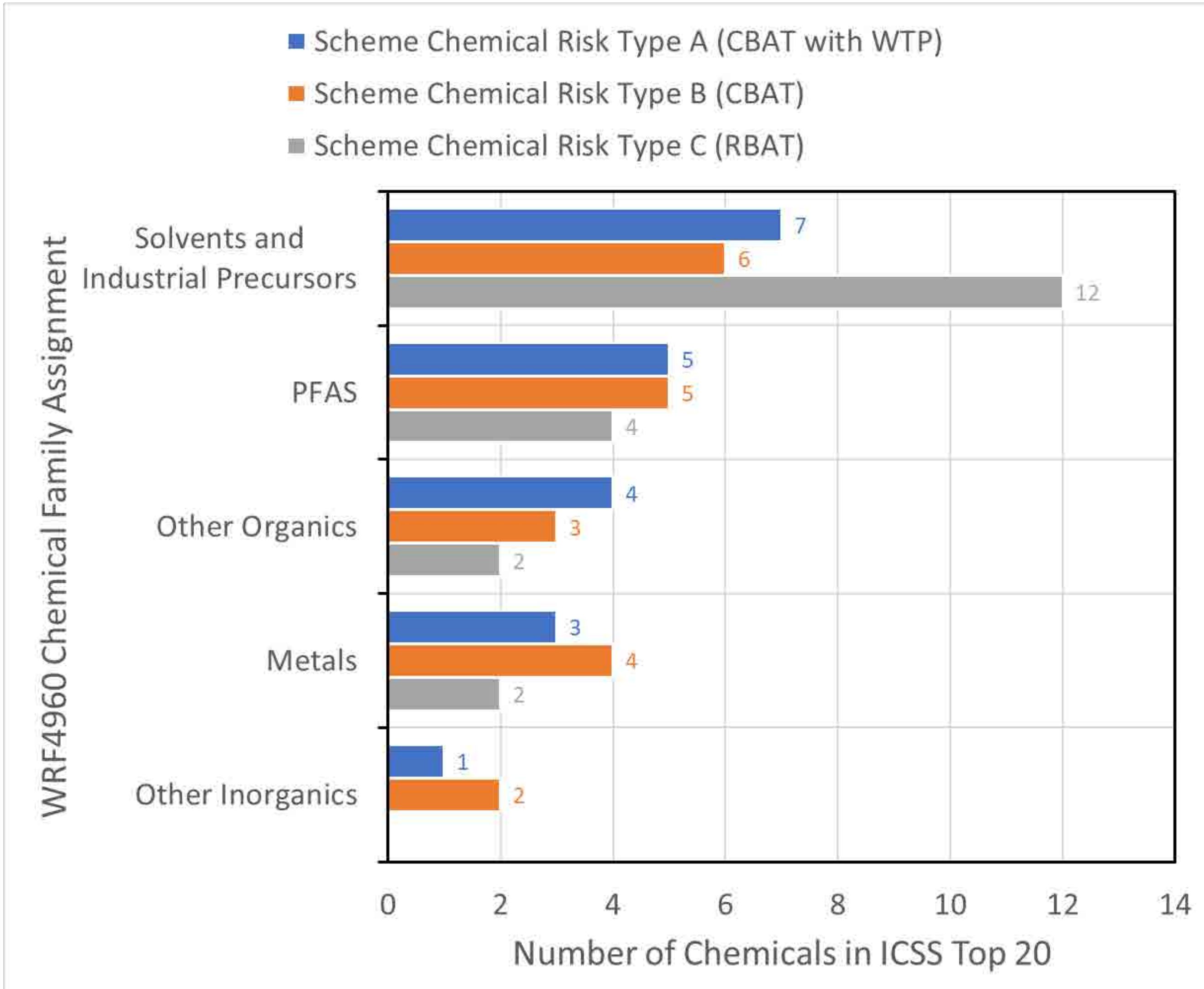

Figure 5-1: Summary of Chemical Families of Concern Based on Conservative ICSS for Each Scheme Chemical Risk Type[10]

Per-and polyfluoroalkyl substances (PFAS)[11] are a challenge for all Scheme Chemical Risk Types, and within this single family of industrial chemicals, four or five are within the top 20 regardless of applied treatment technology (as shown in Figure 5-1.

[10] In Figure 5-1, the numbers associated with the horizontal bars represent the number of chemicals within the top 20 contributors to the summed ICSS are within the given chemical family (as described on the Y axis) for a given Scheme Chemical Risk Type.

[11] Per- and polyfluoroalkyl substances (PFAS) are a large, complex group of synthetic chemicals that have been used in consumer products around the world since about the 1950s. PFAS molecules have a chain of linked carbon and fluorine atoms. Due to the strength of carbon-fluorine bonds is one, these chemicals do not degrade easily in the environment. PFAS are a group of nearly 15,000 synthetic chemicals, according to a chemicals database (CompTox) maintained by the U.S. Environmental Protection Agency. https://www.niehs.nih.gov/health/topics/agents/pfc

Degradation of consumer products in landfills has been associated as a source of PFAS. However, PFAS have been reported to be at a consistently detectable level in municipal effluent with and without significant industrial inputs [10]. In addition, PFAS have been detected in drinking water catchments and correlated to other anthropogenic indicators of de facto reuse, such as sucralose [11]. Accordingly, if the source water for Nightcap WTP is impacted by de facto reuse[12], this would introduce an additional exposure source and also inhibit the effectiveness of reservoir dilution or raw water blending (Scheme Chemical Risk Type A) of controlling PFAS risk. PFAS have also been detected, albeit at very low levels, in all precipitation globally [12].

Consequently, it is challenging to employ industrial source control as a complete barrier against the introduction of PFAS into a potable reuse scheme, given the multitude of other pathways for this family of chemicals to enter and impact broader water supply. Nevertheless, given the practice and introduction of waste from landfills into the proposed catchments of these schemes, it is recommended that a chemical survey of landfill wastewater, in particular for PFAS, be conducted and compared to levels indigenous PFAS levels in the municipal portion of the wastewater for any scheme which is carried forward for further development. Such a comparison would help identify if significant reductions in PFAS loads (and potentially other surveyed chemicals) could be achieved by further onsite treatment or segregation of landfill waste.

Similarly, hospital waste was identified as a potentially relevant source for thallium (although this compound was not detected in the Luggage Point effluent) and hydrazine, which was not assayed. Hospitals, other medical facilities and aged care facilities are anticipated to be point sources of pharmaceutical metabolites which were not risk assessed as part of WRF Project No. 4960. Given the presence of medical and aged care facilities within both proposed catchments, it is recommended to conduct a survey of these inputs to determine:

1. The current concentrations of compounds of concern in their discharge to sewer;
2. The current management practices;
3. Potential improvements to prevailing onsite management practices to reduce risk to the PRW scheme.

Table 5-3 through Table 5-5 show the top 20 individual contributors to the summed ICSS for each Scheme Chemical Risk Type, along with their chemical family, industrial applications and potential sources. In reviewing this information, it must be remembered that the ICCS (and ICRQ) have been calculated based on non-site specific information, hence the risk discussed herein is general to all potable reuse schemes having similar process trains. A number of the applications or sources for the identified chemicals are unlikely to occur within the sewer catchments of any of the proposed RCC schemes. However, it is important to recognise that both landfills and hospitals are present for all Scheme Chemical Risk Types.

[12] There is likely low risk of chemical contamination of Rocky Creek Dam due to the nature of the catchment. However, the Wilsons River Source is located downstream of the discharge from Bangalow STP and downstream of agricultural land (from which fertilizers, pesticides, etc. could run off).

Table 5-3: Family, Application and Sources of the Top 20 ICSS Contributors for Outcome A – CBAT Scheme including WTP

Name	Family	Industrial Application(s)	Potential Source(s)
Perfluorooctanoic Acid	PFAS	Voluntarily phased-out industrial surfactant. Degradation product of polyfluorinated substances in textile	Landfills
Perfluorooctane Sulfonate	PFAS	Firefighting foam; degradation product of polyfluorinated substances	Airport Deicing; Electroplating; Landfills; Metal Finishing
Perfluorohexane Sulfonate	PFAS	Electroplating; Firefighting foam	Landfills; Electroplating; Airport Deicing; Metal Finishing
Thallium	Metals	Optics; Electronics; Nuclear Medicine	Glass Manufacturing; Electrical and Electronic Components; Hospitals; Mineral Mining and Processing
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	Solvent; rubber accelerator; intermediate for 1,1-dimethylhydrazine rocket propellant	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing; Explosives Manufacturing; Textile Mills; Metal Finishing; Electrical and Electronic Components
Perfluorononanoic Acid	PFAS	Degradation product of polyfluorinated substances	Landfills
Hydrazine	Solvents & Industrial Precursors	Rocket fuel; corrosion control; precursor to plastics, pesticides, and medicines; cancer drug; quenching dissolved oxygen in the water-steam cycle	Pharmaceutical Manufacturing; Hospitals; Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals; Steam Electric Power Generation
Lanthanum	Metals	Batteries, lighter flints, hydrogen sponge alloys	Battery Manufacturing; Nonferrous Metals Manufacturing
1,2,3-Trichloropropane	Solvents & Industrial Precursors	Precursor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Bis(2-chloroethyl) ether	Solvents & Industrial Precursors	Chemical intermediate for pesticides. Solvent.	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals
N-nitrosomorpholine	Other Organics	Unknown	Unknown
Nitroglycerine	Other Organics	Explosive, rocket propellant	Explosives Manufacturing
Ethylene Oxide	Solvents & Industrial Precursors	Precursor in the manufacture of ethylene glycol, surfactants, acrylonitrile, and ethanolamines	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Ethylene thiourea	Other Organics	Accelerator for vulcanizing neoprene and polyacrylate rubbers	Rubber Manufacturing
1,3-Dinitrobenzene	Solvents & Industrial Precursors	Chemical intermediate for synthetic fibers, dyes, explosives	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Explosives Manufacturing
Perfluorobutane Sulfonic Acid	PFAS	Surfactant, electroplating, integrated circuits	Landfills; Electroplating; Electrical and Electronic Components; Metal Finishing
Cobalt	Metals	Electroplating, lamp filaments, catalyst for sulfur removal from petroleum, dyes	Electroplating; Nonferrous Metals Manufacturing; Petroleum Refining; Textile Mills; Metal Finishing
Hexachloroethane	Other Organics	Smoke-producing military devices, pyrotechnics, anhelmintic	Pesticide Chemicals; Explosives Manufacturing
Antimony	Other Inorganics	Flame Retardants, Alloys, Batteries, Stabilizer, Catalyst, Glass, Electronics, Pigments	Battery Manufacturing; Electrical and Electronic Components; Glass Manufacturing; Ink Formulating; Petroleum Refining
2,4,6-Trichlorophenol	Solvents & Industrial Precursors	Disinfectant, antiseptic, bleaching at pulp and paper mills, leather tanning, wood preservative	Pesticide Chemicals; Pulp, Paper and Paperboard; Leather Tanning and Finishing; Timber Products Processing

Table 5-4: Family, Application and Sources of the Top 20 ICSS Contributors for Outcome B – CBAT Scheme excluding WTP

Name	Family	Industrial Application(s)	Potential Source(s)
Perfluorooctanoic Acid	PFAS	Voluntarily phased-out industrial surfactant. Degradation product of polyfluorinated substances in textile	Landfills
Perfluorooctane Sulfonate	PFAS	Firefighting foam; degradation product of polyfluorinated substances	Airport Deicing; Electroplating; Landfills; Metal Finishing
Perfluorohexane Sulfonate	PFAS	Electroplating; Firefighting foam	Landfills; Electroplating; Airport Deicing; Metal Finishing
Thallium	Metals	Optics; Electronics; Nuclear Medicine	Glass Manufacturing; Electrical and Electronic Components; Hospitals; Mineral Mining and Processing
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	Solvent; rubber accelerator; intermediate for 1,1-dimethylhydrazine rocket propellant	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing; Explosives Manufacturing; Textile Mills; Metal Finishing; Electrical and Electronic Components
Perfluorononanoic Acid	PFAS	Degradation product of polyfluorinated substances	Landfills
Hydrazine	Solvents & Industrial Precursors	Rocket fuel; corrosion control; precursor to plastics, pesticides, and medicines; cancer drug; quenching dissolved oxygen in the water-steam cycle	Pharmaceutical Manufacturing; Hospitals; Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals; Steam Electric Power Generation
Lanthanum	Metals	Batteries, lighter flints, hydrogen sponge alloys	Battery Manufacturing; Nonferrous Metals Manufacturing
1,2,3-Trichloropropane	Solvents & Industrial Precursors	Precursor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Bis(2-chloroethyl)ether	Solvents & Industrial Precursors	Chemical intermediate for pesticides. Solvent.	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals
N-nitrosomorpholine	Other Organics	Unknown	Unknown
Nitroglycerine	Other Organics	Explosive, rocket propellant	Explosives Manufacturing
Ethylene Oxide	Solvents & Industrial Precursors	Precursor in the manufacture of ethylene glycol, surfactants, acrylonitrile, and ethanolamines	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Ethylene Thiourea	Other Organics	Accelerator for vulcanizing neoprene and polyacrylate rubbers	Rubber Manufacturing
Arsenic	Other Inorganics	Glass and electronics production, herbicide, insecticide, wood preservatives, leather	Electrical / Electronic Components; Pesticide Chemicals; Leather Tanning and Finishing; Timber Products Processing; Mineral Mining and Processing; Battery Manufacturing; Copper Forming; Glass Manufacturing; Textile Mills
1,3-Dinitrobenzene	Solvents & Industrial Precursors	Chemical intermediate for synthetic fibers, dyes, explosives	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Explosives Manufacturing
Antimony	Other Inorganics	Flame Retardants, Alloys, Batteries, Stabilizer, Catalyst, Glass, Electronics, Pigments	Battery Manufacturing; Electrical and Electronic Components; Glass Manufacturing; Ink Formulating; Petroleum Refining
Perfluorobutane Sulfonic Acid	PFAS	Surfactant, electroplating, integrated circuits	Landfills; Electroplating; Electrical and Electronic Components; Metal Finishing

Cobalt	Metals	Electroplating, lamp filaments, catalyst for sulfur removal from petroleum, dyes	Electroplating; Nonferrous Metals Manufacturing; Petroleum Refining; Textile Mills; Metal Finishing
Mercury	Metals	Thermometers, barometers, pressure-sensing devices, batteries, and lamps	Electrical and Electronic Components; Battery Manufacturing; Petroleum Refining; Nonferrous Metals Manufacturing; Pharmaceutical Manufacturing

Table 5-5: Family, Application and Sources of the top 20 ICSS contributors for Outcome C – RBAT Scheme excluding WTP

Name	Family	Industrial Application(s)	Potential Source(s)
Perfluorooctanoic Acid	PFAS	Voluntarily phased-out industrial surfactant. Degradation product of polyfluorinated substances in textile	Landfills
Perfluorooctane Sulfonate	PFAS	Firefighting foam; degradation product of polyfluorinated substances	Airport Deicing; Electroplating; Landfills; Metal Finishing
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	Solvent; rubber accelerator; intermediate for 1,1-dimethylhydrazine rocket propellant	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing; Explosives Manufacturing; Textile Mills; Metal Finishing; Electrical and Electronic Components
Hydrazine	Solvents & Industrial Precursors	Rocket fuel; corrosion control; precursor to plastics, pesticides, and medicines; cancer drug; quenching dissolved oxygen in the water-steam cycle	Pharmaceutical Manufacturing; Hospitals; Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals; Steam Electric Power Generation
1,2,3-Trichloropropane	Solvents & Industrial Precursors	Precursor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Perfluorohexane Sulfonate	PFAS	Electroplating; Firefighting foam	Landfills; Electroplating; Airport Deicing; Metal Finishing
1,2-Dibromoethane	Solvents & Industrial Precursors	Precursor for dyes and pharmaceuticals, solvent	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pharmaceutical Manufacturing
Perfluorononanoic Acid	PFAS	Degradation product of polyfluorinated substances	Landfills
Vinyl Chloride	Solvents & Industrial Precursors	Chemical synthesis intermediate; Monomer for PVC; Solvent	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
1,3-Dinitrobenzene	Solvents & Industrial Precursors	Chemical intermediate for synthetic fibers, dyes, explosives	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Explosives Manufacturing
1,3-Butadiene	Solvents & Industrial Precursors	Used to make synthetic rubber, plastics, and resins	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Acrylonitrile	Solvents & Industrial Precursors	Polymer precusor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing
Thallium	Metals	Optics; Electronics; Nuclear Medicine	Glass Manufacturing; Electrical and Electronic Components; Hospitals; Mineral Mining and Processing
Ethylene thiourea	Other Organics	Accelerator for vulcanizing neoprene and polyacrylate rubbers	Rubber Manufacturing
Ethylene Oxide	Solvents & Industrial Precursors	Precursor in the manufacture of ethylene glycol, surfactants, acrylonitrile, and ethanolamines	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
2,4-dinitrotoluene	Solvents & Industrial Precursors	Intermediate in the manufacture of polyurethanes	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Quinoline	Solvents & Industrial Precursors	Precursor for dyes, niacin. Solvent for resins	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Lanthanum	Metals	Batteries, lighter flints, hydrogen sponge alloys	Battery Manufacturing; Nonferrous Metals Manufacturing
Bis(2-chloroethyl)ether	Solvents & Industrial Precursors	Chemical intermediate for pesticides. Solvent.	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals
N-nitrosomorpholine	Other Organics	Unknown	Unknown

5.3 PASS–THROUGH RISKS

Of the 262 chemicals considered as part of WRF Project No. 4960, 171 have human health impact data to allow development of an ICSS (at least assuming the worst-case removal of zero). A number of chemical removals were unknown for specific treatment processes. To assess the risk of these, a zero removal was conservatively applied.

A pass–through risk was defined in WRF Project No. 4960 as a chemical with a cumulative removal across a planned treatment train of less than 90% (i.e. the individual percent removal of a given chemical across each unit process are multiplied and if the product is less than 90% this chemical is defined as a pass-through risk for that process train). Table 5-6 summarises the number of pass-through chemicals based on cumulative removal across a planned treatment train for a given chemical of less than 90%, noting that the summary in Table 5-6 potentially overestimates the number of pass-through chemical risks due to the conservative removals assigned for this analysis .

In Table 5-6:

- The first row includes any chemicals (of the 262 chemicals considered as part of WRF Project No. 4960) with a cumulative removal of less than 90%. This number is highly conservative as it may assign a removal of 0% to any treatment process where data on removal is not available, which in turn reduces the overall cumulative removal.
- The second row counts the number of chemicals (of the 262 chemicals considered as part of WRF Project No. 4960) for which removal data is known for each chemical barrier in a proposed Scheme Chemical Removal Type.
- The third row considers the number of chemicals with known removal data representing a potential pass-through risk. That is, of the number of chemicals that are completely specified in row 2, how many may be removed at less than 90% for a given Scheme Chemical Risk Type.

Table 5-6: Pass– Through Risk Summary from WRF Project No. 4960 Data

Parameter	Metric Description/Limitation	Scheme Chemical Removal Type A	Scheme Chemical Removal Type B	Scheme Chemical Removal Type C
Train		CBAT + Nightcap WTP	CBAT no WTP	RBAT no WTP
Pass Through Chemicals (Conservative Removal < 90%)	This may include chemicals for which there are no removals reported and are assigned a 0% removal.	99	104	55
Chemicals With Known Removal for All Barriers	This is the number of chemicals, from 262 total, that have removal data for each chemical barrier in the proposed outcome.	78	79	102
Chemicals with Known Pass-Through Risks	Of the chemicals in the row above with known removal for all barriers, this is how many may be removed less than 90%.	30	35	3

The data in Table 5-6 highlights that, in general, RBAT performance is better studied than CBAT, and for most compounds the high RO removal results in low pass-through (assuming the membrane barrier is intact). The pass-through risks for RO are nitrate, 1,4-Dioxane and NDMA. All three of these chemical hazards can be managed. For example, STP optimization can reduce the incoming level of nitrate, while adjustments to the design and operation of UV/AOP (UV dose for NDMA and UV dose times oxidant concentration for 1,4 Dioxane) can be made to control risks in the RBAT train.

While RBAT is better studied than CBAT, Table 5-6 highlights the need for more research on removals through RBAT (i.e. of the 262 chemicals considered in WRF Project No. 4960 only 102 currently have removals defined for all barriers in the RBAT train).

Table 5-7 summarises the chemicals that have a known pass-through risk for CBAT trains, based on the information available in WRF Project No. 4960. Further work will be required to fully define site specific pass-through risks (i.e. development of an understanding of chemicals potentially present in the catchment, their concentration in the feed water and their removal through each unit process in the treatment train (through review of literature as more information becomes available and through onsite testing via a demonstration plant treating the intended source water for the scheme), whether the treatment train is CBAT or RBAT).

Table 5-7: Chemicals with Known Pass-Through Risks (Potential Overall Removal of < 90% Based on Literature)

Chemical Name	Family	CBAT + WTP (Scheme Chemical Removal Type A)	CBAT only (Scheme Chemical Type B)
Cadmium	Metals	✓	✓
Chromium	Metals	✓	✓
Cobalt	Metals	✓	✓
Iron	Metals		✓
Nickel	Metals	✓	✓
Copper	Metals	✓	✓
Uranium	Metals	✓	✓
Zinc	Metals	✓	✓
Mercury	Metals	✓	✓
Tin	Metals		✓
Nitrate	Nitrogen	✓	✓
Calcium	Other Inorganics	✓	✓
Sulphate	Other Inorganics	✓	✓
Chloride	Other Inorganics	✓	✓
Barium	Other Inorganics	✓	✓
Fluoride	Other Inorganics	✓	✓
Arsenic	Other Inorganics		✓
Bromide[13]	Other Inorganics		✓
Strontium	Other Inorganics	✓	✓
Selenium	Other Inorganics		✓
N-nitrosomorpholine	Other Organics	✓	✓
Perfluorobutane Sulfonic Acid	PFAS	✓	✓
Perfluorobutanoic acid	PFAS	✓	✓
Perfluoropentanoic Acid	PFAS	✓	✓
Perfluorohexanoic Acid	PFAS	✓	✓
Perfluorodecanoic acid	PFAS	✓	✓
Perfluoroheptanoic Acid	PFAS	✓	✓
Perfluorooctanoic Acid	PFAS	✓	✓
Perfluorooctane Sulfonate	PFAS	✓	✓
Perfluorohexane Sulfonate	PFAS	✓	✓
Perfluorononanoic acid	PFAS	✓	✓
Gabapentin	Pharmaceuticals	✓	✓
Diatrizoic Acid	Pharmaceuticals	✓	✓
1,4-Dioxane	Solvents & Industrial Precursors	✓	✓
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	✓	✓

The chemicals identified as known pass-through risks should be analysed to confirm that they are below acceptable levels in the source water and/or removed to a higher extent than assumed, and efforts to control these chemicals with a source control program should be implemented. The presence of these chemicals does not indicate a direct risk to PRW quality, but rather their presence does indicate a need for monitoring and verification. The CBAT trains include the same three

[13] The difference between Scheme Chemical Risk Type A and Type B is likely the result of default WTP removals in Water Research Foundation Project 9640 for coagulation, flocculation and sedimentation. If coagulation, flocculation and sedimentation is used in the CBAT train the pass-through risk may be similar. Further investigation would be required to provide better understanding of pass-through risk for bromide.

pass-through risks as for the RBAT train (nitrate, 1,4-Dioxane and NDMA). In addition, there are a number of other compounds, including metals and inorganics, that would require further investigation to determine if they are expected to be at acceptable concentrations in the feed to the AWTP. Again, a large number of PFAS are also present within the list of chemicals of concern. PFAS removal from the product stream could be optimized based on design and operation of the GAC.

5.4 Assessment of Excluded Chemicals

WRF Project No. 4960 did not attempt to collate human health impact data for all possible industrial chemicals. From an initial pool of 490 chemicals, 228 were excluded from further classification. The reasons for exclusion of chemicals are included in Appendix A.

The comprehensive water quality analysis of Luggage Point secondary effluent included the analysis of 587 different constituents. As a means to investigate potential omission of risk rating from compounds that have been specified in potable reuse monitoring plans, the list of WRF Project No. 4960 exclusions was cross referenced against the Luggage Point secondary effluent results.

In total, there were 32 of the 228 chemicals excluded from assessment as part of WRF Project No. 4960 that were detected, typically at very low concentrations, in the data from Luggage Point. A majority of these chemicals were excluded from WRF Project No. 4960 as they are rare or banned pesticides in the United States. Of these 32 chemicals, an ICRQ was calculated using drinking water health based guideline levels. This is a conservative assumption as it assumes all chemical barriers downstream of a STP are ineffective (i.e.it does not take into account cumulative removal through the downstream AWTP processes). Only two chemicals resulted in an ICRQ of greater than 1.0. These were Haloxyfop, a rare pesticide and N-Nitroso-di-n-propylamine.

A third compound, the pharmaceutical Ranitidine (Zantac), was rated as if it were an NDMA precursor that could convert 100% into NDMA. The California notification level of 10 ng/L was used and resulted in an ICRQ of 6.0. This is an unrealistic assumption on conversion to NDMA and hence an overly conservative ICRQ. Notwithstanding, NDMA could be effectively removed by high dose UV if required.

The ICRQ for the remaining 29 detected chemicals, based on the maximum Luggage Point secondary effluent concentration, was less than 1.0. This implies that for these chemicals, even without treatment, they could be at safe drinking water levels.

An additional 82 chemicals were tested for at Luggage Point but were not detected in all samples. The remaining 109 chemicals excluded from WRF Project No. 4960 were not analysed for in the Luggage Point secondary effluent. The full list of cross-checked exclusions is available in Appendix A.

Table 5-8 summarises chemicals found in Luggage Point secondary effluent at concentrations greater than the limit of reporting that were excluded from WRF Project No. 4906, along with the reason for exclusion from WRF Project No. 4960 and the maximum occurrence in the Luggage Point water quality report.

Table 5-8: Chemicals Omitted from WRF Project No. 4960 Assessment that were Detected in Luggage Point Effluent, the Detected Concentration and the ICRQ

Name	Reason Omitted from WRF4960	Maximum Detected Luggage Point Concentration (mg/L)	Guidance Value (mg/L)	Guidance Source	ICRQ
Ranitidine	Discontinued or restricted pharmaceutical	0.00006	0.00001[(1)]	Not Available[(1)]	< 6
Haloxyfop	Rare pesticide	0.0035	0.001	ADWG	3.5
N-Nitroso-di-n-propylamine	Impurity only	0.00001	0.000005	CA Toxics Rule	2
Cholesterol	Biological origin	0.0044	0.007	AGWR Phase 2 2008	0.6
Ethoprophos	Rare pesticide	0.000474	0.001	ADWG	0.5
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	Rare pesticide	0.018	0.04	ADWG	0.5
1,7-dimethylxanthine	Metabolite	0.0003	0.0007	AGWR Phase 2 2008	0.40
Triclopyr	Rare pesticide	0.0076	0.02	ADWG	0.38
Bromoxynil	Rare pesticide	0.0031	0.01	ADWG	0.31
N-Nitrosodiethylamine	Byproduct only	0.00002	0.0001	CA Notification Level	0.20
Terbuthylazine	Rare pesticide	0.0015	0.01	ADWG	0.15
Mecoprop	Rare pesticide	0.0013	0.01	WHO DWG	0.13
Diuron	Rare pesticide	0.0015	0.02	ADWG	0.08
Cyanazine	Rare pesticide	0.00003	0.0006	WHO DWG	0.05
Tebuconazole	Rare pesticide	0.0076	0.17	CA Pesticide Regulation	0.04
Baygon	Rare pesticide	0.00006	0.003	USEPA HAL	0.02
2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T)	Rare pesticide	0.00013	0.009	WHO DWG	0.01
Fluometuron	Rare pesticide	0.00096	0.07	ADWG	0.01
Diazinon	Rare pesticide	0.00005	0.004	ADWG	0.01
Metsulfuron-methyl	Rare pesticide	0.00041	0.04	ADWG	0.01
Metolachlor oxanilic acid[2]	Pesticide metabolite	0.0018	0.3	AGWR Phase 2 2008 (based on Metolachlor)	0.006
Metribuzin	Rare pesticide	0.00025	0.07	ADWG	0.004
Hexazinone	Rare pesticide	0.001	0.4	ADWG	0.003
Carbendazim	Rare pesticide	0.0001	0.09	ADWG	0.001
Methomyl	Rare pesticide	0.000018	0.02	ADWG	0.0009
Ametryn	Rare pesticide	0.00004	0.07	ADWG	0.0006
Tebuthiuron	Rare pesticide	0.00023	0.5	USEPA HAL	0.0005
Terbutryn	Banned pesticide	0.00008	0.4	ADWG	0.0002
Clopyralid	Rare pesticide	0.0003	2	ADWG	0.0002
4,4'-DDT	Banned pesticide	1.2E-06	0.009	ADWG	0.0001
Bromacil	Rare pesticide	0.00002	0.4	ADWG	0.00005
Imazapyr	Rare pesticide	0.00012	9	ADWG	1.33E-05

1. Ranitidine safe drinking water guidance levels were unavailable. It was noted that 94% conversion of Ranitidine to NDMA was possible (with unrealistically high applied doses of chloramine 28 mg/L). To that end, the CA notification level of 10 ng/L for NDMA was used to evaluate a risk quotient for Ranitidine assuming 100% conversion. This evaluation is likely overly conservative. NDMA could be effectively managed through higher dose UV and should be determined by site specific occurrence measurements for UV design.

5.5 Process Related Chemical Risks

Chemical risks specific to how a potable reuse train is operated were identified based on review of recent literature related to CBAT and RBAT processes. This review shows that the majority of the chemical risk is associated with formation of DBPs, which, with the exception of NDMA and NMOR, were not assessed as part of WRF Project No. 4960. The most widely reported DBPs included nitrosamines, bromate, trihalomethanes (THMs) and halo acetic acids (HAAs). The key considerations for process related chemical risks are summarized in Table 5-9, and elaborated on in Appendix C.

Table 5-9: Process Related Chemical Risk Summary

Chemical Class	Causes	Risk	Process	Mitigation Strategies (Refer to Appendix C for further details)
Bromate	Oxidation of bromide by ozone	Carcinogen, the 10 ug/L California maximum contaminant level (MCL) for bromate represents a 10^{-4} excess lifetime cancer risk.	Formation potential during ozonation	Chlorine Ammonia process Hydrogen Peroxide addition to convert ozone to hydroxyl radicals pH Depression
NDMA/ Nitrosamines	Chloramination and ozonation of wastewater, incomplete upstream removal of nitrogen (in particular ammonia). Biofiltration under anoxic denitrifying conditions forms NDMA.	Carcinogen, the 10 ng/L notification level for NDMA in California reflects a 10^{-5} lifetime excess cancer risk.	Formation potential during ozone/BAC Formation potential during disinfection/biocide addition	BAC treatment under aerobic conditions (i.e. avoiding anaerobic conditions) UV/AOP
THMs and HAA5s	Chlorine disinfection, high total organic carbon (TOC) level	Carcinogen	Formation potential during chlorination	TOC minimization prior to chlorine disinfection (e.g. coagulation/flocculation/sedimentation, ozone/BAC, GAC or RO) High UV/AOP dose
Cyanide	Reaction of chlorine with nitrate or nitrite	Nerve damage, thyroid problems	Formation potential during chlorine disinfection	Nitrate removal
Aldehydes	Ozonation and chlorination	Adversely affect drinking water stability	Potential formation during ozonation, disinfection, UV/AOP	Monitoring of formaldehyde removal by BAC as a surrogate. Optimization and demonstration of disinfection and UV/AOP

6 NEW TOOLS

New tools are being developed for use in prioritization and risk assessment of constituents of emerging concern (CECs). The ECHIDNA database, developed by Water Research Australia, has focused on a different approach to prioritization of chemicals in the environment. It includes categorical ratings based on persistence and human health impact and also some information on raw wastewater occurrence and treatment process removal.

ECHIDNA focuses on all CECs – that is, chemicals that do not yet have a strict guideline or regulatory limit by which safety can be measured. ECHIDNA is also not necessarily limited to chemicals of industrial origin, and therefore provides a broader approach to chemical hazard identification. Unfortunately, there is no present function to bulk export data from the ECHIDNA database and there are not consistently available removals presented for a majority of treatment processes of relevance to the entire water reuse train. However, once this information becomes available, a similar mass screening approach could be applied as was done in this work. Use of ECHIDNA would be proactive and advantageous, as using this database would provide inclusion of another 1,600 plus chemicals that do not necessarily have established guidance values at this time.

7 CONCLUSIONS AND RECOMMENDATIONS

This report presents a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW. The assessment was conducted using paradigms developed in WRF Project No. 4960[14] for chemicals of industrial origin to provide indication of possible chemical risk and to provide an example of how to better understand and prioritize chemicals of concern – as a first step in understanding potential chemical risks in the absence of detailed scheme-specific source water information. Further assessment of chemical risk will need to be conducted when sufficient catchment specific data becomes available for any scheme which is to be progressed. The approach described in this memorandum can be used to guide the future detailed, quantitative chemical risk assessment. Further assessment with ECHIDNA could also be considered. Further investigations required to support a future detailed chemical risk assessment would include, but not be limited to:

- Source characterisation (refer to the *Purified Recycled Water for Drinking Investigation Project Report* completed as part of the PRW Investigations for further information on source characterisation, and the material developed in the AGWR [1] and WHO (2017, [13]);
- Development of an enhanced source water control program (including a detailed study of all dischargers and the chemicals they use that could end up in the sewer);
- Demonstration plant testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water and their removal through the various unit processes within the demonstration advanced water treatment plant; and
- Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available.

Any future detailed chemical risk assessment should incorporate consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1]. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, such as the Australian Drinking Water Guidelines, World Health Organization guidelines, etc. should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP. The detailed risk assessment would be a "live" document and updated over the operational life of the AWTP based on changes in the source water characteristics and/or changes or additions to the guideline values.

[14] A cancer risk level of one-in-ten-thousand is applied by the US EPA when deciding whether cancer or non-cancer risk levels provide more meaningful scenario-specific risk reduction [4]. The AGWR uses a risk target on one-in-one-million for non-threshold chemicals whose carcinogenicity has been characterised by experimental determination of potency (i.e. by derivation of a 'slope factor') [1]. Health guideline values derived in the AGWR using the one-in-one-million risk target "is taken to mean that, if a population of one million people were to consume water at the guideline concentration for a lifetime, then one additional cancer might plausibly be expected to occur" [1]. Hence, the RSD used for this assessment is less conservative than if the RSD were developed based on the AGWR risk target. However, this is not important for this assessment as this screening process is used to demonstrate a methodology as to how chemicals could be prioritised for further investigation. Future detailed chemical risk assessment will need to include consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1] and ensure that the RSD used aligns with the one-in-one million AGWR risk target. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, including the Australian Drinking Water Guidelines, World Health Organization guidelines, etc should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP.

ICRQ cutoff values would be two orders of magnitude lower (i.e. 0.002 and 0.01) when calculating ICSS and ICRQ based on the AGWR risk target of one-in-one-million. It is imperative that the approach used is consistent (i.e. the acceptable risk target must be consistent across calculations). As noted previously, the risk target selected does not effect the prioritisation of chemicals for further investigation. However, using the correct risk target is critical when establishing the guideline to be used for acceptable concentration of a given chemical in PRW.

Based on this assessment, PFAS appears to be a broad concern for all proposed treatment trains. This concern is driven almost solely by the risk to human health posed by these compounds[15].

A further concern is the origin of PFAS. While landfill leachate may contribute a significant load, it is equally possible that a majority of the load originates from households. It is recommended that chemical characterisation of leachate be compared to raw wastewater to determine the potential extent of contamination for this source for any schemes carried forward for further consideration. If leachate is shown to be a significant contributor of chemical load, then segregation from a potable reuse scheme or enhanced point source treatment may be more effective than addition of further unit operations to the potable reuse treatment train.

This assessment indicated that the permitted Trade Waste volume was likely to be consistently less than 4% of the volumetric load for Scheme Chemical Risk Type A and B (sourced from Lismore) – subject to confirmation through a more detailed evaluation. The volumetric load of Trade Waste for Byron is also about 4%. Both catchments include landfill leachate. Leachate is treated onsite to some extent for East Lismore, but Byron STP receives leachate with no prior treatment.

Hospital and aged care waste may be of concern, but volumetric contributions appear to be low. Similarly, there are automotive and machine work related industries in the catchment. An assessment of chemicals of industrial concern in the raw wastewater should be conducted for any schemes carried forward for further consideration to better understand if these industries contribute significantly to chemical load.

While chemical risk is highly specific to individual catchments, the high-level analysis of the catchments (i.e. lower percentage trade waste, limited heavy industry) gives some indication that risks could be similar to or lower than a typical catchment, including the Seqwater data considered in this work.

As discussed in Section 3, both RBAT and CBAT process trains similar to the conceptual process trains selected for the PRW Investigations have been demonstrated to provide robust treatment for compounds of concern. This high-level chemical risk assessment did not identify any issues that would drive recommending additional chemical barriers to be included in the conceptual process trains (noting that the potential need for further unit processes to address chemical risk is considered in the *AWTP Process Trains Memorandum*).

Therefore, this analysis effectively shows the proposed treatment trains should provide good control of chemical risk in the proposed catchments, where the underlying chemical risk of the proposed catchment is expected to be lower than or similar to a typical catchment. This however does not significantly reduce the overarching uncertainty of actual chemical risk of the source catchments, nor does it negate the need for detailed source characterisation, AWTP demonstration testing, implementation of enhanced source control, or ongoing monitoring of chemical indicators and surrogates.

[15] The current Australian Drinking Water Guideline (ADWG) limits for PFAS are 1) for PFOS and PFHxS, the limit is a combined total of less than 0.07 µg/L and 2) for PFOA, the limit is less than 0.56 µg/L [26]. Currently, the National Health and Medical Research Council (NHMRC) is conducting an independent review of the ADWG health-based guideline values for PFAS, including examining recent international PFAS guidance and reviews, such as the recommendations from the United States Environmental Protection Agency, to determine if the current NHMRC advice remains appropriate (https://www.nhmrc.gov.au/about-us/news-centre/nhmrc-update-australian-drinking-water-guidelines). On April 10, 2024, EPA announced the final National Primary Drinking Water Regulation for six PFAS compounds: PFOA – 4 mg/L, PFOS – 4 ng/L, PFHxS – 10 ng/L, PFNA – 10 ng/L, HFPO-DA – 10 ng/L, Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS – 1 Hazard Index (https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas)

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APPENDIX A: CHEMICAL RISK ASSESSMENT DATA (REFER TO SPREADSHEET PROVIDED)

APPENDIX B: TRADE WASTE

B. TRADE WASTE

Trade Waste is received at Lismore City Council and Byron Shire Council plants in the form of permitted network inputs, tankered waste and leachate. Trade Waste data relevant to the STPs in both councils have been analysed and are summarised in Section B.1 and B.2.

B.1 Lismore City Council

Discharges of non-domestic wastewater to Lismore City Council plants primarily come from liquid Trade Waste received via the sewer network at both Lismore South STP and Lismore East STP. Lismore City Council maintains Trade Waste discharge permits for these network inputs, with close to 300 clients in the catchment of both plants.

The dischargers are summarised by business type in Table B-1. Note that Table B-1 shows only dischargers holding permits with non-zero discharge volumes. The values shown in Table B-1 are the volumes permitted to be discharged, not actual volume discharges (as this data was not available). The vast majority of dischargers include restaurants, cafes, supermarkets and other food-related businesses. The second largest group of dischargers includes mechanical repair workshops and service industry.

Table B-1: Summary of Trade Waste Dischargers with Non-Zero Discharge Permits to Lismore City Council STPs

Discharger Type	No. of Permitted Dischargers	Total Volume Permitted (kL/d)
Administration Office	1	1.8
Automotive-related	10	2.5
Club	5	9.7
Food Processing	3	5.5
Food-Related	113	126.8
Function Centre	1	2.0
Government Service	9	5.6
Hotel/Accommodation	7	10.4
Laboratory	2	1.6
Laundry	4	5.2
Mechanical Repair Workshop	52	37.9
Medical	8	17.0
Metal Finishing	2	2.2
Nursing Home	2	4.0
Preschool	1	1.0
Recycling	2	5.2
Retail	6	7.4
School	8	6.0
Service Industry	21	16.2
Service Station	3	2.4
Swimming Pool	2	0.4

Food-related businesses do not generally pose a threat to potable reuse schemes. Businesses of concern would include hospitals and other medical facilities, service industry, auto-related businesses (including mechanical repair), as these Trade Waste customers are more likely to discharge pollutants that are either untransformed across sewage treatment and advanced treatment processes, or impact certain treatment processes negatively. No heavy industry inputs are noted in the discharger data in Table B-1.

If a PRW scheme involving Lismore plants is implemented, additional investigations into the nature of Trade Waste discharges, particularly from medical facilities, service industry and auto-related businesses (including mechanical repair), should be investigated. Additionally, comprehensive contaminant characterisation and monitoring programmes need to be undertaken as part of source characterisation and enhanced source control.

Values in Table B-1 do not include landfill leachate. Lismore City Council holds a licence to discharge leachate to East Lismore STP, after pre-treatment through a vertical flow wetland. However, the licence also allows other disposal options. It is understood that the vertical flow wetland is currently not in operation. However, this leachate is pre-treated via a containerised plant (flocculation, pH adjustment, GAC and algal treatment to reduce PFAS). Lismore City Council have indicated other options to divert/discharge leachate are being considered, but there is no clear plan yet. Volume data has been requested but not received at the time of writing.

B.2 Byron Shire Council

Discharges of non-domestic wastewater to Byron Shire Councils plants come from multiple sources. These sources are:

- Liquid Trade Waste received via sewer network at both Byron STP and Brunswick Valley STP;
- Backwash waste from sand filters at Mullumbimby Water Treatment Plant, delivered to Byron STP by tanker;
- Leachate BSC Resource Recovery Centre, delivered to Byron STP by tanker:
- Tankered liquid waste to Byron STP, categorised into two types:
  - Low-strength commercial; and,
  - Low-strength domestic.

Table B-2 provides a summary of the total volumes of tankered liquid waste and leachate delivered to both Byron STP and Brunswick Valley STP. Note that Brunswick Valley STP does not receive tankered waste or leachate.

Table B-2: Summary of Leachate and Tankered Liquid Waste to Byron STP, Calendar Year 2022.

Discharger	Total Volume Discharged to Byron STP, 2022 Note 1 (kL/year)	Description
Resource Recovery Centre	12,500	Leachate
Mullumbimby Water Treatment Plant	890	Backwash waste from sand filters at the WTP, which are dosed with soda ash and alum.
Low-Strength Domestic Tankered Waste	840	
Low-Strength Commercial Tankered Waste	2,770	

Notes:

1. Data from January 2022 to December 2022. This calendar year is representative of previous years.

Table B-3 summarises liquid Trade Waste discharged to the network to both Byron STP and Brunswick Valley STP, categorised by customer type. Unless otherwise noted in Table B-3, these discharge volumes are estimated based on an assumption of a discharge factor applied to metered potable water consumption, depending on the customer category.

Table B-3: Summary of Trade Waste Dischargers Volumes to Byron STP and Brunswick Valley STP during 2022

Discharger Type	Total Volume Discharged to Byron STP (kL/year)	Total Volume Discharged to Brunswick Valley STP (kL/year)	Total Volume Discharged to Both STPs (kL/year)
Food-related/Hospitality Note 1	6,696	6,126	12,821
Medical	2,546 Note 2	227	2,773
Club	1,602	2,406	4,008
Construction	30	0	30
Mixed Industry	8,909	2,922	11,831
Food Processing	639	947	1,586
Hotel/Accommodation	15,170	2,333	17,502
Laundry	245	0	245
Mechanical/Auto	2,123	624	2,747
Panel Beater	32	0	32
School/Education Facility	5,484 Note 3	52	5,536
Service Station	5,976	230	6,206
Retail	8,641	748	9,388
Total	**58,093**	**16,613**	**74,706**

Notes:

1. Related to restaurants, cafes, takeaways and other hospitality-related businesses.
2. The Byron Bay Hospital (categorised as a "Medical" discharger) uses a magflow meter for more accurate readings of discharge volume. This hospital accounts for greater than 95% of the volume discharged under the "Medical" category.
3. The SAE College (categorised as a "School/Education Facility" discharger), uses a magflow meter for more accurate readings of discharge volume. This facility accounts for roughly half the volume discharged under the "School/Education Facility" category.

As in the case of the Lismore catchments (Section B.1), the majority of network dischargers in the catchment of these two plants include food-related and hospitality businesses. However, there are also network inputs from medical, auto-related and mixed industry dischargers to both plants. Additionally, there are inputs of leachate, WTP waste and commercial waste tankered directly to Byron STP. No heavy industry inputs are noted in the discharger data in Table B-3.

If a PRW scheme involving Byron Shire Council plants is implemented, additional investigations into the nature of these higher-risk discharges, particularly from medical facilities, mixed industry, auto-related businesses (including mechanical repair), leachate and commercial tankered waste, should be investigated. Additionally, comprehensive contaminant characterisation and monitoring programmes need to be undertaken as part of source characterisation and enhanced source control.

APPENDIX C: PROCESS RELATED RISKS

C.1 BROMATE

Bromate is a known carcinogen that is regulated in the USA with an MCL of 10 ug/L. Bromate formation occurs when its precursor, bromide, is oxidized through ozonation of water. Typically, ozonation can lead to bromate generation in matrices containing greater than 20 ug/L of bromide [14]. Given this formation pathway, bromate formation is more of a concern for CBAT trains than RBAT trains. Other factors that have a documented effect on bromate formation include natural organic matter, temperature, pH, and alkalinity [15].

When ozone is added to water, it reacts with compounds present in the water resulting in its decomposition to the hydroxyl radical. These reactions are complex and depend on a variety of factors, with a strong dependence on pH. [16] For the purposes of illustrating bromate formation to allow understanding of potential mitigation strategies discussed below, Figure C-1 provides a simplistic description of the formation pathways for bromate due to ozone addition [17] (a more detailed, but still simplified, diagram of bromate formation mechanism during ozonation of bromide containing waters is provided in reference [16]).

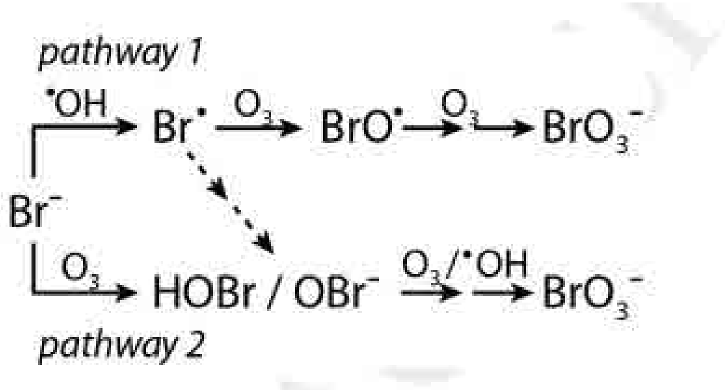

Figure C-1: Simplified Bromate Formation Pathways

During the ozonation process, the ratio of ozone to TOC in the water can be controlled to limit bromate formation. Recommendations for an optimal ozone:TOC ratio vary between 0.6 to 0.9 mg ozone/mg TOC, with evidence of an increase in bromate at a ratio as low as 0.4 mg ozone/mg TOC [14], [18]. However, limiting this ratio as a means of controlling bromate results in a decrease in the C.t.[16], reducing disinfection achieved by ozone following a C.t. concept. Virus and bacteria disinfection have been demonstrated in the absence of C.t., using the ozone:TOC ratio, after accounting for ozone demand from nitrite, to predict virus and bacteria disinfection performance [19]. Other mitigation strategies are described below, each with potential drawbacks [15]:

- Chlorine-ammonia process: Free chlorine is dosed to oxidize bromide to hypobromous acid. The subsequent addition of ammonia prior to ozonation forms bromamines, which sequesters the bromide and prevents it from forming bromate. However, NDMA may be formed with this strategy.
- Hydrogen Peroxide Addition: Hydrogen peroxide can be used to quench hypobromous acid, however in this strategy ozone reacts preferentially with the hydrogen peroxide instead of microorganisms, reducing disinfection efficacy. The effectiveness of hydrogen peroxide addition also depends strongly on the specific wastewater matrix.
- pH Depression: As shown in Figure C-1, the presence of the hydroxyl radical is necessary for the bromate formation pathway from ozone oxidation, so depressing the pH is another mitigation strategy as pH depression lowers the rate of hydroxyl radical production [17]. However, both ozone and the hydroxyl radical are necessary for removal of micropollutants, which is one of the main goals of ozone/BAC.

[16] C.t. = concentration of ozone times contact time

C.2 NDMA/NITROSAMINES

Nitrosamines are carcinogens that occur in raw sewage and certain industrial discharges, with NDMA and NMOR being the most commonly detected nitrosamines in primary effluent [20]. While nitrosamines are not currently regulated in the USA, California has a notification level of 10 ng/L for NDMA. Formation of NDMA is associated with chloramination and ozonation of wastewater, often because of the incomplete removal of nitrogen in upstream wastewater treatment processes.

Chloramination, even at higher doses, does not result in the levels of NDMA formation seen with ozone oxidation [20]. While the specific precursors and reaction pathways may differ with oxidant type, in both cases precursor loadings are largely dominated by domestic sources except for where specific industrial discharges featuring elevated NDMA or NDMA precursor concentrations contribute significantly to the flow to a STP [21].

Strong correlations have been observed between nitrosamine formation and ammonia, natural organic matter content, hydrazine compounds, carbamate compounds, semicarbazide compounds, tertiary and quaternary amines, and formaldehyde. Common sources of N-nitrosamines include beverages, food, consumer products, chlorinated water, and polymers [15].

Cationic treatment polymers (e.g. polyDADMAC and Mannich polymers) feature amine functional groups that can be strong precursors for nitrosamine, and especially NDMA, formation [20]. PolyDADMAC is a commonly used coagulant aid polymer [15]. Mannich polymers are used for sludge management to control foam in the mixed liquor and to enhance settling in the secondary clarifiers [22]. Use of polymers in the source STPs should be investigated to understand the risk of their presence in the secondary effluent and the associated risk of increased NDMA formation potential.

BAC systems have been shown to offset NDMA formation from ozonation by removing 50% to 90% of the NDMA in the feed to the BAC. NDMA removal of 90% has been demonstrated using an empty bed contact time of 10 minutes [18]. However, biofiltration under anaerobic denitrifying conditions forms NDMA [15]. This is a concern because incomplete nitrogen removal can also lead to NDMA formation, especially if chlorine is added to the filter effluent [14]. Dissolved oxygen and ORP could be monitored in the BAC effluent to confirm that aerobic conditions within the biofilter are being maintained and that excessive NDMA formation is unlikely.

Additionally, in a study on a treatment train representative of a typical RBAT train in California, RO membranes averaged an NDMA rejection of 31%. A similar treatment train that was preceded by ozonation only achieved an average RO NDMA rejection of 22%. Removal of NDMA by UV systems varies by treatment train but is consistent with first-order removal [22].

One study found that an RBAT system was more effective for the removal of chloramine-reactive NDMA precursors than a CBAT system, even though the median NDMA concentration measured after ozone/BAC was lower than that for membrane filtration/RO. Overall, these results still suggest that a CBAT system is more efficient than the membrane filtration/RO system for the control of NDMA. However, a CBAT system is far less efficient for the control of NMOR, the second most commonly found nitrosamine, which is poorly removed by BAC [21].

C.3 THMS AND HAAS

THMs and HAAs are both known carcinogens regulated in the USA by MCLs. Total THMs in finished drinking water must adhere to an MCL of 0.08 mg/L and HAA5 (the sum of the five regulated HAAs) must adhere to an MCL of 0.06 mg/L.

Chlorinated and brominated analogues of THMs and HAAs are primarily associated with chlorine disinfection. Predominant precursors are believed to be phenolic moieties of humic substances present as part of the dissolved organic carbon of a water. Formation frequently correlates with UV 254 because phenols absorb light strongly at this wavelength. While chloramines also generate THMs and HAAs, the generation rate is far lower because chloramines are weaker oxidants. However, iodinated THMs and HAAs formation is typically greater with chloramination [20].

Effluent TOC levels from BAC systems are higher than permeate TOC levels from RO systems. One study reports BAC effluent TOC levels as being on average 17 times greater than RO permeate TOC levels, calculated using samples ranging from 2.0-5.0 mg/L TOC in BAC effluent and 0.1-0.8 mg/L TOC in RO permeate [14]. This results in a substantial difference in precursors to form THMs. The average THM formation potential in a BAC system has been documented as 281 ug/L, compared to an average THM formation potential in an RO system of 8.7 ug/L [13]. Formation potential test results exceeding a limit do not imply that the limit will be exceeded, as the test is designed to maximize conversion of all possible THM precursors.

The average HAA is also higher for the BAC system (137.2 ug/L) than the RO system (3.7 ug/L). The difference in HAA formation potentials is likely similarly related to RO's higher removal of TOC. However, use of upstream disinfection to minimize biological growth in RO systems can lead to higher THM and HAA concentrations in the RO permeate compared to BAC effluent [13].

To better control THMs and HAAs in CBAT systems, TOC controls such as an enhanced coagulation/flocculation/sedimentation (or filtration) step upstream of the ozone/BAC system may help if THM of HAA formation is an issue. In addition to upstream TOC removal, UV/AOP systems have been documented as a potential mitigation step for THM and HAA. For UV doses of less than 500 mJ/cm^2, UV/hydrogen peroxide advanced oxidation did not significantly affect THM and HAA formation in subsequent chlorination processes. However, higher UV doses (>1,000 mJ/cm^2), which are more typical of AOP in potable reuse, resulted in approximately 50% lower concentrations of THMs and HAAs [23].

C.4 ADDITIONAL CHEMICAL RISKS

Cyanide, which can lead to nerve damage or thyroid problems, has an MCL of 0.2 mg/L. Cyanide has been cited as an additional concern due to its detection above the MCL in pilot experiments after chlorine disinfection, despite not being detected in the pilot influent. In past reports, the presence of cyanide was attributed to the reaction of chlorine with nitrate or nitrite. In the presence of chlorine, nitrate and nitrite can be converted to nitric and nitrous acid, which can subsequently react with organic compounds to form intermediate oximes, nitro-alkenes, and hydroxamic acids. These compounds can break down to produce cyanide [15]. The removal of nitrate and nitrite upstream of chlorine disinfection can help mitigate this risk.

Aldehydes can form during ozonation or chlorination, although ozonation produces significantly larger concentrations of aldehydes than chlorination [20]. UV/hydrogen peroxide oxidation can result in the formation of aldehydes and carboxylic acids at UV doses above 500 mJ/cm^2 [23]. Aldehydes are known to adversely affect drinking water stability, although no mitigation strategies are presented in the literature reviewed. Monitoring of formaldehyde is recommended across ozone/BAC to confirm that 1) low molecular weight neutral compounds are managed and 2) that formaldehyde is not generated to an excessive level by ozonation.

APPENDIX E: AWTP PROCESS TRAINS MEMORANDUM

Rous County Council
Purified Recycled Water Investigations
Memorandum – AWTP Process Trains

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This disclaimer shall apply notwithstanding that the report may be made available to other persons for an application for permission or approval or to fulfil a legal requirement.

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ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AOP	Advance Oxidation Process
AWTP	Advanced Water Treatment Plant
BAC	Biologically Active Carbon
CBAT	Carbon-Based Advanced Treatment
CCPP	Calcium Carbonate Precipitation Potential
CCP	Critical Control Point
CIP	Clean-In-Place
C.t.	Concentration x Contact Time
DALY	Disability Adjusted Life Year
DPR	Direct Potable Reuse
EBCT	Empty Bed Contact Time
GAC	Granular Activated Carbon
IPR	Indirect Potable Reuse
HRT	Hydraulic Retention Time
LMH	Litres per Square Meter per Hour
LRV	Log Reduction Value
LSI	Langelier Saturation Index
MBBR	Moving Bed Bioreactor
ORP	Oxidation-Reduction Potential
PDT	Pressure Decay Test
PRW	Purified Recycled Water
PFAS	Per- and Polyfluoroalkyl Substances
RBAT	RO-Based Advanced Treatment
RCC	Rous County Council
RO	Reverse Osmosis
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
UF	Ultrafiltration
UV	Ultraviolet Light Disinfection
WRF	Water Research Foundation
WHO	World Health Organization
WTP	Water Treatment Plant

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1 INTRODUCTION

1.1 BACKGROUND

Rous County Council (RCC) is investigating the potential to utilise purified recycled water (PRW) as a climate resilient source of water for supply of potable water. As part of the *Purified Recycled Water for Drinking Investigations* project, it is necessary to develop conceptual advanced water treatment plant (AWTP) process trains to allow for:

- Development of capital cost estimates for each short-listed potable reuse scheme;
- Identification of site configuration and area requirements (needed to identify suitable locations for each AWTP);
- Determination of return streams and impacts of these on the sewage treatment plant (STP);
- Identification of potential discharges to the environment (e.g. reverse osmosis (RO) concentrate);
- Determination of operation and maintenance requirements and associated costs;
- Engagement with regulators (as part of demonstrating the focus on protection of public health in the investigations); and,
- Setting expectations for RCC stakeholders regarding the nature and attributes of the treatment processes.

The investigation has short-listed various scheme options for use of PRW, including:

- Indirect potable reuse (IPR) via surface water augmentation – PRW produced using source water from the East and South Lismore STPs is discharged to a new engineered storage which acts as an environmental buffer. Water from the Wilsons River Source may also be directed to the dam to potentially provide improved utilisation of this source. Water from the Engineered Environmental Buffer Storage is pumped to Nightcap WTP for further treatment;
- Direct potable reuse (DPR) via raw water augmentation – PRW produced using source water from the Lismore STPs is blended with water from Rocky Creek Dam and/or Wilsons River Source, and fed directly to the start of the Nightcap Water Treatment Plant (WTP) process without an environmental buffer;
- DPR via treated water augmentation:
  - PRW produced using source water from the East Lismore STP (and possibly South Lismore STP, based on the adopted blend ratio) is blended with treated water in the distribution system from Nightcap WTP:
    - New connections from the AWTP to the City View, Belvedere Drive, High Street and Ross Street Reservoirs with flow meters and flow control valves to allow control of the blend ratio at each reservoir based on influent flow;
  - PRW produced using source water from the Byron and Brunswick Valley STPs is blended with treated water in the distribution system from the WTP in the drinking water distribution system:
    - A new connection from the AWTP to the St Helena Reservoir with flow meters and flow control valves to allow control of the blend ratio into this reservoir
    - A new rising main to carry PRW from the offtake at St Helena Reservoir to a new Blending Reservoir (located near the existing rising main branch that feeds Knockrow Reservoir), with flow meters and flow control valves to allow control of the blend ratio into this reservoir.
    - A new pump station to direct flow from the Blending Reservoir to Knockrow Reservoir via the existing rising main to Knockrow Reservoir[1].

To develop the AWTP process trains for the various schemes, target pathogen removal requirements need to be established. In addition, chemical risks also need to be addressed by the AWTP process trains. Minimum pathogen log

[1] It may be possible to develop a system without the need for a new pump station, but detailed hydraulic analysis/modelling would be required. This should be investigated if this option is taken forward.

reduction value (LRV) targets adopted for the investigation are detailed in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (see Appendix A). A high-level chemical risk assessment has been conducted based on the process trains presented in this memorandum (see Appendix B). The conclusions of these two appendices are summarised in Sections 4 and 6.

1.2 Purpose and Scope

The purpose and scope of this memorandum is:

- To summarise the estimated pathogen removal credits for the STPs and Nightcap WTP to be considered in the development of the conceptual AWTP process trains;
- To summarise the minimum pathogen log reduction value (LRV) targets adopted for the investigation, as derived and detailed in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (included in Appendix A);
- To present the proposed conceptual AWTP process trains for each short-listed scheme; and,
- To summarise the outcomes of the chemical risk assessment for the proposed conceptual AWTP process trains performed as part of the overall PRW investigations (included in Appendix B).

2 SEWAGE TREATMENT PLANTS

2.1 STP PATHOGEN REDUCTION

The secondary wastewater treatment process provides a level of pathogen removal and hence can be considered a barrier for pathogens. Table 2-1 summarises the pathogen LRV assumed for secondary treatment at the Lismore and Byron STPs (further description is provided in Appendix A in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development*).

Table 2-1: Pathogen LRV for Secondary Treatment of Wastewater at Lismore and Byron STPs

Treatment Process	LRV			Online analysers for verification
	Virus	Protozoa	Bacteria[1]	
Secondary Treatment	0.5	0.5	0.5	Ammonia – analysis results returned every 15 minutes Turbidity – continuously reporting analyser results[2]

1. The value of 0.5 LRV for bacteria claimed here is conservative. WHO [1] and Victoria Department of Health [2] both support an LRV of 1.0 for bacteria by an activated sludge STP process.
2. Critical control point (CCP) would require analyser reading to be above the critical limit for a defined time (e.g. > 10 NTU for more than 5 minutes) before the CCP would be considered breached.

The performance of the STP must be safeguarded through strict and relevant Trade Waste regulations (enhanced source control), the imposition of which is the first barrier on any PRW application.

The values shown in Table 2-1 are appropriately conservative for the purpose of developing the conceptual AWTP process trains and associated cost estimates. It is likely additional LRV could be claimed for the STP, but further site-specific study would be required to justify this.[2]

2.2 STP CHEMICAL REMOVAL

Removal of contaminants of concern (e.g. pharmaceuticals, endocrine disrupting compounds, personal care products, etc.) varies widely depending on the compound and the sewage treatment plant's process train [3]. To understand the likely removal of contaminants of concern, as will be essential to inform further development of any potable reuse scheme, the following would be required:

- A comprehensive source characterisation study to identify specific contaminants of concern present in the given catchments; and,
- Study of the contaminant removal performance within the source STPs, including targeted assessment for the specific compounds identified in the source characterisation study.

[2] References [1] and [5] suggest LRVs for all pathogen groups listed in Table 2-1 LRVs of up to 2 may be achievable, however site-specific investigations would be required to validate these figures.

3 NIGHTCAP WTP PATHOGEN REMOVAL

Two of short-listed scheme options direct PRW to the inlet of Nightcap WTP - IPR via surface water augmentation, and DPR via raw water augmentation. Table 3-1 summarises the LRVs claimed through the Nightcap WTP[3] process train within RCC's existing Drinking Water Management System, and the basis applied to their verification.

Table 3-1: Nightcap WTP LRVs

Treatment Process	Virus	Protozoa	Bacteria	Basis
Dissolved Air Flotation + Filtration	2	3.5	2	Effluent turbidity < 0.2 NTU 95% of the time and not > 0.5 NTU for > 15 min
Ozone	4	0.5	4	Ct value of 3.2 mg-min/L, based on achieving ozone residual of 0.135 mg/L
BAC	1	0.5	1	Effluent turbidity < 0.15 NTU 95% of the time and not > 0.3 NTU for > 15 min
Chlorine	4	0	4	Ct value of 16 mg-min/L, when > 1.2 mg/L free chlorine residual
Total	11	4.5	11	

Nightcap WTP has two different sets of treatment requirements to achieve the health-based targets in alignment with Australian Drinking Water Guidelines (ADWG) [4] – one for each of the Rocky Creek Dam and Wilsons River raw water sources due to the differing levels of protection to water quality provided by each of these catchments. As the Wilsons River is less protected than Rocky Creek Dam, higher pathogen LRVs are required for water sourced from the Wilsons River. Table 3-2 compares the total claimed LRVs to the pathogen removal required for the two source waters.

Table 3-2: Nightcap WTP Required versus Claimed LRVs

Pathogen	Claimed LRV	Rocky Creek Dam		Wilsons River	
		Required LRV	Difference	Required LRV	Difference
Virus	11	4	+7	6	+5
Protozoa	4.5	3	+1.5	5	-0.5
Bacteria	11	4	+7	6	+5

Table 3-2 shows that the Nightcap WTP provides surplus LRV for virus and bacteria for both water sources, and surplus LRV for protozoa for the Rocky Creek Dam source. The plant has a shortfall of 0.5 LRV for protozoa for the Wilsons River source, noting that this is acceptable under the ADWG [4] as the microbial health outcome target of 10^{-6} disability adjusted life years (DALYs) per person per year is applied as an operational benchmark (rather than as a pass/fail criteria).

[3] From an extract of a draft update to RCC's Drinking Water Management System, provided by email from Jeremy Wilson on August 1, 2023.

4 MINIMUM PATHOGEN LRV FOR PROTECTION OF PUBLIC HEALTH IN POTABLE REUSE SCHEMES

As discussed in Section 1.2, the rationale behind the selected minimum pathogen LRV requirements is described in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (included in Appendix A). This section summarises the outputs of that analysis.

Disability adjusted life years (DALY) convert the likelihood of infection or illness into burdens of disease. The Australian Guidelines for Water Recycling (AGWR) [5], ADWG [4] and World Health Organization (WHO) [6], [1] define a tolerable risk as 10^{-6} DALYs per person per year for each pathogen type (virus, protozoa and bacteria).

Disability adjusted life years dose (DALYd) is the dose of pathogens equivalent to a DALY of 10^{-6} per person per year. DALYd includes consideration of dose response[4], ratios of infection to illness and severity weighting of the illness.

Table 4-1 shows the minimum LRV required using the dose-response relationships, the relationships of infection to illness and the DALY per illness information provided in the ADWG [4] and raw wastewater pathogen concentrations as defined in WHO [1].

Table 4-1: Minimum LRV Required to Meet DALY of 10^{-6} in Drinking Water

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus / Adenovirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	20,000	2,700	7,000
DALYd	number per year	3.6×10^{-3}	4.2×10^{-3}	7.5×10^{-3}
Exposure	L/d	2	2	2
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	5.0×10^{-6}	5.8×10^{-6}	1.0×10^{-5}
Minimum Pathogen Removal	LRV	9.6	8.7	8.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**10.0**	**9.0**	**9.0**

Considering this project is in the early investigation stage without knowing future regulatory requirements, the approach for the conceptual AWTP designs and sensitivity analyses is described in Table 4-2. This approach is taken to ensure conservative, but reasonable in the Australian context, AWTP cost estimates are developed.

It is essential to note that the “excess LRVs” included in the targets listed in Table 4-2 have been considered <u>exclusively for the purpose of cost estimating, and do not reflect the opinion of the project team as required for the management of pathogen risks</u>. The final minimum pathogen LRV requirements used in design of the AWTP (which will be subject to consultation and agreement with regulators) should be based on pathogen barrier failure modelling with consideration of:

- The maximum LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere[5]);
- The failure mode of each unit process (i.e. instantaneous (e.g. disinfectant dosing system failure) or gradual (e.g. loss of UF membrane integrity which normally occurs slowly and can be seen by monitoring pressure decay test (PDT) trends);
- The response time of online analysers used for CCPs;
- The reliability and redundancy provided for these analysers (including consideration of the maintenance strategy for the analysers and the frequency of calibration);

[4] Relationship between dose of organism and incidence or likelihood of illness.
[5] Sylvestre et.al. [21] indicates that for a barrier with rapid loss in LRV performance credited with 6.0 LRV failure durations of 10 seconds per year need to be controlled, whereas for the same process claiming 4 LRV performance can be verified by controlling a failure of 15 minutes per year.

- The use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk[6]; and,
- Other design features used to mitigate risk (e.g. use of "off spec" diversions at CCP alert levels, use of Engineered Storage Buffer Tanks to allow for capture and diversion of water produced between analyser readings, etc.).

Table 4-2: Approach for Conceptual AWTP Designs and Sensitivity Analyses[1]

Scheme	Baseline AWTP LRV Basis	Sensitivity Analyses Basis
IPR via Surface Water Augmentation	Apply values from Table 4-1: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0	None
DPR via Raw Water Augmentation	Apply values from Table 4-1: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0 Assume blending of source water to and treatment in the downstream WTP is sufficient to manage the risk of barrier failure	Consider a worst case as aligning with <u>an excess LRV of 2 for all pathogen types</u> (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0
DPR via Treated Water Augmentation	Consider a case <u>of excess LRV of 2 for all pathogen types</u> (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0	Consider ***an absolute worst case*** as aligning with <u>an excess LRV of 4 for all pathogen types</u> (i.e. 100% redundancy) – i.e. the process would provide: Virus LRV – 14.0 Protozoa LRV – 13.0 Bacteria LRV – 13.0 **<u>It is not the opinion of the project team that this is suitable from a public health risk perspective, and is only presented to represent an extreme worst-case scenario for AWTP costing (with respect to pathogen removal).</u>**

1. See the *Minimum Pathogen Reductions for Potable Reuse Development* discussion paper (Appendix A) for further information on the approach presented in Table 4-2.

California has recently legislated minimum target LRVs for DPR [7]. It is demonstrated in the *Minimum Pathogen Reductions for Potable Reuse Development* discussion paper (Appendix A) that the California DPR minimum LRV targets <u>are excessively conservative</u> for use as a basis for the purposes of this investigation, based on:

- Different raw wastewater pathogen loads as compared to AGWR/WHO;
- Different tolerable drinking water pathogen concentration as compared to AGWR/ADWG/WHO (based on the difference between achieving 10^{-6} DALYs per person per year and limiting infections to 1 in 10,000 per person per year (which is the California approach)); and,
- Different assumptions for maximum claimable LRV per process unit (6 for California versus 4 assumed for the purposes of this investigation).

<u>To this end, the Discussion Paper identified that application of the proposed California DPR regulations would result in excessive treatment requirements, resulting in increased costs and complexity without providing meaningful improvements to public health protection.</u>

[6] More information on CCPs is provided in Section 19 of the *Purified Recycled Water for Drinking Water Investigations Project Report*. CCP critical limits would be set at the point where the claimed LRV would be breached. CCP alert limits would be set sufficiently below the critical limit to allow operations personnel to respond before the critical limit is reached.

5 AWTP PROCESS TRAINS

The conceptual AWTP process trains have been developed based on process technologies that have been proven in potable reuse applications elsewhere. The technologies applied to the conceptual AWTP process trains are shown in Table 5-1, along with the pathogen LRV claimed for each process, and the online analysis applied to verification of pathogen barrier integrity. The conceptual process trains described below are intended to provide a reasonable basis on which to develop costs and site area requirements. Significant additional work will be required to verify the pathogen LRVs claimed in Table 5-1, including:

- Confirming validated LRVs for equipment selected during design (e.g. UV disinfection); and,
- Confirming Claimed LRVs by testing in a demonstration AWTP (e.g. LRVs claimed for direct filtration via biologically active carbon (BAC)).

Table 5-1: AWTP Treatment Processes and Claimed LRV

Treatment Process	Claimed LRVs[1]			Online analysers for verification of CCP for Pathogen LRV
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)	
Ultrafiltration (UF)	0.0	4.0	4.0	Turbidity – continuously reporting analyser results PDT – daily
Ozone [2]	4.0	0.0	4.0	Influent total organic carbon (TOC) analyser – results returned every ten minutes Influent nitrite analyser – results returned every 15 minutes Ozone analyser for verification of applied ozone dose – continuously reporting analyser results pH analyser – continuously reporting results Ozone:TOC –value of mg ozone/mg TOC (corrected for nitrite) calculated automatically by the plant control system
BAC [3, 4]	1.0	2.0	1.0	BAC effluent turbidity (individual filters and combined effluent)– continuously reporting analyser results BAC also provides removal of compounds of concern that pose chronic health risks. Monitoring of the BAC for chemical removal performance is discussed in Section 6.2
Granular Activated Carbon (GAC)[5]	0.0	0.5	0.0	Refer to note 5 below with respect to claimed pathogen LRV GAC also provides removal of compounds of concern that pose chronic health risks. Monitoring of the GAC for chemical removal performance is discussed in Section 6.2
Reverse Osmosis (RO)[6]	1.5			Conductivity – continuously reporting analyser results
Ultraviolet Light Disinfection (UV) [7,8]	4.0			Flow – continuously reporting results UV transmittance – continuously reporting analyser results UV Intensity – continuously reporting analyser results
UV/Advanced Oxidation Process (AOP) [9, 10]	4.0			Flow – continuously reporting results UV dose – continuously reporting results UV transmissivity – continuously reporting analyser results Free chlorine – analysis results returned every 3 to 5 minutes to verify dose of free chlorine prior to UV

Treatment Process	Claimed LRVs[1]			Online analysers for verification of CCP for Pathogen LRV
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)	
Chlorine Disinfection[11]	4.0	0.0	4.0	Free chlorine residual – analysis results returned every 3 to 5 minutes Flow – continuously reporting results Chlorine C.t – automatically calculated by the plant control system based on flow and free chlorine residual

1. Claimed LRVs listed in Table 5-1 are consistent with minimum values listed in Table 5.6 of the ADWG [4], with the exception of ozone, which is based on ozone:TOC control as opposed to C.t, and GAC which is based on the USEPA Long Term 2 Enhanced Surface Water Treatment Rule [8]. See notes 2 and 5 for further information.
2. For the purpose of this investigation, it is assumed that the ozone system will be controlled based on ozone to TOC ratio (corrected for influent nitrite).– US Water Research Foundation Project 5129 (*Demonstration of Innovation to Improve Pathogen Removal, Validation and/or Monitoring in Carbon Based Advanced Treatment (CBAT) Potable Reuse*) has demonstrated that using ozone to TOC ratio (corrected for influent nitrite) is an accurate and controllable method to demonstrate up to 5 LRV of virus[7]. LRVs claimed are based on ozone to TOC (corrected for influent nitrite) of 0.8 mg ozone/mg TOC – an upper threshold adopted to limit bromate formation. An alternative control approach would be based on ozone C.t. (ozone concentration times contact time). Under this alternative approach, measurement of flow (to calculate contact time) and ozone residual (by continuously reporting online ozone analyser) would be CCPs, as would the calculated C.t. The WaterVal Ozone Disinfection Validation Protocol [9] indicates that up to 4 LRV for virus is achievable at an ozone C.t. of 1.4 mg-min/L at 15°C, with this same C.t. providing less than 0.25 LRV for *Cryptosporidium.*
3. Acting in a direct filtration mode of operation, with coagulation and flocculation upstream of the BAC filters. The *Cryptosporidium* LRV claimed for BAC in Table 5-1 is higher than that claimed for Nightcap WTP (Table 3-1). Nightcap WTP has upstream conventional filtration claiming 3.5 LRV for *Cryptosporidium*. RCC has assigned 0.5 LRV *Cryptosporidium* so as not to exceed a total of 4 LRV for the combined media filtration steps.
4. Preliminary results of pilot trials using a direct filtration configuration similar to that proposed here conducted at Hampton Roads Sanitation District in the United States have shown greater than 4 LRV for virus may be achievable.[8] The LRVs claimed in Table 5-1 for BAC are consistent with indicative pathogen LRVs listed in Table 5.6 of the ADWG for direct filtration . The actual LRVs claimable for the BAC in direct filtration would need to be verified, likely via an onsite demonstration trial.
5. USEPA allows a 0.5 LRV credit for *Cryptosporidium* when GAC is used as a second stage filtration, following a first stage of filtration that includes coagulation [8]. To receive this credit, 100% of the flow must be treated through both filtration stages and the combined and individual filter effluent turbidity must be reported for the first stage of filtration only. The two stages (BAC and GAC) claim a total *Cryptosporidium* LRV of 2.5 for this project, which is less than the total claimable *Cryptosporidium* LRV under the USEPA Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules [10], [8] (2 LRV under the Long Term 1 Rule (based on maintaining filter effluent turbidity under 0.3 NTU), an additional 1 LRV under the Long Term 2 Rule (based on individual and combined first stage filter effluent turbidity under 0.15 NTU), and an additional 0.5 LRV under the Long Term 2 Rule for second stage filtration – total claimable 3.5 LRV) and within the range listed in Table 5.6 of the ADWG [4] (range of 2.0 to 3.5 for direct filtration). It is likely that the Claimed LRV would need to be validated during demonstration plant operation and through challenge testing during plant commissioning.
6. Conservative LRVs have been claimed based on online measurement of influent and permeate conductivity. LRV of 2 could be claimed using online TOC analysis [11].
7. UV dose of 186 mJ/cm^2 for 4 LRV for virus based on US EPA [8]. The WaterVal UV Disinfection Validation Protocol also supports up to 4 LRV for all pathogen types [12].
8. UV LRVs have been limited to 4 (refer to *Minimum Pathogen Reductions for Potable Reuse Development* discussion paper (Appendix A)). Other jurisdictions (e.g. California) allow up to 6 LRV for UV (at higher UV dose).
9. UV dose for a UV/AOP system will be much higher than the 186 mJ/cm^2 for 4 LRV for virus based on US EPA [8], on the order of 500 mJ/cm^2 to 1,000 mJ/cm^2.
10. While disinfection via hydroxyl radical chemistry has been demonstrated for UV/AOP systems, it is not currently possible to monitor and properly control at this time. For the purposes of establishing AWTP process trains, it is proposed that UV/AOP

[7] Direct communication with Andy Salveson, Principal Investigator for Water Research Foundation Project 5129 – this work followed recommendations within the WaterVal Ozone Disinfection Validation Protocol [9] to obtain LRV credits with higher turbidity water and demonstrated virus LRV at turbidity of around 4 NTU.
[8] Direct communication with Andy Salveson from Carollo Engineers, who are involved in this pilot work.

pathogen Claimed LRV is based entirely from UV standard monitoring methods. The WaterVal UV Disinfection Validation Protocol supports up to 4 LRV for all pathogen types [12].

11. The WaterVal Chlorine Disinfection Validation Protocol supports up to 4 LRV for virus and bacteria [13]. Based on a pH of 7.0 and a minimum temperature of 15°C a C.t. of 4 mg-min/L has been assumed [13].

The assumptions applied to the claimed pathogen LRVs used in the design process train designs would be subject to significant additional investigations prior to finalisation of the AWTP process design (noting that higher LRVs than claimed here may be possible), including, but not limited to:

- Site-specific bench scale testing of source water (e.g. ozone decay);
- On site demonstration of treatment processes using intended source water;
- Review of performance of operating full-scale system;
- Review of advancements in technology over time (e.g. ability for real time monitoring of virus for UF LRV verification);
- Detailed risk assessment;
- Engagement with regulators; and,
- Potentially, input from an expert panel review.

The claimed pathogen LRVs would also likely be subject to onsite validation (e.g. challenge testing where suitable) and verification testing (e.g. water quality sampling) during commissioning of the plant prior to regulatory approval to add PRW to the drinking water supply.

If an online CCP analyser records a value in excess of the alert level for that CCP, the process (or process unit) would be taken offline, or the output flow from the process (or process unit) diverted (i.e. returned to the STP for retreatment).

The process trains treat compounds of concern using either:

- Carbon-based, utilising ozone/BAC, and GAC; or,
- RO-based, utilising RO treatment and UV-AOP.

Similar to the pathogen LRVs, the understanding of chemical removal by the AWTP process trains will require significant additional work, including, but not limited to:

- A comprehensive source characterisation study to identify specific contaminants of concern present in the given catchments;
- Study of the contaminant removal performance within the specific source STPs, including targeted assessment for the specific compounds identified in the source characterisation;
- Literature review to understand the latest research into removal of specific compounds of concern through unit processes expected to be utilised within the AWTP;
- Study of the contaminant removal performance through the unit processes in a demonstration AWTP, including targeted assessment for the specific compounds identified in the source characterisation; and
- Detailed chemical risk assessment.

Sections 5.1 through 5.4 present the proposed conceptual AWTP process trains for each short-listed potable reuse scheme (including pathogen base cases and sensitivity cases as defined in Table 4-2), while Section 5.5 presents a process schedule summarising the key elements (a more detailed process schedule is included in Appendix C). Sensitivity for removal of chemical constituents is addressed in Section 6.

All sizings provided are high-level, preliminary values only, and used exclusively for the purposes of cost estimating and determining footprint requirements for the AWTP sites. Sizing of all components of each AWTP would be the subject of significant additional engineering in any proposed scheme which is carried forward.

5.1 Lismore IPR via Surface Water Augmentation

For the IPR via surface water augmentation scheme, PRW produced using source water from the Lismore STPs is discharged to a new engineered storage which acts as an environmental buffer.

As noted previously, water from the Wilsons River Source may also be directed to the Engineered Environmental Buffer Storage to potentially provide improved utilization of this source (see Section 5.1.1.10 for further information).

Lismore's inland location and climatic conditions make disposal of concentrate from an RO system both costly and relatively impractical. Due to this limitation, and noting that the total dissolved solids (TDS) concentration of the Lismore wastewater is around 400 mg/L to 500 mg/L, a carbon-based process train has been adopted for this scheme option. The carbon-based process train is not expected to significantly increase the TDS (an increase in TDS on the order of 20 mg/L through the AWTP is estimated, but this would need to be confirmed in future project phases)).

Accumulation of salinity (or more specifically TDS) in the system is not expected to be an issue for this scheme (as well as the Lismore DPR via raw water augmentation scheme), as only the potable water delivered to the catchment of the East Lismore STP and South Lismore STP is returned as PRW. Preliminary mass balance calculations suggest the TDS in the potable water supplied for these schemes would increase by about 150 mg/L[9], from the current average level of about 120 mg/L to about 270 mg/L (see Appendix E for mass balance calculations). This level of TDS in the potable water is still well below the aesthetic limit in the ADWG of 600 mg/L [4]

As no RO concentrate stream will be generated, the AWTP would have no discharge to the environment. This eliminates the need for additional nutrient removal processes (as there may be for an RO-based system). All waste flows (e.g. filter backwash) are returned to the nearest source STP[10].

The proposed treatment process for this scheme is shown in Figure 5-1 and described in Section 5.1.1. A high-level flow balance is included in Appendix D.

[9] The actual increase would likely be less than 150 mg/L, as hardness in the PRW would result in lower lime dosing at Nightcap WTP.
[10] For the Lismore IPR via surface water augmentation and Lismore DPR via raw water augmentation options the nearest STP would be South Lismore. For the Lismore DPR via treated water augmentation scheme the nearest STP is East Lismore.

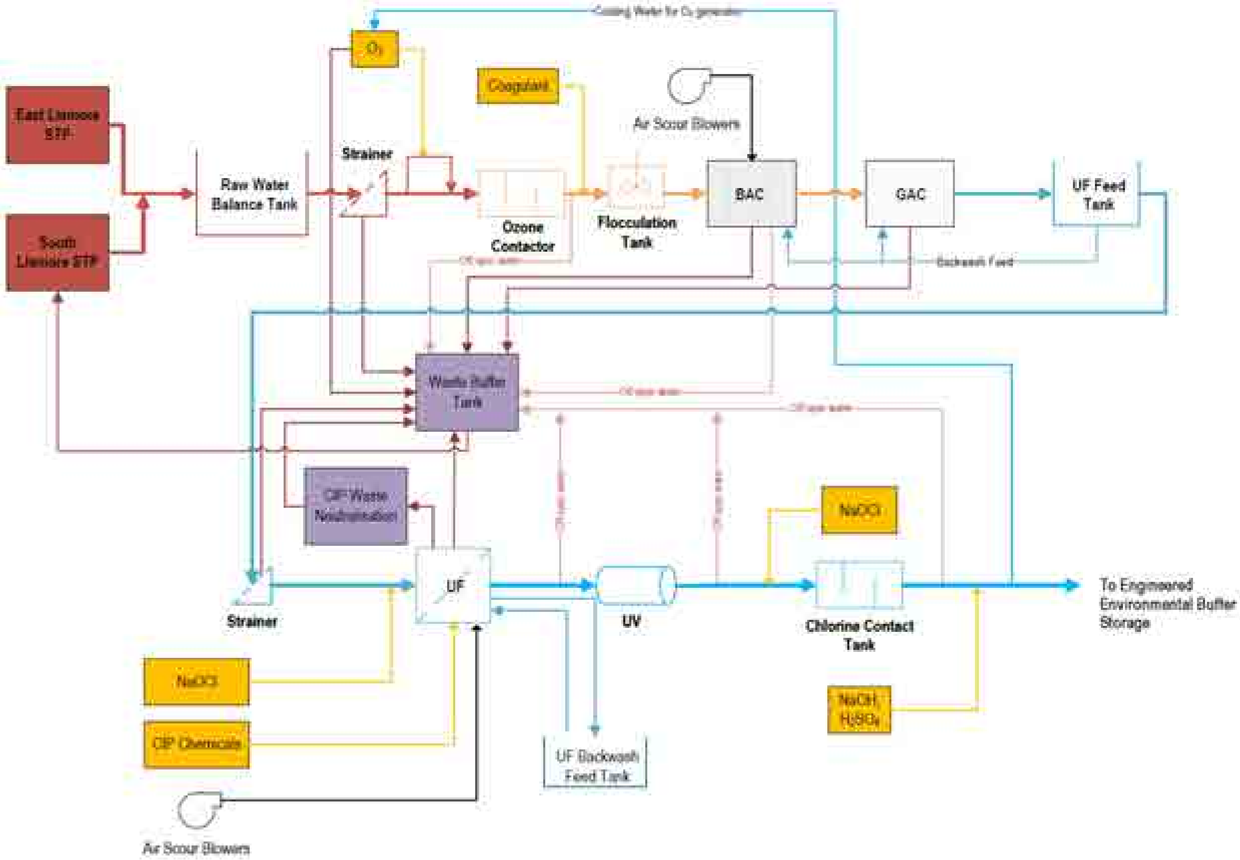

Figure 5-1: Lismore IPR via Surface Water Augmentation Process Flow Diagram

Table 5-2 shows the main process units of conceptual AWTP process train to produce PRW from the Lismore sources (from raw wastewater to PRW supplied to the Engineered Environmental Buffer Storage as part of the IPR scheme), along with the pathogen LRVs claimed for each unit process.

Table 5-2: Lismore IPR via Surface Water Augmentation – Process Train Pathogen Removal

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
Sewage Treatment Plant	0.5	0.5	0.5
Ozone	4.0	0.0	4.0
BAC	1.0	2.0	1.0
GAC	0.0	0.5	0.0
UF	0.0	4.0	4.0
UV Disinfection	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**13.5**	**11.0**	**17.5**
Minimum Required LRVs	**10.0**	**9.0**	**9.0**

Removal of chemical contaminants from the raw wastewater through to the final PRW occurs via:

- Treatment through the STPs (by physical/chemical (e.g. sorption to biomass, stripping via aeration) and biological processes);

- Oxidation and biodegradation within the ozone/BAC (and some adsorption to the media in the BAC filter); and,
- Adsorption to the media in the GAC[11].

