WATER RECYCLING; LUGGAGE POINT ADVANCED WATER TREATMENT PLANT

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ABSTRACT

The $2.5 billion Western Corridor Recycled Water (WCRW) project is Australia's largest recycled water project and the third largest advanced water treatment project in the world. Part of the South East Queensland Water Grid, the project includes more than 200 kilometres of large-diameter pipeline, three advanced water treatment plants at Bundamba, Gibson Island and Luggage Point, 12 major pump stations and nine balance tanks.

The WCRW project will have the capacity to provide up to 232 ML of purified recycled water a day to power stations, industry and agriculture, as well as to Wivenhoe Dam if the 40% critical reservoir level is exceeded. The project has the potential to significantly reduce the demand on the Wivenhoe Dam and extend the long-term water supply capacity of the region.

The Luggage Point Advanced Water Treatment Plant (LPAWTP) was constructed adjacent to the existing Brisbane wastewater treatment plant (Brisbane's largest wastewater treatment facility) and is designed to produce 70 ML/d of purified recycled water.

Due to the low levels of water storage in the Wivenhoe Dam the project construction schedule had a very tight time frame of 18 months from start of piling through to commissioning and completion. In addition to the challenge of designing an Indirect Potable Reuse plant on a fast track basis, the Luggage Point AWTP design had to take into account a significant nutrient load contained in the secondary treated effluent. Both the Nitrogen and Phosphorus load received at the plant can be elevated and variable.

This paper describes the treatment process used at the Luggage Point AWTP to produce high quality water capable of meeting the Australian Drinking Water Quality (AWDG) guidelines.

KEYWORDS

Water recycling, indirect potable reuse, Advanced Water Treatment Plant,

1 INTRODUCTION

August 2007 the City of Brisbane had seen its water supply steadily decline to a low point of less than 17% of total supply storage (SEQWater website). Through the latter period of declining reserves, commencing January 2004, alternative sources of water were investigated and, as part of an overall strategy, including the tapping of additional groundwater supplies and construction of a large desalination plant, the decision was made that the city's wastewater should be recycled to supplement the supply. Major potential users of recycled wastewater included the city's two coal fired power stations, Swanbank and Tarong.

To deliver recycled water to these facilities a pipe line, three advanced water treatment plants, 12 pump stations and nine balance tanks would be constructed. Ultimately the pipeline would stretch some 200 km from Luggage Point, near the mouth of the Brisbane River, to Tarong, located North West of Brisbane.

As the Western Corridor scheme evolved and the water supply situation deteriorated the decision was made that the wastewater would be treated to potable standard, thus enabling a large number of reuse options, including indirect potable reuse.

Three sites were selected for the construction of Indirect Potable Reuse (IPR) facilities, known as Advanced Water Treatment Plants (AWTP). The first site was Bundamba, where a 20ML/d facility was constructed. This was later updated to 33ML/d and then to 66ML/d. Two additional sites at Luggage Point and Gibson Island were chosen, with capacities of 66ML/d and 100ML/d respectively.

The Luggage Point Advanced Water Treatment Plant (AWTP) has been designed to provide high quality treated water through multiple barriers including; flocculation and clarification, microfiltration (MF), reverse osmosis (RO), and ultraviolet advanced oxidation (UV/AO).

The design of the Luggage Point AWTP was required to account for elevated and variable levels of nutrients in the secondary treated raw water it treats. An approximate summary of incoming nutrients, based on a 9 month pilot trial was observed to be as follows:

Table 1: Influent Nutrient Levels

Parameter	**Median**	**95% ile**
Ammonia Nitrogen	0.24 mg/L	0.72 mg/L
Total Organic Nitrogen	1.9 mg/L	3.2 mg/L
Nitrate Nitrogen	3.7 mg/L	10.8 mg/L
Nitrite Nitrogen	0.06 mg/L	0.45 mg/L
Total Nitrogen	5.95 mg/L	13.7 mg/L
Ortho-phosphorus as P	8.5 mg/L	13.4 mg/L
Total Phosphorus	8.3 mg/L	10.7 mg/L

In consideration of the end uses of the recycled water, and the release of the waste streams, the following water quality requirements, with regard to nutrients, had to be met by the plant. The plant would be required to achieve an 86.5% Total Nitrogen removal, and a 98.5% removal of Total Phosphorus.

Table 2: Nutrient Water Quality Requirements

Parameter	**Stream**	**Requirement**
Total Nitrogen	Product Water	$< 0.8 – 1.2$ mg/L
Total Phosphorus	Product Water	< 0.13 mg/L
Total Phosphorus	RO Concentrate	< 4mg/L

The following schematic illustrates the process flow that was selected to achieve these stringent requirements, along with meeting all of the requirements of the Australian Drinking Water Quality (ADWG) guidelines

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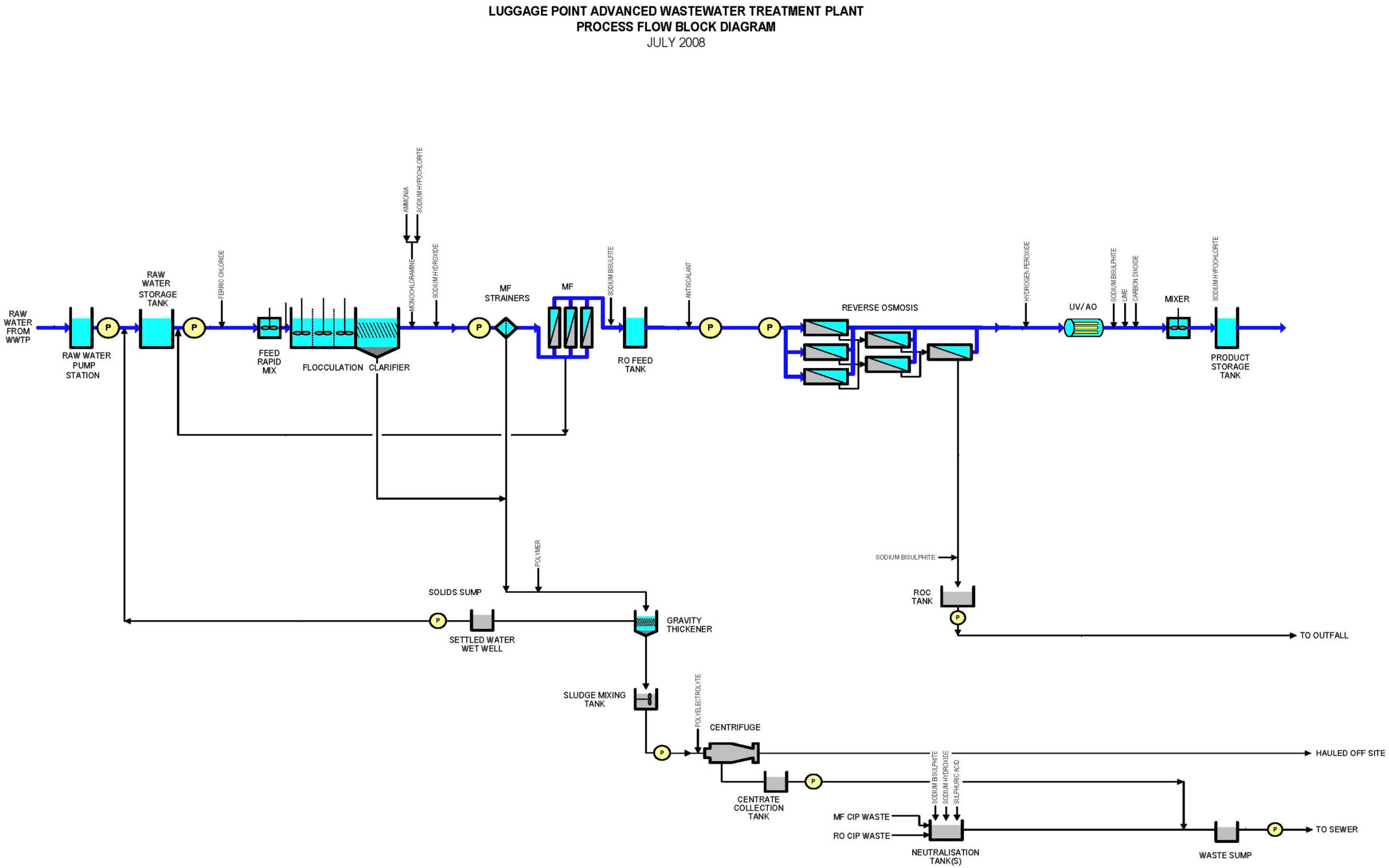
Figure 1: Luggage Point AWTP- Process Flow diagram



2 PROCESS FLOW

2.1 RAW WATER PUMPING AND STORAGE

The Raw Water Pump Station, located on the Luggage Point Wastewater Treatment Plant outfall channel, transfers secondary treated water to the Raw Water Storage Tank located within the AWTP. The available flow of raw water varies diurnally and from day to day. To account for this variable speed vertical turbine pumps in the raw water pump station transfer up to 1350 L/s of raw water to the 15 ML storage tank, allowing the AWTP to operate independently of the source. The Raw water storage tank does not however provide sufficient capacity to balance inter-day or raw water compositional equalisation.

Photograph 1: Raw water pumps (clarifier feed)

Internal recycle flows, including supernatant from the sludge thickener and MF/RO start-up flushes or process excursions, are returned to raw water storage. Two, high speed, submersible mixers are provided to minimise the settling of fine solids

2.2 FLOCCULATION – CLARIFICATION

The Flocculation-Clarification (Pre-treatment) unit of the AWTP comprises of two parallel process trains that include the following operations:

- Feed water (plus internal recycle streams) is pumped via variable speed turbine pumps to the flocculation zone.
- Chemical dosing is via an in-line, mechanical rapid mixer. Ferric Chloride is dosed to precipitate Orthophosphate and coagulate poorly settling solids in the raw water.
- The flocculators gently mix the dosed raw water to facilitate the growth of floc in a three-stage flocculation tank with a retention time of 20 minutes at full flow.
- The separation of the flocculated solids is carried out in a clarifier fitted with incline (Lamella) plates. Sludge is removed via a scraper system on the bottom of the rectangular tank.