While additional pathogen and chemical reduction will occur via treatment of the PRW through Nightcap WTP, no credits have been applied for these reductions as a part of this investigation.

The AWTP for this option has been sized to process 9.1 ML/d of effluent flow - the projected average dry weather flow in 2040 from both the South and East Lismore STPs (2.6 ML/d from South Lismore and 6.5 ML/d from East Lismore).

5.1.1 Process Description

5.1.1.1 Sewage Treatment Plants

The East Lismore and South Lismore STP are the first treatment barrier in the scheme, providing removal of pathogens and chemicals of concern from the sewer network (noting that enhanced source control is an upstream barrier to the STP to reduce chemical risk). Pathogen LRV claimed for the STPs for the purpose of this investigation is 0.5 for each pathogen type.

Effluent from the STPs would be pumped to the Raw Water Balance Tank.

5.1.1.2 Raw Water Balance Tank

The Raw Water Balance Tank, which receives the effluent from the STPs, represents the start of the AWTP process train. For this scheme, it is anticipated that the AWTP would be located adjacent to the existing South Lismore STP (largely within the same parcel of land). In combination with the effluent balance tank at South Lismore STP, the Raw Water Balance Tank would attenuate the diurnal flow variations such that STP effluent could be delivered at a relatively constant rate of ~9.1 ML/d (plus return flows to the STP from the AWTP (e.g. UF backwash)). The required size of the Raw Water Balance Tank will depend on the diurnal flow patterns for the STPs feeding the tank. For the current early phase of design, provision of about four hours storage of the average daily flow (or around 1.8 ML) is expected to be adequate. Mixing would be provided maximise the consistency of the feed to the AWTP and prevent solids deposition in the tank.

Feed to the Raw Water Balance Tank would be monitored with online analysers to monitor performance of the STPs. Analysers would likely include[12]:

- Ammonia: CCP, with water not allowed to enter the AWTP if the ammonia concentration breaches the alert or critical level;
- Turbidity: CCP, with water not allowed to enter the AWTP if the turbidity breaches the alert or critical level;
- Conductivity (may be considered for use as a CCP, further assessment will be required to determine);
- pH;
- Oxidation-reduction Potential (ORP);
- TOC: CCP, with water not allowed to enter the AWTP if the TOC concentration breaches the alert or critical level; and,
- Nitrate[13]: CCP, with water not allowed to enter the AWTP if the nitrate concentration breaches the alert or critical level.

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[11] Chemical risks are discussed in Section 6.

[12] Means of communicating effluent water quality issues identified by the CCP analysers with the STP operators would need to be established.

[13] Nitrate has a health-based guideline value of 50 mg/L as nitrate (11.3 mg/L as N) in the ADWG [4]. The source STPs perform nitrogen removal and historic plant effluent data shows nitrate/total nitrogen well below the guideline value. The STPs will have diurnal variation in effluent nitrate. This will need to be further investigated to ensure the diurnal variation in nitrate is understood and to evaluate potential impacts on AWTP production and/or the possible need for further nitrate removal within the AWTP. As RO effectively rejects nitrate

STP effluent from the Raw Water Balance tank would be pumped to the Ozone/BAC system, via microstrainers installed for removal of gross solids.

5.1.1.3 Strainers

Gross solids such as fruit and vegetable stickers, cotton buds, leaves, and the like can be present in the STP effluent. Strainers with a 500 µm aperture size would be provided on the feed to the AWTP to protect the Ozone/BAC from these solids and the resulting operational and maintenance issues.

The strainers would be equipped with an automatic backwash function (typically not requiring a separate backwash water supply). Strainer waste would be directed to a Waste Buffer Tank prior to being returned to the STP.

N + 1 redundancy is assumed for the strainers.

5.1.1.4 Ozone/BAC

The feed flow to the Ozone Contactor would be dosed with ozone to oxidise compounds of concern - either directly, or as a pretreatment to enable subsequent degradation in the BAC filters. Application of ozone will also provide LRV credits for virus and bacteria.

Based on a blended STP effluent TOC concentration of 8.3 mg/L[14], and an assumed ozone dose of 1.25 times the TOC concentration[15], an Ozone Generator of about 3.7 kg/h capacity would be required. For the purpose of this investigation, the Ozone Generator is assumed to be supplied with oxygen gas which is trucked to site rather than relying on on-site pressure swing absorption with air. The preliminary design has avoided pressure swing absorption due to its higher energy demand, and risk of damage to the ozone generators in the event of issues in the quality of oxygen in their gas feed. The Ozone Generator will require a supply of cooling water (likely supplied from the final product water from the AWTP, but water quality requirements would need to be confirmed with the generator supplier). N + 1 redundancy is assumed for the Ozone Generator.

Ozone could either be supplied to the system by dosing into a side stream of the feed to the Ozone Contactor, or by diffusers located within the Ozone Contactor. Side stream dosing is assumed as the means of ozone addition for the purposes of this investigation. The use of diffusers could be investigated by RCC in a subsequent phase of the program.

The Ozone Contactor would be configured as a baffled tank to minimise the risk of short circuiting. For the current investigation, it has been assumed that the ozonation system will be controlled based on Ozone/TOC ratio (for control of Bromate formation)[16]. For this mode of control, the applied ozone dose is based on a ratio to the TOC (corrected for nitrite) in the feed water. As an alternative, C.t.[17] based control could be utilised (potentially increasing the risk of bromate formation), as RCC currently does at Nightcap and Emigrant Creek WTPs[18]. Both control regimes could be trialled as part of the operation of a demonstration plant to compare their effectiveness at removing compounds or concern, achieving pathogen reduction, and formation of disinfection byproducts (bromate in particular).

(generally to a level in the order of 90%, but dependent on several factors), the Byron DPR via treated water augmentation scheme (RO-based treatment) is not expected to have issues with nitrate at concentrations that would be problematic for the carbon-based Lismore schemes.

14 Based on sample results from "additional sampling" program conducted in October and November 2023 (three samples for South Lismore and four samples for East Lismore – each sample for each site was collected at least a week apart)

15 High ozone dose selected to provide conservatism in ozone generator sizing.

16 US Water Research Foundation Project 5129 demonstrated that using the ozone/TOC ratio is a much more accurate and controllable method to demonstrate up to 5 LRV of virus as compared to C.t. based control. As ozone dose increases the risk of bromate formation increases.

17 The C.t. value is the concentration of oxidant/disinfectant (in this case ozone) applied times the amount of time the oxidant/disinfectant is in contact with the water.

18 Melbourne Water's Eastern Treatment Plant also employs ozone for colour and pathogen removal

Project team experience suggests a T_{10} time[19] of five minutes is likely to be adequate. Assuming a conservative baffling factor[20] of 0.5, this results in a hydraulic retention time (HRT) of ten minutes and a total contactor volume of about 75 kL[21].

The Ozone Contactor would need to be equipped with thermal or catalytic ozone destruction units to remove trace levels of unreacted ozone in the headspace of the contactor before this air is released to the atmosphere.

Consistent with the approach described in Table 5-1, claimed pathogen LRVs for the ozonation process are 4.0 for virus, 0.0 for *Cryptosporidium* and 4.0 for bacteria. The CCPs for this process would comprise online monitoring of influent TOC, nitrite and pH, and ozone concentration for verification of the ozone to TOC ratio.

The preliminary design includes addition of coagulant followed by a flocculation tank upstream of the BAC filters to improve turbidity reduction and to provide for pathogen LRV to be claimed. Based on provision of coagulant dosing and flocculation upstream of the BAC, claimed pathogen LRVs are assumed to be 1.0 for virus, 2.0 for *Cryptosporidium* and 1.0 for bacteria (based on direct filtration, in alignment with ADWG Table 5.6 [4] and USEPA Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules [10], [8]).[22].

The BAC filters comprise deep bed media filters loaded with GAC media populated with fixed-film biological growth. Selection of appropriate GAC media would require careful consideration of characteristics such as headloss and rate of attrition, which would need to be the subject of further investigation in subsequent stages of project development[23]. The microorganisms within the BAC filter degrade organic compounds of concern that have been made biodegradable through the ozone pretreatment. Compounds of concern are also potentially removed through adsorption onto the GAC media within the BAC filter. *Cryptosporidium* reduction occurs through the filtration provided by the media bed.

In the absence of site-specific information, the BAC filters have been sized with an empty bed contact time (EBCT) of 15 minutes and a hydraulic loading rate of 10 m/h or less (with one filter in backwash, 7.5 m/h with all filters online). For the current investigation, the BAC filters are configured as pressure filters[24]. Based on a GAC bed depth of 1.8 m, six filters with a diameter of 3.5 m would be required. Optimisation of the Ozone/BAC arrangement and operating parameters through demonstration plant testing may deliver substantial value, and should be considered in further development of this scheme type.

The CCP for this process would be continuous online monitoring of turbidity of the effluent of each BAC filter and the combined BAC filter effluent stream. In the event that a CCP limit were breached for a given filter, the filter effluent would be diverted to waste to prevent BAC filter effluent passing to downstream process units (and the PRW product stream). The pipework for diversion effluent to waste on each filter cell would additionally allow for a “filter to waste” period after backwash.

BAC filters require backwashing to control the thickness of biofilm that develops on the GAC. Backwash would be initiated based on filter headloss or run time for the filter. Backwash water would be supplied from the downstream UF Feed Tank. Backwash waste would be directed to the Waste Buffer Tank. Air scour blowers would also be provided to provide additional agitation of the media during backwash.

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[19] T_{10} is determined using tracer studies and is the time at which 90 percent of the water that enters the chamber will remain for at least T_{10} minutes [16].

[20] Baffling factors help estimate the contact time of a basin, pipe, or unit process based on the volume of and flow rate through the basin, pipe, or unit process [16].

[21] If C.t. control is used in lieu of ozone:TOC control slightly longer HRT, and hence slightly larger contactor volume, will likely be required.

[22] Preliminary results of pilot trials using a direct filtration configuration similar to that proposed here conducted at Hampton Roads Sanitation District in the United States have shown greater than 4 LRV for virus may be achievable (via direct communication with Andy Salveson from Carollo who are involved in this pilot work). The LRVs assumed here for BAC are consistent with indicative pathogen LRVs listed in Table 5.6 of the ADWG for direct filtration. The actual LRVs claimable for the BAC in direct filtration would need to be verified, likely via an onsite demonstration trial.

[23] GAC derived from bituminous coal, having a mesh size of 8 x 30 and an iodine number of > 900 mg/g, has proven effective on other projects, but appropriateness of any given GAC specification would need to be confirmed based on detailed, project specific analysis.

[24] Pressure filters have been assumed for this high-level conceptual design based on simplicity of installation, minimization of site construction work and flexibility in plant hydraulics provided. Future phases should consider cast-in-place concrete structures as an alternative.

During infrequent maintenance activities that require a BAC filter to be taken offline, it is anticipated that flow to the plant would be managed such that the BAC filters remaining online operate within their design parameters. On this basis, no dedicated redundant BAC filter has been included in the AWTP process trains for the purposes of this investigation.

As an alternative to the direct filtration approach of ozone-coagulation-flocculation-BAC arrangement presented here, future phases of the project should consider investigating an alternative "conventional filtration" configuration comprising coagulation-flocculation-sedimentation-ozone-BAC[25] combined with enhanced coagulation (to reduce TOC prior to ozonation). The solids removal provided by an upstream sedimentation process could increase resilience and reliability of the AWTP. While the alternative arrangement is likely to have higher capital cost, it may provide benefits including:

- Increased ability to tolerate higher suspended solids in the feed to the AWTP;
- Potentially lower backwash frequency for BAC filters;
- Potentially allowing for higher coagulant dosages;
- Longer GAC bed life;
- Lower disinfection byproduct formation potential; and,
- Potentially lower ozone demand.

It is recommended jar testing be conducted to estimate required coagulant dose ranges and the resulting suspended solids post coagulation. Direct filtration and conventional filtration arrangements could then both be trialled in an onsite demonstration plant to allow for determination of the most cost-effective solution that provides the most robust outcome in terms of management of pathogen and chemical risks, as well as resilience with respect to solids in the AWTP feed.

5.1.1.5 GAC

Effluent from the BAC filters would be discharged to the GAC system. The GAC system would be provided to adsorb compounds of concern not removed by the upstream Ozone/BAC system. PFAS would represent one of the key contaminants captured in the GAC. In addition, the GAC system provides Claimed LRV of 0.5 for Cryptosporidium based on the USEPA Long Term 2 Enhanced Surface Water Treatment Rule [8].

In the absence of site-specific information, the GAC filters have been sized with a hydraulic loading rate of 10 m/h. A lower loading rate may be required depending on the specific pollutant loads reaching this process unit. The GAC filters are assumed to be pressure filters[26]. Based on a GAC bed depth of 1.8 m, six filters, each having a diameter of 3.5 m, would be required (noting that it may be possible to optimise this arrangement based on demonstration plant testing and through further design development).[27]

Sample taps would be provided at a range of heights through the GAC media bed (e.g. 25%, 50% and 75%) to allow the progression of the contaminant(s) through the bed to be monitored. This allows the rate of exhaustion of the media to be determined, and estimation of the time until change out of the media.

Periodic backwashing of the GAC filters will be required[28], with frequency dependent on feed water quality. Turbidity in the effluent from the upstream BAC filters is expected to typically low, but there is likely to be periodic sloughing of solids from the biofilm that could impact the GAC filters. Backwashing will also be necessary to remove fines from the system on the

[25] A variation of this configuration is used at the Goreangab Reclamation Plant in Windhoek, Namibia. This plant includes coagulation-DAF-media filtration-ozonation-BAC-GAC. [22]

[26] Pressure filters have been assumed for this high-level conceptual design based on simplicity of installation, minimisation of site construction work, and flexibility in plant hydraulics. Future phases should consider cast-in-place concrete structures as an alternative.

[27] It may be advantageous to operate GAC filters in a lead/lag arrangement, as breakthrough of certain compound (e.g. PFAS) may occur much sooner than other compounds. This arrangement may allow for sorption of other compounds in the lead vessels after the primary compound has broken through. However, as this is likely to increase capital costs and footprint requirements (depending on acceptable loading rates), further investigation of this approach would be required.

[28] Air scour may be required as part of GAC filter backwash. but should only be used as needed to minimise GAC attrition. For the purpose of this investigation, it is assumed that the air scour blowers provided for the BAC filters would also be used for GAC filter air scour – suitability of this would need to be confirmed by further investigation.

initial loading of media and on each media change out. Backwash water would be supplied from the downstream UF Feed Tank. Backwash waste would be directed to the Waste Buffer Tank.

Bench scale testing (e.g. isotherm testing), followed by testing in the demonstration plant, would be required to select the appropriate GAC media for use in the system to confirm removal effectiveness for specific compounds of concern and characteristics such as headloss and rate of attrition. In addition, it is likely that the Claimed LRV for *Cryptosporidium* would need to be validated through operation of a demonstration plant.

During infrequent maintenance activities that require a GAC filter to be taken offline, flow to the plant will be managed such that the GAC filters remaining online operate within their design parameters. On this basis, no dedicated redundant GAC filter has been included in the AWTP process train for the purpose of this investigation.

5.1.1.6 UF System

Effluent from the GAC filters would gravitate to the UF Feed Tank. The UF Feed Tank is required to facilitate relatively constant flow through the upstream process units while the flow forward to the UF units varies (e.g. for backwash, PDT etc.). The UF Feed Tank also acts as a source for backwash water for the BAC and GAC filters. For the purposes of this investigation, the UF Feed Tank is assumed to provide an HRT of 30 minutes, equating to a storage volume of about 200 kL.

Water would be pumped to the UF system, via strainers (likely to be required by membrane supplier as a warranty condition with aperture size as specified by the membrane system supplier, with 500 µm aperture being typical). The strainers would be equipped with an automatic backwash function. Strainer waste would be directed to a Waste Buffer Tank prior to being pumped back to the STP.

For the purpose of this investigation, it is assumed that the feed to the UF system would be dosed with sodium hypochlorite to provide a low free chlorine residual to control biofouling of the membranes. An alternative of dosing preformed monochloramine could also be considered[29]. The membrane supplier would specify the acceptable level of chlorine exposure as part of the membrane warranty.

The UF system would consist of multiple units. Each UF unit would be equipped with multiple modules housing polymeric (PVDF) ultrafiltration membrane fibres[30]. Feed water would be distributed across the modules within each online UF unit and flow from the outside of each fibre through the membrane to the hollow inner core (lumen) and be collected into manifolds. Particles greater than the absolute pore size of the membrane would be retained on the feed side, this includes suspended and colloidal solids and pathogens including viruses, protozoa (including *Cryptosporidium*) and bacteria. Typical nominal pore size for UF membranes is from 0.01 µm to 0.04 µm (depending on the manufacturer).

For the purpose of this investigation, the pathogen LRVs claimed for the UF units are 4.0 for *Cryptosporidium* and bacteria. While the UF membranes can provide LRV for virus, online verification of the removal is currently challenging. On this basis, no virus LRV are claimed in this investigation.[31]

Membrane flux (filtrate flow rate per membrane area) is a key parameter for design of the UF system. Given the UF system is downstream of the Ozone/BAC/GAC combination, a maximum instantaneous flux of 70 LMH (litres per square meter membrane area per hour) has been applied as the basis for this investigation. The design flux would need to be confirmed by further study of plants utilising the same membranes under similar operating conditions and/or as part of the

[29] The biofouling control used will require further investigation and consultation with the membrane supplier. Application of pre-formed monochloramine instead of sodium hypochlorite may be beneficial with respect to formation of disinfection byproducts (e.g. NDMA, trihalomethanes). Free chlorine and monochloramine have different impacts on the life of polymeric membranes – this, as well as the water quality impacts, would need to be investigated before adopting a final biofouling control method.

[30] Ceramic membranes could also be considered. Further investigation is recommended if any of the potable reuse schemes are carried forward.

[31] Yokogawa Electric Corporation have developed a "Rapid Pathogen Assessment Identification" system that has potential to allow for online, real-time analysis of pathogens, which has been investigated by an Expert Panel [23]. It is understood (via direct communication with Andy Salveson, Chair of the Expert Panel) that the system has continued to develop and is expected to be tested in potable reuse application in the near future.

demonstration plant (including investigating whether or not adverse impacts on flux occur related to GAC fines exiting the GAC columns).

For the purpose of this investigation, the UF system is conservatively assumed to have a recovery[32] of 90%. Sustainable recovery will be dependent on the quality of the feed water to the UF (as well as operating conditions such as flux). It is likely that the recovery of the UF system would be slightly higher than this assumed value.

Filtrate from the UF units would flow to the downstream UV system. One CCP for this process would be continuous online monitoring of turbidity of the filtrate of each UF unit (the second CCP would be daily PDTs, discussed further below). A diversion to waste would be provided on the effluent of each UF unit to allow diversion of filtrate if a CCP limit were breached. A portion of the filtrate would be directed to a tank dedicated to storing water to be used for backwashing the UF units (the tank is assumed to be the same size as the UF Feed Tank for the purpose of this investigation).

The UF units would be required to perform routine PDTs as a measure of the UF membrane integrity. PDTs are automatically controlled and can be either automatically or manually initiated. During a PDT, the filtrate side of the membranes is pressurised with air, then held for a set period of time. The rate of pressure decay is logged and reported to ascertain the membrane integrity. Air for the PDT would be provided by a compressed air system.

The failure mode of membrane fibres is typically such that the PDT result slowly increases over time as membrane fibres sustain damaged. It is typical to monitor PDT results and plan membrane maintenance (pinning)[33] to occur before a CCP alert level is reached. This CCP would have a critical level set at the PDT result corresponding with the manufacturer's validated LRV claimed for the project, and an alert level set sufficiently below the critical level to enable corrective action to be undertaken before the critical level is reached. If a unit were to record a result above the critical limit, the unit would be immediately retested. If the second test were to be above the critical level, the UF unit would be taken out of service for troubleshooting.

UF units require regular backwashing to maintain performance. Backwashing involves reverse flow of water through the membranes in combination physical scouring with air bubbles. The solids flushed during backwashing are removed from the system via a backwash stream which drains to the Waste Buffer Tank. Backwashes occur automatically and can be automatically initiated based on time or change in transmembrane pressure over a filtration interval. The specific backwash process and associated equipment will vary depending on the design of the UF units and the requirements of the membrane supplier, but generally will include backwash pumps to supply clean water for backwashing (and displacing the dirty backwash water), and blower to supply air for scouring the membranes.

Chemical cleaning is also required on a periodic basis to maintain acceptable performance of the UF units. Two forms of chemical cleaning are generally applied - maintenance washes and clean in place (CIP). Both of these processes introduce clean water (i.e. filtrate) that has been dosed either with:

- Acid - usually citric acid for removal of inorganic fouling, or,
- Sodium hypochlorite for removal of biological and/or organic fouling - sometimes in combination with sodium hydroxide addition to raise pH.

Maintenance washes are shorter duration, lower strength cleans that could occur around once every four days (for example), depending on the nature of the feed water and the efficiency of the backwash process. CIPs are generally performed on a monthly basis using higher concentrations of chemicals. Maintenance washes and CIPs would utilise the same cleaning system, which would likely include a tank (potentially including a heater to allow heating of the water for CIP) and a pump to deliver the solution and recirculate during the cleaning cycle (which would likely consist of recirculation and soak steps of

[32] Recovery is the daily volume of filtrate produced divided by the daily volume of feed water to the UF system.
[33] Pinning is the process of identifying the membrane module(s) having an integrity breach (by either watching for bubble through an observation area (e.g. a clear section of pipe) or listening for air passing through the damaged fibre (referred to as sonic testing) with air pressure applied to the filtrate side of the membranes) removing membrane modules from the UF unit, identifying where broken fibres are located within the given membrane, inserting a pin in both ends of the broken fibre and returning the pinned module to the UF unit.

varying duration). At the end of the clean, the spent solution would be discharged to a Neutralisation Tank[34], prior to being directed to the Waste Buffer Tank for return to the STP.

UF membranes generally have a design life of about seven to ten years.

The conceptual design has assumed N + 1 redundancy for the UF Feed Pumps, strainers, UF units, backwash pumps, cleaning system recirculation pumps, air scour blowers and air compressors.

5.1.1.7 UV Disinfection

UF filtrate would flow to the UV reactors, where UV light is applied in the wavelength range that is absorbed by microorganisms (200 – 300 nm). This causes changes in the DNA/RNA of the organism, rendering them unable to replicate (or cause infection). The level of inactivation of a given microorganism is a function of the applied UV dose and the resistance of the organism to UV light [14].

The UV system would consist of at least two reactors operating in parallel. The reactors would contain the number of lamps required to apply the desired UV dose to the water. The UV system would utilise low-pressure, high-output amalgam lamps housed in quartz sleeves.

A UV dose of 186 mJ/cm^2 has been applied to the conceptual design to achieve the claimed LRV of 4.0 for all pathogen types [15]. This UV dose accounts for uncertainty in the UV dose-response relationships of the target pathogens, but does not address other significant sources of uncertainty in full-scale UV disinfection applications, including uncertainty due to the hydraulic effects of the UV installation, the UV reactor equipment (e.g., UV sensors), and the monitoring approach.

UV reactor designs are subjected to validation testing to determine the operating conditions under which the reactor delivers the required UV dose for treatment credit. These operating conditions must account for UV transmittance of the water, lamp fouling and aging, measurement uncertainty of online sensors, UV dose distributions arising from the velocity profiles through the reactor, failure of UV lamps or other critical system components, and inlet and outlet piping and internal hydrodynamics within the UV reactor.

The UV system installed at the AWTP would include:

- Inlet and outlet piping or channel configurations in full accordance with the manufacturer's requirements (and the configuration applied during validation testing);
- A UV transmissivity analyser on the common feed to the UV system to monitor the UV transmittance;
- UV intensity sensors within the reactors to measure the actual intensity of UV light delivered to the water, and,
- A flow meter to monitor flow through each individual reactor.

A minimum UV transmittance of 80% has been applied to the conceptual design (downstream of Ozone/BAC, GAC and UF) for the purposes of this investigation. This key design parameter would need to be confirmed during operation of the demonstration plant.

CCPs for the UV system would include flow rate, UV transmittance and UV intensity (or validated UV dose derived from the UV intensity and flow). A diversion to waste would be provided on the effluent of each UV reactor to allow diversion of water if a CCP limit were breached (or alternatively the whole UV system could be shut down (e.g. if the UV transmittance analyser records a value below the design minimum UV transmittance)).

The two main consumables for the UV system are UV lamps and ballasts (which increase the voltage of the power supply to the lamps). UV lamps are generally warranted for at least 12,000 hours of operation, and ballasts are generally warranted for 10 years.

The UV reactors are assumed to be provided with N + 1 redundancy.

[34] It may be feasible to directly discharge the spent cleaning solutions to the Waste Buffer Tank/STP without prior neutralisation or buffering. Detailed analysis would be required to determine if this is appropriate. To ensure the cost estimates are suitably conservative, the conceptual design has included a neutralization system.

5.1.1.8 Chlorine Disinfection

Effluent from the UV system will discharge to the chlorine disinfection system. The flow will be dosed with sodium hypochlorite, then retained in chlorine contact tanks (CCTs). To ensure the kill is achieved (and efficient chemical utilisation), the contact tanks would include baffles to minimise short circuiting.

To achieve the claimed LRV of 4.0 for virus and bacteria, a C.t. value of 4 mg-min/L of free chlorine is required [16]. Based on a free chlorine residual of 0.5 mg/L at the end of the CCT and a baffling factor of 0.7, a minimum theoretical HRT of about 15 minutes would be required within the CCT, equating to volume of about 85 kL.

The minimum CCPs associated with the chlorine disinfection would be based on:

- Flow measurement for flows entering the CCTs;
- Free chlorine analysers at the end of the CCTs to monitor residual chlorine levels; and,
- C.t. calculated automatically by the plant control system.

The CCT effluent would be equipped with piping to allow water influenced by exceedance of a critical limit to be diverted to waste.

5.1.1.9 Stabilisation

An allowance has been included in the process train for sodium hydroxide and sulphuric acid dosing to adjust the final pH of the PRW prior to discharge. Initial high-level modelling of the plant chemistry suggests a small dose of sodium hydroxide is all that would be needed to produce PRW within typical values targeted for corrosion indices (e.g. 0 to -5 for calcium carbonate precipitation potential). Further investigation will be required to determine:

- If either of these chemicals could be eliminated from the process train;
- If addition of an alkalinity source would be required; and,
- The range of chemical doses required.

Detailed modelling of the plant chemistry will need to be performed to ensure PRW exiting the plant meets RCC targets with respect to corrosivity (e.g. calcium carbonate precipitation potential, Langelier saturation index).

5.1.1.10 Engineered Environmental Buffer Storage

PRW from the CCT would be pumped to an Engineered Environmental Buffer Storage. The engineered environmental buffer would provide for a minimum storage time of PRW (notionally 70 days[35]). If only PRW were directed to this storage, a theoretical minimum working volume of 0.6 GL would be sufficient. However, in practice the actual provided working volume would need to be larger than this to account for short circuiting, mixing issues and the like. However, additional volume within the buffer could enable the practical yield from the Wilsons River Source to be maximised through:

- Withdrawing water from the Wilsons River while flows at the Eltham gauge are sufficient and Rocky Creek Dam is at or close to 100% full; and,
- Subsequently transferring the stored water to Nightcap WTP when the level in Rocky Creek Dam drops below 100% full (and the level at the Eltham gauge is below the acceptable level for utilisation of the Wilsons River Source.

[35] Assuming routine sampling of the PRW occurs monthly, a minimum retention time of 70 days has been applied for preliminary consideration of the minimum residence time in environmental buffers based on:

- 30 days between sampling events;
- 14 days to obtain laboratory results;
- 7 days to organise resampling if required;
- 14 days to obtain laboratory results for second sample event; and,
- 5 days contingency

Detailed analysis will be required to determine the impacts of blending PRW with Wilsons River Source water.

As the amount of Wilsons River Source water that may be stored in the engineered environmental buffer storage cannot be adequately defined at this time it is not possible to provide an estimate of additional storage requirements with any certainty.[36]

5.1.1.11 Waste Buffer Tank

A Waste Buffer Tank would be provided to collect waste flows from routine operations (e.g. backwash water), as well as water diverted within the process due to not meeting quality specifications (e.g. breach of a CCP). The Waste Buffer Tank would balance these flows prior to pumping back to the source STP.

The conceptual design of the Waste Buffer Tank includes mixers to prevent solids collecting on the floor.

It may be preferred to direct water diverted within the process due to not meeting quality specifications back to the Raw Water Balance Tank rather than to the source STP. This should be investigated in future project phases if this option is taken forward.

5.1.1.12 Neutralisation Tank

CIP waste from the UF system could have either low pH (typically < 2), a high pH (>10), or a high concentration of chlorine (e.g. 1,000 mg/L). For the purpose of this assessment, it is assumed that these streams need to be neutralised prior to discharge to the source STP (via the Waste Buffer Tank). The impact of directly discharging the spent chemical cleaning streams to the Waste Buffer Tank and then subsequently on to the source STP could be investigated during subsequent design phases.

Within the Neutralisation Tank appropriate chemicals to raise/lower the pH and/or to dechlorinate the waste stream are added and allowed to mix. When online analysers indicate that the pH and/or chlorine levels are acceptable, the neutralised waste is discharge to the Waste Buffer Tank.

5.1.1.13 Chemicals

Table 5-3 summarises the chemicals expected to be utilised in the AWTP and their purpose.

Table 5-3: Lismore IPR via Surface Water Augmentation AWTP (Carbon-Based) Chemicals

Chemical	Purpose
Aluminium Sulphate (Alum)	Coagulation of BAC filter feed[1]
Sodium Hypochlorite (NaOCl)	Biofouling control of UF Chlorine disinfection UF chlorine CIP/maintenance wash
Sodium Hydroxide (NaOH)	Final PRW pH adjustment (if required) Neutralisation of acid CIP/maintenance wash waste May be used in UF CIP
Sulphuric Acid (H_2SO_4)	Final PRW pH adjustment (if required) Acid UF CIP/ maintenance wash Neutralisation of high pH CIP waste
Citric Acid	Acid UF CIP/ maintenance wash
Sodium Bisulphite	Dechlorination of chlorine CIP/ maintenance wash waste

1. Addition of alum will also result in reduction in phosphorus in the PRW.

For the purpose of estimating overall AWTP footprint, a minimum storage time for each chemical of 14 days has been assumed.

[36] As noted in the *Potable Reuse Scheme Identification and Short-Listing Memorandum* produced for this project, high level review of contours of rural land in vicinity of Lagoon Grass suggests an engineered storage on the order of 0.6 GL to 1.2 GL could be implemented.

5.1.1.14 Return Flows to the STP

The daily flow returned to the STP (from backwash waste, etc.) is expected to be in the order of 1.5 ML/d, with the majority of this flow being generated by backwash of the UF units. Depending on the design of the system, the instantaneous return flows could be much higher. This, and any limits on the rate of return flow which can be accepted by the STP, should be considered in subsequent development phases of this scheme option.

5.2 LISMORE DPR VIA RAW WATER AUGMENTATION

The Lismore DPR via raw water augmentation scheme is similar to the IPR via surface water augmentation scheme, with the key difference being that the PRW produced by the AWTP is directed to the head of the Nightcap WTP (rather than the engineered environmental buffer).

Engineered Storage Buffer Tanks are included in the AWTP process train for this scheme to allow for capture and diversion of water produced between CCP analyser readings (to ensure water produced from the time of the last verified acceptable CCP reading is not allowed to be discharged to Nightcap WTP). Two tanks would be provided, each providing on the order of 30 minutes of storage time (the actual storage time provided would need to be confirmed based on the design of the AWTP).

5.2.1 Base Case Minimum Pathogen LRV Targets

As shown in Table 4-2, the base case for minimum pathogen LRV targets for this scheme are the same as for the IPR via surface water augmentation scheme described in Section 5.1 As such, the AWTP process train for this scheme is the same as described in Section 5.1, except for the inclusion of the Engineered Storage Buffer Tanks and the subsequent direction of PRW to Nightcap WTP.

Figure 5-2 shows a process flow diagram of the proposed treatment process for this scheme. The proposed AWTP treatment process is the identical to that provided in Section 5.1.1, with the exceptions noted above (i.e. use of Engineered Storage Buffer Tanks rather than an Engineered Environmental Buffer Storage. A high-level flow balance is included in Appendix D.

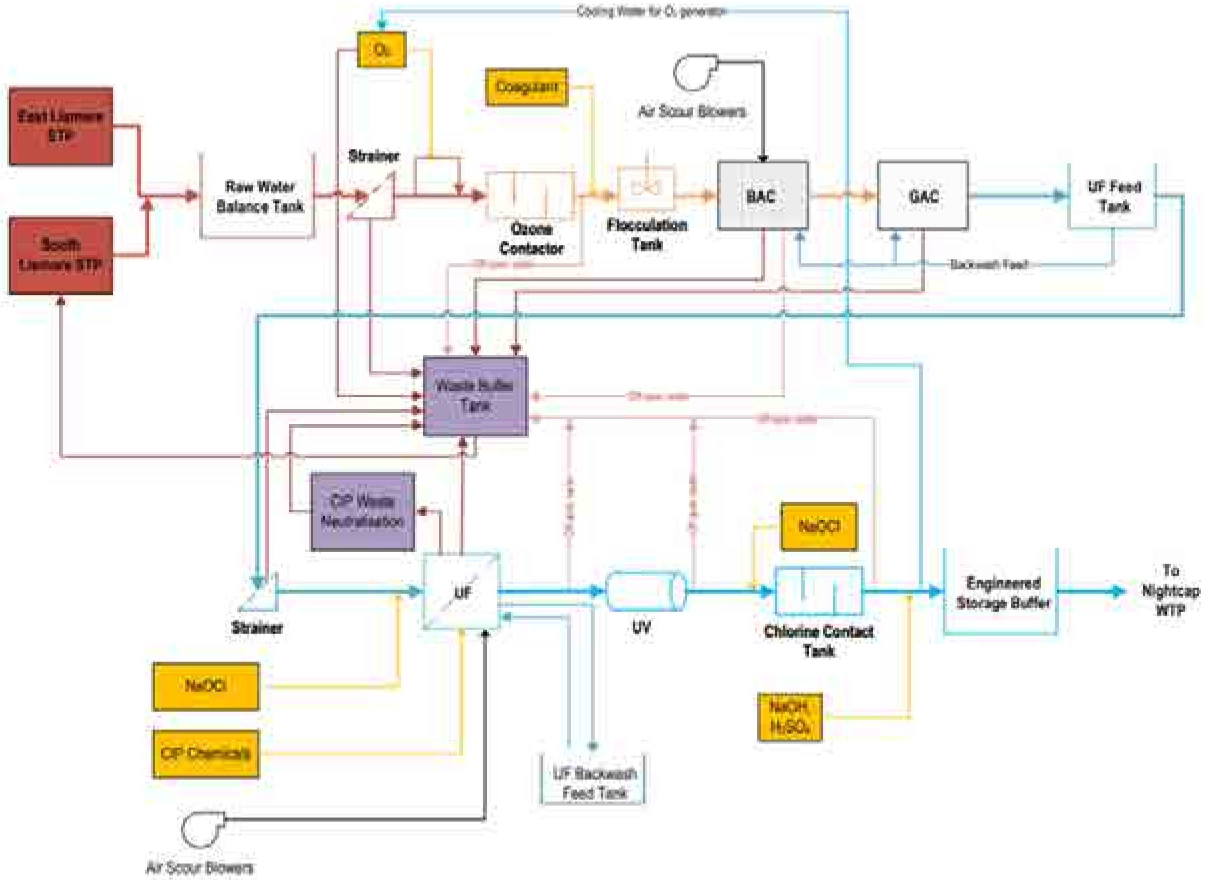

Figure 5-2: Lismore DPR via Raw Water Augmentation Process Flow Diagram (Base Case Minimum Pathogen LRV Targets)

The main process units and their associated claimed pathogen LRVs are identical those shown in Table 5-2.

While additional pathogen and chemical reduction will occur via treatment of the PRW through Nightcap WTP, no credits have been applied for these reductions as a part of this investigation.

5.2.2 Sensitivity Case Minimum Pathogen LRV Targets

As shown in Table 4-2, the sensitivity case assumes minimum pathogen LRV targets that are 2.0 LRV higher than the base case for each pathogen type, based on initial failure assessment and associated excess LRVs. As the AWTP process train used for the base case (as discussed in Section 5.2.1) meets the pathogen LRV sensitivity case target, no further processes are required to meet the pathogen targets established for this investigation. The process train for this pathogen sensitivity case is the same as for the Lismore DPR via raw water augmentation base case.

Table 5-4 shows the main process units of conceptual AWTP process train to produce PRW from the Lismore sources (from raw wastewater through to PRW supplied to the Nightcap WTP as part of the DPR scheme), along with the pathogen LRVs claimed for each unit process for the sensitivity case.

Table 5-4: Lismore DPR via RWA – Sensitivity Case - Process Train Pathogen Removal

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
Ozone	4.0	0.0	4.0
BAC	1.0	2.0	1.0
GAC	0.0	0.5	0.0
UF	0.0	4.0	4.0
UV Disinfection	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**13.5**	**11.0**	**17.5**
Minimum Required LRVs with Sensitivity Provisions	**12.0**	**11.0**	**11.0**

As for the system described in Section 5.1, removal of chemical contaminants through the AWTP will primarily occur through the ozone/BAC and GAC systems. While additional pathogen and chemical reduction will occur via treatment of the PRW through Nightcap WTP, no credits have been applied for these reductions as a part of this investigation.

5.2.3 Raw Water Augmentation Blending

The PRW produced under this scheme would be blended with water from Rocky Creek Dam and/or the Wilsons River Source. As an example, at a very high-level:

- PRW produced from this scheme (and the IPR scheme) is about 9 ML/d;
- Nightcap WTP capacity is about 70 ML/d;
- Based on the PRW produced and Nightcap's capacity, the blend ratio would be just above 10%.

The blending would act to reduce the pathogen load to Nightcap WTP, with the impact being dependent on the amount of water drawn from each of the sources under different operating scenarios. Hence, the true impact of blending cannot be determined at this stage of investigation. Detailed analysis will be required to determine the impacts of raw water blending, including analysis of the water qualities from the various sources and a range of operating scenarios.

The LRV targets for Nightcap WTP listed in Table 3-2 may be impacted by the introduction of PRW. If either the raw water augmentation or IPR options are carried forward, source water assessments for Nightcap WTP should be updated. It is possible that the very low pathogen load (and risk) associated with the PRW (as compared to Rocky Creek Dam and Wilsons River water) will reduce the LRV requirements for Nightcap WTP when PRW is directed to the plant – noting that this will be dependent on the amount of water drawn from each of the sources under different operating scenarios.

5.3 LISMORE DPR VIA TREATED WATER AUGMENTATION

The Lismore DPR via treated water augmentation scheme is the similar to the DPR via raw water augmentation scheme, with three key differences being:

- Effluent will be sourced from East Lismore STP only;
- The PRW produced by the AWTP will be blended with treated water from Nightcap WTP within the main reservoirs of drinking water distribution network (rather than being discharged to the inlet of Nightcap WTP); and
- The amount of PRW supplied to the network will be limited (to an assumed maximum of 5.4 ML/d) to align with a blend ratio of 50% (based on predicted 2040 demand from the City View, Belvedere Drive, High Street and Ross Street Reservoirs) to maintain TDS in the supplied drinking water at acceptable level. Treated water blending TDS impacts are discussed in Section 5.4.4. On this basis, the unit process sizes are smaller than those derived for the Lismore IPR via surface water augmentation and DPR via raw water augmentation options.

5.3.1 Base Case Minimum Pathogen LRV Targets

As shown in Table 4-2, the base case for minimum pathogen LRV targets for this scheme are the same as for the sensitivity case for the DPR via raw water augmentation sensitivity case described in Section 5.2.2. Hence, the AWTP process train is identical to that described in Section 5.2.2 except for the destination of the PRW, the capacity of the system, and the quantity of PRW supplied to the system.

Figure 5-3 shows a process flow diagram of the proposed treatment process for this scheme.

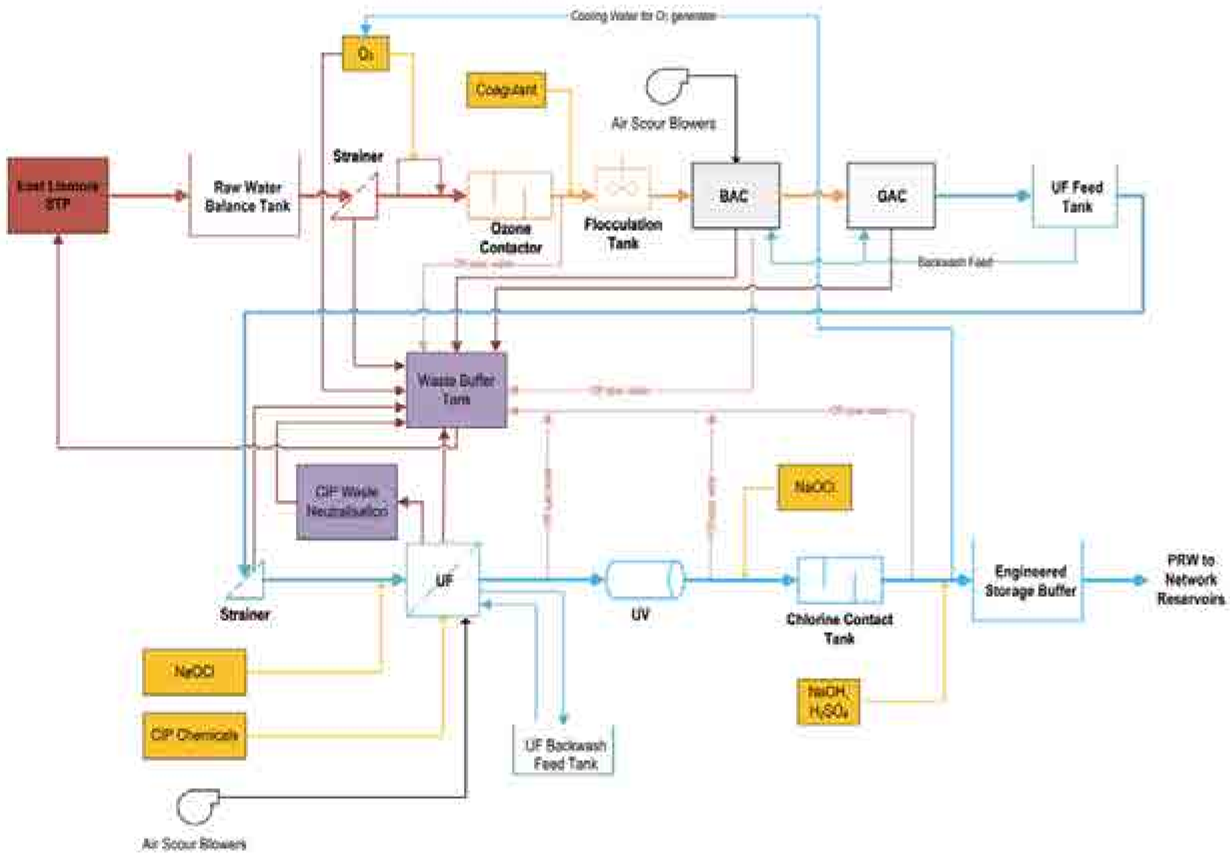

Figure 5-3: Lismore DPR via Treated Water Augmentation Process Flow Diagram (Base Case Minimum Pathogen LRV Targets)

5.3.2 Sensitivity Case Minimum Pathogen LRV Targets

As shown in Table 4-2, the sensitivity case assumes minimum pathogen LRV targets that are 4.0 LRV higher than the minimum required LRVs to meet a DALY of 10^{-6} in drinking water for each pathogen type (based on an absolute worst-case scenario of 4.0 LRV failure 100% of the time). The AWTP process train used for the Lismore DPR via treated water augmentation base case has a shortfall of 0.5 LRV for virus and 2.0 LRV for *Cryptosporidium* compared to the sensitivity case targets.

To overcome this shortfall, a secondary UV disinfection system is included in the process train for this case. This process unit is not required to provide pathogen LRV to meet requirements for protection of public health (as described in Table 4-1), but rather to make up a shortfall that may occur under the sensitivity case (i.e. a 4 LRV failure occurring for four hours four times per year as per the initial failure assessment). The lack of available additional conventional AWTP treatment processes that could be reasonably added may provide a valid basis under which this duplication of process units may be acceptable[37].

Site-specific testing may show higher (or lower) claimable pathogen LRVs for the process train without the secondary UV system. If sufficiently higher claimable pathogen LRVs can be demonstrated, then the secondary UV system would not be required to meet even this assumed worst case. As noted in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (Appendix A), the proposed considerations of minimum LRVs for DPR in this document are not intended to provide direction or guidance on what minimum LRV requirement may ultimately be required. Rather, the intent is to develop reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes (and consider the sensitivity to higher LRVs that remain still potentially realistic in the Australian context).

Table 5-5 shows the main process units of a conceptual AWTP process train to produce PRW from the Lismore sources (from raw wastewater through to supply of PRW to the drinking water reservoirs), along with the pathogen LRVs claimed for each unit process (inclusive of the secondary UV system).

Table 5-5: Lismore DPR via Treated Water Augmentation – Sensitivity Case - Process Train Pathogen Removal

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
Ozone	4.0	0.0	4.0
BAC	1.0	2.0	1.0
GAC	0.0	0.5	0.0
UF	0.0	4.0	4.0
UV Disinfection	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**13.5**	**11.0**	**17.5**
Minimum Required LRVs to Meet DALY of 10^{-6} in Drinking Water	**10.0**	**9.0**	**9.0**
Secondary UV Disinfection (to meet sensitivity requirement)	4.0	4.0	4.0
Total Claimed LRVs with Secondary UV	**17.5**	**15.0**	**21.5**
Minimum Required LRVs with Sensitivity Provisions	**14.0**	**13.0**	**13.0**

Figure 5-4 shows a process flow diagram of the proposed treatment process for this scheme. The process description of the proposed AWTP treatment process is identical to that provided in Section 5.2.1, with the exceptions of the addition of the secondary UV disinfection system.

[37] The addition of an RO unit to this process train to increase pathogen LRV is likely to make the treatment system cost prohibitive, due to the difficulty associated with managing an RO concentrate stream due to Lismore's inland location.

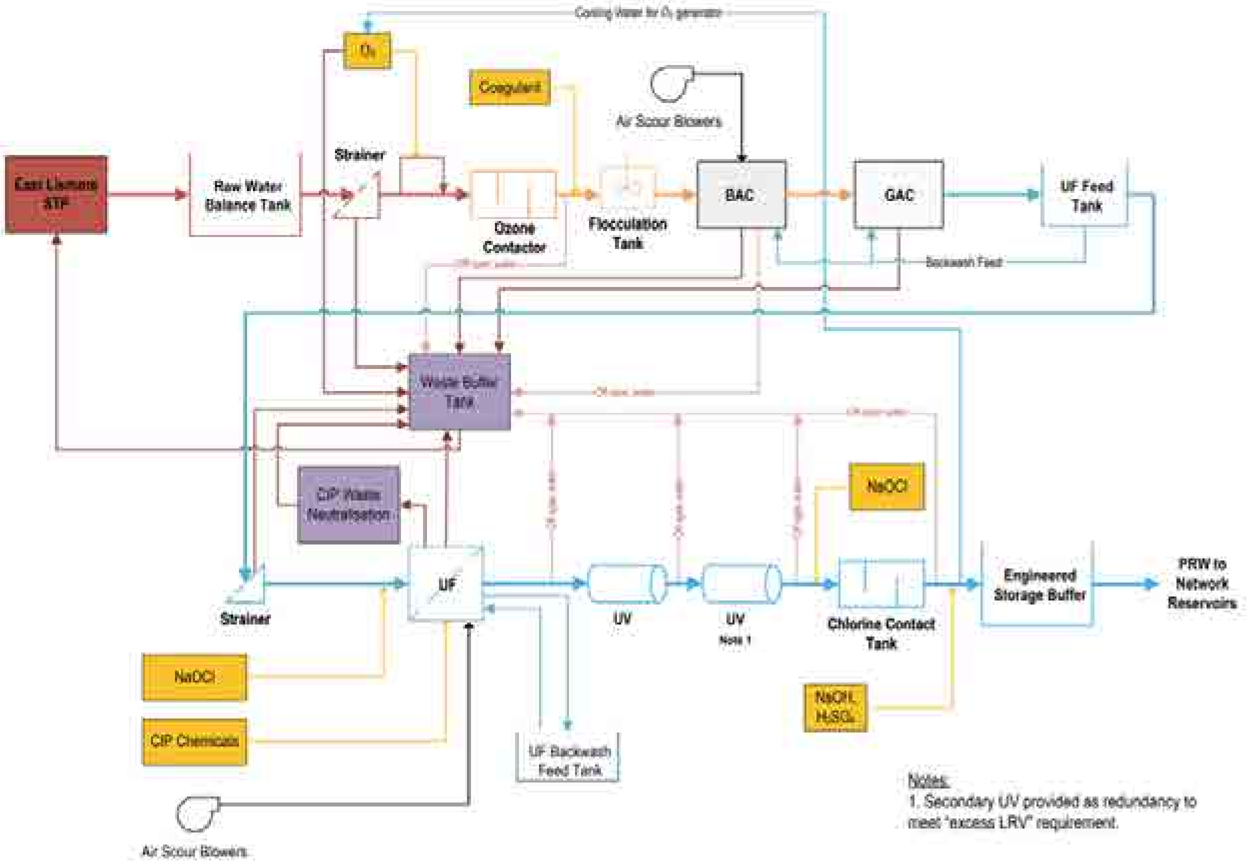

Figure 5-4: Lismore DPR via Treated Water Augmentation Process Flow Diagram (Sensitivity Case Minimum Pathogen LRV Targets)

As for the other Lismore AWTP process trains, removal of chemical contaminants will primarily occur through the ozone/BAC and GAC systems.

5.3.3 Treated Water Augmentation Blending

The Lismore IPR via surface water augmentation and DPR via raw water augmentation supply PRW to the feed of Nightcap WTP. This results in the distribution of the PRW across reservoirs servicing Byron Shire, Ballina Shire and Lismore. Accumulation of salinity (or more specifically TDS) in the system is not expected to be an issue for these schemes, as only the potable water delivered to the catchment of the East Lismore STP and South Lismore STP is returned as PRW. Preliminary mass balance calculations suggest the TDS in the potable water supplied for these schemes would increase by about 150 mg/L[38], from the current average level of about 120 mg/L to about 270 mg/L (see Appendix E for mass balance calculations). This level of TDS in the potable water is still well below the aesthetic limit in the ADWG of 600 mg/L [4].

By contrast, in the Lismore DPR via treated water augmentation scheme, the PRW sourced from the East Lismore STP (and possibly South Lismore STP[39]) will be distributed to reservoirs which only supply Lismore. As this scheme is also carbon-based rather than RO-based, this scheme option will increase the TDS in the drinking water supplied to customers. The increase in TDS depends on the proportion of water being recycled within the system as PRW (which depends on the amount of water exiting the system (e. g. water used for outdoor purposes such as irrigation within the East Lismore STP catchment that do not return to the sewer and water sent to South Lismore STP which exits the system through

[38] The actual increase would likely be less than 150 mg/L, as hardness in the PRW would result in lower lime dosing at Nightcap WTP.
[39] PRW would only be sourced from South Lismore STP is further investigation indicates a blend ratio higher than about 60% is acceptable.

environmental discharge), and the amount of water entering the system having lower salinity (i.e. water from Rocky Creek Dam)). This is defined through the 'blend ratio' (i.e. the percentage of PRW supplied compared to the total drinking water supplied), which has been capped at 50% for investigation of this scheme option.

While detailed analysis will be required to confirm the blend ratio that will consistently achieve TDS levels that will be acceptable to customers, an initial high-level TDS mass balance suggests blended potable water TDS concentrations would be around 450 mg/L at a blend ratio of 50%. This would represent an increase of about 320 mg/L from the current average potable water TDS of about 120 mg/L, and is less than the aesthetic limit in the ADWG of 600 mg/L [4]. See Appendix E for additional details on the initial TDS mass balance for this scheme option.

The 2040 demand for the City View, Belvedere Drive, High Street and Ross Street Reservoirs is 10.8 ML/d [17]. A 50% blend ratio requires supply of 5.4 ML/d of PRW as an average daily flow.

RCC's current network operation allows for supply to each of the reservoirs at a much higher rate than the average day demand. To provide the target blend ratio in each of the reservoirs, the PRW will need to be supplied in proportion to the inflow rate to the reservoirs. Table 5-6 summarises the average demand, peak inflow and instantaneous flows of PRW required to achieve the target 50% blend ratio.

Table 5-6: Average Demand, Peak Inflow and PRW Flow Required to Achieve 50% Blend Ratio at Each Reservoir

Reservoir	Projected 2040 Average Daily Demand (ML/d)	Projected 2040 Average Daily Demand (L/s)	Average PRW Required to Achieve 50% Blend Ratio (ML/d)	Average PRW Required to Achieve 50% Blend Ratio (L/s)	Peak Inflow to Reservoir (L/s)	Peak PRW Required to Achieve 50% Blend Ratio (L/s)
City View	2.98	34	1.5	17	200	100
Belvedere Drive	2.98	34	1.5	17	165	83
High Street	1.47	17	0.7	9	400	200
Ross Street	3.4	39	1.7	20	90	45
Total	10.8	125	5.4	63	855	428

To supply the peak PRW flow rate, storage will be required (in addition to the 30-minute Engineered Storage Buffer described in Section 5.2). The size required for this peak PRW storage tank will depend on how the network is operated (i.e. at what time each reservoir is filled and at what rate). Preliminary investigation suggests the required tank volume could be in the range of 2 ML to 4 ML. For the purpose of this investigation, a storage volume of 3 ML has been assumed. However, a detailed analysis of network operation with the inclusion of the PRW supply will be required to determine the required storage volume and confirm the peak PRW flow rates.

5.4 BYRON DPR VIA TREATED WATER AUGMENTATION

For the Byron DPR via treated water augmentation scheme, PRW produced from source water from the Byron STPs is discharged to reservoirs in the drinking water distribution network.

Byron's coastal location provides opportunity for disposal of concentrate from an RO system. The TDS concentration of the Byron wastewater is around 500 mg/L, making either RO-based or carbon-based treatment viable options. For this investigation, the conceptual design has adopted an RO-based solution for this this scheme option. This provides at least one short-listed option utilising this process train.

The discharge of RO concentrate to the environment would require investigation to determine requirements for additional treatment of the concentrate (e.g. nutrient removal). For the purpose of this investigation, it is assumed that processes for nitrification, denitrification and phosphorus removal would be required to treat the RO concentrate stream prior to discharge.

5.4.1 Base Case Minimum Pathogen LRV Targets

Table 5-7 shows the main process units of conceptual AWTP process train to produce PRW from the Byron sources (from raw wastewater through to PRW supply to the drinking water reservoirs as part of the DPR scheme), along with the pathogen LRVs claimed for each unit process.

While an RO-based AWTP process train can meet the minimum LRV requirements for protection of public health (see Table 4-1) without duplication of pathogen barriers, the base case for this scheme assumes minimum pathogen LRV targets that are 2.0 LRV higher than the minimum LRV requirements for protection of public health for each pathogen type (based on initial failure assessment and associated excess LRVs). This additional 2.0 LRV target results in a shortfall of 1.5 LRV for virus and 1.0 LRV for *Cryptosporidium* for a "traditional" RO-based AWTP train consisting of UF, RO and UV/AOP (based on the conservative LRV assumptions made for these unit processes in this investigation).

Provision of a secondary UV system (following the UV/AOP system) would deliver sufficient LRV to make up for this shortfall. This additional process unit is not required to provide pathogen LRV to meet requirements for protection of public health (as described in Table 4-1). Rather, the secondary UV unit makes up a shortfall that may occur as result of a 4 LRV failure occurring for four hours, four times per year (as per the initial failure assessment). Under this approach, there is a valid basis under which this duplication of process units may be acceptable[40] [41].

The inclusion of the secondary UV is driven by the excess LRV assumptions made for this investigation to ensure conservative capital cost estimates are developed. Further work will be required to confirm and agree the final LRV targets with the Regulator and to confirm that claimed pathogen LRVs that can be verified and validated. There is potential that additional pathogen LRVs may be claimable, including:

- Additional virus, protozoa and bacteria LRVs by treatment through the STP;
- Virus LRV through the UF;
- Additional virus, protozoa and bacteria LRVs through the RO system; and,
- Allowing for greater than 4 LRV to be claimed through the UV/AOP and/or the chlorine disinfection system (noting that this would also change the "excess LRV" failure assessment).

As noted in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development* (Appendix A), the proposed considerations of minimum LRVs for DPR in this document are not intended to provide direction or guidance on what minimum LRV requirement may ultimately be required. Rather, the intent is to develop reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes (and consider the sensitivity to higher, but still realistic in the Australian context, LRVs).

The secondary UV system would be the same as the UV system discussed in Section 5.1.1.

[40] For this scheme ozone/BAC could be considered rather than a secondary UV unit. To provide LRV redundancy for *Cryptosporidium* a high dose of ozone would be required, which would significantly increase the likelihood of bromate formation which would then need to be managed. Using ozone/BAC to provide 4/4/4 LRV redundancy (matching the secondary UV) would increase cost and operational complexity as compared to a secondary UV unit without providing any tangible benefit to protection of public health. Ozone/BAC is discussed further in relation to chemical risks for this scheme in Section 6.

[41] Additional LRV could also be provided by inclusion of media filtration (by either conventional treatment or direct filtration). This would significantly increase the footprint requirement for the plant and add operational and maintenance activities likely in excess of that required for the secondary UV. Hence, this option is less preferable than the secondary UV system.

Table 5-7: Byron DPR via TWA – Proposed Process Train for Base Case Minimum Pathogen LRV Targets

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
UF	0.0	4.0	4.0
RO	1.5	1.5	1.5
UV/AOP	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**10.0**	**10.0**	**14.0**
Minimum Required LRVs to Meet DALY of 10^{-6} in Drinking Water	**10.0**	**9.0**	**9.0**
Secondary UV Disinfection (for Excess LRV requirements)	4.0	4.0	4.0
Total Claimed LRVs to Meet Excess LRVs	**14.0**	**14.0**	**18.0**
Minimum Required LRVs including Excess LRVs	**12.0**	**11.0**	**11.0**

Figure 5-5 shows a process flow diagram of the proposed treatment process for this scheme. Section 5.4.3 provides a brief process description of the proposed AWTP treatment process. A high-level flow balance is included in Appendix D.

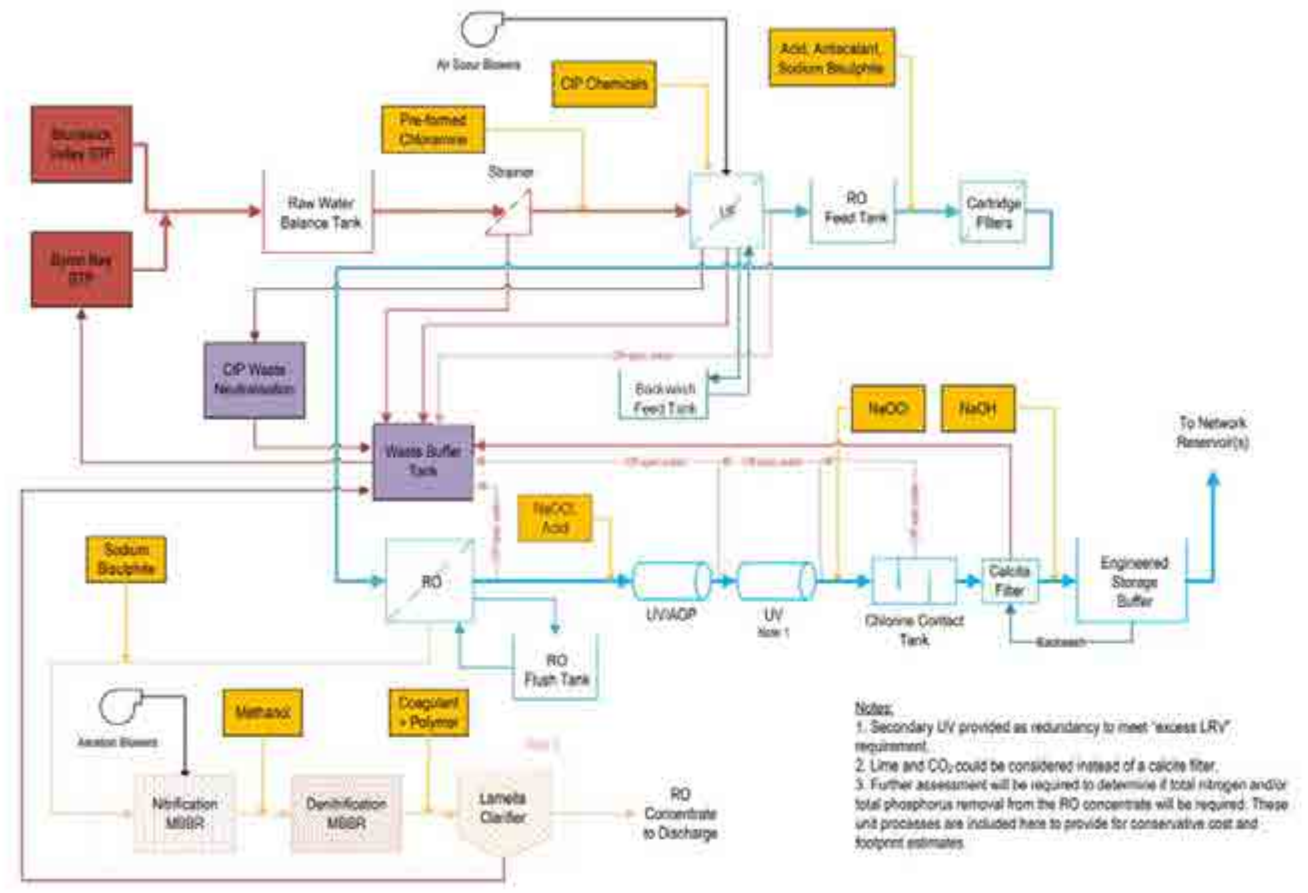

Figure 5-5: Byron DPR via Treated Water Augmentation Process Flow Diagram

In the RO-based process, removal of chemical contaminants occurs through:

- Rejection of these compounds by the RO membranes; and,
- Oxidation of low molecular weight compounds in the subsequent UV/AOP process – specifically compounds which are not well rejected by the RO membranes and therefore may be present in the RO permeate.

5.4.2 Sensitivity Case Minimum Pathogen LRV Targets

The AWTP process train for the sensitivity case is the same as for the base case for RO-based DPR via treated water augmentation, as the secondary UV system provides sufficient LRV to meet this assumed extreme worst case. Table 5-8 compares the claimed LRVs to the minimum LRV target assumed for the sensitivity case. The process flow diagram for this case is identical to that shown in Figure 5-5.

Table 5-8: Byron DPR via TWA – Proposed Process Train for Sensitivity Case Minimum Pathogen LRV Targets

Treatment Process	Claimed LRVs		
	Virus (Norovirus)	Protozoa (*Cryptosporidium*)	Bacteria (*Campylobacter*)
STP	0.5	0.5	0.5
UF	0.0	4.0	4.0
RO	1.5	1.5	1.5
UV/AOP	4.0	4.0	4.0
Chlorine	4.0	0.0	4.0
Total Claimed LRVs	**10.0**	**10.0**	**14.0**
Minimum Required LRVs to Meet DALY of 10^{-6} in Drinking Water	**10.0**	**9.0**	**9.0**
Secondary UV Disinfection (for Excess LRV requirements)	4.0	4.0	4.0
Total Claimed LRVs to Meet Excess LRVs	**14.0**	**14.0**	**18.0**
Minimum Required LRVs including Excess LRVs	**14.0**	**13.0**	**13.0**

5.4.3 Process Description

5.4.3.1 Sewage Treatment Plants

The Byron and Brunswick Valley STPs represent the first treatment barrier in the scheme, providing removal of pathogens and chemicals of concern from the sewer network (noting that enhance source control is an upstream barrier to the STP to reduce chemical risk). Pathogen LRV claimed for the STPs for the purpose of this investigation is 0.5 for each pathogen type.

Effluent from the STPs would be pumped to the Raw Water Balance Tank. The total available ADWF in 2040 is projected to be 8.35 ML/d (6.6 from Byron STP and 1.75 from Brunswick Valley STP).

5.4.3.2 Raw Water Balance Tank

The function of the Raw Water Balance Tank would be identical to that described in Section 5.1.1.2. To provide four hours storage at the average daily flow, a working volume of about 1.6 ML would be required.

Effluent from the Raw Water Balance tank would be pumped forward to the UF system, via strainers installed for removal of gross solids. Consideration should be given to pre-treatment to the UF (e.g. sedimentation) to increase system resilience and reliability with respect to influent suspended solids.

5.4.3.3 UF System

The UF system for the RO-based AWTP would be identical to that described in Section 5.1.1.6, with the following key differences:

- STP effluent would flow directly to the UF units from the Raw Water Balance Tank, via strainers (i.e. there would be no UF Feed Tank);
- The UF feed would be dosed with pre-formed monochloramine (rather than the potential for sodium hypochlorite as assumed for the carbon-based system, as free chlorine would damage the downstream RO membranes);
- The assumed maximum instantaneous flux for STP effluent is 50 LMH; and
- Filtrate from the UF would flow to the RO Feed Tank.

5.4.3.4 RO System

Filtrate from the UF system would gravitate to the RO Feed Tank. The RO Feed Tank is required to enable a near constant flow through the downstream RO units while the upstream UF units come on and offline for various operating functions (e.g. backwash, PDT, etc.). For the purposes of this investigation, the RO Feed Tank is assumed to provide an HRT of 30 minutes, equating to a storage volume of about 200 kL.

Low-pressure feed pumps would deliver UF filtrate from the RO Feed Tank, through cartridge filters, to the suction side of the high-pressure feed pump on each RO unit. The low-pressure feed pumps would be equipped with a flow meter on the common discharge line to allow for flow pacing of chemical dosing. The speed of these pumps would be controlled to maintain pressure at a setpoint value downstream of the cartridge filters, based on a pressure transmitter reading.

Chemicals would be dosed upstream of the cartridge filters to condition the water prior to the RO units, including:

- Sulfuric acid to maintain the feed pH low enough to minimise the risk of membrane scaling;
- An additional anti-scalant chemical to further reduce scaling risk, and,
- Sodium bisulphite to dechlorinate the feed to the RO units if free chlorine was detected (due to a failure in the upstream pre-formed chloramine system), to protect the RO membranes.

RO operates by pumping feedwater through a semi-permeable membrane that concentrates around 99% of the dissolved solids into one stream (the rejected concentrate or brine), and the purified water into a separate "permeate" stream. To achieve reverse osmosis, the feedwater pressure must be sufficient to overcome the osmotic pressure gradient that naturally exists between waters of different salt concentrations. This pressure is delivered by a high-pressure feed pump associated with each RO unit.

Viruses, the smallest of the reference pathogenic microorganisms, are typically greater than 20 Angstroms in size, and have a molecular weight in the range of 100,000 Daltons. For comparison purposes, polyamide RO membranes are typically manufactured with a pore size less than 5 Angstroms and a molecular weight cut off less than 100 Daltons [18]. As a result, viruses (and other pathogens) are prevented from entering the permeate by size exclusion.

For the purpose of this investigation, 1.5 LRV is claimed for each pathogen type for the RO treatment system. While the actual pathogen LRV will generally be much greater (based on the physical characteristics of the membranes), online verification of higher LRVs is currently difficult in practice. Online TOC analysis may allow up to 2.0 LRV to be claimed, and is just one of a number of verifications techniques in development. To this end, ongoing monitoring of developments in on-line RO verification is recommended, as the ability to claim additional LRV for the RO has the potential to yield substantial improvements in the efficiency of the AWTP.

The conceptual design has conservatively assumed a recovery of 80% through the RO system[42]. While detailed analysis would be required to confirm the recovery rate which is possible, an initial review of the available water quality data suggests

[42] The selected recovery of 80% is expected to be a practical minimum for this source water. Higher recovery could be investigated in future phases of the project if this scheme were to move forward.

that higher recoveries are likely to be attainable. To achieve 80% recovery, the conceptual design is based on a two-stage RO system, with the concentrate from the first stage becoming the feed to the second stage. At 80% recovery, an RO concentrate flow of about 1.7 ML/d would be produced.

Residual monochloramine, present in the UF filtrate from the upstream dosing, will be present in the feed to the RO units to control biofouling. The conceptual design has been based on limiting flux in the lead element to 20 LMH or less to control biofouling.

The common feed and the permeate streams from each stage of each RO unit would be monitored using online conductivity analysers to allow for online verification of claimed pathogen LRVs. Conductivity analysers would also be provided on concentrate from each stage. In addition, flow meters and pressure transmitters would be provided on the stage 1 feed as well as on the permeate and concentrate streams generated in each stage.

On-line TOC analysers would be installed on the combined RO feed and permeate for process monitoring of membrane integrity as a means to control both chemical and pathogen risk. These analysers could also be used as a CCP if RCC wish to claim higher LRV for the RO).

Routine flushing of the RO units with permeate helps control fouling and scaling. The conceptual design assumes that each RO unit would be flushed on each shut down, and every 24 hours when the unit is offline (provided sufficient flush water is available). A portion of the permeate would be directed to an RO Flush Tank to assure sufficient flush water is available for routine operation of the plant. For the purposes of this investigation, the RO Flush Tank has been assumed to be the same size as the RO Feed Tank (i.e. 200 kL).

Even with appropriate control measures in place, fouling and/or scaling of the RO membranes can be expected over time. To maintain acceptable performance of the RO system, CIP of membranes is undertaken using clean water (i.e. permeate) that has been dosed either with acid (for removal of mineral scale and/metals) or sodium hydroxide (for removal of biological and/or organic fouling).

CIPs are generally assumed to be required on a monthly basis, but the actual frequency will depend on the specific water quality and operating conditions applied to the system. The CIP system would comprise a tank (or possibly two tanks), equipped with a heater to allow heating of the CIP solution, and a pump to deliver the solution and recirculate during the cleaning cycle. At the end of the cleaning cycle, the spent solution would be discharged to the Neutralisation Tank[43], then transferred to the Waste Buffer Tank for return to the STP.

N + 1 redundancy is assumed for the low-pressure feed pumps, cartridge filters, RO units and CIP system recirculation pumps.

RO membranes generally have a design life of about five years in this type of application.

Permeate from the RO units would discharge to the UV/AOP system.

5.4.3.5 UV/AOP System

The UV/AOP system utilises a large dose of UV light to both directly oxidise organic molecules (such as NDMA), and to split an oxidant applied to the feed water (e.g. hydrogen peroxide, sodium hypochlorite) into radicals that can oxidise other organic species (such as 1-4 dioxane).

Hydrogen peroxide dosing for UV/AOP has a long history of use in wastewater reuse applications, but imposes a high operating cost for purchase of the chemical, and demands special design and handling. As a result, UV/AOP systems utilising chlorine (or sodium hypochlorite) have become popular in recent years. Of the active-design and under-construction potable reuse UV-AOP projects in the United States recently reported, 76% were pursuing UV-chlorine versus UV-hydrogen peroxide [19].

[43] It may be possible to directly discharge the spent cleaning solution to the Waste Buffer Tank/STP, however detailed analysis would be required to determine this. To provide a conservative cost estimate a neutralization system is assumed to be included in the AWTP process.

In the case of H_2O_2 decomposition, the main useful product is the hydroxyl radical (·OH). Chlorine photolysis also produces ·OH, but also generates several reactive chlorine species, including Cl· and ClO·. [19].

Scavenging of radicals and reactive species by chlorine is one of the key factors governing the performance of a UV-chlorine system. As the scavenging suffered by hypochlorous acid is substantially lower than that by hypochlorite ion, UV-chlorine based AOP becomes more effective at pH where hypochlorous acid is the dominant chlorine species [19]. At pH 7.5 and 25°C the chlorine speciation is roughly 50% hypochlorous acid and 50% hypochlorite ion, with hypochlorous acid content increasing with decreasing pH.

To ensure conservatism in the cost estimation, the conceptual design includes acid dosing to the feed to the UV/AOP system. However, given that the pH of the RO permeate in this type of application is generally in the range of 5 to 6 (partially due to upstream acid addition to control scaling), the need for this additional acid dose may potentially be eliminated through more detailed analysis.

The UV reactors are similar to those described for UV disinfection in Section 5.1.1.7. The main difference is the UV dose that needs to be applied for creation of hydroxyl radicals and reactive chlorine species (on the order of 1,000 mJ/cm^2) compared to the dose required for disinfection (186 mJ/cm^2).

For this investigation, the pathogen LRV credit claimed for the UV/AOP system is 4.0 for all pathogen types – the maximum which can be claimed for a single process unit. This is based on the applied UV dose alone. While the radicals generated within the system can be expected to provide substantial pathogen log reductions, these mechanisms are not currently well understood, and methods for the validation and verification of LRVs from radicals have not yet been developed. To this end, ongoing developments in this area may enable additional credits to be claimed for this process unit, improving AWTP efficiency.

The CCPs for UV/AOP would be the same as for UV disinfection as described in Section 5.1.1.7 (noting that the system would only need to achieve a validated dose of 186 mJ/cm^2 to achieve the claimed pathogen LRV). Treated effluent from the UV/AOP would flow to the downstream secondary UV system. A diversion to waste would be provided on the effluent of each UV reactor to allow diversion of water if a CCP limit were breached.

The inclusion of the secondary UV is driven by the “excess LRV” assumptions made for this investigation to ensure conservative capital cost estimates are developed[44] [45]. Further work will be required to confirm and agree the final LRV targets with the Regulator and to confirm that claimed pathogen LRVs that can be verified and validated. There is potential that additional pathogen LRVs may be claimable, including:

- Additional virus, protozoa and bacteria LRVs by treatment through the STP;
- Virus removal by the UF;
- Additional virus, protozoa and bacteria LRVs by the RO system; and,
- Allowing for greater than 4 LRV to be claimed through the UV/AOP and/or the chlorine disinfection system (noting that this would also change the “excess LRV” failure assessment).

The minimum UV transmittance of the feed water (i.e. RO permeate) is assumed to be 90 - 95% (prior to addition of sodium hypochlorite) based on project team experience.

The conceptual design has been based on provision of UV reactors with N + 1 redundancy.

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[44] For this scheme ozone/BAC could be considered rather than a secondary UV unit. To provide 4 LRV redundancy for *Cryptosporidium* a high dose of ozone would be required, which would significantly increase the likelihood of bromate formation which would then need to be managed. Using ozone/BAC to provide 4/4/4 LRV redundancy would increase cost and operational complexity as compared to a secondary UV unit without providing any tangible benefit to protection of public health. Ozone/BAC is discussed further in relation to chemical risks for this scheme in Section 6.

[45] Additional LRV could also be provided by inclusion of media filtration (by either conventional treatment or direct filtration). This would significantly increase the footprint requirement for the plant and add operational and maintenance activities likely in excess of that require for the secondary UV. Hence, this option is less preferable than the secondary UV system.

5.4.3.6 Secondary UV Disinfection

The secondary UV disinfection system would be conceptually similar to the UV disinfection system discussed in Section 5.1.1.7, with the main difference being that the RO-based system would feed water to the secondary UV system having a higher minimum UV transmittance (e.g. 95%) than the carbon-based system (e.g. 80%), resulting in a lower power input and lower capital cost.

5.4.3.7 Chlorine Disinfection

The chlorine disinfection system would be the same as that described in Section 5.1.1.8, with the only exception being a proportionately smaller flow rate and a correspondingly smaller CCT.

5.4.3.8 Calcite Filter

The RO permeate will have low pH and low levels of alkalinity and hardness, making it aggressive towards concrete and steel. To protect downstream assets, the PRW will need to be remineralised prior to discharge to the distribution system. To this end, the conceptual design includes calcite filters for this purpose. As an alternative, lime and carbon dioxide dosing could be used to achieve the same outcome (similar to that undertaken at the existing Nightcap WTP).

In a calcite filter, water flows through a bed of crushed, sieved calcite (a form of calcium carbonate). As water flows through the calcite bed, calcite dissolves releasing calcium carbonate into solution, adding both alkalinity and calcium hardness to the water, and raising the pH. The rate of dissolution of calcite is dependent on the characteristics of the feed water, with RO permeate being an ideal water for use with calcite filters based on its low pH and low concentrations of alkalinity and calcium. The process is self-limiting as the pH of the flow through the calcite bed increases until it nears equilibrium with calcium carbonate. Depending on the final pH and corrosion index targets for the treated water (e.g. LSI, CCPP), a small dose of sodium hydroxide may need to be added to the effluent of the calcite filter.

In the absence of site-specific information, the Calcite Filters have been sized with a minimum EBCT of 10 minutes and a hydraulic loading rate of 7.5 m/h. For the current investigation, the Calcite Filters are configured as pressure filters[46]. Based on a calcite bed depth of 1.2 m, four filters, each having a diameter of 3.5 m, would be required. This arrangement could be optimised through demonstration plant testing and further design development.

Backwash of the Calcite Filters will be required periodically. Backwash water would be sourced from the downstream Engineered Storage Buffer Tanks, and the spent backwash water discharged to the Waste Buffer Tank.

Replenishment of the calcite bed will be required when the calcite dissolves down to a minimum level. For the purposes of this investigation, it is assumed that this will be a manual procedure (with appropriate lifting equipment provided). Testing during operation of a demonstration plant will allow for understanding of the required frequency of calcite replenishment (and any requirements for automation to be investigated further).

Remineralised water would be directed to the Engineered Storage Buffer Tanks.

5.4.3.9 Engineered Storage Buffer Tanks

As described for the carbon-based DPR systems, the PRW from the CCT for this scheme would be pumped to Engineered Storage Buffer Tanks. The Engineered Storage Buffer Tanks would allow for capture and diversion of water produced between CCP analyser readings, ensuring that potentially off-spec water produced from the time of the last verified acceptable CCP reading is not discharged to the drinking water system. The conceptual design is based on provision of at least 30 minutes of storage time in these tanks. However, it should be noted that the actual storage time provided would need to be confirmed based on the design of the AWTP, including the selection and operating regime applied to the instruments under the HACCP system.

[46] Pressure filters have been assumed for this high-level conceptual design based on simplicity of installation, minimisation of site construction work and flexibility in plant hydraulics provided. Future phases should consider cast-in-place concrete structures as an alternative.

5.4.3.10 Waste Buffer Tank

The Waste Buffer Tank would collect waste flows from routine operations (e.g. backwash water, RO flushing, etc.), as well as water diverted within the process due to not meeting quality specifications (e.g. exceedance of a CCP). The Waste Buffer Tank would attenuate these flows prior to their return to the nearest source STP.

The Waste Buffer Tank would be equipped with mixers to prevent solids collecting on the floor.

5.4.3.11 Neutralisation Tank

CIP waste from the UF and RO systems could have either low pH (< 2) or high pH (> 10), and for the UF system, a high concentration of chlorine (e.g. 1,000 mg/L). For the purposes of this assessment, the conceptual design has assumed that these streams will require neutralisation prior to discharge to the source STP (via the Waste Buffer Tank). The viability of directly discharging these streams to the Waste Buffer Tank, and then subsequently on to the source STP, should be investigated during subsequent design phases.

Chemicals to raise or lower the pH, and/or to dechlorinate the waste stream, would be dosed to the Neutralisation Tank, and mixed through the waste stream. Online analysers would be used to verify that the pH and/or chlorine levels are acceptable prior to commencement of discharge to the Waste Buffer Tank.

5.4.3.12 RO Concentrate Treatment

The conceptual design has assumed that total nitrogen and total phosphorus in the RO concentrate stream would need to be reduced prior to discharge to the environment. Results from the recent sampling program for Brunswick Valley STP shows that effluent ammonia is typically about 0.3 mg/L as N, effluent nitrate is typically about 0.2 mg/L as N, and effluent total phosphorus is about 0.1 mg/L. Results for Byron STP show lower levels of ammonia and nitrate and similar levels of total phosphorus. For high-level sizing of the RO Concentrate treatment system, the Brunswick Valley STP values are assumed to apply to the whole feed to the AWTP (i.e. all STP effluent flow to the AWTP is assumed to have the water quality characteristics described for Brunswick Valley STP).

The RO units will provide high rates of rejection for ammonia, nitrate, recalcitrant dissolved organic nitrogen and total phosphorus, resulting in concentration of these components in concentrate stream. Based on an RO recovery of 80%, and conservatively assuming 100% rejection of these chemicals[47], the concentration of these compounds in the RO concentrate will be five times higher than in the RO feed.

Table 5-9 summarises the nitrogen and phosphorus concentrations in the feed to the AWTP and in the RO concentrate.

Table 5-9: AWTP Feed and RO Concentrate Nitrogen and Phosphorus Concentration

Parameter	AWTP Feed Concentration (mg/L)	RO Concentrate Concentration (mg/L)
Ammonia Nitrogen (from STP)	0.3	1.5
Ammonia Nitrogen (added in AWTP process)[1]	-	1.8
Nitrite Nitrogen	< 0.02	-
Nitrate Nitrogen	0.2	1
Recalcitrant Dissolved Organic Nitrogen[2]	0.7	3.5
Total Nitrogen	1.1	7.8
Total Phosphorus	0.1	0.5

1. In addition to the nitrogen in the STP effluent, the use of monochloramine will add ammonia of about 0.6 mg/L as N to the feed to the RO. Monochloramine is not rejected as well by the RO membranes (roughly 50% rejection). At this rejection and 80% recovery, the ammonia associated with monochloramine in the RO concentrate will increase by a factor of 3 (i.e. to 1.8 mg/L as N) as compared to the feed concentration
2. Results from a sampling program conducted in November and December 2023 indicate the recalcitrant dissolved organic nitrogen in the Byron and Brunswick Valley STP effluent is about 0.6 to 0.7 mg/L.

[47] This assumption is being used as a worst case in terms of sizing the RO Concentrate nitrogen removal system. The different nitrogen species will have different rejections (with all of these being less than 100%).

Dechlorination

Sodium bisulphite would be dosed to the RO concentrate prior to nutrient removal to quench the residual chlorine associated with the monochloramine used for fouling control on the UF and RO membranes. This serves to protect the downstream biological process, and to prevent chlorine discharge to the environment.

Nitrification

Following dechlorination, the conceptual design has been based on an aerobic moving bed bioreactor (MBBR) to nitrify the ammonia in the RO concentrate stream to nitrate. Within the MBBR process, the treatment would be performed by nitrifying bacteria within biofilms on mobile plastic carriers, with oxygen provided through coarse or medium bubble aeration. Effluent from the MBBR would pass through fixed sieves mounted on the outlet of the tank to retain the plastic carriers in the reactor.

Based on the assumptions outlined above, around 3.3 mg/L of ammonia as N would be present in the feed to the Nitrification MBBR. The conceptual design has identified an aerobic MBBR volume of about 80 kL would be required based on a 60% fill of carriers within the reactor, a carrier specific surface area of 500 m^2/m^3, and a target effluent ammonia concentration of 0.1 mg/L as N. Based on a water depth of 4 m, the reactor length would be about 5.5 m x 4 m in area. At an RO concentrate flow of 1.7 ML/d, this volume would result in a nominal HRT in this reactor would be about 70 minutes.

Assuming a dissolved oxygen concentration of 3 mg/L is to be maintained in the reactor, an airflow of about 200 Nm^3/h at a discharge pressure of about 30 kPa would be required to be provided by aeration blowers. The aeration would also maintain the carriers in suspension within the MBBR, and provide mixing.

Denitrification

Effluent from the Nitrification MBBR would flow to the Denitrification MBBR. The nitrate concentration in this feed would be around 4.2 mg/L as N (3.2 mg/L converted in the Nitrification MBBR plus 1 mg/L present in the RO concentrate from the secondary effluent).

High-level sizing, based on 30% of the reactor volume filled with carrier, a specific surface area of the carriers of 500 m^2/m^3 and a target effluent nitrate concentration of 0.1 mg/L as N indicates a reactor volume of about 120 m^3 would be required. Based on a water depth of 4 m, the reactor would be about 6.5 m x 5 m in area. At an RO concentrate flow of 1.76 ML/d, the HRT in this reactor would be about 105 minutes.

As the RO concentrate stream lacks available carbon to drive denitrification, the conceptual design includes a dose of methanol to the denitrification MBBR. A methanol dose of around 20 mg/L would be required to deliver complete denitrification.

The Denitrification MBBR would be equipped with low-speed mechanical mixing to keep the carriers in suspension.

Phosphorus Removal

The biofilms used for treatment in the MBBRs would be subject to sloughing over time, resulting in increased solids in the MBBR effluent. To capture these solids, and remove additional phosphorus, the conceptual design includes provision to dose the Denitrification MBBR effluent with alum and polyelectrolyte to precipitate phosphorus and flocculate the solids, followed by Lamella Clarifiers to settle the suspended solids from the treated RO concentrate stream prior to discharge. Lamella Clarifiers use a series of inclined plates to increase the settling area for a given tank footprint.

Table 5-10 summarises the alum dosing and solids load to the Lamella Clarifiers.

Table 5-10: Alum Dosing and Solids Load to Lamella Clarifiers

Parameter	Value
Lamella Clarifier Feed Total Phosphorus	0.5 mg/L
Lamella Clarifier Effluent Total Phosphorus	0.1 mg/L
Alum Dose Required	10 mg/L (as $Al_2(SO_4)_3.14H_2O$)
Solids Produced from Alum Dose	3 mg/L
Solids Produced from Anoxic MBBR (assumption)	30 mg/L
Total Solids Load	56 kg/d

Table 5-11 summarises the Lamella Clarifier design parameters.

Table 5-11: AWTP Feed and RO Concentrate Nitrogen and Phosphorus Concentration

Parameter	Value
Number of Clarifiers	2
Footprint of Each Clarifier	~ 4.5 m x 3 m (13.3 m^2)
Number of Inclined Plates per Clarifier	60
Projected Settling Area of Inclined Plates	52 m^2
Hydraulic Loading Rate Based on Projected Settling Area	0.7 m/h
Solids Loading Rate Based on Projected Settling Area	0.02 kg/m^2-h

Solids would collect at the bottom of the clarifier, and be periodically withdrawn and transferred to the Waste Buffer Tank (e.g. the sludge pumps may run say 5 minutes every hour). The total solids returned to the STP via the Waste Buffer Tank are estimated to be in the order of 60 kg/d.

5.4.3.13 Chemicals

Table 5-12 summarises the chemicals expected to be utilised in the AWTP and their purpose.

Table 5-12: Byron DPR via Treated Water Augmentation AWTP (RO-Based) Chemicals

Chemical	Purpose
Sodium Hypochlorite (NaOCl)	Biofouling control of UF (part of pre-formed monochloramine) Oxidant for UV/AOP Chlorine disinfection UF chlorine CIP/maintenance wash
Aqueous ammonia	Biofouling control of UF (part of pre-formed monochloramine)
Anti-scalant	Scale control for RO membranes
Sulphuric Acid (H_2SO_4)	pH adjustment to RO feed Acid UF CIP/ maintenance wash Acid RO CIP Neutralisation of high pH CIP waste
Citric Acid	Acid UF CIP/ maintenance wash Acid RO CIP
Sodium Hydroxide (NaOH)	Final PRW pH adjustment (if required) Neutralisation of acid UF CIP/maintenance wash waste Neutralisation of acid RO CIP May be used in UF CIP Final pH adjustment post Calcite Filters
Sodium Bisulphite	Dechlorination of RO concentrate Dechlorination of chlorine CIP/ maintenance wash waste
Aluminium Sulphate (Alum)	Phosphorus removal from RO concentrate stream
Polymer	Flocculant aid

For the purposes of estimating overall AWTP footprint, a minimum storage time for each chemical of 14 days is assumed.

Return Flows to the STP

The daily flow returned to the STP (from backwash waste, etc.) is expected to be on the order of 1.0 ML/d. Depending on the design of the system, the instantaneous return flows could be much higher. This, and any constraints within the STP limiting the allowable rate of return flow, will need to be considered in subsequent design phases.

5.4.4 Treated Water Augmentation Blending

The Byron DPR via treated water augmentation scheme would deliver PRW to St Helena and Knockrow Reservoirs. An RO-based AWTP at 80% recovery will produce about 6.7 ML/d of PRW in 2040. The combined 2040 demand for the St Helena and Knockrow Reservoirs is 22.15 ML/d [17], which would enable a blend ratio of about 30%. As the RO removes almost all of the dissolved solids from the feed water, the risk of cycling up dissolved solids is eliminated for this scheme option, and does not place an upper limit to the blend ratio.

If carbon-based treatment were used for the Byron DPR via treated water augmentation scheme rather than the RO-based scheme discussed in this memorandum, the available PRW in 2040 would be about 8.35 ML/d with a TDS on the order of 500 mg/L to 600 mg/L. This would result in a blend ratio of about 38%. As discussed in Section 5.3.3 for the Lismore treated water augmentation scheme, a detailed analysis would be required to confirm the blend ratio that will consistently achieve TDS levels that will be acceptable to customers. However, a blend ratio of 38% is considered likely to provide acceptable water quality (from a TDS perspective).

RCC's current network operation allows for supply to each of the reservoirs at a much higher rate than the average day demand. To provide the target blend ratio in each of the reservoirs the PRW will need to be supplied in proportion to the inflow rate to the reservoirs. Table 5-13 summarises the average demand, peak inflow and flow of PRW required to achieve the target 30% blend ratio.

Table 5-13: Average Demand, Peak Inflow and PRW Flow Required to Achieve 50% Blend Ratio at Each Reservoir

Reservoir	Projected 2040 Average Daily Demand (ML/d)	Projected 2040 Average Daily Demand (L/s)	Average PRW Required to Achieve 30% Blend Ratio (ML/d)	Average PRW Required to Achieve 30% Blend Ratio (L/s)	Peak Inflow to Reservoir (L/s)	Peak PRW Required to Achieve 30% Blend Ratio (L/s)
St Helena	8.95	153	2.70	31	200	60
Knockrow	13.20	104	3.98	46	200	60
Total	22.15	256	6.68	77	400	120

To supply the peak PRW flow rate, storage in addition to the 30-minute Engineered Storage Buffer described in Section 5.4.3.9 will be required. The size required for this peak PRW storage tank will depend on how the network is operated (i.e. at what time each reservoir is filled and at what rate). Preliminary investigation suggests the required tank volume could be about 2 ML. A detailed analysis of network operation with the inclusion of the PRW supply will be required to determine the required storage volume and confirm the peak PRW flow rates.

5.5 PROCESS TRAIN SUMMARY

Table 5-14 provides a summary of the design criteria and sizing for the major unit processes for each short-listed scheme.

Table 5-14: Summary Process Schedule for Major Unit Processes for Each Short-Listed Scheme

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Raw Water Balance Tank						
STP Feed (prior to recycle)	ML/d	9.1	9.1	5.4	8.35	
Flow to Raw Water Balance Tank (including Recycles)	ML/d	10.7	10.7	6.4	9.3	
Raw Water Balance Tank Residence Time	h	4	4	4	4	
Raw Water Balance Tank Working Volume	ML	1.8	1.8	1.1	1.6	Size will need to be confirmed based on analysis of STP diurnal flow patterns
Ozone System						
Control Basis		Ozone:TOC	Ozone:TOC	Ozone:TOC	N/A	
TOC	mg/L	8.3	8.3	8.3		
Ozone:TOC for Ozone Generator Sizing		1.25	1.25	1.25		
Ozone Dose	mg/L	10.4	10.4	10.4		
Virus LRV Claimed for Ozone		4	4	4		
Cryptosporidium LRV Claimed for Ozone		0	0	0		
Bacteria LRV Claimed for Ozone		4	4	4		
Ozone Generator Capacity Required	kg/h	3.7	3.7	2.2		
Ozone Generator Cooling Water	kL/h	6.7	6.7	3.3		Based on advice from vendor
Number of Ozone Generators		2	2	2		
Ozone Generator Redundancy		N + 1	N + 1	N + 1		
Ozone Contactor HRT	min	5	5	5		
Ozone Contactor Baffling Factor		0.5	0.5	0.5		
Ozone Contactor Volume	kL	74.6	74.6	44.8		
Ozone Contactor Headspace Volume	kL	18.5	18.5	11.2		
Ozone Contactor Air Changes	#/h	20	20	20		
Ozone Contactor Ventilation Rate	m^3/h	369	369	224		
Flash Mix Tank						
Hydraulic Residence Time	min	0.5	0.5	0.5	N/A	
G Value	sec^{-1}	500	500	500		
Tank Volume	kL	3.7	3.7	2.2		
Water Depth	m	2.0	2.0	2.0		
Flocculation Tank						
Hydraulic Residence Time	min	20	20	20	N/A	
Type		Baffled tank	Baffled tank	Baffled tank		
Tank volume	kL	149	149	90		
Number of Stages	m	3	3	3		
Stage 1 G Value	sec^{-1}	70	70	70		
Stage 2 G Value	sec^{-1}	35	35	35		
Stage 3 G Value	sec^{-1}	20	20	20		
(BAC System						
Virus LRV Claimed for BAC		1	1	1	N/A	

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Cryptosporidium LRV Claimed for BAC		2	2	2		
Bacteria LRV Claimed for BAC		1	1	1		
Number of Filters		6	6	5		
Filter Bed Depth	m	1.8	1.8	1.8		
Filter Diameter	m	3.5	3.5	3		
EBCT Design Basis	min	15	15	15		
Hydraulic Loading Rate Design Basis	m/h	7.5	7.5	7.5		
EBCT Provided	min	14.2	14.2	14.4		
Hydraulic Loading Rate Provided	m/h	7.8	7.8	7.6		
Backwash Rate	m/h	50	50	50		
Backwash Flow	m^3/h	481	481	353		
Air Scour Flow Rate	$Nm^3/h-m^2$	85	85	85		
Air Flow Rate	Nm^3/h	820	820	600		
Air Scour Pressure	kPa	70	70	70		10 psi assumed
GAC System						
Virus LRV Claimed for GAC		0	0	0	N/A	
Cryptosporidium LRV Claimed for GAC		0.5	0.5	0.5		
Bacteria LRV Claimed for GAC		0	0	0		
Number of Filters		5	5	4		
Filter Bed Depth	m	1.8	1.8	1.8		
Filter Diameter	m	3.5	3.5	3		
Hydraulic Loading Rate Design Basis	m/h	10	10	10		
Hydraulic Loading Rate Provided	m/h	9.3	9.3	9.5		
Backwash Rate	m/h	50	50	50		
Backwash Flow	m^3/h	481	481	353		
UF System						
UF Feed Tank Residence Time	h	0.5	0.5	0.5	N/A	
UF Feed Tank Working Volume	kL	224	224	134		
Virus LRV Claimed for UF		0	0	0	0	
Cryptosporidium LRV Claimed for UF		4	4	4	4	
Bacteria LRV Claimed for UF		4	4	4	4	
UF System Maximum Instantaneous Flux	LMH	70	70	70	50	
UF System Recovery		95%	95%	95%	92%	As advised by vendor
Number of UF Units		3	3	3	3	As advised by vendor
UF Unit Redundancy		N + 1	N + 1	N + 1	N + 1	
UF Backwash Supply Tank Working Volume	kL	224	224	134	194	
RO System						
RO Feed Tank Residence Time	h	N/A			0.5	
RO Feed Tank Working Volume	kL				175	
Virus LRV Claimed for RO					1.5	
Cryptosporidium LRV Claimed for RO					1.5	
Bacteria LRV Claimed for RO					1.5	

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
RO System Maximum Lead Element Flux	LMH				20	
RO System Recovery					80%	
Number of RO Stages					2	
Number of RO Units					3	As advised by vendor
RO Unit Redundancy					N + 1	
RO Flush Tank Working Volume	kL				175	
Primary UV						
UV Dose	mJ/cm^2	186	186	186	N/A	
Virus LRV Claimed for UV		4	4	4		
Cryptosporidium LRV Claimed for UV		4	4	4		
Bacteria LRV Claimed for UV		4	4	4		
Minimum UV Transmittance		80%	80%	80%		
UV Unit Redundancy		N + 1	N + 1	N + 1		
UV-AOP System						
UV Dose	mJ/cm^2	N/A			> 500	
Virus LRV Claimed for UV-AOP					4	
Cryptosporidium LRV Claimed for UV-AOP					4	
Bacteria LRV Claimed for UV-AOP					4	
Minimum UV Transmittance					95%	
Oxidant Dose	mg/L free chlorine				4	
UV Unit Redundancy					N + 1	
Secondary UV Unit						
UV Dose	mJ/cm^2	N/A		186	186	Secondary UV not included in Lismore IPR via surface water augmentation or Lismore DPR via raw water augmentation base case. Included in Lismore DPR via treated water augmentation for sensitivity case only.
Virus LRV Claimed for UV				4	4	Claimed to address sensitivity/"excess LRV"
Cryptosporidium LRV Claimed for UV				4	4	Claimed to address sensitivity/"excess LRV"
Bacteria LRV Claimed for UV				4	4	Claimed to address sensitivity/"excess LRV"
Minimum UV Transmittance				80%	95%	
UV Unit Redundancy				N + 1	N + 1	
Chlorine Contact Tank						
Ct	mg-min/L	4	4	4	4	
Virus LRV Claimed for Chlorine		4	4	4	4	
Cryptosporidium LRV Claimed for Chlorine		0	0	0	0	
Bacteria LRV Claimed for Chlorine		4	4	4	4	
Chlorine Residual	mg/L as Cl_2	0.5	0.5	0.5	0.5	
Required Contact Time		8	8	8	8	
Baffle Factor		0.7	0.7	0.7	0.7	
Hydraulic Residence Time	min	15	15	15	15	
Chlorine Contact Tank Volume	kL	97	97	58	70	
Calcite Filters						
Number of Filters		N/A			4	
Filter Bed Depth	m				1.2	

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Filter Diameter	m				3.5	
EBCT Design Basis	min				10	
Hydraulic Loading Rate Design Basis	m/h				7.5	
EBCT Provided	min				10	
Hydraulic Loading Rate Provided	m/h				7.3	
Backwash Rate	m/h				29	
Backwash Flow	m^3/h				282	
Engineered Storage Buffer						
Buffer Tank Residence Time	min	N/A	30	30	30	Lismore IPR does not include an engineered storage buffer - PRW flows directly to an environmental buffer
Buffer Tank Working Volume	kL		190	113	140	
Waste Buffer Tank						
Sizing Basis		0.5 h storage of peak flow through process (including recycles)				
Waste Buffer Tank Volume	kL	224	224	134	195	
Number of Waste Buffer Tanks		1	1	1	1	
Waste Buffer Tank Redundancy		N	N	N	N	
RO Concentrate Treatment						
Nitrification MBBR						
RO Concentrate Ammonia	mg/L as N	N/A			3.3	
Effluent Ammonia	mg/L as N				0.1	
MBBR Volume	kL				80	
Carrier Fill					60%	
Carrier Specific Surface Area	m^2/m^3				500	
Hydraulic Residence Time	min				70	
Approximate Airflow Required	Nm^3/h				200	
Denitrification MBBR						
Denitrification MBBR Feed Nitrate	mg/L as N	N/A			4.2	
Denitrification MBBR Effluent Nitrate	mg/L as N				0.1	
Denitrification MBBR Volume	kL				120	
Denitrification MBBR Carrier Fill					30%	
Carrier Specific Surface Area	m^2/m^3				500	
Denitrification MBBR Hydraulic Residence Time	min				105	
Methanol Dose	mg/L				20	
Lamella Clarifier						
Lamella Clarifier Feed Total Phosphorus		N/A			0.5	
Lamella Clarifier Effluent Total Phosphorus					0.1	
Alum Dose	mg/L as $Al_2(SO_4)_3.14H_2O$				10	
Lamella Feed Total Suspended Solids (including solids from alum)	mg/L				33	
Solids Load	kg/d				56	
Number of Lamella Clarifiers					2	
Lamella Clarifier Redundancy					N	
Number of Inclined Plates per Clarifier					60	

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Projected Settling Area	m^2				52	
Hydraulic Loading Rate	m/h				0.7	
Solids Loading Rate	kg/m^2-h				0.02	

6 CHEMICAL RISKS

6.1 CHEMICAL RISK ASSESSMENT SUMMARY

The chemical risk assessment (Appendix B) presents a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW. The assessment was conducted using paradigms developed in WRF Project No. 4960 for chemicals of industrial origin. As a first step in understanding potential chemical risks (as limited by the scheme-specific information available at this stage), this assessment provides a general indication of possible chemical risk, and serves as an example of how to better understand and prioritise chemicals of concern. It is essential to note that further assessment of chemical risk will need to be conducted when sufficient catchment-specific data becomes available. The approach described in Appendix B can be used to guide the future detailed, quantitative chemical risk assessment. Further investigations required to support a future detailed chemical risk assessment would include, but not be limited to:

- Source characterisation;
- Development of an enhanced source control program (including a detailed study of all dischargers and the chemicals they use that could end up in the sewer as well as a program to track and regulate troublesome discharges/dischargers);
- Pilot/demonstration plant testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water and their removal through the various unit processes within the demonstration advanced water treatment plant); and
- Additional literature review as more information regarding occurrence data, health risk factors and treatment process removal performance becomes available.

Based on this assessment, PFAS appears to be a broad concern for all proposed treatment trains. This concern is driven almost solely by the risk to human health posed by these compounds (rather than concerns about the potential to manage their removal by either GAC or RO in the AWTP process trains)[48].

In general, the assessment of the proposed process trains suggests that each of the proposed schemes can be expected to provide good control of chemical risk in the proposed catchments. The high-level chemical risk assessment did not identify any issues that would drive recommending additional chemical barriers to be included in the conceptual process trains discussed in Section 5. Regardless of chosen unit operations (i.e. RO-based or carbon-based treatment), the performance can and should be verified by testing with a demonstration plant.

6.2 PROCESS CONTROLS TO MINIMISE CHEMICAL RISK

As with pathogen CCPs (discussed in Section 5), online monitoring will be used as one of the key methods for managing chemical risks. This would include:

- Monitoring of TOC, pH, ammonia, conductivity and nitrate in the STP effluent to allow for feed to the AWTP to be suspended when these parameters exceed a selected concentration to manage acute chemical risks. Under this approach, TOC, pH and conductivity are used as indicators of a potential illicit discharge that results in a high concentration of a compound of concern passing through the STP, and nitrate is used as an indicator of poor performance of the STP (e.g. loss of denitrification);
- Monitoring of TOC/DOC and nitrate in the treated PRW (prior to discharge to the Engineered Storage Buffer Tanks) to prevent release of PRW impacted by high TOC or nitrate to manage acute chemical risks (i.e. to prevent water

[48] The US EPA has recently set enforceable health based maximum contaminant levels for several PFAS compounds. These include PFOA (4 ng/L), PFOS (4 ng/L), PFHxS (10 ng/L), PFNA (10 ng/L) and HFPO-DA (also known as GenX Chemicals, 10 ng/L), as well as Hazard Index for mixtures containing two or more of PFHxS, PFNA, HFPO-DA and PFBS. Public water systems have until 2029 to implement solutions that reduce the levels of these PFAS compounds if monitoring shows that drinking water levels exceed these maximum contaminant levels. (https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas)

that presents an acute chemical health risk from being forwarded to drinking water production/supply – this point would be provided over and above the AWTP feed monitoring); and,

- Online monitoring at other locations within the process to manage chronic chemical health risks[49], as determined by a detailed chemical risk assessment and HACCP process, but likely to include:
  - DOC analyser on the effluent of the BAC system (to monitor overall removal of organic chemicals through this process)
  - UV transmittance analysers on ozone contactor feed and effluent
  - UV transmittance analysers on the BAC effluent (GAC feed) and GAC effluent to monitor increase in UVT across the GAC filters (allows for monitoring GAC performance over time)
  - DOC analyser on the GAC effluent to allow monitoring of DOC removal over time. When combined with the BAC effluent DOC analyser, this provides another means of monitoring GAC performance over time (in addition to manual sampling point located at various points within the GAC bed to allow monitor the progression chemicals indicative of GAC performance to determine when GAC media replacement is required)
  - TOC analysers on the RO feed and RO permeate to monitor for membrane integrity issues (which could affect both chemical and pathogen risk)

As discussed in Section 5, Engineered Storage Buffer Tanks are included in the AWTP process train for all of the short-listed schemes (except IPR via surface water augmentation) to allow for capture and diversion of water produced between successive CCP analyser readings. These tanks would also be used in the same manner to manage chemical peaks, where the water produced between TOC analyser readings would be captured to allow diversion on detection of TOC above a selected critical level.

Some pathogen barriers will divert or shutdown individual units on an alert or critical CCP level being reached. For example, one UF unit in a system containing multiple UF units can be diverted due to a high effluent turbidity reading on that specific unit. By contrast, it is anticipated that diversion or shutdown based on chemical risk, as detected by the TOC analyser, would likely result in:

- Shutdown of the whole AWTP (for example, STP effluent TOC measures high resulting in no water being accepted into the AWTP), or,
- Diversion of the whole AWTP flow (for example, a spike in TOC in the RO permeate resulting in diversion of all permeate flow, not just that from a single RO unit).

In addition to these controls within the AWTP, online monitoring within the sewer catchment and/or the feed to the STP could also be considered (as part of an enhanced source control program) as a means to help identify the source of illicit discharges.

6.3 Chemical Removal Capital Cost Sensitivity

Given the early stage of this investigation and the associated unknowns, RCC has requested that consideration be given to capital cost sensitivity cases in the event that further investigation shows additional chemical removal unit processes are required.

6.3.1 Carbon-Based Process

In the event that further investigations indicate that additional chemical removal capability is required for the carbon-based process trains, consideration could be given to:

- ***Inclusion of UV/AOP instead of UV***. However, as advanced oxidation (i.e. creation of hydroxyl radicals) already occurs in the ozonation step, there is no additional benefit expected from inclusion of UV/AOP (other than direct photolysis due to the high UV dose. UV/AOP also has challenges in a carbon-based train as compared to in an RO-based train including;

  - Radical scavenging is not readily monitored online (which is important for carbon-based treatment whose effluent is expected to have lower matrix stability than RO permeate);
  - Much lower UV transmittance, which significantly increases the capital and operating costs of the system; and,
  - Additional chemical dosing to either 1) lower pH in the case of use of chlorine as the oxidant, and/or 2) quench peroxide prior to downstream chlorination in a hydrogen peroxide based AOP system.

- ***Use of direct nanofiltration[50] in lieu of ultrafiltration***. Nanofiltration would reject some chemical compounds (depending on the membranes selected, the chemical compounds of interest, and the design and operating conditions of the nanofiltration system), and possibly allow for some virus LRV to be claimed (by monitoring on TOC), while allowing most of the TDS to pass through to the downstream process. The nanofiltration reject stream would be returned to the STP, which is not viable for RO concentrate. Considerable additional investigation would be required to understand the feasibility, advantages and disadvantages of using nanofiltration.
- ***Addition of GAC***. A secondary GAC system (i.e. lead/lag GAC units) would provide additional polishing with respect to chemicals, and may enable enhanced utilisation of the GAC in the primary stage (depending on the breakthrough characteristics of the chemicals of concern).
- ***Addition of ion exchange***. Depending on the nature of the feed to the AWTP and resultant effluent from the carbon-based process train described in Section 5.1.1, addition of a future novel ion exchange may provide benefit.

Inclusion of a secondary GAC in the carbon-based train will be considered as a cost sensitivity case.

6.3.2 RO-Based Process

RO and UV/AOP are the main chemical removal processes in the RO-based AWTP described in Section 5.4. Removal is achieved by:

- Size exclusion through the RO;
- Oxidation by hydroxyl radicals formed in the AOP, and,
- Direct photolysis from the high UV dose (e.g. on the order of 1,000 mJ/cm^2).

While not a recommendation of this memorandum, if further investigation indicates additional chemical removal capability is required for the RO-based process train, consideration could be given to:

- ***Addition of Ozone/BAC***. The ozone/BAC system would be included upstream of the UF and RO. The removal mechanism provided by ozonation (i.e. oxidation by ozone and hydroxyl radicals generated in the process) would likely mean that no significant additional removal via oxidation would occur in the downstream AOP system. Hence, chemical dosing to the AOP (for the production of hydroxyl radicals) would likely provide little benefit. The high dose UV associated with the UV/AOP system may also provide little additional benefit in this arrangement (further investigation would be required to confirm). As discussed in Section 5.4, inclusion of ozone/BAC would increase capital cost[51] and operational complexity for limited benefit when there is AOP already in the process train.

  While adding complexity and capital cost, addition of ozone/BAC upstream of the UF and RO could be anticipated to provide meaningful benefits in addition to chemical removal, including:

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[50] NX Filtration offers an inside-out hollow fiber nanofiltration membrane that they proport to be suitable for direct filtration with only strainers as pre-treatment. Further investigation would be required to determine the feasibility of using this product for any of the short-listed schemes.

[51] Trussell (2024, [26]) suggests that the benefits in performance to the downstream membrane processes reduce operating cost such that the annualized cost to produce PRW is similar for an RO-based train with ozone/BAC pretreatment as that for an RO-based train without pretreatment (based on an interest rate of 3% per annum and a 30 year period). If an RO-based scheme is carried forward by RCC a detailed cost/benefit assessment of ozone/BAC pretreatment should be considered.

  - A more biologically stable effluent, resulting in lower levels of organic/biological fouling on downstream membrane processes;
  - A more filterable effluent, meaning the UF system could potentially be operated at a significantly higher design flux, reducing capital cost and also membrane replacement cost;
  - A reduction in loads of TOC and other chemicals of concern in the RO concentrate (relative to a flowsheet without ozone/BAC pre-treatment); and,
  - If the RO is not recovery limited due to inorganic constituents, potential for higher recovery operation.
- ***Addition of GAC***. As GAC operates through adsorption, addition of GAC may provide for additional chemical removal. Inclusion of GAC in the process train will increase capital cost and operational complexity, though to a lesser degree than ozone/BAC. The GAC would be located either downstream of the RO or downstream of the UV/AOP.

Inclusion of GAC in the RO-based train will be considered as a cost sensitivity case.

6.4 CHEMICAL PEAKS

The chemical risk assessment described in Section 6.1 is based on "steady state" chemical concentrations in the feed to the STP and AWTP. Additional consideration needs to be made with respect to the risk of peaks in the concentration of contaminants in the sewer network.

With respect to chemical peaks, the chemical risk assessment described in Section 6.1 suggests that risks for the short-listed scheme options could be similar to (or lower than) a typical catchment based on:

- The contribution of trade waste as a proportion of the overall STP average dry weather flow, and,
- The lack of heavy industry.

Water Research Foundation Project 4991 [20] suggests that utilities implementing DPR should pursue a balanced approach to control chemical peaks that includes an appropriate combination of two or more of the following: source control, enhanced monitoring, additional treatment barriers, and/or blending. As indicated in Section 6.1, enhanced source control is a recommendation of this investigation. Enhanced monitoring is also recommended as described in Section 6.2.

In the event that further investigation determines that the combination of enhanced source control and enhanced monitoring is insufficient to manage the risks associated with peaks in chemical concentrations, the additional chemical barriers considered in Section 6.3 (in the context of cost sensitivity to mitigate "steady state" chemical risks) could also provide some level of mitigation to chemical peaks. For example, the GAC added to the carbon-based train would be expected to help mitigate chemical peak risks, as would the addition of either ozone/BAC or GAC to the RO-based train. Other additional chemical barriers could be also considered for mitigation of chemical peak risks in the carbon-based train, such addition of a second GAC system to the carbon-based processes.

For the purpose of providing an indication of cost related to additional barriers to manage chemical peak risk, addition of a second GAC system to the carbon-based train has been included as a cost sensitivity case. An additional cost sensitivity case for the RO-based train is not included as the cost sensitivity case described in Section 6.3.2 would also be expected to help mitigate chemical peak risks.

7 CONCLUSIONS AND RECOMMENDATIONS

The conceptual AWTP process trains presented in this memorandum have been developed to allow for:

- Development of capital cost estimates for each short-listed potable reuse scheme;
- Identification of site configuration and area requirements (needed to identify suitable locations for each AWTP);
- Determination of return streams and impacts of these on the sewage treatment plant (STP);
- Identification of potential discharges to the environment (e.g. reverse osmosis (RO) concentrate);
- Determination of operation and maintenance requirements and associated costs;
- Engagement with regulators (as part of demonstrating the focus on protection of public health in the investigations); and,
- Setting expectations for RCC stakeholders regarding the nature and attributes of the treatment processes.

The conceptual AWTP process trains have been designed to achieve the pathogen LRV targets established for the project and to provide removal of compounds of concern. With respect to pathogen LRVs:

- The minimum pathogen LRV targets have been set to:
  - Ensure protection of public health, and,
  - Provide for robust, but reasonable in the Australian context, capital cost estimates.
- All process trains presented meet minimum pathogen LRV requirements to meet the drinking water target of 10^{-6} DALY;
- Process trains have also been assessed against preliminary "excess LRV" targets established to ensure cost estimates are sufficiently robust to facilitate RCC's decision-making process (with some cases requiring an additional unit process to meet the "excess LRV" target);
- The "Claimed LRVs" presented are a reasonable starting basis for the purposes of this investigation.

It is essential to note that the "excess LRVs" included in the targets have been considered exclusively for the purpose of cost estimating, and are not considered to be required for the management of pathogen risks in the opinion of the project team. The final minimum pathogen LRV requirements used in design of the AWTP (which will be subject to consultation and agreement with regulators) should be based on pathogen barrier failure modelling with consideration of:

- The LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere);
- The failure mode of each unit process (i.e. instantaneous, such as disinfectant dosing system failure, or gradual such as loss of UF membrane integrity which normally occurs slowly and can be observed through monitoring pressure decay test (PDT) trends;
- The response time of online analysers used for CCPs;
- The reliability and redundancy provided for these analysers;
- The use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk; and,
- Other design features used to mitigate risk (e.g. use of "off spec" diversions at CCP alert levels, use of Engineered Storage Buffer Tanks to allow for capture and diversion of water produced between analyser readings, etc.).

The conceptual process trains are intended to provide a reasonable basis on which to develop costs and site area requirements. Significant additional work will be required to verify the pathogen LRVs claimed in Table 5-1, including confirming validated LRVs for equipment selected during design (e.g. UV disinfection) and confirming Claimed LRVs by testing in a demonstration AWTP (e.g. LRVs claimed for direct filtration via biologically active carbon (BAC)). The claimed pathogen LRVs would also likely be subject to onsite validation (e.g. challenge testing) and verification testing (e.g. water quality sampling) during commissioning of the plant prior to regulatory approval to add PRW to the drinking water supply.

A high-level chemical risk assessment indicated that, in general, chemical control between each of the proposed schemes is expected to provide good control of chemical risk in the proposed catchments. The high-level chemical risk assessment did not identify any issues that would drive inclusion of additional chemical barriers in the conceptual process trains discussed in Section 5. Given the early stage of the project, the current level of unknowns with respect to compounds of concern likely to be present in the catchment, and the associated removals of those compounds through the AWTP process, sensitivity cases have been developed to provide a complete picture of worst-case costs and complexity to RCC. Where suitable, this includes additional unit processes that may provide additional chemical risk mitigation.

If any of the proposed schemes is carried forward, **it is strongly recommended that a demonstration plant be included**. Some key outputs from operating a demonstration plant could include:

- Validation of the claimed pathogen LRVs and chemical removal capability of each unit process and of the AWTP process train as a whole;
- Testing of various process configurations to allow RCC to determine the most cost-effective solution that provides the most robust outcome in terms of management of pathogen and chemical risks;
- Confirmation of appropriate media (e.g. for the BAC and GAC filters);
- Confirmation of appropriate design basis information (e.g. membrane flux, ozone decay, coagulant dose, etc.);
- Confirmation of appropriate process control strategies (e.g. ozone:TOC control instead of ozone C.t. control);
- Establishment of appropriate locations for and types of analysers for CCPs and general process monitoring and control;
- Development of initial alert and critical setpoints for CCPs;
- Training for operations staff;
- Opportunities for public education; and,
- Opportunities for senior management and administration personnel to be made aware of the reuse journey that RCC could be embarking on, together with all the components that must be carefully managed for the scheme to be a success and produce a sustainable future water supply for Rous.

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APPENDIX A: DISCUSSION PAPER – MINIMUM PATHOGEN REDUCTIONS FOR POTABLE REUSE SCHEME DEVELOPMENT

Rous County Council
Purified Recycled Water Investigations
Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development

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ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AOP	Advance Oxidation Process
AWTP	Advanced Water Treatment Plant
BAC	Biological Activated Carbon
CCPs	Critical Control Points
CIP	Clean-In-Place
Ct	Concentration x Contact Time
DALY	Disability Adjusted Life Year
DPR	Direct Potable Reuse
ESB	Engineered Storage Buffer
HACCP	Hazard Analysis and Critical Control Point
IPR	Indirect Potable Reuse
LRV	Log Reduction Value
MBR	Membrane Bioreactor
NWRI	National Water Research Institute
NSW	New South Wales
PDT	Pressure Decay Test
PRW	Purified Recycled Water
QMRA	Quantitative Microbial Risk Assessment
RCC	Rous County Council
RO	Reverse Osmosis
UV	Ultraviolet Light Disinfection
WHO	World Health Organization
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

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1 BACKGROUND

Rous County Council (RCC) is investigating the potential to utilise purified recycled water (PRW) as a climate resilient source of water for supply of potable water. As part of the *Purified Recycled Water for Drinking Investigations* project it is necessary to establish minimum pathogen log reduction values (LRV) to allow development of conceptual advanced water treatment plant (AWTP) process trains. The investigation has short-listed various scheme options for use of PRW, including:

- Indirect potable reuse (IPR) via surface water augmentation – PRW is discharged to an environmental buffer (e.g. dam or other large surface water storage) where it is blended with other water sources. The environmental buffer provides a minimum detention time for the water prior it being fed to a drinking water treatment plant (WTP);
- Direct potable reuse (DPR) via raw water augmentation – PRW is blended with other water sources and fed directly to the start of the WTP process without an environmental buffer; and,
- DPR via treated water augmentation – PRW is blended with treated water from the WTP in the drinking water distribution system.

At the time of writing, New South Wales (NSW) does not have any guidelines or regulations for potable reuse. However, the NSW Water Strategy does include actions associated with development of a *Recycled Water Roadmap* to identify policy and regulatory options.

The Greater Sydney Water Strategy [1] references the use of PRW as follows:

"Purified recycled water involves releasing highly purified wastewater into an 'environmental buffer', such as a river or underground aquifer before re-extracting and treating the water for drinking. Currently there are no indirect potable schemes in NSW." [1, p. 69]

Notably, the Draft Regional Water Strategy for the Far North Coast [2, p. 111] identified both indirect and direct potable reuse as long list options to improve town water security, and to protect and enhance the environment.

The current regulatory approach adopted by NSW regulatory agencies toward DPR is guided by the *Australian Guidelines for Water Recycling: Phase 2 Augmentation of Drinking Water (2008)*.

The current Australian Guidelines for Water Recycling (AGWR) [3] detail an approach for determining the minimum LRV requirements for schemes based on indirect augmentation. The approach adopted by NSW regulatory agencies toward DPR is guided by this document. While the AGWR [3] do not exclude direct augmentation schemes, they do not provide a prescribed pathway for approval. More specifically, the AGWR [3] indicate that[1]:

- *"Direct augmentation will require higher levels of treatment to provide sufficient assurance that water-quality targets can be met and maintained."* [3, p. 45], and,
- *"The need for reliability of processes, vigilance of monitoring and highly skilled operators — already high for indirect use — is magnified for direct augmentation. Knowledge and understanding of system reliability and control of variability is essential before direct augmentation can proceed. Further research is required in this area."* [3, p. 4].

The feed water to the AWTP comprises treated effluent from wastewater treatment plants (WWTPs) under each of the short-listed schemes. In considering the pathogen load that needs to be treated, the AGWR [3] considers the minimum log removal values (LRVs) from raw wastewater (rather than WWTP effluent).

[1] Significant work has been undertaken with respect to DPR since the AGWR was published in 2008. Section 5 discusses the current approach to address these concerns raised in the AGWR.

Pathogen reduction is achieved by treatment through the WWTP and AWTP, and in the case of surface water augmentation and raw water augmentation also through treatment through the downstream WTP. For surface augmentation, some level of pathogen reduction may also be possible through the environmental buffer.

In addition to pathogen risks, the risks associated with chemicals in the raw wastewater also need to be considered. Chemical risks are being considered as a separate task within the investigation.

Minimum LRV targets presented in this report have been developed based on high-level quantitative microbial risk assessment (QMRA). The high-level QMRAs provide a broad overview to specifically highlight or eliminate concerns. In the absence of substantial scheme-specific data, the QMRAs have:

- Applied documented typical and literature values, assessment methodology and data (as sourced from the AGWR [3], Australian Drinking Water Guidelines (ADWG) [4] and World Health Organization (WHO) guidance [5]);
- Developed minimum pathogen LRV targets based on the AGWR methodology using typical pathogen densities and DALY values, and,
- Included limited modelling of failure scenarios.

2 PURPOSE

This discussion paper describes the derivation of the minimum pathogen LRV requirements proposed to be applied to development of the conceptual AWTP process trains for each of the short-listed schemes**, for the purpose of providing cost estimates for RCC's forward planning (this document is not intended to establish pathogen LRV criteria with which a future design would be based as additional work (e.g. site-specific testing/demonstration, engagement with the regulator, etc.) will be required to establish these criteria)**. In combination with the chemical removal requirements, the minimum pathogen removal will have a strong bearing on the key attributes of the schemes, including:

- The process units to be utilised in the process trains, and their configuration;
- Operational and maintenance requirements (e.g. critical control points (CCPs), operator skills, sampling/monitoring, etc.) required to verify the required water quality is delivered at all times;
- High level estimates of the capital costs for each scheme; and,
- High level estimates of the operating costs for each scheme.

A key aim of this discussion paper is to establish the proposed pathogen removal requirements for each scheme type (for costing purposes) that:

1. Are consistent with robust protection of public health, while,
2. Not imposing excessive treatment requirements that increase costs or complexity without providing meaningful improvements to public health protection.

3 PATHOGEN REDUCTION

Pathogen reduction is achieved by treating the source water with various treatment processes, referred to as "barriers". Similar to the methodology prescribed by the ADWG [4], the AGWR [3] requires a multiple barrier approach. The AGWR [3] states:

"Multiple barriers protect against variations in performance of individual barriers. Variations in different barriers are unlikely to align to the extent that all perform poorly at the same time; nevertheless, every effort should be taken to ensure that barriers operate within acceptable ranges." [3, p. 8]

There is a distinction between the "Achievable LRV" for a given barrier (as demonstrated in field investigations, challenge tests and laboratory trials), and the "Validated LRV" (which can be confirmed through validation in the design and commissioning of the plant, and then verified by monitoring ongoing operation). The Validated LRV is limited by practical limitations on the operational monitoring and quality of evidence available regarding the minimum pathogen removal.

For the purposes of establishing conceptual treatment process trains for which "Claimed LRVs" meet or exceed the minimum LRV requirement, it is proposed that Claimed LRVs consider Validated LRVs that are based on short term verification (e.g. online analysers reporting results in minutes) and longer-term verification (e.g. daily pressure decay tests (PDTs) on membrane filtration units). Using membrane filtration as an example:

1. Failures in membrane integrity would be detected in real time by turbidity;
2. Spikes in turbidity would be used to trigger an out of schedule/immediate PDT which can verify if there is an actual integrity issue;
3. The act of triggering a PDT is a corrective action in itself, as the suspect unit is no longer producing water;
4. There are no known reports of membrane systems that have failed significantly (e.g. more than 2 log) within 24 hours and not shown other symptoms.
5. It is assumed the system would be well designed and have multiple trains. Each train would have a scheduled PDT performed every day. The PDTs would not occur at the same time, but be scheduled across the day. In this way, the whole treatment process is incrementally checked multiple times a day.

There is currently no national guidance on the maximum LRV that can be claimed per treatment process. A maximum of 4 LRV per treatment process has generally been applied for recycled water applications in Australia (both potable and non-potable), including in:

- Victoria's *Guidelines for validating processes for pathogen reduction* [6] (for non-potable reuse applications);
- The NSW Department of Primary Industries Office of Water's *Recycled Water Guidance Document* [7], and,
- The Australian Drinking Water Guidelines (ADWG) [4].

For the purpose of developing the conceptual AWTP treatment process trains, <u>a maximum 4 LRV per unit process has been assumed</u> for this investigation, noting that other jurisdictions (e.g. California) permit up to 6 LRV to be claimed for certain processes (e.g. ozonation, UV disinfection, chlorination).

With respect to operation of a potable reuse scheme, the pathogen removal requirements have been considered based on the expectation that the system would be managed and operated in accordance with prevailing best practice, including:

- Operation in accordance with comprehensive and appropriate management systems and documentation (e.g. Hazard Analysis and Critical Control Point (HACCP) Plan, standard operating procedures, incident response procedures, etc.);
- The AWTP treatment process utilises a multiple barrier approach, with no one barrier claiming more than 4 LRV for a given pathogen type;

- Treatment process units utilised have been demonstrated to provide the required performance, reliability and robustness to ensure protection of public health and can be validated to achieve the Claimed LRV;
- Operations personnel have suitable qualifications, training[2] and experience, and the team is adequately resourced;
- The plant design and configuration are consistent with the comprehensive HACCP Plan, with:
  - CCPs with both “alert” and “critical” limits, where:
    - Critical limits set at the point where the claimed LRV would be breached; and,
    - Alert limits set sufficiently below the critical limit to allow operations personnel to respond before the critical limit is reached;
  - Automated shutdown of the relevant process unit and/or diversion of product water or if the critical limit is reached;
  - Robust control system design and testing (initial and ongoing) to ensure all CCPs function as intended;
  - Redundancy for CCP analyser systems, where appropriate;
  - For DPR via treated water augmentation: Product water tankage sized and configured with a minimum residence time in excess of the duration between the longest consecutive monitoring events for any CCP analyser. This will ensure any water produced prior to any CCP critical level breach being recorded is captured prior to discharge from the AWTP. The tankage would be equipped with an automated diversion system to allow the contents of the tank to be returned to the WWTP and/or AWTP for retreatment.
- Maintenance personnel have suitable qualifications, training and experience, and the team is adequately resourced. Additionally, it is the expectation that maintenance staff are trained such that they understand the potential impacts of their actions on operation of the plant;
- Predictive, preventative and reactive maintenance is performed in accordance with an approved maintenance system to ensure optimal plant performance;
- A clear communication plan is in place for interaction between operations and maintenance activities (generally including a permit to work type of system where Operations has to sign off on maintenance activities before they commence); and,
- A change management system is in place and followed to prevent unexpected/unknown changes from occurring (e.g. changes to the coding of the plant control system).

3.1 Source Control

Source control can be used as a means of reducing chemical risk in the source water (e.g. stringent discharge limits on trade waste users and the ability to stop their discharge to sewer if they are not meeting their discharge condition). However, source control is not considered as a means to directly reduce pathogen concentrations.

Another aspect of source control is its role as the first barrier in the treatment process. While source control directly reduces the chemical risk within the treated water from the AWTP, the control of adverse chemicals also helps prevent upsets at the WWTP which helps ensure the AWTP process units operate optimally and as intended. An example of this would be an enhanced source control program removing chemicals that are fouling to membrane systems, resulting in extension of the time interval between chemical clean-in-place (CIPs) events and prolonging the life of the membranes.

[2] Operator understanding of how to operate the plant and why the plant needs to be operated in accordance with the design is critical to success, hence operator training needs appropriate consideration in the overall development of any PRW scheme. Operator training will need to start well before commissioning of the full scale AWTP and will depend on whether RCC intends to utilize its own operations staff, for which RCC would need to develop a training program, or if RCC intend to hire a contract operator with experience operating this type of scheme (e.g. Veolia). Training would likely include operators gaining experience with the process units by participating in operation of a demonstration plant, developing an understanding of the design of the AWTP by taking part in design reviews and workshops (e.g. HACCP, HAZOP, etc.), attending training delivered by the design team (including the equipment suppliers) with the design team tasked with ensuring operator understanding (i.e. just attending the training would not be sufficient, a means to test the operators knowledge following the training would be needed), and could also include visits to other operating AWTP facilities (e.g. multiple weeks working directly with operators of these facilities).

3.2 WASTEWATER TREATMENT[3]

The secondary wastewater treatment process provides a level of pathogen removal and hence can be considered as a barrier. Table 3-1 provides indicative achievable and validated pathogen LRV for secondary treatment [6].

Table 3-1: Indicative Pathogen LRV for Secondary Treatment of Wastewater

Treatment Process	Achievable LRVs			Validated LRVs			Online analysers for verification
	Virus	Protozoa	Bacteria	Virus	Protozoa	Bacteria	
Secondary Treatment[1]	2	2	2	0.5 - 1	0.5 - 1	1 - 2	Ammonia – analysis results returned every 15 to 30 minutes Turbidity – continuously reporting analyser results[2]

1. Ballina WWTP utilises membrane bioreactor (MBR) technology. MBRs have higher validated LRVs based on the membrane process, but Ballina has historically had issues with the membranes at this plant. Hence, no consideration is given to the potential higher MBR LRVs in this work. The existing membranes are being replaced with new membranes from a different manufacturer. Should any schemes be developed in future that utilise Ballina WWTP effluent, the LRV claimed for this plant should be considered further.
2. CCP would require analyser reading to be above the critical limit for a defined time (e.g. > 10 NTU for more than 5 minutes) before the CCP would be considered breached.

For the purpose of this investigation, a conservative validated LRV of 0.5 is proposed to be claimed for each pathogen type for the WWTP. For reference, the Beenyup WWTP is credited with an LRV of 1.0 for each of virus and bacteria and of 0.5 for protozoa as part of Water Corporation's groundwater replenishment scheme [5].

It is likely additional LRV could be claimed for the WWTP, but further site-specific study would be required to justify. This would include collecting an extensive data set over the biological treatment operational range, which would mean defining the nutrient removal values, effluent BOD, effluent UV transmittance, and effluent turbidity.

3.3 ADVANCED WATER TREATMENT PLANT

A variety of treatment processes can be used in an AWTP for pathogen reduction. Table 3-2 provides indicative achievable and validated pathogen LRV for various treatment processes that could be included in the conceptual AWTP design (validated LRVs are from the ADWG[4] [4]).

[3] Reference to protozoa in Section 3.2 through 3.4 means *Cryptosporidium.*
[4] With some modification as described in the table notes.

Table 3-2: Indicative Pathogen LRV for Potential AWTP Treatment Processes

<table>
<tr><th rowspan="2">Treatment Process</th><th colspan="3">Achievable LRVs</th><th colspan="3">Validated LRVs</th><th rowspan="2">Online analysers for verification of CCP</th></tr>
<tr><th>Virus</th><th>Protozoa</th><th>Bacteria</th><th>Virus</th><th>Protozoa</th><th>Bacteria</th></tr>
<tr><td>Microfiltration/Ultrafiltration[1]</td><td>3</td><td>6</td><td>6</td><td>0</td><td>4</td><td>4</td><td>Turbidity – continuously reporting analyser results[2] PDT – daily</td></tr>
<tr><td>Ozone[3]</td><td>4</td><td>3</td><td>4</td><td>4</td><td>0</td><td>4</td><td>Ozone residual – continuously reporting analyser results
Flow – continuously reporting (to allow determination of Ct)</td></tr>
<tr><td>Biological Activated Carbon (BAC)[4]</td><td>-</td><td>-</td><td>-</td><td>1</td><td>0.5</td><td>1</td><td>BAC effluent turbidity – continuously reporting analyser results</td></tr>
<tr><td rowspan="2">Reverse Osmosis (RO)[5]</td><td rowspan="2">6</td><td rowspan="2">6</td><td rowspan="2">6</td><td colspan="3">1.5 – 2</td><td>Conductivity – continuously reporting analyser results
TOC - analysis results returned every 10 minutes</td></tr>
<tr><td colspan="3">2.5 – 4</td><td>Sulphate/fluorescent dye testing</td></tr>
<tr><td>Ultraviolet Light Disinfection (UV) [6]</td><td>6</td><td>6</td><td>6</td><td colspan="3">4</td><td>Flow – continuously reporting results

UV transmittance – continuously reporting analyser results
UV Intensity – continuously reporting analyser results</td></tr>
<tr><td>UV/Advanced Oxidation Process (AOP)</td><td>6</td><td>6</td><td>6</td><td colspan="3">4</td><td>Flow – continuously reporting results
UV dose – continuously reporting results
UV transmissivity – continuously reporting analyser results</td></tr>
<tr><td>Chlorine</td><td>6</td><td>0</td><td>6</td><td>4</td><td>0</td><td>4</td><td>Free chlorine – analysis results returned every 3 to 5 minutes</td></tr>
</table>

Notes:

1. Ultrafiltration systems can obtain 3+ LRV of virus, whereas microfiltration systems can obtain 1+ LRV of virus. The UF system at Beenyup AWRP claims 3 log virus removal [5]. There is current work studying real time measurement of virus with online analysers that would allow for frequent (e.g. daily) challenge testing of UF systems to allow for claiming higher virus LRVs. The ADWG [4] currently allocates no virus LRV credit for microfiltration or ultrafiltration.
2. CCP would require analyser reading to be above the critical limit for a defined time (e.g. > 0.15 NTU for more than 5 minutes) before the CCP would be considered breached.
3. Control of the ozone system could be based on Ozone/TOC ratio (for control of Bromate formation) or Ozone C.t. Where Ozone C.t is utilised, the US EPA Long Term 2 Enhanced Surface Water Treatment Rule: Toolbox Guidance Manual [8] indicates claimable *Cryptosporidium* LRV of 0.25 to 3 (based on increasing ozone C.t). The WaterVal Ozone Disinfection Validation Protocol [9] (and ADWG [4]), include the same *Cryptosporidium* LRV information as US EPA [8], and supports up to 4 LRV for virus. US Water Research Foundation Project 5129 demonstrated that using the ozone/TOC ratio is a much more accurate and controllable method to demonstrate up to 5 LRV of virus. As ozone dose increases the risk of bromate formation increases.
4. RCC currently claim separate LRV for ozonation and the BAC filters at Nightcap WTP. This approach is proposed to be considered in the development of the AWTP process trains where/if appropriate, noting that the indicative pathogen LRV attributable to media filtration (as described in Table 5.6 of the ADWG [4]) currently relies on coagulation upstream of the filtration to be credited for virus removal (there is currently a WaterVal project underway to investigate validation of granular media filters) .
5. The approach to AWTP process train development will be to limit claimed LRV to that which can be validated LRV based on online conductivity/TOC only. The WaterVal Reverse Osmosis and Nanofiltration Validation Protocol supports RO LRV of up to 4 [10]. The RO system at Beenyup AWRP claims 3 log virus, protozoa and bacteria removal [5] (understood to be based on weekly sulphate testing).
6. While disinfection via hydroxyl radical chemistry has been demonstrated for ozone/peroxide systems, it is not currently possible to monitor and properly control at this time. For the purposes of establishing AWTP process trains, it is proposed that UV/AOP pathogen Claimed LRV is based entirely from UV standard monitoring methods. The WaterVal UV Disinfection Validation Protocol supports up to 4 LRV for all pathogen types [11].
7. The WaterVal Chlorine Disinfection Validation Protocol supports up to 4 LRV for virus and bacteria [12].

3.4 RCC DRINKING WATER PLANTS

Two short-listed scheme options direct the PRW to the inlet of Nightcap WTP (IPR via surface augmentation and DPR via raw water augmentation). Table 3-3 shows the LRVs claimed for Nightcap WTP within its Drinking Water Management System, and the basis applied to verification of those LRVs.

Table 3-3: Nightcap WTP LRVs

Treatment Process	Virus	Protozoa	Bacteria	Basis
Dissolved Air Flotation + Filtration	2	3.5	2	Effluent turbidity < 0.2 NTU 95% of the time and not > 0.5 NTU for > 15 min
Ozone	4	0.5	4	Ct value of 3.2 mg-min/L, based on achieving ozone residual of 0.135 mg/L
BAC	1	0.5	1	Effluent turbidity < 0.15 NTU 95% of the time and not > 0.3 NTU for > 15 min
Chlorine	4	0	4	Ct value of 16 mg-min/L, when > 1.2 mg/L free chlorine residual
Total	**11**	**4.5**	**11**	

Nightcap WTP has two different sets of treatment requirements to achieve the health-based targets in alignment with ADWG [4] – one for each of the Rocky Creek Dam and Wilsons River raw water sources. Table 3-4 compares the total claimed LRVs to the pathogen removal required for the two source waters. With improvements to control of the ozonation system it is likely that higher LRVs will be claimable.

Table 3-4: Nightcap WTP Required versus Claimed LRVs

Pathogen	Claimed LRV	Rocky Creek Dam		Wilsons River	
		Required LRV	Difference	Required LRV	Difference
Virus	11	4	+7	6	+5
Protozoa	4.5	3	+1.5	5	-0.5
Bacteria	11	4	+7	6	+5

Table 3-4 shows that the Nightcap WTP provides surplus LRV for virus and bacteria for both water sources and surplus for protozoa for the Rocky Creek Dam source. The plant has a shortfall of 0.5 LRV for protozoa for the Wilsons River source, however this is acceptable under the ADWG [4] as the microbial health outcome target of 10^{-6} disability adjusted life years (DALYs) per person per year is applied as an operational benchmark (rather than as a pass/fail criteria).

Traditionally in Australia, potable reuse schemes have not considered the LRVs in the WTP. While the WTP processes are not proposed to be claimed for the IPR or treated water augmentation options, they may be relevant to raw water augmentation options (particularly in relation to excess "LRV" requirements). For this investigation, it is proposed that LRVs achieved within the WTP be considered in the pathogen risk controls for the short-listed raw water augmentation scheme.

4 MINIMUM PATHOGEN LRV FOR PROTECTION OF PUBLIC HEALTH IN POTABLE REUSE SCHEMES

4.1 Baseline Pathogen LRVs

The AGWR [3] uses DALYs to convert the likelihood of infection or illness into burdens of disease, and sets a tolerable risk as 10^{-6} DALYs per person per year. The latest version of the ADWG [4] sets the same DALY target as an operational benchmark (rather than a pass/fail criteria). Disability adjusted life years dose (DALYd) is the dose of pathogens equivalent to a DALY of 10^{-6}. DALYd includes consideration of dose response[5], ratios of infection to illness and severity weighting of the illness.

As it is impractical to set targets for all pathogens potentially present in a source of recycled water, the AGWR [3] specifies the use of the following reference pathogens:

- Virus – amalgam rotavirus and adenovirus (where the dose response relationship for rotavirus is used in conjunction with occurrence data for adenovirus)
- Protozoa and helminths – *Cryptosporidium*
- Bacteria – *Campylobacter*

The following equation is used to determine the minimum LRV for each reference pathogen to meet the target of 10^{-6} DALYs per person per year:

$$\text{Minimum LRV} = \log_{10} (\text{pathogen concentration in source water} \times \text{exposure} \times N \div \text{DALYd})$$

where:

- Pathogen concentration is the 95th percentile of reference pathogen concentration in source water. Default values are provided in AGWR [3] as follows:
  - Rotavirus – 8,000 per L
  - *Cryptosporidium* – 2,000 per L
  - *Campylobacter* – 7,000 per L
- Exposure can be defined as the amount of water consumed (2 L/d per AGWR [3])
- N is the number of exposures per year (assumed daily)
- DALYd is given by AGWR as:
  - Rotavirus – 2.5×10^{-3} per year
  - *Cryptosporidium* – 1.6×10^{-2} per year
  - *Campylobacter* – 3.8×10^{-2} per year

Table 4-1 summarises the QMRA based on the above parameters and the resulting minimum LRV for each reference pathogen based on this approach.

[5] Relationship between dose of organism and incidence or likelihood of illness.

Table 4-1: Minimum LRV Required Based on AGWR [3] based on 2 L/d Ingestion

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Rotavirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	8,000	2,000	7,000
DALYd	number per year	2.5×10^{-3}	1.6×10^{-2}	3.8×10^{-2}
Exposure	L/d	2	2	2
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	3.4×10^{-6}	2.2×10^{-5}	5.2×10^{-5}
Minimum Pathogen Removal	LRV	9.4	8.0	8.1
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**9.5**	**8.5**	**8.5**

The ADWG [4] suggest a reference exposure volume of 1 L unheated (unboiled) water per person per day. Table 4-2 shows the QMRA based on the above parameters and the resulting minimum LRV requirements based on this lower exposure volume.

Table 4-2: Minimum LRV Required Based on AGWR [3] based on 1 L/d Ingestion

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Rotavirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	8,000	2,000	7,000
DALYd	number per year	2.5×10^{-3}	1.6×10^{-2}	3.8×10^{-2}
Exposure	L/d	1	1	1
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	6.9×10^{-6}	4.4×10^{-5}	1.0×10^{-4}
Minimum Pathogen Removal	LRV	9.1	7.7	7.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**9.5**	**8.0**	**8.0**

Where the AGWR [3] considers Rotavirus, the ADWG [4] utilises the dose-response relationship of Norovirus in combination with the concentration of Adenovirus. As the ADWG does not have default concentrations for reference pathogens in raw wastewater, the concentrations for these pathogens in the WHO document *Potable Reuse Guidance for Producing Safe Drinking Water* [5] can be applied. Using the dose-response relationships, the relationships of infection to illness and the DALY per illness information provided in the ADWG [4] and the WHO pathogen concentration default values, there are differences in the calculated minimum pathogen removal requirements as compared to Table 4-1. Table 4-3 shows the revised DALYd values and the resultant minimum LRV that would need to be met under:

- The ADWG values for Norovirus dose-response;
- A raw wastewater concentration of Adenovirus based on WHO guidance, and,
- Ingestion of 2 L/d.

Table 4-3: Minimum LRV Required Based on ADWG [4] **combined with WHO** [5]

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus / Adenovirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	20,000	2,700	7,000
DALYd	number per year	3.6×10^{-3}	4.2×10^{-3}	7.5×10^{-3}
Exposure	L/d	2	2	2
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	5.0×10^{-6}	5.8×10^{-6}	1.0×10^{-5}
Minimum Pathogen Removal	LRV	9.6	8.7	8.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**10.0**	**9.0**	**9.0**

WHO uses 1 L/d ingestion of unboiled drinking water as per ADWG [4]. Table 4-4 summarises the QMRA that derives the WHO default LRV targets [5].

Table 4-4: WHO 2017 Default LRV Targets [5]

Parameter	Units	Virus	Protozoa	Bacteria
Reference pathogen		Norovirus / Adenovirus	*Cryptosporidium*	*Campylobacter*
Pathogen concentration in source water	number per L	20,000	2,700	7,000
DALYd	number per year	4.2×10^{-3}	4.4×10^{-3}	7.3×10^{-3}
Exposure	L/d	1	1	1
N	d/year	365	365	365
Equivalent tolerable pathogen concentration in drinking water	number per L	1.1×10^{-5}	1.2×10^{-5}	2.0×10^{-5}
Minimum Pathogen Removal	LRV	9.3	8.4	8.5
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**9.5**	**8.5**	**8.5**

WHO [5] does not differentiate LRV targets for IPR and DPR (i.e. the same target applies for both). There is discussion in WHO [5] related to the use of engineered storage buffers (ESBs) for DPR, with much shorter detention times than that provided by environmental buffers in an IPR system. The following is an excerpt from WHO [5] related to the use of ESBs:

"*An ESB is a storage basin or system that provides sufficient time, termed the failure and response time, to interrogate and respond to any faults, including exceedances of critical limits in operational monitoring of the treatment train. Storage times in ESBs are likely to be of the order of hours to days. The failure and response time should take into account sampling intervals, time to complete analyses and time to respond. For example, for online parameters such as turbidity or disinfectant residuals, sampling intervals are very short, analyses are completed immediately and actions can be implemented within minutes. This can involve interrogating system performance by an operator or making a decision to stop the supply of water.*"

As the LRVs derived based on the ADWG (Table 4-3) are slightly more conservative for protozoa and bacteria than current AGWR [3], and slightly more conservative on bacteria than WHO [5], these values are the minimum LRV requirements proposed for this investigation.

The industry's knowledge of raw wastewater pathogen loads is evolving. For example, Gerrity et.al. [14] indicates a 95th percentile adenovirus (culture) concentration in raw wastewater of 2.5 x 10^4 per L. This is similar to the value listed in WHO guidance [5] of 2.0 x 10^4 per L. Using the slightly more conservative Gerrity et. al. value, and an assumed exposure of 2 L per person per day, the minimum virus LRV increases to 9.7 (which would result in a rounded value of 10). Potential increases in the minimum pathogen LRVs based on changes to the reference pathogen default values will be considered as part of a discussion of risks.[6]

4.2 Other Pathogen Removal Considerations

Given that there is not a prescribed pathway for DPR schemes in the current AGWR [3] (see Section 1), RCC has requested consideration of potential requirements for "excess LRVs" based on approaches in other jurisdictions - primarily in order to estimate the cost impacts should the regulator choose to require higher LRVs than those determined based on AGWR [3].

It is important to note that this study will not be able to identify or resolve all issues that may arise during the implementation of the risk-based framework as:

1. As noted in the NSW Office of Water Recycled Water Guidance Document (Recycled Water Management Systems, 2015), *Commercial and other considerations should be made ahead of the risk-based recycled water management system (RWMS) process and in the context of an Integrated Water Cycle Management (IWCM) Strategy and best practice.*" [7];
2. The RWMS is essentially the application of the AGWR, and,
3. The information required for application of the full AGWR methodology is not available for the current stage of scheme investigation.

IMPORTANT: It is important to note that it is not viable for the minimum LRVs required for DPR schemes in the Australian context to be derived or specified as a part of this investigation – the prevailing guidelines and lack of precedent within Australian (or NSW) regulations makes this impractical. To this end, the proposed considerations of minimum LRVs for DPR in this document are not intended to provide direction or guidance on what minimum LRV requirement may ultimately be required. Rather, the intent of this section is to develop reasonable assumptions with respect to pathogen LRVs to allow development of realistic cost estimates for the short-listed schemes (and consider the sensitivity to higher, but still realistic in the Australian context, LRVs).

4.2.1 Indirect Potable Reuse via Surface Water Augmentation

The short-listed option utilising IPR via SWA assumes an engineered storage will be constructed to provide an environmental buffer between the AWTP discharge and the supply to the Nightcap WTP. For this scheme, PRW produced from the effluent of the South Lismore and East Lismore WWTPs would be discharged to an open surface water storage of at least 600-1,200 ML volume. The storage may also receive flow from the Wilsons River Source to improve the effective yield of this source, and the combined PRW / Wilsons River water transferred from the storage to the inlet of Nightcap WTP via the existing Wilsons River Source High Lift Pump Station.

As IPR schemes are covered by the AGWR, the minimum LRV requirements detailed in Table 4-3 are proposed to be adopted for the conceptual design of the AWTP for the surface water augmentation scheme option. On this basis, no sensitivity to higher LRVs is proposed for this option.

[6] QMRA conducted by RCC using the DPRisk tool and point estimates for influent pathogen concentration derived from probability distribution functions (which differ from the point estimates for pathogen load as used in AGWR/ADWG) suggest virus LRV would increase to 9.7 (rounded to 10) (matching the result by Gerrity et.al. [14], *Cryptosporidium* LRV would increase to 8.7 (rounded to 9.0) and *Campylobacter* LRV would increase to 10.3 (rounded to 10.5).

4.2.2 Direct Potable Reuse via Raw Water Augmentation

The three DPR options short-listed for assessment under the investigation comprise:

- Raw water augmentation – PRW produced from Lismore source waters transferred to inlet of Nightcap WTP (without an environmental buffer);
- Treated water augmentation:
  - PRW produced from Byron source waters delivered to St Helena Reservoir and blended with potable water from the distribution network; and,
  - PRW produced from Lismore sources delivered to the main Lismore reservoirs and blended with potable water from the distribution network.

For reference, three examples of regulatory approaches to DPR in the US are outlined in Section 4.2.2.1 through 4.2.2.3. Note that these examples are provided for information only. The approach to derivation of LRV requirements is vastly different between the approaches taken in these examples and the approach used in Australian and as endorsed by WHO [5] (i.e. used on DALYd taking into account dose response, ratios of infection to illness and severity weighting of the illness) and **therefore it is not reasonable to directly compare these examples to the Australian approach**.

4.2.2.1 Colorado

Colorado's approved *Direct Potable Reuse Policy* [15] sets the following default minimum LRV requirements for system lacking data on pathogen concentration in the treated wastewater effluent source water:

- Virus (Adenovirus) - 12
- *Cryptosporidium* – 10

The Colorado policy [15] provides flexibility for a DPR proponent to demonstrate alternative minimum LRV targets based a "dedicated sampling program", with the alternative minimum LRV targets not allowed to be lower than 8 LRV for virus and 5.5 log for *Cryptosporidium*.

Colorado's policy [15] states the definition of DPR as:

"using a series of processes that produce finished drinking water utilizing a source containing treated wastewater that has not passed through an environmental buffer."

Additionally, Colorado's approach would consider the unit processes in the drinking water treatment plant as part of the treatment system to achieve these minimum LRV requirements (for raw water augmentation).

4.2.2.2 Texas

The Texas Commission on Environmental Quality's approach to DPR [16] sets a minimum LRV of 8 for virus and 5.5 for *Cryptosporidium*. These minima are then potentially subject to increase based on:

1. Site-specific pathogen measurements, with the LRVs required for each pathogen calculated as the difference between the incoming WWTP effluent and the maximum permissible EPA finished water pathogen concentrations of 2.2×10^{-7} MPN/L for virus and 3.0×10^{-5} oocysts/L for *Cryptosporidium*, and,
2. A quantitative microbial risk assessment (QMRA).

While the Texas approach is efficient (in that each project need only provide pathogen reduction as required based on site specific conditions), it does not readily provide confirmation of the LRV requirements during the early investigation/planning stages due to the lack of site-specific information. The Texas approach is not considered further here.

4.2.2.3 California Indirect Potable Reuse

California has regulations for IPR by direct groundwater recharge[7] and by surface water augmentation[8]. Gerrity et. al. [14] describes the derivation of the California LRV requirements for IPR by direct groundwater recharge. This information is summarised in Table 4-5.

Table 4-5: California IPR LRV Requirements

Parameter	Units	Virus	Protozoa
Reference pathogen		Norovirus	*Cryptosporidium*
Pathogen concentration in source water	number per L	100,000	10,000
Exposure	L/d	2	2
Acceptable pathogen concentration in drinking water	number per L	2.5×10^{-7}	1.6×10^{-6}
Minimum Pathogen Removal	LRV	11.6	9.8
Minimum Pathogen Removal (rounded to next highest 0.5 log)	**LRV**	**12**	**10**

California's regulations for IPR by surface water augmentation have lower LRV targets than the targets for direct groundwater discharge, due to the ability to utilize LRV credits from the surface water treatment plant[9]. Specifically[10]:

- 8 LRV are required for both virus and *Cryptosporidium* if the volume of water withdrawn from the augmented reservoir to be ultimately supplied for human consumption contains no more than one percent, by volume, of recycled municipal wastewater that was delivered to the surface water reservoir during any 24-hour period; or,
- 9 LRV are required for both virus and *Cryptosporidium* if the volume of water withdrawn from the augmented reservoir to be ultimately supplied for human consumption contains no more than ten percent, by volume, of recycled municipal wastewater that was delivered to the surface water reservoir during any 24-hour period.

For the purposes of this investigation, only the more conservative IPR by direct groundwater discharge LRV requirements are considered further (see Section 4.2.2.3).

The approach used in the California IPR regulation for protection of public health differs from that applied within the AGWR [3], ADWG [4] and WHO guidelines [5]. The California IPR approach is based on limiting infections to 1 in 10,000 per person per year [14], whereas AGWR/ADWG/WHO is based on achieving a disease burden of 10^{-6} DALYs per person per year.

The California IPR criteria lower the tolerable drinking water pathogen concentrations by 1 to 2 orders of magnitude compared to the AGWR/ADWG/WHO approach. The California IPR regulation also uses significantly higher source water pathogen concentrations than either AGWR [3] or WHO [5] (1 to 2 orders of magnitude difference for virus and 1 order of magnitude difference for *Cryptosporidium*). These differences have a direct impact on the significant differences in the LRV requirement.

[7] California Title 22, Division 4, Chapter 3, Article 5.2 (https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I735469B05B6111EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default))
[8] California Title 22, Division 4, Chapter 3, Article 5.3 (https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I73ECB2105B6111EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default))
[9] California's Surface Water Treatment Rule requires the surface water treatment plant to achieve a minimum LRV for virus of 4 and for Cryptosporidium of [20]
[10] https://www.law.cornell.edu/regulations/california/22-CCR-64668.30

4.2.2.3 California Direct Potable Reuse

Prior to enacting DPR regulations in November 2023[11], California published a *Proposed Framework for Regulating Direct Potable Reuse* [17].

The draft DPR criteria [17] modified the assumptions applied in the development of California's IPR criteria. These changes result in the following <u>baseline</u> LRV requirements:

- Virus (Norovirus) – 16 (increase from 12 for IPR)
- *Cryptosporidium* – 11 (increase from 10 for IPR)

In addition to the baseline LRV requirement, the draft California DPR criteria [17] include additional LRV requirements to account for failure of a unit process (6-log reduction in system LRV) once per year for 15 minutes. This provision further increases the LRV requirements to:

- Virus (Norovirus) – 20 (increase from 12 for IPR)
- *Cryptosporidium* – 15 (increase from 10 for IPR)

California has recently made available the *Notice of Public Availability of Changes to Proposed Direct Potable Reuse Regulations and Addition of Material to the Rulemaking Record* (SBDDW-23-001) [18]. This document does not change the pathogen LRV requirements from the previous values.

One of the changes California made in their assessment of baseline LRV requirements was shifting from an annual infection risk benchmark of 10^{-4} to a daily infection risk benchmark of 2.7×10^{-7}, related to decreased response time relative to IPR applications [14]. Gerrity et. al. analysed excess LRV requirement on the basis of a 10^{-4} to a daily infection risk [14] and determined that this change would result in the following LRV targets for a 6 LRV failure scenario:

- Virus (Norovirus) – 17
- *Cryptosporidium* – 12

An NWRI expert panel[12] review of California's draft DPR criteria [19] found that the "*draft pathogen control criteria are based on numerous conservative assumptions that result in an over-engineered treatment facility. Thus, the draft pathogen control criteria require additional treatment that does not contribute additional public health protection.*"

More specifically, with respect to the baseline LRV conditions, the NWRI expert panel indicated [19]:

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[11] The draft LRV targets in the proposed criteria have been adopted in the enacted regulation.

[12] The NWRI expert panel consisted of:

- James Crook, PhD, PE, Panel Co-Chair • Environmental Engineering Consultant
- Adam Olivieri, DrPH, PE, Panel Co-Chair • EOA, Inc.
- Richard Bull, PhD • Washington State University (Emeritus)
- Jörg E. Drewes, PhD • Technical Univ of Munich
- Charles Gerba, PhD • University of Arizona
- Charles Haas, PhD • Drexel University
- Amy Pruden, PhD • Virginia Polytechnic Institute
- Joan B. Rose, PhD • Michigan State University
- Shane Snyder, PhD • Nanyang Technological University
- Jacqueline E. Taylor, REHS, MPA • Los Angeles County Department of Public Health (Retired)
- George Tchobanoglous, PhD, PE • University of California, Davis (Emeritus)
- Michael P. Wehner, MPA • Orange County Water District (Retired)

"*When the Panel reviewed the variables above, it appeared that DDW*[13] *chose the most conservative assumptions to protect public health. However, layering the most conservative assumptions upon each other results in unrealistic and impracticable processes that offer no additional significant positive effects on public health.*"

The NWRI expert panel note that two assumptions made (dose response and influent virus load), where the most conservative assumption was chosen by California, result in 7 orders of magnitude (i.e. 7 log) of uncertainty in LRV requirements (for virus) [19][11].

Based on their own analysis, the expert panel suggested minimum treatment for public health protection (without consideration of failure scenarios) of[14]:

- Norovirus – 13
- *Cryptosporidium* – 10

The expert panel analysis [19] indicated that a 5 LRV increase (i.e. virus – 18 LRV, *Cryptosporidium* – 15 LRV) would adequately protect public health in the event of an undetected 6 LRV failure 1% of the time and recommended California evaluate other alternatives.

4.2.2.4 Comparison of LRV Target Derivation

The purpose of this section is to highlight differences in the derivation of LRV targets for direct potable reuse as a caution against direct adoption of targets from other jurisdictions that have been derived by different methods. There are a number of different LRV targets specified for direct potable reuse. The targets from California, Colorado and the WHO are summarized in Table 4-6.

Table 4-6: Comparison of LRV Targets from Different Jurisdictions

Jurisdiction	Virus	Bacteria	Protozoa	
			Cryptosporidium	*Giardia*
California	20	-(1)	15	14
Colorado	12(3)	-(1)	10(3)	10(3)
WHO	9.5	8.5	8.5	-(2)

1. Bacteria LRV targets are not typically set for potable reuse in the US, as it is assumed that bacterial hazards are adequately controlled provided that protozoa and virus targets are met.
2. The WHO uses Cryptosporidium as a reference pathogen for protozoa and does not stipulate a target for Giardia.
3. Utilities may elect to perform a sanitary survey of the proposed source water for a potable reuse scheme. Upon completion of the sanitary survey, a revised log reduction target may be calculated using the 95th percentile concentration of reference pathogens and lower LRV targets can be proposed based on this provided that the revised targets exceed a minimum LRV target of 8.0, 5.5 and 6.0 for viruses, *Cryptosporidium* and *Giardia*, respectively.

The targets listed in Table 4-6 are notably different. However, each has been proposed within the jurisdiction as a suitable target to produce safe drinking water. There are important differences between each of the examples above, including:

- The WHO values utilize an acceptable risk metric of 1 x 10^{-6} DALY per person per year. A DALY dosage for a pathogen takes into account the risk of infection as well as the weighted severity of an infection. This is particularly important for Norovirus, which has a high infectivity, but will only in rare cases cause severe health impacts upon infection.
- The California and Colorado LRV targets use a risk level of 1 in 10,000 infections per person per year ([14], [15]). This does not consider the severity of infection (which can moderate the LRV requirements for particular pathogens).

[13] California State Water Resources Control Board, Division of Drinking Water
[14] Values taken from Appendix 6 of reference 11.

- The LRV targets for Colorado also differ from California as:
  - California elected to use Norovirus as the reference virus while Colorado elected to use adenovirus. The differences in dose response models and also typical wastewater abundance between these pathogens partially explain the different targets.
  - California DDW used the maximum point estimate for Norovirus that exceeded the wastewater occurrence data previously used and also exceeded the Norovirus concentrations reported in a study of California wastewaters. That is, an unrealistically conservative virus loading was assumed for wastewater.
  - California DDW included an arbitrary additional 4 log to the calculated treatment targets in an effort to increase pathogen control redundancy. The addition of 4 log was not related to pathogen infectivity or justified based on documented failure scenarios.

While the California DPR LRVs appear to be high compared to those based on WHO (and the AGWR and ADWG which use the same approach as WHO), there are differences in crediting approaches for treatment processes, including:

- In California, it is acceptable to claim a LRV up to a maximum of 6-log for a treatment process. For example, chlorine contact tables may be extrapolated and UV dose exceeding 6-log of a validated pathogen may be used to claim up to 6 log for UV.
- In California, multiple treatment processes in series using the same disinfection mechanism may be used to claim LRVs. For example, in recent California DPR planning efforts, it has been acceptable to propose UV disinfection by UV/AOP meeting 6 log reduction of all pathogen groups and then to claim further pathogen reduction, based on installation of a secondary UV system installed in the same treatment train. This would be achieved by installation of a UV reactor with a validated dose delivery exceeding 186 mJ/cm^2 downstream of the UV/AOP, which would be credited with 4 log additional adenovirus reduction and 6 log reduction of protozoa (i.e. in addition to any LRV claimed for the UV/AOP).

When compared to the Californian approach, current practices in Australia rely on substantially different methodologies to achieve treatment resilience, including:

1. Capping maximum LRVs at 4 log (as opposed to 6 log) per process, and,
2. Not allowing crediting of the same removal mechanism in the same treatment train (e.g. an additional UF membrane not receiving credit downstream of a membrane bioreactor).

In this way, the Australian approach encourages resilience by 1) diversifying mechanisms and 2) putting a maximum cap of 4 LRV on possible failures. However, this methodology makes it effectively impossible to meet excessive LRV targets (such as 20/14/15) with established AWTP process units – largely as there are simply not enough unit operations with different fundamental mechanisms.

To highlight these key differences, Table 4-7 summarises indicative LRVs for virus/*Giardia* and *Cryptosporidium* (v/g/c) for a hypothetical treatment train credited in California and Australia.

Table 4-7: Comparison of the total LRV for the same treatment train credited in California and Australia for Virus LRV/Giardia LRV and Cryptosporidium LRV (V/G/C)

Jurisdiction\Process (validation approach)	UF (pressure decay test)	RO (conductivity reduction)	UVAOP (1,000 mJ/cm^2)	UV (186 mJ/cm^2)	Free Chlorination (WaterVal CT equivalent to 6 log virus)	Total Scheme LRVs
California LRVs	0/4/4	1.5/1.5/1.5	6/6/6	4/6/6	6/0/0	18.5/17.5/17.5
Australia LRVs	0/4/4	1.5/1.5/1.5	4/4/4	0/0/0	4/0/0	9.5/9.5/9.5

Clearly, the same treatment train, operated the same way on the same wastewater will achieve the same pathogen reduction. However, the pathogen reduction accepted under the regulations is completely different in different jurisdictions such that the status quo in Australia would result in a credited LRV around half that credited in California (9.5 Australia vs 17.5 – 18.5 in California).

Based on the considerations above, LRV targets from other jurisdictions should not be directly applied unless the process crediting framework is also reconsidered. In addition, LRV targets from the US pertain to a substantially different metric for acceptable risk.

4.2.2.5 Excess LRV Analysis

Based on the information presented in Section 4.2.2.4, the project team believe the California DPR minimum LRV targets are excessively conservative for use as a basis for the purposes of this investigation, based on:

- The different raw wastewater pathogen loads (as compared to AGWR/WHO);
- Different tolerable drinking water pathogen concentration as compared to AGWR/ADWG/WHO (based on the difference between achieving 10^{-6} DALYs per person per year and limiting infections to 1 in 10,000 per person per year), and,
- Different assumptions for maximum claimable LRV per process unit (6 for California versus 4 assumed for the purposes of this investigation).

As a result, it is contended that application of the proposed California DPR regulations would result in excessive treatment requirements that increase costs and complexity without providing meaningful improvements to public health protection.

To better understand the potential impact of AWTP process unit failures on LRV requirements, RCC undertook preliminary analysis of possible failure scenarios using DPRisk - a calculation tool developed by Water Research Foundation for DPR systems[15]. Table 4-8 summarises the output of the preliminary QMRA investigations undertaken by RCC using DPRisk.

Table 4-8: Preliminary Assessment of Undetected Failure Scenarios

Scenario	Additional LRV Required			Conclusion
	Virus (Adenovirus)	Protozoa (*Cryptosporidium*)	Bacteria (Campylobacter)	
4 LRV undetected failure for four hours four times per year	2	2	2	A process train assumed to provide a total of 12 LRV for virus, 11.0 for *Cryptosporidium* and 12.5 for *Campylobacter* with no failure results in a 99th percentile annual risk with this failure scenario of less than 10^{-6} DALYs per person per year for each pathogen type.

In an effort to understand the absolute worst-case scenario for AWTP costs and complexity, a failure scenario of 4 LRV 100% of the time has been considered (correlating to an excess LRV of 4). This assumes that the AWTP is claiming a maximum of 4 LRV per unit process, and that treatment barrier is providing no pathogen removal. **Critically, it is not the opinion of the project team that this is necessary or suitable from a pathogen risk perspective. Rather, an excess**

[15] From the DPRisk web page (https://cawaterdatadive.shinyapps.io/DPRisk/): This tool is intended to facilitate quantitative microbial risk assessment (QMRA) and probabilistic assessment of treatment train performance (PATTP) for various direct potable reuse (DPR) scenarios. There are many possible analyses that you can conduct with this tool, including:

There are many possible analyses that you can conduct with this tool, including:
- Developing a distribution of treatment train performance for different potential DPR treatment trains.
- Evaluating daily and annual risks of infection for multiple microbial pathogens for different potential DPR treatment trains.
- Comparing different DPR treatment trains in terms of treatment performance and risk.
- Evaluating the impact of failures on treatment performance and risk.

LRV of 4 has been considered only to elucidate an extreme worst-case in terms of AWTP costing with respect to pathogen removal.

The final minimum pathogen LRV requirement applied to design of the AWTP (as ultimately agreed with the regulators) should be based on pathogen barrier failure modelling with consideration of:

- the LRV credited per unit process (i.e. 4 LRV in Australia vs. 6 LRV elsewhere[16]);
- the failure mode of each unit process (i.e. instantaneous (e.g. disinfectant dosing system failure) or gradual (e.g. loss of UF membrane integrity which normally occurs slowly and can be seen by monitoring PDT trends);
- the response time of online analysers used for CCPs;
- the reliability of these analysers and any redundancy provided for these analysers;
- the use of alert and critical CCP levels and other operational and maintenance strategies that reduce risk; and,
- other design features used to mitigate risk (e.g. use of "off spec" diversions at CCP alert levels, use of engineered storage buffer tank to allow for capture and diversion of water produced between analyser readings, etc.).

[16] Sylvestre et.al. [21] indicates that for a barrier with rapid loss in LRV performance credited with 6.0 LRV failure durations of 10 seconds per year need to be controlled, whereas for the same process claiming 4 LRV performance can be verified by controlling a failure of 15 minutes per year.

5 PROPOSED LOG REMOVAL VALUES FOR AWTP CONCEPTUAL DESIGNS

Based on the information presented in Section 4, uncertainties in regard to future regulatory requirements, and that this project represents an early investigation stage, the baseline and sensitivity analysis scenarios summarised in Table 5-1 are proposed to be applied to the conceptual AWTP designs for the short-listed scheme options.

Table 5-1: Proposed Approach for Conceptual AWTP Designs and Sensitivity Analyses

Scheme	Baseline AWTP LRV Basis	Sensitivity Analyses
IPR via Surface Water Augmentation	Apply values from Table 4-3: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0	None
DPR via Raw Water Augmentation	Apply values from Table 4-3: Virus – 10.0 Protozoa – 9.0 Bacteria – 9.0 Assume blending of source water to and treatment in the downstream WTP is sufficient to manage the risk of barrier failure	Consider a worst case as aligning with an excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0
DPR via Treated Water Augmentation	Consider a case of excess LRV of 2 for all pathogen types (aligning with a 4 LRV failure occurring for 4 hours 4 times per year) – i.e. the process would provide: Virus LRV – 12.0 LRV Protozoa LRV – 11.0 Bacteria LRV – 11.0	Consider ***an absolute worst case*** as aligning with an excess LRV of 4 for all pathogen types (i.e. 100% redundancy) – i.e. the process would provide: Virus LRV – 14.0 Protozoa LRV – 13.0 Bacteria LRV – 13.0 **It is not the opinion of the project team that this is suitable from a public health risk perspective, and is only presented to represent an extreme worst-case scenario for AWTP costing (with respect to pathogen removal).**

The conceptual AWTP process trains will be developed based on process technologies that have been proven for potable reuse applications elsewhere. The assumptions for Claimed LRV used in the design of the process trains would be subject to significant additional work, including, but not limited to:

- Site specific bench scale testing of source water (e.g. ozone decay);
- On site demonstration of treatment processes using intended source water;
- Review of performance of operating full scale system;
- Review of advancements in technology over time (e.g. ability for real time monitoring of virus for UF LRV verification);
- Engagement with regulators; and,
- Potentially, expert panel review.

This additional work would address the concerns raised in the AGWR with respect to DPR, as described in Section 1.

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APPENDIX B: CHEMICAL RISK ASSESSMENT MEMORANDUM

Rous County Council
Purified Recycled Water Investigations
Memorandum – Chemical Risk Assessment

This report has been prepared solely for the benefit of Rous County Council for the Purified Recycled Water Investigations. No liability is accepted by Tyr Group or any employee or sub-consultant of Tyr Group with respect to its use by any other person or in relation to any other project.

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ABBREVIATIONS

ADWF	Average Dry Weather Flow
ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AOP	Advanced Oxidation Process
AWTP	Advanced Water Treatment Plant
BAC	Biological Activated Carbon
BOM	Bureau of Meteorology
CBAT	Carbon-Based Advanced Treatment
CEC	Constituents of Emerging Concern
DBP	Disinfection Byproduct
DPR	Direct Potable Reuse
GAC	Granular Activated Carbon
HAA	Halo Acetic Acid
ICCS	Industrial Contaminant Screening Score
ICRQ	Industrial Contaminant Risk Quotient
IPR	Indirect Potable Reuse
LRV	Log Reduction Value
MCL	Maximum Contaminant Level
NHMRC	National Health and Medical Research Council
PFAS	Per- and Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic Acid
PRW	Purified Recycled Water
RBAT	Reverse Osmosis Based Treatment
RCC	Rous County Council
RfD	Oral Reference Dose
RO	Reverse Osmosis
RSD	Risk Specific Dose
STP	Sewage Treatment Plant
THM	Trihalomethane
TOC	Total Organic Carbon
UF	Ultrafiltration
US EPA	United States Environmental Protection Agency
UV	Ultraviolet Light Disinfection
WRF	Water Research Foundation
WTP	Water Treatment Plant

1 INTRODUCTION

1.1 BACKGROUND

Rous County Council (RCC) is investigating the potential to utilise purified recycled water (PRW) as a climate resilient source of potable water. This study, *Purified Recycled Water for Drinking Investigations* (PRW Investigations), has short-listed various scheme options for use of PRW, including configurations based on:

- Indirect potable reuse (IPR) via surface water augmentation – PRW is discharged to an environmental buffer (e.g. dam or other large surface water storage) where it is blended with other water sources. The environmental buffer provides a minimum detention time for the water prior it being fed to a drinking water treatment plant (WTP);
- Direct potable reuse (DPR) via raw water augmentation – PRW is blended with other water sources and fed directly to the start of the WTP process without an environmental buffer; and,
- DPR via treated water augmentation – PRW is blended with treated water from the WTP in the drinking water distribution system.

The Australian Guidelines for Water Recycling (AGWR) highlight the need for chemical risk assessment and source control to ensure production of water that is safe for use in drinking water augmentation [1]. Correspondingly, the *Purified Recycled Water for Drinking Investigations* includes a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW - a first step in understanding potential chemical risks in the absence of detailed scheme-specific source water information. Should one or more scheme be carried forward for development, these risks, and the methods by which they will be controlled, will need to be further defined through future investigations including:

- Source characterisation;
- Development of an enhanced source control program (including detailed study of all dischargers and the chemicals they use that could potentially emerge in the sewage stream);
- Pilot/demonstration advanced water treatment plant (AWTP) testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water, and their removal through the various unit processes required for the production of the PRW;
- Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available; and,
- Detailed quantitative chemical risk assessment based on the information gathered as described above.

Any future detailed chemical risk assessment should incorporate consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1]. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, such as the Australian Drinking Water Guidelines, World Health Organization guidelines, etc. should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP. The detailed risk assessment would be a "live" document and updated over the operational life of the AWTP based on changes in the source water characteristics and/or changes or additions to the guideline values.

1.2 SCOPE

Due to the very early phase of the project and corresponding lack of project specific data, the chemical risk assessment described herein is very high level in nature. As such, this chemical risk assessment is presented to provide a general understanding of the chemical risk assessment process and provide an example, as a starting point for RCC, should any of the short-listed PRW schemes be carried forward.

As defined in the *AWTP Process Trains Memorandum* produced for the PRW Investigations, conceptual AWTP process trains have been developed based on achieving the minimum pathogen log reduction value (LRV) targets set in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development*. The chemical risk assessment documented in this memorandum is based on these conceptual process trains (refer to Section 3 for descriptions of the process trains).

As there is currently no catchment specific data available defining chemicals of concern in the source water and their concentration, this memorandum presents a high-level assessment of chemical risks based on:

- The 262 chemicals examined in the Water Research Foundation (WRF) Project No. 4960 (*An Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse*) for which there were available health risk metrics and/or removal data [2]; and,
- Publicly available occurrence data for chemicals in the feed to the Luggage Point AWTP (owned by Seqwater) [3], where compounds found in this source water overlap with the chemicals examined within WRF Project No. 4960.

Should one or more PRW schemes be carried forward for development, catchment specific data will need to be collected and analysed to support further assessment of chemical risk, and supported with appropriate removal performance data. The approach described in this memorandum can be used to guide this programme of monitoring and investigation, and the subsequent future detailed chemical risk assessment.

More specifically, the chemicals included in this risk assessment may or may not be relevant to any RCC potable reuse scheme, based on occurrence, or the risk of occurrence, of specific chemicals in the catchments providing source water for a given scheme. Further investigation would be a key first step to defining the occurrence (or risk of occurrence) of chemicals within the relevant catchment(s).

It should also be noted that Table 4.4 of the AGWR [1] also includes a list of 221 chemicals detected in secondary treated sewage, and health based guideline values for those chemicals in PRW. Any future source characterisation and/or chemical risk assessment should incorporate consideration of those specific chemicals. While the example application of the WRF Project No. 4960 methodology applied in this investigation could have included the chemicals listed in the AGWR, this has not been undertaken as:

1. Health guideline values derived in the AGWR using a one-in-one-million risk target "is taken to mean that, if a population of one million people were to consume water at the guideline concentration for a lifetime, then one additional cancer might plausibly be expected to occur" [1]. By contrast, the risk specific dose used in WRF Project 4960 refers to one-in-ten thousand excess lifetime cancer risk. Application of the methodology to chemicals derived using different acceptable risk criteria would compromise the risk ranking and prioritisation.
2. 85 of the chemicals listed in the AGWR list are within the 262 chemicals examined in the WRF Project No. 4960. Hence, there is some cross-over. Further, given the AGWR was published around 16 years ago, the list of chemicals in WRF Project No. 4960 may be more contemporary (even in the Australian context).
3. Of the remaining 136 chemicals on the AGWR list which are not included in WRF project No. 4960, there is no removal data listed for the AWTP processes. On this basis, the screening level assessment conducted

herein would apply a zero removal (see next section), limiting its value in terms of identification of specific chemicals of concern.

4. As noted above, given the absence of source-specific chemical occurrence data, this investigation presents an example screening approach for chemical species. The specific chemicals analysed are used to illustrate the methodology. Until specific occurrence data is obtained for the source water for any schemes to be developed, the specific chemical species considered in the methodology applied to this study are not critical.

For this study, preliminary identification, screening and prioritisation of the high-level chemical risks was undertaken through:

- Project Definition:
  - High-level definition of the proposed potable reuse schemes in terms of treatment barriers that influence chemical risk.
- Source Water Assessment
  - Collation and summary of the available information on Trade Waste volumes received by the sewage treatment plants (STPs) which would provide source water to the AWTPs.
  - Benchmarking of the proportion and nature of the industrial (i.e. Trade Waste) loads against an existing potable reuse scheme in Australia (Luggage Point, for which a significant amount of chemical analysis had been reported for the secondary effluent).
- Industrial Chemical Risk Assessment:
  - Prioritisation of the chemical risks associated with Trade Waste discharges using the WRF Project No. 4960 framework [2], with reference to anticipated chemical removal performance for each proposed treatment train (as described within WRF Project No. 4960).
  - Where complementary data was available (approximately 26%, 68 chemicals of the 262 included for consideration in WRF Project No. 4960), a risk quotient was developed to provide an example of how to better understand and prioritize chemicals of concern (noting that site specific risk quotients can only be developed when catchment specific data is available).
- Process Related Chemical Risks:
  - Process related chemicals risks, i.e. risks that can be caused by, as well as controlled due to operation and design changes (such as disinfection by-products), were identified through review of recent literature on potable reuse treatment trains.
  - Absolute chemical risk assessment of these chemicals is site specific in nature and was therefore not quantitatively assessed.

Due to a number of conservative assumptions required in processing the data, the risk characterisation figures presented within do not represent an absolute risk. In the absence of occurrence data for chemicals of concern for the project area, risk quotients were developed based on Luggage Point data (a much larger and more urbanised catchment) to provide an indication of possible chemical risk. Consequently, the assessment outputs should be considered as:

1. Broadly indicative of the relative chemical risk control that is likely to be achieved with the shortlisted schemes, and,
2. Of value in targeting and developing the further investigations required to appropriately characterise the absolute, scheme-specific risk.

2 INDUSTRIAL CONTAMINANT SCREENING METHODOLOGY

WRF Project No. 4960 [4] compiled a list of representative removals of industrial chemicals and paired these with health risk factors. While the tool is not exhaustive, it allows for a rapid assessment and prioritisation based on a list of 262 chemicals that have either health risk metrics and/or removal data. In the development of the list of chemicals within WRF Project No. 4960, a further 228 chemicals were considered, but were omitted from detailed assessment – typically due to a contaminant being phased out of use and/or banned. Appendix A lists the omitted chemicals.

The WRF tool prioritises the chemicals based on an Industrial Contaminant Screening Score (ICSS). A high ICSS results from either a perceived high pass-through risk and/or high potential to impact human health, and is calculated as the normalised cumulative pass-through risk (1 – the rejection across cumulative processes) multiplied by a health risk factor (the inverse of the lower of the reference dose or risk specific dose) as shown in Equation 1.

$$\boldsymbol{ICSS = (1 - R_{overall}) / \min\,(RfD, RSD)} \qquad \textbf{Equation 1}$$

Where:

- ICSS = Industrial Contaminant Screening Score (kg-d/mg)
- $R_{overall}$ = the rejection (as a decimal) of a compound through all chemical barriers in series that is being assessed (i.e. the product of rejection through each chemical barrier in the treatment process). Where known, WRF Project No. 4960 provides both average and conservative removals. For the purposes of this work, conservative removals of chemicals have been applied.
- Min (RfD, RSD) = the minimum of either:
  - The oral reference dose (RfD) – refers to non-cancer endpoints (mg/kg/d); or,
  - Risk specific dose (RSD) – refers to the 1 in 10,000 excess lifetime cancer risk[1], calculated by dividing 10^{-4} by the cancer slope factor (mg/kg-d).

Note that ICSS is not a metric of risk because it does not incorporate compound concentration or exposure. Rather, ICSS is a tool to prioritize contaminants for collecting occurrence data. [2]

[1] A cancer risk level of one-in-ten-thousand is applied by the US EPA when deciding whether cancer or non-cancer risk levels provide more meaningful scenario-specific risk reduction [4]. The AGWR uses a risk target on one-in-one-million for non-threshold chemicals whose carcinogenicity has been characterised by experimental determination of potency (i.e. by derivation of a 'slope factor') [1]. Health guideline values derived in the AGWR using the one-in-one-million risk target "is taken to mean that, if a population of one million people were to consume water at the guideline concentration for a lifetime, then one additional cancer might plausibly be expected to occur" [1]. Hence, the RSD used for this assessment is less conservative than if the RSD were developed based on the AGWR risk target. However, this is not important for this assessment as this screening process is used to demonstrate a methodology as to how chemicals could be prioritised for further investigation. Future detailed chemical risk assessment will need to include consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1] and ensure that the RSD used aligns with the one-in-one million AGWR risk target. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, including the Australian Drinking Water Guidelines, World Health Organization guidelines, etc should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP.

If concentration of a compound in the source water is known, the ICSS can be converted into an Industrial Contaminant Risk Quotient (ICRQ) by multiplying by typical conservative risk assessment assumptions of:

- Body weight: 70 kg;
- $Exposure_1$: 2 L per person per day; and,
- $Exposure_2$: 20% (i.e. water ingestion accounts for only 20% of broader exposure (e.g. inhalation or food ingestion)).

ICRQ calculation is defined as:

$$ICRQ = C \times Exposure_1 \times ICSS/(Exposure_2 \times Body\ Weight) \qquad \textbf{Equation 2}$$

Where C = the concentration in the source water for which the ICSS was calculated (mg/L).

In WRF Project No. 4960, ICRQs of greater than 0.2 were elected as the cutoff to trigger concern and necessitate additional sampling and investigation, and values above 1.0 indicate compounds which "merit focused attention to identify potential sources and consider ways to eliminate the source or improve treatment"[2].

For this exercise, two ICSSs were calculated – one including and one excluding the contaminant removal achieved in the STP. The overall ICSS (i.e. including removal by the STP) was used to prioritise contaminants.

The WRF Project No. 4960 database includes an RfD or RSD for 65% of the listed chemicals. With the available RfDs or RSDs it is possible to calculate an ICSS, assuming a worst-case removal of zero through all treatment processes, to perform a risk rating for 171 chemicals in this database.

The ICSS excluding the STP removal was translated into an ICRQ using occurrence data for chemicals in secondary effluent, available from the Luggage Point water quality report [3], to provide indication of possible chemical risk and to provide an example of how to better understand and prioritize chemicals of concern. Of the 262 chemicals included in WRF Project No. 4960, the available Luggage Point secondary effluent concentration data included occurrence data for 121 of these chemicals.

Of the 121 chemicals with Luggage Point occurrence data, only 68 had human health impact data. This enabled ICRQs to be developed for 26% of the chemicals identified in WRF Project No. 4960 (i.e. 68 of 262), and 55% of chemicals where there was available occurrence data (i.e. 68 of 121).

The primarily focus of WRF Project No. 4960 is industrial chemicals, as these are anticipated to be key contributors to the STP catchment that could be effectively managed via source control practices (through an effective source control program in partnership with Trade Waste customers). Source control is anticipated to be less effective at controlling chemical emissions from municipal/residential customers - public education is a key part of minimising these specific risks.

In addition, with the exception of NDMA (which was shown to originate in a significant extent from industry as well as disinfection practices), most disinfection byproducts (DBP) were excluded from the scope of WRF Project No. 4960 as they are largely produced as a function of treatment practices. To this end, the perceived risks of DBPs relevant to the treatment schemes developed within this project are qualitatively reviewed in Section 5.5.

[2] ICRQ cutoff values would be two orders of magnitude lower (i.e. 0.002 and 0.01) when calculating ICSS and ICRQ based on the AGWR risk target of one-in-one-million. It is imperative that the approach used is consistent (i.e. the acceptable risk target must be consistent across calculations). As noted previously, the risk target selected does not effect the prioritisation of chemicals for further investigation. However, using the correct risk target is critical when establishing the guideline to be used for acceptable concentration of a given chemical in PRW.

3 PROJECT DEFINITION - TREATMENT SCHEMES CONSIDERED

Conceptual reverse osmosis-based advanced treatment (RBAT) and carbon-based advanced treatment (CBAT) trains have been developed, as described in the *AWTP Process Trains Memorandum* produced for the PRW Investigations, to achieve the minimum pathogen LRV targets set in *Discussion Paper – Minimum Pathogen Reductions for Potable Reuse Scheme Development*.

The conceptual RBAT train consists of ultrafiltration (UF), reverse osmosis (RO), ultraviolet light (UV) advanced oxidation (AOP), chlorine disinfection and stabilisation. The conceptual CBAT train consists of ozonation, coagulation, flocculation, biological active carbon (BAC), granular activated carbon (GAC), UF, UV disinfection and chlorine disinfection.

RBAT process trains similar to the conceptual RBAT train developed for the PRW Investigation have been used for many years in potable reuse applications due to their ability to effectively remove pathogens and compounds of concern, with examples including:

- Raw Water Production Facility – Big Spring, Texas, USA: a DPR via raw augmentation scheme that has been in operation since 2013, utilizing microfiltration, RO and UV/AOP to produce PRW that is blended with surface water from Moss Creek Lake prior to treatment in conventional drinking water plants. Sampling has shown lower concentrations of concern in the PRW than the concentrations found in the surface water source (Moss Creek Lake) [5];
- Groundwater Replenishment System – Orange County, California, USA: an IPR via groundwater augmentation scheme that has been in operation since 2008, utilizing microfiltration, RO and UV/AOP to produce PRW that is utilized aquifer injection. The plant produces PRW with:
    - "Concentrations of inorganic constituents in the purified recycled water, such as aluminum and chromium, were either non-detectable or if detectable, far below the permit limits. All potentially toxic organics, such as volatile organic compounds, pesticides, and other synthetic organic compounds, were also non-detectable or far below the permit limits. Analyses of purified recycled water for unregulated compounds and chemicals of emerging concern, such as endocrine disrupting chemicals and pharmaceuticals, were either non-detectable or if detectable, not found at levels thought to pose any significant public health risk." [6]

CBAT process trains similar to the conceptual CBAT train developed for the PRW Investigation are also serving as the basis for potable reuse treatment trains based on their ability to provide robust removal of both pathogens and compounds of concern. A notable example of this is the Hampton Roads Sanitation District's SWIFT program, which will be based on an ozone-BAC-GAC treatment train to produce PRW for managed aquifer recharge. Pilot testing has shown that the treatment train can remove the 96 compounds of concern measured in the trial to below the limit of quantification for up to 10,000 bed volumes, and provide 70% removal of these compounds up to 20,000 bed volumes [7].

Results from a study performed by Lau et.al (2022) indicate that PRW treatment trains, whether RBAT or CBAT produce waters of lower cytotoxicity than surface-water-derived conventional drinking waters [8].

California DPR regulations require the inclusion of ozone/BAC in an RBAT process train to provide treatment for compounds of concern. Based on the examples provided above, both the conceptual RBAT and CBAT process trains can reasonably be expected to provide robust treatment for compounds of concern, hence ozone/BAC has not been added to the conceptual RBAT process train. The potential need for further unit processes is considered in the *AWTP Process Trains Memorandum* but is not included in this high-level chemical risk assessment.

Figure 3-1 outlines the conceptual treatment process trains for the AWTPs[3] and highlights the treatment barriers relevant for the control of chemicals in the four advanced treatment schemes shortlisted for progression as part of this project (including the upstream STP and the downstream WTP (for the two scheme options where this is relevant)). The schemes are categorised as:

- CBAT with:
  - Scheme Chemical Risk Type A: Lismore IPR or Lismore DPR - Raw Water Augmentation
  - Scheme Chemical Risk Type B: Lismore DPR - Treated Water Augmentation OR
  - Scheme Chemical Risk Type B: Byron DPR - Treated Water Augmentation (CBAT option) (not listed further as AWTP process train equivalent to Lismore DPR - Treated Water Augmentation option) ; and,
- RBAT with Scheme Chemical Risk Type C: *Byron DPR - Treated Water Augmentation (RBAT option)*.

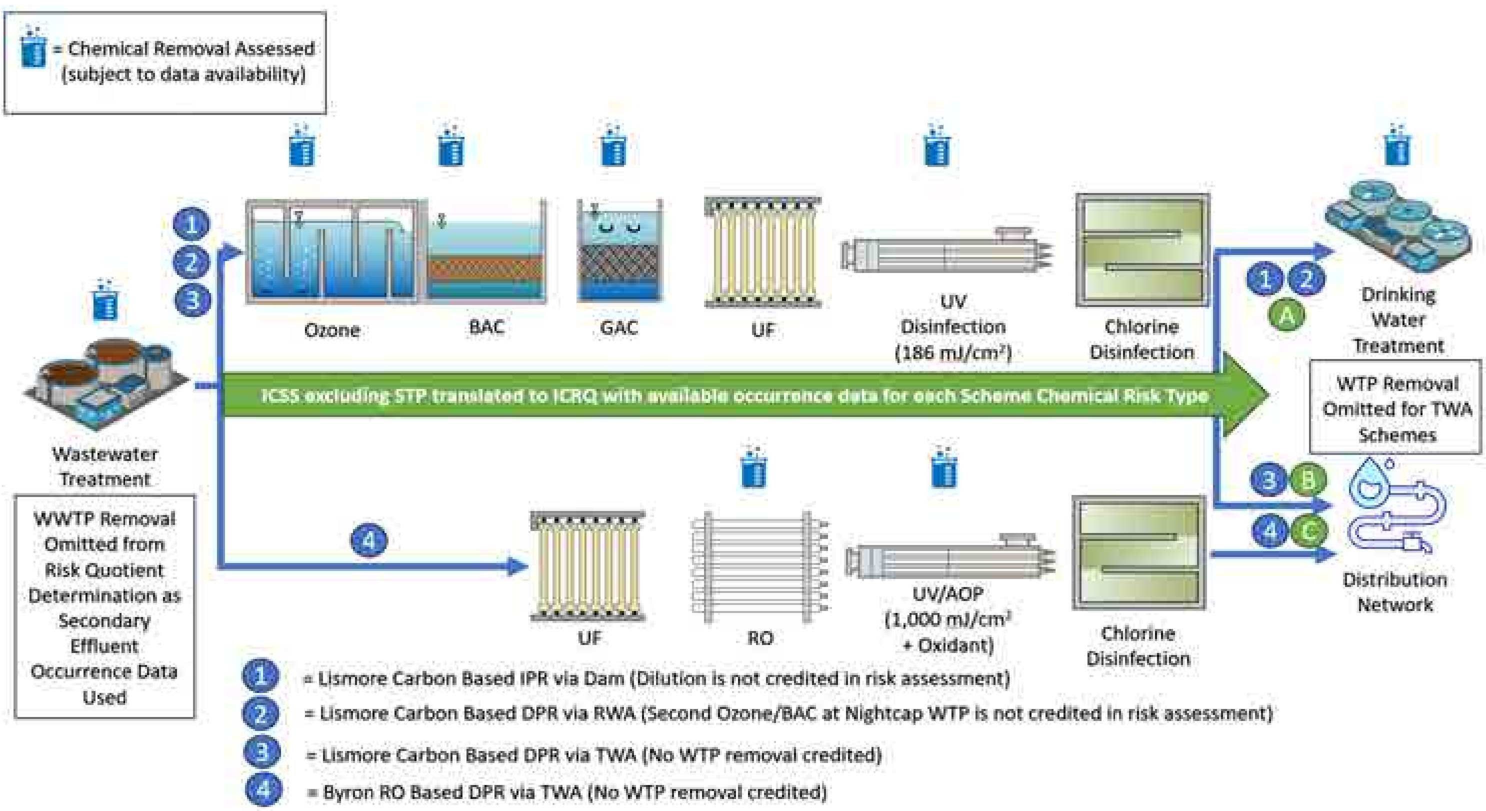

Figure 3-1: Simplified Process Flow Diagram Showing Chemical Barriers and Boundaries of Assessment for Shortlisted Schemes

[3] Scheme 3 and 4 in Figure 3-1 do not show a secondary UV process, that may be included for pathogen risk management, as no chemical removal credit is assumed for this process.

Table 3-1 summarises the scheme descriptions and the chemical risk classification outcomes for the ICSS and ICRQ development. Additionally, the table lists items that were not included in the chemical risk assessment that are likely to reduce risk.

Table 3-1: PRW Schemes and Chemical Barriers Considered for ICSS and ICRQ Development

Scheme ID	Scheme Name	Scheme Description	Scheme Chemical Barrier Omissions	Scheme Chemical Risk Type
1	Lismore IPR	Effluent from Lismore STP treated via ozone/BAC, GAC, UF, UV disinfection and chlorine disinfection prior to discharge to an engineered storage buffer (i.e. dam) and subsequent treatment via Nightcap WTP	Dilution and reservoir mixing in the Dam	A (CBAT + WTP)
2	Lismore DPR – Raw Water Augmentation	Effluent from Lismore STPs treated via ozone/BAC, GAC, UF, UV disinfection and chlorine disinfection prior to treatment via Nightcap WTP	Second ozone/BAC at Nightcap is not counted for chemical removal. Raw water blending and dilution is not counted.	A (CBAT + WTP)
3	Lismore DPR – Treated Water Augmentation	Effluent from Lismore STPs treated via ozone/BAC, GAC, UF, UV disinfection and chlorine disinfection (and potentially secondary UV disinfection) prior to discharge to the drinking water distribution system	In distribution blending is not counted. Secondary UV potential for chemical reduction is not counted.	B (CBAT)
4	Byron DPR – Treated Water Augmentation (RBAT Option considered for risk assessment)	Effluent from Byron STPs treated via UF, RO, UV advanced oxidation (AOP) and chlorine disinfection (and potentially secondary UV disinfection) prior to discharge to the drinking water distribution system	In distribution blending is not counted. Secondary UV potential for chemical reduction is not counted.	C (RBAT)

With the PRW Investigations at a strategy level, and corresponding available information, this risk assessment has been streamlined through adoption of the following conservative assumptions:

- Multiple chemical barriers of the same type were only claimed once in a scheme – even when employed as two separate treatment processes. Key implications of this assumption are expected to have included:
    - Likely overestimation of the chemical risk when a CBAT train is used to send water to the Nightcap WTP (which also uses ozone/BAC).
    - Low dose secondary UV disinfection systems, targeting additional removal of protozoa and virus, were not included. It is anticipated that the doses of these systems would not exceed 186 mJ/cm^2

required to treat for up to 4-log adenovirus. The potential contribution of these systems was not included as the level of chemical photolysis of these systems was presumed to be low[4].

  - Potential chemical removal via oxidation with chlorine was not included as there is no removal data on this within WRF Project No. 4960 (noting that disinfection has the potential to introduce is DBPs - the DBPs risks relevant to the treatment schemes are discussed in Section 5.5).

- Dilution credits were not claimed for raw water augmentation or IPR. This assumption results in overestimation of chemical risk for these options[5]. For this high-level screening level assessment, it was not considered appropriate to include reservoir dilution or dilution with a WTP inlet flow as:

  - The concentration of the chemical in the raw water was not known and could not reasonably be assigned a value of zero[6], and,

  - The exact minimum blending ratio was not known as this would require set limits and study of in reservoir mixing and raw water flows from other source waters relative to maximum wastewater contributions.

- WTP removal performance of chemicals and potential dilution and blending with existing source water were not applied for treated water augmentation schemes as:

  - For treated water augmentation, the WTP is not in the treatment train hence its contribution to removal was excluded, and,

  - During treated water augmentation, there will be some in-distribution dilution of PRW with existing treated surface water[7]. However, this dilution may change as a complex function of both distribution system location and relative flows of PRW versus treated surface water. Consideration of dilution impacts should be included in the detailed chemical risk assessment should any of the short-listed options be considered further.

Due to the conservatism associated with these assumptions and the non site-specific nature of the assessment (i.e. use of Luggage Point data), any exceedance of an ICRQ does not necessarily imply a risk. Rather, a high ICSS or ICRQ within this document should be managed through characterisation of occurrence and process removal performance (noting that site specific data may also highlight different risks to those developed in this assessment), and a full risk assessment.

[4] Glover et.al. (2019) suggest that, as an example, a UV dose of 325 mJ/cm^2 is required for 90% removal of N-nitrosomorpholine (which is completely recalcitrant to ozonation and GAC [25]) as compared to the disinfection dose of 186 mJ/cm^2 [24].

[5] For an IPR scheme, both dilution benefits and short-circuiting risks within the environmental buffer storage would need to be considered based on water quality and hydrodynamic models.

[6] There is likely low risk of chemical contamination of Rocky Creek Dam due to the nature of the catchment. However, the Wilsons River Source is located downstream of the discharge from Bangalow STP and downstream of agricultural land (from which fertilizers, pesticides, etc. could run off).

[7] Initial high-level calculations suggest that the blend ratio (amount of PRW divided by the total amount of dinking water supplied) would be about 40% for the Byron DPR via treated water augmentation scheme and limited to 50% for the Lismore DPR via treated water augmentation scheme (to maintain acceptable total dissolved solids concentration in the drinking water). Refer to the *AWTP Process Trains Memorandum* prepared as part of this investigation for further information.

4 SOURCE WATER ASSESSMENT

The two catchments under consideration are operated by Lismore City Council (East and South Lismore STPs) and Byron Shire Council (Byron and Brunswick Valley STPs). While specific details of the trade waste management programmes operating in these Council areas have not been reviewed, it is understood that:

- Trade waste customers generally operate trade waste limits for bulk pollutants which are relevant to the sewage treatment processes (e.g. BOD, TSS, Nitrogen, Phosphorus, and Oil and Grease), and,
- Medical facilities within the catchment operate under medical waste management programmes.

The project team reviewed Trade Waste and landfill leachate volumetric data for these catchments, and categorised each source based on whether or not the industry identified in question had the potential to have substances posing risks to human health within their inventory. Additional information on Trade Waste discharges is located in Appendix B. In the following sections, reference to "Medical" as Trade Waste discharger type referees to all medical facilities (e.g. cancer treatment clinics, radiological services, etc.) not just hospitals.

If any of the short-listed schemes are considered further, the following should be investigated:

- Existing Trade Waste regulations in the relevant catchment(s), including conditions of acceptance for medical facilities;
- Chemicals included in the Trade Waste regulations and agreements;
- Information on any illegal discharges and if available:
  - The legacy of those events; and
  - Steps that were taken to control the discharges.

4.1 LISMORE

Lismore City Council maintains Trade Waste discharge permits with close to 300 permitted dischargers in the catchment of South Lismore STP and East Lismore STP. The permitted dischargers are summarized by business type and total permitted discharge volume in Table 4-1. Table 4-1 shows only dischargers holding permits with non-zero discharge volumes. No actual discharge data are available, and the permitted amount represents a maximum approved.

The estimated average dry weather flow (ADWF) influent to South Lismore STP is 2.1 ML/d, and the estimated ADWF to East Lismore STP is 5.4 ML/d. The total Trade Waste volume permitted for both plants amounts to about 271 kL/d, comprising a maximum of 4% of the combined ADWF flow into both plants. The total volume permitted of dischargers with a high presumptive risk (as per Table 4-1) is 90 kL/d, or 1% of the total ADWF flow into both Lismore STPs on a combined basis.

Table 4-1: Permitted Trade Waste Dischargers and Estimated Flows to South and East Lismore STPs

Discharger Type	Total Volume Permitted (kL/d)	High Presumptive Risk
Administration Office	1.8	
Auto-Related	2.5	Yes – May contain solvents or hydrocarbons
Club	9.7	
Food Processing	5.5	
Food-Related	126.8	
Function Centre	2.0	
Government Service	5.6	
Hotel/Accommodation	10.4	
Laboratory	1.6	Yes – May contain a range of chemicals
Laundry	5.2	Yes – Includes hospital laundry
Mechanical Repair Workshop	37.9	Yes – May contain solvents or hydrocarbons
Medical(1)	17.0	Yes – May contain a range of chemicals
Metal Finishing	2.2	Yes – May contain metals and solvents
Nursing Home	4.0	
Preschool	1.0	
Recycling	5.2	Yes – Leachate and other chemicals
Retail	7.4	
School	6.0	
Service Industry	16.2	Yes - Unknown
Service Station	2.4	Yes – May contain solvents or hydrocarbons
Swimming Pool	0.4	
Landfill Leachate(2)	Data Not Available	Yes – Leachate containing PFAS and other chemicals
Total	**271**	

1. Based on Kumari et. al. (2020, [9]), these wastes could include drugs and their metabolites such as antibiotics, lipid regulators, analgesics, antidepressants, antiepileptics, antineoplastic, antipyretics, antiphlogistic, antirheumatics, estrogens, organic matter, radionuclides, solvents, metals, disinfectants, cytostatic agents, anaesthetics and sterilization products, specific detergents for endoscopes and other instruments, radioactive markers, and iodinated contrast media. Metals present could include platinum, mercury, rare earth elements (gadolinium, indium, osmium), and iodinated X-ray contrast media. Depending on the waste management practices employed in the relevant facilities, a number of these components may be not present in the sewage stream.
2. Lismore City Council holds a license to discharge leachate to East Lismore STP after pre-treatment. However, the current license also allows discharge of the treated leachate to the environment without passing the flow to the STP. The leachate is pre-treated via a containerised plant (flocculation, pH adjustment, GAC and algal treatment to reduce PFAS). The Council are considering other options to divert/discharge leachate, and licencing for the STP may be revisited as part of an upcoming upgrade.

4.2 BYRON

Byron Shire Council accepts Trade Waste in the form of liquid tankered waste, as well as via the sewer network. All tankered waste goes to Byron STP, while network Trade Waste is accepted at both Byron STP and Brunswick Valley STP.

The breakdown of network waste by discharger and their estimated volumes discharged for calendar year 2022 are provided in Table 4-2. Table 4-2 also provides tankered waste volumes over the calendar year 2022.

Table 4-2: Estimated Volumetric Trade Waste to Byron and Brunswick Valley STPs by Discharger Type (2022)

Discharger Type	Total Volume Discharged to Byron STP (kL)(1)	Total Volume Discharged to Brunswick Valley STP (kL) (1)	High Presumptive Risk
Food-related/Hospitality(2)	6,696	6,126	
Medical(3), (4)	2,546	227	Yes – May contain a range of chemicals
Club	1,602	2,406	
Construction	30	0	Yes – May contain solvents
Mixed Industry	8,909	2,922	Yes - Unknown
Food Processing	639	947	
Hotel/Accommodation	15,170	2,333	
Laundry	245	0	
Mechanical/Auto	2,123	624	Yes – May contain solvents or hydrocarbons
Panel Beater	32	0	Yes – May contain solvents
School/Education Facility(5)	5,484	52	
Service Station	5,976	230	Yes – May contain solvents or hydrocarbons
Retail	8,641	748	
Total Network Volume, 2022	**58,093**	**16,613**	**Byron STP: 19,617 Brunswick Valley STP: 4,002**
Low-strength Domestic	840	0	
Low-strength Commercial	2,771	0	
Mullumbimby WTP Waste(6)	890	0	
Byron Resource Recovery Facility (Leachate)	12,500	0	Yes - Leachate containing PFAS and other chemicals
Total Tankered Volume, 2022	**17,000**	**0**	
Total Tankered + Network, 2022	**75,094**	**16,613**	**12,500 (Byron STP)**

1. Except where a flowmeter is used (as noted below), discharge volumes are estimated by Byron Shire Council as a percentage of metered water use, variable with type of business.
2. Related to restaurants, cafes, takeaways and other hospitality-related businesses.
3. The Byron Bay Hospital (categorised as a "Medical" discharger) uses an electromagnetic type flowmeter for more accurate readings of discharge volume. This hospital accounts for greater than 95% of the volume discharged under the "Medical" category.
4. Based on Kumari et. al. (2020, [9]), these wastes could include drugs and their metabolites such as antibiotics, lipid regulators, analgesics, antidepressants, antiepileptics, antineoplastic, antipyretics, antiphlogistic, antirheumatics, estrogens, organic matter, radionuclides, solvents, metals, disinfectants, cytostatic agents, anaesthetics and sterilization products, specific detergents for endoscopes and other instruments, radioactive markers, and iodinated contrast media. Metals present could include platinum, mercury, rare earth elements (gadolinium, indium, osmium), and iodinated X-ray contrast media. Depending on the waste management practices employed in the relevant facilities, a number of these components may be not present in the sewage stream.

5. The SAE College (categorised as a "School/Education Facility" discharger), uses an electromagnetic type flowmeter for more accurate readings of discharge volume. This facility accounts for roughly half the volume discharged under the "School/Education Facility" category.
6. Backwash waste from sand filters at the WTP, which are dosed with soda ash and alum.

The estimated ADWF influent to Byron STP is 4.6 ML/d and the estimated ADWF to Brunswick Valley STP is 1.5 ML/d.

Network Trade Waste constitutes about 3.5% of the ADWF to Byron STP and about 3% to Brunswick Valley STP. The network inputs deemed higher-risk (as per Table 4-2) constitute about 1.2% of the ADWF to Byron STP and about 0.7% to Brunswick Valley STP.

Among tankered Trade Waste, the only input deemed higher-risk is leachate from the Byron Resource Recovery Facility, at about 12,500 kL over calendar year 2022, which goes to Byron STP. The total tankered and network Trade Waste to Byron STP constitute about 4.5% of ADWF, while higher-risk inputs constitute 1.9% of ADWF.

The total Trade Waste volume to both plants amounts to about 251 kL/d, comprising about 4.1% of the combined ADWF into both plants. The total volume with a high presumptive risk is about 100 kL/d, or 1.6% of the combined ADWF into both plants.

The Bureau of Meteorology (BOM) collects summary statistics for public utilities. As part of these studies, the total volume of wastewater effluent (excluding Trade Waste) and also total volume of Trade Waste is reported annually. The reported total volume of effluent for Urban Utilities (for the 27 STPs in the Urban Utilities network), excluding Trade Waste, was 116,750 ML for the 2020 – 2021, and the reported total volume of Trade Waste was 10,205 ML[8]. The proportion of Trade Waste within the raw wastewater is in the order of 8.0 %.

Assuming the Trade Waste is distributed evenly to each plant in proportion to the raw wastewater flow, for the purposes of comparison, a Trade Waste contribution to the Luggage Point STP can be assumed to be 8%. This proportion of Trade Waste is:

- About double for which permits are in place at East Lismore STP and South Lismore STP; and,
- About double that received at Byron STP and Brunswick Valley STP.

Given the higher proportion of Trade Waste for Luggage Point, and the more urban nature of the catchment as compared to any of the short-listed schemes, benchmarking chemical contamination of Lismore or Byron sourced secondary effluent by use of Luggage Point effluent data is anticipated to be conservative[9].

[8] BOM, 2021, "Urban National Performance Report 2020 – 2021", Bureau of Meterology, Australian Government, URL: http://www.bom.gov.au/water/npr/npr_2020-21.shtm, Date Accessed: 2/19/2024

[9] The proportion of Trade Waste to Luggage Point could be higher than the assumed 8%, given the urban nature of the catchment (as compared to many of Urban Utilities smaller plants located in more rural areas). If this is the case, the use of Luggage Point data is even more conservative.

5 INDUSTRIAL CHEMICAL RISK ASSESSMENT

This section discusses:

- The ICSS values calculated based on the data available in WRF Project No. 4960;
- The ICRQ values calculated based on occurrence data for Luggage Point (i.e. contaminant concentrations measured in Luggage Point secondary effluent);
- Potential blending impact of ICRQ;
- The 20 compounds with the highest ICSS for each Scheme Chemical Risk Type;
- Chemicals which present a pass-through risk for each Scheme Chemical Risk Type;
- An assessment of chemicals that were present in Luggage Point secondary effluent at concentrations greater than the limit report which were excluded from consideration in WRF Project No. 4960; and,
- Risks associated with compounds that could be formed through the AWTP treatment process (i.e. DBPs).

This section presents a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW – as a first step in understanding potential chemical risks in the absence of detailed scheme specific source water information. Further assessment of chemical risk will need to be conducted when sufficient catchment specific data becomes available. The approach described in this memorandum can be used to guide the future detailed chemical risk assessment.

5.1 Relative Chemical Management of Proposed Treatment Trains

5.1.1 ICSS and ICRQ

In an effort to comment on the relative management barriers for industrial chemicals, the ICSS of industrial chemicals for which data was available within WRF Project No. 4960 were summed for each of the individual Scheme Chemical Risk types. The sensitivity or drivers of the ICSS total were also noted. A higher summed ICSS relative to a different option would imply a higher relative risk – provided the quality of input data (e.g. chemical removals for each unit process) is equal.

A similar approach has been applied to ranking the ICRQ, where this value was able to be developed for compounds with Luggage Point occurrence data that were able to be paired with risk and removal metrics from WRF Project No. 4960, to provide indication of possible chemical risk and to provide an example of how to better understand and prioritize chemicals of concern.

Table 5-1 summarises the relative risk assessment between the proposed process trains.

Table 5-1: Relative Risk Assessment Between Proposed Process Trains

Parameter	Scheme Chemical Risk Type A	Scheme Chemical Risk Type B	Scheme Chemical Risk Type C
Train Type	CBAT + WTP with IPR or raw water augmentation	CBAT DPR	RBAT DPR
Total Conservative ICSS	1.6×10^8	1.6×10^8	1.5×10^7
Total Conservative ICSS - PFOA	2.0×10^6	2.0×10^6	5.0×10^5
Total Conservative ICRQ	1.6×10^3	1.9×10^3	3.9×10^2
Total Conservative ICRQ – PFOA	7.3×10^2	9.7×10^2	3.1×10^2
Total Conservative ICRQ – Non detect contributors	4.1×10^1	5.1×10^1	2.0×10^0
Number of Chemicals with ICRQ > 0.2	17	21	11
Top 5 Chemicals Contributing to ICSS (% of Total ICSS)	1. PFOA (98.8%) 2. PFOS (0.9%) 3. PFHxS (0.1%) 4. Thallium (<0.1%) 5. NDMA (<0.1%)	1. PFOA (98.8%) 2. PFOS (0.9%) 3. PFHxS (0.1%) 4. Thallium (<0.1%) 5. NDMA (<0.1%)	1. PFOA (96.7%) 2. PFOS (2.0%) 3. NDMA (0.5%) 4. Hydrazine (0.2%) 5. 1,2,3-Trichloropropane
Top 20 Chemical Risks by ICRQ (ICRQ, %Total ICRQ)	PFOA (924, 55.8%) Cadmium (343, 20.7%) Thallium (286, 17.2%) Butylated Hydroxytoluene (64, 3.9%) PFOS (28, 1.7%) Chromium (2.5, 0.15%) Fluoride (2.3, 0.13%) PFHxS (2.0, 0.12%) Cobalt (1.0, 0.06%) Cyanide (1.0, 0.06%) Arsenic (0.9, 0.05%) NDMA (0.6, 0.04%) Nitrate (0.5, 0.03%) Boron (0.3, 0.02%) Manganese (0.3, 0.02%) NMOR (0.2, 0.01%) Nickel (0.2, 0.01%) Antimony (0.2, 0.01%) Iodide (0.14, <0.01%) Molybdenum (0.14, <0.01%)	PFOA (924, 48.8%) Cadmium (571, 30.1%) Thallium (286, 15.1%) Butylated Hydroxytoluene (64, 3.4%) PFOS (28, 1.5%) Fluoride (4.6, 0.3%) Arsenic (4.5, 0.2%) Chromium (4.1, 0.2%) PFHxS (2.0, 0.10%) Cyanide (1.7, 0.09%) Cobalt (1.0, 0.05%) NDMA (0.6, 0.03%) Nitrate (0.5, 0.03%) Bromide (0.4, 0.02%) Antimony (0.4, 0.02%) Boron (0.3, 0.02%) Manganese (0.3, 0.02%) Iron (0.3, 0.02%) NMOR (0.2, 0.01%) Molybdenum (0.2, 0.01%)	Butylated Hydroxytoluene (255, 65.3%) PFOA (84, 21.5%) Cadmium (29, 7.3%) Thallium (14, 3.7%) PFOS (5.6, 1.5%) NDMA (0.6, 0.2%) Iodide (0.6, 0.2%) Fluoride (0.2, 0.06%) Arsenic (0.2, 0.06%) Chromium (0.2, 0.05%) Boron (0.2, 0.05%) PFHxS (0.14, 0.04%) Nitrate (0.13, 0.03%) Cyanide (0.08, 0.02%) Bromide (0.08, 0.02% Beryllium (0.07, 0.02% Manganese (0.06, 0.02% Cobalt (0.05, 0.01% Nitrite (0.04, 0.01% Fipronil (0.04, <0.01%
Compounds in the top 20 contributing to the ICRQ below the detection limit at max concentration in Luggage Point secondary effluent	Cadmium, Thallium and Butylated Hydroxytoluene	Cadmium, Thallium and Butylated Hydroxytoluene	Butylated Hydroxytoluene, Cadmium, Thallium and Beryllium

For both Scheme Chemical Risk A and B, CBAT with and without a drinking water treatment plant, the total conservative ICSS was approximately ten times higher than Scheme Chemical Risk C (RBAT). The likely explanation for this differential is that RO is a well-studied and broad–spectrum barrier and may achieve much greater than 90% removal for a number of constituents of concern. When comparing based on summed metrics, a process that controls a larger number of compounds would likely result in a lower summed ICSS.

In general, when constructing the WRF Project No. 4960 framework, there were fewer compounds for which non–RO process removals were available and within this assessment, those compounds were assigned a removal of 0%. This likely leads to a far more conservative risk estimation for CBAT simply due to a lack of information on removals. This highlights the need for more research in this area, and specific to any RCC scheme, the need for demonstrating removals of the actual chemicals of concern through on site testing with the source water(s) intended to be used for the scheme.

A similar trend to ICSS was seen with the subset of data for ICRQ. Within the top 20 contributors for the total ICRQ, butylated hydroxytoluene, cadmium, thallium and beryllium were risk rated at the analytical detection limit as no samples in the Luggage Point effluent tested positive for these chemicals. Beryllium was only in the top 20 contributors for Scheme Chemical Risk Type C. Subtracting the ICRQ for these compounds reduced the ICRQ for Scheme Chemical Risk Types A, B and C to from 1,600, 1,900 and 390 to 41, 51 and 2.0 respectively. With more appropriate site-specific secondary effluent or raw wastewater data and less conservative process removal assumptions it is anticipated that the chemical risk would likely be lower than this.

When excluding the significant impact of Perfluorooctanoic Acid (PFOA), which accounts for more than 97% of the ICSS in each data set), the gap between the ICSS narrowed to less than a factor of four between the CBAT and RBAT trains, Similarly, the difference in ICRQ for the two train types narrowed to less than a factor of three. For the purpose of establishing conceptual process trains for the PRW Investigations, given the high level and conservative nature of the screening assessment conducted, the chemical control of all proposed treatment options should be considered equivalent. Further quantitative study, and potential chemical removal optimisation through AWTP design (based on data from demonstration plant operation), would be required to establish the absolute risk profile for any scheme/AWTP process train type that RCC chooses to pursue.

5.1.2 Potential Impact of Blending

The risk of Scheme Chemical Risk Type A could be anticipated to scale down linearly (assuming no presence of chemicals in surface water) based on the minimum volume of surface water in the environmental buffer storage (for IPR), or minimum blending ratio between PRW and surface water as part of raw water augmentation.

Similarly, assuming no presence of the same chemicals in the drinking water from Nightcap WTP, for Scheme Chemical Risk Types B and C the risk could be anticipated to scale down in relation to the blend ratio (amount of PRW delivered to the network (i.e. a given reservoir) divided by the total demand served by the network (i.e. the total combined flow of Nightcap WTP produced water plus PRW blended in the reservoir and sent out to the distribution system)).

Table 5-2 provides an example of blending impacts for a treated water augmentation scheme.

Table 5-2: Treated Water Augmentation Blending Example

	Lismore				Ballina	Byron
Reservoirs	Ross St	City View	High St	Belvedere Dr.	Knockrow	St Helena Reservoir
Projected 2040 Average Daily Demand	3.4 ML/d	2.98 ML/d	1.47 ML/d	2.98 ML/d	13.2 ML/d	8.95 ML/d
	10.8 ML/d with all four main reservoirs 7.4 ML/d without Ross St				22.15 ML (for St Helena with Knockrow backfeed)	
PRW Available[1]	9.1 ML/d				8.35 ML/d	
Blend Ratio[2]	84% (based on PRW blended across all four reservoirs)				38% (based on St Helena with Knockrow backfeed)	
Example Contaminant ICRQ without Blending	1				1	
Example Contaminant ICRQ with Blending[3]	0.84				0.38	

1. Assumes full projected 2040 ADWF from both STPs in scheme is used to create PRW. Note that the Lismore Treated Water Augmentation scheme option applied to the preliminary design and costing was reduced to meet a blend ratio of 50% at the projected 2040 flows to manage build-up of total dissolved solids within the system.
2. Volume of PRW supplied to the reservoir/total volume of water supplied from the reservoir.
3. Assumes the concentration of the example contaminant if the drinking water supplied to the reservoir from sources other than PRW is zero.

This highlights the need to develop an understanding of the water quality from other sources and the intended blending flows, and characteristics of the environmental buffer storage in the IPR scheme, for all foreseen operating conditions prior to conducting the detailed chemical risk assessment (with site specific chemical occurrence data and better-defined removal rates).

5.2 Highest Contributors to Summed ICSS

As discussed in Section 5.1.1, the ICSS of each individual industrial chemical for which data was available within WRF Project No. 4960 were summed to create a total ICSS for each Scheme Chemical Risk Type. This section summarises the chemicals that make up the top 20 individual contributors to the summed ICSS for each Scheme Chemical Risk Type (i.e. of the 171 chemicals for which ICSS could be calculated, the chemicals with the 20 highest individual ICSS, for each Scheme Chemical Risk Type), along with their chemical family and potential sources as grouped within WRF Project No. 4960. The full set of data is included in Appendix A.

Figure 5-1 presents, for each Scheme Chemical Risk Type, a breakdown of the top 20 individual contributors to the summed ICSS based on chemical family. Scheme Chemical Risk Type A and B, which predominantly rely on CBAT, have similar chemical families of concern. Relative to Scheme Chemical Risk Type B, the addition of assumed removals via the WTP shows marginally improved controls of metals and other inorganics. Scheme Chemical Risk Type C, using RBAT, shifts the focus of chemical control to solvents and industrial precursors, likely as a result of a large proportion of this family having lower molecular weights and some being neutrally charged thus contributing a challenge to removal by RO.

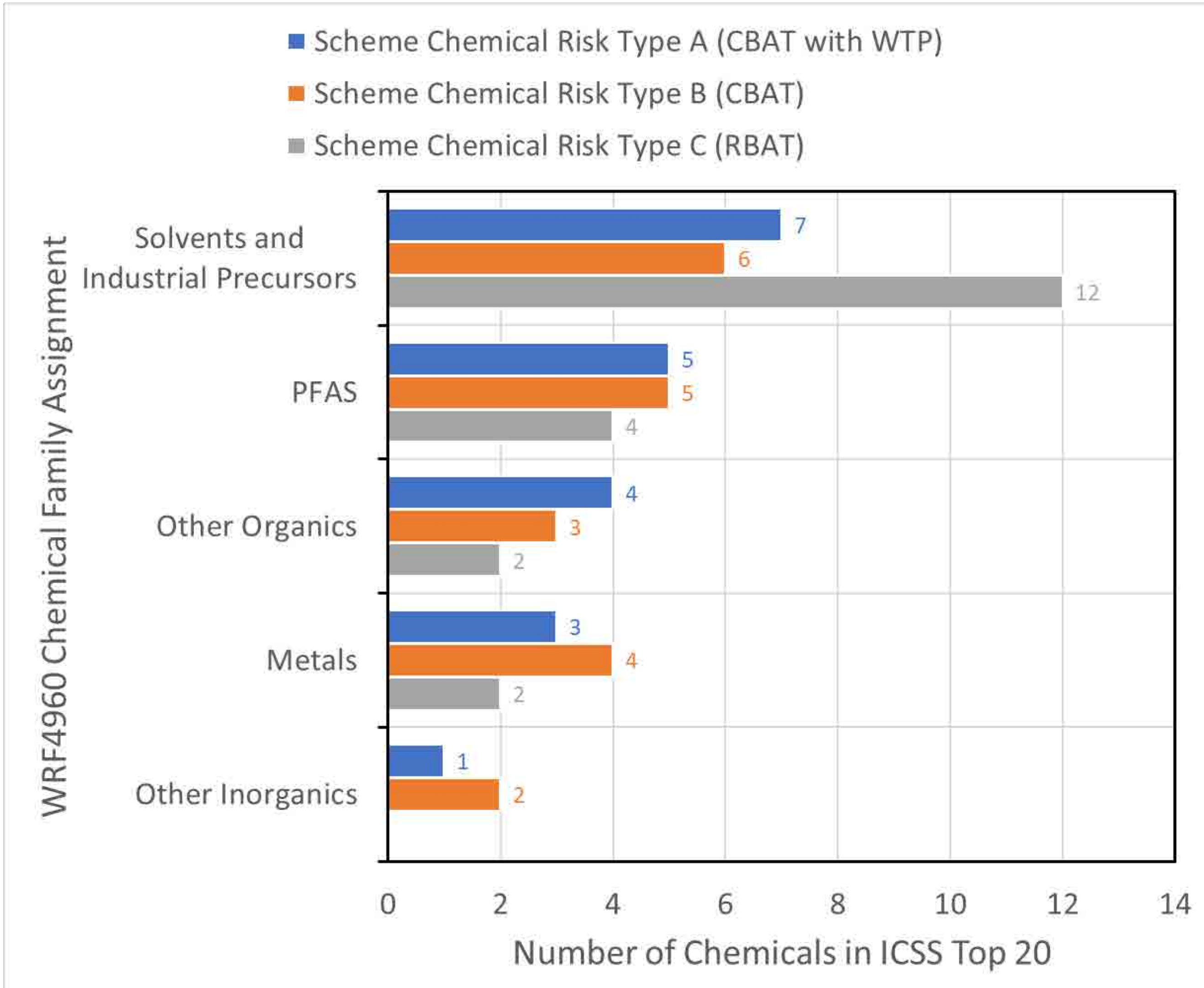

Figure 5-1: Summary of Chemical Families of Concern Based on Conservative ICSS for Each Scheme Chemical Risk Type[10]

Per-and polyfluoroalkyl substances (PFAS)[11] are a challenge for all Scheme Chemical Risk Types, and within this single family of industrial chemicals, four or five are within the top 20 regardless of applied treatment technology (as shown in Figure 5-1.

[10] In Figure 5-1, the numbers associated with the horizontal bars represent the number of chemicals within the top 20 contributors to the summed ICSS are within the given chemical family (as described on the Y axis) for a given Scheme Chemical Risk Type.

[11] Per- and polyfluoroalkyl substances (PFAS) are a large, complex group of synthetic chemicals that have been used in consumer products around the world since about the 1950s. PFAS molecules have a chain of linked carbon and fluorine atoms. Due to the strength of carbon-fluorine bonds is one, these chemicals do not degrade easily in the environment. PFAS are a group of nearly 15,000 synthetic chemicals, according to a chemicals database (CompTox) maintained by the U.S. Environmental Protection Agency. https://www.niehs.nih.gov/health/topics/agents/pfc

Degradation of consumer products in landfills has been associated as a source of PFAS. However, PFAS have been reported to be at a consistently detectable level in municipal effluent with and without significant industrial inputs [10]. In addition, PFAS have been detected in drinking water catchments and correlated to other anthropogenic indicators of de facto reuse, such as sucralose [11]. Accordingly, if the source water for Nightcap WTP is impacted by de facto reuse[12], this would introduce an additional exposure source and also inhibit the effectiveness of reservoir dilution or raw water blending (Scheme Chemical Risk Type A) of controlling PFAS risk. PFAS have also been detected, albeit at very low levels, in all precipitation globally [12].

Consequently, it is challenging to employ industrial source control as a complete barrier against the introduction of PFAS into a potable reuse scheme, given the multitude of other pathways for this family of chemicals to enter and impact broader water supply. Nevertheless, given the practice and introduction of waste from landfills into the proposed catchments of these schemes, it is recommended that a chemical survey of landfill wastewater, in particular for PFAS, be conducted and compared to levels indigenous PFAS levels in the municipal portion of the wastewater for any scheme which is carried forward for further development. Such a comparison would help identify if significant reductions in PFAS loads (and potentially other surveyed chemicals) could be achieved by further onsite treatment or segregation of landfill waste.

Similarly, hospital waste was identified as a potentially relevant source for thallium (although this compound was not detected in the Luggage Point effluent) and hydrazine, which was not assayed. Hospitals, other medical facilities and aged care facilities are anticipated to be point sources of pharmaceutical metabolites which were not risk assessed as part of WRF Project No. 4960. Given the presence of medical and aged care facilities within both proposed catchments, it is recommended to conduct a survey of these inputs to determine:

1. The current concentrations of compounds of concern in their discharge to sewer;
2. The current management practices;
3. Potential improvements to prevailing onsite management practices to reduce risk to the PRW scheme.

Table 5-3 through Table 5-5 show the top 20 individual contributors to the summed ICSS for each Scheme Chemical Risk Type, along with their chemical family, industrial applications and potential sources. In reviewing this information, it must be remembered that the ICCS (and ICRQ) have been calculated based on non-site specific information, hence the risk discussed herein is general to all potable reuse schemes having similar process trains. A number of the applications or sources for the identified chemicals are unlikely to occur within the sewer catchments of any of the proposed RCC schemes. However, it is important to recognise that both landfills and hospitals are present for all Scheme Chemical Risk Types.

[12] There is likely low risk of chemical contamination of Rocky Creek Dam due to the nature of the catchment. However, the Wilsons River Source is located downstream of the discharge from Bangalow STP and downstream of agricultural land (from which fertilizers, pesticides, etc. could run off).

Table 5-3: Family, Application and Sources of the Top 20 ICSS Contributors for Outcome A – CBAT Scheme including WTP

Name	Family	Industrial Application(s)	Potential Source(s)
Perfluorooctanoic Acid	PFAS	Voluntarily phased-out industrial surfactant. Degradation product of polyfluorinated substances in textile	Landfills
Perfluorooctane Sulfonate	PFAS	Firefighting foam; degradation product of polyfluorinated substances	Airport Deicing; Electroplating; Landfills; Metal Finishing
Perfluorohexane Sulfonate	PFAS	Electroplating; Firefighting foam	Landfills; Electroplating; Airport Deicing; Metal Finishing
Thallium	Metals	Optics; Electronics; Nuclear Medicine	Glass Manufacturing; Electrical and Electronic Components; Hospitals; Mineral Mining and Processing
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	Solvent; rubber accelerator; intermediate for 1,1-dimethylhydrazine rocket propellant	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing; Explosives Manufacturing; Textile Mills; Metal Finishing; Electrical and Electronic Components
Perfluorononanoic Acid	PFAS	Degradation product of polyfluorinated substances	Landfills
Hydrazine	Solvents & Industrial Precursors	Rocket fuel; corrosion control; precursor to plastics, pesticides, and medicines; cancer drug; quenching dissolved oxygen in the water-steam cycle	Pharmaceutical Manufacturing; Hospitals; Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals; Steam Electric Power Generation
Lanthanum	Metals	Batteries, lighter flints, hydrogen sponge alloys	Battery Manufacturing; Nonferrous Metals Manufacturing
1,2,3-Trichloropropane	Solvents & Industrial Precursors	Precursor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Bis(2-chloroethyl) ether	Solvents & Industrial Precursors	Chemical intermediate for pesticides. Solvent.	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals
N-nitrosomorpholine	Other Organics	Unknown	Unknown
Nitroglycerine	Other Organics	Explosive, rocket propellant	Explosives Manufacturing
Ethylene Oxide	Solvents & Industrial Precursors	Precursor in the manufacture of ethylene glycol, surfactants, acrylonitrile, and ethanolamines	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Ethylene thiourea	Other Organics	Accelerator for vulcanizing neoprene and polyacrylate rubbers	Rubber Manufacturing
1,3-Dinitrobenzene	Solvents & Industrial Precursors	Chemical intermediate for synthetic fibers, dyes, explosives	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Explosives Manufacturing
Perfluorobutane Sulfonic Acid	PFAS	Surfactant, electroplating, integrated circuits	Landfills; Electroplating; Electrical and Electronic Components; Metal Finishing
Cobalt	Metals	Electroplating, lamp filaments, catalyst for sulfur removal from petroleum, dyes	Electroplating; Nonferrous Metals Manufacturing; Petroleum Refining; Textile Mills; Metal Finishing
Hexachloroethane	Other Organics	Smoke-producing military devices, pyrotechnics, anhelmintic	Pesticide Chemicals; Explosives Manufacturing
Antimony	Other Inorganics	Flame Retardants, Alloys, Batteries, Stabilizer, Catalyst, Glass, Electronics, Pigments	Battery Manufacturing; Electrical and Electronic Components; Glass Manufacturing; Ink Formulating; Petroleum Refining
2,4,6-Trichlorophenol	Solvents & Industrial Precursors	Disinfectant, antiseptic, bleaching at pulp and paper mills, leather tanning, wood preservative	Pesticide Chemicals; Pulp, Paper and Paperboard; Leather Tanning and Finishing; Timber Products Processing

Table 5-4: Family, Application and Sources of the Top 20 ICSS Contributors for Outcome B – CBAT Scheme excluding WTP

Name	Family	Industrial Application(s)	Potential Source(s)
Perfluorooctanoic Acid	PFAS	Voluntarily phased-out industrial surfactant. Degradation product of polyfluorinated substances in textile	Landfills
Perfluorooctane Sulfonate	PFAS	Firefighting foam; degradation product of polyfluorinated substances	Airport Deicing; Electroplating; Landfills; Metal Finishing
Perfluorohexane Sulfonate	PFAS	Electroplating; Firefighting foam	Landfills; Electroplating; Airport Deicing; Metal Finishing
Thallium	Metals	Optics; Electronics; Nuclear Medicine	Glass Manufacturing; Electrical and Electronic Components; Hospitals; Mineral Mining and Processing
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	Solvent; rubber accelerator; intermediate for 1,1-dimethylhydrazine rocket propellant	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing; Explosives Manufacturing; Textile Mills; Metal Finishing; Electrical and Electronic Components
Perfluorononanoic Acid	PFAS	Degradation product of polyfluorinated substances	Landfills
Hydrazine	Solvents & Industrial Precursors	Rocket fuel; corrosion control; precursor to plastics, pesticides, and medicines; cancer drug; quenching dissolved oxygen in the water-steam cycle	Pharmaceutical Manufacturing; Hospitals; Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals; Steam Electric Power Generation
Lanthanum	Metals	Batteries, lighter flints, hydrogen sponge alloys	Battery Manufacturing; Nonferrous Metals Manufacturing
1,2,3-Trichloropropane	Solvents & Industrial Precursors	Precursor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Bis(2-chloroethyl)ether	Solvents & Industrial Precursors	Chemical intermediate for pesticides. Solvent.	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals
N-nitrosomorpholine	Other Organics	Unknown	Unknown
Nitroglycerine	Other Organics	Explosive, rocket propellant	Explosives Manufacturing
Ethylene Oxide	Solvents & Industrial Precursors	Precursor in the manufacture of ethylene glycol, surfactants, acrylonitrile, and ethanolamines	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Ethylene Thiourea	Other Organics	Accelerator for vulcanizing neoprene and polyacrylate rubbers	Rubber Manufacturing
Arsenic	Other Inorganics	Glass and electronics production, herbicide, insecticide, wood preservatives, leather	Electrical / Electronic Components; Pesticide Chemicals; Leather Tanning and Finishing; Timber Products Processing; Mineral Mining and Processing; Battery Manufacturing; Copper Forming; Glass Manufacturing; Textile Mills
1,3-Dinitrobenzene	Solvents & Industrial Precursors	Chemical intermediate for synthetic fibers, dyes, explosives	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Explosives Manufacturing
Antimony	Other Inorganics	Flame Retardants, Alloys, Batteries, Stabilizer, Catalyst, Glass, Electronics, Pigments	Battery Manufacturing; Electrical and Electronic Components; Glass Manufacturing; Ink Formulating; Petroleum Refining
Perfluorobutane Sulfonic Acid	PFAS	Surfactant, electroplating, integrated circuits	Landfills; Electroplating; Electrical and Electronic Components; Metal Finishing

Cobalt	Metals	Electroplating, lamp filaments, catalyst for sulfur removal from petroleum, dyes	Electroplating; Nonferrous Metals Manufacturing; Petroleum Refining; Textile Mills; Metal Finishing
Mercury	Metals	Thermometers, barometers, pressure-sensing devices, batteries, and lamps	Electrical and Electronic Components; Battery Manufacturing; Petroleum Refining; Nonferrous Metals Manufacturing; Pharmaceutical Manufacturing

Table 5-5: Family, Application and Sources of the top 20 ICSS contributors for Outcome C – RBAT Scheme excluding WTP

Name	Family	Industrial Application(s)	Potential Source(s)
Perfluorooctanoic Acid	PFAS	Voluntarily phased-out industrial surfactant. Degradation product of polyfluorinated substances in textile	Landfills
Perfluorooctane Sulfonate	PFAS	Firefighting foam; degradation product of polyfluorinated substances	Airport Deicing; Electroplating; Landfills; Metal Finishing
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	Solvent; rubber accelerator; intermediate for 1,1-dimethylhydrazine rocket propellant	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing; Explosives Manufacturing; Textile Mills; Metal Finishing; Electrical and Electronic Components
Hydrazine	Solvents & Industrial Precursors	Rocket fuel; corrosion control; precursor to plastics, pesticides, and medicines; cancer drug; quenching dissolved oxygen in the water-steam cycle	Pharmaceutical Manufacturing; Hospitals; Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals; Steam Electric Power Generation
1,2,3-Trichloropropane	Solvents & Industrial Precursors	Precursor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Perfluorohexane Sulfonate	PFAS	Electroplating; Firefighting foam	Landfills; Electroplating; Airport Deicing; Metal Finishing
1,2-Dibromoethane	Solvents & Industrial Precursors	Precursor for dyes and pharmaceuticals, solvent	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pharmaceutical Manufacturing
Perfluorononanoic Acid	PFAS	Degradation product of polyfluorinated substances	Landfills
Vinyl Chloride	Solvents & Industrial Precursors	Chemical synthesis intermediate; Monomer for PVC; Solvent	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
1,3-Dinitrobenzene	Solvents & Industrial Precursors	Chemical intermediate for synthetic fibers, dyes, explosives	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Explosives Manufacturing
1,3-Butadiene	Solvents & Industrial Precursors	Used to make synthetic rubber, plastics, and resins	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Acrylonitrile	Solvents & Industrial Precursors	Polymer precusor	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Rubber Manufacturing
Thallium	Metals	Optics; Electronics; Nuclear Medicine	Glass Manufacturing; Electrical and Electronic Components; Hospitals; Mineral Mining and Processing
Ethylene thiourea	Other Organics	Accelerator for vulcanizing neoprene and polyacrylate rubbers	Rubber Manufacturing
Ethylene Oxide	Solvents & Industrial Precursors	Precursor in the manufacture of ethylene glycol, surfactants, acrylonitrile, and ethanolamines	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
2,4-dinitrotoluene	Solvents & Industrial Precursors	Intermediate in the manufacture of polyurethanes	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Quinoline	Solvents & Industrial Precursors	Precursor for dyes, niacin. Solvent for resins	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)
Lanthanum	Metals	Batteries, lighter flints, hydrogen sponge alloys	Battery Manufacturing; Nonferrous Metals Manufacturing
Bis(2-chloroethyl)ether	Solvents & Industrial Precursors	Chemical intermediate for pesticides. Solvent.	Organic Chemicals, Plastics and Synthetic Fibers (OCPSF); Pesticide Chemicals
N-nitrosomorpholine	Other Organics	Unknown	Unknown

5.3 PASS–THROUGH RISKS

Of the 262 chemicals considered as part of WRF Project No. 4960, 171 have human health impact data to allow development of an ICSS (at least assuming the worst-case removal of zero). A number of chemical removals were unknown for specific treatment processes. To assess the risk of these, a zero removal was conservatively applied.

A pass–through risk was defined in WRF Project No. 4960 as a chemical with a cumulative removal across a planned treatment train of less than 90% (i.e. the individual percent removal of a given chemical across each unit process are multiplied and if the product is less than 90% this chemical is defined as a pass-through risk for that process train). Table 5-6 summarises the number of pass-through chemicals based on cumulative removal across a planned treatment train for a given chemical of less than 90%, noting that the summary in Table 5-6 potentially overestimates the number of pass-through chemical risks due to the conservative removals assigned for this analysis .

In Table 5-6:

- The first row includes any chemicals (of the 262 chemicals considered as part of WRF Project No. 4960) with a cumulative removal of less than 90%. This number is highly conservative as it may assign a removal of 0% to any treatment process where data on removal is not available, which in turn reduces the overall cumulative removal.
- The second row counts the number of chemicals (of the 262 chemicals considered as part of WRF Project No. 4960) for which removal data is known for each chemical barrier in a proposed Scheme Chemical Removal Type.
- The third row considers the number of chemicals with known removal data representing a potential pass-through risk. That is, of the number of chemicals that are completely specified in row 2, how many may be removed at less than 90% for a given Scheme Chemical Risk Type.

Table 5-6: Pass– Through Risk Summary from WRF Project No. 4960 Data

Parameter	Metric Description/Limitation	Scheme Chemical Removal Type A	Scheme Chemical Removal Type B	Scheme Chemical Removal Type C
Train		CBAT + Nightcap WTP	CBAT no WTP	RBAT no WTP
Pass Through Chemicals (Conservative Removal < 90%)	This may include chemicals for which there are no removals reported and are assigned a 0% removal.	99	104	55
Chemicals With Known Removal for All Barriers	This is the number of chemicals, from 262 total, that have removal data for each chemical barrier in the proposed outcome.	78	79	102
Chemicals with Known Pass-Through Risks	Of the chemicals in the row above with known removal for all barriers, this is how many may be removed less than 90%.	30	35	3

The data in Table 5-6 highlights that, in general, RBAT performance is better studied than CBAT, and for most compounds the high RO removal results in low pass-through (assuming the membrane barrier is intact). The pass-through risks for RO are nitrate, 1,4-Dioxane and NDMA. All three of these chemical hazards can be managed. For example, STP optimization can reduce the incoming level of nitrate, while adjustments to the design and operation of UV/AOP (UV dose for NDMA and UV dose times oxidant concentration for 1,4 Dioxane) can be made to control risks in the RBAT train.

While RBAT is better studied than CBAT, Table 5-6 highlights the need for more research on removals through RBAT (i.e. of the 262 chemicals considered in WRF Project No. 4960 only 102 currently have removals defined for all barriers in the RBAT train).

Table 5-7 summarises the chemicals that have a known pass-through risk for CBAT trains, based on the information available in WRF Project No. 4960. Further work will be required to fully define site specific pass-through risks (i.e. development of an understanding of chemicals potentially present in the catchment, their concentration in the feed water and their removal through each unit process in the treatment train (through review of literature as more information becomes available and through onsite testing via a demonstration plant treating the intended source water for the scheme), whether the treatment train is CBAT or RBAT).

Table 5-7: Chemicals with Known Pass-Through Risks (Potential Overall Removal of < 90% Based on Literature)

Chemical Name	Family	CBAT + WTP (Scheme Chemical Removal Type A)	CBAT only (Scheme Chemical Type B)
Cadmium	Metals	✓	✓
Chromium	Metals	✓	✓
Cobalt	Metals	✓	✓
Iron	Metals		✓
Nickel	Metals	✓	✓
Copper	Metals	✓	✓
Uranium	Metals	✓	✓
Zinc	Metals	✓	✓
Mercury	Metals	✓	✓
Tin	Metals		✓
Nitrate	Nitrogen	✓	✓
Calcium	Other Inorganics	✓	✓
Sulphate	Other Inorganics	✓	✓
Chloride	Other Inorganics	✓	✓
Barium	Other Inorganics	✓	✓
Fluoride	Other Inorganics	✓	✓
Arsenic	Other Inorganics		✓
Bromide[13]	Other Inorganics		✓
Strontium	Other Inorganics	✓	✓
Selenium	Other Inorganics		✓
N-nitrosomorpholine	Other Organics	✓	✓
Perfluorobutane Sulfonic Acid	PFAS	✓	✓
Perfluorobutanoic acid	PFAS	✓	✓
Perfluoropentanoic Acid	PFAS	✓	✓
Perfluorohexanoic Acid	PFAS	✓	✓
Perfluorodecanoic acid	PFAS	✓	✓
Perfluoroheptanoic Acid	PFAS	✓	✓
Perfluorooctanoic Acid	PFAS	✓	✓
Perfluorooctane Sulfonate	PFAS	✓	✓
Perfluorohexane Sulfonate	PFAS	✓	✓
Perfluorononanoic acid	PFAS	✓	✓
Gabapentin	Pharmaceuticals	✓	✓
Diatrizoic Acid	Pharmaceuticals	✓	✓
1,4-Dioxane	Solvents & Industrial Precursors	✓	✓
N-Nitrosodimethylamine (NDMA)	Solvents & Industrial Precursors	✓	✓

The chemicals identified as known pass-through risks should be analysed to confirm that they are below acceptable levels in the source water and/or removed to a higher extent than assumed, and efforts to control these chemicals with a source control program should be implemented. The presence of these chemicals does not indicate a direct risk to PRW quality, but rather their presence does indicate a need for monitoring and verification. The CBAT trains include the same three

[13] The difference between Scheme Chemical Risk Type A and Type B is likely the result of default WTP removals in Water Research Foundation Project 9640 for coagulation, flocculation and sedimentation. If coagulation, flocculation and sedimentation is used in the CBAT train the pass-through risk may be similar. Further investigation would be required to provide better understanding of pass-through risk for bromide.

pass-through risks as for the RBAT train (nitrate, 1,4-Dioxane and NDMA). In addition, there are a number of other compounds, including metals and inorganics, that would require further investigation to determine if they are expected to be at acceptable concentrations in the feed to the AWTP. Again, a large number of PFAS are also present within the list of chemicals of concern. PFAS removal from the product stream could be optimized based on design and operation of the GAC.

5.4 Assessment of Excluded Chemicals

WRF Project No. 4960 did not attempt to collate human health impact data for all possible industrial chemicals. From an initial pool of 490 chemicals, 228 were excluded from further classification. The reasons for exclusion of chemicals are included in Appendix A.

The comprehensive water quality analysis of Luggage Point secondary effluent included the analysis of 587 different constituents. As a means to investigate potential omission of risk rating from compounds that have been specified in potable reuse monitoring plans, the list of WRF Project No. 4960 exclusions was cross referenced against the Luggage Point secondary effluent results.

In total, there were 32 of the 228 chemicals excluded from assessment as part of WRF Project No. 4960 that were detected, typically at very low concentrations, in the data from Luggage Point. A majority of these chemicals were excluded from WRF Project No. 4960 as they are rare or banned pesticides in the United States. Of these 32 chemicals, an ICRQ was calculated using drinking water health based guideline levels. This is a conservative assumption as it assumes all chemical barriers downstream of a STP are ineffective (i.e.it does not take into account cumulative removal through the downstream AWTP processes). Only two chemicals resulted in an ICRQ of greater than 1.0. These were Haloxyfop, a rare pesticide and N-Nitroso-di-n-propylamine.

A third compound, the pharmaceutical Ranitidine (Zantac), was rated as if it were an NDMA precursor that could convert 100% into NDMA. The California notification level of 10 ng/L was used and resulted in an ICRQ of 6.0. This is an unrealistic assumption on conversion to NDMA and hence an overly conservative ICRQ. Notwithstanding, NDMA could be effectively removed by high dose UV if required.

The ICRQ for the remaining 29 detected chemicals, based on the maximum Luggage Point secondary effluent concentration, was less than 1.0. This implies that for these chemicals, even without treatment, they could be at safe drinking water levels.

An additional 82 chemicals were tested for at Luggage Point but were not detected in all samples. The remaining 109 chemicals excluded from WRF Project No. 4960 were not analysed for in the Luggage Point secondary effluent. The full list of cross-checked exclusions is available in Appendix A.

Table 5-8 summarises chemicals found in Luggage Point secondary effluent at concentrations greater than the limit of reporting that were excluded from WRF Project No. 4906, along with the reason for exclusion from WRF Project No. 4960 and the maximum occurrence in the Luggage Point water quality report.

Table 5-8: Chemicals Omitted from WRF Project No. 4960 Assessment that were Detected in Luggage Point Effluent, the Detected Concentration and the ICRQ

Name	Reason Omitted from WRF4960	Maximum Detected Luggage Point Concentration (mg/L)	Guidance Value (mg/L)	Guidance Source	ICRQ
Ranitidine	Discontinued or restricted pharmaceutical	0.00006	0.00001(1)	Not Available(1)	< 6
Haloxyfop	Rare pesticide	0.0035	0.001	ADWG	3.5
N-Nitroso-di-n-propylamine	Impurity only	0.00001	0.000005	CA Toxics Rule	2
Cholesterol	Biological origin	0.0044	0.007	AGWR Phase 2 2008	0.6
Ethoprophos	Rare pesticide	0.000474	0.001	ADWG	0.5
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	Rare pesticide	0.018	0.04	ADWG	0.5
1,7-dimethylxanthine	Metabolite	0.0003	0.0007	AGWR Phase 2 2008	0.40
Triclopyr	Rare pesticide	0.0076	0.02	ADWG	0.38
Bromoxynil	Rare pesticide	0.0031	0.01	ADWG	0.31
N-Nitrosodiethylamine	Byproduct only	0.00002	0.0001	CA Notification Level	0.20
Terbuthylazine	Rare pesticide	0.0015	0.01	ADWG	0.15
Mecoprop	Rare pesticide	0.0013	0.01	WHO DWG	0.13
Diuron	Rare pesticide	0.0015	0.02	ADWG	0.08
Cyanazine	Rare pesticide	0.00003	0.0006	WHO DWG	0.05
Tebuconazole	Rare pesticide	0.0076	0.17	CA Pesticide Regulation	0.04
Baygon	Rare pesticide	0.00006	0.003	USEPA HAL	0.02
2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T)	Rare pesticide	0.00013	0.009	WHO DWG	0.01
Fluometuron	Rare pesticide	0.00096	0.07	ADWG	0.01
Diazinon	Rare pesticide	0.00005	0.004	ADWG	0.01
Metsulfuron-methyl	Rare pesticide	0.00041	0.04	ADWG	0.01
Metolachlor oxanilic acid[2]	Pesticide metabolite	0.0018	0.3	AGWR Phase 2 2008 (based on Metolachlor)	0.006
Metribuzin	Rare pesticide	0.00025	0.07	ADWG	0.004
Hexazinone	Rare pesticide	0.001	0.4	ADWG	0.003
Carbendazim	Rare pesticide	0.0001	0.09	ADWG	0.001
Methomyl	Rare pesticide	0.000018	0.02	ADWG	0.0009
Ametryn	Rare pesticide	0.00004	0.07	ADWG	0.0006
Tebuthiuron	Rare pesticide	0.00023	0.5	USEPA HAL	0.0005
Terbutryn	Banned pesticide	0.00008	0.4	ADWG	0.0002
Clopyralid	Rare pesticide	0.0003	2	ADWG	0.0002
4,4'-DDT	Banned pesticide	1.2E-06	0.009	ADWG	0.0001
Bromacil	Rare pesticide	0.00002	0.4	ADWG	0.00005
Imazapyr	Rare pesticide	0.00012	9	ADWG	1.33E-05

1. Ranitidine safe drinking water guidance levels were unavailable. It was noted that 94% conversion of Ranitidine to NDMA was possible (with unrealistically high applied doses of chloramine 28 mg/L). To that end, the CA notification level of 10 ng/L for NDMA was used to evaluate a risk quotient for Ranitidine assuming 100% conversion. This evaluation is likely overly conservative. NDMA could be effectively managed through higher dose UV and should be determined by site specific occurrence measurements for UV design.

5.5 PROCESS RELATED CHEMICAL RISKS

Chemical risks specific to how a potable reuse train is operated were identified based on review of recent literature related to CBAT and RBAT processes. This review shows that the majority of the chemical risk is associated with formation of DBPs, which, with the exception of NDMA and NMOR, were not assessed as part of WRF Project No. 4960. The most widely reported DBPs included nitrosamines, bromate, trihalomethanes (THMs) and halo acetic acids (HAAs). The key considerations for process related chemical risks are summarized in Table 5-9, and elaborated on in Appendix C.

Table 5-9: Process Related Chemical Risk Summary

Chemical Class	Causes	Risk	Process	Mitigation Strategies (Refer to Appendix C for further details)
Bromate	Oxidation of bromide by ozone	Carcinogen, the 10 ug/L California maximum contaminant level (MCL) for bromate represents a 10^{-4} excess lifetime cancer risk.	Formation potential during ozonation	Chlorine Ammonia process Hydrogen Peroxide addition to convert ozone to hydroxyl radicals pH Depression
NDMA/ Nitrosamines	Chloramination and ozonation of wastewater, incomplete upstream removal of nitrogen (in particular ammonia). Biofiltration under anoxic denitrifying conditions forms NDMA.	Carcinogen, the 10 ng/L notification level for NDMA in California reflects a 10^{-5} lifetime excess cancer risk.	Formation potential during ozone/BAC Formation potential during disinfection/biocide addition	BAC treatment under aerobic conditions (i.e. avoiding anaerobic conditions) UV/AOP
THMs and HAA5s	Chlorine disinfection, high total organic carbon (TOC) level	Carcinogen	Formation potential during chlorination	TOC minimization prior to chlorine disinfection (e.g. coagulation/flocculation/sedimentation, ozone/BAC, GAC or RO) High UV/AOP dose
Cyanide	Reaction of chlorine with nitrate or nitrite	Nerve damage, thyroid problems	Formation potential during chlorine disinfection	Nitrate removal
Aldehydes	Ozonation and chlorination	Adversely affect drinking water stability	Potential formation during ozonation, disinfection, UV/AOP	Monitoring of formaldehyde removal by BAC as a surrogate. Optimization and demonstration of disinfection and UV/AOP

6 NEW TOOLS

New tools are being developed for use in prioritization and risk assessment of constituents of emerging concern (CECs). The ECHIDNA database, developed by Water Research Australia, has focused on a different approach to prioritization of chemicals in the environment. It includes categorical ratings based on persistence and human health impact and also some information on raw wastewater occurrence and treatment process removal.

ECHIDNA focuses on all CECs – that is, chemicals that do not yet have a strict guideline or regulatory limit by which safety can be measured. ECHIDNA is also not necessarily limited to chemicals of industrial origin, and therefore provides a broader approach to chemical hazard identification. Unfortunately, there is no present function to bulk export data from the ECHIDNA database and there are not consistently available removals presented for a majority of treatment processes of relevance to the entire water reuse train. However, once this information becomes available, a similar mass screening approach could be applied as was done in this work. Use of ECHIDNA would be proactive and advantageous, as using this database would provide inclusion of another 1,600 plus chemicals that do not necessarily have established guidance values at this time.

7 CONCLUSIONS AND RECOMMENDATIONS

This report presents a high-level assessment of the risks associated with chemicals that may be present in the source water used in the production of PRW. The assessment was conducted using paradigms developed in WRF Project No. 4960[14] for chemicals of industrial origin to provide indication of possible chemical risk and to provide an example of how to better understand and prioritize chemicals of concern – as a first step in understanding potential chemical risks in the absence of detailed scheme-specific source water information. Further assessment of chemical risk will need to be conducted when sufficient catchment specific data becomes available for any scheme which is to be progressed. The approach described in this memorandum can be used to guide the future detailed, quantitative chemical risk assessment. Further assessment with ECHIDNA could also be considered. Further investigations required to support a future detailed chemical risk assessment would include, but not be limited to:

- Source characterisation (refer to the *Purified Recycled Water for Drinking Investigation Project Report* completed as part of the PRW Investigations for further information on source characterisation, and the material developed in the AGWR [1] and WHO (2017, [13]);
- Development of an enhanced source water control program (including a detailed study of all dischargers and the chemicals they use that could end up in the sewer);
- Demonstration plant testing on the source water intended for use at full scale (including monitoring for chemicals of concern in the source water and their removal through the various unit processes within the demonstration advanced water treatment plant; and
- Additional literature review as more information of occurrence data, health risk factors and treatment process removal performance becomes available.

Any future detailed chemical risk assessment should incorporate consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1]. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, such as the Australian Drinking Water Guidelines, World Health Organization guidelines, etc. should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP. The detailed risk assessment would be a "live" document and updated over the operational life of the AWTP based on changes in the source water characteristics and/or changes or additions to the guideline values.

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[14] A cancer risk level of one-in-ten-thousand is applied by the US EPA when deciding whether cancer or non-cancer risk levels provide more meaningful scenario-specific risk reduction [4]. The AGWR uses a risk target on one-in-one-million for non-threshold chemicals whose carcinogenicity has been characterised by experimental determination of potency (i.e. by derivation of a 'slope factor') [1]. Health guideline values derived in the AGWR using the one-in-one-million risk target "is taken to mean that, if a population of one million people were to consume water at the guideline concentration for a lifetime, then one additional cancer might plausibly be expected to occur" [1]. Hence, the RSD used for this assessment is less conservative than if the RSD were developed based on the AGWR risk target. However, this is not important for this assessment as this screening process is used to demonstrate a methodology as to how chemicals could be prioritised for further investigation. Future detailed chemical risk assessment will need to include consideration of predicted PRW concentrations for various chemicals against guideline values presented in Table 4.4 of AGWR [1] and ensure that the RSD used aligns with the one-in-one million AGWR risk target. Where guideline values are not available in AGWR (or where more stringent values than those presented in AGWR have been identified and there may be justification for their consideration), other sources for health-based guidelines, including the Australian Drinking Water Guidelines, World Health Organization guidelines, etc should be referred to. The PRW concentrations would then need to be verified, first by demonstration plant operation, and subsequently during commissioning and ongoing operation of the full-scale AWTP.

ICRQ cutoff values would be two orders of magnitude lower (i.e. 0.002 and 0.01) when calculating ICSS and ICRQ based on the AGWR risk target of one-in-one-million. It is imperative that the approach used is consistent (i.e. the acceptable risk target must be consistent across calculations). As noted previously, the risk target selected does not effect the prioritisation of chemicals for further investigation. However, using the correct risk target is critical when establishing the guideline to be used for acceptable concentration of a given chemical in PRW.

Based on this assessment, PFAS appears to be a broad concern for all proposed treatment trains. This concern is driven almost solely by the risk to human health posed by these compounds[15].

A further concern is the origin of PFAS. While landfill leachate may contribute a significant load, it is equally possible that a majority of the load originates from households. It is recommended that chemical characterisation of leachate be compared to raw wastewater to determine the potential extent of contamination for this source for any schemes carried forward for further consideration. If leachate is shown to be a significant contributor of chemical load, then segregation from a potable reuse scheme or enhanced point source treatment may be more effective than addition of further unit operations to the potable reuse treatment train.

This assessment indicated that the permitted Trade Waste volume was likely to be consistently less than 4% of the volumetric load for Scheme Chemical Risk Type A and B (sourced from Lismore) – subject to confirmation through a more detailed evaluation. The volumetric load of Trade Waste for Byron is also about 4%. Both catchments include landfill leachate. Leachate is treated onsite to some extent for East Lismore, but Byron STP receives leachate with no prior treatment.

Hospital and aged care waste may be of concern, but volumetric contributions appear to be low. Similarly, there are automotive and machine work related industries in the catchment. An assessment of chemicals of industrial concern in the raw wastewater should be conducted for any schemes carried forward for further consideration to better understand if these industries contribute significantly to chemical load.

While chemical risk is highly specific to individual catchments, the high-level analysis of the catchments (i.e. lower percentage trade waste, limited heavy industry) gives some indication that risks could be similar to or lower than a typical catchment, including the Seqwater data considered in this work.

As discussed in Section 3, both RBAT and CBAT process trains similar to the conceptual process trains selected for the PRW Investigations have been demonstrated to provide robust treatment for compounds of concern. This high-level chemical risk assessment did not identify any issues that would drive recommending additional chemical barriers to be included in the conceptual process trains (noting that the potential need for further unit processes to address chemical risk is considered in the *AWTP Process Trains Memorandum*).

Therefore, this analysis effectively shows the proposed treatment trains should provide good control of chemical risk in the proposed catchments, where the underlying chemical risk of the proposed catchment is expected to be lower than or similar to a typical catchment. This however does not significantly reduce the overarching uncertainty of actual chemical risk of the source catchments, nor does it negate the need for detailed source characterisation, AWTP demonstration testing, implementation of enhanced source control, or ongoing monitoring of chemical indicators and surrogates.

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[15] The current Australian Drinking Water Guideline (ADWG) limits for PFAS are 1) for PFOS and PFHxS, the limit is a combined total of less than 0.07 µg/L and 2) for PFOA, the limit is less than 0.56 µg/L [26]. Currently, the National Health and Medical Research Council (NHMRC) is conducting an independent review of the ADWG health-based guideline values for PFAS, including examining recent international PFAS guidance and reviews, such as the recommendations from the United States Environmental Protection Agency, to determine if the current NHMRC advice remains appropriate (https://www.nhmrc.gov.au/about-us/news-centre/nhmrc-update-australian-drinking-water-guidelines). On April 10, 2024, EPA announced the final National Primary Drinking Water Regulation for six PFAS compounds: PFOA – 4 mg/L, PFOS – 4 ng/L, PFHxS – 10 ng/L, PFNA – 10 ng/L, HFPO-DA – 10 ng/L, Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS – 1 Hazard Index (https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas)

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APPENDIX A: CHEMICAL RISK ASSESSMENT DATA (REFER TO SPREADSHEET PROVIDED)

APPENDIX B: TRADE WASTE

B. Trade Waste

Trade Waste is received at Lismore City Council and Byron Shire Council plants in the form of permitted network inputs, tankered waste and leachate. Trade Waste data relevant to the STPs in both councils have been analysed and are summarised in Section B.1 and B.2.

B.1 Lismore City Council

Discharges of non-domestic wastewater to Lismore City Council plants primarily come from liquid Trade Waste received via the sewer network at both Lismore South STP and Lismore East STP. Lismore City Council maintains Trade Waste discharge permits for these network inputs, with close to 300 clients in the catchment of both plants.

The dischargers are summarised by business type in Table B-1. Note that Table B-1 shows only dischargers holding permits with non-zero discharge volumes. The values shown in Table B-1 are the volumes permitted to be discharged, not actual volume discharges (as this data was not available). The vast majority of dischargers include restaurants, cafes, supermarkets and other food-related businesses. The second largest group of dischargers includes mechanical repair workshops and service industry.

Table B-1: Summary of Trade Waste Dischargers with Non-Zero Discharge Permits to Lismore City Council STPs

Discharger Type	No. of Permitted Dischargers	Total Volume Permitted (kL/d)
Administration Office	1	1.8
Automotive-related	10	2.5
Club	5	9.7
Food Processing	3	5.5
Food-Related	113	126.8
Function Centre	1	2.0
Government Service	9	5.6
Hotel/Accommodation	7	10.4
Laboratory	2	1.6
Laundry	4	5.2
Mechanical Repair Workshop	52	37.9
Medical	8	17.0
Metal Finishing	2	2.2
Nursing Home	2	4.0
Preschool	1	1.0
Recycling	2	5.2
Retail	6	7.4
School	8	6.0
Service Industry	21	16.2
Service Station	3	2.4
Swimming Pool	2	0.4

Food-related businesses do not generally pose a threat to potable reuse schemes. Businesses of concern would include hospitals and other medical facilities, service industry, auto-related businesses (including mechanical repair), as these Trade Waste customers are more likely to discharge pollutants that are either untransformed across sewage treatment and advanced treatment processes, or impact certain treatment processes negatively. No heavy industry inputs are noted in the discharger data in Table B-1.

If a PRW scheme involving Lismore plants is implemented, additional investigations into the nature of Trade Waste discharges, particularly from medical facilities, service industry and auto-related businesses (including mechanical repair), should be investigated. Additionally, comprehensive contaminant characterisation and monitoring programmes need to be undertaken as part of source characterisation and enhanced source control.

Values in Table B-1 do not include landfill leachate. Lismore City Council holds a licence to discharge leachate to East Lismore STP, after pre-treatment through a vertical flow wetland. However, the licence also allows other disposal options. It is understood that the vertical flow wetland is currently not in operation. However, this leachate is pre-treated via a containerised plant (flocculation, pH adjustment, GAC and algal treatment to reduce PFAS). Lismore City Council have indicated other options to divert/discharge leachate are being considered, but there is no clear plan yet. Volume data has been requested but not received at the time of writing.

B.2 Byron Shire Council

Discharges of non-domestic wastewater to Byron Shire Councils plants come from multiple sources. These sources are:

- Liquid Trade Waste received via sewer network at both Byron STP and Brunswick Valley STP;
- Backwash waste from sand filters at Mullumbimby Water Treatment Plant, delivered to Byron STP by tanker;
- Leachate BSC Resource Recovery Centre, delivered to Byron STP by tanker:
- Tankered liquid waste to Byron STP, categorised into two types:
  - Low-strength commercial; and,
  - Low-strength domestic.

Table B-2 provides a summary of the total volumes of tankered liquid waste and leachate delivered to both Byron STP and Brunswick Valley STP. Note that Brunswick Valley STP does not receive tankered waste or leachate.

Table B-2: Summary of Leachate and Tankered Liquid Waste to Byron STP, Calendar Year 2022.

Discharger	Total Volume Discharged to Byron STP, 2022 Note 1 (kL/year)	Description
Resource Recovery Centre	12,500	Leachate
Mullumbimby Water Treatment Plant	890	Backwash waste from sand filters at the WTP, which are dosed with soda ash and alum.
Low-Strength Domestic Tankered Waste	840	
Low-Strength Commercial Tankered Waste	2,770	

Notes:

1. Data from January 2022 to December 2022. This calendar year is representative of previous years.

Table B-3 summarises liquid Trade Waste discharged to the network to both Byron STP and Brunswick Valley STP, categorised by customer type. Unless otherwise noted in Table B-3, these discharge volumes are estimated based on an assumption of a discharge factor applied to metered potable water consumption, depending on the customer category.

Table B-3: Summary of Trade Waste Dischargers Volumes to Byron STP and Brunswick Valley STP during 2022

Discharger Type	Total Volume Discharged to Byron STP (kL/year)	Total Volume Discharged to Brunswick Valley STP (kL/year)	Total Volume Discharged to Both STPs (kL/year)
Food-related/Hospitality Note 1	6,696	6,126	12,821
Medical	2,546 Note 2	227	2,773
Club	1,602	2,406	4,008
Construction	30	0	30
Mixed Industry	8,909	2,922	11,831
Food Processing	639	947	1,586
Hotel/Accommodation	15,170	2,333	17,502
Laundry	245	0	245
Mechanical/Auto	2,123	624	2,747
Panel Beater	32	0	32
School/Education Facility	5,484 Note 3	52	5,536
Service Station	5,976	230	6,206
Retail	8,641	748	9,388
Total	**58,093**	**16,613**	**74,706**

Notes:

1. Related to restaurants, cafes, takeaways and other hospitality-related businesses.
2. The Byron Bay Hospital (categorised as a "Medical" discharger) uses a magflow meter for more accurate readings of discharge volume. This hospital accounts for greater than 95% of the volume discharged under the "Medical" category.
3. The SAE College (categorised as a "School/Education Facility" discharger), uses a magflow meter for more accurate readings of discharge volume. This facility accounts for roughly half the volume discharged under the "School/Education Facility" category.

As in the case of the Lismore catchments (Section B.1), the majority of network dischargers in the catchment of these two plants include food-related and hospitality businesses. However, there are also network inputs from medical, auto-related and mixed industry dischargers to both plants. Additionally, there are inputs of leachate, WTP waste and commercial waste tankered directly to Byron STP. No heavy industry inputs are noted in the discharger data in Table B-3.

If a PRW scheme involving Byron Shire Council plants is implemented, additional investigations into the nature of these higher-risk discharges, particularly from medical facilities, mixed industry, auto-related businesses (including mechanical repair), leachate and commercial tankered waste, should be investigated. Additionally, comprehensive contaminant characterisation and monitoring programmes need to be undertaken as part of source characterisation and enhanced source control.

APPENDIX C: PROCESS RELATED RISKS

C.1 BROMATE

Bromate is a known carcinogen that is regulated in the USA with an MCL of 10 ug/L. Bromate formation occurs when its precursor, bromide, is oxidized through ozonation of water. Typically, ozonation can lead to bromate generation in matrices containing greater than 20 ug/L of bromide [14]. Given this formation pathway, bromate formation is more of a concern for CBAT trains than RBAT trains. Other factors that have a documented effect on bromate formation include natural organic matter, temperature, pH, and alkalinity [15].

When ozone is added to water, it reacts with compounds present in the water resulting in its decomposition to the hydroxyl radical. These reactions are complex and depend on a variety of factors, with a strong dependence on pH. [16] For the purposes of illustrating bromate formation to allow understanding of potential mitigation strategies discussed below, Figure C-1 provides a simplistic description of the formation pathways for bromate due to ozone addition [17] (a more detailed, but still simplified, diagram of bromate formation mechanism during ozonation of bromide containing waters is provided in reference [16]).

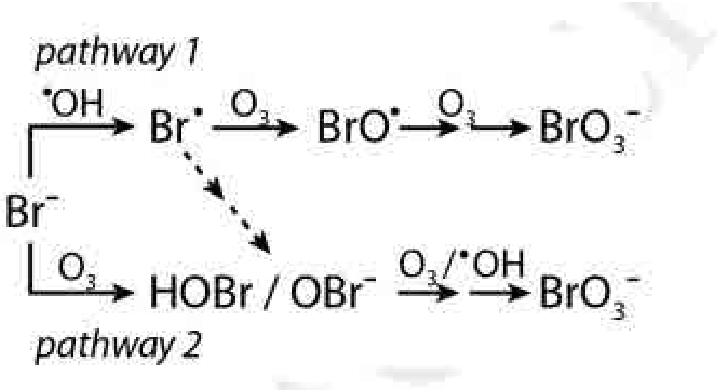


Figure C-1: Simplified Bromate Formation Pathways

During the ozonation process, the ratio of ozone to TOC in the water can be controlled to limit bromate formation. Recommendations for an optimal ozone:TOC ratio vary between 0.6 to 0.9 mg ozone/mg TOC, with evidence of an increase in bromate at a ratio as low as 0.4 mg ozone/mg TOC [14], [18]. However, limiting this ratio as a means of controlling bromate results in a decrease in the C.t.[16], reducing disinfection achieved by ozone following a C.t. concept. Virus and bacteria disinfection have been demonstrated in the absence of C.t., using the ozone:TOC ratio, after accounting for ozone demand from nitrite, to predict virus and bacteria disinfection performance [19]. Other mitigation strategies are described below, each with potential drawbacks [15]:

- Chlorine-ammonia process: Free chlorine is dosed to oxidize bromide to hypobromous acid. The subsequent addition of ammonia prior to ozonation forms bromamines, which sequesters the bromide and prevents it from forming bromate. However, NDMA may be formed with this strategy.
- Hydrogen Peroxide Addition: Hydrogen peroxide can be used to quench hypobromous acid, however in this strategy ozone reacts preferentially with the hydrogen peroxide instead of microorganisms, reducing disinfection efficacy. The effectiveness of hydrogen peroxide addition also depends strongly on the specific wastewater matrix.
- pH Depression: As shown in Figure C-1, the presence of the hydroxyl radical is necessary for the bromate formation pathway from ozone oxidation, so depressing the pH is another mitigation strategy as pH depression lowers the rate of hydroxyl radical production [17]. However, both ozone and the hydroxyl radical are necessary for removal of micropollutants, which is one of the main goals of ozone/BAC.

[16] C.t. = concentration of ozone times contact time

C.2 NDMA/NITROSAMINES

Nitrosamines are carcinogens that occur in raw sewage and certain industrial discharges, with NDMA and NMOR being the most commonly detected nitrosamines in primary effluent [20]. While nitrosamines are not currently regulated in the USA, California has a notification level of 10 ng/L for NDMA. Formation of NDMA is associated with chloramination and ozonation of wastewater, often because of the incomplete removal of nitrogen in upstream wastewater treatment processes.

Chloramination, even at higher doses, does not result in the levels of NDMA formation seen with ozone oxidation [20]. While the specific precursors and reaction pathways may differ with oxidant type, in both cases precursor loadings are largely dominated by domestic sources except for where specific industrial discharges featuring elevated NDMA or NDMA precursor concentrations contribute significantly to the flow to a STP [21].

Strong correlations have been observed between nitrosamine formation and ammonia, natural organic matter content, hydrazine compounds, carbamate compounds, semicarbazide compounds, tertiary and quaternary amines, and formaldehyde. Common sources of N-nitrosamines include beverages, food, consumer products, chlorinated water, and polymers [15].

Cationic treatment polymers (e.g. polyDADMAC and Mannich polymers) feature amine functional groups that can be strong precursors for nitrosamine, and especially NDMA, formation [20]. PolyDADMAC is a commonly used coagulant aid polymer [15]. Mannich polymers are used for sludge management to control foam in the mixed liquor and to enhance settling in the secondary clarifiers [22]. Use of polymers in the source STPs should be investigated to understand the risk of their presence in the secondary effluent and the associated risk of increased NDMA formation potential.

BAC systems have been shown to offset NDMA formation from ozonation by removing 50% to 90% of the NDMA in the feed to the BAC. NDMA removal of 90% has been demonstrated using an empty bed contact time of 10 minutes [18]. However, biofiltration under anaerobic denitrifying conditions forms NDMA [15]. This is a concern because incomplete nitrogen removal can also lead to NDMA formation, especially if chlorine is added to the filter effluent [14]. Dissolved oxygen and ORP could be monitored in the BAC effluent to confirm that aerobic conditions within the biofilter are being maintained and that excessive NDMA formation is unlikely.

Additionally, in a study on a treatment train representative of a typical RBAT train in California, RO membranes averaged an NDMA rejection of 31%. A similar treatment train that was preceded by ozonation only achieved an average RO NDMA rejection of 22%. Removal of NDMA by UV systems varies by treatment train but is consistent with first-order removal [22].

One study found that an RBAT system was more effective for the removal of chloramine-reactive NDMA precursors than a CBAT system, even though the median NDMA concentration measured after ozone/BAC was lower than that for membrane filtration/RO. Overall, these results still suggest that a CBAT system is more efficient than the membrane filtration/RO system for the control of NDMA. However, a CBAT system is far less efficient for the control of NMOR, the second most commonly found nitrosamine, which is poorly removed by BAC [21].

C.3 THMS AND HAAS

THMs and HAAs are both known carcinogens regulated in the USA by MCLs. Total THMs in finished drinking water must adhere to an MCL of 0.08 mg/L and HAA5 (the sum of the five regulated HAAs) must adhere to an MCL of 0.06 mg/L.

Chlorinated and brominated analogues of THMs and HAAs are primarily associated with chlorine disinfection. Predominant precursors are believed to be phenolic moieties of humic substances present as part of the dissolved organic carbon of a water. Formation frequently correlates with UV 254 because phenols absorb light strongly at this wavelength. While chloramines also generate THMs and HAAs, the generation rate is far lower because chloramines are weaker oxidants. However, iodinated THMs and HAAs formation is typically greater with chloramination [20].

Effluent TOC levels from BAC systems are higher than permeate TOC levels from RO systems. One study reports BAC effluent TOC levels as being on average 17 times greater than RO permeate TOC levels, calculated using samples ranging from 2.0-5.0 mg/L TOC in BAC effluent and 0.1-0.8 mg/L TOC in RO permeate [14]. This results in a substantial difference in precursors to form THMs. The average THM formation potential in a BAC system has been documented as 281 ug/L, compared to an average THM formation potential in an RO system of 8.7 ug/L [13]. Formation potential test results exceeding a limit do not imply that the limit will be exceeded, as the test is designed to maximize conversion of all possible THM precursors.

The average HAA is also higher for the BAC system (137.2 ug/L) than the RO system (3.7 ug/L). The difference in HAA formation potentials is likely similarly related to RO's higher removal of TOC. However, use of upstream disinfection to minimize biological growth in RO systems can lead to higher THM and HAA concentrations in the RO permeate compared to BAC effluent [13].

To better control THMs and HAAs in CBAT systems, TOC controls such as an enhanced coagulation/flocculation/sedimentation (or filtration) step upstream of the ozone/BAC system may help if THM of HAA formation is an issue. In addition to upstream TOC removal, UV/AOP systems have been documented as a potential mitigation step for THM and HAA. For UV doses of less than 500 mJ/cm^2, UV/hydrogen peroxide advanced oxidation did not significantly affect THM and HAA formation in subsequent chlorination processes. However, higher UV doses (>1,000 mJ/cm^2), which are more typical of AOP in potable reuse, resulted in approximately 50% lower concentrations of THMs and HAAs [23].

C.4 ADDITIONAL CHEMICAL RISKS

Cyanide, which can lead to nerve damage or thyroid problems, has an MCL of 0.2 mg/L. Cyanide has been cited as an additional concern due to its detection above the MCL in pilot experiments after chlorine disinfection, despite not being detected in the pilot influent. In past reports, the presence of cyanide was attributed to the reaction of chlorine with nitrate or nitrite. In the presence of chlorine, nitrate and nitrite can be converted to nitric and nitrous acid, which can subsequently react with organic compounds to form intermediate oximes, nitro-alkenes, and hydroxamic acids. These compounds can break down to produce cyanide [15]. The removal of nitrate and nitrite upstream of chlorine disinfection can help mitigate this risk.

Aldehydes can form during ozonation or chlorination, although ozonation produces significantly larger concentrations of aldehydes than chlorination [20]. UV/hydrogen peroxide oxidation can result in the formation of aldehydes and carboxylic acids at UV doses above 500 mJ/cm^2 [23]. Aldehydes are known to adversely affect drinking water stability, although no mitigation strategies are presented in the literature reviewed. Monitoring of formaldehyde is recommended across ozone/BAC to confirm that 1) low molecular weight neutral compounds are managed and 2) that formaldehyde is not generated to an excessive level by ozonation.

APPENDIX C: PROCESS SCHEDULE

Process Schedule for Major Unit Processes for Each Short-Listed Scheme

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Raw Water Balance Tank						
STP Feed (prior to recycle)	ML/d	9.1	9.1	5.4	8.35	
Flow to Raw Water Balance Tank (including Recycles)	ML/d	10.7	10.7	6.4	9.3	
Raw Water Balance Tank Residence Time	h	4	4	4	4	
Raw Water Balance Tank Working Volume	ML	1.8	1.8	1.1	1.6	Size will need to be confirmed based on analysis of STP diurnal flow patterns
Tank Top Water Level	m	5.5	5.5	5.5	5.5	
Tank Bottom Water Level	m	0.5	0.5	0.5	0.5	For pump power estimate assumes site is flat and this is the RL above finish grade
Tank Freeboard	m	0.5	0.5	0.5	0.5	
Tank Height (including freeboard and dead volume)	m	6.0	6.0	6.0	6.0	
Mixing energy	w/m³	5.0	5.0	5.0	5.0	
Mixer power	kW	9.0	9.0	5.4	7.8	
Number of mixers		2	2	2	2	
Mixer size	kW	5.5	5.5	3.0	4.0	
Ozone Contactor Feed Pump						
Static Head	m	3.3	3.3	3.3	N/A	
TDH	m	4.0	4.0	4.0		Assumes 20% increase on static head
Pump Power	kW	4.8	4.8	2.9		
Pump Efficiency		70%	70%	70%		
Motor Power	kW	6.9	6.9	4.1		
Motor Size	kW	7.5	7.5	5.5		
Number of Pumps		2	2	2		
Ozone Contactor						
HRT	min	5	5	5		
Baffling Factor		0.5	0.5	0.5		
Volume	kL	74.6	74.6	44.8		
Water Depth	m	2	2	2		
Top Water Level	m	3.8	3.8	3.8		Assumes gravity flow from contactor through downstream flocculation tank (i.e. contactor is elevated to allow gravity flow), then pumped flow through BAC and GAC to UF Feed Tank. One meter conservatively added to account for other losses.
Ozone System						
Control Basis		Ozone:TOC	Ozone:TOC	Ozone:TOC	N/A	
TOC	mg/L	8.3	8.3	8.3		
Ozone:TOC for Ozone Generator Sizing		1.25	1.25	1.25		
Ozone Dose	mg/L	10.4	10.4	10.4		
Virus LRV Claimed for Ozone		4	4	4		
Cryptosporidium LRV Claimed for Ozone		0	0	0		
Bacteria LRV Claimed for Ozone		4	4	4		
Ozone Generator Capacity Required	kg/h	3.7	3.7	2.2		
Number of Ozone Generators		2	2	2		

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Ozone Generator Redundancy		N + 1	N + 1	N + 1		
Ozone Generator Power	kW	41	41	25.8		Based on advice from vendor
Ozone Generator Cooling Water	kL/h	6.7	6.7	3.3		Based on advice from vendor
Cooling Water Pump TDH (assumed)	m	5	5	5		
Cooling Water Pump Power	kW	0.1	0.1	0.04		
Cooling Water Pump Efficiency		70%	70%	70%		
Cooling Water Pump Motor Power	kW	0.1	0.1	0.1		
Cooling Water Pump Motor Size	kW	0.55	0.55	0.55		
Number of Cooling Water Pumps		2	2	2		
Cooling Water Pump Redundancy		N + 1	N + 1	N + 1		
Ozone Contactor HRT	min	5	5	5		
Ozone Contactor Baffling Factor		0.5	0.5	0.5		
Ozone Contactor Volume	kL	74.6	74.6	44.8		
Ozone Contactor Headspace Volume	kL	18.5	18.5	11.2		
Ozone Contactor Air Changes	#/h	20	20	20		
Ozone Contactor Ventilation Rate	m^3/h	369	369	224		
Ozone Destruction Unit Power	kW	5.1	5.1	3.8		Based on advice from vendor
Number of Ozone Destruction Units		2	2	2		
Ozone Destruction Unit Redundancy		N + 1	N + 1	N + 1		
Ozone Sidestream Flow	ML/d	1.6	1.6	1.0		Assumed to be 15% of total feed flow to ozone contactor
Ozone Sidestream Operating Pressure	kPa	240	240	240		35 psi assumed
Ozone Sidestream Pump Power	kW	4.4	4.4	2.6		
Ozone Sidestream Pump Efficiency		70%	70%	70%		
Ozone Sidestream Pump Motor Power	kW	6.3	6.3	3.8		
Ozone Sidestream Pump Motor Size	kW	7.5	7.5	4.0		
Number of Ozone Sidestream Pumps		2	2	2		
Ozone Sidestream Pump Redundancy		N + 1	N + 1	N + 1		
Flash Mix Tank						
Hydraulic Residence Time	min	0.5	0.5	0.5	N/A	
G Value	sec^{-1}	500	500	500		
Mixing Energy Required	kW	0.9	0.9	0.6		
Mixer Motor size	kW	1.5	1.5	1.1		
Number of Mixers		1	1	1		
Mixer Redundancy		N	N	N		
Tank Volume	kL	3.7	3.7	2.2		
Water Depth	m	2.0	2.0	2.0		
Flocculation Tank						
Hydraulic Residence Time	min	20	20	20	N/A	
Type		Baffled tank	Baffled tank	Baffled tank		
Flocculation Tank volume	kL	149	149	90		

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Number of Stages	m	3	3	3		
Stage 1 G Value	sec^{-1}	70	70	70		
Stage 1 Headloss	m	0.60	0.60	0.60		
Stage 2 G Value	sec^{-1}	35	35	35		
Stage 2 Headloss	m	0.15	0.15	0.15		
Stage 3 G Value	sec^{-1}	20	20	20		
Stage 3 Headloss	m	0.05	0.05	0.05		
Total Headloss	m	0.80	0.80	0.80		
Water Depth at Tail end	m	2	2	2		
Water Depth at Head End	m	2.80	2.80	2.80		
Overall Flocculation Tank Height	m	3.30	3.30	3.30		
BAC Feed Pumps						
Feed Flow	ML/d	10.74	10.74	6.45	N/A	
Static Head	m	2.5	2.5	2.5		
TDH	m	4.5	4.5	4.5		
BAC Feed Pump Power	kW	5.5	5.5	3.3		
BAC Feed Pump Efficiency		70%	70%	70%		
BAC Feed Pump Motor Power	kW	7.8	7.8	4.7		
BAC Feed Pump Motor Size	kW	11	11	5.5		
Number of BAC Feed Pumps		2	2	2		
BAC Feed Pump Redundancy		N + 1	N + 1	N + 1		
BAC System						
Virus LRV Claimed for BAC		1	1	1	N/A	
Cryptosporidium LRV Claimed for BAC		2	2	2		
Bacteria LRV Claimed for BAC		1	1	1		
Number of BAC Filters		6	6	5		
BAC Filter Bed Depth	m	1.8	1.8	1.8		
BAC Filter Diameter	m	3.5	3.5	3		
EBCT Design Basis	min	15	15	15		
Hydraulic Loading Rate Design Basis	m/h	10	10	10		
EBCT Provided	min	14.2	14.2	14.4		
Hydraulic Loading Rate Provided	m/h	7.8	7.8	7.6		
Differential Pressure Prior to Backwash	m	0.5	0.5	0.5		
Backwash Rate	m/h	50	50	50		
Backwash Flow	m^3/h	481	481	353		
Backwash Pump TDH	m	10	10	10		
Backwash Pump Power	kW	13.1	13.1	9.6		
Backwash Pump Efficiency		70%	70%	70%		
Backwash Pump Motor Power	kW	18.7	18.7	13.8		
Backwash Pump Motor Size	kW	22	22	15		

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Number of Backwash Pumps		2	2	2		
Backwash Pump Redundancy		N + 1	N + 1	N + 1		
Air Scour Flow Rate	Nm³/h-m²	85	85	85		
Air Flow Rate	Nm³/h	820	820	600		
Air Scour Pressure	kPa	70	70	70		10 psi assumed
Blower Power	kW	15.9	15.9	11.7		
Blower Motor Size	kW	18.5	18.5	15.0		
Number of Air Scour Blowers		2	2	2		
Air Scour Blower Redundancy		N + 1	N + 1	N + 1		
GAC System						
Virus LRV Claimed for GAC		0	0	0		
Cryptosporidium LRV Claimed for GAC		0.5	0.5	0.5		
Bacteria LRV Claimed for GAC		0	0	0		
Number of Filters		5	5	4		
Filter Redundancy		N	N	N		
Filter Bed Depth	m	1.8	1.8	1.8		
Filter Diameter	m	3.5	3.5	3		
Hydraulic Loading Rate Design Basis	m/h	10	10	10		
Hydraulic Loading Rate Provided	m/h	9.3	9.3	9.5		
Differential Pressure	m	0.5	0.5	0.5		
Backwash Rate	m/h	50	50	50	N/A	
Backwash Flow	m3/h	481	481	353		
Backwash Pump TDH	m	10	10	10		
Pump Power	kW	13.1	13.1	9.6		
Pump Efficiency		70%	70%	70%		
Motor Power	kW	18.7	18.7	13.8		
Backwash Pump Motor Size	kW	22	22	15		
Number of Backwash Pumps		2	2	2		
Backwash Pump Redundancy		N + 1	N + 1	N + 1		
UF System						
UF Feed Tank Residence Time	h	0.5	0.5	0.5		
UF Feed Tank Working Volume	kL	224	224	134		
Tank Top Water Level	m	4.5	4.5	4.5	N/A	
Tank Bottom Water Level	m	0.5	0.5	0.5		
Tank Freeboard	m	0.5	0.5	0.5		
Tank Height (including freeboard and dead volume)	m	5.0	5.0	5.0		
Virus LRV Claimed for UF		0	0	0	0	
Cryptosporidium LRV Claimed for UF		4	4	4	4	
Bacteria LRV Claimed for UF		4	4	4	4	
UF System Maximum Instantaneous Flux	LMH	70	70	70	50	

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
UF System Recovery		95%	95%	95%	92%	As advised by vendor
Number of UF Units		3	3	3	3	As advised by vendor
UF Unit Redundancy		N + 1	N + 1	N + 1	N + 1	
UF Backwash Supply Tank Working Volume	kL	224	224	134	194	
RO System						
RO Feed Tank Residence Time	h	N/A			0.5	
RO Feed Tank Working Volume	kL				175	
Virus LRV Claimed for RO					1.5	
Cryptosporidium LRV Claimed for RO					1.5	
Bacteria LRV Claimed for RO					1.5	
RO System Maximum Lead Element Flux	LMH				20	
RO System Recovery					80%	
Number of RO Stages					2	
Number of RO Units					3	As advised by vendor
RO Unit Redundancy					N + 1	
RO Flush Tank Working Volume	kL				175	
Primary UV						
UV Dose	mJ/cm^2	186	186	186	N/A	
Virus LRV Claimed for UV		4	4	4		
Cryptosporidium LRV Claimed for UV		4	4	4		
Bacteria LRV Claimed for UV		4	4	4		
Minimum UV Transmittance		80%	80%	80%		
UV Unit Redundancy		N + 1	N + 1	N + 1		
UV-AOP System						
UV Dose	mJ/cm^2	N/A			> 500	
Virus LRV Claimed for UV-AOP					4	
Cryptosporidium LRV Claimed for UV-AOP					4	
Bacteria LRV Claimed for UV-AOP					4	
Minimum UV Transmittance					95%	
Oxidant Dose	mg/L free chlorine				4	
UV Unit Redundancy					N + 1	
Secondary UV Unit						
UV Dose	mJ/cm^2	N/A		186	186	Secondary UV not included in Lismore IPR via surface water augmentation or Lismore DPR via raw water augmentation base case. Included in Lismore DPR via treated water augmentation for sensitivity case only.
Virus LRV Claimed for UV				4	4	Claimed to address sensitivity/"excess LRV"
Cryptosporidium LRV Claimed for UV				4	4	Claimed to address sensitivity/"excess LRV"
Bacteria LRV Claimed for UV				4	4	Claimed to address sensitivity/"excess LRV"
Minimum UV Transmittance				80%	95%	
UV Unit Redundancy				N + 1	N + 1	
Chlorine Contact Tank						

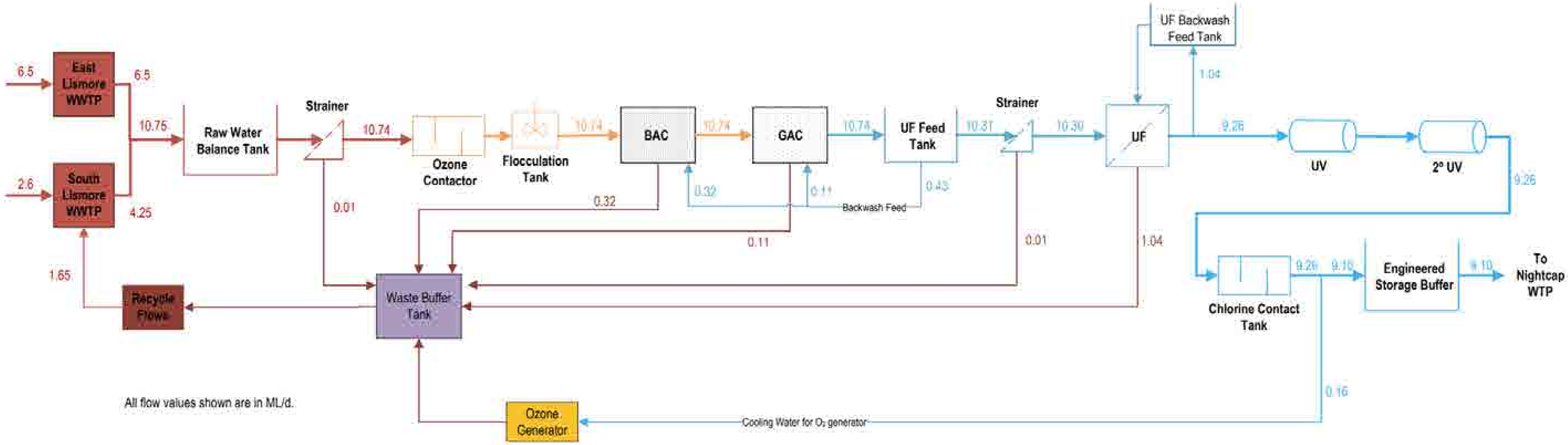
Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Ct	mg-min/L	4	4	4	4	
Virus LRV Claimed for Chlorine		4	4	4	4	
Cryptosporidium LRV Claimed for Chlorine		0	0	0	0	
Bacteria LRV Claimed for Chlorine		4	4	4	4	
Chlorine Residual	mg/L as Cl_2	0.5	0.5	0.5	0.5	
Required Contact Time		8	8	8	8	
Baffle Factor		0.7	0.7	0.7	0.7	
Hydraulic Residence Time	min	15	15	15	15	
Chlorine Contact Tank Volume	kL	97	97	58	70	
Calcite Filters						
Calcite Filter Feed Pump Static Head	m	N/A	N/A	N/A	5.5	
Calcite Filter Feed Pump TDH	m	N/A	N/A	N/A	6.6	
Calcite Filter Feed Pump Power	kW	N/A	N/A	N/A	5.0	
Calcite Filter Feed Pump Efficiency		N/A	N/A	N/A	70%	
Calcite Filter Feed Pump Motor Power	kW	N/A	N/A	N/A	7.2	
Calcite Filter Feed Pump Motor Size	kW	N/A	N/A	N/A	7.5	
Number of Calcite Filter Feed Pump Pumps		N/A	N/A	N/A	2	
Calcite Filter Feed Pump Redundancy		N/A	N/A	N/A	N + 1	
Number of Filters		N/A	N/A	N/A	4	
Filter Bed Depth	m	N/A	N/A	N/A	1.2	
Filter Diameter	m	N/A	N/A	N/A	3.5	
EBCT Design Basis	min	N/A	N/A	N/A	10	
Hydraulic Loading Rate Design Basis	m/h	N/A	N/A	N/A	7.5	
EBCT Provided	min	N/A	N/A	N/A	10	
Hydraulic Loading Rate Provided	m/h	N/A	N/A	N/A	7.3	
Differential Pressure Prior to Backwash	m	N/A	N/A	N/A	0.5	
Backwash Rate	m/h	N/A	N/A	N/A	29.3	
Backwash Flow	m^3/h	N/A	N/A	N/A	282	
Backwash Pump TDH	m	N/A	N/A	N/A	10	
Backwash Pump Power	kW	N/A	N/A	N/A	7.7	
Backwash Pump Efficiency		N/A	N/A	N/A	70%	
Backwash Pump Motor Power	kW	N/A	N/A	N/A	11.0	
Backwash Pump Motor Size	kW	N/A	N/A	N/A	11	
Number of Backwash Pumps		N/A	N/A	N/A	2	
Backwash Pump Redundancy		N/A	N/A	N/A	N + 1	
Engineered Storage Buffer Tank/Treated Water Tank						
Tank Residence Time	min	30	30	30	30	Lismore IPR does not include an engineered storage buffer tank system (i.e. two tanks with diversions), but a treated water tank is provided prior to PRW flowing directly to the Engineered Environmental Buffer Storage)
Tank Working Volume	kL	190	190	113	140	
Tank Top Water Level		5.5	5.5	5.5	5.5	

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Tank Bottom Water Level		0.5	0.5	0.5	0.5	
Tank Freeboard		0.5	0.5	0.5	0.5	
Tank Height (including freeboard and dead volume)		6	6	6	6	
Number of Tanks		1	2	2	2	
Waste Buffer Tank						
Sizing Basis		0.5 h storage of peak flow through process (including recycles)				
Waste Buffer Tank Volume	kL	224	224	134	195	
Waste Buffer Tank Pump Flow	m3/h	110	110	65	95	To empty tank contents in 2 hours
Waste Buffer Tank Pump TDH	m	12	12	10.3	40.3	As per transfer infrastructure calculations
Number of duty pumps		1	1	1	1	
Pump Redundancy		N + 1	N + 1	N + 1	N + 1	
Pump Power	kW	3.6	3.6	1.8	10.4	
Pump Efficiency		70%	70%	70%	70%	
Motor Power	kW	5.1	5.1	2.6	14.9	
Motor size	kW	5.5	5.5	5.5	15	
Neutralisation Tank						
Tank Volume	m^3	40	40	40	40	Pro-rata based on previous project
Mixing type		Eductor/jet mixer	Eductor/jet mixer	Eductor/jet mixer	Eductor/jet mixer	
Pump Motor Size	kW	15	15	15	15	Pro-rata based on previous project
Pump Redundancy		N + 1	N + 1	N + 1	N + 1	
RO Concentrate Treatment						
Nitrification MBBR						
RO Concentrate Ammonia	mg/L as N	N/A			3.3	
Effluent Ammonia	mg/L as N				0.1	
MBBR Volume	kL				80	
Carrier Fill					60%	
Carrier Specific Surface Area	m^2/m^3				500	
Hydraulic Residence Time	min				70	
Approximate Airflow Required	Nm^3/h				200	
Denitrification MBBR						
Denitrification MBBR Feed Nitrate	mg/L as N	N/A			4.2	
Denitrification MBBR Effluent Nitrate	mg/L as N				0.1	
Denitrification MBBR Volume	kL				120	
Denitrification MBBR Carrier Fill					30%	
Carrier Specific Surface Area	m^2/m^3				500	
Denitrification MBBR Hydraulic Residence Time	min				105	
Lamella Clarifier						
Lamella Clarifier Feed Total Phosphorus		N/A			0.5	
Lamella Clarifier Effluent Total Phosphorus					0.1	
Lamella Feed Total Suspended Solids (including solids from coagulant)	mg/L				33	

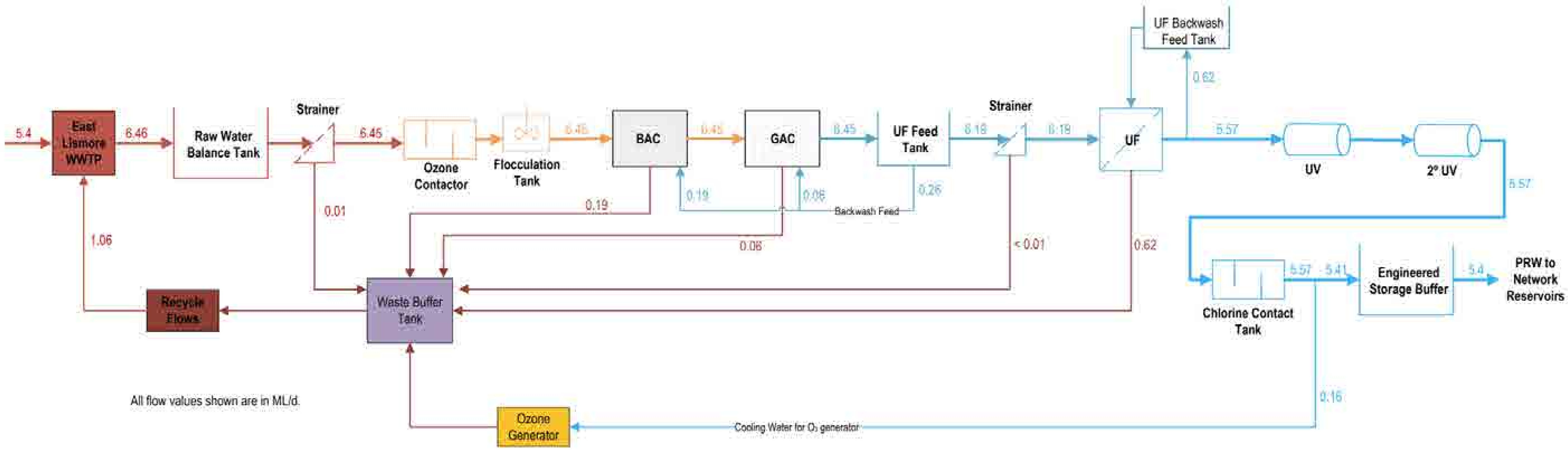
Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Solids Load	kg/d				56	
Number of Lamella Clarifiers					2	
Lamella Clarifier Redundancy					N	
Number of Inclined Plates per Clarifier					60	
Projected Settling Area	m^2				52	
Hydraulic Loading Rate	m/h				0.7	
Solids Loading Rate	kg/m^2-h				0.02	
Chemicals						
Sodium Hypochlorite						
Upstream Dose (pre UF)	mg/L as Cl_2	2	2	2	2	
AOP Dose	mg/L as Cl_2	N/A			8.6	Dose includes allowance of 7.6 times ammonia in permeate (from chloramine) to account for breakpoint plus free chlorine residual of 4 mg/L as Cl_2 upstream of AOP
Chlorine Contact Tank Dose	mg/L as Cl_2	2	2	2	1	
Solution Strength		10%	10%	10%	10%	
Specific Gravity		1.14	1.14	1.14	1.14	
Available Chlorine		95%	95%	95%	95%	
Storage Time	d	14	14	14	14	
Mass Rate	kg Cl_2/d	39.1	39.1	23.5	83.3	
Volumetric Flow Rate	L solution/d	361	361	217	769	
Storage Volume Required	kL	5.1	5.1	3.0	10.8	Storage volumes to be rounded up to account for UF maintenance clean/CIP
Ammonia (Chloramine Dosing)						
NH_3-N:Cl_2 weight ratio		N/A			4 to 1	
Ammonia Dose	mg/L as NH_3				0.6	
Liquid Ammonium Sulphate Solution Strength					40%	
Percent Ammonia in Liquid Ammonium Sulphate Solution					11%	
Liquid Ammonium Sulphate Specific Gravity					1.23	
Storage Time	d				14	
Mass Rate	kg NH_3/d				5.7	
Volumetric Flow Rate	L solution/d				40	
Storage Volume Required	L				564	
Antiscalant						
Dose	mg/L	N/A			3	Dose based on advice of supplier
Solution Strength					100%	
Specific Gravity					1.21	
Storage Time	d				14	
Mass Rate	kg/d				25.2	
Volumetric Flow Rate	L solution/d				20.8	
Storage Volume	L				292	
Sulphuric Acid (pre-RO pH adjustment, UF/RO CIP, neutralisation)						
Dose	mg/L	–	–	–	20	Based on Toray projection software

Parameter	Units	Lismore IPR	Lismore DPR-RWA	Lismore DPR-TWA	Byron DPR-TWA	Comments
Solution Strength		–	–	–	98%	
Specific Gravity		–	–	–	1.85	
Storage Time	d	–	–	–	14	
Mass Rate	kg/d	–	–	–	168	
Volumetric Flow Rate	L solution/d	–	–	–	92.6	
Storage Volume	L	1,000 (assume IBC for UF cleans and neutralisation)	1,000 (assume IBC for UF cleans and neutralisation)	1,000 (assume IBC for UF cleans and neutralisation)	1,297	Round up Byron volume to account for UF/RO cleans and neutralisation
Sodium Bisulphite (dechlorination of RO concentrate, neutralisation of UF chlorine cleans)						
Dose	mg/L	–	–	–	3	1.5 times chlorine in RO concentrate
Solution Strength		–	–	–	33%	
Specific Gravity		–	–	–	1.17	
Storage Time	d	–	–	–	14	
Mass Rate	kg/d	–	–	–	5.0	
Volumetric Flow Rate	L solution/d	–	–	–	13	
Storage Volume	L	1,000 (assume IBC for neutralisation)	1,000 (assume IBC for neutralisation)	1,000 (assume IBC for neutralisation)	183	
Citric Acid (UF/RO CIP)						
Storage Volume	L	1,000	1,000	1,000	1,000	Assume IBC
Sodium Hydroxide (UF/RO CIP, neutralisation)						
Storage Volume	L	1,000	1,000	1,000	1,000	Assume IBC
Coagulant (assume ACH – upstream of BAC, feed to RO concentrate Lamella clarifiers)						
Dose	mg/L as $Al_2(OH)_5Cl$	2.6	2.6	2.6	5	
Solution Strength		40.2%	40.2%	40.2%	40.2%	
Specific Gravity		1.34	1.34	1.34	1.34	
Storage Time	d	14	14	14	14	
Mass Rate	kg/d	27.9	27.9	16.8	8.4	
Volumetric Flow Rate	L solution/d	52	52	31	16	
Storage Volume	L	726	726	436	218	
Polyelectrolyte (upstream of BAC, feed to RO concentrate Lamella clarifiers)						
Dose	mg/L active product	0.5	0.5	0.5	1	
Solution Strength	% active product	50	50	50	50	
Specific Gravity		1.05	1.05	1.05	1.05	
Storage Time	d	14	14	14	14	
Mass Rate	kg/d	5.4	5.4	3.2	1.7	
Volumetric Flow Rate	L solution/d	10.2	10.2	6.1	3.2	
Storage Volume	L	143	143	86	45	

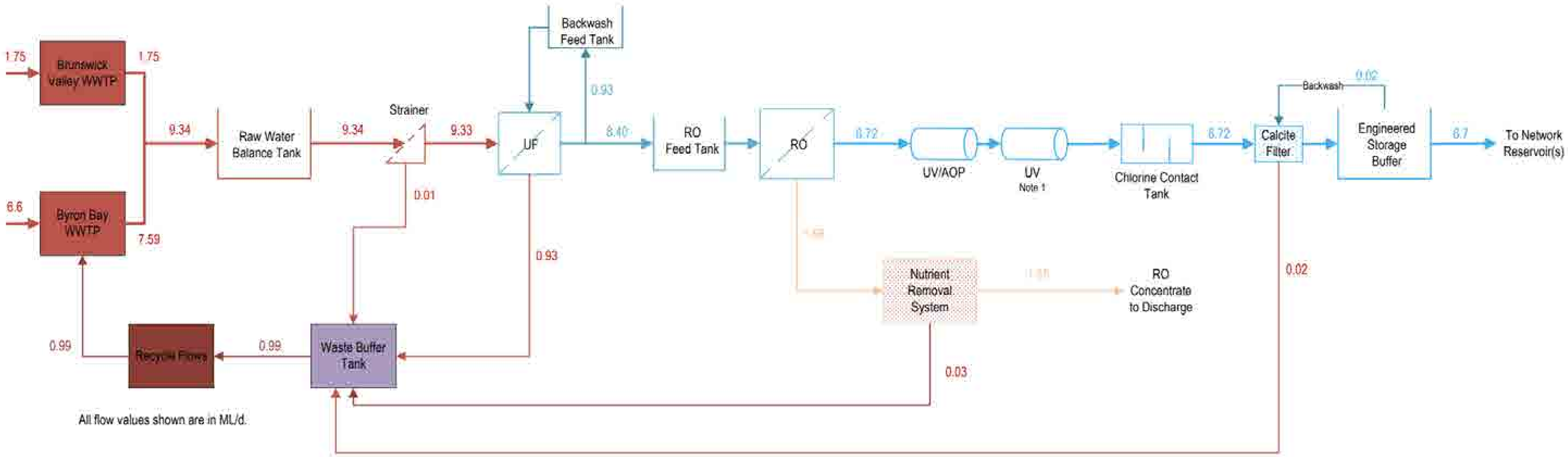
APPENDIX D: FLOW BALANCES



Lismore DPR via Raw Water Augmentation Flow Balance (flow balance also applies to Lismore IPR scheme)



Lismore DPR via Treated Water Augmentation Flow Balance



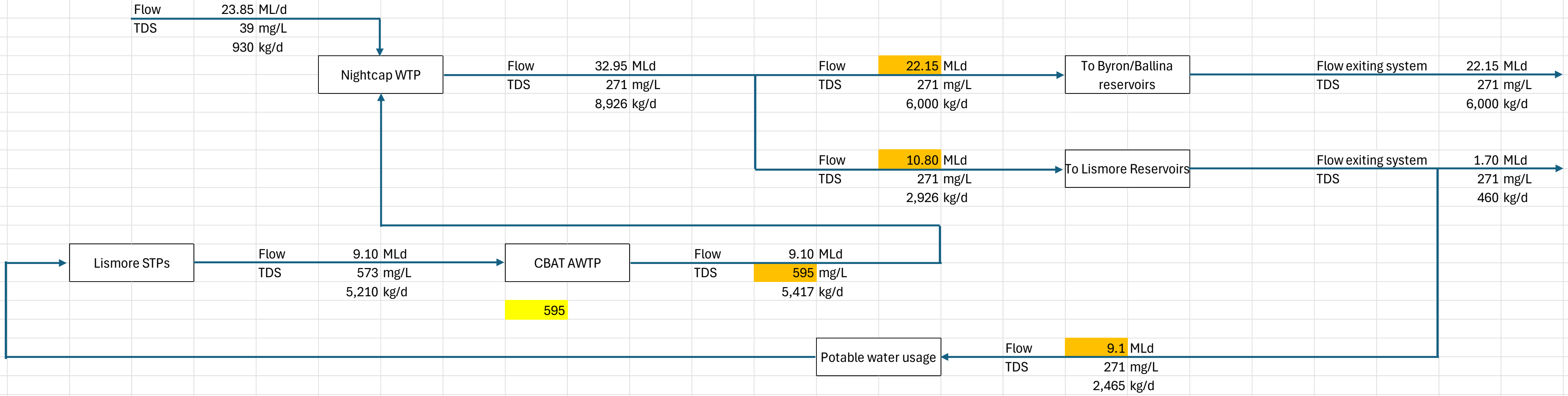
Byron DPR via Treated Water Augmentation Flow Balance

APPENDIX E: TDS MASS BALANCES

Lismore IPR via Surface Water Augmentation and Lismore DPR via Raw Water Augmentation TDS Mass Balance

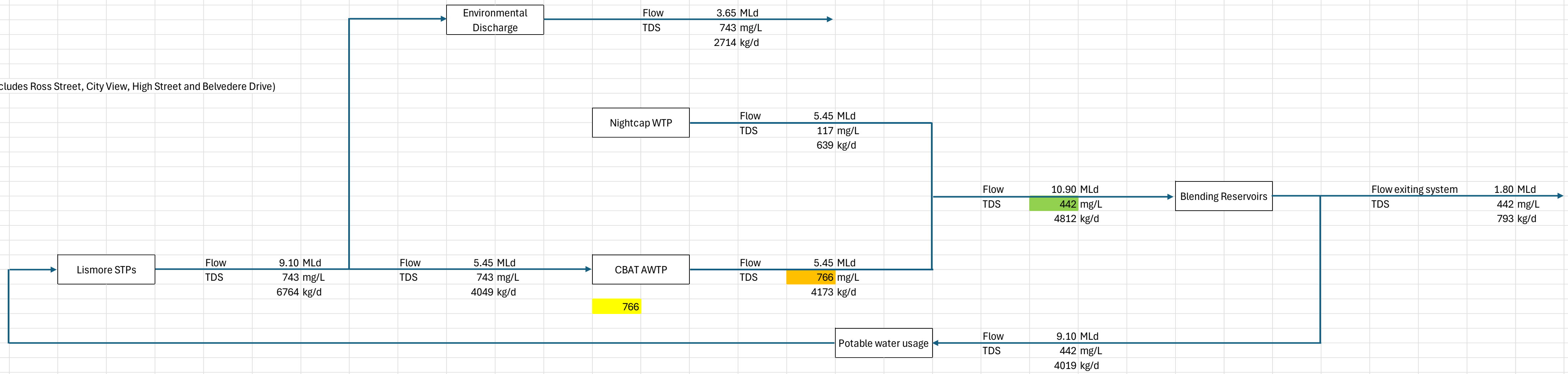
Average Rocky Creek Dam TDS	39	mg/L
Average Nightcap WTP Treated Water TDS	117	mg/L
TDS added through Nightcap process	78	mg/L
Average Lismore STP TDS	419	mg/L
TDS added through water usage and STP	302	mg/L
2040 Average Daily Potable Water Demand	32.95	ML/d
TDS added through AWTP process	23	mg/L
Mass in =	6461	
Mass out =	6461	
TDS increase in potable water	154	mg/L

(acutal TDS increase will likely be somewhat less than this as hardness retained in the PRW would likely reduce the lime dose required at Nightcap WTP)



Lismore DPR via Treated Water Augmentation TDS Mass Balance

Average Nightcap WTP Treated Water TDS	117	mg/L
Average Lismore STP TDS	419	mg/L
TDS added through water usage and STP	302	mg/L
Lismore 2040 Average Daily Potable Water Demand	10.90	ML/d (includes Ross Street, City View, High Street and Belvedere Drive)
Blend ratio	50%	
South Lismore 2040 ADWF	2.6	ML/d
East Lismore 2040 ADWF	6.5	ML/d
Total 2040 ADWF	9.1	ML/d
TDS added through AWTP process	23	mg/L
Mass in =	3508	
Mass out =	3508	
TDS increase in potable water	324	mg/L



APPENDIX F: LAYOUT SKETCHES

TYR GROUP

RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS

OPTIONS ASSESSMENT OF INDIRECT AND DIRECT POTABLE REUSE SCHEMES

DRAWING REGISTER		
DRAWING NUMBER	DRAWING TITLE	DRAWING REVISION
SK0001	COVER PAGE	B
SK0010	EXISTING WATER SUPPLY NETWORK	B
SK0011	EXISTING WATER SUPPLY NETWORK	B
SK0012	EXISTING WATER SUPPLY NETWORK	B
SK0013	EXISTING WATER SUPPLY NETWORK	B
SK0014	EXISTING WATER SUPPLY NETWORK	B
SK0050	BYRON DPR SOURCE WATER AND PRW MAIN ALIGNMENTS	B
SK0051	BYRON DPR SOURCE WATER, PRW, RO CONCENTRATE AND RETURN MAIN	B
SK0052	BYRON DPR POWER SUPPLY AND RO CONCENTRATE DISHARGE	B
SK0101	LISMORE IPR VIA SURFACE WATER AUGMENTATION WATER AND PRW	F
SK0102	LISMORE DPR VIA RAW WATER AUGMENTATION WATER & PRW MAIN	D
SK0103	LISMORE DPR VIA TREATED WATER AUGMENTATION WATER, PRW & RETURN	E
SK0200	BYRON AWTP & PRW RESERVOIR SITE PLAN	B
SK0201	BYRON AWTP PLANT LAYOUT	A
SK0300	SOUTH LISMORE AWTP SITE PLAN	B
SK0301	SOUTH LISMORE AWTP PLANT LAYOUT	A
SK0400	EAST LISMORE AWTP & PRW RESERVOIR SITE PLAN	B
SK0401	EAST LISMORE AWTP PLANT LAYOUT	A

PLANIT CONSULTING

TYR GROUP

ROUS COUNTY COUNCIL

BULK WATER SUPPLY | WEED BIOSECURITY | FLOOD MITIGATION

IMAGE SOURCE: NEARMAPS

LOCALITY PLAN
NOT TO SCALE

NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW
B	FOR INFORMATION	16/04/24	DM	RW	RW	RW

SCALES:
NOT TO SCALE
DO NOT SCALE FROM DRAWING

APPROVED BY:

DATE:

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EMAIL: administration@planitconsulting.com.au

CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
COVER PAGE

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0001	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0001 COVER.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:10:52 PM

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	09/06/23	DM	DM	SM	SM
B	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES: 0 1000 2000 4000 6000
Full Size 1:100 000 ; Half Size 1:200 000
Scale (m)

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CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
EXISTING WATER SUPPLY NETWORK
SHEET 1 OF 5

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0010	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0010 - SK0014.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:12:41 PM

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B	FOR INFORMATION	28/03/24	DM	RW	RW	RW

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Full Size 1:50000 ; Half Size 1:100000
Scale (m)
DO NOT SCALE FROM DRAWING

APPROVED BY:

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CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
EXISTING WATER SUPPLY NETWORK
SHEET 2 OF 5

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0011	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0010 - SK0014.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:13:13 PM

NOT FOR CONSTRUCTION

LEGEND

TREATMENT AND TRANSFER INFRASTRUCTURE

- WATER TREATMENT PLANTS
- SEWAGE/ WASTEWATER TREATMENT PLANTS
- GROUNDWATER AREAS

RESERVOIRS

- RCC
- CONSTIUENT COUNCIL

ROUS CONSTITUENT LGA BOUNDARIES

- BALLINA
- BYRON
- LISMORE
- RICHMOND VALLEY

WATER MAINS (mm)

- RETICULATION <DN250
- TRUNK DN250-DN500
- TRUNK >DN500
- RECYCLED WATER

PUMP STATIONS

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	09/06/23	DM	DM	SM	SM
B	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES:
0 500 1000 2000 3000
Full Size 1:50000 ; Half Size 1:100000
Scale (m)

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DATE:

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CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
EXISTING WATER SUPPLY NETWORK
SHEET 3 OF 5

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0012	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0010 - SK0014.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:13:31 PM

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A	PRELIMINARY ISSUE	09/06/23	DM	DM	SM	SM
B	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES: 0 500 1000 2000 3000
Full Size 1:50000 ; Half Size 1:100000
Scale (m)

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DATE:

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CLIENT:
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ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
EXISTING WATER SUPPLY NETWORK
SHEET 4 OF 5

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0013	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0010 - SK0014.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:12:12 PM

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A	PRELIMINARY ISSUE	09/06/23	DM	DM	SM	SM
B	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES: 0 500 1000 2000 3000
Full Size 1:50000 ; Half Size 1:100000
Scale (m)
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DATE:

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PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
EXISTING WATER SUPPLY NETWORK
SHEET 5 OF 5

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0014	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0010 - SK0014.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:14:08 PM

100mm AT ORIGINAL SIZE

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
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B	FOR INFORMATION	16/04/24	DM	RW	RW	RW

SCALES: 0 500 1000 2000 3000
Full Size 1:50000 ; Half Size 1:100000
Scale (m)

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PLANIT

CLIENT:
TYR GROUP PTY LTD

TYR GROUP

ROUS COUNTY COUNCIL

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
BYRON DPR VIA TREATED WATER AUGMENTATION SOURCE WATER AND PRW MAIN ALIGNMENTS

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0050	B

CAD FILE: C:\12DS\DATA\PLANITSYNJ7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0050.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:11:06 PM

LEGEND

- PROPOSED EFFLUENT MAINS (RECOMMENDED OPTION)
- PROPOSED EFFLUENT MAINS (ALTERNATE OPTION)
- PROPOSED PRW MAINS (RECOMMENDED OPTION)
- PROPOSED PRW MAINS (ALTERNATE OPTION)
- PROPOSED EFFLUENT PUMP STATIONS
- PROPOSED PRW PUMP STATIONS
- PROPOSED AWTP LOCATION
- PROPOSED RO CONCENTRATE DISHARGE LINE
- PROPOSED RETURN LINE
- EXISTING LOCAL COUNCIL WATER MAINS
- EXISTING ROUS WATER MAINS
- EXISTING PUMP STATIONS \
- COASTAL WETLANDS

STREAM	PEAK DESIGN FLOW	NOTES
BVSTP to AWTP	30 L/s (DN200 PVC)	Assumes that on site RW storage at BVSTP used to attenuate peak dry weather flow. 1.2 Peaking factor applied.
Byron STP / Byron STP Wetland outlet to AWTP	158 L/s (DN300 PVC)	Assuming peaking factor of 2.0 x ADWF from STP to accommodate dry weather peak flows. Includes return flows from AWTP.
Return stream from AWTP to Byron STP inlet works	14 L/s (DN100 PVC)	1 ML/d return flows, attenuated in AWTP, 1.2 peaking applied.
RO Concentrate to Belongil (down Ewingsdale Road) (Note somewhat corrosive). PRW to St Helena Reservoir	19 L/s (DN150 PVC)	Based on constant flow at 80% RO recovery.
PRW to St Helena Reservoir Offtake	200 L/s (DN450 DICL)	50% total peak inflow to St Helena Reservoir and Knockrow Reservoir
PRW to St Helena Reservoir	100 L/s (DN300 PVC)	50% of total peak inflow to St Helena Reservoir
PRW to new Blending Reservoir	100 L/s (DN375 PVC)	50% of peak inflow to Knockrow Reservoir.
Blended water from Blending Reservoir to Knockrow in existing rising main	200 L/s (ex. DN450)	100% of peak inflow to Knockrow Reservoir.
Estimated AWTP Site Power Supply Required	2.6 MW	Includes PRW transfer pump station

	OPPORTUNITIES	CONTRAINTS
EFFLUENT ALIGNMENT OPTION 1	- Only traverses Coastal Wetlands in existing road reserves or where existing pipelines exist. - Shorter Length than Option 2	- Waterbody Crossings - Traverses Coastal Wetland - Works adjacent to busy highway.
EFFLUENT ALIGNMENT OPTION 2		- 2x Additional Waterbody Crossings - Additional Traversing of Coastal Wetland - Works adjacent to busy roadway.
PRW OPTION1	- Does not impact Vegetation & Coastal Wetlands - Shorter Length than Option 2	- Works adjacent to busy roadway.
PRW OPTION 2		- Traverses Coastal Wetland - Impacts Vegetation - Works adjacent to busy roadway.

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
C	FOR INFORMATION	28/03/24	DM	RW	RW	RW
B	FOR INFORMATION	16/04/24	DM	RW	RW	RW
C	FOR INFORMATION	16/05/24	DM	RW	RW	RW

SCALES:
0 250 500 1000 1500
Full Size 1:25000 ; Half Size 1:50000
Scale (m)
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DATE:

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CLIENT:
TYR GROUP PTY LTD

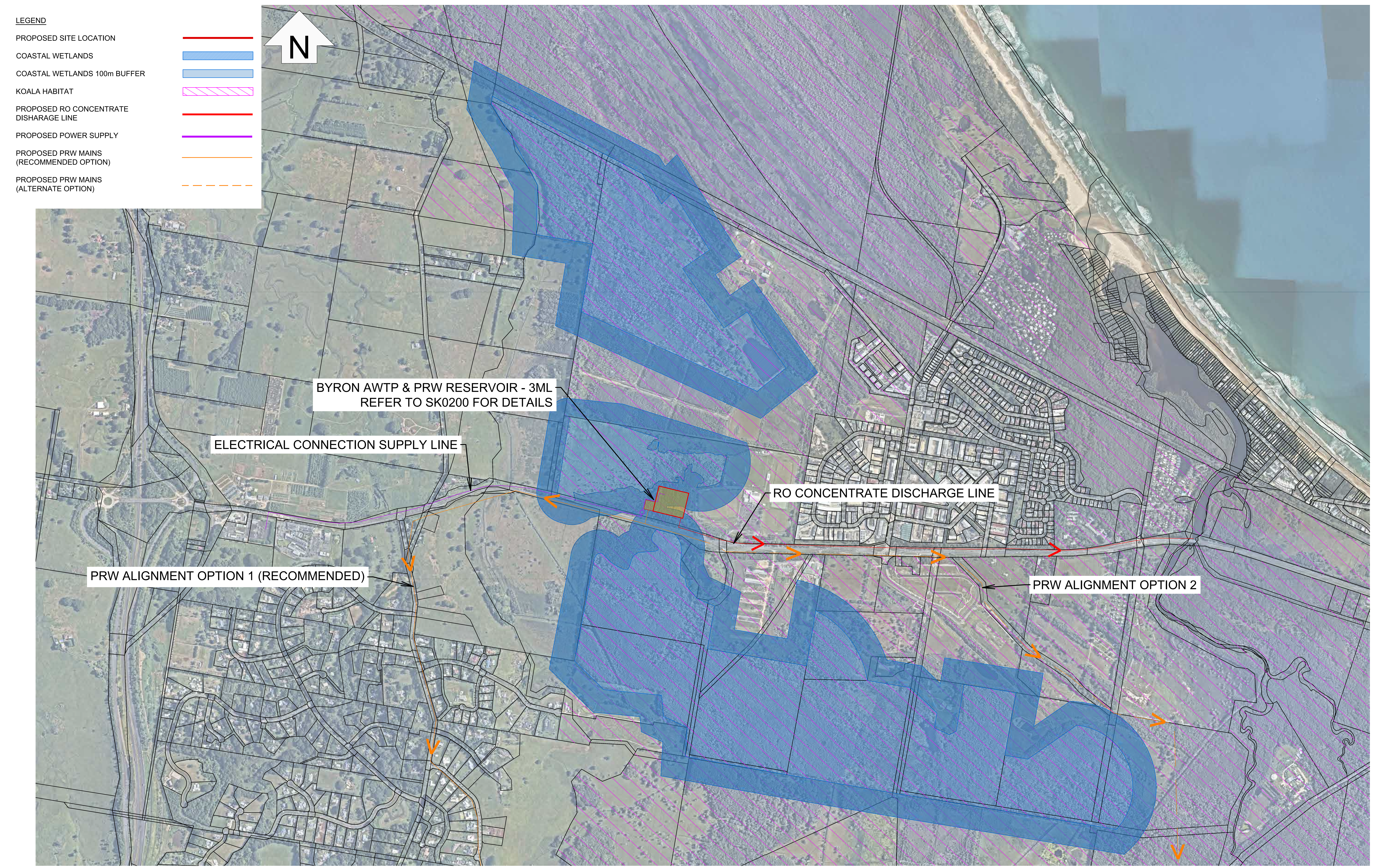
LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
BYRON DPR VIA TREATED WATER AUGMENTATION SOURCE WATER, PRW, RO CONCENTRATE AND RETURN MAIN ALIGNMENTS

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0051	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0100-SK0103.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:13:46 PM



100mm AT ORIGINAL SIZE

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REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW
B	FOR INFORMATION	16/04/24	DM	RW	RW	RW

SCALES: 0 10 20 40 60
Full Size 1:1000 ; Half Size 1:2000
Scale (m)

DO NOT SCALE FROM DRAWING

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DATE:

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CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
BYRON DPR VIA TREATED WATER AUGMENTATION POWER SUPPLY AND RO CONCENTRATE DISHARGE

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0052	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0200.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:12:55 PM

LEGEND

PROPOSED EFFLUENT MAINS (RECOMMENDED OPTION)	yellow solid line
PROPOSED EFFLUENT MAINS (ALTERNATE OPTION)	yellow dashed line
PROPOSED PRW MAINS (RECOMMENDED OPTION)	orange solid line
PROPOSED PRW MAINS (ALTERNATE OPTION)	orange dashed line
PROPOSED EFFLUENT PUMP STATIONS	yellow symbol
PROPOSED PRW PUMP STATIONS	orange symbol
PROPOSED AWTP LOCATION	red dot
EXISTING LOCAL COUNCIL WATER MAINS	blue line
EXISTING ROUS WATER MAINS	cyan line
EXISTING PUMP STATIONS	white symbol

	OPPORTUNITIES	CONTRAINTS
PRW OPTION1	- Utilises existing pipe bridge for river crossing with other Rous Mains. - Proposed alignment in mostly road reserves adjacent to undeveloped parcels of land.	- Pipe bridge likely to require upgrades to accommodate new main.
PRW OPTION 2	- River crossing to be strapped to bridge.	- Proposed alignment in mostly road reserves adjacent to developed parcels of land. Potential issues with service clashes and public impacts during construction.

STREAM	PEAK DESIGN FLOW	NOTES
South Lismore STP to AWTP	56 L/s (DN200 PVC)	Assumes that on site effluent balance tank at SLSTP used to attenuate peak dry weather flow. 1.2 Peaking factor applied.
East Lismore STP outlet to AWTP at South Lismore	120 L/s (DN300 PVC)	1.6 x ADWF factor applied. Details of new STP unknown.
Return stream from AWTP to South Lismore STP inlet works	19 L/s (DN100 PVC)	1.2 ML/d of UF backwash and BAC backwash, with 1.2 peaking factor applied
PRW to Engineered Environmental Storage Buffer	126 L/s (DN375 PVC)	9.1 ML/d, 1.2 peaking factor
PRW from Engineered Environmental Storage Buffer to Wilsons River Source Pump Station	405 L/s (DN500 DICL)	To match Wilsons River Source Pump Station Capacity
Estimated AWTP Site Power Supply Required	1.8 MW	Includes PRW transfer pump station

100mm AT ORIGINAL SIZE

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	27/09/23	DM	RW	RW	RW
B	FOR INFORMATION	23/10/23	DM	RW	RW	RW
C	FOR INFORMATION	28/03/24	DM	RW	RW	RW
D	FOR INFORMATION	16/04/24	DM	RW	RW	RW
E	FOR INFORMATION	19/04/24	DM	RW	RW	RW
F	FOR INFORMATION	16/05/24	DM	RW	RW	RW

SCALES:
0 200 400 800 1200
Full Size 1:20000 ; Half Size 1:40000
Scale (m)

DO NOT SCALE FROM DRAWING

APPROVED BY:

DATE:

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ABN: 20 099 261 711
EMAIL: administration@planitconsulting.com.au

CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
LISMORE IPR VIA SURFACE WATER AUGMENTATION SOURCE WATER AND PRW MAIN ALIGNMENTS

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0101	F

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0100-SK0103.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:11:53 PM

LEGEND

- PROPOSED EFFLUENT MAINS (RECOMMENDED OPTION)
- PROPOSED EFFLUENT MAINS (ALTERNATE OPTION)
- PROPOSED PRW MAINS (RECOMMENDED OPTION)
- PROPOSED PRW MAINS (ALTERNATE OPTION)
- PROPOSED EFFLUENT PUMP STATIONS
- PROPOSED PRW PUMP STATIONS
- PROPOSED AWTP LOCATION
- EXISTING LOCAL COUNCIL WATER MAINS
- EXISTING ROUS WATER MAINS
- EXISTING PUMP STATIONS

100mm AT ORIGINAL SIZE

	OPPORTUNITIES	CONTRAINTS
PRW OPTION1	- Utilises existing pipe bridge for river crossing with other Rous Mains. - Proposed alignment in mostly road reserves adjacent to undeveloped parcels of land.	- Pipe bridge likely to require upgrades to accommodate new main.
PRW OPTION 2	- River crossing to be strapped to bridge.	- Proposed alignment in mostly road reserves adjacent to developed parcels of land. Potential issues with service clashes and public impacts during construction.

STREAM	PEAK DESIGN FLOW	NOTES
South Lismore STP to AWTP	56 L/s (DN200 PVC)	Assumes that on site effluent balance tank at SLSTP used to attenuate peak dry weather flow. 1.2 Peaking factor applied.
East Lismore STP outlet to AWTP at South Lismore	120 L/s (DN300 PVC)	1.6 x ADWF factor applied. Details of new STP unknown.
Return stream from AWTP to South Lismore STP inlet works	19 L/s (DN100 PVC)	1.2 ML/d of UF backwash and BAC backwash, with 1.2 peaking factor applied
PRW to Wilsons River Source Pump Station	126 L/s (DN375 PVC)	9.1 ML/d, 1.2 peaking factor
Estimated AWTP Site Power Supply Required	1.8 MW	Includes PRW transfer pump station

NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	27/09/23	DM	RW	RW	RW
B	FOR INFORTMATION	23/10/23	DM	RW	RW	RW
C	FOR INFORMATION	28/03/24	DM	RW	RW	RW
D	FOR INFORMATION	16/05/24	DM	RW	RW	RW

SCALES:
0 200 400 800 1200
Full Size 1:20000 ; Half Size 1:40000
Scale (m)

DO NOT SCALE FROM DRAWING

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DATE:

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EMAIL: administration@planitconsulting.com.au

CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
LISMORE DPR VIA RAW WATER AUGMENTATION SOURCE WATER AND PRW MAIN ALIGNMENTS

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0102	D

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0100-SK0103.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:11:38 PM

LEGEND

- PROPOSED EFFLUENT MAINS (RECOMMENDED OPTION)
- PROPOSED EFFLUENT MAINS (ALTERNATE OPTION)
- PROPOSED PRW MAINS (RECOMMENDED OPTION)
- PROPOSED PRW MAINS (ALTERNATE OPTION)
- PROPOSED EFFLUENT PUMP STATIONS
- PROPOSED PRW PUMP STATIONS
- PROPOSED AWTP LOCATION
- PROPOSED RETURN LINE
- EXISTING LOCAL COUNCIL WATER MAINS
- EXISTING ROUS WATER MAINS
- EXISTING PUMP STATIONS

100mm AT ORIGINAL SIZE

	OPPORTUNITIES	CONTRAINTS
PRW OPTION1	- Utilises Ross Street road reserve to minimise works within Ballina Road.	- Partially aligned on main road. - Limited space to locate the pump station at the intersection of Dibbs St and Ballina Road.
PRW OPTION 2		- Partially aligned on main road. - Limited space to locate the pump station at the intersection of Dibbs St and McKenzie St. - Heavily vegetated alignment.

STREAM	PEAK DESIGN FLOW	NOTES
South Lismore STP effluent to East Lismore STP	36 L/s (DN200 PVC)	Assumes that on-site effluent balance tank at SLSTP used to attenuate peak dry weather flow. 1.2 Peaking factor applied
East Lismore STP outlet (and South Lismore effluent) to AWTP at East Lismore	160 L/s (DN300 PVC)	1.6 peaking factor applied, includes peaked AWTP return flow.
Return stream from AWTP to East Lismore STP inlet works	17 L/s (DN100 PVC)	1.2 ML/d of UF backwash and BAC backwash, with 1.2 peaking factor applied
PRW to City View Reservoir - full flow	430 L/s (DN600 DICL)	50% of total peak inflow rate to City View, Belvedere, Ross Street and High Street reservoirs.
City View Offtake PRW flow	100 L/s (DN300 PVC)	50% of peak inflow rate to City View Reservoir
PRW Flow from City View to Belvedere	330 L/s (DN500 DICL)	Total peak inflow rate less City View Offtake
Belvedere Offtake PRW Flow	85 L/s (DN300 PVC)	50% of the peak inflow rate to Belvedere Reservoir
PRW flow from Belvedere to High Street/Ross Street Split	245 L/s (DN450 DICL)	50% of total peak inflow rate to High Street Reservoir and Ross Street Reservoir
PRW flow to Ross St	45 L/s (DN200 PVC)	50% of total peak inflow rate to Ross Street Reservoir
PRW flow to High Street	100 L/s (DN375 PVC)	50% of total peak inflow rate to High Street Reservoir
Estimated AWTP Site Power Supply Required	2.5 MW	Includes PRW transfer pump station

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	27/09/23	DM	RW	RW	RW
B	FOR INFORMATION	23/10/23	DM	RW	RW	RW
C	FOR INFORMATION	28/03/24	DM	RW	RW	RW
D	FOR INFORMATION	16/04/24	DM	RW	RW	RW
E	FOR INFORMATION	16/05/24	DM	RW	RW	RW

SCALES: 0 200 400 800 1200
Full Size 1:20000 ; Half Size 1:40000
Scale (m)

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CLIENT:
TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
LISMORE DPR VIA TREATED WATER AUGMENTATION WATER, PRW & RETURN MAIN ALIGNMENTS

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0103	E

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0100-SK0103.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:15:03 PM

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REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW
B	FOR INFORMATION	16/04/24	DM	RW	RW	RW

SCALES:
0 10 20 40 60
Full Size 1:1000 ; Half Size 1:2000
Scale (m)

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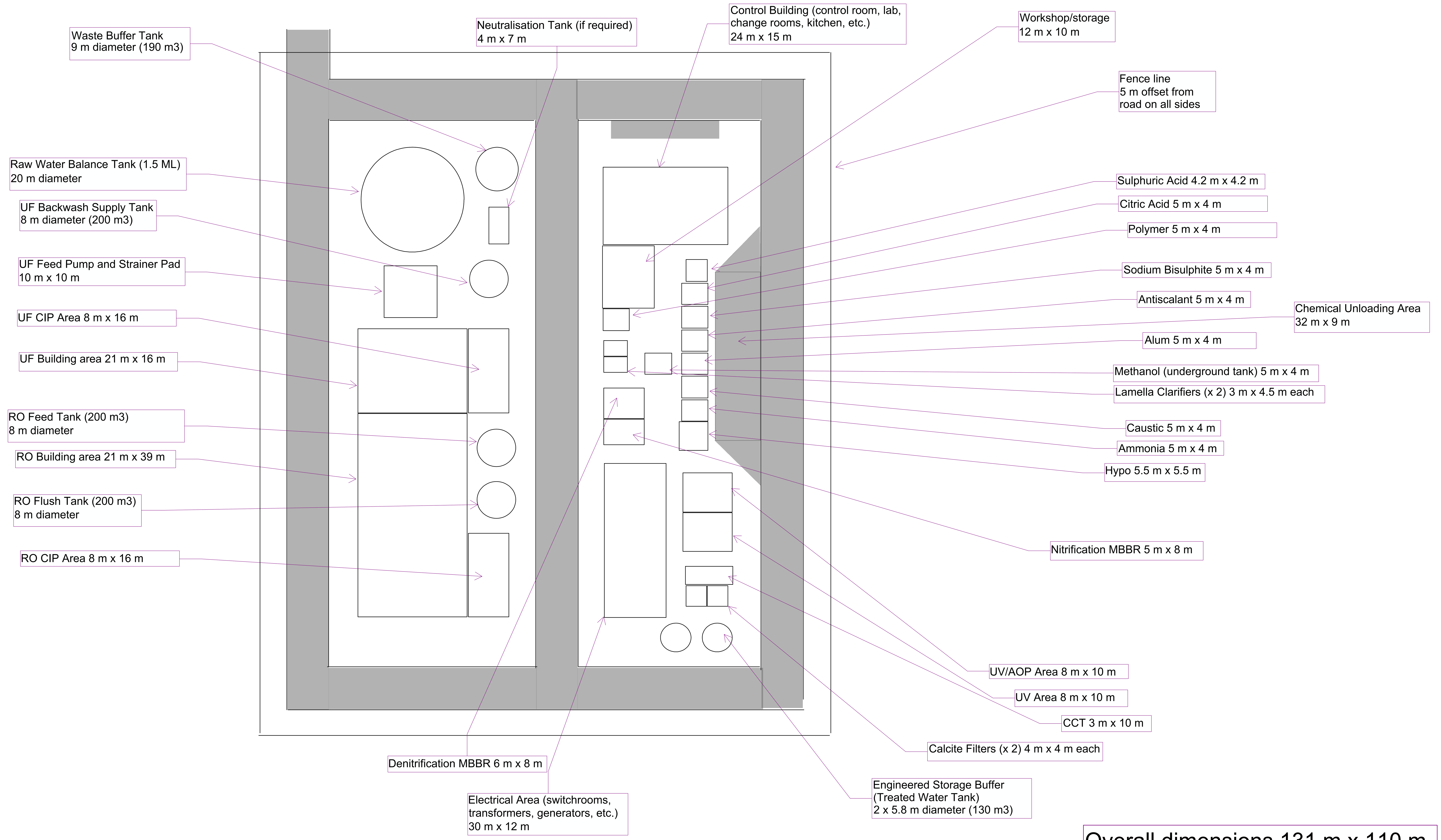
LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
BYRON AWTP & PRW RESERVOIR SITE PLAN

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0200	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0200.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:14:31 PM



Overall dimensions 131 m x 110 m

NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES: NOT TO SCALE

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CLIENT: TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY: ROUS COUNTY COUNCIL

PROJECT: ROUS PRW INVESTIGATION

DRAWING TITLE: BYRON AWTP PLANT LAYOUT

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0201	A

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0200.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:12:20 PM

100mm AT ORIGINAL SIZE

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REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW
B	FOR INFORMATION	16/04/24	DM	RW	RW	RW

SCALES: 0 10 20 40 60
Full Size 1:1000 ; Half Size 1:2000
Scale (m)

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CLIENT:
TYR GROUP PTY LTD

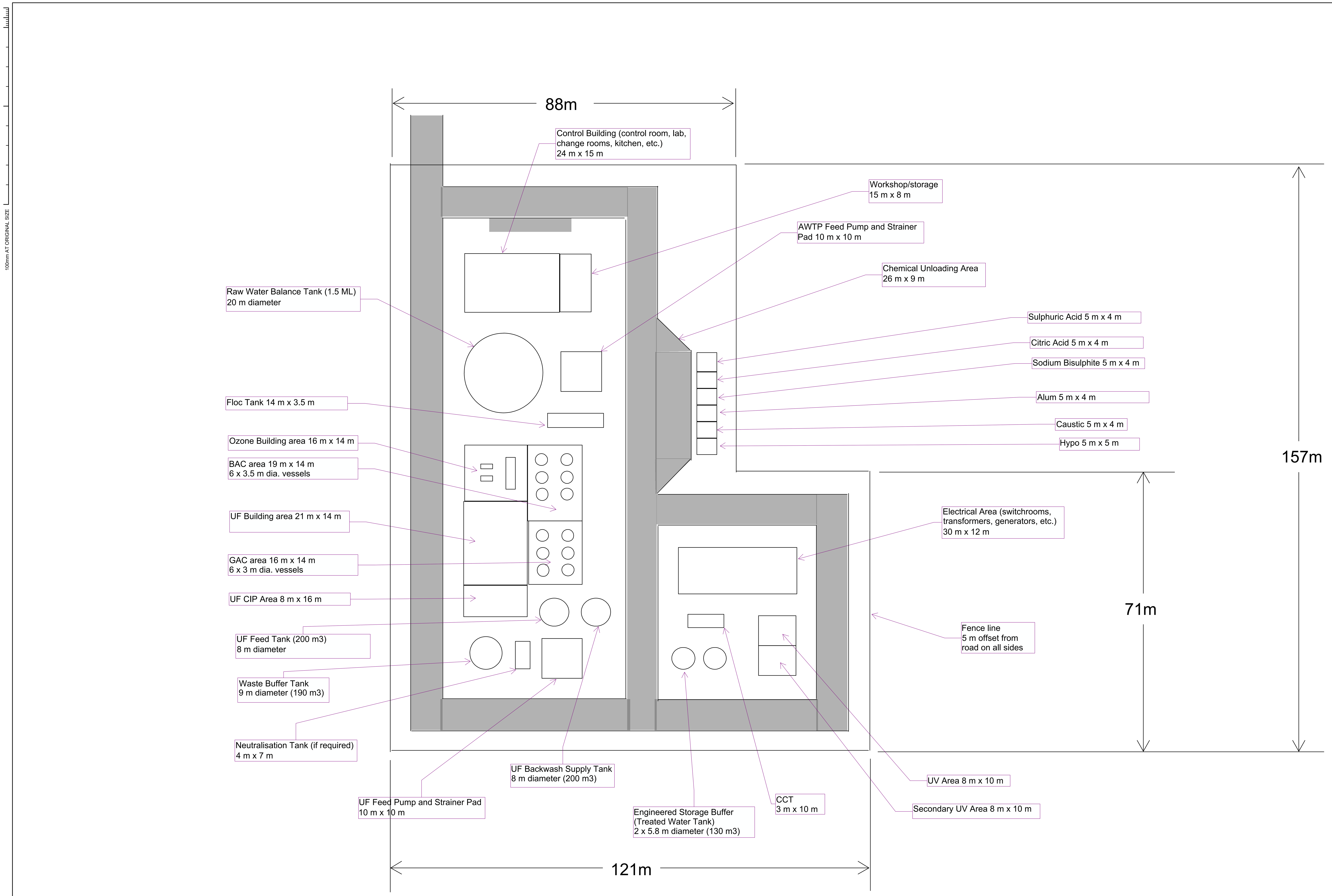
LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
SOUTH LISMORE AWTP SITE PLAN

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0300	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0300 SOUTH LISMORE AWTP SITE PLAN.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:11:22 PM



NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES: NOT TO SCALE

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CLIENT: TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY: ROUS COUNTY COUNCIL

PROJECT: ROUS PRW INVESTIGATION

DRAWING TITLE: SOUTH LISMORE AWTP PLANT LAYOUT

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0301	A

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0300 SOUTH LISMORE AWTP SITE PLAN.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:15:12 PM

NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW
B	FOR INFORMATION	16/04/24	DM	RW	RW	RW

SCALES: 0 10 20 40 60
Full Size 1:1000 ; Half Size 1:2000
Scale (m)

DO NOT SCALE FROM DRAWING

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LOCAL GOVERNMENT AUTHORITY:
ROUS COUNTY COUNCIL

PROJECT:
ROUS PRW INVESTIGATION

DRAWING TITLE:
EAST LISMORE AWTP & PRW RESERVOIR SITE PLAN

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0400	B

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0400.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:14:47 PM

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REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	FOR INFORMATION	28/03/24	DM	RW	RW	RW

SCALES: NOT TO SCALE

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CLIENT: TYR GROUP PTY LTD

LOCAL GOVERNMENT AUTHORITY: ROUS COUNTY COUNCIL

PROJECT: ROUS PRW INVESTIGATION

DRAWING TITLE: EAST LISMORE AWTP PLANT LAYOUT

ORIGINAL SIZE:	PLANIT JOB No.:	DRAWING No.:	REV:
A1	J7854	SK0401	A

CAD FILE: C:\12DS\DATA\PLANITSYN\J7854 - RCC PURIFIED RECYCLED WATER FOR DRINKING INVESTIGATIONS_1148\6. ENGINEERING\3. DRAFTING\SK0400.DWG PLOTTED BY: DANE PLOT DATE: 16/05/2024 3:14:17 PM

APPENDIX G: SOURCE CHARACTERISATION ANALYTES FROM AGWR AND SEQ AND WESTERN AUSTRALIA AWTPS

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
General			
Ammonia	Y		Y
Bicarbonate Alkalinity as $CaCO_3$	Y		
Biochemical Oxygen Demand	Y		
Bromide	Y		Y
Bromine			Y
Chemical Oxygen Demand	Y		
Chlorine	Y		
Dissolved Oxygen	Y		
Dissolved Organic Carbon			
Electrical conductivity	Y		
Nitrate	Y		Y
Nitrite	Y		Y
Oil and Grease	Y		
Orthophosphate	Y		
pH	Y		
Silica	Y		
Sulphate	Y		Y
Sulphide	Y		
Sulphur	Y		
Total Alkalinity as $CaCO_3$	Y		
Total Dissolved Solids	Y		
Total Hardness as $CaCO_3$	Y		
Total Kjeldahl Nitrogen	Y		
Total Nitrogen	Y		
Total Organic Carbon	Y		
Total Phosphorus	Y		
TSS	Y		
Turbidity	Y		
Metals			
Aluminium	Y	Y	Y
Antimony	Y	Y	Y
Arsenic	Y	Y	Y
Barium	Y	Y	Y
Beryllium	Y	Y	
Boron			Y
Cadmium	Y	Y	Y
Calcium	Y		
Chromium	Y	Y	Y

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Cobalt	Y	Y	
Copper	Y	Y	Y
Cyanide	Y		Y
Fluoride	Y		Y
Hexavalent Chromium	Y		
Iodide	Y		Y
Iron	Y		Y
Lead	Y	Y	Y
Lithium	Y	Y	
Manganese	Y	Y	Y
Magnesium	Y		
Mercury	Y	Y	Y
Molybdenum	Y	Y	Y
Nickel	Y	Y	Y
Potassium	Y		
Selenium	Y	Y	Y
Silver	Y	Y	Y
Sodium	Y		
Strontium	Y	Y	
Thallium	Y	Y	
Tin	Y	Y	
Vanadium	Y	Y	
Zinc	Y	Y	Y
Disinfection Byproducts			
2.4.6-Trichlorophenol	Y	Y	Y
2.4-Dichlorophenol	Y	Y	Y
2.6-Dichlorophenol	Y	Y	Y
Bromate	Y		
Bromoacetic acid		Y	Y
Bromoacetonitrile		Y	
Bromochloroacetic acid		Y	
Bromochloroacetonitrile		Y	Y
Bromochloromethane			
Bromodichloromethane	Y	Y	Y
Bromoform	Y	Y	Y
Chlorate	Y		
Chlorite	Y		
Chloroacetic acid		Y	
Chloroform	Y	Y	Y

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Dibromoacetic acid		Y	
Dibromoacetonitrile		Y	
Dibromochloroacetic acid		Y	
Dibromochloromethane	Y	Y	Y
Dichlorobromoacetic acid		Y	Y
Dichloroacetic acid		Y	
Dichloroacetonitrile		Y	Y
Monochloroacetonitrile		Y	
NDBA	Y	Y	
NDEA	Y	Y	Y
NDMA	Y	Y	Y
NDPA		Y	
NEMA		Y	
Nitroso-pyrrolidine	Y	Y	
Nitroso-piperidine	Y	Y	
NMOR		Y	Y
Perchlorate	Y		
Tribromoacetic acid		Y	
Trichloroacetic acid		Y	Y
Trichloroacetonitrile		Y	
Chelating Agents			
ADA		Y	
DTPA		Y	
EDTA	Y	Y	Y
Nitriloacetic acid		Y	Y
NTA		Y	
PDTA		Y	Y
Surfactants			
Anionic Surfactants as MBAS	Y		
Pharmaceuticals			
Acetylsalicylic acid	Y		Y
Alprazolam			Y
Amidotrizoic acid		Y	
Amoxycillin		Y	Y
Anhydroerythromycin A			Y
Antipyrine (phenazone)			Y
Atenolol	Y		
Atrovastatin	Y		Y
Azithromycin			Y

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Betaxolol			Y
Bezafibrate		Y	Y
Bisoprolol			Y
Caffeine	Y		Y
Carazolol			Y
Carbamazepine	Y	Y	Y
Cefaclor			Y
Cephalexin	Y		Y
Chloramphenicol	Y	Y	Y
Chlorotetracycline	Y		Y
Cimetidine			Y
Ciprofloxacin	Y		Y
Citalopram	Y		
Clarithromycin		Y	Y
Clenbuterol			Y
Clindamycin		Y	Y
Clofibric acid		Y	Y
Cloxacillin		Y	
Codeine	Y		Y
Cotinine			Y
Cyclophosphamide	Y		Y
Dapsone	Y	Y	
Dehydronifedipine			Y
Demeclocycline			Y
Desmethyl Citalopram	Y		
Desmethyl Diazepam	Y		
Diazepam (Valium)	Y	Y	
Diclofenac	Y	Y	Y
Dicloxacillin		Y	
Diltiazem			Y
Dipyrone			Y
Doxycycline			Y
Doxylamine	Y		
Enalaprilat			Y
Enrofloxacin	Y		Y
Erythromycin	Y	Y	Y
Etofibrate		Y	
Fenofibrate		Y	
Fenofibric acid		Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Fenoprofen		Y	Y
Fluoxetine	Y		Y
Fluvastatin	Y		
Frusemide	Y		
Furazolidone		Y	
Gabapentin	Y		
Gemfibrozol	Y	Y	Y
Hydrochlorthiadzide	Y		
Ibuprofen	Y	Y	Y
Ifosfamide	Y		
Indomethacin	Y	Y	Y
Iodipamide		Y	
Iohexol		Y	Y
Iomeprol		Y	
Iopamidol		Y	Y
Iopromide	Y	Y	Y
Iotalamic acid		Y	
Ioxaglic acid		Y	
Ioxithalamic acid			
Isophosphamide			Y
Ketoprofen		Y	Y
Levonorgestrel			
Lincomycin	Y		
Metformin (1,1- Dimethylbiguanide)			Y
Methampthetamine			
Metronidazole		Y	
Metroprolol	Y		Y
Monensin			Y
Nadolol			Y
Nafcillin			
Naladixic acid			Y
Naproxen			Y
Norfloxacin	Y		Y
Oleandomycin		Y	
Oxacillin		Y	
Oxazepam	Y		
Oxycodone	Y		
Oxytetracycline	Y		Y
Paracetamol	Y		Y

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Penicillin G		Y	Y
Penicillin V		Y	Y
Pentoxifylline		Y	
Phenytoin	Y		
Praziquantel	Y		
Propranolol	Y		Y
Ranitidine	Y		
Ronidazole		Y	
Roxithromycin	Y	Y	Y
Salicylic acid	Y	Y	Y
Salbutamol			Y
Sertraline	Y		
Simvastatin	Y		
Spiramycin		Y	
Sulfsalazine	Y		Y
Sulphadiazine	Y	Y	
Sulphadimidine		Y	
Sulphamerazine		Y	
Sulphamethoxazole	Y	Y	Y
Sulfamethoxine			Y
Sulfamethazine			Y
Sulfamethizole			Y
Sulphathiazole	Y		
Temazepam	Y		Y
Terbutaline			Y
Tetracycline	Y		Y
Timolol			Y
Tolfenamic acid			Y
Tramadol	Y		
Triclosan	Y		Y
Trimethoprim	Y	Y	Y
Tylosin	Y	Y	Y
Venlafaxine	Y		
Warfarin	Y		
Endocrine Disrupting Compounds/Estrogenic & Androgenic Hormones			
Androsterone	Y		Y
Bisphenol A	Y		Y
Cholesterol (not an EDC)	Y		Y
Equilenin			Y

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Equilin			Y
17-alpha-estradiol			Y
17-beta-estradiol	Y	Y	Y
Estriol	Y		Y
Estrone	Y	Y	Y
17-alpha-ethynylestradiol	Y	Y	Y
Eticholanolone	Y		
Mestranol			Y
Nonylphenol	Y	Y	
4-Nonylphenol			Y
Norethindrone			Y
Norgestrel	Y		
4-t-Octyphenol	Y		
Progesterone			Y
Testosterone	Y		Y
Monocyclic Aromatic Hydrocarbons			
Benzene	Y	Y	
Toluene	Y	Y	
Ethylbenzene	Y	Y	
meta- & para-Xylene	Y	Y	
Styrene	Y	Y	
ortho-Xylene	Y	Y	
Isopropylbenzene	Y	Y	
n-Propylbenzene	Y	Y	
1.3.5-Trimethylbenzene	Y	Y	
sec-Butylbenzene	Y	Y	
1.2.4-Trimethylbenzene	Y	Y	
tert-Butylbenzene	Y	Y	
p-Isopropyltoluene	Y		
n-Butylbenzene	Y	Y	
Oxygenated Compounds			
Vinyl Acetate	Y		
Acetophenone			Y
2-Butanone (MEK)	Y		
4-Methyl-2-pentanone (MIBK)	Y		
2-Hexanone (MBK)	Y		
Sulfonated Compounds			
Carbon disulfide	Y		
Fumigants			

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
2.2-Dichloropropane	Y		
1.2-Dichloropropane	Y	Y	
cis-1.3-Dichloropropylene	Y		
trans-1.3-Dichloropropylene	Y		
1.2-Dibromoethane (EDB)	Y		
Halogenated Aliphatic Compounds			
Dichlorodifluoromethane	Y		
Chloromethane	Y		
Vinyl chloride	Y		
Bromomethane	Y		
Chloroethane	Y		
Trichlorofluoromethane	Y	Y	
1.1-Dichloroethene	Y	Y	Y
trans-1.2-Dichloroethene	Y		
1.1-Dichloroethane	Y	Y	
Iodomethane	Y		
cis-1.2-Dichloroethene	Y	Y	
1.1.1-Trichloroethane	Y	Y	
Carbon Tetrachloride	Y		
1.2-Dichloroethane	Y	Y	
Trichloroethene	Y	Y	
1.1-Dichloropropylene	Y		
Tetrachloroethene	Y	Y	
1.1.1.2-Tetrachloroethane	Y		
1.1.2.2-Tetrachloroethane	Y	Y	
Hexachlorobutadiene	Y	Y	
Dibromomethane	Y		
1.1.2-Trichloroethane	Y	Y	
1.3-Dichloropropane	Y		
trans-1.4-Dichloro-2-butene	Y		
cis-1.4-Dichloro-2-butene	Y		
1.2.3-Trichloropropane	Y		
Pentachloroethane	Y		
1.2-Dibromo-3-chloropropane	Y	Y	
Dichloromethane		Y	Y
Halogenated Aromatic Compounds			
Benzyl Chloride			Y
Bromobenzene	Y		
Chlorobenzene	Y	Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
2-Chlorotoluene	Y	Y	
4-Chlorotoluene	Y	Y	
1.3-Dichlorobenzene	Y	Y	
1.4-Dichlorobenzene	Y	Y	
1.2-Dichlorobenzene	Y	Y	
1.2.4-Trichlorobenzene	Y	Y	
1.2.3-Trichlorobenzene	Y	Y	
Aliphatic Hydrocarbons			
Cyclohexane	Y		
Hexane	Y		
Phthalate Esters			
Dimethyl phthalate	Y		
Diethyl phthalate	Y		
Di-n-butyl phthalate	Y		Y
Butyl benzyl phthalate	Y		
bis(2-ethylhexyl) phthalate	Y		
Di-n-octylphthalate	Y		
Chlorinated Hydrocarbons			
1.3-Dichlorobenzene	Y		
1.4-Dichlorobenzene	Y		
1.2-Dichlorobenzene	Y		
Hexachloroethane	Y		
1.2.4-Trichlorobenzene	Y	Y	
Hexachloropropylene	Y		
Hexachlorobutadiene	Y		
Hexachlorocyclopentadiene	Y		
Pentachlorobenzene	Y		
Hexachlorobenzene (HCB)	Y		
Organotin Compounds			
Dibutyl tin		Y	Y
Diphenyl tin		Y	
Monobutyl tin		Y	Y
Monophenyl tin		Y	
Tetrabutyl tin		Y	
Tributyl tin	Y	Y	Y
Triphenyl tin		Y	
Phenolic Compounds			
2-sec-Butylphenol		Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
2,6-di-tert-butylphenol (2,6-bis(1,1-dimethylethyl)phenol)			Y
2-Chlorophenol	Y	Y	
4-Chlorophenol		Y	
4-Chloro-3-Methylphenol	Y		
m-Cresol	Y		
o-Cresol	Y		
p-Cresol	Y		
4-cumylphenol			Y
Cyclohexyphenol		Y	
2.4-Dimethylphenol	Y	Y	
Hexachlorophene	Y		
2-Nitrophenol	Y		
4-Nitrophenol	Y		Y
4 n-Octylphenol		Y	
4-tert Octylphenol			Y
Pentachlorophenol	Y	Y	Y
Phenol	Y	Y	Y
Tetrachlorophenol	Y		
2.4.5-Trichlorophenol	Y		
Polynuclear Aromatic Hydrocarbons			
3-Methylcholanthrene	Y		
2-Methylnaphthalene	Y		
7.12-Dimethylbenz(a)anthracene	Y		
Acenaphthene	Y		
Acenaphthylene	Y		
Anthracene	Y		Y
Benz(a)anthracene	Y		
Benzo(a)pyrene	Y		Y
Benzo(b)fluoranthene	Y		
Benzo(e)pyrene	Y		
Benzo(g.h.i)perylene	Y		
Benzo(k)fluoranthene	Y		
Chrysene	Y		
Coronene	Y		
Dibenz(a.h)anthracene	Y		
Fluoranthene	Y		
Fluorene	Y		
Indeno(1.2.3.cd)pyrene	Y		

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
N-2-Fluorenyl Acetamide	Y		
Naphthalene	Y	Y	Y
Perylene	Y		
Phenanthrene	Y		Y
Pyrene	Y		Y
Sum of PAHs	Y		
Chlorinated Napthalenes			
1-Chloronaphthalene	Y		
2-Chloronaphthalene	Y		
Chloronaphthalenes (1- + 2-)	Y		
Trichloronaphthalene	Y		
Organophosphorus Pesticides			
Acephate		Y	
Azinphos methyl	Y	Y	Y
Bromophos-ethyl	Y	Y	Y
Cadusafos	Y		
Carbophenothion	Y	Y	
Chlorfenvinphos (Z)	Y	Y	
Chlorpyrifos	Y	Y	Y
Chlorpyrifos-methyl	Y		Y
Chlorpyrifos oxon	Y		
Coumaphos	Y		
Demeton-S-methyl	Y	Y	Y
Diazinon	Y	Y	Y
Dichlorvos	Y	Y	Y
Dimethoate	Y	Y	Y
Disulfoton		Y	
Ethion	Y	Y	Y
Ethoprophos	Y	Y	Y
Etrimphos	Y		
Famphur	Y		
Fenamiphos	Y	Y	
Fenchlorphos	Y	Y	
Fenitrothion	Y	Y	
Fensulfothion		Y	
Fenthion	Y	Y	Y
Fenthion ethyl	Y		
Fenthion methyl	Y		
Formothion		Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Isophenphos	Y		
Malathion	Y		Y
Methidathion	Y	Y	
Mevinphos	Y	Y	
Monocrotophos	Y		
Parathion	Y		
Parathion ethyl	Y	Y	Y
Parathion methyl	Y	Y	Y
Phorate	Y	Y	
Phosmet	Y		
Pirimiphos ethyl		Y	
Pirimiphos methyl	Y	Y	
Profenofos	Y	Y	
Prothiofos	Y		
Pyrazophos	Y	Y	
Sulprofos		Y	
Temephos		Y	
Tetrachlorvinphos	Y	Y	
Terbufos	Y	Y	
Thiometon		Y	
Trichlorfon		Y	
Organochlorine Pesticides			
4.4`-DDD	Y		
4.4`-DDE	Y		Y
4.4`-DDT	Y		Y
Aldrin	Y	Y	
Azinphos ethyl	Y		
BHC-alpha	Y		Y
BHC-beta	Y		Y
BHC-delta	Y		
BHC-gamma	Y		
Chlordane cis	Y		
Chlordane gamma			Y
Chlordane Trans	Y		
Chlordane (sum)	Y	Y	
Chlordene	Y		
Chlordene Epoxide	Y		
DDD (o,p)	Y		
DDD (p,p)	Y	Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
DDE (o,p)	Y		
DDE (p,p)	Y	Y	
DDT (o,p)	Y		
DDT (p,p)	Y		
DDT (total)	Y	Y	
Dicofol	Y		
1,3 Dichloropropene		Y	
Dieldrin	Y	Y	
Endosulfan alpha	Y	Y	
Endosulfan beta	Y	Y	
Endosulfan sulfate	Y	Y	Y
Endosulfan Ehter	Y		
Endosulfan Lactone	Y		
Endosulfan (sum)	Y		
Endrin	Y	Y	
Endrin aldehyde	Y		
Endrin ketone	Y		
Heptachlor	Y	Y	
Heptachlor epoxide	Y		
Hexachlorobenzene (HCB)	Y		
HCH alpha	Y		
HCH beta	Y		
HCH delta	Y		
Heptachlor	Y		
Heptachlor Epoxide	Y		
Lindane	Y	Y	Y
Methoxychlor	Y	Y	
Nonachlor trans	Y		
Oxychlordane	Y		
Carbamate Pesticides by Liquid Chromatography Mass Spectrometry			
Aldicarb	Y	Y	
Bendiocarb	Y		
Carbofuran	Y	Y	
3-Hydroxy Carbofuran	Y	Y	
Carbaryl	Y		
Oxamyl	Y		
Methiocarb	Y	Y	
Methomyl	Y		
Thiodicarb	Y		

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Glyphosate and AMPA			
AMPA	Y		
Glyphosate	Y		
Quaternary Ammonium Herbicides			
Diquat	Y		
Paraquat	Y		
Phenoxyacid Herbicides, Dalapon			
2,4-D	Y	Y	Y
Dalapon	Y		
2,4-DB	Y		
Dicamba	Y	Y	
2,4-DP	Y		
Fluroxypyr	Y		
MCPA	Y	Y	
MCPB	Y		
Mecoprop	Y		
Picloram	Y	Y	
Triclopyr	Y	Y	
Herbicides by Liquid Chromatography Mass Spectrometry			
Ametryn	Y	Y	
Atrazine	Y	Y	Y
desethyl Atrazine	Y		
desisopropyl Atrazine	Y		
Bromacil	Y	Y	
Carbaryl	Y		
DEET	Y		Y
Diazinon	Y		
3,4 Dichloroaniline	Y		
Diuron	Y	Y	Y
Fluometuron	Y		
Hexazinone	Y	Y	
Metolachlor	Y	Y	Y
Prometryn	Y		
Propoxur	Y	Y	
Simazine	Y	Y	Y
Tebuthiuron	Y	Y	
Terbutryn	Y	Y	
Triclosan	Y		

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Herbicides by Gas Chromatography Mass Spectrometry			
Aldrin	Y		
Allethrin	Y		
Bifenthrim	Y		
Bioresmethrin	Y		
Cyfluthrin	Y		
lambda-Cyhalothrin	Y		
Cypermethrin	Y		Y
Deltamethrin	Y		
Diclofop methyl	Y	Y	
Fenvalerate	Y	Y	
Fluvatine	Y		
Haloxyfop 2-etotyl	Y		
Haloxyfop methyl	Y		
Metribuzin	Y	Y	
Oxyfluorfen	Y		
Pendimethalin	Y	Y	
Peremethrin	Y		
Phenothrin	Y		
Propanil	Y	Y	
Propazine	Y	Y	
Terbuthylazine	Y		
Tertamethrin	Y		
Tri-allate	Y		
Transfluthrin	Y		
Trifluralin	Y	Y	Y
Other Herbicides/Pesticides/Fungicides			
2,4,5-T		Y	
Alachlor			Y
Benalaxyl	Y		
Bentazone		Y	
Bitertinol	Y		
Butylate		Y	
Carbaryl	Y	Y	
Carbendazim		Y	Y
Carboxin		Y	
n-Carboxymethyl imino bis(ethylenedinitrilo)tetra			Y
Cycloate		Y	
Clopyralid		Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Dichlobenil		Y	
Dichlorfluanid	Y		
Dichloran	Y		
Diphenamid		Y	
Endothal		Y	
EPTC		Y	
Fenarimol		Y	
Fenoprop		Y	
Fipronil	Y		
Fluometuron		Y	
Furalaxyl	Y		
Linuron		Y	
Metalaxyl	Y		
Metasulfuron-methyl		Y	
Methabenzthiazuron		Y	
Methamidophos		Y	
Molinate		Y	
Napropamide		Y	
Norflurazon		Y	
Oryzalin		Y	
Oxadiazinon	Y		
Pebulate		Y	
Permethrin		Y	
2-Phenylphenol			Y
Piperonyl Butoxide	Y	Y	
Pirimicarb	Y	Y	
Procymidone	Y		
Promecarb		Y	
Propachlor		Y	
Propargite		Y	
Propiconazole	Y	Y	
Propoxur	Y		
Propyzamide		Y	
Quintozene		Y	
Tebuconazole	Y		
Terbacil		Y	
Tertadifon	Y		
Thiophanate-methyl		Y	Y
Triadimefon		Y	

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Vernolate		Y	
Vinclozolin	Y		
Radiological			
Be-7	Y		
Cr-51	Y		
Co-57	Y		
Ga-67	Y		
Tc-99m	Y		
In-111	Y		
I-123	Y		
I-125	Y		
I-131	Y		
Sm-153	Y		
Lu-177	Y		
Tl-201	Y		
U-238	Y		
Ra-226	Y		
Pb-210	Y		
Ra-224	Y		
Ra-228	Y		
Gross Alpha	Y		Y
Gross Beta	Y		Y
Gross Beta (-40K)	Y		
Gross Gamma			Y
Other chemicals			
n-nitroso dicyclohexylamine		Y	
Methylglycinediacetic acid		Y	
1,7-Dimethylxanthine			Y
Coprastanol			Y
Coumarin			Y
2,6-di-tert-butyl-1,4-benzoquinone (2,6-bis(1,1-dimethylethyl)-2,5-Cyclohexadiene-1,4-dione)			Y
5-methyl-1Hbenzotriazole			Y
2,5-Dihydroxybenzoic acid			Y
Diatrizoate Sodium			Y
Diatrizoic acid			Y

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Butylated hydroxytoluene (2,6-Di-tert-Butyl-pCresol)			Y
Butylated hydroxyanisole (3-tert-butyl-4-hydroxy anisole)			Y
Chlorophene			Y
Phthalic anhydride			Y
Stigmastanol			Y
Tributyl phosphate			Y
Tri(butyl cellosolve) phosphate (ethanol,2-butoxy-phosphate)			Y
Triphenyl phosphate			Y
Fire Retardants			
Fyrol FR 2 (tri(dichlorisopropyl) phosphate)			Y
Tris(2- chloroethyl)phosphate (TCEP)			Y
Dioxins and Dioxin-like Compounds			
2,3,3',4,4',5-Hexachlorobiphenyl (PCB156)			Y
2,3,3',4,4'-pentachlorobiphenyl (PCB105)			Y
2,3',4,4',5- Pentachlorobiphenyl (PCB118)			Y
2,4,5,3',4',5'- Hexachlorobiphenyl (PCB167)			Y
2,7-Dichlorodibenzo-pdioxin (DCDD)			Y
3,4,5,3',4',5'- Hexachlorobiphenyl (PCB169)			Y
Octachlorodibenzo-pdioxin (OCDD)			Y
PCB77			Y
Fragrances			
2,4,6-Trinitro-1,3-dimethyl-5-tertbutylbenzene (musk xylene)			Y
4-Acetyl-6-t-butyl-1,1-dimethylindan			Y
6-Acetyl-1,1,2,4,4,7-hexamethyltetraline			Y
Galaxolide			Y
Musk ketone			Y
Musk tibetene			Y
Pentamethyl-4,6-dinitroindane			Y
PFAS Compounds			
Perfluorooctanoic acid (PFOA)			

Source Characterisation Analytes from AGWR and SEQ and Western Australia AWTPs (continued)

Parameter	In SEQ plant sampling?	In Beenyup sampling?	Included in AGWR Phase 2, Table 4.4?
Perfluorooctane sulfonate (PFOS)			
Perfluorononanoic acid (PFNA)			
Perfluorohexane Sulfonic Acid (PFHxS)			
Perfluorohexanoic Acid (PFHxA)			
Perfluorobutyrate Acid (PFBA)			

APPENDIX H: LABORATORY RESPONSES

Laboratory Responses

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
General										
1	Ammonia	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
2	Bicarbonate Alkalinity as $CaCO_3$	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
3	Biochemical Oxygen Demand	Yes	Yes	Yes	Yes	Yes	No	Not Requested		
4	Bromide	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
5	Bromine	Yes	Yes	No	No	No	No	Not Requested		Best done field measured
6	Chemical Oxygen Demand	Yes	Yes	Yes	Yes	Yes	No	Not Requested		
7	Chlorine	Yes	Yes	Yes	Yes	Yes	No	Not Requested		Best done field measured
8	Dissolved Oxygen	Yes	Yes	Yes	Yes	Yes	No	Not Requested		Best done field measured
9	Dissolved Organic Carbon	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
10	Electrical conductivity	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
11	Nickel	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
12	Nitrate	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
13	Nitrite	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
14	Oil and Grease	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
15	Orthophosphate	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
16	pH	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
17	Silica	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
18	Sulphate	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
19	Sulphide	Yes	Yes	No	Yes	Yes	No	Not Requested		
20	Sulphur	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
21	Total Alkalinity as $CaCO_3$	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
22	Total Dissolved Solids	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
23	Total Hardness as $CaCO_3$	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
24	Total Kjeldahl Nitrogen	Yes	Yes	Yes	Yes	Yes	No	Not Requested		
25	Total Nitrogen	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
26	Total Organic Carbon	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
27	Total Phosphorus	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
28	TSS	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
29	Turbidity	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
Metals										
30	Aluminium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
31	Antimony	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
32	Arsenic	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
33	Barium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
34	Beryllium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
35	Boron	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
36	Cadmium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
37	Calcium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
38	Chromium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
39	Cobalt	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
40	Copper	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
41	Cyanide	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
42	Fluoride	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
43	Hexavalent Chromium	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
44	Iodide	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
45	Iron	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
46	Lead	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
47	Lithium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
48	Manganese	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
49	Magnesium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
50	Mercury	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
51	Molybdenum	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
52	Potassium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
53	Selenium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
54	Silver	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
55	Sodium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
56	Strontium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
57	Thallium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
58	Tin	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
59	Vanadium	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
60	Zinc	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
Disinfection Byproducts										
61	2,4,6-Trichlorophenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
62	2,4-Dichlorophenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
63	2,6-Dichlorophenol	Yes	Yes	No	No	Yes	Yes	Not Requested		
64	Bromate	Yes	Yes	No	No	No	Yes	Not Requested		
65	Bromoacetic acid	Yes	Yes	No	No	No	Prob	Not Requested		
66	Bromoacetonitrile	Yes	Yes	No	No	No	Prob	Not Requested		
67	Bromochloroacetic acid	Yes	Yes	No	No	No	Yes	Not Requested		
68	Bromochloroacetonitrile	Yes	Yes	No	No	No	Yes	Not Requested		
69	Bromochloromethane	Yes	Yes	No	No	Yes	Yes	Not Requested		
70	Bromodichloromethane	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
71	Bromoform	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
72	Chlorate	Yes	Yes	No	No	No	Yes	Not Requested		
73	Chlorite	No	Yes	No	No	No	Yes	Not Requested		
74	Chloroacetic acid	Yes	Yes	No	No	No	Prob	Not Requested		
75	Chloroform	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
76	Dibromoacetic acid	Yes	Yes	No	No	No	Yes	Not Requested		
77	Dibromoacetonitrile	Yes	Yes	No	No	No	Yes	Not Requested		
78	Dibromochloroacetic acid	Yes	Yes	No	No	No	Yes	Not Requested		
79	Dibromochloromethane	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
80	Dichlorobromoacetic acid	Yes	Yes	No	No	No	Yes	Not Requested		
81	Dichloroacetic acid	Yes	Yes	No	No	No	Yes	Not Requested		
82	Dichloroacetonitrile	Yes	Yes	No	No	No	Yes	Not Requested		
83	Monochloroacetonitrile	Yes	No	No	No	No	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
84	NDBA	Yes	Yes	No	No	No	Yes	Not Requested		
85	NDEA	Yes	Yes	No	No	No	Yes	Not Requested		
86	NDMA	Yes	Yes	No	No	No	Yes	Not Requested		
87	NDPA	Yes	Yes	No	No	No	No	Not Requested		
88	NEMA	Yes	Yes	No	No	No	No	Not Requested		
89	Nitroso-pyrrolidine	Yes	Yes	No	No	No	No	Not Requested		
90	Nitroso-piperidine	Yes	Yes	No	No	No	Yes	Not Requested		
91	NMOR	Yes	Yes	No	No	No	Yes	Not Requested		
92	Perchlorate	Yes	Yes	No	No	No	Yes	Not Requested		
93	Tribromoacetic acid	No	Yes	No	No	No	No	Not Requested		
94	Trichloroacetic acid	Yes	Yes	No	No	No	Yes	Not Requested		
95	Trichloroacetonitrile	Yes	No	No	No	No	Yes	Not Requested		
Chelating Agents										
96	ADA	No	No	No	No	No	No	Not Requested		
97	DTPA	Yes	No	No	No	No	No	Not Requested		
98	EDTA	Yes	No	No	No	No	Yes	Not Requested		
99	Nitriloacetic acid	Yes	No	No	No	No	Prob	Not Requested		
100	NTA	Yes	No	No	No	No	Yes	Not Requested		
101	PDTA	No	No	No	No	No	No	Not Requested		
Surfactants										
102	Anionic Surfactants as MBAS	Yes		No	Yes	Yes	Yes	Not Requested		
Pharmaceuticals										
103	Acetylsalicylic acid	No	No	No	No	No	Probable	No		
104	Alprazolam	No	No	No	No	No	Yes	Not Requested		
105	Amidotrizoic acid	No	No	No	No	No	No	No	All No	
106	Amoxycillin	Yes	No	No	No	No	No	Yes		
107	Anhydroerythromycin A	No	No	No	No	No	Yes	Yes		
108	Antipyrine (phenazone)	No	No	No	No	No	No	No	All No	
109	Atenolol	Yes	No	No	No	No	Yes	Not Requested		
110	Atrovastatin	No	No	No	No	No	Yes	Not Requested		
111	Azithromycin	No	No	No	No	No	No	Yes		
112	Betaxolol	No	No	No	No	No	Yes	Yes		
113	Bezafibrate	No	No	No	No	No	No	No	All No	
114	Bisoprolol	No	No	No	No	No	No	No	All No	
115	Caffeine	Yes	No	No	No	No	Yes	Yes		
116	Carazolol	No	No	No	No	No	No	No	All No	
117	Carbamazepine	Yes	No	No	No	No	Yes	Yes		
118	Cefaclor	No	No	No	No	No	No	Yes		
119	Cephalexin	Yes	No	No	No	No	Yes	Yes		
120	Chloramphenicol	No	No	No	No	No	Yes	Yes		
121	Chlorotetracycline	No	No	No	No	No	No	Yes		Chlortetracycline
122	Cimetidine	No	No	No	No	No	No	No	All No	
123	Ciprofloxacin	No	No	No	No	No	No	Yes		
124	Citalopram	Yes	No	No	No	No	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
125	Clarithromycin	No	No	No	No	No	No	Yes		
126	Clenbuterol	No	No	No	No	No	No	No	All No	
127	Clindamycin	No	No	No	No	No	No	Yes		
128	Clofibric acid	No	No	No	No	No	No	No	All No	882-09-7
129	Cloxacillin	No	No	No	No	No	No	Yes		61-72-3
130	Codeine	No	No	No	No	No	Yes	Not Requested		
131	Cotinine	No	No	No	No	No	No	Yes		486-56-6
132	Cyclophosphamide	No	No	No	No	No	Yes	Not Requested		
133	Dapsone	No	No	No	No	No	Yes	Not Requested		
134	Dehydronifedipine	No	No	No	No	No	No	No	All No	67035-22-7
135	Demeclocycline	No	No	No	No	No	No	Yes		127-33-3
136	Desmethyl Citalopram	No	No	No	No	No	Yes	Not Requested		
137	Desmethyl Diazepam	No	No	No	No	No	Yes	Not Requested		
138	Diazepam (Valium)	No	No	No	No	No	Yes	Not Requested		439-14-5
139	Diclofenac	Yes	No	No	No	No	Yes	Not Requested		
140	Dicloxacillin	No	No	No	No	No	No	Yes		3119-76-5
141	Diltiazem	No	No	No	No	No	No	No	All No	
142	Dipyrone	No	No	No	No	No	No	No	All No	68-89-3
143	Doxycycline	No	No	No	No	No	No	Yes		564-25-0
144	Doxylamine	No	No	No	No	No	Yes	Yes		
145	Enalaprilat	No	No	No	No	No	No	No	All No	75847-73-3
146	Enrofloxacin	No	No	No	No	No	No	Yes		93106-60-6
147	Erythromycin	No	No	No	No	No	Probable	Yes		114-07-8
148	Etofibrate	No	No	No	No	No	No	No	All No	
149	Fenofibrate	No	No	No	No	No	No	No	All No	49562-28-9
150	Fenofibric acid	No	No	No	No	No	No	No	All No	42107-89-0
151	Fenoprofen	No	No	No	No	No	No	No	All No	29679-58-1
152	Fluoxetine	Yes	No	No	No	No	Yes	Yes		
153	Fluvastatin	No	No	No	No	No	Yes	Not Requested		
154	Frusemide	No	No	No	No	No	Yes	Yes		Furosemide - 54-31-9
155	Furazolidone	No	No	No	No	No	No	No	All No	67-45-8
156	Gabapentin	Yes	No	No	No	No	Yes	Not Requested		
157	Gemfibrozol	Yes	No	No	No	No	Yes	Not Requested		
158	Hydrochlorthiadzide	No	No	No	No	No	Yes	Not Requested		Hydrochlorthiazide - 58-93-5
159	Ibuprofen	Yes	No	No	No	No	Yes	Yes		
160	Ifosfamide	No	No	No	No	No	Yes	Not Requested		
161	Indomethacin	No	No	No	No	No	Yes	Not Requested		
162	Iodipamide	No	No	No	No	No	No	No	All No	606-17-7
163	Iohexol	No	No	No	No	No	No	No	All No	66108-95-0
164	Iomeprol	No	No	No	No	No	No	No	All No	78649-41-9
165	Iopamidol	No	No	No	No	No	No	No	All No	60166-93-0
166	Iopromide	No	No	No	No	No	Yes	Yes		
167	Iotalamic acid	No	No	No	No	No	No	No	All No	2276-90-6
168	Ioxaglic acid	No	No	No	No	No	No	No	All No	59017-64-0

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
169	Ioxithalamic acid	No	No	No	No	No	No	No	All No	Ioxitalamic acid - 28179-44-4
170	Isophosphamide	No	No	No	No	No	Yes	Not Requested		aka Ifosfamide - 3778-73-2
171	Ketoprofen	No	No	No	No	No	No	No	All No	22071-15-4
172	Levonorgestrel	Yes	No	No	No	No	No	Not Requested		797-63-7
173	Lincomycin	No	No	No	No	No	Yes	Not Requested		154-21-2
174	Metformin (1,1-Dimethylbiguanide)	No	No	No	No	No	No	No	All No	1,1-Dimethylbiguanide Hydrochloride - 657-24-9
175	Methampthetamine	Yes	No	No	No	No	Yes	Not Requested		537-46-2
176	Metronidazole	No	No	No	No	No	No	Yes		443-48-1
177	Metroprolol	No	No	No	No	No	Yes	Not Requested		37350-58-6
178	Monensin	No	No	No	No	No	No	No	All No	17090-79-8
179	Nadolol	No	No	No	No	No	No	No	All No	42200-33-9
180	Nafcillin	No	No	No	No	No	No	No	All No	985-16-0
181	Naladixic acid	No	No	No	No	No	No	No	All No	389-08-2
182	Naproxen	Yes	No	No	No	No	Yes	Not Requested		
183	Norfloxacin	No	No	No	No	No	No	Yes		70458-96-7
184	Oleandomycin	No	No	No	No	No	No	No	All No	3922-90-5
185	Oxacillin	No	No	No	No	No	No	No	All No	66-79-5
186	Oxazepam	No	No	No	No	No	Yes	Not Requested		
187	Oxycodone	No	No	No	No	No	Yes	Not Requested		
188	Oxytetracycline	No	No	No	No	No	No	Yes		79-57-2
189	Paracetamol	Yes	No	No	No	No	Yes	Not Requested		
190	Penicillin G	No	No	No	No	No	No	No	All No	61-33-6
191	Penicillin V	No	No	No	No	No	No	Yes		87-08-1
192	Pentoxifylline	No	No	No	No	No	No	No	All No	6493-05-6
193	Phenytoin	No	No	No	No	No	Yes	Not Requested		
194	Praziquantel	No	No	No	No	No	Yes	Not Requested		
195	Propranolol	Yes	No	No	No	No	Yes	Not Requested		
196	Ranitidine	Yes	No	No	No	No	Yes	Not Requested		
197	Ronidazole	No	No	No	No	No	No	No	All No	7681-76-7
198	Roxithromycin	No	No	No	No	No	Yes	Not Requested		
199	Salicylic acid	No	No	No	No	No	Yes	Not Requested		69-72-7
200	Salbutamol	No	No	No	No	No	No	No	All No	18559-94-9
201	Sertraline	Yes	No	No	No	No	Yes	Not Requested		
202	Simvastatin	No	No	No	No	No	No	No	All No	79902-63-9
203	Spiramycin	No	No	No	No	No	No	Yes		8025-81-8
204	Sulfsalazine	No	No	No	No	No	Yes	Not Requested		Sulfasalazine - 599-79-1
205	Sulphadiazine	No	No	No	No	No	Yes	Not Requested		68-35-9
206	Sulphadimidine	No	No	No	No	No	No	No	All No	57-68-1
207	Sulphamerazine	No	No	No	No	No	No	No	All No	127-79-7
208	Sulphamethoxazole	Yes	No	No	No	No	Yes	Not Requested		723-46-6
209	Sulfamethoxine	No	No	No	No	No	No	No	All No	
210	Sulfamethazine	No	No	No	No	No	No	Yes		57-68-1
211	Sulfamethizole	No	No	No	No	No	No	Yes		144-82-1

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
212	Sulphathiazole	No	No	No	No	No	Yes	Not Requested		72-14-0
213	Temazepam	No	No	No	No	No	Yes	Not Requested		
214	Terbutaline	No	No	No	No	No	No	No	All No	23031-25-6
215	Tetracycline	No	No	No	No	No	No	Yes		60-54-8
216	Timolol	No	No	No	No	No	No	No	All No	26839-75-8
217	Tolfenamic acid	No	No	No	No	No	No	No	All No	13710-19-5
218	Tramadol	Yes	No	No	No	No	Yes	Not Requested		
219	Triclosan	Yes	No	No	No	Yes	Yes	Not Requested		
220	Trimethoprim	No	No	No	No	No	Yes	Not Requested		
221	Tylosin	No	No	No	No	No	Yes	Not Requested		
222	Venlafaxine	Yes	No	No	No	No	Yes	Not Requested		
223	Warfarin	No	No	No	No	Yes	Yes	Not Requested		
Endocrine Disrupting Compounds/Estrogenic & Androgenic Hormones										
224	Androsterone	Yes	No	No	No	No	Yes	Not Requested		
225	Bisphenol A	Yes	No	No	No	No	Yes	Not Requested		
226	Cholesterol (not an EDC)	Yes	No	No	No	No	Yes	Not Requested		
227	Equilenin	Yes	No	No	No	No	Yes	Not Requested		
228	Equilin	Yes	No	No	No	No	Yes	Not Requested		
229	17-alpha-estradiol	Yes	No	No	No	No	Yes	Not Requested		
230	17-beta-estradiol	Yes	No	No	No	No	Yes	Not Requested		
231	Estriol	Yes	No	No	No	No	Yes	Not Requested		
232	Estrone	Yes	No	No	No	No	Yes	Not Requested		
233	17-alpha-ethynylestradiol	Yes	No	No	No	No	Yes	Not Requested		
234	Eticholanolone	Yes	No	No	No	No	Yes	Not Requested		
235	Mestranol	Yes	No	No	No	No	Yes	Not Requested		
236	Nonylphenol	Yes	No	No	No	No	Yes	Not Requested		
237	4-Nonylphenol	Yes	No	No	No	No	Yes	Not Requested		Measured as total nonylphenol
238	Norethindrone	Yes	No	No	No	No	Yes	Not Requested		
239	Norgestrel	Yes	No	No	No	No	Yes	Not Requested		
240	4-t-Octyphenol	Yes	No	No	No	No	Yes	Not Requested		
241	Progesterone	Yes	No	No	No	No	Yes	Not Requested		
242	Testosterone	Yes	No	No	No	No	Yes	Not Requested		
Monocyclic Aromatic Hydrocarbons										
243	Benzene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
244	Toluene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
245	Ethylbenzene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
246	meta- & para-Xylene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
247	Styrene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
248	ortho-Xylene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
249	Isopropylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
250	n-Propylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
251	1,3,5-Trimethylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
252	sec-Butylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
253	1,2,4-Trimethylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
254	tert-Butylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
255	p-Isopropyltoluene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		4-isopropyltoluene
256	n-Butylbenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Oxygenated Compounds										
257	Vinyl Acetate	Yes	Yes	No	Yes	Yes	No	Not Requested		
258	Acetophenone	Yes	Yes	No	Yes	Yes	No	Not Requested		
259	2-Butanone (MEK)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
260	4-Methyl-2-pentanone (MIBK)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
261	2-Hexanone (MBK)	Yes	Yes	No	Yes	No	Yes	Not Requested		
Sulfonated Compounds										
262	Carbon disulfide	Yes	Yes	No	No	Yes	Yes	Not Requested		
Fumigants										
263	2,2-Dichloropropane	Yes	Yes	No	No	No	Yes	Not Requested		
264	1,2-Dichloropropane	Yes	Yes	No	No	Yes	Yes	Not Requested		
265	cis-1,3-Dichloropropylene	Yes	Yes	No	No	No	Probable	Not Requested		
266	trans-1,3-Dichloropropylene	Yes	Yes	No	No	No	Yes	Not Requested		
267	1,2-Dibromoethane (EDB)	Yes	Yes	No	No	Yes	Yes	Not Requested		
Halogenated Aliphatic Compounds										
268	Dichlorodifluoromethane	Yes	Yes	No	Yes	Yes	No	Not Requested		75-71-8
269	Chloromethane	Yes	Yes	No	Yes	Yes	No	Not Requested		74-87-3
270	Vinyl chloride	Yes	Yes	No	Yes	Yes	No	Not Requested		75-01-4
271	Bromomethane	Yes	Yes	No	Yes	Yes	No	Not Requested		74-83-9
272	Chloroethane	Yes	Yes	No	Yes	Yes	No	Not Requested		75-00-3
273	Trichlorofluoromethane	Yes	Yes	No	Yes	Yes	No	Not Requested		75-69-4
274	1,1-Dichloroethene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
275	trans-1,2-Dichloroethene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
276	1,1-Dichloroethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
277	Iodomethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
278	cis-1,2-Dichloroethene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
279	1,1,1-Trichloroethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
280	Carbon Tetrachloride	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
281	1,2-Dichloroethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
282	Trichloroethene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
283	1,1-Dichloropropylene	Yes	Yes	No	Yes	No	Yes	Not Requested		563-58-6
284	Tetrachloroethene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
285	1,1,1,2-Tetrachloroethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
286	1,1,2,2-Tetrachloroethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
287	Hexachlorobutadiene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
288	Dibromomethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
289	1,1,2-Trichloroethane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
290	1,3-Dichloropropane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
291	trans-1,4-Dichloro-2-butene	Yes	Yes	No	Yes	No	Yes	Not Requested		110-57-6
292	cis-1,4-Dichloro-2-butene	Yes	Yes	No	Yes	No	Yes	Not Requested		1476-11-5
293	1,2,3-Trichloropropane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
294	Pentachloroethane	Yes	Yes	No	Yes	No	Probable	Not Requested		76-01-7
295	1,2-Dibromo-3-chloropropane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
296	Dichloromethane	Yes	Yes	No	Yes	No	Probable	Not Requested		75-09-2
Halogenated Aromatic Compounds										
297	Benzyl Chloride	Yes	Yes	No	Yes	Yes	No	Not Requested		100-44-7
298	Bromobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
299	Chlorobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
300	2-Chlorotoluene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
301	4-Chlorotoluene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
302	1,3-Dichlorobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
303	1,4-Dichlorobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
304	1,2-Dichlorobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
305	1,2,4-Trichlorobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
306	1,2,3-Trichlorobenzene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Aliphatic Hydrocarbons										
307	Cyclohexane	Yes	Yes	No	No	No	No	Not Requested		12217-02-6 and others
308	Hexane	Yes	Yes	Yes	No	Yes	No	Not Requested		110-54-3
Phthalate Esters										
309	Dimethyl phthalate	Yes	No	No	No	Yes	No	Not Requested		131-11-3
310	Diethyl phthalate	Yes	No	No	No	Yes	No	Not Requested		68988-18-1 and others
311	Di-n-butyl phthalate	Yes	No	No	No	Yes	No	Not Requested		84-74-2
312	Butyl benzyl phthalate	Yes	No	No	No	Yes	No	Not Requested		85-68-7
313	bis(2-ethylhexyl) phthalate	Yes	No	No	No	Yes	No	Not Requested		82208-43-3 and others
314	Di-n-octylphthalate	Yes	No	No	No	No	No	Not Requested		117-84-0
Chlorinated Hydrocarbons										
315	1,3-Dichlorobenzene	Yes	Yes	No	No	Yes	Yes	Not Requested		
316	1,4-Dichlorobenzene	Yes	Yes	No	No	Yes	Yes	Not Requested		
317	1,2-Dichlorobenzene	Yes	Yes	No	No	Yes	Yes	Not Requested		
318	Hexachloroethane	Yes	Yes	No	No	Yes	Yes	Not Requested		
319	1,2,4-Trichlorobenzene	Yes	Yes	No	No	Yes	Yes	Not Requested		
320	Hexachloropropylene	Yes	Yes	No	No	No	No	Not Requested		188-71-7
321	Hexachlorobutadiene	Yes	Yes	No	No	Yes	Yes	Not Requested		
322	Hexachlorocyclopentadiene	Yes	Yes	No	No	Yes	No	Not Requested		77-47-4
323	Pentachlorobenzene	Yes	Yes	No	No	Yes	No	Not Requested		608-93-5
324	Hexachlorobenzene (HCB)	Yes	Yes	Yes	No	Yes	Yes	Not Requested		118-74-1
Organotin Compounds										
325	Dibutyl tin	Yes	Yes	No	Yes	Yes	No	Not Requested		1002-53-5
326	Diphenyl tin	No	No	No	Yes	No	No	Not Requested		1011-95-6
327	Monobutyl tin	Yes	Yes	No	Yes	Yes	No	Not Requested		78763-54-9
328	Monophenyl tin	No	No	No	Yes	No	No	Not Requested		1124-19-2 phenyltin trichloride.
329	Tetrabutyl tin	No	No	No	Yes	No	No	Not Requested		1461-25-2
330	Tributyl tin	Yes	Yes	No	Yes	Yes	No	Not Requested		688-73-3
331	Triphenyl tin	No	No	No	Yes	No	No	Not Requested		639-58-7

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
Phenolic Compounds										
332	2-sec-Butylphenol	No	Yes	No	No	No	No	Not Requested		89-72-5
333	2,6-di-tert-butylphenol (2,6-bis(1,1-dimethylethyl)phenol)	No	Yes	No	No	No	Yes	Not Requested		128-39-2
334	2-Chlorophenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
335	4-Chlorophenol	Yes	Yes	No	No	Yes	Yes	Not Requested		
336	4-Chloro-3-Methylphenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
337	m-Cresol	Yes	Yes	No	No	Yes	Probable	Not Requested		108-39-4 3-methylphenol
338	o-Cresol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		95-48-7 2-methylphenol
339	p-Cresol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		106-44-5 4-methyl phenol
340	4-cumylphenol	Yes	Yes	No	No	No	Yes	Not Requested		599-64-4
341	Cyclohexyphenol	No	Yes	No	No	No	No	Not Requested		There are multiple cyclohexylphenols - 2-, 3- and 4- (ortho, meta and para-)
342	2,4-Dimethylphenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
343	Hexachlorophene	Yes	Yes	No	No	No	No	Not Requested		70-30-4
344	2-Nitrophenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
345	4-Nitrophenol	Yes	Yes	No	No	Yes	Yes	Not Requested		
346	4 n-Octylphenol	Yes	Yes	No	No	No	No	Not Requested		1806-26-4 and others; 4-octylphenol
347	4-tert Octylphenol	Yes	Yes	No	No	No	Yes	Not Requested		140-66-9
348	Pentachlorophenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
349	Phenol	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
350	Tetrachlorophenol	Yes	Yes	No	No	Yes	No	Not Requested		58-90-2 (2,3,4,6-TTP); however, there would be other TTPs, like 2,3,4,5-TTP.
351	2,4,5-Trichlorophenol	Yes	Yes	Yes	No	Yes	Yes	Not Requested		
Polynuclear Aromatic Hydrocarbons										
352	3-Methylcholanthrene	Yes	Yes	No	Yes	Yes	No	Not Requested		56-49-5
353	2-Methylnaphthalene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
354	7,12-Dimethylbenz(a)anthracene	Yes	Yes	No	Yes	Yes	No	Not Requested		57-97-6
355	Acenaphthene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
356	Acenaphthylene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
357	Anthracene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
358	Benz(a)anthracene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
359	Benzo(a)pyrene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
360	Benzo(b)fluoranthene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
361	Benzo(e)pyrene	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
362	Benzo(g,h,i)perylene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		191-24-2
363	Benzo(k)fluoranthene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		207-08-9
364	Chrysene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
365	Coronene	Yes	Yes	No	Yes	No	No	Not Requested		191-07-1
366	Dibenz(a,h)anthracene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
367	Fluoranthene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
368	Fluorene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
369	Indeno(1,2,3,cd)pyrene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		193-39-5
370	N-2-Fluorenyl Acetamide	No	Yes	No	Yes	No	No	Not Requested		53-96-3
371	Naphthalene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
372	Perylene	Yes	Yes	No	Yes	No	Yes	Not Requested		
373	Phenanthrene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
374	Pyrene	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
375	Sum of PAHs	Yes	Yes	Yes	Yes	Yes	Prob	Not Requested		
Chlorinated Napthalenes										
376	1-Chloronaphthalene	Yes	No	No	No	No	No	Not Requested		90-13-1
377	2-Chloronaphthalene	Yes	No	No	No	No	No	Not Requested		91-58-7
378	Chloronaphthalenes (1- + 2-)	Yes	No	No	No	No	No	Not Requested		
379	Trichloronaphthalene	No	No	No	No	No	No	Not Requested		1321-65-9 (1,2,3-trichloronaphthalene)
Organophosphorus Pesticides										
380	Acephate	Yes	Yes	No	Yes	No	No	Not Requested		30560-19-1
381	Azinphos methyl	Yes	Yes	No	Yes	No	Yes	Not Requested		86-50-0
382	Bromophos-ethyl	Yes	Yes	No	Yes	No	Yes	Not Requested		
383	Cadusafos	No	Yes	No	Yes	No	Yes	Not Requested		
384	Carbophenothion	Yes	Yes	No	Yes	No	Yes	Not Requested		
385	Chlorfenvinphos (Z)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		470-90-6
386	Chlorpyrifos	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
387	Chlorpyrifos-methyl	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
388	Chlorpyrifos oxon	Yes	Yes	No	Yes	No	Yes	Not Requested		
389	Coumaphos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
390	Demeton-S-methyl	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
391	Diazinon	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
392	Dichlorvos	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
393	Dimethoate	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
394	Disulfoton	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
395	Ethion	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
396	Ethoprophos	Yes	Yes	No	Yes	No	Yes	Not Requested		
397	Etrimphos	No	Yes	No	Yes	No	Yes	Not Requested		
398	Famphur	No	Yes	No	Yes	No	Yes	Not Requested		
399	Fenamiphos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
400	Fenchlorphos	Yes	Yes	Yes	Yes	No	Yes	Not Requested		
401	Fenitrothion	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
402	Fensulfothion	No	Yes	No	Yes	Yes	No	Not Requested		115-90-2
403	Fenthion	Yes	Yes	Yes	Yes	Yes	No	Not Requested		
404	Fenthion ethyl	No	Yes	No	Yes	No	Yes	Not Requested		55-38-9 (methyl fenthion)
405	Fenthion methyl	No	Yes	No	Yes	No	Yes	Not Requested		1716-09-2 (ethyl fenthion)
406	Formothion	No	Yes	No	Yes	No	No	Not Requested		2540-82-1
407	Isophenphos	No	Yes	No	Yes	No	Yes	Not Requested		25311-71-1
408	Malathion	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		121-75-5
409	Methidathion	Yes	Yes	No	Yes	No	Yes	Not Requested		
410	Mevinphos	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
411	Monocrotophos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
412	Parathion	Yes	Yes	Yes	Yes	Yes	No	Not Requested		
413	Parathion ethyl	Yes	Yes	No	Yes	Yes	Yes	Not Requested		56-38-2

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
414	Parathion methyl	Yes	Yes	Yes	Yes	No	Yes	Not Requested		298-00-0
415	Phorate	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
416	Phosmet	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
417	Pirimiphos ethyl	Yes	Yes	No	Yes	No	No	Not Requested		
418	Pirimiphos methyl	Yes	Yes	No	Yes	No	Yes	Not Requested		29232-93-7
419	Profenofos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
420	Prothiofos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		34643-46-4
421	Pyrazophos	No	Yes	No	Yes	Yes	Yes	Not Requested		
422	Sulprofos	No	Yes	No	Yes	No	Yes	Not Requested		
423	Temephos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
424	Tetrachlorvinphos	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
425	Terbufos	No	Yes	No	Yes	Yes	Yes	Not Requested		
426	Thiometon	No	Yes	No	Yes	No	No	Not Requested		640-15-3
427	Trichlorfon	Yes	Yes	No	Yes	No	No	Not Requested		52-68-6 and others
Organochlorine Pesticides										
428	4,4`-DDD	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		72-54-8
429	4,4`-DDE	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		72-55-9
430	4,4`-DDT	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		50-29-3
431	Aldrin	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		309-00-2
432	Azinphos ethyl	Yes	Yes	No	Yes	No	Yes	Not Requested		2642-71-9
433	BHC-alpha	Yes	Yes	Yes	Yes	No	Yes	Not Requested		319-84-6
434	BHC-beta	Yes	Yes	Yes	Yes	No	Yes	Not Requested		319-85-7
435	BHC-delta	Yes	Yes	Yes	Yes	No	Yes	Not Requested		319-86-8
436	BHC-gamma	Yes	Yes	Yes	Yes	No	Yes	Not Requested		58-89-9
437	Chlordane cis	Yes	Yes	Yes	Yes	No	Yes	Not Requested		5103-71-9
438	Chlordane gamma	Yes	Yes	No	Yes	No	No	Not Requested		
439	Chlordane Trans	Yes	Yes	Yes	Yes	No	Yes	Not Requested		5103-74-2
440	Chlordane (sum)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
441	Chlordene	No	Yes	No	Yes	No	Yes	Not Requested		
442	Chlordene Epoxide	No	Yes	No	Yes	No	Yes	Not Requested		
443	DDD (o,p)	Yes	Yes	No	Yes	No	Yes	Not Requested		53-19-0
444	DDD (p,p)	Yes	Yes	No	Yes	No	Yes	Not Requested		72-54-8
445	DDE (o,p)	Yes	Yes	No	Yes	No	Yes	Not Requested		3424-82-6
446	DDE (p,p)	Yes	Yes	No	Yes	No	Yes	Not Requested		72-55-9
447	DDT (o,p)	Yes	Yes	No	Yes	No	Yes	Not Requested		789-02-6
448	DDT (p,p)	Yes	Yes	No	Yes	No	Yes	Not Requested		20-29-3
449	DDT (total)	Yes	Yes	No	Yes	No	Yes	Not Requested		
450	Dicofol	Yes	Yes	No	Yes	No	No	Not Requested		115-32-2
451	1,3 Dichloropropene	Yes	Yes	No	Yes	No	Probable	Not Requested		542-75-6
452	Dieldrin	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		60-57-1
453	Endosulfan alpha	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		959-98-8
454	Endosulfan beta	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		33213-65-9
455	Endosulfan sulfate	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		1031-07-8
456	Endosulfan Ehter	No	Yes	No	Yes	No	Yes	Not Requested		Endosulfan Ether: 3369-52-6

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
457	Endosulfan Lactone	No	Yes	No	Yes	No	Yes	Not Requested		3868-61-9
458	Endosulfan (sum)	Yes	Yes	No	Yes	No	Yes	Not Requested		
459	Endrin	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
460	Endrin aldehyde	No	Yes	Yes	Yes	Yes	Yes	Not Requested		
461	Endrin ketone	Yes	Yes	Yes	Yes	Yes	Probable	Not Requested		
462	Heptachlor	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		76-44-8
463	Heptachlor epoxide	Yes	Yes	Yes	Yes	Yes	No	Not Requested		Heptachlor endo epoxide 1024-57-3
464	Hexachlorobenzene (HCB)	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		118-74-1
465	HCH alpha	Yes	Yes	No	Yes	Yes	No	Not Requested		
466	HCH beta	Yes	Yes	No	Yes	Yes	No	Not Requested		
467	HCH delta	Yes	Yes	No	Yes	Yes	No	Not Requested		
468	Heptachlor	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
469	Heptachlor Epoxide	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		Heptachlor exo epoxide 1024-57-3
470	Lindane	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		58-89-9
471	Methoxychlor	Yes	Yes	Yes	Yes	Yes	Yes	Not Requested		
472	Nonachlor trans	Yes	Yes	No	Yes	No	Yes	Not Requested		39765-80-5
473	Oxychlordane	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Carbamate Pesticides by Liquid Chromatography Mass Spectrometry										
474	Aldicarb	Yes	Yes	No	No	Yes	Yes	Not Requested		
475	Bendiocarb	No	Yes	No	No	Yes	Yes	Not Requested		
476	Carbofuran	Yes	Yes	No	No	Yes	Yes	Not Requested		
477	3-Hydroxy Carbofuran	No	Yes	No	No	No	Yes	Not Requested		16655-82-6
478	Carbaryl	Yes	Yes	No	No	Yes	Yes	Not Requested		
479	Oxamyl	Yes	Yes	No	No	Yes	Yes	Not Requested		
480	Methiocarb	Yes	Yes	No	No	Yes	Yes	Not Requested		
481	Methomyl	Yes	Yes	No	No	Yes	Yes	Not Requested		
482	Thiodicarb	Yes	Yes	No	No	No	Yes	Not Requested		
Glyphosate and AMPA										
483	AMPA	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
484	Glyphosate	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Quaternary Ammonium Herbicides										
485	Diquat	Yes	Yes	No	No	No	Yes	Not Requested		
486	Paraquat	Yes	Yes	No	No	No	Yes	Not Requested		
Phenoxyacid Herbicides, Dalapon										
487	2,4-D	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
488	Dalapon	Yes	Yes	No	Yes	No	Yes	Not Requested		75-99-0
489	2,4-DB	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
490	Dicamba	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
491	2,4-DP	Yes	Yes	No	Yes	Yes	No	Not Requested		2,4-D: 94-75-7
492	Fluroxypyr	Yes	Yes	No	Yes	No	Yes	Not Requested		
493	MCPA	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
494	MCPB	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
495	Mecoprop	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
496	Picloram	Yes	Yes	No	Yes	Yes	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
497	Triclopyr	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Herbicides by Liquid Chromatography Mass Spectrometry										
498	Ametryn	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
499	Atrazine	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
500	desethyl Atrazine	Yes	Yes	No	Yes	No	Yes	Not Requested		
501	desisopropyl Atrazine	Yes	Yes	No	Yes	No	Yes	Not Requested		
502	Bromacil	Yes	Yes	No	Yes	No	Yes	Not Requested		
503	Carbaryl	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
504	DEET	Yes	Yes	No	Yes	No	Yes	Not Requested		134-62-3
505	Diazinon	Yes	Yes	No	Yes	Yes	Yes	Not Requested		duplication - also in organophosphate pesticides
506	3,4 Dichloroaniline	No	Yes	No	Yes	No	Yes	Not Requested		95-76-1
507	Diuron	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
508	Fluometuron	Yes	Yes	No	Yes	Yes	Yes	Not Requested		duplication - also in item 563 in "other herbicides".
509	Hexazinone	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
510	Metolachlor	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
511	Prometryn	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
512	Propoxur	Yes	Yes	No	Yes	Yes	Yes	Not Requested		duplication - also in item 585 in "other herbicides".
513	Simazine	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
514	Tebuthiuron	Yes	Yes	No	Yes	No	Yes	Not Requested		
515	Terbutryn	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Herbicides by Gas Chromatography Mass Spectrometry										
517	Aldrin	Yes	Yes	No	Yes	Yes	No	Not Requested		309-00-2
518	Allethrin	No	Yes	No	Yes	Yes	Yes	Not Requested		
519	Bifenthrim	Yes	Yes	No	Yes	Yes	Yes	Not Requested		82657-04-3
520	Bioresmethrin	Yes	Yes	No	Yes	No	Yes	Not Requested		
521	Cyfluthrin	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
522	lambda-Cyhalothrin	Yes	Yes	No	Yes	No	Yes	Not Requested		
523	Cypermethrin	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
524	Deltamethrin	Yes	Yes	No	Yes	No	Yes	Not Requested		
525	Diclofop methyl	Yes	Yes	No	Yes	No	Yes	Not Requested		51338-27-3
526	Fenvalerate	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
527	Fluvatine	No	Yes	No	Yes	No	No	Not Requested		
528	Haloxyfop 2-etotyl	No	Yes	No	Yes	No	Yes	Not Requested		87237-48-7
529	Haloxyfop methyl	Yes	Yes	No	Yes	No	Yes	Not Requested		69806-40-2
530	Metribuzin	Yes	Yes	No	Yes	No	Yes	Not Requested		
531	Oxyfluorfen	Yes	Yes	No	Yes	No	Yes	Not Requested		
532	Pendimethalin	Yes	Yes	No	Yes	No	Yes	Not Requested		
533	Peremethrin	No	Yes	No	Yes	No	Yes	Not Requested		Permethrin - insecticide - 52645-53-1
534	Phenothrin	No	Yes	No	Yes	Yes	Yes	Not Requested		
535	Propanil	Yes	Yes	No	Yes	No	Yes	Not Requested		
536	Propazine	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
537	Terbuthylazine	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
538	Tertamethrin	No	Yes	No	Yes	No	Yes	Not Requested		Tetramethrin - 7696-12-0
539	Tri-allate	No	Yes	No	Yes	No	Yes	Not Requested		2303-17-5

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
540	Transfluthrin	No	Yes	No	Yes	No	Yes	Not Requested		
541	Trifluralin	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
Other Herbicides/Pesticides/Fungicides										
542	2,4,5-T	Yes	Yes	No	Yes	No	Yes	Not Requested		
543	Alachlor	Yes	Yes	No	Yes	No	No	Not Requested		15972-60-8
544	Benalaxyl	Yes	Yes	No	Yes	No	Yes	Not Requested		
545	Bentazone	Yes	Yes	No	Yes	No	No	Not Requested		25057-89-0
546	Bitertinol	No	Yes	No	Yes	No	Yes	Not Requested		55179-31-2
547	Butylate	No	Yes	No	Yes	No	No	Not Requested		2008-41-5
548	Carbaryl	Yes	Yes	No	Yes	Yes	Yes	Not Requested		duplication - also in LCMS herbicide list and carbamate pesticides list.
549	Carbendazim	Yes	Yes	No	Yes	No	Yes	Not Requested		
550	Carboxin	No	Yes	No	Yes	No	No	Not Requested		5234-68-4
551	n-Carboxymethyl imino bis(ethylenedinitrilo)tetra	No	Yes	No	Yes	No	No	Not Requested		
552	Cycloate	No	Yes	No	Yes	No	No	Not Requested		1134-23-2
553	Clopyralid	Yes	Yes	No	Yes	No	Yes	Not Requested		
554	Dichlobenil	Yes	Yes	No	Yes	No	No	Not Requested		1194-65-6
555	Dichlorfluanid	No	Yes	No	Yes	No	No	Not Requested		Dichlofluanid - 1085-98-9
556	Dichloran	No	Yes	No	Yes	No	No	Not Requested		99-30-9
557	Diphenamid	No	Yes	No	Yes	No	No	Not Requested		957-51-7
558	Endothal	No	Yes	No	Yes	No	Yes	Not Requested		145-73-3
559	EPTC	Yes	Yes	No	Yes	No	No	Not Requested		S-ethyl dipropyl thiocarbamate 759-94-7
560	Fenarimol	Yes	Yes	No	Yes	No	No	Not Requested		60168-88-9
561	Fenoprop	Yes	Yes	No	Yes	No	Yes	Not Requested		93-72-1
562	Fipronil	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
563	Fluometuron	Yes	Yes	No	Yes	Yes	Yes	Not Requested		2164-17-2
564	Furalaxyl	Yes	Yes	No	Yes	No	Yes	Not Requested		
565	Linuron	Yes	Yes	No	Yes	No	No	Not Requested		330-55-2
566	Metalaxyl	Yes	Yes	No	Yes	No	Yes	Not Requested		
567	Metasulfuron-methyl	Yes	Yes	No	Yes	No	Yes	Not Requested		74223-64-6
568	Methabenzthiazuron	No	Yes	No	Yes	No	No	Not Requested		18691-97-9
569	Methamidophos	No	Yes	No	Yes	No	No	Not Requested		10265-92-6
570	Molinate	Yes	Yes	No	Yes	Yes	Yes	Not Requested		2212-67-1
571	Napropamide	Yes	Yes	No	Yes	No	Yes	Not Requested		
572	Norflurazon	No	Yes	No	Yes	No	No	Not Requested		27314-13-2
573	Oryzalin	No	Yes	No	Yes	No	No	Not Requested		19044-88-3
574	Oxadiazinon	No	Yes	No	Yes	No	No	Not Requested		19666-30-9
575	Pebulate	Yes	Yes	No	Yes	No	No	Not Requested		1114-71-2
576	Permethrin	Yes	Yes	No	Yes	Yes	No	Not Requested		52645-53-1
577	2-Phenylphenol	No	Yes	No	Yes	No	No	Not Requested		90-43-7
578	Piperonyl Butoxide	Yes	Yes	No	Yes	No	Yes	Not Requested		
579	Pirimicarb	Yes	Yes	No	Yes	No	Yes	Not Requested		
580	Procymidone	Yes	Yes	No	Yes	No	Yes	Not Requested		
581	Promecarb	No	Yes	No	Yes	No	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
582	Propachlor	Yes	Yes	No	Yes	No	Yes	Not Requested		
583	Propargite	Yes	Yes	No	Yes	No	Yes	Not Requested		
584	Propiconazole	Yes	Yes	No	Yes	No	Yes	Not Requested		
585	Propoxur	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
586	Propyzamide	Yes	Yes	No	Yes	No	No	Not Requested		23950-58-5
587	Quintozene	Yes	Yes	No	Yes	No	Yes	Not Requested		82-68-8
588	Tebuconazole	Yes	Yes	No	Yes	No	Yes	Not Requested		
589	Terbacil	No	Yes	No	Yes	No	No	Not Requested		5902-51-2
590	Tertadifon	No	Yes	No	Yes	No	Yes	Not Requested		Tetradifon: 116-29-0
591	Thiophanate-methyl	No	Yes	No	Yes	No	Yes	Not Requested		23564-05-8
592	Triadimefon	No	Yes	No	Yes	No	Yes	Not Requested		43121-43-3
593	Vernolate	Yes	Yes	No	Yes	No	No	Not Requested		1929-77-7
594	Vinclozolin	No	Yes	No	Yes	No	Yes	Not Requested		
Radiological										
595	Be-7	No	No	No	No	No	Yes	Not Requested		
596	Cr-51	No	No	No	No	No	Yes	Not Requested		
597	Co-57	No	No	No	No	No	Yes	Not Requested		
598	Ga-67	No	No	No	No	No	Yes	Not Requested		
599	Tc-99m	No	No	No	No	No	Yes	Not Requested		
600	In-111	No	No	No	No	No	Yes	Not Requested		
601	I-123	No	No	No	No	No	Yes	Not Requested		
602	I-125	No	No	No	No	No	No	Not Requested		
603	I-131	No	No	No	No	No	Yes	Not Requested		
604	Sm-153	No	No	No	No	No	Yes	Not Requested		
605	Lu-177	No	No	No	No	No	Yes	Not Requested		
606	Tl-201	No	No	No	No	No	Yes	Not Requested		
607	U-238	No	Yes	No	No	Yes	Yes	Not Requested		
608	Ra-226	No	Yes	No	No	Yes	Yes	Not Requested		
609	Pb-210	No	Yes	No	No	Yes	Yes	Not Requested		
610	Ra-224	No	No	No	No	No	Yes	Not Requested		
611	Ra-228	No	Yes	No	No	Yes	Yes	Not Requested		
612	Gross Alpha	No	Yes	No	No	Yes	Yes	Not Requested		
613	Gross Beta	No	Yes	No	No	Yes	Yes	Not Requested		
614	Gross Beta (-40K)	No	Yes	No	No	No	Yes	Not Requested		
615	Gross Gamma	No	No	No	No	No	Yes	Not Requested		
Other Chemicals										
616	n-nitroso dicyclohexylamine	No	No	No	No	No	No	Not Requested		947-92-2
617	Methylglycinediacetic acid	No	No	No	No	No	No	Not Requested		
618	1,7-Dimethylxanthine	No	No	No	No	No	Yes	Not Requested		611-59-6
619	Coprastanol	Yes	No	No	No	No	No	Not Requested		360-68-9
620	Coumarin	No	No	No	No	No	Yes	Not Requested		

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
621	2,6-di-tert-butyl-1,4-benzoquinone (2,6-bis(1,1-dimethylethyl)-2,5-Cyclohexadiene-1,4-dione)	No	No	No	No	No	No	Not Requested		
622	5-methyl-1Hbenzotriazole	No	No	No	No	No	Yes	Not Requested		136-85-6
623	2,5-Dihydroxybenzoic acid	No	No	No	No	No	No	Not Requested		490-79-9
624	Diatrizoate Sodium	No	No	No	No	No	Yes	Not Requested		737-31-5
625	Diatrizoic acid	No	No	No	No	No	No	Not Requested		117-96-4
626	Butylated hydroxytoluene (2,6-Di-tert-Butyl-pCresol)	Yes	No	No	No	No	Yes	Not Requested		128-37-0
627	Butylated hydroxyanisole (3-tert-butyl-4-hydroxy anisole)	No	No	No	No	No	No	Not Requested		25013-16-5
628	Chlorophene	No	No	No	No	No	Yes	Not Requested		120-32-1
629	Phthalic anhydride	No	No	No	No	No	No	Not Requested		85-44-9
630	Stigmastanol	No	No	No	No	No	No	Not Requested		83-45-4
631	Tributyl phosphate	Yes	No	No	No	No	Yes	Not Requested		123-76-8
632	Tri(butyl cellosolve) phosphate (ethanol,2-butoxy-phosphate)	No	No	No	No	No	Yes	Not Requested		78-51-3
633	Triphenyl phosphate	Yes	No	No	No	No	No	Not Requested		115-86-6
Fire Retardants										
634	Fyrol FR 2 (tri(dichlorisopropyl) phosphate)	No	No	No	No	No	Yes	Not Requested		13674-87-8
635	Tris(2- chloroethyl)phosphate (TCEP)	No	No	No	No	No	Yes	Not Requested		115-96-8
Dioxins and Dioxin-like Compounds										
636	2,3,3',4,4',5-Hexachlorobiphenyl (PCB156)	Yes	Yes	No	No	Yes	Yes	Not Requested		38380-08-4
637	2,3,3',4,4'-pentachlorobiphenyl (PCB105)	Yes	Yes	No	No	Yes	Yes	Not Requested		
638	2,3',4,4',5-Pentachlorobiphenyl (PCB118)	Yes	Yes	No	No	Yes	Yes	Not Requested		31508-00-6
639	2,4,5,3',4',5'-Hexachlorobiphenyl (PCB167)	Yes	Yes	No	No	Yes	Yes	Not Requested		52663-72-6
640	2,7-Dichlorodibenzo-pdioxin (DCDD)	No	Yes	No	No	No	No	Not Requested		33857-26-0
641	3,4,5,3',4',5'-Hexachlorobiphenyl (PCB169)	Yes	Yes	No	No	Yes	Yes	Not Requested		32774-16-6
642	Octachlorodibenzo-pdioxin (OCDD)	Yes	Yes	No	No	No	No	Not Requested		3268-87-9
643	PCB77	Yes	Yes	No	No	Yes	Yes	Not Requested		32598-13-3

Laboratory Responses (continued)

Parameter No.	Parameter	ENVIROLAB	ALS	TWEED LAB	EAL	EUROFINS	QLD Health	QAEHS	All No's incl. QAEHS	CAS No./other notes
Fragrances										
644	2,4,6-Trinitro-1,3-dimethyl-5-tertbutylbenzene (musk xylene)	No	No	No	No	No	Yes	Not Requested		81-15-2
645	4-Acetyl-6-t-butyl-1,1-dimethylindan	No	No	No	No	No	No	Not Requested		13171-00-1 (Celestolide)
646	6-Acetyl-1,1,2,4,4,7-hexamethyltetraline	No	No	No	No	No	No	Not Requested		
647	Galaxolide	Yes	No	No	No	No	Yes	Not Requested		1222-05-5
648	Musk ketone	No	No	No	No	No	Yes	Not Requested		
649	Musk tibetene	No	No	No	No	No	No	Not Requested		145-39-1
650	Pentamethyl-4,6-dinitroindane	No	No	No	No	No	No	Not Requested		116-66-5 Musk Moskene
PFAS Compounds										
651	Perfluorooctanoic acid (PFOA)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
652	Perfluorooctane sulfonate (PFOS)	Yes	Yes	No	Yes	Yes	Prob - have most other PFAS compounds	Not Requested		45298-90-6
653	Perfluorononanoic acid (PFNA)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
654	Perfluorohexane Sulfonic Acid (PFHxS)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		355-46-4
655	Perfluorohexanoic Acid (PFHxA)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		
656	Perfluorobutyrate Acid (PFBA)	Yes	Yes	No	Yes	Yes	Yes	Not Requested		Perfluorobutyric Acid: 375-22-4

APPENDIX I: CALIFORNIA IPR PRW MONITORING PARAMETERS

California IPR PRW Monitoring Parameters

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
Primary MCLs - Inorganics		
Aluminum	Monthly	Quarterly
Antimony	Monthly	Quarterly
Arsenic	Monthly	Quarterly
Asbestos	Monthly	Quarterly
Barium	Monthly	Quarterly
Beryllium	Monthly	Quarterly
Cadmium	Monthly	Quarterly
Chromium VI	Monthly	Quarterly
Copper	Monthly	Quarterly
Cyanide	Monthly	Quarterly
Fluoride	Monthly	Quarterly
Mercury	Monthly	Quarterly
Nickel	Monthly	Quarterly
Selenium	Monthly	Quarterly
Thallium	Monthly	Quarterly
Primary MCLs - Radioactivity		
Uranium	Monthly	Quarterly
Combined radium 226 and 228	Monthly	Quarterly
Gross alpha particle activity	Monthly	Quarterly
Beta/photon emitters	Monthly	Quarterly
Strontium-90	Monthly	Quarterly
Tritium	Monthly	Quarterly
Primary MCLs - Organics		
Benzene	Monthly	Quarterly
Carbon Tetrachloride	Monthly	Quarterly
1,2-Dichlorobenzene	Monthly	Quarterly
1,4-Dichlorobenzene	Monthly	Quarterly
1,1-Dichloroethane	Monthly	Quarterly
1,2-Dichloroethane	Monthly	Quarterly
1,1-Dichloroethylene	Monthly	Quarterly
cis-1,2-Dichloroethylene	Monthly	Quarterly
trans-1,2-Dichloroethylene	Monthly	Quarterly
Dichloromethane	Monthly	Quarterly
1,3-Dichloropropene	Monthly	Quarterly
1,2-Dichloropropane	Monthly	Quarterly
Ethylbenzene	Monthly	Quarterly

California IPR PRW Monitoring Parameters (continued)

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
MTBE	Monthly	Quarterly
Monochlorobenzene	Monthly	Quarterly
Styrene	Monthly	Quarterly
1,1,2,2-Tetrachloroethane	Monthly	Quarterly
Tetrachloroethylene	Monthly	Quarterly
Toluene	Monthly	Quarterly
1,2,4 Trichlorobenzene	Monthly	Quarterly
1,1,1-Trichloroethane	Monthly	Quarterly
1,1,2-Trichloroethane	Monthly	Quarterly
Trichloroethylene	Monthly	Quarterly
Trichlorofluoromethane	Monthly	Quarterly
1,1,2-Trichloro-1,2,2-Trifluoroethane	Monthly	Quarterly
Vinyl chloride	Monthly	Quarterly
Xylenes	Monthly	Quarterly
Alachlor	Monthly	Quarterly
Atrazine	Monthly	Quarterly
Bentazon	Monthly	Quarterly
Benzo(a) Pyrene	Monthly	Quarterly
Carbofuran	Monthly	Quarterly
Chlordane	Monthly	Quarterly
Dalapon	Monthly	Quarterly
Dibromochloropropane (DBCP)	Monthly	Quarterly
Di(2-ethylhexyl)adipate	Monthly	Quarterly
Di(2-ethylhexyl)phthalate	Monthly	Quarterly
2,4-D	Monthly	Quarterly
Dinoseb	Monthly	Quarterly
Diquat	Monthly	Quarterly
Endothall	Monthly	Quarterly
Endrin	Monthly	Quarterly
Ethylene Dibromide (EDB)	Monthly	Quarterly
Glyphosate	Monthly	Quarterly
Heptachlor	Monthly	Quarterly
Heptachlor Epoxide	Monthly	Quarterly
Hexachlorobenzene	Monthly	Quarterly
Hexachlorocyclopentadiene	Monthly	Quarterly
Lindane	Monthly	Quarterly
Methoxychlor	Monthly	Quarterly

California IPR PRW Monitoring Parameters (continued)

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
Molinate	Monthly	Quarterly
Oxamyl	Monthly	Quarterly
Pentachlorophenol	Monthly	Quarterly
Picloram	Monthly	Quarterly
Polychlorinated Biphenyls (PCBs)	Monthly	Quarterly
Simazine	Monthly	Quarterly
Thiobencarb	Monthly	Quarterly
Toxaphene	Monthly	Quarterly
1,2,3-Trichloropropane (TCP)	Monthly	Quarterly
2,3,7.8-TCDD (Dioxin)	Monthly	Quarterly
2,4,5-TP (Silvex)	Monthly	Quarterly
Primary MCLs - DBPs		
Total THMs	Monthly	Quarterly
Total HAAs (5)	Monthly	Quarterly
Bromate	Monthly	Quarterly
Chlorite	Monthly	Quarterly
Secondary MCLs		
Aluminum	Monthly	Annually
Chloride	Monthly	Annually
Color	Monthly	Annually
Copper	Monthly	Annually
Foaming Agents (MBAs)	Monthly	Annually
Iron	Monthly	Annually
Manganese	Monthly	Annually
Methyl-tert-butyl ether (MTBE)	Monthly	Annually
Odor Threshold	Monthly	Annually
Silver	Monthly	Annually
Specific Conductance	Monthly	Annually
Sulfate	Monthly	Annually
TDS	Monthly	Annually
Thiobencarb	Monthly	Annually
Turbidity	Monthly	Annually
Zinc	Monthly	Annually
Notification Levels		
Boron	Monthly	Quarterly
n-Butylbenzene	Monthly	Quarterly
sec-Butylbenzene	Monthly	Quarterly

California IPR PRW Monitoring Parameters (continued)

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
tert-Butylbenzene	Monthly	Quarterly
Carbon Disulfide	Monthly	Quarterly
Chlorate	Monthly	Quarterly
2-Chlorotoluene	Monthly	Quarterly
4-Chlorotoluene	Monthly	Quarterly
Diazinon	Monthly	Quarterly
Dichlorodifluoromethane (Freon 12)	Monthly	Quarterly
1,4-Dioxane	Monthly	Quarterly
Ethylene Glycol	Monthly	Quarterly
Formaldehyde	Monthly	Quarterly
HMX	Monthly	Quarterly
Isopropylbenzene	Monthly	Quarterly
Methol Isobutyl Ketone (MIBK)	Monthly	Quarterly
Naphthalene	Monthly	Quarterly
N-Nitrosodiethylamine (NDEA)	Monthly	Quarterly
NDMA	Monthly	Quarterly
NDPA	Monthly	Quarterly
PFOA	Monthly	Quarterly
PFOS	Monthly	Quarterly
Propachlor	Monthly	Quarterly
N-propylbenzene	Monthly	Quarterly
RDX	Monthly	Quarterly
Tertiary Butyl Alcohol (TBA)	Monthly	Quarterly
1,2,4-Trimethylbenzene	Monthly	Quarterly
1,3,5-Trimethylbenzene	Monthly	Quarterly
2,4,6-Trinitrotoluene (TNT)	Monthly	Quarterly
Vanadium	Monthly	Quarterly
Priority Toxic Pollutants		
Acrolein	Quarterly	Quarterly
Acrylonitrile	Quarterly	Quarterly
Chromium III	Quarterly	Quarterly
Bromoform	Quarterly	Quarterly
Carbon Tetrachloride	Quarterly	Quarterly
Chlorobenzene	Quarterly	Quarterly
Chlorodibromomethane	Quarterly	Quarterly
Chloroethane	Quarterly	Quarterly
2-Chloroethylvinyl Ether	Quarterly	Quarterly

California IPR PRW Monitoring Parameters (continued)

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
Chloroform	Quarterly	Quarterly
Dichlorobromomethane	Quarterly	Quarterly
1,1-Dichloroethane	Quarterly	Quarterly
1,2-Dichloroethane	Quarterly	Quarterly
1,1-Dichloroethylene	Quarterly	Quarterly
1,2-Dichloropropane	Quarterly	Quarterly
1,3-Dichloropropylene	Quarterly	Quarterly
Ethylbenzene	Quarterly	Quarterly
Methyl Bromide (Bromomethane)	Quarterly	Quarterly
Methyl Chloride (Chloromethane)	Quarterly	Quarterly
Methylene Chloride	Quarterly	Quarterly
1,1,2,2-Tetrachloroethane	Quarterly	Quarterly
Tetrachloroethylene (Tetrachloroethene)	Quarterly	Quarterly
Toluene	Quarterly	Quarterly
1,2-Trans-Dichloroethylene	Quarterly	Quarterly
1,1,1-Trichloroethane	Quarterly	Quarterly
1,1,2-Trichloroethane	Quarterly	Quarterly
Trichloroethylene	Quarterly	Quarterly
Vinyl Chloride	Quarterly	Quarterly
2-Chlorophenol	Quarterly	Quarterly
2,4-Dichlorophenol	Quarterly	Quarterly
2,4-Dimethylphenol	Quarterly	Quarterly
2-Methyl-4,6-Dinitrophenol	Quarterly	Quarterly
2,4-Dinitrophenol	Quarterly	Quarterly
2-Nitrophenol	Quarterly	Quarterly
4-Nitrophenol	Quarterly	Quarterly
3-Methyl-4-Chlorophenol	Quarterly	Quarterly
Pentachlorophenol	Quarterly	Quarterly
Phenol	Quarterly	Quarterly
2,4,6-Trichlorophenol	Quarterly	Quarterly
Acenaphthene	Quarterly	Quarterly
Acenaphthylene	Quarterly	Quarterly
Anthracene	Quarterly	Quarterly
Benzidine	Quarterly	Quarterly
Benzo(a)Anthracene	Quarterly	Quarterly
Benzo(b)Fluoranthene	Quarterly	Quarterly
Benzo(ghi)Perylene	Quarterly	Quarterly

California IPR PRW Monitoring Parameters (continued)

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
Benzo(k)Fluoranthene	Quarterly	Quarterly
Bis(2-Chloroethoxy)Methane	Quarterly	Quarterly
Bis(2-Chloroethyl)Ether	Quarterly	Quarterly
Bis(2-Chloroisopropyl)Ether	Quarterly	Quarterly
Bis(2-Ethylhexyl)Phthalate	Quarterly	Quarterly
4-Bromophenyl Phenyl Ether	Quarterly	Quarterly
Butylbenzyl Phthalate	Quarterly	Quarterly
2-Chloronaphthalene	Quarterly	Quarterly
4-Chlorophenyl Phenyl Ether	Quarterly	Quarterly
Chrysene	Quarterly	Quarterly
Dibenzo(a,h)Anthracene	Quarterly	Quarterly
1,2 Dichlorobenzene	Quarterly	Quarterly
1,3 Dichlorobenzene	Quarterly	Quarterly
1,4 Dichlorobenzene	Quarterly	Quarterly
3,3'-Dichlorobenzidine	Quarterly	Quarterly
Diethyl Phthalate	Quarterly	Quarterly
Dimethyl Phthalate	Quarterly	Quarterly
Di-n-Butyl Phthalate	Quarterly	Quarterly
2,4-Dinitrotoluene	Quarterly	Quarterly
2,6-Dinitrotoluene	Quarterly	Quarterly
Di-n-Octyl Phthalate	Quarterly	Quarterly
1,2-Diphenylhydrazine	Quarterly	Quarterly
Fluoranthene	Quarterly	Quarterly
Fluorene	Quarterly	Quarterly
Hexachlorobenzene	Quarterly	Quarterly
Hexachlorobutadiene	Quarterly	Quarterly
Hexachlorocyclopentadiene	Quarterly	Quarterly
Hexachloroethane	Quarterly	Quarterly
Indeno(1,2,3-cd) Pyrene	Quarterly	Quarterly
Isophorone	Quarterly	Quarterly
Naphthalene	Quarterly	Quarterly
Nitrobenzene	Quarterly	Quarterly
N-Nitrosodiphenylamine (NDPHA)	Quarterly	Quarterly
Phenanthrene	Quarterly	Quarterly
Pyrene	Quarterly	Quarterly
1,2,4-Trichlorobenzene	Quarterly	Quarterly
Aldrin	Quarterly	Quarterly

California IPR PRW Monitoring Parameters (continued)

Parameter	Frequency	
	Baseline (Year 1)	Routine (Year 2+)
alpha-BHC	Quarterly	Quarterly
beta-BHC	Quarterly	Quarterly
gamma-BHC	Quarterly	Quarterly
delta-BHC	Quarterly	Quarterly
Chlordane	Quarterly	Quarterly
4,4'-DDT	Quarterly	Quarterly
4,4'-DDE	Quarterly	Quarterly
4,4'-DDD	Quarterly	Quarterly
Dieldrin	Quarterly	Quarterly
alpha-Endosulfan	Quarterly	Quarterly
beta-Endosulfan	Quarterly	Quarterly
Endosulfan Sulfate	Quarterly	Quarterly
Endrin	Quarterly	Quarterly
Endrin Aldehyde	Quarterly	Quarterly
Heptachlor	Quarterly	Quarterly
Heptachlor Epoxide	Quarterly	Quarterly
Polychlorinated biphenyls (PCBs)	Quarterly	Quarterly
Toxaphene	Quarterly	Quarterly
Other Constituents		
Total Nitrogen	Bi-weekly	Bi-weekly
TOC	Weekly	Weekly
Performance CECs:		
NDMA (included above)	Bi-weekly	Indefinitely
Gemfibrozil	Bi-weekly	Indefinitely
Iohexol	Bi-weekly	Indefinitely
Sucralose	Bi-weekly	Indefinitely
Sulfamethoxazole	Bi-weekly	Indefinitely
Health-Based CECs:		
NDMA (included above)	Weekly	Indefinitely
NMOR	Weekly	Indefinitely
1,4-Dioxane (included above)	Weekly	Indefinitely

APPENDIX J: WESTERN CORRIDOR RECYCLED WATER SCHEME RECYCLED WATER MANAGEMENT PLAN ANNUAL REPORT 2021-2022

Luggage Point AWTP Point of Supply - July 2020 to June 2021

Parameter	CAS RN	Unit of measure	Number of samples	Minimum	Average	Maximum	Count of exceedances	Guideline value
1,1,1,2-Tetrachloroethane	630-20-6	ug/L	47	<1	<1	<1	n/a	
1,1,1-Trichloroethane	71-55-6	ug/L	47	<0.1	<0.9617	<1	n/a	
1,1,2,2-Tetrachloroethane	79-34-5	ug/L	47	<1	<1	<1	n/a	
1,1,2-Trichloroethane	79-00-5	ug/L	47	<1	<1	<1	n/a	
1,1,2-Trichlorotrifluoroethane	76-13-1	ug/L	2	<0.5	<0.5	<0.5	n/a	
1,1-Dichloroethane	75-34-3	ug/L	47	<0.1	<0.9617	<1	n/a	
1,1-Dichloroethene	75-35-4	ug/L	47	<0.1	<0.9617	<1	0	30
1,1-Dichloropropene	563-58-6	ug/L	3	<0.1	<0.7	<1	n/a	
1,2,3-Trichlorobenzene	87-61-6	ug/L	47	<1	<1	<1	n/a[e]	
1,2,3-Trichloropropane	96-18-4	ug/L	47	<1	<1	<1	n/a	
1,2,4-Trichlorobenzene	120-82-1	ug/L	47	<1	<1	<1	n/a[e]	
1,2,4-Trimethylbenzene	95-63-6	ug/L	47	<1	<1	<1	n/a	
1,2-Dibromo-3-chloropropane	96-12-8	ug/L	3	<0.5	<0.8333	<1	n/a	
1,2-Dibromoethane (EDB)	106-93-4	ug/L	47	<1	<1	<1	0	1
1,2-Dichlorobenzene	95-50-1	ug/L	47	<1	<1	<1	0	1500
1,2-Dichloroethane	107-06-2	ug/L	47	<0.1	<0.9617	<1	0	3
1,2-Dichloroethene	540-59-0	ug/L	45	<1	<1	<1	0	60
1,2-Dichloroethene (cis)	156-59-2	ug/L	47	<0.1	<0.9617	<1	n/a[e]	
1,2-Dichloroethene (trans)	156-60-5	ug/L	47	<0.1	<0.9617	<1	n/a[e]	
1,2-Dichloropropane	78-87-5	ug/L	47	<1	<1	<1	n/a	
1,3,5-Trimethylbenzene	108-67-8	ug/L	47	<1	<1	<1	n/a	
1,3-Dichlorobenzene	541-73-1	ug/L	47	<1	<1	<1	n/a	
1,3-Dichloropropane	142-28-9	ug/L	47	<1	<1	<1	n/a	
1,3-Dichloropropene	542-75-6	ug/L	44	<0.7	<1.0159	<2	0	100
1,3-Dichloropropene (cis)	10061-01-5	ug/L	44	<1	<1.0455	<2	n/a[e]	
1,3-Dichloropropene (trans)	10061-02-6	ug/L	44	<1	<1.0455	<2	n/a[e]	
1,4-Dichloro-2-butene (cis)	1476-11-5	ug/L	47	<1	<1	<1	n/a	
1,4-Dichloro-2-butene (trans)	110-57-6	ug/L	47	<1	<1	<1	n/a	
1,4-Dichlorobenzene	106-46-7	ug/L	47	<0.1	<0.2532	<1	0	40
1,4-Dioxane	123-91-1	ug/L	45	<0.03	<3.4338	<70	n/a	
1,7-Dimethylxanthine (Paraxanthine)	611-59-6	ug/L	2	<0.1	<0.1	<0.1	n/a	
12346789-Octachlorodibenzofuran (12346789-OCDF)	39001-02-0	pg/L	13	<50	<50	<50	n/a	
12346789-Octachlorodibenzo-p-dioxin (12346789-OCDD)	3268-87-9	pg/L	13	<50	<50	<50	n/a	
1234678-Heptachlorodibenzofuran (1234678-HpCDF)	67562-39-4	pg/L	13	<20	<20	<20	n/a	
1234678-Heptachlorodibenzo-p-dioxin (1234678-HpCDD)	35822-46-9	pg/L	13	<20	<20	<20	n/a	
1234789-Heptachlorodibenzofuran (1234789-HpCDF)	55673-89-7	pg/L	13	<20	<20	<20	n/a	
123478-Hexachlorodibenzofuran (123478-HxCDF)	70648-26-9	pg/L	13	<20	<20	<20	n/a	
123478-Hexachlorodibenzo-p-dioxin (123478-HxCDD)	39227-28-6	pg/L	13	<20	<20	<20	n/a	
123678-Hexachlorodibenzofuran (123678-HxCDF)	57117-44-9	pg/L	13	<20	<20	<20	n/a	
123678-Hexachlorodibenzo-p-dioxin (123678-HxCDD)	57653-85-7	pg/L	13	<20	<20	<20	n/a	
123789-Hexachlorodibenzofuran (123789-HxCDF)	72918-21-9	pg/L	13	<20	<20	<20	n/a	
123789-Hexachlorodibenzo-p-dioxin (123789-HxCDD)	19408-74-3	pg/L	13	<20	<20	<20	n/a	
12378-Pentachlorodibenzofuran (12378-PeCDF)	57117-41-6	pg/L	13	<20	<20	<20	n/a	
12378-Pentachlorodibenzo-p-dioxin (12378-PeCDD)	40321-76-4	pg/L	13	<20	<20	<20	n/a	
17-alpha-Estradiol	57-91-0	ng/L	46	<2	<5.913	<170	0	200
17-alpha-ethynylestradiol	57-63-6	ng/L	46	<2	<6.1957	<170	0	2
17-beta-estradiol	50-28-2	ng/L	46	<2	<5.7174	<170	0	200
17-beta-Trenbolone	10161-33-8	ng/L	2	<7	<7.5	<8	n/a	
1-Chlorobutane	109-69-3	ug/L	1	<0.1	<0.1	<0.1	n/a	
1H.1H.2H.2H-perfluorodecanesulfonic acid (8:2 FTS)	39108-34-4	ug/L	1	<0.005	<0.005	<0.005	n/a	
1H.1H.2H.2H-perfluorohexanesulfonic acid (4:2 FTS)	757124-72-4	ug/L	1	<0.005	<0.005	<0.005	n/a	
1H.1H.2H.2H-perfluorooctanesulfonic acid (6:2 FTS)	27619-97-2	ug/L	1	<0.005	<0.005	<0.005	n/a	
1H-Benzotriazole	95-14-7	ug/L	47	<0.7	0.01489	0.7	n/a	
1H-Benzotriazole, 1-Methyl	13351-73-0	ug/L	47	<0.1	0.002128	0.1	n/a	
1H-Benzotriazole, 4-Methyl	29878-31-7	ug/L	47	<0.1	0.01064	0.5	n/a	
1H-Benzotriazole, 5-Methyl	136-85-6	ug/L	47	<0.2	0.004255	0.2	0	500
2,2-Dichloropropane	594-20-7	ug/L	47	<1	<1	<1	n/a	
2,2-Dichloropropionic acid (DPA) (Dalapon)	75-99-0	ug/L	47	<0.2	<0.3872	<1	0	500
2,3,4,6-Tetrachlorophenol	58-90-2	ug/L	8	<0.1	<0.2125	<1	n/a	
2,4,5-Trichlorophenol	95-95-4	ug/L	8	<0.1	<0.2125	<1	n/a	
2,4,6-Trichlorophenol (2,4,6-T)	88-06-2	ug/L	8	<0.1	<0.2125	<1	0	20
2,4-DB (4-(2,4-Dichlorophenoxy)butyric Acid)	94-82-6	ug/L	4	<0.05	<0.05	<0.05	n/a	
2,4-Dichlorophenol	120-83-2	ug/L	8	<0.1	<0.2125	<1	0	200
2,4-Dichlorophenoxyacetic acid (2,4-D)	94-75-7	ug/L	47	<0.02	<0.03362	<0.1	0	30
2,4-Dichloropheoxypropionic acid (2,4-DP) (Dichlorprop)	120-36-5	ug/L	47	<0.05	<0.05319	<0.1	0	100
2,4-Dimethylphenol	105-67-9	ug/L	8	<0.1	<0.2125	<1	n/a	
2,4-Dinitrophenol	51-28-5	ug/L	3	<0.01	<0.67	<1	n/a	
2,4-Di-t-butylphenol	96-76-4	ug/L	4	<0.1	<0.1	<0.1	n/a	
2,6-Dichlorophenol	87-65-0	ug/L	8	<0.1	<0.2125	<1	n/a	
2,6-Di-t-butylphenol	128-39-2	ug/L	47	<0.1	<0.1213	<1	0	50
234678-Hexachlorodibenzofuran (234678-HxCDF)	60851-34-5	pg/L	13	<20	<20	<20	n/a	
23478-Pentachlorodibenzofuran (23478-PeCDF)	57117-31-4	pg/L	13	<20	<20	<20	n/a	
2378-Tetrachlorodibenzofuran (2378-TCDF)	51207-31-9	pg/L	13	<5	<5	<5	n/a	
2378-Tetrachlorodibenzo-p-dioxin (2378-TCDD)	1746-01-6	pg/L	13	<5	<5	<5	n/a	
2-Aminobenzimidazole	934-32-7	ug/L	26	<0.01	<0.01692	<0.1	n/a	
2-Benzyl-4-chlorophenol	120-32-1	ug/L	4	<0.2	<0.2	<0.2	n/a	
2-Butanone (MEK)	78-93-3	ug/L	47	<2	<9.8298	<10	n/a	
2-Chlorophenol	95-57-8	ug/L	8	<0.05	<0.2063	<1	0	300
2-Chlorotoluene	95-49-8	ug/L	47	<1	<1	<1	n/a	

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2-Hexanone (MBK)	591-78-6	ug/L	47	<1	<9.8085	<10	n/a	
2-Methoxynaphthalene	93-04-9	ug/L	27	<0.004	<0.004444	<0.01	n/a	
2-Methyl-4,6-dinitrophenol	534-52-1	ug/L	47	<0.05	<0.09043	<1	n/a	
2-Methylnaphthalene	91-57-6	ug/L	2	<0.01	<0.01	<0.01	n/a	
2-Methylphenol	95-48-7	ug/L	8	<0.1	<0.2125	<1	n/a	
2-Nitrophenol	88-75-5	ug/L	8	<0.1	<0.2125	<1	n/a	
2-Nitropropane	79-46-9	ug/L	2	<1	<1	<1	n/a	
3,4-Dichloroaniline (3,4-DCA)	95-76-1	ug/L	29	<0.02	<0.08966	<0.2	0	90
3/4-Methylphenol (m/p-cresol)	108-39-4+106-	ug/L	6	<0.2	<1.8333	<10	n/a	
3-Hydroxycarbofuran	16655-82-6	ug/L	28	<0.02	<0.02214	<0.05	0	0.5
4-Androstenedione	63-05-8	ng/L	2	<5	<5	<5	n/a	
4-Chloro-3,5-dimethylphenol	88-04-0	ug/L	47	<0.1	<0.1213	<1	n/a	
4-Chloro-3-methylphenol	59-50-7	ug/L	8	<0.05	<0.1688	<1	n/a	
4-Chlorophenol	106-48-9	ug/L	3	<0.5	<0.5	<0.5	n/a	
4-Chlorotoluene	106-43-4	ug/L	47	<1	<1	<1	n/a	
4-Cumylphenol	599-64-4	ng/L	46	<10	0.2826	13	n/a	
4-Isopropyltoluene	99-87-6	ug/L	47	<1	<1	<1	n/a	
4-Methyl-2-pentanone (MIBK)	108-10-1	ug/L	3	<0.1	<6.7	<10	n/a	
4-Methylphenol (p-cresol)	106-44-5	ug/L	3	<0.1	<0.4	<1	0	600
4-Nitrophenol	100-02-7	ug/L	8	<0.1	<0.2125	<1	0	30
4-Nonylphenol (mixture of isomers)	104-40-5	ug/L	4	<0.1	<25.05	<50	0	500
4-t-Octylphenol	140-66-9	ng/L	46	<10	<11.6087	<84	0	50000
Acenaphtene	83-32-9	ug/L	3	<0.01	<0.01	<0.01	n/a	
Acenaphthene	208-96-8	ug/L	27	<0.001	<0.001333	<0.01	n/a	
Acenaphthylene	208-96-8	ug/L	28	<0.001	<0.001964	<0.01	0	400
Acesulfame K (Sweetener)	55589-62-3	ug/L	46	<0.02	<0.06087	<1	n/a	
Acetaldehyde	75-07-0	mg/L	4	<0.002	<0.002	<0.002	n/a	
Acetaldehyde (ug/L)	75-07-0	ug/L	25	<0.1	1.044	6	n/a	
Acetamiprid	135410-20-7	ug/L	4	<0.01	<0.01	<0.01	n/a	
Acetamiprid - Total		ug/L	4	<0.02	<0.02	<0.02	n/a	
Acetamiprid-N-desmethyl	190604-92-3	ug/L	4	<0.01	<0.01	<0.01	n/a	
Acetone	67-64-1	ug/L	46	<2	<9.8261	<10	n/a	
Acifluorfen	50594-66-6	ug/L	4	<0.02	<0.0275	<0.05	n/a	
Acrolein (Propenal)	107-02-8	ug/L	28	<0.1	<1.7964	<2	n/a	
Acrylamide (2-propenamide)	79-06-1	ug/L	3	<0.1	<0.1	<0.1	0	0.2
Acrylonitrile (Vinyl Cyanide)	107-13-1	ug/L	2	<0.2	<0.2	<0.2	n/a	
Aldicarb	116-06-3	ug/L	28	<0.02	<0.02571	<0.07	n/a[e]	
Aldicarb - Total	116-06-3	ug/L	2	<0.3	<0.3	<0.3	0	4
Aldicarb sulphone (aldoxycarb)	1646-88-4	ug/L	2	<0.07	<0.07	<0.07	n/a[e]	
Aldicarb sulphoxide	1646-87-3	ug/L	2	<0.07	<0.07	<0.07	n/a[e]	
Aldrin	309-00-2	ug/L	45	<0.1	<0.1222	<1	0	0.3
Allethrin	584-79-2	ug/L	2	<0.5	<0.5	<0.5	n/a	
Allyl Chloride (3-Chloro-1-propene)	107-05-1	ug/L	1	<1	<1	<1	n/a	
Alprazolam (Xanax)	28981-97-7	ug/L	47	<0.02	<0.02383	<0.2	0	0.2
Aluminium - Total	7429-90-5	mg/L	48	<0.005	0.02929	0.049	n/a	
Americium-241	14596-10-2	Bq/L	48	<0.1	0.01125	0.2	n/a[b]	
Ametryn	834-12-8	ug/L	4	<0.01	<0.0325	<0.1	0	70
Amicarbazone	129909-90-6	ug/L	4	<0.05	<0.05	<0.05	n/a	
Aminomethylphosphonic acid (AMPA)	1066-51-9	ug/L	29	<0.5	<7.9138	<70	n/a	
Amitraz	33089-61-1	ug/L	47	<0.1	<0.1213	<1	0	9
Amitriptyline	50-48-6	ug/L	47	<0.02	<0.02383	<0.2	n/a	
Amitrole	61-82-5	ug/L	2	<0.1	<0.1	<0.1	0	0.9
Ammonia (as N) - Total	7664-41-7	mg/L	49	<0.004	0.002571	0.085	n/a	
Anaerobic Plate Count (at 22C)		orgs/ml	2	<2	<2	<2	n/a	
Androsterone	53-41-8	ng/L	46	<2	<6.2609	<84	0	10000
Anthracene	120-12-7	ug/L	28	<0.001	<0.001964	<0.01	n/a	
Antimony - Total	7440-36-0	mg/L	27	<0.0001	0.00001926	0.00037	0	0.003
Arsenic - Total	7440-38-2	mg/L	28	<0.0002	0.0000525	0.00094	0	0.01
Asulam	3337-71-1	ug/L	4	<0.02	<0.02	<0.02	0	70
Atenolol	29122-68-7	ug/L	46	<0.02	<0.02391	<0.2	0	20
Atorvastatin	134523-00-5	ug/L	36	<1	<1.25	<10	0	5
Atrazine	1912-24-9	ug/L	47	<0.01	<0.1091	<1	0	20
Azinphos-ethyl	2642-71-9	ug/L	47	<0.02	<0.1179	<1	n/a	
Azinphos-methyl (Guthion)	86-50-0	ug/L	47	<0.02	<0.1196	<1	0	30
Azithromycin	83905-01-5	ug/L	1	<40	<40	<40	0	4
Baclofen	69318-44-1	ug/L	47	<0.1	<0.1191	<1	n/a	
Barium - Total	7440-39-3	mg/L	27	<0.0001	0.0005767	0.0012	0	2
Benalaxyl	71626-11-4	ug/L	47	<0.1	<0.1213	<1	n/a	
Bendiocarb	22781-23-3	ug/L	15	<0.1	<0.1	<0.1	n/a	
Benomyl	17804-35-2	ug/L	2	<0.01	<0.01	<0.01	0	90
Benz[a]anthracene	56-55-3	ug/L	28	<0.001	<0.003036	<0.02	n/a	
Benzene	71-43-2	ug/L	47	<1	<1	<1	0	1
Benzenesulfonanilide	1678-25-7	ug/L	4	<0.2	<0.2	<0.2	n/a	
Benzo(a)pyrene	50-32-8	ug/L	28	<0.001	<0.001964	<0.01	0	0.01
Benzo(b+j)fluoranthene	205-99-2+205-	ug/L	26	<0.004	<0.004	<0.004	n/a	
Benzo(e)pyrene	192-97-2	ug/L	2	<0.02	<0.02	<0.02	n/a	
Benzo(k)fluoranthene	207-08-9	ug/L	26	<0.004	<0.004	<0.004	n/a	
Benzo[ghi]perylene	191-24-2	ug/L	28	<0.004	<0.004643	<0.01	n/a	
Benzyl Butyl Phthalate	85-68-7	ug/L	2	<2	<2	<2	n/a	

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Beryllium-7	13966-02-4	Bq/L	48	<0.05	0.025	0.3	n/a[b]	
Betaxolol	63659-18-7	ug/L	47	<0.02	<0.02383	<0.2	0	10
Bezafibrate (Benzafibrate)	41859-67-0	ug/L	1	<1	<1	<1	0	300
Bifenthrin	82657-04-3	ug/L	45	<0.1	<0.14	<1	n/a	
Bioresmethrin	28434-01-7	ug/L	47	<0.1	<0.1383	<1	0	100
Bis(2-ethylhexyl) Adipate	103-23-1	ug/L	1	<2	<2	<2	n/a	
Bis(2-ethylhexyl)adipate	103-23-1	ug/L	2	<2	<2	<2	n/a	
Bis(2-ethylhexyl)phthalate	117- 81-7	ug/L	2	<10	<10	<10	0	10
Bisphenol A (ng/L)	80-05-7	ng/L	46	<10	24.5652	440	0	200000
Bitertanol	55179-31-2	ug/L	47	<0.1	<0.1213	<1	n/a	
Boron - Total	7440-42-8	mg/L	44	0.086	0.1355	0.19	0	4
Brodifacoum (Bromfenacoum)	56073-10-0	ug/L	1	<0.05	<0.05	<0.05	n/a	
Bromacil	314-40-9	ug/L	4	<0.02	<0.04	<0.1	0	400
Bromate	15541-45-4	mg/L	14	<0.001	<0.005143	<0.01	0	0.02
Bromide	24959-67-9	mg/L	46	<0.01	0.0002174	0.01	0	7
Bromobenzene	108-86-1	ug/L	47	<1	<1	<1	n/a	
Bromochloroacetic Acid	5589-96-8	ug/L	27	<0.1	0.05926	0.3	n/a	
Bromochloromethane	74-97-5	ug/L	47	<0.5	<1.1489	<5	0	40
Bromodichloroacetic Acid	71133-14-7	ug/L	46	<1	<1	<1	n/a	
Bromodichloromethane (BDCM)	75-27-4	ug/L	48	<1	0.04167	2	n/a[a]	
Bromoform	75-25-2	ug/L	48	<1	<1.0833	<5	n/a[a]	
Bromophos-ethyl	4824-78-6	ug/L	47	<0.1	<0.1213	<1	0	10
Bromoxynil	1689-84-5	ug/L	4	<0.02	<0.0275	<0.05	0	10
Butylated hydroxytoluene (2,6-Di-tert-Butyl-p-Cresol) (BHT)	128-37-0	ug/L	47	<0.1	<0.1213	<1	0	1000
Butyraldehyde	123-72-8	ug/L	28	<0.1	<1.7964	<2	n/a	
CaCO3 Precipitation Potential			44	-4.113	-1.0227	0.1479	n/a[c]	
Cadmium - Total	7440-43-9	mg/L	28	<0.0001	<0.0001964	<0.001	0	0.002
Cadusafos	95465-99-9	ug/L	47	<0.1	<0.1213	<1	n/a	
Caesium-137	10045-97-3	Bq/L	47	<0.05	0.00766	0.1	n/a[b]	
Caffeine	58-08-2	ug/L	47	<0.1	0.004255	0.2	n/a	
Calcium - Soluble	7440-70-2	mg/L	60	22	27.5833	75	n/a	
Calcium - Total	7440-70-2	mg/L	49	21	26.1633	30	n/a	
Calcium Hardness (as CaCO3)		mg/L	55	55	65.0545	74	n/a	
Captan	133-06-2	ug/L	47	<0.1	<0.1213	<1	0	400
Carbamazepine	298-46-4	ug/L	47	<0.02	<0.04468	<1	0	100
Carbaryl	63-25-2	ug/L	29	<0.01	<0.01897	<0.1	0	30
Carbendazim	10605-21-7	ug/L	26	<0.02	<0.08462	<0.1	n/a[e]	
Carbendazim - Total	10605-21-7	ug/L	2	<0.25	<0.25	<0.25	0	90
Carbofuran	1563-66-2	ug/L	28	<0.01	<0.01286	<0.05	n/a[e]	
Carbofuran - Total	1563-66-2	ug/L	2	<0.1	<0.1	<0.1	0	10
Carbon disulphide	75-15-0	ug/L	47	<1	<1	<1	n/a	
Carbon tetrachloride	56-23-5	ug/L	45	<1	<1	<1	0	3
Carbophenothion	786-19-6	ug/L	47	<0.02	<0.1196	<1	0	0.5
Cefalexin	15686-71-2	ug/L	43	<0.2	<0.614	<10	0	40
Chloral Hydrate (Trichloroacetaldehyde)	302-17-0	ug/L	1	<1	<1	<1	0	100
Chloramphenicol	56-75-7	ug/L	47	<0.2	<0.2553	<2	0	200
Chlorate	14866-68-3	mg/L	3	0.048	0.057	0.062	0	0.8
Chlordane - Total	57-74-9	ug/L	47	<0.1	<0.2298	<2	0	2
Chlordane-cis	5103-71-9	ug/L	45	<0.1	<0.1222	<1	n/a[e]	
Chlordane-trans	57-74-9	ug/L	45	<0.1	<0.1222	<1	n/a[e]	
Chlordene	3734-48-3	ug/L	47	<0.1	<0.1213	<1	n/a	
Chlordene Epoxide	6058-23-7	ug/L	47	<0.1	<0.1213	<1	n/a	
Chlordene-1-hydroxy	24009-05-0	ug/L	47	<0.1	<0.1213	<1	n/a	
Chlordene-1-hydroxy-2,3-epoxide	24009-06-1	ug/L	47	<0.1	<0.1213	<1	n/a	
Chlorfenvinphos	470-90-6	ug/L	47	<0.02	<0.1196	<1	0	2
Chlorine - Free	7782-50-5	mg/L	1	1.5	1.5	1.5	0[d]	5
Chlorine - Total	7782-50-5	mg/L	2	1.39	1.43	1.47	0[d]	5
Chlorite	14998-27-7	mg/L	1	<0.001	<0.001	<0.001	0	0.8
Chloroacetonitrile	107-14-2	ug/L	1	<2	<2	<2	n/a	
Chlorobenzene	108-90-7	ug/L	45	<1	<1	<1	0	300
Chlorodibromoacetic Acid	5278-95-5	ug/L	46	<1	<1	<1	n/a	
Chloroethane (Ethyl Chloride)	75-00-3	ug/L	45	<10	<10	<10	n/a	
Chloroform (Trichloromethane)	67-66-3	ug/L	48	<1	0.3125	4	n/a[a]	
Chloromethane	74-87-3	ug/L	45	<10	<10	<10	n/a	
Chloroprene	126-99-8	ug/L	2	<0.1	<0.1	<0.1	n/a	
Chlorotetracycline	57-62-5	ug/L	45	<1	<1	<1	0	100
Chlorothalonil	1897-45-6	ug/L	27	<0.1	<0.237	<2	0	50
Chlorpyrifos	2921-88-2	ug/L	44	<0.02	<0.1191	<1	0	10
Chlorpyrifos oxon	5598-15-2	ug/L	46	<0.01	<0.1178	<1	n/a	
Chlorpyrifos-methyl	5598-13-0seq	ug/L	45	<0.1	<0.1244	<1	0	10
Cholesterol	57-88-5	ng/L	46	<50	25.0652	240	n/a	
Chromium - Total	7440-47-3	mg/L	29	<0.0005	0.00005931	0.00099	0	0.05
Chromium-51	14392-02-0	Bq/L	48	<0.5	<0.5	<0.5	n/a	
Chrysene (Benzo[a]phenanthrene)	218-01-9	ug/L	28	<0.001	<0.003036	<0.02	n/a	
Ciprofloxacin	85721-33-1	ug/L	45	<1	<1.0222	<2	0	200
Citalopram	59729-33-8	ug/L	47	<0.02	<0.02383	<0.2	0	10
Clarithromycin	81103-11-9	ug/L	1	<10	<10	<10	0	200
Clindamycin	18323-44-9	ug/L	1	<1	<1	<1	0	300

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Clomazone	81777-89-1	ug/L	4	<0.01	<0.01	<0.01	n/a	
Clopyralid	1702-17-6	ug/L	42	<0.1	<0.1	<0.1	0	2000
Clostridium perfringens		cfu/100ml	48	<1	<1	<1	0	0
Clothianidin	210880-92-5	ug/L	4	<0.02	<0.0425	<0.05	n/a	
Cobalt - Total	7440-48-4	mg/L	1	0.0001	0.0001	0.0001	n/a	
Cobalt-57	13981-50-5	Bq/L	48	<0.06	0.001667	0.04	n/a[b]	
Cobalt-60	10198-40-0	Bq/L	48	<0.05	0.006458	0.06	n/a[b]	
Codeine	76-57-3	ug/L	47	<0.02	<0.02383	<0.2	0	50
Conductivity		uS/cm	49	160	203.6735	230	n/a[c]	
Copper - Total	7440-50-8	mg/L	28	<0.0005	<0.0009643	<0.001	0	2
Coumaphos	56-72-4	ug/L	47	<0.01	<0.1174	<1	n/a	
Coumarin	91-64-5	ug/L	3	<0.5	<0.5	<0.5	0	0.5
Cryptosporidium oocysts		/10L	1	<1	<1	<1	n/a	
Cyanazine	21725-46-2	ug/L	4	<0.01	<0.0125	<0.02	n/a	
Cyanide - Free	57-12-5	mg/L	1	<0.005	<0.005	<0.005	n/a	
Cyanide - Total	57-12-5	mg/L	1	<0.001	<0.001	<0.001	0	0.08
Cyclophosphamide	50-18-0	ug/L	47	<0.02	<0.02383	<0.2	0	4
Cyfluthrin	68359-37-5	ug/L	47	<0.1	<0.1383	<1	0	50
Cyhalothrin	68085-85-8	ug/L	47	<0.1	<0.1213	<1	n/a	
Cypermethrin	52315-07-8	ug/L	47	<0.1	<0.1383	<1	0	200
Cyproconazole	94361-06-5	ug/L	2	<0.02	<0.02	<0.02	n/a	
Cyprodinil	121552-61-2	ug/L	2	<0.01	<0.01	<0.01	0	90
Cyromazine	66215-27-8	ug/L	2	<0.05	<0.05	<0.05	n/a	
Dapsone	80-08-0	ug/L	47	<0.02	<0.02383	<0.2	n/a	
DDD (op) (2,4-DDD)	53-19-0	ug/L	47	<0.1	<0.1213	<1	n/a	
DDD (pp) (4,4-DDD)	72-54-8	ug/L	45	<0.1	<0.1222	<1	n/a	
DDE (op) (2,4-DDE)	3424-82-6	ug/L	47	<0.1	<0.1213	<1	n/a	
DDE (pp) (4,4-DDE)	72-55-9	ug/L	45	<0.1	<0.1222	<1	0	20
DDT - Total	50-29-3	ug/L	47	<0.4	<0.4809	<3.9	0	9
DDT (op) (2,4-DDT)	789-02-6	ug/L	47	<0.1	<0.1213	<1	0	9
DDT (pp) (4,4-DDT)	50-29-3	ug/L	45	<0.1	<0.1222	<1	0	9
DEET	134-62-3	ug/L	47	<0.1	<0.2255	<2	0	2000
Deltamethrin	52918-63	ug/L	47	<0.1	<0.1213	<1	0	40
Deltamethrin and Tralomethrin		ug/L	2	<0.5	<0.5	<0.5	n/a	
Demeclocycline	127-33-3	ug/L	1	<1	<1	<1	0	300
Demeton-O + Demeton-S	298-03-3/126-7	ug/L	2	<0.02	<0.02	<0.02	n/a	
Demeton-O-methyl	867-27-6	ug/L	4	<0.1	<0.1	<0.1	n/a	
Demeton-S	126-75-0	ug/L	47	<0.1	<0.1213	<1	0	0.2
Demeton-S-methyl	919-86-8	ug/L	47	<0.02	<0.1196	<1	n/a	
Desethyl Atrazine	6190-65-4	ug/L	3	<0.01	<0.04	<0.1	n/a[e]	
Desisopropyl Atrazine	1007-28-9	ug/L	3	<0.02	<0.04667	<0.1	n/a[e]	
Desmethyl Citalopram	144010-85-5	ug/L	47	<0.05	<0.05957	<0.5	n/a[e]	
Desmethyl Diazepam (Nordazepam)	1088-11-5	ug/L	47	<0.02	<0.02383	<0.2	n/a[e]	
Desmethyl Formamido Pirimicarb	27218-04-8	ug/L	2	<0.5	<0.5	<0.5	n/a	
Desmethyl Pirimicarb	30614-22-3	ug/L	2	<0.05	<0.05	<0.05	n/a	
Di (2-Ethylhexyl) Phthalate	117-81-7	ug/L	2	<10	<10	<10	0	10
Diatrizoate sodium	737-31-5	ug/L	44	<0.02	<0.02	<0.02	n/a	
Diazepam (Valium)	439-14-5	ug/L	47	<0.02	<0.03404	<0.5	n/a	
Diazepam - Total		ug/L	23	<0.4	<0.4	<0.4	0	2
Diazinon	333-41-5	ug/L	47	<0.01	<0.02532	<0.1	0	4
Dibenzo[a,h]anthracene	53-70-3	ug/L	28	<0.004	<0.005714	<0.02	n/a	
Dibromoacetic Acid	631-64-1	ug/L	46	<0.1	0.02826	0.3	n/a	
Dibromochloromethane (DBCM)	124-48-1	ug/L	48	<1	<1.0833	<5	n/a[a]	
Dibromomethane	74-95-3	ug/L	45	<1	<1	<1	n/a	
Dibutyltin (DBT)	1002-53-5	ug/L	1	<0.01	<0.01	<0.01	n/a	
Dicamba	1918-00-9	ug/L	47	<0.05	<0.1245	<1	0	100
Dichloroacetic Acid (DCA)	79-43-6	ug/L	46	<1	0.06522	2	0	100
Dichlorodifluoromethane	75-71-8	ug/L	45	<10	<10	<10	n/a	
Dichloromethane (Methylene chloride)	75-09-2	ug/L	47	<1	<2.2553	<4	0	4
Dichlorophenyl Urea (DCPU)	155998	ug/L	4	<0.02	<0.0275	<0.05	n/a	
Dichlorvos	62-73-7	ug/L	45	<0.1	<0.1222	<1	0	5
Diclofenac	15307-86-5	ug/L	47	<0.02	<0.02383	<0.2	0	2
Diclofop-methyl	51338-27-3	ug/L	45	<0.05	<0.12	<1	0	5
Dicofol	115-32-2	ug/L	14	<0.1	<1.3286	<1.5	0	4
Dieldrin	60-57-1	ug/L	45	<0.1	<0.1222	<1	0	0.3
Diethyl Phthalate	84-66-2	ug/L	2	<2	<2	<2	n/a	
Difenoconazole	119446-68-3	ug/L	2	<0.02	<0.02	<0.02	n/a	
Diflufenican	83164-33-4	ug/L	1	<0.02	<0.02	<0.02	n/a	
Dihydrotestosterone	521-18-6	ng/L	2	<5	<5	<5	n/a	
Dimethoate	60-51-5	ug/L	47	<0.02	<0.3047	<2.9	n/a[e]	
Dimethoate - Total	60-51-5	ug/L	3	<0.2	<0.2	<0.2	0	7
Dimethomorph	110488-70-5	ug/L	47	<0.2	<0.2426	<2	n/a	
Dimethyl Phthalate	131-11-3	ug/L	2	<2	<2	<2	n/a	
Di-n-butyl Phthalate	84-74-2	ug/L	2	<2	<2	<2	0	40
Di-n-octyl Phthalate	117-84-0	ug/L	2	<2	<2	<2	n/a	
Dinotefuran	165252-70-0	ug/L	4	<0.05	<0.05	<0.05	n/a	
Dioxathion	78-34-2	ug/L	47	<0.1	<0.1596	<1	n/a	
Dioxin and Dioxin-like Toxic Equivalent (TEQ)(0LOR)		pg/L	10	<50	0	0	0	16
Diphenhydramine	58-73-1	ug/L	47	<0.02	<0.02383	<0.2	n/a	

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Parameter	CAS RN	Unit of measure	Number of samples	Minimum	Average	Maximum	Count of exceedances	Guideline value
Disulfoton	298-04-4	ug/L	47	<0.05	<0.1202	<1	0	4
Diuron	330-54-1	ug/L	30	<0.02	<0.02	<0.02	n/a[e]	
Diuron - Total	330-54-1	ug/L	29	<0.06	<0.07655	<0.3	0	20
Diuron-desmethyl (DCPMU)	3567-62-2	ug/L	4	<0.02	<0.02	<0.02	n/a	
Doxepin	1668-19-5	ug/L	47	<0.02	<0.02383	<0.2	n/a	
Doxycycline	564-25-0	ug/L	1	<1	<1	<1	0	10
Doxylamine	469-21-6	ug/L	47	<0.02	0.001915	0.05	n/a	
Endosulfan - alpha	959-98-8	ug/L	45	<0.5	<0.6067	<4.9	n/a[e]	
Endosulfan - beta	33213-65-9	ug/L	45	<0.1	<0.1222	<1	n/a[e]	
Endosulfan - Total	115-29-7	ug/L	47	<0.5	<0.8191	<6.9	0	20
Endosulfan Ether	3369-52-6	ug/L	47	<0.1	<0.1213	<1	n/a	
Endosulfan Lactone	3868-61-9	ug/L	47	<0.5	<0.6021	<4.9	n/a	
Endosulfan Sulphate	1031-07-8	ug/L	45	<0.1	<0.1222	<1	n/a[e]	
Endothall	145-73-3	ug/L	1	<1	<1	<1	n/a	
Endrin	72-20-8	ug/L	45	<0.2	<0.2444	<2	n/a	
Endrin aldehyde	7421-93-4	ug/L	47	<0.1	<0.1213	<1	n/a	
Enrofloxacin	93106-60-6	ug/L	45	<1	<1.8667	<40	0	20
Epichlorohydrin	106-89-8	ug/L	3	<0.2	<0.4667	<1	0	0.5
Equilenin	517-09-9	ng/L	46	<2	<5.9348	<170	0	30
Equilin	474-86-2	ng/L	46	<2	<15	<420	0	30
Erythromycin	114-07-8	ug/L	1	<1	<1	<1	0	20
Erythromycin Anhydrate	114-07-8	ug/L	47	<0.02	<0.02383	<0.2	0	20
Escherichia coli (E. coli)		cfu/100ml	48	<1	<1	<1	0	0
Estriol	50-27-1	ng/L	46	<2	<6.1739	<170	0	50
Estrone	53-16-7	ng/L	46	<1	<2.8043	<84	0	30
Ethametsulfuron-methyl	97780-06-8	ug/L	4	<0.01	<0.01	<0.01	n/a	
Ethion	563-12-2	ug/L	45	<0.02	<0.1293	<1	0	4
Ethoprophos (Mocap)	13194-48-4	ug/L	47	<0.01	<0.1194	<1	0	1
Ethoxysulfuron	126801-58-9	ug/L	4	<0.01	<0.01	<0.01	n/a	
Ethyl Methacrylate	97-63-2	ug/L	1	<0.1	<0.1	<0.1	n/a	
Ethylbenzene	100-41-4	ug/L	45	<1	<1	<1	0	300
Ethylenediamine tetraacetic acid (EDTA)	60-00-4	ug/L	29	<10	<33.4483	<80	0	250
Etiocholanolone	53-42-9	ng/L	46	<5	<6.7174	<84	n/a	
Etrimphos	38260-54-7	ug/L	47	<0.1	<0.1213	<1	n/a	
Famphur	52-85-7	ug/L	47	<0.1	<0.1213	<1	n/a	
Fenamiphos	22224-92-6	ug/L	45	<0.01	<0.1202	<1	0	0.5
Fenarimol	60168-88-9	ug/L	2	<0.02	<0.02	<0.02	0	40
Fenchlorphos	299-84-3	ug/L	47	<0.1	<0.3319	<10	n/a	
Fenitrothion	122-14-5	ug/L	44	<0.1	<0.1659	<2	0	7
Fenoprop (2,4,5-TP) Silvex	93-72-1	ug/L	44	<0.1	<0.1	<0.1	0	10
Fensulfothion	115-90-2	ug/L	2	<0.01	<0.01	<0.01	0	10
Fenthion	55-38-9	ug/L	2	<0.05	<0.05	<0.05	0	7
Fenthion-ethyl	1716-09-2	ug/L	47	<0.1	<0.1213	<1	n/a	
Fenthion-methyl	55-38-9	ug/L	47	<0.1	<0.1213	<1	n/a	
Fenvalerate	51630-58-1	ug/L	47	<0.1	<0.1298	<1	0	60
Fenvalerate and Esfenvalerate		ug/L	2	<0.5	<0.5	<0.5	0	30
Fipronil	120068-37-3	ug/L	43	<0.01	<0.1174	<1	n/a	
Fipronil - Total		ug/L	4	<0.05	<0.05	<0.05	0	0.7
Fipronil sulfide	120067-83-6	ug/L	4	<0.01	<0.01	<0.01	n/a	
Fipronil sulfone	120068-36-2	ug/L	4	<0.01	<0.01	<0.01	n/a	
Fipronil-desulfinyl (Fipronyl-desulfinyl)	205650-65-3	ug/L	4	<0.01	<0.01	<0.01	n/a	
Flamprop-methyl	52756-25-9	ug/L	4	<0.01	<0.01	<0.01	0	4
Fluazifop (acid)	69335-91-7	ug/L	4	<0.01	<0.01	<0.01	n/a	
Fluazifop-Butyl	69806-50-4	ug/L	47	<0.1	<0.1213	<1	n/a	
Fluometuron	2164-17-2	ug/L	4	<0.01	<0.0325	<0.1	0	70
Fluoranthene	206-44-0	ug/L	28	<0.001	<0.001964	<0.01	n/a	
Fluorene	86-73-7	ug/L	28	<0.001	<0.001964	<0.01	n/a	
Fluoride	16984-48-8	mg/L	1	<0.01	<0.01	<0.01	0	1.5
Fluoxetine (Prozac)	54910-89-3	ug/L	47	<0.02	<0.02383	<0.2	0	10
Flupropanate	58561-90-3	ug/L	1	<1	<1	<1	0	9
Fluroxypyr	69377-81-7	ug/L	47	<0.05	<0.06383	<0.5	0	700
Flusilazole	85509-19-9	ug/L	4	<0.02	<0.035	<0.05	n/a	
Flutriafol	76674-21-0	ug/L	3	<0.01	<0.04333	<0.1	n/a	
Fluvalinate	69409-94-5	ug/L	28	<0.1	<0.1036	<0.2	n/a	
Fluvastatin	93957-54-1	ug/L	4	<1	<1	<1	n/a	
Formaldehyde	50-00-0	mg/L	7	<0.002	0.0005714	0.004	0	0.5
Formaldehyde (ug/L)	50-00-0	ug/L	21	<2	3.3905	6.9	0	500
F-specific RNA coliphages		pfu/100mL	48	<1	<1	<1	0	0
Frusemide (Furosemide)	54-31-9	ug/L	47	<0.2	<0.2383	<2	0	10
Furalaxyl	57646-30-7	ug/L	47	<0.1	<0.1213	<1	n/a	
Gabapentin	60142-96-3	ug/L	29	<0.02	<0.0231	<0.05	n/a	
Galaxolide	1222-05-5	ug/L	47	<0.1	<0.1213	<1	0	2000
Gallium-67	14119-09-6	Bq/L	47	<0.8	0.04255	1	n/a[b]	
Gemfibrozol (Gemfibrozil)	25812-30-0	ug/L	47	<0.02	<1.1706	<10	0	600
Giardia cysts		/10L	1	<1	<1	<1	n/a	
Glufosinate (acid)	53369-07-6	ug/L	29	<0.5	<5.931	<50	n/a	
Glutaraldehyde	111-30-8	mg/L	2	<0.002	<0.002	<0.002	n/a	
Glutaraldehyde (ug/L)	111-30-8	ug/L	11	<0.1	<1.6545	<2	n/a	
Glyphosate	1071-83-6	ug/L	29	<0.2	<7.6552	<70	n/a[e]	

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Glyphosate - Total	1071-83-6	ug/L	29	<0.5	<20.2759	<180	0	1000
Gross Alpha	12587-46-1	Bq/L	47	<0.1	0.01936	0.2	0	0.5
Gross Beta (K corrected)		Bq/L	47	<0.1	<0.117	<0.4	0	0.5
Halosulfuron-methyl	100784-20-1	ug/L	4	<0.01	<0.01	<0.01	n/a	
Haloxyfop	69806-34-4	ug/L	47	<0.02	0.0008511	0.02	n/a[e]	
Haloxyfop - Total	69806-34-4	ug/L	47	<0.1	<0.1574	<1	0	1
Haloxyfop-2-etotyl	87237-48-7	ug/L	47	<0.1	<0.1213	<1	n/a[e]	
Haloxyfop-methyl	69806-40-2	ug/L	47	<0.1	<0.1213	<1	0	0.2
HCB (Hexachlorobenzene)	118-74-1	ug/L	45	<0.2	<0.2444	<2	n/a	
HCH alpha (alpha-Lindane)	319-84-6	ug/L	45	<0.1	<0.1222	<1	0	10
HCH beta (beta-Lindane)	319-85-7	ug/L	45	<0.1	<0.1222	<1	0	10
HCH delta (delta-Lindane)	89609-19-8	ug/L	45	<0.1	<0.1222	<1	0	10
HCH gamma (gamma-Lindane)	58-89-9	ug/L	45	<0.1	<0.1222	<1	0	10
Heptachlor	76-44-8	ug/L	3	<0.1	<0.1	<0.1	n/a	
Heptachlor - Total	76-44-8	ug/L	47	<0.1	<0.2106	<2	0	0.3
Heptachlor Epoxide	1024-57-3	ug/L	45	<0.1	<0.1222	<1	n/a	
Hexachlorobutadiene	87-68-3	ug/L	45	<0.5	<0.5667	<1	0	0.7
Hexachloroethane	67-72-1	ug/L	3	<0.2	<0.7333	<1	n/a	
Hexachlorophene	120-32-1	ug/L	3	<0.1	<0.1	<0.1	n/a	
Hexaconazole	79983-71-4	ug/L	2	<0.02	<0.02	<0.02	n/a	
Hexaflurate	17029-22-0	ug/L	1	<0.1	<0.1	<0.1	0	30
Hexazinone	51235-04-2	ug/L	4	<0.01	<0.01	<0.01	0	400
Hydrochlorthiazide	58-93-5	ug/L	47	<0.2	<0.6383	<20	0	10
Ibuprofen	15687-27-1	ug/L	47	<5	<5.9574	<50	0	400
Icaridin (Picaridin)	119515-38-7	ug/L	4	<0.1	<0.1	<0.1	n/a	
Imazapic (Imazmethapyr)	104098-48-8	ug/L	4	<0.01	<0.01	<0.01	n/a	
Imazapyr	81334-34-1	ug/L	4	<0.02	<0.02	<0.02	0	9000
Imazethapyr	81335-77-5	ug/L	4	<0.02	<0.02	<0.02	n/a	
Imidacloprid	138261-41-3	ug/L	4	<0.01	<0.0175	<0.02	n/a[e]	
Imidacloprid - Total		ug/L	4	<0.04	<0.045	<0.06	0	200
Imidacloprid metabolites		ug/L	4	<0.02	<0.02	<0.02	n/a	
Indeno[1,2,3-cd]pyrene	193-39-5	ug/L	28	<0.004	<0.005714	<0.02	n/a	
Indium-111	15750-15-9	Bq/L	46	<0.05	0.01652	0.3	n/a[b]	
Indomethacin	53-86-1	ug/L	47	<1	<1.1915	<10	0	20
Iodide	20461-54-5	mg/L	1	<0.01	<0.01	<0.01	0	0.5
Iodine-123	69239-56-1	Bq/L	42	<0.06	5.5286	100	n/a[b]	
Iodine-125	14158-31-7	Bq/L	48	<1.7	0.2167	2	n/a[b]	
Iodine-131	10043-66-0	Bq/L	48	<0.06	0.02729	0.2	n/a[b]	
Iodomethane	74-88-4	ug/L	45	<1	<1.0444	<2	n/a	
Iopromide	73334-07-3	ug/L	3	<2	<2	<2	0	800
Ioxynil (4-hydroxy-3,5-diiodo-benzonitrile)	1689-83-4	ug/L	4	<0.01	<0.0125	<0.02	n/a	
Iprodione	36734-19-7	ug/L	1	<0.05	<0.05	<0.05	0	100
Irgarol	28159-98-0	ug/L	2	<0.002	<0.002	<0.002	n/a	
Iron - Total	7439-89-6	mg/L	45	<0.005	0.02122	0.031	n/a	
Isofenphos	25311-71-1	ug/L	47	<0.1	<0.1213	<1	n/a	
Isophosphamide (Ifosfamide)	3778-73-2	ug/L	4	<0.02	<0.14	<0.5	0	4
Isopropylbenzene	98-82-8	ug/L	45	<1	<1	<1	n/a	
Ketoprofen	22071-15-4	ug/L	1	<0.5	<0.5	<0.5	0	4
Lambda-cyhalothrin		ug/L	2	<0.5	<0.5	<0.5	n/a	
Langelier Saturation Index (LSI)			43	-0.537	-0.1334	0.018	n/a[c]	
Lanthanum - Total	7439-91-0	mg/L	45	<0.0005	<0.0005	<0.0005	0	0.002
Lanthanum-138	15816-87-2	Bq/L	48	<0.08	0.007083	0.1	n/a[b]	
Lead - Total	7439-92-1	mg/L	28	<0.0001	0.00001643	0.00014	0	0.01
Lead-210	14255-04-0	Bq/L	3	<2.3	<2.3	<2.3	n/a	
Lincomycin	154-21-2	ug/L	47	<0.02	<0.03787	<0.5	0	4000
Lutetium-176	14452-47-2	Bq/L	16	<11	1.25	10	n/a[b]	
Lutetium-177	14265-75-9	Bq/L	48	<0.5	0.03125	1	n/a[b]	
Magnesium - Soluble	7439-95-4	mg/L	67	<1	0.1087	0.22	n/a	
Magnesium - Total	7439-95-4	mg/L	30	<0.3	0.1787	0.57	n/a	
Magnesium Hardness (as CaCO3)	null	mg/L	49	<1	0.898	1	n/a	
Malathion (Maldison)	121-75-5	ug/L	47	<0.02	<0.1196	<1	0	70
Manganese - Total	7439-96-5	mg/L	48	<0.0005	0.00769	0.011	0	0.5
MCPA (2-Methyl-4-chlorophenoxyacetic acid)	94-74-6	ug/L	47	<0.01	<0.01255	<0.1	0	40
MCPB (2-Methyl-4-chlorophenoxybutyric acid)	94-81-5	ug/L	47	<0.05	0.002128	0.05	n/a	
Mecoprop	93-65-2	ug/L	47	<0.02	<0.02681	<0.1	0	10
Mercury - Total	7439-97-6	mg/L	2	<0.00001	<0.00001	<0.00001	0	0.001
Mesosulfuron-methyl	208465-21-8	ug/L	4	<0.02	<0.02	<0.02	n/a	
Mestranol	72-33-3	ng/L	46	<5	<6.9348	<84	0	2
Meta and Para Xylenes	108-38-3/106-4	ug/L	45	<1	<1	<1	n/a	
Metalaxyl	57837-19-1	ug/L	47	<0.1	<0.1213	<1	n/a	
Methacrylonitrile	126-98-7	ug/L	2	<0.2	<0.2	<0.2	n/a	
Methadone	76-99-3	ug/L	47	<0.02	<0.02383	<0.2	n/a	
Methidathion	950-37-8	ug/L	47	<0.1	<0.1213	<1	0	6
Methiocarb	2032-65-7	ug/L	28	<0.01	<0.01286	<0.05	0	7
Methomyl	16752-77-5	ug/L	28	<0.01	<0.01286	<0.05	0	20
Methomyl Oxime	13749-94-5	ug/L	2	<0.5	<0.5	<0.5	n/a[e]	
Methoprene	40596-69-8	ug/L	47	<0.1	<0.1213	<1	n/a	
Methotreaxate (Methotrexate)	59-05-2	ug/L	1	<1	<1	<1	0	0.005

Luggage Point AWTP Point of Supply - July 2020 to June 2021

Parameter	CAS RN	Unit of measure	Number of samples	Minimum	Average	Maximum	Count of exceedances	Guideline value
Methoxychlor	72-43-5	ug/L	45	<0.1	<0.1222	<1	0	300
Methoxyfenozide	161050-58-4	ug/L	4	<0.01	<0.01	<0.01	n/a	
Methyl Acrylate	96-33-3	ug/L	2	<0.2	<0.2	<0.2	n/a	
Methyl Amphetamine	537-46-2	ug/L	47	<0.02	<0.02638	<0.2	n/a	
Methyl Bromide (Bromomethane)	74-83-9	ug/L	44	<0.5	<1.3864	<10	0	1
Methyl Methacrylate	80-62-6	ug/L	1	<0.5	<0.5	<0.5	n/a	
Methyl t-Butyl Ether	1634-04-4	ug/L	42	<0.2	<1.9571	<2	n/a	
Metolachlor	51218-45-2	ug/L	4	<0.01	<0.0325	<0.1	0	300
Metolachlor oxanilic acid (OA)(Metolachlor-OXA)	152019-73-3	ug/L	4	<0.05	<0.05	<0.05	n/a	
Metoprolol	51384-51-1	ug/L	47	<0.02	<0.04468	<1	0	20
Metribuzin	21087-64-9	ug/L	47	<0.02	<0.1145	<1	0	70
Metsulfuron-methyl	74223-64-6	ug/L	4	<0.02	<0.0425	<0.05	0	40
Mevinphos	7786-34-7	ug/L	45	<0.02	<0.1204	<1	0	5
Mirtazapine	61337-67-5	ug/L	47	<0.02	0.003404	0.09	n/a	
Moclobemide	71320-77	ug/L	47	<1	<1.2043	<9.8	n/a	
Molinate	2212-67-1	ug/L	47	<0.02	<0.1111	<1	0	4
Molybdenum - Total	7439-98-7	mg/L	27	<0.0001	0.00002741	0.00046	0	0.05
Monobromoacetic Acid	79-08-3	ug/L	46	<0.5	<0.5	<0.5	n/a	
Monobutyltin (MBT)	2406-65-7	ug/L	1	<0.007	<0.007	<0.007	n/a	
Monochloroacetic Acid (MCA)	79-11-8	ug/L	46	<1	<1	<1	0	150
Monocrotophos	6923-22-4	ug/L	47	<0.02	<0.1196	<1	0	2
Musk Ketone	81-14-1	ug/L	47	<0.1	<0.1213	<1	0	400
Musk Xylene	81-15-2	ug/L	47	<0.1	<0.1213	<1	0	400
Naphthalene	91-20-3	ug/L	28	<0.001	<0.001964	<0.01	0	70
Napropamide	15299-99-7	ug/L	29	<0.01	<0.01	<0.01	0	400
Naproxen	22204-53-1	ug/L	47	<0.02	<0.02447	<0.2	0	200
n-Butylbenzene	104-51-8	ug/L	45	<1	<1	<1	n/a	
n-Butylbenzenesulfonamide	3622-84-2	ug/L	47	<0.1	<0.1213	<1	n/a	
n-Butyltoluenesulfonamide	1907-65-9	ug/L	47	<0.1	<0.1213	<1	n/a	
NDEA (n-Nitrosodiethylamine)	55-18-5	ng/L	48	<10	<10	<10	0	10
NDMA (n-Nitrosodimethylamine)(ng/L)	62-75-9	ng/L	48	<3	<9.8542	<10	0	100
N-Ethyl perfluorooctane sulfonamide (N-EtFOSA)	4151-50-2	ug/L	1	<0.005	<0.005	<0.005	n/a	
N-Ethyl perfluorooctane sulfonamidoethanol (N-EtFOSE)	1691-99-2	ug/L	1	<0.005	<0.005	<0.005	n/a	
N-ethyl-perfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	2991-50-6	ug/L	1	<0.005	<0.005	<0.005	n/a	
Nicarbazin	330-95-0	ug/L	1	<0.1	<0.1	<0.1	0	1
Nickel - Total	7440-02-0	mg/L	27	<0.0005	0.00002889	0.00054	0	0.02
Nitrate (as N)	7697-37-2	mg/L	30	<0.02	0.287	0.61	0	50
Nitrilotriacetic Acid (NTA)	139-13-9	ug/L	29	<20	<32.4138	<50	0	200
Nitrite (as N)	14797-65-0	mg/L	30	<0.002	0.009667	0.29	0	3
Nitrobenzene (NB)	98-95-3	ug/L	3	<2	<4.6667	<10	n/a	
Nitroso-piperidine	100-75-4	ng/L	48	<3	<9.8542	<10	n/a	
Nitroso-pyrrolidine	930-52-2	ng/L	29	<10	<10	<10	n/a	
N-Methyl perfluorooctane sulfonamide (N-MeFOSA)	31506-32-8	ug/L	1	<0.005	<0.005	<0.005	n/a	
N-Methyl perfluorooctane sulfonamidoethanol (N-MeFOSE)	200405	ug/L	1	<0.005	<0.005	<0.005	n/a	
N-methyl-perfluorooctanesulfonamidoacetic acid (N-MeFOSAA)	2355-31-9	ug/L	1	<0.005	<0.005	<0.005	n/a	
NMOR (n-Nitrosomorpholine)	59-89-2	ng/L	48	<3	<3.2917	<10	0	1
N-Nitrosodi-n-propylamine (NDPA)	621-64-7	ng/L	3	<3	<5.3333	<10	n/a	
N-Nitrosomethylethylamine (NMEA)	10595-95-6	ng/L	20	<10	<10	<10	n/a	
Nonachlor (cis)	5103-73-1	ug/L	47	<0.1	<0.1213	<1	n/a	
Nonylphenol (ng/L)	25154-52-3	ng/L	46	<50	<58.2609	<420	n/a	
Norethindrone (Norethisterone)	68-22-4	ng/L	46	<2	<7.9348	<170	0	200
Norfloxacin (Norflaxin)	70458-96-7	ug/L	30	<1	<1	<1	0	400
Norgestrel	6533-00-2	ng/L	45	<2	<6.7333	<84	n/a	
n-Propylbenzene	103-65-1	ug/L	45	<1	<1	<1	n/a	
O-Ethyl O-(4-nitrophenyl) phenylphosphonothioate (EPN)	2104-64-5	ug/L	2	<0.05	<0.05	<0.05	n/a	
Omethoate	1113-02-6	ug/L	45	<0.01	<0.236	<2	0	1
Orthophosphate (as P)	14265-44-2	mg/L	26	<0.005	0.0001269	0.0033	n/a[c]	
Ortho-Xylene	95-47-6	ug/L	45	<1	<1	<1	n/a	
Oryzalin	19044-88-3	ug/L	2	<0.05	<0.05	<0.05	0	400
Oxadiazon	19666-30-9	ug/L	47	<0.1	<0.1213	<1	n/a	
Oxamyl	23135-22-0	ug/L	28	<0.01	<0.01286	<0.05	n/a[e]	
Oxamyl - Total	23135-22-0	ug/L	2	<0.15	<0.15	<0.15	0	7
Oxamyl Oxime	30558-43-1	ug/L	2	<0.07	<0.07	<0.07	n/a[e]	
Oxazepam	604-75-1	ug/L	47	<0.02	<0.02383	<0.2	0	20
Oxychlordane	27304-13-8	ug/L	47	<0.1	<0.1213	<1	n/a	
Oxycodone	76-42-6	ug/L	47	<0.02	<0.02383	<0.2	0	10
Oxydemeton-methyl	301-12-2	ug/L	47	<0.2	<0.2426	<2	n/a	
Oxyfluorfen	42874-03-3	ug/L	47	<0.1	<0.1404	<1	n/a	
Oxytetracycline (Terramycin)	79-57-2	ug/L	45	<1	<1	<1	0	100
Paclobutrazol	76738-62-0	ug/L	2	<0.05	<0.05	<0.05	n/a	
Paracetomol (acetaminophen)	103-90-2	ug/L	46	<0.02	0.001087	0.05	0	200
Parathion (ethyl)	56-38-2	ug/L	47	<0.1	<0.1213	<1	0	20
Parathion (methyl)	298-00-0	ug/L	45	<0.1	<0.1222	<1	0	0.7
PCB1 (2-Chlorobiphenyl)	2051-60-7	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB101 (2,2,4,5,5-Pentachlorobiphenyl)	37680-73-2	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB105 (2,3,3,4,4-Pentachlorobiphenyl)	32598-14-4	pg/L	15	<16	<20012.8	<100000	n/a	
PCB110 (2,3,3,4,6-Pentachlorobiphenyl)	38380-03-9	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB114 (2,3,4,4,5-Pentachlorobiphenyl)	74472-37-0	pg/L	15	<0.1	<12.82	<16	n/a	
PCB118 (2,3,4,4,5-Pentachlorobiphenyl)	31508-00-6	pg/L	15	<16	<20012.8	<100000	n/a	

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Parameter	CAS RN	Unit of measure	Number of samples	Minimum	Average	Maximum	Count of exceedances	Guideline value
PCB123 (2,3,4,4,5-Pentachlorobiphenyl)	65510-44-3	pg/L	15	<0.1	<12.82	<16	n/a	
PCB126 (3,3,4,4,5-Pentachlorobiphenyl)	57465-28-8	pg/L	15	<0.1	<12.82	<16	n/a	
PCB128 (2,2,3,3,4,4-Hexachlorobiphenyl)	38380-07-3	pg/L	12	<16	<16	<16	n/a	
PCB138 (2,2,3,4,4,5-Hexachlorobiphenyl)	35065-28-2	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB141 (2,2,3,4,5,5-Hexachlorobiphenyl)	52712-04-6	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB149 (2,2,3,4,5,6-Hexachlorobiphenyl)	38380-04-0	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB151 (2,2,3,5,5,6-Hexachlorobiphenyl)	52663-63-5	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB153 (2,2,4,4,5,5-Hexachlorobiphenyl)	35065-27-1	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB156 (2,3,3,4,4,5-Hexachlorobiphenyl)	38380-08-4	pg/L	15	<16	<20012.8	<100000	n/a	
PCB157 (2,3,3,4,4,5-Hexachlorobiphenyl)	69782-90-7	pg/L	15	<0.1	<12.82	<16	n/a	
PCB167 (2,4,5,3,4,5-Hexachlorobiphenyl)	52663-72-6	pg/L	15	<16	<20012.8	<100000	n/a	
PCB169 (3,4,5,3,4,5-Hexachlorobiphenyl)	32774-16-6	pg/L	15	<16	<20012.8	<100000	n/a	
PCB170 (2,2,3,3,4,4,5-Heptachlorobiphenyl)	35065-30-6	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB18 (2,2,5-Trichlorobiphenyl)	37680-65-2	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB180 (2,2,3,4,4,5,5-Heptachlorobiphenyl)	35065-29-3	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB183 (2,2,3,4,4,5,6-Heptachlorobiphenyl)	52663-69-1	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB189 (2,3,3,4,4,5,5-Heptachlorobiphenyl)	39635-31-9	pg/L	15	<0.1	<12.82	<16	n/a	
PCB194 (2,2,3,3,4,4,5,5-Octachlorobiphenyl)	35694-08-7	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB206 (2,2,3,3,4,4,5,5,6-Nonachlorobiphenyl)	40186-72-9	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB28+31 (2,4,4-Trichlorobiphenyl+2,4,5-Trichlorobiphenyl)	7012-37-5+166	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB44 (2,2,3,5-Tetrachlorobiphenyl)	41464-39-5	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB5 (2,3-Dichlorobiphenyl)	16605-91-7	pg/L	3	<100000	<100000	<100000	n/a	
PCB52 (2,2,5,5-Tetrachlorobiphenyl)	35693-99-3	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB66 (2,3,4,4-Tetrachlorobiphenyl)	32598-10-0	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCB77 (3,3,4,4-Tetrachlorobiphenyl)	32598-13-3	pg/L	15	<16	<20012.8	<100000	n/a	
PCB81 (3,4,4,5-Tetrachlorobiphenyl)	70362-50-4	pg/L	15	<0.1	<12.82	<16	n/a	
PCB87 (2,2,3,4,5-Pentachlorobiphenyl)	38380-02-8	pg/L	3	<0.1	<0.1	<0.1	n/a	
PCBs - Total		pg/L	3	<1.9	<1.9	<1.9	n/a	
Penconazole	66246-88-6	ug/L	2	<0.01	<0.01	<0.01	n/a	
Pendimethalin	40487-42-1	ug/L	47	<0.02	<0.114	<1	0	400
Pentachloroethane	76-01-7	ug/L	45	<1	<2.0889	<50	n/a	
Pentachlorophenol (PCP)	87-86-5	ug/L	8	<0.05	<0.1688	<1	0	10
Perchlorate	14797-73-0	mg/L	1	<1	<1	<1	n/a	
Perfluorobutanesulfonate (PFBS)	45187-15-3	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorobutanoic acid (PFBA)	375- 22-4	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorodecanesulfonic acid (PFDSA)	67906-42-7	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorodecanoic acid (PFDcA)	335-76-2	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorododecanoic acid (PFDoA)	307-55-1	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluoroheptanesulfonate (PFHpS)	375-92-8	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluoroheptanoic acid (PFHpA)	375-85-9	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorohexanesulfonic acid (PFHxSA)	355-46-4	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorohexanoic acid (PFHxA)	307-24-4	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorononanoic acid (PFNA)	375-95-1	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorooctanesulfonate (PFOS)	45298-90-6	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorooctanoic acid (PFOA)	335-67-1	ug/L	1	<0.005	<0.005	<0.005	0	0.56
Perfluoropentanesulfonate (PFPeS)	3872-25-1	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluoropentanesulfonic acid (PFPeSA)	3872-25-1	ug/L	26	<0.02	<0.02	<0.02	n/a	
Perfluoropentanoic acid (PFPeA)	2706-90-3	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorotetradecanoic acid (PFTeDA)	376-06-7	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	ug/L	1	<0.005	<0.005	<0.005	n/a	
Perfluoroundecanoic acid (PFUnDA)	2058-94-8	ug/L	1	<0.005	<0.005	<0.005	n/a	
Permethrin	52645-53-1	ug/L	47	<0.1	<0.1383	<1	0	200
Perylene	198-55-0	ug/L	2	<0.01	<0.01	<0.01	n/a	
Pethidine	57-42-1	ug/L	47	<0.02	<0.02383	<0.2	n/a	
PFAS - Sum of PFHxS and PFOS		ug/L	1	<0.005	<0.005	<0.005	0	0.07
PFAS - Total		ug/L	1	<0.005	<0.005	<0.005	n/a	
pH	12408-02-5		49	7.7	7.9802	8.14	n/a	
Phenanthrene	85-01-8	ug/L	28	<0.001	<0.002286	<0.01	n/a	
Pheniramine	86-21-5	ug/L	47	<0.02	0.002979	0.07	n/a	
Phenol	108-95-2	ug/L	8	<0.1	<0.1188	<0.25	0	200
Phenothrin	26002-80-2	ug/L	47	<0.1	<0.1383	<1	n/a	
Phenytoin	57-41-0	ug/L	46	<0.02	<0.02391	<0.2	n/a	
Pholcodine	509-67-1	ug/L	47	<0.02	<0.1174	<1	n/a	
Phorate	298-02-2	ug/L	47	<0.1	<0.1213	<1	n/a	
Phosmet	732-11-6	ug/L	47	<0.1	<0.1213	<1	n/a	
Phosphamidon	13171-21-6	ug/L	47	<0.1	<0.1213	<1	n/a	
Phthalate - Total	16883-83-3	ug/L	2	<2	<2	<2	n/a	
Picloram	1918-02-1	ug/L	46	<0.02	<0.1874	<0.2	0	300
Piperonyl Butoxide	51-03-6	ug/L	47	<0.1	<0.1447	<1	0	600
Pirimicarb	23103-98-2	ug/L	47	<0.2	<0.2426	<2	0	7
Pirimiphos-ethyl	23505-41-1	ug/L	2	<0.01	<0.01	<0.01	0	0.5
Pirimiphos-methyl	29232-93-7	ug/L	47	<0.01	<0.1194	<1	0	90
Potassium - Total	2023695	mg/L	26	<0.2	0.5035	0.8	n/a	
Potassium-40	13966-00-2	Bq/L	48	<0.5	0.2792	4	n/a[b]	
Praziquantel	55268-74-1	ug/L	46	<0.02	<0.02565	<0.2	0	70
Predicted Estradiol Equivalent		ng/L	46	<2	<5.7174	<170	n/a	
Primidone	125-33-7	ug/L	46	<0.1	<0.1196	<1	n/a	
Procymidone	32809-16-8	ug/L	47	<0.1	<0.1213	<1	n/a	
Profenofos	41198-08-7	ug/L	47	<0.01	<0.1194	<1	0	0.3
Progesterone	57-83-0	ng/L	46	<20	<23.2609	<170	0	100000

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Parameter	CAS RN	Unit of measure	Number of samples	Minimum	Average	Maximum	Count of exceedances	Guideline value
Promecarb	2631-37-0	ug/L	2	<0.05	<0.05	<0.05	n/a	
Prometryn	7287-19-6	ug/L	4	<0.01	<0.0375	<0.1	0	100
Propachlor	1918-16-7	ug/L	29	<0.02	<0.02	<0.02	0	70
Propanil	709-98-8	ug/L	45	<0.1	<0.1222	<1	0	700
Propargite	2312-35-8	ug/L	47	<0.1	<0.1213	<1	0	7
Propazin-2-hydroxy (2-Hydroxypropazine)	7374-53-0	ug/L	4	<0.02	<0.02	<0.02	n/a	
Propazine	139-40-2	ug/L	47	<0.01	<0.1174	<1	0	50
Propiconazole	60207-90-1	ug/L	45	<0.05	<0.1211	<1	0	100
Propionaldehyde (Methylacetaldehyde)	123-38-6	ug/L	28	<0.1	<1.8643	<2	n/a	
Propionitrile	107-12-0	ug/L	2	<0.5	<0.5	<0.5	n/a	
Propoxur	114-26-1	ug/L	6	<0.05	<0.05833	<0.1	0	70
Propranolol	525-66-6	ug/L	46	<0.02	<0.0413	<1	0	40
Propylene Carbonate (PC)	108-32-7	ug/L	8	<1	<1	<1	n/a	
Prothiophos	34643-46-4	ug/L	47	<0.1	<0.1213	<1	n/a	
Pseudoephedrine	90-82-4	ug/L	47	<0.02	<0.02638	<0.2	n/a	
Pyrazophos	13457-18-6	ug/L	47	<0.1	<0.1213	<1	0	20
Pyrene	129-00-0	ug/L	28	<0.001	<0.001964	<0.01	n/a	
Pyrimethanil	53112-28-0	ug/L	2	<0.02	<0.02	<0.02	n/a	
Pyrimethanil	53112-28-0	ug/L	2	<0.02	<0.02	<0.02	n/a	
Radium-224	13233-32-4	Bq/L	3	<0.34	<0.34	<0.34	n/a	
Radium-226	7440-14-4	Bq/L	31	<0.13	0.02258	0.3	n/a[b]	
Radium-228	15262-20-1	Bq/L	48	<0.2	0.1417	1.3	n/a[b]	
Ranitidine	66357-35-5	ug/L	46	<0.05	<0.05978	<0.5	0	80
Rotenone	83-79-4	ug/L	47	<0.1	<0.1213	<1	n/a	
Roxithromycin	80214-83-1	ug/L	46	<0.05	<0.9283	<40	0	200
Salicylic Acid	69-72-7	ug/L	46	<0.2	0.1043	1.8	0	100
Samarium-153	15766-00-4	Bq/L	47	<0.2	0.05532	1	n/a[b]	
sec-Butylbenzene	135-98-8	ug/L	45	<1	<1	<1	n/a	
Selenium - Total	7782-49-2	mg/L	28	<0.0002	0.000000175	0.0000049	0	0.01
Sertraline	79617-96-2	ug/L	46	<0.02	<0.02391	<0.2	n/a	
Sethoxydim	74051-80-2	ug/L	4	<0.02	<0.02	<0.02	n/a	
Silicon - Soluble	7440-21-3	mg/L	26	0.1	0.2031	0.51	n/a	
Silicon - Total	7440-21-3	mg/L	4	<0.05	0.09	0.18	n/a	
Silver - Total	7440-22-4	mg/L	2	<0.0001	<0.00055	<0.001	0	0.1
Simazine	122-34-9	ug/L	4	<0.01	<0.0325	<0.1	0	20
Sodium - Total	7440-23-5	mg/L	26	8.8	13.4923	19	n/a	
Sodium-22	13966-32-0	Bq/L	48	<0.03	0.05	0.5	n/a[b]	
Sodium-24	13982-04-2	Bq/L	42	<0.05	0.669	20	n/a[b]	
Somatic Coliphages		pfu/100mL	48	<1	<1	<1	0	0
Strontium - Total	7440-24-6	mg/L	25	<0.0001	0.01066	0.015	n/a	
Styrene (Vinyl benzene)	100-42-5	ug/L	45	<1	0.08889	4	0	30
Sulfadiazine (Sulphadiazine)	68-35-9	ug/L	46	<0.02	<0.02565	<0.2	0	1000
Sulfamethazine (Sulfadimidine)	57-68-1	ug/L	1	<1	<1	<1	0	70
Sulfamethizole	144-82-1	ug/L	1	<1	<1	<1	n/a	
Sulfamethoxazole (Sulphamethoxazole)	723-46-6	ug/L	46	<0.02	<0.04522	<1	0	200
Sulfasalazine	599-79-1	ug/L	46	<0.02	<0.1178	<1	0	500
Sulfathiazole (Sulphathiazole)	72-14-0	ug/L	46	<0.02	<0.02391	<0.2	0	40
Sulfosulfuron	141776-32-1	ug/L	4	<0.05	<0.05	<0.05	n/a	
Sulfotep	3689-24-5	ug/L	2	<0.005	<0.005	<0.005	n/a	
Sulphur (as SO4) - Total	18785-72-3	mg/L	45	<0.005	0.001578	0.01	n/a	
Sulprofos	35400-43-2	ug/L	47	<0.05	<0.1202	<1	0	10
Tau-fluvalinate		ug/L	2	<0.5	<0.5	<0.5	n/a	
Tebuconazole	107534-96-3	ug/L	45	<0.01	<0.1182	<1	n/a	
Tebuthiuron	34014-18-1	ug/L	4	<0.01	<0.0325	<0.1	n/a	
Technetium-99m	109581-73-9	Bq/L	23	<0.06	26.0896	160	n/a[b]	
Temazepam	846-50-4	ug/L	46	<0.02	<0.02391	<0.2	0	5
Temephos	3383-96-8	ug/L	47	<0.02	<0.2026	<1	0	400
Terbacil	5902-51-2	ug/L	1	<0.1	<0.1	<0.1	0	200
Terbufos	13071-79-9	ug/L	47	<0.01	<0.1194	<1	0	0.9
Terbuthylazine	5915-41-3	ug/L	47	<0.01	<0.1155	<1	0	10
Terbuthylazine-desethyl (Desethylterbuthylazine)	30125-63-4	ug/L	4	<0.02	<0.02	<0.02	n/a	
Terbutryn	886-50-0	ug/L	4	<0.01	<0.0175	<0.02	0	400
tert-Butylbenzene	98-06-6	ug/L	45	<1	<1	<1	n/a	
Testosterone	58-22-0	ng/L	46	<5	<15.7174	<420	0	7000
Tetrachloroethene	127-18-4	ug/L	45	<1	<1	<1	0	50
Tetrachlorvinphos	22248-79-9	ug/L	47	<0.01	<0.1194	<1	0	100
Tetracycline	60-54-8	ug/L	45	<1	<1	<1	0	100
Tetradifon	116-29-0	ug/L	47	<0.1	<0.1213	<1	n/a	
Tetrahydrofuran	109-99-9	ug/L	2	<0.5	<0.5	<0.5	n/a	
Tetramethrin	7696-12-0	ug/L	47	<0.1	<0.1383	<1	n/a	
Thallium-201	15064-65-0	Bq/L	48	<0.05	0.025	0.5	n/a[b]	
Thallium-208	14913-50-9	Bq/L	48	<0.06	0.04583	0.8	n/a[b]	
Theophylline	58-55-9	ug/L	47	<0.02	<0.2515	<2	0	200
Thiabendazole	148-79-8	ug/L	47	<0.2	<0.2426	<2	n/a	
Thiacloprid	111988-49-9	ug/L	4	<0.02	<0.02	<0.02	n/a	
Thiamethoxam	153719-23-4	ug/L	4	<0.02	<0.0275	<0.05	n/a	
Thiobencarb	28249-77-6	ug/L	2	<0.01	<0.01	<0.01	0	40
Thiodicarb	59669-26-0	ug/L	14	<0.01	<0.01	<0.01	n/a	
Tolfenamic acid	13710-19-5	ug/L	1	<1	<1	<1	0	20

Luggage Point AWTP Point of Supply - July 2020 to June 2021

Parameter	CAS RN	Unit of measure	Number of samples	Minimum	Average	Maximum	Count of exceedances	Guideline value
Toluene	108-88-3	ug/L	45	<1	<1	<1	0	800
Tonalid	21145-77-7	ug/L	47	<0.1	<0.1404	<1	0	20
Tot Est Radiological Dose (Gamma)(0LOR)		mSv/yr	48	<0.5	0.03681	0.76966	0	1
Total Aldrin and Dieldrin		ug/L	47	<0.1	<0.2298	<2	0	0.3
Total Alkalinity (as CaCO3)		mg/L	46	54	65.7609	74	n/a[c]	
Total BTEX		ug/L	45	<1	<1	<1	n/a	
Total Dissolved Solids (TDS)		mg/L	49	88	114.1224	150	n/a	
Total Hardness (as CaCO3)		mg/L	68	52	66.9074	77	n/a	
Total HpCDD (Hepta Dioxins)		pg/L	13	<20	<23.0769	<25	n/a	
Total HpCDF (Hepta Furans)		pg/L	13	<20	<23.0769	<25	n/a	
Total HxCDD (Hexa Dioxins)		pg/L	13	<20	<23.0769	<25	n/a	
Total HxCDF (Hexa Furans)		pg/L	13	<20	<23.0769	<25	n/a	
Total Nitrogen (as N)	7727-37-9	mg/L	49	0.18	0.3269	0.58	n/a[c]	
Total Organic Carbon (TOC)		mg/L	50	<0.2	0.3602	0.76	n/a[c]	
Total PeCDD (Penta Dioxins)		pg/L	13	<20	<23.0769	<25	n/a	
Total PeCDF (Penta Furans)		pg/L	13	<20	<23.0769	<25	n/a	
Total Phosphorus (as P)	7723-14-0	mg/L	49	<0.01	0.006204	0.068	n/a[c]	
Total Pirimicarb	23103-98-2	ug/L	2	<0.6	<0.6	<0.6	n/a	
Total TCDD (Tetra Dioxins)		pg/L	13	<5	<5	<5	n/a	
Total TCDF (Tetra Furans)		pg/L	13	<5	<5	<5	n/a	
Total Trichlorobenzene		ug/L	44	<1	<1	<1	0	30
Total Trihalomethanes		ug/L	48	<1	0.3333	6	0	250
Total Xylene	1330-20-7	ug/L	45	<1	<1	<1	0	600
Tramadol	27203-92-5	ug/L	46	<0.02	<0.02391	<0.2	n/a	
Transfluthrin	118712-89-3	ug/L	47	<0.1	<0.1383	<1	n/a	
trans-Nonachlor	39765-80-5	ug/L	47	<0.1	<0.1213	<1	n/a	
Triadimefon	43121-43-3	ug/L	47	<0.1	<0.1213	<1	n/a[e]	
Triadimefon - Total	43121-43-3	ug/L	47	<0.1	<0.3298	<2.9	0	90
Triadimenol	5519-65-3	ug/L	47	<0.1	<0.1213	<1	n/a	
Triallate	2303-17-5	ug/L	47	<0.1	<0.1213	<1	n/a	
Triazophos	24017-47-8	ug/L	2	<0.005	<0.005	<0.005	n/a	
Tribromoacetic Acid	75-96-7	ug/L	46	<1	<1	<1	n/a	
Tributyltin (TBT)	688-73-3	ug/L	1	<0.01	<0.01	<0.01	n/a	
Trichlorfon	52-68-6	ug/L	2	<0.02	<0.02	<0.02	0	7
Trichloroacetic Acid	76-03-9	ug/L	46	<1	<1	<1	0	100
Trichloroethene	79-01-6	ug/L	45	<1	<1	<1	n/a	
Trichlorofluoromethane	75-69-4	ug/L	45	<10	<10	<10	n/a	
Trichlorophenol - Total		ug/L	8	<0.2	<0.4875	<2	n/a	
Trichlorophenoxyacetic acid (2,4,5-T)	93-76-5	ug/L	46	<0.01	<0.03261	<0.1	0	100
Triclopyr	55335-06-3	ug/L	46	<0.05	<0.06087	<0.2	0	20
Triclosan	3380-34-5	ug/L	46	<0.1	<1.1174	<10	0	1000
Triclosan methyl ether	1000766	ug/L	47	<0.1	<0.1213	<1	n/a	
Triethyl phosphate	78-40-0	ug/L	47	<0.1	<0.1213	<1	n/a	
Trifloxysulfuron	145099-21-4	ug/L	4	<0.05	<0.05	<0.05	n/a	
Trifluralin	1582-09-8	ug/L	47	<0.1	<0.1213	<1	0	90
Trimethoprim	738-70-5	ug/L	46	<0.02	<0.04522	<1	0	70
Tri-n-butyl phosphate	126-73-8	ug/L	47	<0.1	<0.1213	<1	0	0.5
Trinexapac (acid)	143294-89-7	ug/L	4	<0.05	<0.05	<0.05	n/a	
Triphenyl Phosphate	115-86-6	ug/L	1	<2	<2	<2	0	600
Tris(chloroethyl) phosphate	115-96-8	ug/L	47	<0.1	<0.1213	<1	0	80
Tris(chloropropyl) phosphate	6145-73-9	ug/L	44	<0.1	<0.1227	<1	n/a	
Tris(chloropropyl) phosphate Isomers		ug/L	47	<0.1	<0.5596	<4.9	n/a	
Tris(dichloropropyl) phosphate (Fyrol)	13674-87-8	ug/L	3	<0.1	<0.1	<0.1	0	1
Turbidity		NTU	49	0.2	0.4637	0.94	n/a	
Tylosin	1401-69-0	ug/L	46	<0.2	<1.1043	<40	0	1000
Uranium - Total	7440-61-1	mg/L	1	<0.001	<0.001	<0.001	0	0.017
Uranium-238	7440-61-1	Bq/L	9	<2.2	1.2222	2	n/a[b]	
Vanadium - Total	7440-62-2	mg/L	26	<0.0001	0.0002204	0.0047	n/a	
Vanadium-50	30486-37-4	Bq/L	48	<0.05	0.006458	0.1	n/a[b]	
Venlafaxine	93413-69-5	ug/L	46	<0.02	<0.02391	<0.2	0	40
Vinclozolin	50471-44-8	ug/L	47	<0.1	<0.1213	<1	n/a	
Vinyl Acetate	108-05-4	ug/L	45	<0.2	<1.5244	<50	n/a	
Vinyl Chloride	75-01-4	ug/L	45	<0.2	<0.4178	<10	0	0.3
Warfarin	81-81-2	ug/L	46	<0.02	<0.02522	<0.2	0	1
Zinc - Total	7440-66-6	mg/L	48	<0.001	0.0005583	0.024	n/a	
Total number of tests in reporting period 2020-21		**n**	**21650**					

Average is calculated such that where a detection exists any less than values have been treated as zero. Where all values are less than, the average has been calculated from the less than figures and reported as less than which is effectively non-detected above LOR.

[a] Parameter is included in Total Trihalomethanes (tTHM).

[b] Paremeter is included in Total Estimated Radiological dose value.

[c] Paremter is operational or environmental.

[d] Chlorine is assessed against health guideline only.

[e] Guideline applies to Total for parameter.

APPENDIX K: SINGAPORE NEWATER PRW SAMPLING

Singapore NEWater PRW Sampling

Parameter Name	Samples per Year
Physical Characteristics	
Conductivity -In-Situ	104
Langelier Saturation Index (LSI)	104
pH-In-Situ	104
Total Dissolved Solids (TDS)	104
Colour	24
Turbidity-In-situ	104
UV-254 Absorbance	4
Inorganic Chemicals Agent & Disinfection By-Products	
Bromate	8
Chlorate	8
Total Residual Chlorine-In-Situ	104
Chlorite	8
Iodide	8
Mono-chloramine (in-situ)	24
Cyanogen Chloride (as Cyanide)	4
Inorganic Chemicals	
Aluminium	104
Ammonia (as N)	104
Antimony	24
Arsenic	24
Asbestos	2
Barium	104
Beryllium	24
Boron	104
Bromide	4
Cadmium	24
Calcium	104
Chloride	104
Chromium	24
Cobalt	24
Copper	104
Cyanide	24
Dissolved Phosphorous (as P)	4
Fluoride	104
Sulphide	2
Iron	104
Lead	24

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Magnesium	8
Manganese	104
Mercury	24
Molybdenum	24
Nickel	24
Nitrate (as N)	104
Nitrite (as N)	24
Perchlorate	4
Potassium	4
Selenium	24
Silica (as SiO2)	104
Silver	24
Sodium	104
Strontium	104
Sulphate	104
Thallium	24
Total Alkalinity	104
Total Hardness (as CaCO3)	4
Total Nitrogen (as N)	4
Total Phosphorous (as P)	4
Vanadium	4
Zinc	104
Organic Disinfection By-Products	
Chlorinated Acetic Acids	
Dibromoacetic Acid	4
Dichloroacetic Acid	4
Monobromoacetic Acid	4
Monochloroacetic Acid	4
Trichloroacetic Acid	4
Haloacetic Acids (HAAs)	4
Chlorophenols	
2-Chlorophenol	4
2,4-Dichlorophenol	4
2,4,6-Trichlorophenol	4
Halogenated Acetonitriles	
Dichloroacetonitrile	4
Trichloroacetonitrile	4
Dibromoacetonitrile	4

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Bromochloroacetonitrile	4
Others	
Chloral Hydrate (Trichloroacetaldehyde)	4
1,1-Dichloroacetone	4
Chloropicrin	4
Formaldehyde	4
N-Nitrosodiethylamine (NDEA)	4
N-Nitrosodimethylamine (NDMA)	24
Trihalomethanes	
Bromodichloromethane	24
Bromoform	24
Chloroform	24
Dibromochloromethane	24
Total Trihalomethanes (TTHMs)	24
TTHM Ratio	24
Organic Compounds	
Aromatic Hydrocarbons	
1,2,4-Trimethylbenzene	4
1,3,5-Trimethylbenzene	4
Benzene	4
Ethylbenzene	4
Isopropylbenzene	4
N-Butylbenzene	4
N-Propylbenzene	4
Sec-Butylbenzene	4
Styrene	4
Tert-Butylbenzene	4
Toluene	4
Xylenes (Total)	4
Chlorinated Alkanes	
Carbon Tetrachloride	4
Dichloromethane (Methylene Chloride)	4
1,1-Dichloroethane	4
1,2-Dichloroethane	4
1,1,1-Trichloroethane	4
1,1,2-Trichloroethane	4
1,2,3-Trichloropropane	4

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Chlorinated Ethenes	
1,1-Dichloroethene	4
1,2-Dichloroethene (cis & trans)	4
Trichloroethene	4
Tetrachloroethene	4
Vinyl Chloride	4
Chlorobenzenes	
Chlorobenzene	4
1,2-Dichlorobenzene (o-Dichlorobenzene)	4
1,3-Dichlorobenzene	4
1,4-Dichlorobenzene (p-Dichlorobenzene)	4
1,2,4-Trichlorobenzene	4
Trichlorobenzenes (Total)	4
Organotins	
Dialkyltins	4
Tributyltin Oxide	4
Others	
Acrylamide	4
Bisphenol A	4
Carbon Disulfide	4
2-Chlorotoluene	4
4-Chlorotoluene	4
Dichlorodifluoromethane	4
2,4-Dinitrophenol	4
2,4-Dinitrotoluene	4
2,6-Dinitrotoluene	4
1,4-Dioxane	4
1,2-Diphenylhydrazine	4
Epichlorohydrin	4
Ethylene Glycol	4
Hexachlorobutadiene	4
Hexane	4
Methyl Isobutyl Ketone (MIBK)	4
Methyl Tertiary Butyl Ether (MTBE)	4
2-Methylphenol	4
Nitrilotriacetic Acid (NTA)	4
Nitrobenzene	4
Nonylphenol	4

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Phenol	4
2-Phenylphenol	4
Polychlorinated Biphenyls (PCBs)	4
Tertiary Butyl Alcohol	4
Polycyclic Aromatic Hydrocarbons	
Benzo(a)pyrene	4
Naphthalene	4
Pesticides	
1,2-Dibromo-3-chloropropane (DBCP)	4
Acetochlor	4
Alachlor	4
Aldicarb	4
Aldicarb Sulfone	4
Aldicarb Sulfoxide	4
Aldicarb Sulfoxide and Aldicarb Sulfone	4
Aldrin	4
Aldrin and dieldrin	4
Atrazine	4
Atrazine and its chloro-s-triazine metabolites	4
Bentazone	4
Carbofuran	4
Chlordane (Total Isomers)	4
Chlorotoluron	4
Chlorpyrifos	4
Cyanazine	4
Dalapon	4
4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	4
DCPA Mono Acid Degradate	4
4,4'-Dichlorodiphenyldichloroethene (4,4'-DDE)	4
DDT and Derivatives (Total isomers)	4
Diazinon	4
1,2-Dibromoethane (Ethylene Dibromide)	4
2,4-Dichlorophenoxyacetic Acid (2,4-D)	4
1,2-Dichloropropane	4
1,3-Dichloropropane	4
1,3-Dichloropropene (cis & trans)	4
Dichlorprop	4
Dieldrin	4

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Dimethoate	4
Dinoseb	4
Diquat	4
Disulfoton	4
Diuron	4
Endosulfan I	4
Endosulfan II	4
Endothall	4
Endrin	4
Sec-Ethyl-dipropylthiocarbamate (EPTC)	4
Fenoprop (2,4,5-TP) / Silvex	4
Fonofos	4
Glyphosate	4
Heptachlor	4
Heptachlor Epoxide	4
Hexachlorobenzene	4
Hexachlorocyclopentadiene	4
Hydroxyatrazine	4
Isoproturon	4
Gamma-BHC (Lindane)	4
Linuron	4
Malathion	4
2-Methyl-4-chlorophenoxyacetic Acid (MCPA)	4
4-(4-Chloro-2-methylphenoxy)butanoic Acid (MCPB)	4
Mecoprop	4
Methoxychlor	4
Metolachlor	4
Mirex	4
Molinate	4
Oxamyl	4
Parathion	4
Pendimethalin	4
Pentachlorophenol	4
Permethrin	4
Picloram	4
Prometon	4
Propanil	4
Pyridate	4

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Pyriproxyfen	8
Simazine	4
2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T)	4
Terbacil	4
Terbufos	4
Terbuthylazine (TBA)	4
Toxaphene	4
Trifluralin	4
Pesticide residues	
Fernvalerate	3
Fipronil	3
Imidacloprid	3
Thiamethoxam	3
Dichlorvos	4
Dicofol	4
Aminomethylphosphonic acid (AMPA) and Glyphosate	4
Organic Indicators	
Biodegradable Organic Carbon (BDOC)	4
Chemical Oxygen Demand (COD)	4
Total Organic Carbon (TOC)	24
Radiological Quality	
Gross Alpha	2
Gross Beta	2
Radium 226	4
Radium 228	2
Radon 222	2
Uranium	2
Microbiological Quality	
Aeromonas	12
Campylobacter	15
Clostridium perfringens	24
Coliphage (male-specific - *E.coli* ATCC 700891)	24
Coliphage (somatic)	24
Cryptosporidium	1
Enterococci	24
Enterovirus	3
Escherichia coli (E. coli)	103
Giardia lamblia	1

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Heterotrophic Plate Count (HPC)	104
Legionella	12
Salmonella	12
Shigella	12
Total coliforms	103
Vibrio cholerae	4
Wastewater 'Signature' Compounds	
Alkylphenol Polyethoxylates (APEO)	4
Caffeine	4
Nonylphenoxyacetic acid (NP1EC)	4
Nonylphenoxyethoxyacetic acid (NP2EC)	4
Ethylenediamine Tetraacetic Acid (EDTA)	4
Anionic Surfactants as MBAS	8
2,6-Naphthalenedicarboxylic Acid (NDC)	4
Contaminants of Emerging Concern (CEC)	
Perfluorinated Compounds	
Perfluorooctane Sulfonate (PFOS)	8
Perfluorooctanoic Acid (PFOA)	8
Pharmaceuticals and personal care products (PPCPs)	
Diclofenac Sodium	8
Gemfibrozil	8
Ibuprofen	8
Ketoprofen	8
Naproxen	8
Trichlorocarban	8
Triclosan	8
Carbamazepine	8
N,N-Diethyl-meta-toluamide (DEET)	8
Paracetamol	8
Salicylic Acid	8
Trimethoprim	8
Plasticisers	
Di(2-Ethylhexyl)adipate	4
Di(2-Ethylhexyl)phthalate	4
Synthetic and Natural Hormones	
Estradiol	4
Estrone	4
Ethinyl Estradiol	4

Singapore NEWater PRW Sampling (continued)

Parameter Name	Samples per Year
Total Estrogens	4
Dioxins & Furans	
1234678-HpCDD	4
Total HpCDD	4
1234678-HpCDF	4
1234789-HpCDF	4
Total HpCDF	4
123478-HxCDD	4
123678-HxCDD	4
123789-HxCDD	4
Total HxCDD	4
123478-HxCDF	4
123678-HxCDF	4
234678-HxCDF	4
123789-HxCDF	4
Total HxCDF	4
OCDF	4
OCDD	4
12378-PeCDD	4
Total PeCDD	4
12378-PeCDF	4
23478-PeCDF	4
Total PeCDF	4
2378-TCDD	4
Total TCDD	4
2378-TCDF	4
Total TCDF	4
Total I-TEQ (Max)	4
Algal parameters	
Algal toxins	
Cylindrospermopsin	1
Microcystin-LR	4
Saxitoxin (ELISA)	1
Microcystins (ELISA)	1

APPENDIX L: DATA SHEETS

Data Sheet - Ozone System

Ozone Generator		
Parameter	Units	Value
Ozone generation capacity required (delivered to process water)	kg/h	0.3 1.0 2.5 4.0 10.0 24.7
Maximum cooling water temperature	°C	30
Redundancy	-	N + 1
Power consumption at design ozone demand above	kWh	Vendor to advise
Liquid oxygen demand at design ozone demand above	kg/h	Vendor to advise
Cooling water required	m3/h	Vendor to advise
Ozone Injection		
Process flow	ML/d	0.6 2.3 5.7 9.2 23.0 57.4
Side stream flow required	m3/h	Vendor to advise
Side stream operating pressure	kPa	Vendor to advise
Power consumption	kWh/d	Vendor to advise
Ozone Destruction Unit		
Power consumption	kWh/d	Vendor to advise
General		
Major maintenance items	-	Vendor to advise cost and replacement frequency

Data Sheet - UF System (Carbon-based Process)

Parameter	Units	Value
Influent flows	ML/d	0.6 2.2 5.6 8.9 22.2 55.6
Source water	-	Filtered Secondary Effluent (following Ozone/BAC treatment)
Maximum Instantaneous Flux	L/m2/h	Vendor to advise
Minimum Pathogen Reduction Required	LRV	Virus – vendor to advise Cryptosporidium – 4 Bacteria - 4
UF System Recovery	%	Vendor to advise
Biofouling Control	-	Preformed Chloramine
Off-Spec Water Control	-	Each unit to be equipped with off-spec diversion
Redundancy	-	N + 1 for UF Units N + 1 for all pumps, blowers, etc.
Pressure at Filtrate Connection Point	kPa	50
Power consumption	kWh/ML	Vendor to advise
Chemical use	L/ML, kg/ML	Vendor to advise (for each chemical)
Membrane life	years	Vendor to advise
Membrane replacement cost	$ per membrane module	Vendor to advise
Influent Quality		
• TSS	mg/L	< 5
• TDS	mg/L	500
• pH	-	7.0
• Alkalinity	mg/L as $CaCO_3$	110
• Calcium	mg/L	20
• Aluminium	mg/L	0.1
• Iron	mg/L	0.3
• Manganese	mg/L	0.12
• TOC	mg/L	4
• DOC	mg/L	3

Data Sheet - UF System (RO-based Process)

Parameter	Units	Value
Influent flows	ML/d	0.6 2.2 5.6 8.9 22.2 55.6
Source water	-	Secondary Effluent
Maximum Instantaneous Flux	L/m2/h	50
Minimum Pathogen Reduction Required	LRV	Virus – vendor to advise Cryptosporidium – 4 Bacteria - 4
UF System Recovery	%	Vendor to advise
Biofouling Control	-	Preformed Chloramine
Off-Spec Water Control	-	Each unit to be equipped with off-spec diversion
Redundancy	-	N + 1 for UF Units N + 1 for all pumps, blowers, etc.
Pressure at Filtrate Connection Point	kPa	50
Power consumption	kWh/ML	Vendor to advise
Chemical use	L/ML, kg/ML	Vendor to advise (for each chemical)
Membrane life	years	Vendor to advise
Membrane replacement cost	$ per membrane module	Vendor to advise
Influent Quality		
• TSS	mg/L	Average 5, Maximum 15
• TDS	mg/L	500
• pH	-	7.0
• Alkalinity	mg/L as $CaCO_3$	95
• Calcium	mg/L	20
• Aluminium	mg/L	0.1
• Iron	mg/L	< 0.2
• Manganese	mg/L	0.12
• TOC	mg/L	8
• DOC	mg/L	7.5

Data Sheet - RO System

Parameter	Units	Value
Influent flows	ML/d	0.5 2 5 8 20 50
Source water	-	UF Filtered Secondary Effluent
Maximum Instantaneous Flux	L/m2/h	20
RO System Recovery	%	80
Biofouling Control	-	Preformed Chloramine
Off-Spec Water Control	-	Each unit to be equipped with off-spec diversion
Redundancy	-	N + 1 for RO Units N + 1 for low pressure feed pumps, cartridge filters, etc. N for high pressure feed pumps (i.e. 1 per RO unit)
Pressure at Permeate Connection	kPa	50
Power consumption	kWh/ML	Vendor to advise
Chemical use	L/ML, kg/ML	Vendor to advise (for each chemical)
Membrane life	years	Vendor to advise
Membrane replacement cost	$ per membrane module	Vendor to advise
Influent Quality:		
• TDS	mg/L	500
• Sodium	mg/L	115
• Chloride	mg/L	140
• pH	-	7.0
• Alkalinity	mg/L as $CaCO_3$	95
• Calcium	mg/L	20
• Orthophosphate	mg/L as P	0.2
• Sulphate	mg/L	80
• Aluminium	mg/L	0.1
• Iron	mg/L	< 0.2
• Manganese	mg/L	0.12
• DOC	mg/L	7.5
• Potassium	mg/L	18
• Magnesium	mg/L	8

Data Sheet - RO System (continued)

Parameter	Units	Value
• Barium	mg/L	0.01
• Strontium	mg/L	0.09
• Fluoride	mg/L	0.05
• Silica	mg/L as SiO_2	12

Data Sheet - UV System (Carbon-based Process)

Parameter	Units	Value
Influent flows	ML/d	0.5 2 5 8 20 50
Source water	-	Secondary effluent treated by ozone/BAC, GAC and ultrafiltration
Minimum UVT	%	80
UV Dose	mJ/cm^2	186
Off-Spec Water Control	-	Each unit to be equipped with off-spec diversion
Redundancy	-	N + 1
Power consumption	kWh/ML	Vendor to advise
Lamp ballast and wiper life	years	Vendor to advise
Lamp ballast and wiper life replacement cost	$ per item	Vendor to advise
Influent Quality:		
• TDS	mg/L	500
• Sodium	mg/L	115
• Chloride	mg/L	140
• pH	-	7.0
• Alkalinity	mg/L as $CaCO_3$	95
• Calcium	mg/L	20
• Orthophosphate	mg/L as P	0.2
• Sulphate	mg/L	80
• Aluminium	mg/L	0.1
• Iron	mg/L	< 0.2
• Manganese	mg/L	0.12
• Potassium	mg/L	18
• Magnesium	mg/L	8
• Barium	mg/L	0.01
• Strontium	mg/L	0.09
• Fluoride	mg/L	0.05
• Silica	mg/L as SiO_2	12

Data Sheet - UV System (RO-based Process)

Parameter	Units	Value
Influent flows	ML/d	0.5 2 5 8 20 50
Source water	-	RO Permeate
Minimum UVT	%	95
UV Dose	mJ/cm^2	186
Off-Spec Water Control	-	Each unit to be equipped with off-spec diversion
Redundancy	-	N + 1
Power consumption	kWh/ML	Vendor to advise
Lamp ballast and wiper life	years	Vendor to advise
Lamp ballast and wiper life replacement cost	$ per item	Vendor to advise
Influent Quality:		
• TDS	mg/L	< 15
• Sodium	mg/L	3
• Chloride	mg/L	3
• pH	-	5.5
• Alkalinity	mg/L as $CaCO_3$	5

Data Sheet – UV/AOP System (RO-based Process)

Parameter	Units	Value
Influent flows	ML/d	0.5 2 5 8 20 50
Source water	-	RO Permeate
Minimum UVT	%	95
Performance requirements	-	0.5 log reduction 1,4 dioxane 1 log reduction NDMA
UV Dose	mJ/cm^2	Vendor to advise
Off-Spec Water Control	-	Each unit to be equipped with off-spec diversion
Redundancy	-	N + 1
Recommended sodium hypochlorite dose	mg/L as Cl_2	Vendor to advise
Power consumption	kWh/ML	Vendor to advise
Lamp ballast and wiper life	years	Vendor to advise
Lamp ballast and wiper life replacement cost	$ per item	Vendor to advise
Influent Quality:		
• TDS	mg/L	< 15
• Sodium	mg/L	3
• Chloride	mg/L	3
• pH	-	5.5
• Alkalinity	mg/L as $CaCO_3$	5

APPENDIX M: CAPITAL COST ESTIMATES

Transfer infrastructure costs for the short-listed options have been derived as follows:

- Initial costs were developed based on piping, pump station and reservoir costs included in the NSW Reference Rates Manual [46];
- Costs were escalated from the June 2014 issue date to the first quarter of 2024 based on the Australian Bureau of Statistics Heavy and Civil Construction Cost Index[77];
- Costs for ductile iron cement lined pipe (DICL) estimated based on the two steps above were compared to recent rates from a southeast Queensland utility for DICL pipe (the utility's rates were escalated to the first quarter of 2024 using the same index). This comparison showed that DICL costs estimated from the NSW manual were about 45% less than the recent utility rates. Hence, costs derived from the NSW manual were increased by a factor of 1.9.
- Unit cost rates were then applied based on the sizing criteria presented in Section 13.1;
- A 40% contingency was added to the costs estimated based on the unit cost rates;
- A 20% allowance was included to account for RCC costs associated with survey, investigation, design, construction supervision and contract administration;
- Costs associated with any required land acquisition and/or unfavourable geotechnical conditions are not included in the cost estimate;
- Costs associated with other investigations (e.g. environmental, cultural heritage, etc.) and approvals are also not included in the cost estimate.

AWTP costs for the short-listed options have been derived as follows:

- Equipment costs for major process equipment were obtained from the Australian market (refer to Section 21);
- Sizing of concrete structures was developed based on unit process sizing presented in *Purified Recycled Water Investigations Memorandum – AWTP Process Trains* (Appendix E);
- The above information, along with AWTP layouts, was provided to Tallai Project Group[78];
- Tallai produced cost estimates for each of the AWTP by:
  - Estimating equipment costs (where quotations from the market were not available) and costs for concrete structures based on their experience to develop direct project costs for these items, as well as for general civil costs (i.e. roads, landscaping, earthworks fencing, etc.) and buildings; and,
  - Applying factors to the above estimated costs for mechanical installation, piping, electrical and controls, and preliminaries.
- The cost estimates produced by Tallai represent the estimated contract cost for construction under a design-construct procurement approach;
- Tyr Group updated the cost estimates produced by Tallai (based on changes to motor sizes, concrete volumes, etc.). and revised the estimate to reflect an estimate of RCC's total costs under a design-bid-build procurement approach by moving the design allowance from the contract price to be an RCC cost (assumed to be 13% of the contract price) and by adding an RCC project management cost (assumed to be 8% of the contract price).

[77] https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/producer-price-indexes-australia/latest-release
[78] Tallai is a licenced building contractor with expertise in cost estimating water industry projects

Lismore IPR via Surface Water Augmentation Transfer Infrastructure Cost Estimate

Asset	Asset Description & Location	Length (m) Qty (No.)	Pipe Size (DN)	Pipe Material	Pump Flow (L/s)	~Static Head (m)	~Friction & Fittings (m)	~Total Head (m)	Single Pump Power (kW)	Number of duty pumps	Power per duty pump (kW)	Duty motor standard size (kW)	Installed capacity including redundancy (kW)	Cost Per Unit Rate ($/unit)	Cost Estimate
Pipe 1	South Lismore STP to AWTP	50	200	PVC										$367	$18,000
Pipe 2	East Lismore STP outlet to AWTP at South Lismore	5,550	300	PVC										$574	$3,184,000
Pipe 3	Return stream from AWTP to South Lismore STP inlet works	50	100	PVC										$195	$10,000
Pipe 4	PRW to Storage (assumed to be 4.25 km from Wilsons River Source Pump Station)	17,710	375	PVC										$849	$15,041,000
Pipe 5	Storage to Wilsons River Source Pump Station	4,250	500	DICL										$1,448	$6,155,000
Pump 1	South Lismore STP to AWTP	1			56	7	1.6	8.6	5.9	1	5.9	7.5	15	$209,000	$209,000
Pump 2	East Lismore STP outlet to AWTP at South Lismore	1			120	4	47.7	51.7	76.1	1	76.1	90.0	180	$1,136,200	$1,136,000
Pump 3	PRW to Engineered Environmental Buffer Storage	1			126	0	56.4	56.4	87.1	1	87.1	90.0	180	$1,136,200	$1,136,000
Pump 4	Engineered Environmental Buffer Storage to Wilsons River Source Pump Station	1			405	0	35.7	35.7	177.3	1	177.3	200.0	400	$2,072,900	$2,073,000
														Subtotal	$29,000,000
														Subtotal plus Contingency (40%)	$40,600,000
														Survey, Investigation, Design, Construction Supervision, Contact Administration (20%)	$8,120,000
														TOTAL	**$48,720,000**
														Low (-30%)	$34,00,0000
														High (+50%)	$73,000,000

Lismore DPR via Raw Water Augmentation Transfer Infrastructure Cost Estimate

Asset	Asset Description & Location	Length (m) Qty (No.)	Pipe Size (DN)	Pipe Material	Pump Flow (L/s)	~Static Head (m)	~Friction & Fittings (m)	~Total Head (m)	Single Pump Power (kW)	Number of duty pumps	Power per duty pump (kW)	Duty motor standard size (kW)	Installed capacity including redundancy (kW)	Cost Per Unit Rate ($/unit)	Cost Estimate
Pipe 1	South Lismore STP to AWTP	50	200	PVC										$367	$18,000
Pipe 2	East Lismore STP outlet to AWTP at South Lismore	5,550	300	PVC										$574	$3,184,000
Pipe 3	Return stream from AWTP to South Lismore STP inlet works	50	100	PVC										$195	$10,000
Pipe 4	PRW to Wilsons River Source Pump Station	6,250	375	PVC										$849	$15,041,000
Pump 1	South Lismore STP to AWTP	1			56	7	1.6	8.6	5.9	1	5.9	7.5	15	$209,000	$209,000
Pump 2	East Lismore STP outlet to AWTP at South Lismore	1			120	4	47.7	51.7	76.1	1	76.1	90	180	$1,136,200	$1,136,000
Pump 3	PRW to Wilsons River Source Pump Station	1			126	0	27.8	27.8	43.0	1	43.0	45	90	$710,600	$711,000
Subtotal															$10,600,000
Subtotal plus Contingency (40%)															$14,800,000
Survey, Investigation, Design, Construction Supervision, Contact Administration (20%)															$2,960,000
TOTAL															**$17,760,000**
Low (-30%)															$12,00,0000
High (+50%)															$27,000,000

Lismore DPR via Treated Water Augmentation Transfer Infrastructure Cost Estimate

Asset	Asset Description & Location	Length (m) Qty (No.)	Pipe Size (DN)	Pipe Material	Pump Flow (L/s)	~Static Head (m)	~Friction & Fittings (m)	~Total Head (m)	Single Pump Power (kW)	Number of duty pumps	Power per duty pump (kW)	Duty motor standard size (kW)	Installed capacity including redundancy (kW)	Cost Per Unit Rate ($/unit)	Cost Estimate
Pipe 1	East Lismore STP outlet (and South Lismore effluent) to AWTP at East Lismore	1530	300	PVC										$574	$878,000
Pipe 2	Return stream from AWTP to East Lismore STP inlet works	1530	100	PVC										$265	$406,000
Pipe 3	PRW to City View Reservoir offtake	810	600	DICL										$1,724	$1,396,000
Pipe 4	PRW into City View Reservoir	10	300	PVC										$574	$6,000
Pipe 5	PRW City View to Belvedere Drive Reservoir offtake	350	500	DICL										$1,448	$507,000
Pipe 6	PRW into Belvedere Drive Reservoir	250	300	PVC										$574	$143,000
Pipe 7	PRW Belvedere Drive offtake to Ross Street/High Street split	1750	450	DICL										$1,173	$2,052,000
Pipe 8	PRW into Ross St (from split)	1250	200	PVC										$367	$458,000
Pipe 9	PRW into High Street (from split)	1750	375	PVC										$849	$1,486,000
Pump 1	East Lismore STP outlet to AWTP at East Lismore	1			160	3	25.6	28.6	56	1	56	75	150	$1,010,800	$1,011,000
Pump 2	PRW to City View Reservoir offtake PRW into City View Reservoir PRW to Belvedere Drive Reservoir offtake PRW into Belvedere Drive Reservoir PRW City View to Ross Street/High Street split PRW into High Street (from split)	1			430	81.5	27.4	108.9	574	1	574	700	1,400	$6,591,100	$6,591,000
Pump 3	PRW into Ross St (from split)	1			45	64.8	16.0	80.8	44.6	1	44.6	45	90	$710,600	$710,600
PRW Storage	3 ML PRW Reservoir at AWTP Site	1		Steel										$2,136,255	$2,136,000
Flow control	Allowance for flow meters and flow control valves at each PRW discharge to existing reservoirs	4												$200,000	$800,000
														Subtotal	$18,600,000
														Subtotal plus Contingency (40%)	$26,000,000
														Survey, Investigation, Design, Construction Supervision, Contact Administration (20%)	$5,200,000
														TOTAL	**$31,200,000**
														Low (-30%)	$22,00,0000
														High (+50%)	$47,000,000

Byron DPR via Treated Water Augmentation Transfer Infrastructure Cost Estimate

Asset	Asset Description & Location	Length (m) Qty (No.)	Pipe Size (DN)	Pipe Material	Pump Flow (L/s)	~Static Head (m)	~Friction & Fittings (m)	~Total Head (m)	Single Pump Power (kW)	Number of duty pumps	Power per duty pump (kW)	Duty motor standard size (kW)	Installed capacity including redundancy (kW)	Cost Per Unit Rate ($/unit)	Cost Estimate
Pipe 1	Brunswick Valley STP to AWTP	17,405	200	PVC										$367	$6,379,000
Pipe 2	Byron STP / Byron STP Wetland outlet to AWTP	1,500	300	PVC										$574	$861,000
Pipe 3	Return stream from AWTP to Byron STP inlet works	1,800	100	PVC										$195	$350,000
Pipe 4	RO Concentrate to Belongil Creek Estuary (down Ewingsdale Road)	1,800	150	PVC										$265	$478,000
Pipe 5	PRW Storage to St Helena Reservoir Offtake	4,725	450	DICL										$1,173	$5,542,000
Pipe 6	PRW to St Helena Reservoir	10	300	PVC										$574	$6,000
Pipe 7	PRW to new Blending Reservoir near Bangalow STP	4,500	375	PVC										$849	$3,822,000
Pump 1	Brunswick Valley STP to AWTP	3			30	6	74.4	80.4	29.6	1	29.6	30	60	$484,500	$1,454,000
Pump 2	Byron STP / Byron STP Wetland outlet to AWTP	2			158	0	25.0	25.0	48.4	1	48.4	55	110	$841,700	$1,683,000
Pump 3	RO Concentrate to Belongil Creek Estuary (down Ewingsdale Road)	1			19	4	13.4	17.4	4.1	1	4.1	5.5	11	$188,100	$188,000
Pump 4	PRW Storage to St Helena Reservoir Offtake PRW to St Helena Reservoir PRW to new Blending Reservoir near Bangalow STP	1			200	111	19.7	130.7	320.5	1	320.5	335	670	$3,250,900	$3,251,000
Pump 5	Blended water from Blending Reservoir to Knockrow in existing rising main	1			200	44	44.0	88.0	215.8	1	215.8	215	430	$2,202,100	$2,202,000
Effluent Storage	0.5 ML for Effluent Transfer Stations (Brunswick Valley STP to AWTP)	2		Steel										$847,093	$1,694,000
PRW Storage	750 kL Blending Reservoir from Bangalow to Knockrow	1		Steel										$1,057,014	$1,057,000
PRW Storage	3 ML PRW Reservoir at AWTP Site	1		Steel										$2,136,255	$2,136,000
Flow control	Allowance for flow meters and flow control valves at each PRW discharge to existing reservoirs	2												$200,000	$400,000
														Subtotal	$31,500,000
														Subtotal plus Contingency (40%)	$44,100,000
														Survey, Investigation, Design, Construction Supervision, Contact Administration (20%)	$8,820,000
														TOTAL	**$52,920,000**
														Low (-30%)	$37,00,0000
														High (+50%)	$79,000,000

Lismore IPR via Surface Water Augmentation AWTP – Breakdown of Contractor's Direct Costs

Component	Item	Units	Quantity	Unit Cost	Total Cost
Raw Water Balance Tank	5.5.kW Mixer	each	2	$12,500	$25,000
	Concrete Walls	m^3	162.2	$4,500	$730,117
	Concrete Base	m^3	139.5	$3,000	$418,542
	Concrete Roof	m^3	125.9	$4,500	$566,497
	Excavation	m^3	139.5	$60	$8,371
	Access to Mixers	each	2	$22,000	$44,000
				Raw Water Balance Tank Total	$1,792,527
				Raw Water Balance Tank Total with 40% Contingency	**$2,510,000**
Ozone Contactor Feed Pump Station	7.5 kW Feed Pump	each	2	$19,000	$38,000
	Automatically Backwashing Strainers	package	1	$190,000	$190,000
	Concrete Slab	m^3	35	$3,000	$105,000
	Excavation	m^3	35	$60	$2,100
				Ozone Contactor Feed Pump Station Total	$335,100
				Ozone Contactor Feed Pump Station Total with 40% Contingency	**$469,000**
Ozone Contactor	Concrete Walls	m^3	44.2	$4,500	$199,112
	Concrete Base	m^3	16.8	$3,000	$50,400
	Concrete Roof	m^3	15.2	$4,500	$68,182
	Baffles	each	4	$6,000	$24,000
	Excavation	m^3	16.8	$60	$1,008
	Handrails	m	29.4	$750	$22,050
	Stairs	each	2	$25,000	$50,000
				Ozone Contactor Total	$414,751
				Ozone Contactor Total with 40% Contingency	**$581,000**
Ozone Generators and Destruction Units	Ozone Generator (4 kg/h)	each	2	$245,000	$490,000
	Ozone Destruction Unit	each	2	$50,000	$100,000
	Ductwork	lump sum	1	$60,000	$60,000
	Concrete Slab	m^3	78.4	$3,000	$235,200
	Excavation	m^3	78.4	$60	$4,704
				Ozone Generators and Destruction Units Total	$889,904
				Ozone Generators and Destruction Units Total with 40% Contingency	**$1,246,000**
Ozone Sidestream Pumps	7.5 kW Sidestream Pump	each	2	$19,000	$38,000
	Concrete Slab	m^3	3.6	$3,000	$10,920
	Excavation	m^3	3.6	$60	$218
				Ozone Sidestream Pumps Total	$49,138
				Ozone Sidestream Pumps Total with 40% Contingency	**$69,000**
Floc Tank	1.5 kW Mixer	each	1	$5,000	$5,000
	Concrete Walls	m^3	55.9	$4,500	$251,559
	Concrete Base	m^3	38.5	$3,000	$115,500
	Concrete Roof	m^3	35.9	$4,500	$161,343
	Baffles	each	4	$6,000	$24,000
	Excavation	m^3	38.5	$60	$2,310
	Handrails	m	48.4	$750	$36,300
	Stairs	each	2	$25,000	$50,000
				Floc Tank Total	$646,012
				Floc Tank Total with 40% Contingency	**$904,000**

Lismore IPR via Surface Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
BAC and GAC	11 kW BAC Feed Pump	each	2	$25,000	$50,000
	22 kW BAC Backwash Pump	each	2	$40,000	$80,000
	18.5 kW BAC Air Scour Blower	each	2	$62,000	$124,000
	22 kW GAC Backwash Pump	each	2	$40,000	$80,000
	BAC Filters	package	1	$4,400,000	$4,400,000
	BAC Filter Media	m³	106	$2,500	$265,000
	GAC Filters	package	1	$3,200,000	$3,200,000
	GAC Filter Media	m³	88	$2,500	$220,000
	Concrete Slab	m³	186.9	$3,000	$560,700
	Excavation	m³	186.9	$60	$11,214
				BAC and GAC Total	$8,990,914
				BAC and GAC Total with 40% Contingency	**$12,587,000**
UF Feed Tank	Concrete Walls	m³	66.2	$4,500	$297,975
	Concrete Base	m³	25.5	$3,000	$76,451
	Concrete Roof	m³	19.9	$4,500	$89,373
	Excavation	m³	25.5	$60	$1,529
				UF Feed Tank Total	$465,329
				UF Feed Tank Total with 40% Contingency	**$651,000**
UF System	UF system including membrane trains, feed pumps, backwash pumps/equipment, CIP equipment and ancillaries	package	1	$3,700,000	$3,700,000
	Automatically Backwashing Strainers	package	1	$190,000	$190,000
	Concrete Slab	m³	147.7	$3,000	$443,100
	Excavation	m³	147.7	$60	$8,862
				UF System Total	$4,341,962
				UF System Total with 40% Contingency	**$6,079,000**
UF Backwash Supply Tank	Concrete Walls	m³	66.2	$4,500	$297,975
	Concrete Base	m³	25.5	$3,000	$76,451
	Concrete Roof	m³	19.9	$4,500	$89,373
	Excavation	m³	25.5	$60	$1,529
				UF Backwash Supply Tank Total	$465,329
				UF Backwash Supply Tank Total with 40% Contingency	**$651,000**
UV System	UV Units	package	1	$600,000	$600,000
	Concrete Slab	m³	28	$3,000	$84,000
	Excavation	m³	28	$60	$1,680
				UV System Total	$685,680
				UV System Total with 40% Contingency	**$960,000**
Chlorine Contact Tank	0.55 kw Ozone Generator Cooling Water Pump	each	2	$4,000	$8,000
	Cooling Water Pumps Slab	m³	1.0	$2,000	$2,000
	Concrete Walls	m³	10.3	$4,500	$46,305
	Concrete Base	m³	15.2	$3,000	$45,455
	Concrete Roof	m³	15.2	$4,500	$68,182
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	18.3	$60	$1,098
	Handrails	m	28.0	$750	$21,000
	Stairs	each	2	$25,000	$50,000
				Chlorine Contact Tank Total	$266,039
				Chlorine Contact Tank Total with 40% Contingency	**$372,000**

Lismore IPR via Surface Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
Treated Water Tank	Concrete Walls	m^3	55.1	$4,500	$247,726
	Concrete Base	m^3	18.2	$3,000	$54,486
	Concrete Roof	m^3	13.5	$4,500	$60,613
	Excavation	m^3	18.2	$60	$1,090
				Treated Water Tank Total	$363,915
				Treated Water Tank Total with 40% Contingency	**$509,000**
Waste Buffer Tank	5.5 kW Discharge Pump	each	2	$15,000	$30,000
	Concrete Walls	m^3	50.1	$4,500	$225,449
	Concrete Base	m^3	32.2	$3,000	$96,695
	Excavation	m^3	288.2	$120	$34,584
				Waste Buffer Tank Total	$386,729
				Waste Buffer Tank Total with 40% Contingency	**$541,000**
Neutralisation Tank	15 kW Discharge Pump	each	2	$64,000	$128,000
	Concrete Walls	m^3	24.6	$4,500	$110,565
	Concrete Base	m^3	12.7	$3,000	$38,000
	Concrete Roof	m^3	12.7	$4,500	$56,999
	Excavation	m^3	183.5	$120	$22,018
	Epoxy Coating	m^2	122.0	$220	$26,840
				Neutralisation Tank Total	$382,422
				Neutralisation Tank Total with 40% Contingency	**$535,000**
Chemical Storage and Dosing	Sodium Hypochlorite System	each	1	$48,000	$48,000
	Sodium Hydroxide System	each	1	$53,000	$53,000
	Aluminium Sulphate System	each	1	$35,000	$35,000
	Sodium Bisulphite System	each	1	$18,000	$18,000
	Citric Acid System	each	1	$18,000	$18,000
	Sulphuric Acid System	each	1	$53,000	$53,000
	Polymer System	each	1	$60,000	$60,000
	Concrete Base and Unloading Area	m^3	162.8	$3,000	$488,250
	Concrete Bund Walls	m^3	9.5	$3,000	$28,350
	Excavation	m^3	162.8	$60	$9,765
	Epoxy Coating	m^2	519.0	$220	$114,180
	Handrails	m	70.0	$500	$35,000
	Stairs	each	6	$8,000	$48,000
	Platforms	m^2	12.0	$1,500	$18,000
	Carport Style Roof	m^2	150.0	$1,600	$240,000
	Water Quality Analysers	lump sum	1	$1,500,000	$1,500,000
				Chemical Storage and Dosing Total	$2,766,545
				Chemical Storage and Dosing Total with 40% Contingency	**$3,873,000**
Buildings	Control Building	m^2	360	$8,000	$2,880,000
	Workshop	m^2	120	$4,000	$480,000
	Ozone Building	m^2	224	$4,000	$896,000
	UF Building	m^2	294	$4,000	$1,176,000
	Switchroom	m^2	360	$8,000	$2,880,000
				Buildings Total	$8,312,000
				Buildings Total with 40% Contingency	**$11,637,000**

Lismore IPR via Surface Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
General Civil	Bulk Earthworks	m^3	18,000	$100	$1,800,000
	Site Road	m^2	1,680	$200	$336,000
	Landscaping	lump sum	1	$100,000	$100,000
	Admin Building Car Park	m^2	200	$200	$40,000
	Fencing	m	556	$420	$233,520
General Civil Total					$2,509,520
General Civil Total with 40% Contingency					**$3,513,000**
Total Equipment Costs (including 40% Contingency)					$22,044,000
Mechanical Equipment Installation Costs (15% of Total Equipment Costs)					**$3,307,000**
Piping Costs (20% of Total Equipment Costs)					**$4,409,000**
Total Contractor's Direct Costs excluding Preliminaries and Electrical and Controls (including 40% Contingency)					$55,403,000
Electrical and Control Costs (15% of Total Contractor's Direct Cost excluding Preliminaries and EIC, including 40% Contingency)					**$8,311,000**
Total Contractor's Direct Cost excluding Preliminaries (including 40% Contingency)					$63,714,000
Preliminaries (10% of Total Contractor's Direct Cost excluding Preliminaries, including 40% Contingency)					**$6,372,000**
Total Contractor's Direct Costs (including 40% Contingency)					**$70,086,000**

Lismore DPR via Raw Water Augmentation AWTP – Breakdown of Contractor's Direct Costs

Component	Item	Units	Quantity	Unit Cost	Total Cost
Raw Water Balance Tank	5.5.kW Mixer	each	2	$12,500	$25,000
	Concrete Walls	m³	162.2	$4,500	$730,117
	Concrete Base	m³	139.5	$3,000	$418,542
	Concrete Roof	m³	125.9	$4,500	$566,497
	Excavation	m³	139.5	$60	$8,371
	Access to Mixers	each	2	$22,000	$44,000
Raw Water Balance Tank Total					$1,792,527
Raw Water Balance Tank Total with 40% Contingency					**$2,510,000**
Ozone Contactor Feed Pump Station	7.5 kW Feed Pump	each	2	$19,000	$38,000
	Automatically Backwashing Strainers	package	1	$190,000	$190,000
	Concrete Slab	m³	35	$3,000	$105,000
	Excavation	m³	35	$60	$2,100
Ozone Contactor Feed Pump Station Total					$335,100
Ozone Contactor Feed Pump Station Total with 40% Contingency					**$469,000**
Ozone Contactor	Concrete Walls	m³	44.2	$4,500	$199,112
	Concrete Base	m³	16.8	$3,000	$50,400
	Concrete Roof	m³	15.2	$4,500	$68,182
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	16.8	$60	$1,008
	Handrails	m	29.4	$750	$22,050
	Stairs	each	2	$25,000	$50,000
Ozone Contactor Total					$414,751
Ozone Contactor Total with 40% Contingency					**$581,000**
Ozone Generators and Destruction Units	Ozone Generator (4 kg/h)	each	2	$245,000	$490,000
	Ozone Destruction Unit	each	2	$50,000	$100,000
	Ductwork	lump sum	1	$60,000	$60,000
	Concrete Slab	m³	78.4	$3,000	$235,200
	Excavation	m³	78.4	$60	$4,704
Ozone Generators and Destruction Units Total					$889,904
Ozone Generators and Destruction Units Total with 40% Contingency					**$1,246,000**
Ozone Sidestream Pumps	7.5 kW Sidestream Pump	each	2	$19,000	$38,000
	Concrete Slab	m³	3.6	$3,000	$10,920
	Excavation	m³	3.6	$60	$218
Ozone Sidestream Pumps Total					$49,138
Ozone Sidestream Pumps Total with 40% Contingency					**$69,000**
Floc Tank	1.5 kW Mixer	each	1	$5,000	$5,000
	Concrete Walls	m³	55.9	$4,500	$251,559
	Concrete Base	m³	38.5	$3,000	$115,500
	Concrete Roof	m³	35.9	$4,500	$161,343
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	38.5	$60	$2,310
	Handrails	m	48.4	$750	$36,300
	Stairs	each	2	$25,000	$50,000
Floc Tank Total					$646,012
Floc Tank Total with 40% Contingency					**$904,000**

Lismore DPR via Raw Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
BAC and GAC	11 kW BAC Feed Pump	each	2	$25,000	$50,000
	22 kW BAC Backwash Pump	each	2	$40,000	$80,000
	18.5 kW BAC Air Scour Blower	each	2	$62,000	$124,000
	22 kW GAC Backwash Pump	each	2	$40,000	$80,000
	BAC Filters	package	1	$4,400,000	$4,400,000
	BAC Filter Media	m³	106	$2,500	$265,000
	GAC Filters	package	1	$3,200,000	$3,200,000
	GAC Filter Media	m³	88	$2,500	$220,000
	Concrete Slab	m³	186.9	$3,000	$560,700
	Excavation	m³	186.9	$60	$11,214
				BAC and GAC Total	$8,990,914
				BAC and GAC Total with 40% Contingency	**$12,587,000**
UF Feed Tank	Concrete Walls	m³	66.2	$4,500	$297,975
	Concrete Base	m³	25.5	$3,000	$76,451
	Concrete Roof	m³	19.9	$4,500	$89,373
	Excavation	m³	25.5	$60	$1,529
				UF Feed Tank Total	$465,329
				UF Feed Tank Total with 40% Contingency	**$651,000**
UF System	UF system including membrane trains, feed pumps, backwash pumps/equipment, CIP equipment and ancillaries	package	1	$3,700,000	$3,700,000
	Automatically Backwashing Strainers	package	1	$190,000	$190,000
	Concrete Slab	m³	147.7	$3,000	$443,100
	Excavation	m³	147.7	$60	$8,862
				UF System Total	$4,341,962
				UF System Total with 40% Contingency	**$6,079,000**
UF Backwash Supply Tank	Concrete Walls	m³	66.2	$4,500	$297,975
	Concrete Base	m³	25.5	$3,000	$76,451
	Concrete Roof	m³	19.9	$4,500	$89,373
	Excavation	m³	25.5	$60	$1,529
				UF Backwash Supply Tank Total	$465,329
				UF Backwash Supply Tank Total with 40% Contingency	**$651,000**
UV System	UV Units	package	1	$600,000	$600,000
	Concrete Slab	m³	28	$3,000	$84,000
	Excavation	m³	28	$60	$1,680
				UV System Total	$685,680
				UV System Total with 40% Contingency	**$960,000**
Chlorine Contact Tank	0.55 kw Ozone Generator Cooling Water Pump	each	2	$4,000	$8,000
	Cooling Water Pumps Slab	m³	1.0	$2,000	$2,000
	Concrete Walls	m³	10.3	$4,500	$46,305
	Concrete Base	m³	15.2	$3,000	$45,455
	Concrete Roof	m³	15.2	$4,500	$68,182
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	18.3	$60	$881
	Handrails	m	28.0	$750	$21,000
	Stairs	each	2	$25,000	$50,000
				Chlorine Contact Tank Total	$265,823
				Chlorine Contact Tank Total with 40% Contingency	**$372,000**

Lismore DPR via Raw Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
Engineered Buffer Storage Tank	Concrete Walls	m³	55.1	$4,500	$247,726
	Concrete Base	m³	18.2	$3,000	$54,486
	Concrete Roof	m³	13.5	$4,500	$60,613
	Excavation	m³	18.2	$60	$1,090
Engineered Buffer Storage Tank Cost per Tank					$363,915
Engineered Buffer Storage Tank Total for Two Tanks					$727,829
Engineered Buffer Storage Tank Total (for Two Tanks) with 40% Contingency					**$1,019,000**
Waste Buffer Tank	5.5 kW Discharge Pump	each	2	$15,000	$30,000
	Concrete Walls	m³	50.1	$4,500	$225,449
	Concrete Base	m³	32.2	$3,000	$96,695
	Excavation	m³	288.2	$120	$34,584
Waste Buffer Tank Total					$386,729
Waste Buffer Tank Total with 40% Contingency					**$541,000**
Neutralisation Tank	15 kW Discharge Pump	each	2	$64,000	$128,000
	Concrete Walls	m³	24.6	$4,500	$110,565
	Concrete Base	m³	12.7	$3,000	$38,000
	Concrete Roof	m³	12.7	$4,500	$56,999
	Excavation	m³	183.5	$120	$22,018
	Epoxy Coating	m²	122.0	$220	$26,840
Neutralisation Tank Total					$382,422
Neutralisation Tank Total with 40% Contingency					**$535,000**
Chemical Storage and Dosing	Sodium Hypochlorite System	each	1	$48,000	$48,000
	Sodium Hydroxide System	each	1	$53,000	$53,000
	Aluminium Sulphate System	each	1	$35,000	$35,000
	Sodium Bisulphite System	each	1	$18,000	$18,000
	Citric Acid System	each	1	$18,000	$18,000
	Sulphuric Acid System	each	1	$53,000	$53,000
	Polymer System	each	1	$60,000	$60,000
	Concrete Base and Unloading Area	m³	162.8	$3,000	$488,250
	Concrete Bund Walls	m³	9.5	$3,000	$28,350
	Excavation	m³	162.8	$60	$9,765
	Epoxy Coating	m²	519.0	$220	$114,180
	Handrails	m	70.0	$500	$35,000
	Stairs	each	6	$8,000	$48,000
	Platforms	m²	12.0	$1,500	$18,000
	Carport Style Roof	m²	150.0	$1,600	$240,000
	Water Quality Analysers	lump sum	1	$1,500,000	$1,500,000
Chemical Storage and Dosing Total					$2,766,545
Chemical Storage and Dosing Total with 40% Contingency					**$3,873,000**
Buildings	Control Building	m²	360	$8,000	$2,880,000
	Workshop	m²	120	$4,000	$480,000
	Ozone Building	m²	224	$4,000	$896,000
	UF Building	m²	294	$4,000	$1,176,000
	Switchroom	m²	360	$8,000	$2,880,000
Buildings Total					$8,312,000
Buildings Total with 40% Contingency					**$11,637,000**

Lismore DPR via Raw Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
General Civil	Bulk Earthworks	m^3	18,000	$100	$1,800,000
	Site Road	m^2	1,680	$200	$336,000
	Landscaping	lump sum	1	$100,000	$100,000
	Admin Building Car Park	m^2	200	$200	$40,000
	Fencing	m	556	$420	$233,520
General Civil Total					$2,509,520
General Civil Total with 40% Contingency					**$3,513,000**
Total Equipment Costs (including 40% Contingency)					$22,044,000
Mechanical Equipment Installation Costs (15% of Total Equipment Costs)					**$3,307,000**
Piping Costs (20% of Total Equipment Costs)					**$4,409,000**
Total Contractor's Direct Costs excluding Preliminaries and Electrical and Controls (including 40% Contingency)					$55,913,000
Electrical and Control Costs (15% of Total Contractor's Direct Cost excluding Preliminaries and EIC, including 40% Contingency)					**$8,387,000**
Total Contractor's Direct Cost excluding Preliminaries (including 40% Contingency)					$64,300,000
Preliminaries (10% of Total Contractor's Direct Cost excluding Preliminaries, including 40% Contingency)					**$6,430,000**
Total Contractor's Direct Costs (including 40% Contingency)					**$70,730,000**

Lismore DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs

Component	Item	Units	Quantity	Unit Cost	Total Cost
Raw Water Balance Tank	5.5.kW Mixer	each	2	$12,500	$25,000
	Concrete Walls	m³	125.8	$4,500	$565,970
	Concrete Base	m³	85.4	$3,000	$256,274
	Concrete Roof	m³	74.8	$4,500	$336,774
	Excavation	m³	85.4	$60	$5,125
	Access to Mixers	each	2	$22,000	$44,000
Raw Water Balance Tank Total					$1,233,143
Raw Water Balance Tank Total with 40% Contingency					**$1,726,000**
Ozone Contactor Feed Pump Station	5.5 kW Feed Pump	each	2	$15,000	$30,000
	Automatically Backwashing Strainers	package	1	$130,000	$130,000
	Concrete Slab	m³	35.0	$3,000	$105,000
	Excavation	m³	35.0	$60	$2,100
Ozone Contactor Feed Pump Station Total					$267,100
Ozone Contactor Feed Pump Station Total with 40% Contingency					**$374,000**
Ozone Contactor	Concrete Walls	m³	38.2	$4,500	$133,795
	Concrete Base	m³	12.9	$3,000	$32,156
	Concrete Roof	m³	11.4	$4,500	$51,408
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	12.9	$60	$772
	Handrails	m	25.4	$750	$19,050
	Stairs	each	1	$25,000	$25,000
Ozone Contactor Total					$286,181
Ozone Contactor Total with 40% Contingency					**$401,000**
Ozone Generators and Destruction Units	Ozone Generator (2.5 kg/h)	each	2	$165,000	$330,000
	Ozone Destruction Unit	each	2	$50,000	$100,000
	Ductwork	lump sum	1	$60,000	$60,000
	Concrete Slab	m³	78.4	$3,000	$235,200
	Excavation	m³	78.4	$60	$4,704
Ozone Generators and Destruction Units Total					$729,904
Ozone Generators and Destruction Units Total with 40% Contingency					**$1,022,000**
Ozone Sidestream Pumps	4 kW Sidestream Pump	each	2	$12,000	$24,000
	Concrete Slab	m³	2.6	$3,000	$7,800
	Excavation	m³	2.6	$60	$156
Ozone Sidestream Pumps Total					$31,956
Ozone Sidestream Pumps Total with 40% Contingency					**$45,000**
Floc Tank	1.1 kW Mixer	each	1	$3,800	$3,800
	Concrete Walls	m³	42.0	$4,500	$189,189
	Concrete Base	m³	23.6	$3,000	$70,875
	Concrete Roof	m³	21.6	$4,500	$97,241
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	23.6	$60	$1,418
	Handrails	m	36.4	$750	$27,300
	Stairs	each	2	$25,000	$50,000
Floc Tank Total					$463,822
Floc Tank Total with 40% Contingency					**$649,000**

Lismore DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
BAC and GAC	5.5 kW BAC Feed Pump	each	2	$15,000	$30,000
	11 kW BAC Backwash Pump	each	2	$32,000	$64,000
	15 kW BAC Air Scour Blower	each	2	$51,000	$102,000
	15 kW GAC Backwash Pump	each	2	$32,000	$64,000
	BAC Filters	package	1	$2,600,000	$2,600,000
	BAC Filter Media	m³	65.0	$2,500	$162,500
	GAC Filters	package	1	$2,000,000	$2,000,000
	GAC Filter Media	m³	52.0	$2,500	$130,000
	Concrete Slab	m³	186.9	$3,000	$560,700
	Excavation	m³	186.9	$60	$11,214
				BAC and GAC Total	$5,724,414
				BAC and GAC Total with 40% Contingency	**$8,014,000**
UF Feed Tank	Concrete Walls	m³	51.3	$4,500	$230,976
	Concrete Base	m³	16.0	$3,000	$47,989
	Concrete Roof	m³	11.6	$4,500	$52,263
	Excavation	m³	16.0	$60	$960
				UF Feed Tank Total	$322,188
				UF Feed Tank Total with 40% Contingency	**$465,000**
UF System	UF system including membrane trains, feed pumps, backwash pumps/equipment, CIP equipment and ancillaries	package	1	$2,700,000	$2,700,000
	Automatically Backwashing Strainers	package	1	$130,000	$130,000
	Concrete Slab	m³	147.7	$3,000	$443,100
	Excavation	m³	147.7	$60	$8,862
				UF System Total	$3,281,962
				UF System Total with 40% Contingency	**$4,595,000**
UF Backwash Supply Tank	Concrete Walls	m³	51.3	$4,500	$230,976
	Concrete Base	m³	16.0	$3,000	$47,989
	Concrete Roof	m³	11.6	$4,500	$52,263
	Excavation	m³	16.0	$60	$960
				UF Backwash Supply Tank Total	$322,188
				UF Backwash Supply Tank Total with 40% Contingency	**$465,000**
UV System	UV Units	package	1	$600,000	$600,000
	Concrete Slab	m³	28.0	$3,000	$84,000
	Excavation	m³	28.0	$60	$1,680
				UV System Total	$685,680
				UV System Total with 40% Contingency	**$960,000**
Chlorine Contact Tank	0.55 kw Ozone Generator Cooling Water Pump	each	2	$4,000	$8,000
	Cooling Water Pumps Slab	m³	1.0	$2,000	$2,000
	Concrete Walls	m³	8.5	$4,500	$38,430
	Concrete Base	m³	10.9	$3,000	$32,592
	Concrete Roof	m³	110.9	$4,500	$48,888
	Baffles	each	4	$6,000	$24,000
	Excavation	m³	11.0	$60	$681
	Handrails	m	23.0	$750	$17,250
	Stairs	each	2	$25,000	$50,000
				Chlorine Contact Tank Total	$221,821
				Chlorine Contact Tank Total with 40% Contingency	**$311,000**

Lismore DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
PRW Pumps	5.5 kW PRW Pump	each	2	$15,000	$30,000
	Concrete Slab	m³	5.6	$3,000	$16,800
	Excavation	m³	5.6	$60	$336
				PWR Pumps Total	$47,136
				PWR Pumps Total with 40% Contingency	**$66,000**
Engineered Buffer Storage Tank	Concrete Walls	m³	43.9	$4,500	$199,477
	Concrete Base	m³	12.1	$3,000	$36,232
	Concrete Roof	m³	8.3	$4,500	$37,419
	Excavation	m³	12.1	$60	$725
				Engineered Buffer Storage Tank Cost per Tank	$271,853
				Engineered Buffer Storage Tank Total for Two Tanks	$543,705
				Engineered Buffer Storage Tank Total (for Two Tanks) with 40% Contingency	**$761,000**
Waste Buffer Tank	3 kW Discharge Pump	each	2	$9,000	$18,000
	Concrete Walls	m³	46.6	$4,500	$209,816
	Concrete Base	m³	28.2	$3,000	$84,598
	Excavation	m³	248.1	$120	$29,773
				Waste Buffer Tank Total	$342,187
				Waste Buffer Tank Total with 40% Contingency	**$479,000**
Neutralisation Tank	15 kW Discharge Pump	each	2	$64,000	$128,000
	Concrete Walls	m³	24.6	$4,500	$110,565
	Concrete Base	m³	12.7	$3,000	$38,000
	Concrete Roof	m³	12.7	$4,500	$56,999
	Excavation	m³	183.5	$120	$22,018
	Epoxy Coating	m²	122.0	$220	$26,840
				Neutralisation Tank Total	$382,422
				Neutralisation Tank Total with 40% Contingency	**$535,000**
Chemical Storage and Dosing	Sodium Hypochlorite System	each	1	$48,000	$48,000
	Sodium Hydroxide System	each	1	$53,000	$53,000
	Aluminium Sulphate System	each	1	$35,000	$35,000
	Sodium Bisulphite System	each	1	$18,000	$18,000
	Citric Acid System	each	1	$18,000	$18,000
	Sulphuric Acid System	each	1	$53,000	$53,000
	Polymer System	each	1	$60,000	$60,000
	Concrete Base and Unloading Area	m³	162.8	$3,000	$488,250
	Concrete Bund Walls	m³	9.5	$3,000	$28,350
	Excavation	m³	162.8	$60	$9,765
	Epoxy Coating	m²	519.0	$220	$114,180
	Handrails	m	70.0	$500	$35,000
	Stairs	each	6	$8,000	$48,000
	Platforms	m²	12.0	$1,500	$18,000
	Carport Style Roof	m²	150.0	$1,600	$240,000
	Water Quality Analysers	lump sum	1	$1,500,000	$1,500,000
				Chemical Storage and Dosing Total	$2,766,545
				Chemical Storage and Dosing Total with 40% Contingency	**$3,873,000**

Lismore DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
Buildings	Control Building	m^2	360	$8,000	$2,880,000
	Workshop	m^2	120	$4,000	$480,000
	Ozone Building	m^2	224	$4,000	$896,000
	UF Building	m^2	294	$4,000	$1,176,000
	Switchroom	m^2	360	$8,000	$2,880,000
Buildings Total					$8,312,000
Buildings Total with 40% Contingency					**$11,637,000**
General Civil	Bulk Earthworks	m^3	13,000	$100	$1,300,000
	Site Road	m^2	1,680	$200	$336,000
	Landscaping	lump sum	1	$100,000	$100,000
	Admin Building Car Park	m^2	200	$200	$40,000
	Fencing	m	556	$420	$233,520
General Civil Total					$2,009,520
General Civil Total with 40% Contingency					**$2,813,000**
Total Equipment Costs (including 40% Contingency)					$15,651,020
Mechanical Equipment Installation Costs (15% of Total Equipment Costs)					**$2,348,000**
Piping Costs (20% of Total Equipment Costs)					**$3,130,000**
Total Contractor's Direct Costs excluding Preliminaries and Electrical and Controls (including 40% Contingency)					$44,699,000
Electrical and Control Costs (15% of Total Contractor's Direct Cost excluding Preliminaries and EIC, including 40% Contingency)					**$6,700,000**
Total Contractor's Direct Cost excluding Preliminaries (including 40% Contingency)					$51,369,000
Preliminaries (10% of Total Contractor's Direct Cost excluding Preliminaries, including 40% Contingency)					**$5,137,000**
Total Contractor's Direct Costs (including 40% Contingency)					**$56,506,000**

Byron DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs

Component	Item	Units	Quantity	Unit Cost	Total Cost
Raw Water Balance Tank	5.5.kW Mixer	each	2	$12,500	$25,000
	Concrete Walls	m^3	151.8	$4,500	$683,218
	Concrete Base	m^3	122.7	$3,000	$368,139
	Concrete Roof	m^3	110.0	$4,500	$494,801
	Excavation	m^3	122.7	$60	$7,363
	Access to Mixers	each	2	$22,000	$44,000
				Raw Water Balance Tank Total	$1,622,520
				Raw Water Balance Tank Total with 40% Contingency	**$2,272,000**
UF System	UF system including membrane trains, feed pumps, backwash pumps/equipment, CIP equipment and ancillaries	package	1	$3,300,000	$3,300,000
	Automatically Backwashing Strainers	package	1	$170,000	$170,000
	Concrete Slab	m^3	164.2	$3,000	$487,200
	Excavation	m^3	164.2	$60	$9,744
				UF System Total	$3,966,944
				UF System Total with 40% Contingency	**$5,554,000**
UF Backwash Supply Tank	Concrete Walls	m^3	62.5	$4,500	$281,225
	Concrete Base	m^3	22.9	$3,000	$68,717
	Concrete Roof	m^3	17.6	$4,500	$79,168
	Excavation	m^3	22.9	$60	$1,374
				UF Backwash Supply Tank Total	$430,485
				UF Backwash Supply Tank Total with 40% Contingency	**$603,000**
RO Feed Tank	Concrete Walls	m^3	58.8	$4,500	$264,475
	Concrete Base	m^3	20.5	$3,000	$61,396
	Concrete Roof	m^3	15.5	$4,500	$69,581
	Excavation	m^3	20.5	$60	$1,228
				RO Feed Tank Total	$396,680
				RO Feed Tank Total with 40% Contingency	**$555,000**
RO System	RO system including membrane trains, feed pumps, flush pumps, CIP equipment and ancillaries	package	1	$2,800,000	$2,800,000
	Concrete Slab	m^3	331.5	$3,000	$994,350
	Excavation	m^3	331.5	$60	$19,887
				UF System Total	$3,814,237
				UF System Total with 40% Contingency	**$5,340,000**
RO Flush Tank	Concrete Walls	m^3	58.8	$4,500	$264,475
	Concrete Base	m^3	20.5	$3,000	$61,396
	Concrete Roof	m^3	15.5	$4,500	$69,581
	Excavation	m^3	20.5	$60	$1,228
				RO Flush Tank Total	$396,680
				RO Flush Tank Total with 40% Contingency	**$555,000**
UV AOP System	UV Units	package	1	$800,000	$800,000
	Concrete Slab	m^3	28.0	$3,000	$84,000
	Excavation	m^3	28.0	$60	$1,680
				UV AOP System Total	$885,680
				UV AOP System Total with 40% Contingency	**$1,240,000**

Byron DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
Secondary UV System	UV Units	package	1	$300,000	$300,000
	Concrete Slab	m^3	28.0	$3,000	$84,000
	Excavation	m^3	28.0	$60	$1,680
Secondary UV System Total					$385,680
Secondary UV System Total with 40% Contingency					**$540,000**
Chlorine Contact Tank	Concrete Walls	m^3	9.2	$4,500	$41,580
	Concrete Base	m^3	12.0	$3,000	$35,952
	Concrete Roof	m^3	12.0	$4,500	$53,298
	Baffles	each	4	$6,000	$24,000
	Excavation	m^3	12.0	$60	$719
	Handrails	m	28.0	$750	$21,000
	Stairs	each	2	$25,000	$50,000
Chlorine Contact Tank Total					$227,179
Chlorine Contact Tank Total with 40% Contingency					**$318,000**
Calcite Filter Feed Pumps	11 kW Feed Pump	each	2	$25,000	$50,000
	Concrete Slab	m^3	5.6	$3,000	$16,800
	Excavation	m^3	5.6	$60	$336
Calcite Filter Feed Pumps Total					$67,136
Calcite Filter Feed Pumps Total with 40% Contingency					**$94,000**
Calcite Filters	Calcite Filters	package	1	$2,700,000	$2,700,000
	Concrete Slab	m^3	42.1	$3,000	$126,263
	Excavation	m^3	42.1	$60	$2,525
Calcite Filters Total					$2,828,788
Calcite Filter Total with 40% Contingency					**$3,960,000**
Calcite Filter Backwash Pumps	11 kW Backwash Pump	each	2	$25,000	$50,000
	Concrete Slab	m^3	5.6	$3,000	$16,800
	Excavation	m^3	5.6	$60	$336
Calcite Filter Backwash Pumps Total					$67,136
Calcite Filter Backwash Pumps Total with 40% Contingency					**$94,000**
PRW Pumps	5.5 kW PRW Pump	each	2	$15,000	$30,000
	Concrete Slab	m^3	5.6	$3,000	$16,800
	Excavation	m^3	5.6	$60	$336
PWR Pumps Total					$47,136
PWR Pumps Total with 40% Contingency					**$66,000**
Engineered Buffer Storage Tank	Concrete Walls	m^3	47.6	$4,500	$214,226
	Concrete Base	m^3	14.0	$3,000	$41,905
	Concrete Roof	m^3	9.9	$4,500	$44,532
	Excavation	m^3	14.0	$60	$838
Engineered Buffer Storage Tank Cost per Tank					$301,501
Engineered Buffer Storage Tank Total for Two Tanks					$603,002
Engineered Buffer Storage Tank Total (for Two Tanks) with 40% Contingency					**$844,000**
Waste Buffer Tank	15 kW Discharge Pump	each	2	$32,000	$64,000
	Concrete Walls	m^3	46.6	$4,500	$209,816
	Concrete Base	m^3	28.2	$3,000	$84,598
	Excavation	m^3	248.1	$120	$29,773
Waste Buffer Tank Total					$388,187
Waste Buffer Tank Total with 40% Contingency					**$543,000**

Byron DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
Neutralisation Tank	15 kW Discharge Pump	each	2	$64,000	$128,000
	Concrete Walls	m³	24.6	$4,500	$110,565
	Concrete Base	m³	12.7	$3,000	$38,000
	Concrete Roof	m³	12.7	$4,500	$56,999
	Excavation	m³	183.5	$120	$22,018
	Epoxy Coating	m²	122.0	$220	$26,840
				Neutralisation Tank Total	$382,422
				Neutralisation Tank Total with 40% Contingency	**$535,000**
Nitrification MBBR	MBBR Equipment (diffusers, blowers) and Media	each	1	$200,000	$200,000
	Concrete Walls	m³	32.1	$4,500	$144,585
	Concrete Base	m³	10.2	$3,000	$30,597
	Excavation	m³	10.2	$60	$612
	Handrails	m	20.4	$750	$15,300
	Stairs	each	2	$25,000	$50,000
	Platforms	m²	22.0	$1,500	$33,000
				Nitrification MBBR Total	$474,094
				Nitrification MBBR Total with 40% Contingency	**$664,000**
Denitrification MBBR	1.1 kW Mixer	each	1	$5,200	$5,200
	Media	lump sum	1	$40,000	$40,000
	Concrete Walls	m³	38.4	$4,500	$172,935
	Concrete Base	m³	14.4	$3,000	$43,092
	Excavation	m³	14.4	$60	$862
	Handrails	m	24.4	$750	$18,300
	Stairs	each	2	$25,000	$50,000
	Platforms	m²	32.5	$1,500	$48,750
				Denitrification MBBR Total	$379,139
				Denitrification MBBR Total with 40% Contingency	**$531,000**
Lamella Clarifiers	Clarifier Plates	lump sum	1	$150,000	$150,000
	Concrete Walls	m³	25.8	$4,500	$116,235
	Concrete Base	m³	6.7	$3,000	$20,202
	Excavation	m³	6.7	$60	$404
	Handrails	m	46.0	$750	$34,500
	Stairs	each	2	$25,000	$50,000
	Platforms	m²	13.5	$1,500	$20,250
				Lamella Clarifiers Cost per Clarifier	$391,591
				Lamella Clarifiers Total for Two Clarifiers	$783,182
				Lamella Clarifiers Total (for Two Clarifiers) with 40% Contingency	**$1,096,000**
Lamella Flash Mixer	0.55 kW Mixer	each	1	$4,200	$4,200
	Concrete Walls	m³	2	$4,500	$10,631
	Concrete Base	m³	0.1	$3,000	$263
	Excavation	m³	0.1	$60	$5
	Handrails	m	2	$750	$1,125
	Platforms	m²	0.3	$1,500	$375
				Lamella Flash Mixer per Clarifier	$16,599
				Lamella Flash Mixer Total for Two Clarifiers	$33,198
				Lamella Flash Mixer Total (for Two Clarifiers) with 40% Contingency	**$46,000**

Byron DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
Lamella Floc Tank	0.55 kW Mixer	each	1	$4,200	$4,200
	Concrete Walls	m^3	11.8	$4,500	$53,156
	Concrete Base	m^3	2.2	$3,000	$6,563
	Excavation	m^3	2.2	$60	$131
	Handrails	m	7.5	$750	$5,625
	Platforms	m^2	6.3	$1,500	$9,375
				Lamella Floc Tank per Clarifier	$79,050
				Lamella Floc Tank Total for Two Clarifiers	$158,100
				Lamella Floc Tank Total (for Two Clarifiers) with 40% Contingency	**$221,000**
Chemical Storage and Dosing	Sodium Hypochlorite System	each	1	$72,000	$72,000
	Sodium Hydroxide System	each	1	$53,000	$53,000
	Aluminium Sulphate System	each	1	$35,000	$35,000
	Sodium Bisulphite System	each	1	$18,000	$18,000
	Citric Acid System	each	1	$18,000	$18,000
	Sulphuric Acid System	each	1	$53,000	$53,000
	Polymer System	each	1	$60,000	$60,000
	Ammonium Sulphate System	each	1	$24,000	$24,000
	Antiscalant System	each	1	$24,000	$24,000
	Methanol System	each	1	$60,000	$60,000
	Concrete Base and Unloading Area	m^3	211.8	$3,000	$635,250
	Concrete Bund Walls	m^3	12.5	$3,000	$37,359
	Excavation	m^3	225.3	$60	$13,515
	Epoxy Coating	m^2	676.2	$220	$148,755
	Handrails	m	200.0	$500	$100,000
	Stairs	each	8	$8,000	$64,000
	Platforms	m^2	16.0	$1,500	$24,000
	Carport Style Roof	m^2	200.0	$1,600	$320,000
	Water Quality Analysers	lump sum	1	$1,500,000	$1,500,000
				Chemical Storage and Dosing Total	$3,259,879
				Chemical Storage and Dosing Total with 40% Contingency	**$4,564,000**
Buildings	Control Building	m^2	360	$8,000	$2,880,000
	Workshop	m^2	120	$4,000	$480,000
	UF Building	m^2	224	$4,000	$1,344,000
	RO Building	m^2	294	$4,000	$3,276,000
	Switchroom	m^2	360	$8,000	$2,880,000
				Buildings Total	$10,860,000
				Buildings Total with 40% Contingency	**$15,204,000**

Byron DPR via Treated Water Augmentation AWTP – Breakdown of Contractor's Direct Costs (continued)

Component	Item	Units	Quantity	Unit Cost	Total Cost
General Civil	Bulk Earthworks	m^3	22,000	$100	$2,200,000
	Site Road	m^2	2,000	$200	$400,000
	Landscaping	lump sum	1	$100,000	$100,000
	Admin Building Car Park	m^2	200	$200	$40,000
	Fencing	m	580	$420	$243,600
General Civil Total					$2,983,600
General Civil Total with 40% Contingency					**$4,177,000**
Total Equipment Costs (including 40% Contingency)					$18,054,400
Mechanical Equipment Installation Costs (15% of Total Equipment Costs)					**$2,708,000**
Piping Costs (20% of Total Equipment Costs)					**$3,611,000**
Total Contractor's Direct Costs excluding Preliminaries and Electrical and Controls (including 40% Contingency)					$55,935,000
Electrical and Control Costs (15% of Total Contractor's Direct Cost excluding Preliminaries and EIC, including 40% Contingency)					**$8,390,000**
Total Contractor's Direct Cost excluding Preliminaries (including 40% Contingency)					$64,325,000
Preliminaries (10% of Total Contractor's Direct Cost excluding Preliminaries, including 40% Contingency)					**$6,433,000**
Total Contractor's Direct Costs (including 40% Contingency)					**$70,758,000**

APPENDIX N: NPC CALCULATIONS

40 Year NPC at 5% Discount Rate

Year	Lismore IPR via SWA – 0.6 GL Storage		Lismore IPR via SWA – 1.2 GL Storage		Lismore DPR via RWA		Lismore DPR via TWA		Byron DPR via TWA	
	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost
1	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$1,800,000	$1,800,000	$2,200,000	$2,200,000
2	$2,525,000	$2,404,762	$2,525,000	$2,404,762	$2,525,000	$2,404,762	$2,125,000	$2,023,810	$2,525,000	$2,404,762
3	$5,500,000	$4,988,662	$5,500,000	$4,988,662	$5,500,000	$4,988,662	$5,500,000	$4,988,662	$5,500,000	$4,988,662
4	$3,775,000	$3,260,987	$3,775,000	$3,260,987	$3,775,000	$3,260,987	$3,775,000	$3,260,987	$3,775,000	$3,260,987
5	$9,641,667	$7,932,223	$10,108,333	$8,316,151	$10,108,333	$8,316,151	$6,875,000	$5,656,080	$8,508,333	$6,999,827
6	$16,908,333	$13,248,122	$17,841,667	$13,979,413	$17,841,667	$13,979,413	$11,375,000	$8,912,610	$14,641,667	$11,472,129
7	$95,025,000	$70,909,118	$100,975,000	$75,349,100	$100,975,000	$75,349,100	$59,750,000	$44,586,370	$80,575,000	$60,126,306
8	$100,475,000	$71,405,707	$106,775,000	$75,882,999	$106,775,000	$75,882,999	$63,125,000	$44,861,759	$85,175,000	$60,532,282
9	$12,266,300	$8,302,315	$12,616,300	$8,539,208	$12,616,300	$8,539,208	$9,415,400	$6,372,713	$11,794,700	$7,983,117
10	$4,410,600	$2,843,112	$4,410,600	$2,843,112	$4,410,600	$2,843,112	$4,410,600	$2,843,112	$4,410,600	$2,843,112
11	$4,410,600	$2,707,726	$4,410,600	$2,707,726	$4,410,600	$2,707,726	$4,410,600	$2,707,726	$4,410,600	$2,707,726
12	$4,410,600	$2,578,786	$4,410,600	$2,578,786	$4,410,600	$2,578,786	$4,410,600	$2,578,786	$4,410,600	$2,578,786
13	$4,410,600	$2,455,987	$4,410,600	$2,455,987	$4,410,600	$2,455,987	$4,410,600	$2,455,987	$4,410,600	$2,455,987
14	$4,410,600	$2,339,035	$4,410,600	$2,339,035	$4,410,600	$2,339,035	$4,410,600	$2,339,035	$4,410,600	$2,339,035
15	$4,410,600	$2,227,653	$4,410,600	$2,227,653	$4,410,600	$2,227,653	$4,410,600	$2,227,653	$4,410,600	$2,227,653
16	$4,410,600	$2,121,574	$4,410,600	$2,121,574	$4,410,600	$2,121,574	$4,410,600	$2,121,574	$4,410,600	$2,121,574
17	$4,410,600	$2,020,547	$4,410,600	$2,020,547	$4,410,600	$2,020,547	$4,410,600	$2,020,547	$4,410,600	$2,020,547
18	$4,410,600	$1,924,330	$4,410,600	$1,924,330	$4,410,600	$1,924,330	$4,410,600	$1,924,330	$4,410,600	$1,924,330
19	$4,410,600	$1,832,695	$4,410,600	$1,832,695	$4,410,600	$1,832,695	$4,410,600	$1,832,695	$4,410,600	$1,832,695
20	$4,410,600	$1,745,424	$4,410,600	$1,745,424	$4,410,600	$1,745,424	$4,410,600	$1,745,424	$4,410,600	$1,745,424
21	$4,410,600	$1,662,309	$4,410,600	$1,662,309	$4,410,600	$1,662,309	$4,410,600	$1,662,309	$4,410,600	$1,662,309
22	$4,410,600	$1,583,151	$4,410,600	$1,583,151	$4,410,600	$1,583,151	$4,410,600	$1,583,151	$4,410,600	$1,583,151
23	$4,410,600	$1,507,763	$4,410,600	$1,507,763	$4,410,600	$1,507,763	$4,410,600	$1,507,763	$4,410,600	$1,507,763

40 Year NPC at 5% Discount Rate (continued)

Year	Lismore IPR via SWA – 0.6 GL Storage		Lismore IPR via SWA – 1.2 GL Storage		Lismore DPR via RWA		Lismore DPR via TWA		Byron DPR via TWA	
	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure		Expenditure	Present Cost	Expenditure	Present Cost
24	$4,410,600	$1,435,965	$4,410,600	$1,435,965	$4,410,600	$1,435,965	$4,410,600	$1,435,965	$4,410,600	$1,435,965
25	$4,410,600	$1,367,586	$4,410,600	$1,367,586	$4,410,600	$1,367,586	$4,410,600	$1,367,586	$4,410,600	$1,367,586
26	$4,410,600	$1,302,462	$4,410,600	$1,302,462	$4,410,600	$1,302,462	$4,410,600	$1,302,462	$4,410,600	$1,302,462
27	$4,410,600	$1,240,440	$4,410,600	$1,240,440	$4,410,600	$1,240,440	$4,410,600	$1,240,440	$4,410,600	$1,240,440
28	$4,410,600	$1,181,372	$4,410,600	$1,181,372	$4,410,600	$1,181,372	$4,410,600	$1,181,372	$4,410,600	$1,181,372
29	$4,410,600	$1,125,116	$4,410,600	$1,125,116	$4,410,600	$1,125,116	$4,410,600	$1,125,116	$4,410,600	$1,125,116
30	$4,410,600	$1,071,539	$4,410,600	$1,071,539	$4,410,600	$1,071,539	$4,410,600	$1,071,539	$4,410,600	$1,071,539
31	$4,410,600	$1,020,513	$4,410,600	$1,020,513	$4,410,600	$1,020,513	$4,410,600	$1,020,513	$4,410,600	$1,020,513
32	$4,410,600	$971,918	$4,410,600	$971,918	$4,410,600	$971,918	$4,410,600	$971,918	$4,410,600	$971,918
33	$4,410,600	$925,636	$4,410,600	$925,636	$4,410,600	$925,636	$4,410,600	$925,636	$4,410,600	$925,636
34	$4,410,600	$881,558	$4,410,600	$881,558	$4,410,600	$881,558	$4,410,600	$881,558	$4,410,600	$881,558
35	$4,410,600	$839,579	$4,410,600	$839,579	$4,410,600	$839,579	$4,410,600	$839,579	$4,410,600	$839,579
36	$4,410,600	$799,599	$4,410,600	$799,599	$4,410,600	$799,599	$4,410,600	$799,599	$4,410,600	$799,599
37	$4,410,600	$761,523	$4,410,600	$761,523	$4,410,600	$761,523	$4,410,600	$761,523	$4,410,600	$761,523
38	$4,410,600	$725,260	$4,410,600	$725,260	$4,410,600	$725,260	$4,410,600	$725,260	$4,410,600	$725,260
39	$4,410,600	$690,724	$4,410,600	$690,724	$4,410,600	$690,724	$4,410,600	$690,724	$4,410,600	$690,724
40	$4,410,600	$657,832	$4,410,600	$657,832	$4,410,600	$657,832	$4,410,600	$657,832	$4,410,600	$657,832
NPC	$385,044,900	$231,200,608	$399,044,900	$241,469,995	$314,985,800	$179,813,674	$301,469,000	$169,011,704	$351,423,300	$206,516,785
Specific NPC		$25.4m per ML/d		$26.5m per ML/d		$19.8m per ML/d		$31.3m per ML/d		$30.8m per ML/d

40 Year NPC at 3% Discount Rate

Year	Lismore IPR via SWA – 0.6 GL Storage		Lismore IPR via SWA – 1.2 GL Storage		Lismore DPR via RWA		Lismore DPR via TWA		Byron DPR via TWA	
	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost
1	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$1,800,000	$1,800,000	$2,200,000	$2,200,000
2	$2,525,000	$2,451,456	$2,525,000	$2,451,456	$2,525,000	$2,451,456	$2,125,000	$2,063,107	$2,525,000	$2,451,456
3	$5,500,000	$5,184,278	$5,500,000	$5,184,278	$5,500,000	$5,184,278	$5,500,000	$5,184,278	$5,500,000	$5,184,278
4	$3,775,000	$3,454,660	$3,775,000	$3,454,660	$3,775,000	$3,454,660	$3,775,000	$3,454,660	$3,775,000	$3,454,660
5	$9,641,667	$8,566,496	$10,108,333	$8,981,123	$7,308,333	$6,493,360	$6,875,000	$6,108,348	$8,508,333	$7,559,544
6	$16,908,333	$14,585,277	$17,841,667	$15,390,378	$12,241,667	$10,559,769	$11,375,000	$9,812,175	$14,641,667	$12,630,030
7	$95,025,000	$79,581,941	$100,975,000	$84,564,973	$65,275,000	$54,666,785	$59,750,000	$50,039,684	$80,575,000	$67,480,294
8	$100,475,000	$81,695,370	$106,775,000	$86,817,846	$68,975,000	$56,082,987	$63,125,000	$51,326,402	$85,175,000	$69,255,069
9	$12,266,300	$9,683,130	$12,616,300	$9,959,424	$10,457,200	$8,255,010	$9,415,400	$7,432,604	$11,794,700	$9,310,845
10	$4,410,600	$3,380,358	$4,410,600	$3,380,358	$4,410,600	$3,380,358	$4,410,600	$3,380,358	$4,410,600	$3,380,358
11	$4,410,600	$3,281,901	$4,410,600	$3,281,901	$4,410,600	$3,281,901	$4,410,600	$3,281,901	$4,410,600	$3,281,901
12	$4,410,600	$3,186,311	$4,410,600	$3,186,311	$4,410,600	$3,186,311	$4,410,600	$3,186,311	$4,410,600	$3,186,311
13	$4,410,600	$3,093,506	$4,410,600	$3,093,506	$4,410,600	$3,093,506	$4,410,600	$3,093,506	$4,410,600	$3,093,506
14	$4,410,600	$3,003,404	$4,410,600	$3,003,404	$4,410,600	$3,003,404	$4,410,600	$3,003,404	$4,410,600	$3,003,404
15	$4,410,600	$2,915,926	$4,410,600	$2,915,926	$4,410,600	$2,915,926	$4,410,600	$2,915,926	$4,410,600	$2,915,926
16	$4,410,600	$2,830,996	$4,410,600	$2,830,996	$4,410,600	$2,830,996	$4,410,600	$2,830,996	$4,410,600	$2,830,996
17	$4,410,600	$2,748,540	$4,410,600	$2,748,540	$4,410,600	$2,748,540	$4,410,600	$2,748,540	$4,410,600	$2,748,540
18	$4,410,600	$2,668,486	$4,410,600	$2,668,486	$4,410,600	$2,668,486	$4,410,600	$2,668,486	$4,410,600	$2,668,486
19	$4,410,600	$2,590,763	$4,410,600	$2,590,763	$4,410,600	$2,590,763	$4,410,600	$2,590,763	$4,410,600	$2,590,763
20	$4,410,600	$2,515,304	$4,410,600	$2,515,304	$4,410,600	$2,515,304	$4,410,600	$2,515,304	$4,410,600	$2,515,304
21	$4,410,600	$2,442,042	$4,410,600	$2,442,042	$4,410,600	$2,442,042	$4,410,600	$2,442,042	$4,410,600	$2,442,042
22	$4,410,600	$2,370,915	$4,410,600	$2,370,915	$4,410,600	$2,370,915	$4,410,600	$2,370,915	$4,410,600	$2,370,915
23	$4,410,600	$2,301,859	$4,410,600	$2,301,859	$4,410,600	$2,301,859	$4,410,600	$2,301,859	$4,410,600	$2,301,859

40 Year NPC at 3% Discount Rate (continued)

Year	Lismore IPR via SWA – 0.6 GL Storage		Lismore IPR via SWA – 1.2 GL Storage		Lismore DPR via RWA		Lismore DPR via TWA		Byron DPR via TWA	
	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure		Expenditure	Present Cost	Expenditure	Present Cost
24	$4,410,600	$2,234,815	$4,410,600	$2,234,815	$4,410,600	$2,234,815	$4,410,600	$2,234,815	$4,410,600	$2,234,815
25	$4,410,600	$2,169,723	$4,410,600	$2,169,723	$4,410,600	$2,169,723	$4,410,600	$2,169,723	$4,410,600	$2,169,723
26	$4,410,600	$2,106,527	$4,410,600	$2,106,527	$4,410,600	$2,106,527	$4,410,600	$2,106,527	$4,410,600	$2,106,527
27	$4,410,600	$2,045,172	$4,410,600	$2,045,172	$4,410,600	$2,045,172	$4,410,600	$2,045,172	$4,410,600	$2,045,172
28	$4,410,600	$1,985,604	$4,410,600	$1,985,604	$4,410,600	$1,985,604	$4,410,600	$1,985,604	$4,410,600	$1,985,604
29	$4,410,600	$1,927,771	$4,410,600	$1,927,771	$4,410,600	$1,927,771	$4,410,600	$1,927,771	$4,410,600	$1,927,771
30	$4,410,600	$1,871,622	$4,410,600	$1,871,622	$4,410,600	$1,871,622	$4,410,600	$1,871,622	$4,410,600	$1,871,622
31	$4,410,600	$1,817,109	$4,410,600	$1,817,109	$4,410,600	$1,817,109	$4,410,600	$1,817,109	$4,410,600	$1,817,109
32	$4,410,600	$1,764,183	$4,410,600	$1,764,183	$4,410,600	$1,764,183	$4,410,600	$1,764,183	$4,410,600	$1,764,183
33	$4,410,600	$1,712,799	$4,410,600	$1,712,799	$4,410,600	$1,712,799	$4,410,600	$1,712,799	$4,410,600	$1,712,799
34	$4,410,600	$1,662,912	$4,410,600	$1,662,912	$4,410,600	$1,662,912	$4,410,600	$1,662,912	$4,410,600	$1,662,912
35	$4,410,600	$1,614,478	$4,410,600	$1,614,478	$4,410,600	$1,614,478	$4,410,600	$1,614,478	$4,410,600	$1,614,478
36	$4,410,600	$1,567,454	$4,410,600	$1,567,454	$4,410,600	$1,567,454	$4,410,600	$1,567,454	$4,410,600	$1,567,454
37	$4,410,600	$1,521,800	$4,410,600	$1,521,800	$4,410,600	$1,521,800	$4,410,600	$1,521,800	$4,410,600	$1,521,800
38	$4,410,600	$1,477,476	$4,410,600	$1,477,476	$4,410,600	$1,477,476	$4,410,600	$1,477,476	$4,410,600	$1,477,476
39	$4,410,600	$1,434,442	$4,410,600	$1,434,442	$4,410,600	$1,434,442	$4,410,600	$1,434,442	$4,410,600	$1,434,442
40	$4,410,600	$1,392,663	$4,410,600	$1,392,663	$4,410,600	$1,392,663	$4,410,600	$1,392,663	$4,410,600	$1,392,663
NPC	$385,044,900	$277,039,467	$399,044,900	$288,640,997	$314,985,800	$218,985,164	$301,468,900	$206,858,116	$351,423,300	$249,163,036
Specific NPC		$30.4m per ML/d		$31.7m per ML/d		$24.1m per ML/d		$38.3m per ML/d		$37.2m per ML/d

40 Year NPC at 7% Discount Rate

Year	Lismore IPR via SWA – 0.6 GL Storage		Lismore IPR via SWA – 1.2 GL Storage		Lismore DPR via RWA		Lismore DPR via TWA		Byron DPR via TWA	
	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure	Present Cost
1	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$2,200,000	$1,800,000	$1,800,000	$2,200,000	$2,200,000
2	$2,525,000	$2,359,813	$2,525,000	$2,359,813	$2,525,000	$2,359,813	$2,125,000	$1,985,981	$2,525,000	$2,359,813
3	$5,500,000	$4,803,913	$5,500,000	$4,803,913	$5,500,000	$4,803,913	$5,500,000	$4,803,913	$5,500,000	$4,803,913
4	$3,775,000	$3,081,524	$3,775,000	$3,081,524	$3,775,000	$3,081,524	$3,775,000	$3,081,524	$3,775,000	$3,081,524
5	$9,641,667	$7,355,581	$10,108,333	$7,711,599	$7,308,333	$5,575,493	$6,875,000	$5,244,905	$8,508,333	$6,490,967
6	$16,908,333	$12,055,408	$17,841,667	$12,720,862	$12,241,667	$8,728,139	$11,375,000	$8,110,218	$14,641,667	$10,439,306
7	$95,025,000	$63,319,170	$100,975,000	$67,283,906	$65,275,000	$43,495,489	$59,750,000	$39,813,948	$80,575,000	$53,690,525
8	$100,475,000	$62,570,780	$106,775,000	$66,494,104	$68,975,000	$42,954,163	$63,125,000	$39,311,077	$85,175,000	$53,042,709
9	$12,266,300	$7,139,098	$12,616,300	$7,342,801	$10,457,200	$6,086,186	$9,415,400	$5,479,849	$11,794,700	$6,864,623
10	$4,410,600	$2,399,074	$4,410,600	$2,399,074	$4,410,600	$2,399,074	$4,410,600	$2,399,074	$4,410,600	$2,399,074
11	$4,410,600	$2,242,125	$4,410,600	$2,242,125	$4,410,600	$2,242,125	$4,410,600	$2,242,125	$4,410,600	$2,242,125
12	$4,410,600	$2,095,444	$4,410,600	$2,095,444	$4,410,600	$2,095,444	$4,410,600	$2,095,444	$4,410,600	$2,095,444
13	$4,410,600	$1,958,359	$4,410,600	$1,958,359	$4,410,600	$1,958,359	$4,410,600	$1,958,359	$4,410,600	$1,958,359
14	$4,410,600	$1,830,242	$4,410,600	$1,830,242	$4,410,600	$1,830,242	$4,410,600	$1,830,242	$4,410,600	$1,830,242
15	$4,410,600	$1,710,507	$4,410,600	$1,710,507	$4,410,600	$1,710,507	$4,410,600	$1,710,507	$4,410,600	$1,710,507
16	$4,410,600	$1,598,604	$4,410,600	$1,598,604	$4,410,600	$1,598,604	$4,410,600	$1,598,604	$4,410,600	$1,598,604
17	$4,410,600	$1,494,023	$4,410,600	$1,494,023	$4,410,600	$1,494,023	$4,410,600	$1,494,023	$4,410,600	$1,494,023
18	$4,410,600	$1,396,283	$4,410,600	$1,396,283	$4,410,600	$1,396,283	$4,410,600	$1,396,283	$4,410,600	$1,396,283
19	$4,410,600	$1,304,937	$4,410,600	$1,304,937	$4,410,600	$1,304,937	$4,410,600	$1,304,937	$4,410,600	$1,304,937
20	$4,410,600	$1,219,568	$4,410,600	$1,219,568	$4,410,600	$1,219,568	$4,410,600	$1,219,568	$4,410,600	$1,219,568
21	$4,410,600	$1,139,783	$4,410,600	$1,139,783	$4,410,600	$1,139,783	$4,410,600	$1,139,783	$4,410,600	$1,139,783
22	$4,410,600	$1,065,218	$4,410,600	$1,065,218	$4,410,600	$1,065,218	$4,410,600	$1,065,218	$4,410,600	$1,065,218
23	$4,410,600	$995,530	$4,410,600	$995,530	$4,410,600	$995,530	$4,410,600	$995,530	$4,410,600	$995,530

40 Year NPC at 7% Discount Rate (continued)

Year	Lismore IPR via SWA – 0.6 GL Storage		Lismore IPR via SWA – 1.2 GL Storage		Lismore DPR via RWA		Lismore DPR via TWA		Byron DPR via TWA	
	Expenditure	Present Cost	Expenditure	Present Cost	Expenditure		Expenditure	Present Cost	Expenditure	Present Cost
24	$4,410,600	$930,402	$4,410,600	$930,402	$4,410,600	$930,402	$4,410,600	$930,402	$4,410,600	$930,402
25	$4,410,600	$869,535	$4,410,600	$869,535	$4,410,600	$869,535	$4,410,600	$869,535	$4,410,600	$869,535
26	$4,410,600	$812,649	$4,410,600	$812,649	$4,410,600	$812,649	$4,410,600	$812,649	$4,410,600	$812,649
27	$4,410,600	$759,485	$4,410,600	$759,485	$4,410,600	$759,485	$4,410,600	$759,485	$4,410,600	$759,485
28	$4,410,600	$709,799	$4,410,600	$709,799	$4,410,600	$709,799	$4,410,600	$709,799	$4,410,600	$709,799
29	$4,410,600	$663,364	$4,410,600	$663,364	$4,410,600	$663,364	$4,410,600	$663,364	$4,410,600	$663,364
30	$4,410,600	$619,966	$4,410,600	$619,966	$4,410,600	$619,966	$4,410,600	$619,966	$4,410,600	$619,966
31	$4,410,600	$579,408	$4,410,600	$579,408	$4,410,600	$579,408	$4,410,600	$579,408	$4,410,600	$579,408
32	$4,410,600	$541,503	$4,410,600	$541,503	$4,410,600	$541,503	$4,410,600	$541,503	$4,410,600	$541,503
33	$4,410,600	$506,077	$4,410,600	$506,077	$4,410,600	$506,077	$4,410,600	$506,077	$4,410,600	$506,077
34	$4,410,600	$472,969	$4,410,600	$472,969	$4,410,600	$472,969	$4,410,600	$472,969	$4,410,600	$472,969
35	$4,410,600	$442,027	$4,410,600	$442,027	$4,410,600	$442,027	$4,410,600	$442,027	$4,410,600	$442,027
36	$4,410,600	$413,110	$4,410,600	$413,110	$4,410,600	$413,110	$4,410,600	$413,110	$4,410,600	$413,110
37	$4,410,600	$386,084	$4,410,600	$386,084	$4,410,600	$386,084	$4,410,600	$386,084	$4,410,600	$386,084
38	$4,410,600	$360,826	$4,410,600	$360,826	$4,410,600	$360,826	$4,410,600	$360,826	$4,410,600	$360,826
39	$4,410,600	$337,221	$4,410,600	$337,221	$4,410,600	$337,221	$4,410,600	$337,221	$4,410,600	$337,221
40	$4,410,600	$315,159	$4,410,600	$315,159	$4,410,600	$315,159	$4,410,600	$315,159	$4,410,600	$315,159
NPC	$385,044,900	$197,054,573	$399,044,900	$206,167,807	$314,985,800	$151,454,004	$301,469,000	$141,800,699	$351,423,300	$175,142,664
Specific NPC		$21.7m per ML/d		$22.7m per ML/d		$16.6m per ML/d		$26.3m per ML/d		$26.1m per ML/d