Photograph 2: Incline Plate Clarifiers

Ferric Chloride dosing results in precipitation of both Ferric Hydroxide and Ferric Phosphate solids. The minimum Ferric Chloride dose to achieve phosphorus precipitation in the absence of Ferric Hydroxide formation is 5.2 mg $FeCl_3$ per mg P removed. Observations from the pilot plant and jar tests demonstrated that a typical dose of 1.8 times this minimum stoichiometric dose was required.

The overall objective of the process is to reduce the soluble phosphorus concentration in the Microfiltration (MF) feed to less than 0.6 mg/L as P, ensuring compliance with total phosphorus criteria for both product water and RO concentrate (ROC).

2.3 SLUDGE THICKENING AND DEWATERING

The 19m diameter gravity thickener collects sludge from the clarifiers and the MF strainers and is designed to concentrates it to 2.5% Dry Solids, with a minimum solids capture of 90 percent.

To promote thickening polymer is dosed and there is a motor driven picket fence sludge rake that directs the flocculated solids to the centre of the thickener where it is pumped to the sludge mixing tank (centrifuge feed tank)

Photograph 3: Thickener clarifier and dewatering building

The settled water overflows from the thickener and is pumped back to the raw water tank. Sludge is drawn from the bottom of the thickener and is held in the sludge mixing tank before it is pumped to the centrifuge for dewatering. Although capable of 24 hours a day, 7 days a week operation, the system operates on a 10 hr/day 6 day/wk basis. The centrifuges are designed to produce $3.5m^3/h$ of solids which is transferred to trailer bins via a series of load out conveyors. The centrate is gravity fed to a waste sump and pumped as trade waste to the LPWWTP.

2.4 MICROFILTRATION

Supernatant from the inclined plate clarifiers is pumped via MF Feed Pumps through 300 micron strainers, into a common manifold that feeds the MF system. At the Luggage Point AWTP the Pall Microza membrane system was selected as the Microfiltration system. The system is designed to produce up to 85ML/d of water with a

Turbidity <0.1 NTU. MF is primarily included in the design to remove solids and treat the water to a sufficiently high quality to feed the RO system.

Eleven MF racks, each capable of producing 111 L/s of flow were installed based on 10 Duty and 1 Standby regime. Typically one of the duty racks will be undergoing an Enhanced Flux Maintenance (EFM) procedure at any time. Each rack contains 122 modules of 50m2 filtration surface area. A flux rate of 65L/m^2/h was adopted and proven to be suitable through the pilot operations.

Photograph 4: Microfiltration system.

The racks are subject to a number of maintenance procedures, including Air Scour, Reverse Flush, Forward Flush, Acid EFM, Sodium Hypochlorite EFM, and Clean in Place (CIP).

The EFM sequences are effectively an automated short duration CIP. CIP waste is sent to dedicated neutralisation tanks. Reverse Flush waste is returned to the Raw Water Tank.

To assist with biological fouling control on the MF and RO membranes, Chloramines are dosed prior to the MF Strainers. Solutions of Aqueous Ammonia and Sodium Hypochlorite are combined to pre-form Monochloramines so that NDMA production is minimised.

Monochloramines behave in a similar fashion to chlorine, such that the chlorine demand of both the influent water (clarifier supernatant) and the membranes use the chlorine component of the Monochloramine, and release the Ammonia component. While a theoretical 4:1 dosing ratio is required to pre-form Monochloramines a lower ratio is adopted to ensure that there is always Free Ammonia present. The presence of free ammonia ensures there is no Free Chlorine in the RO Feed Water, as this could result in damage to the RO Membranes.

2.5 REVERSE OSMOSIS

The purpose of the RO system is to reduce the dissolved inorganic and organic components in the water. The system consists of the RO feed tank, RO booster pumps, RO feed chemical dosing systems, cartridge filters, RO feed pumps, the RO trains, and the RO CIP system. The RO system has a design treatment capacity of 70 ML/d, and consists of four parallel trains (three duty/one standby) with a treatment capacity of 23.3 ML/d each.

The Luggage point AWTP the RO system is supplied by Doosan Hydro Technologies utilising Toray membrane elements. Four independent RO trains are utilised, each train has 210 modules (tubes) and each module contains 7 elements. All 5880 elements are manually loaded into the modules during commissioning.

Photograph 5: Reverse Osmosis System

The RO Feed System consists of the following components:

- RO Feed Tank
- RO Booster Pumps
- RO Cartridge Filters
- RO Feed Pumps
- Process Analysers for RO Feedwater Quality
- RO Feedwater Antiscalant Dosing

The filtrate from the MF pre-treatment system is fed to the RO Feed Tank, which serves as a hydraulic buffer between the MF pre-treatment and RO system. The RO Feed Tank also serves as the source of water supply for the periodic reverse flush of the MF membrane racks.

The 630 kW variable speed RO Booster Pumps (low pressure) withdraw MF filtrate from the RO Feed Tank and pump this through Cartridge Filters to the RO Feed Pumps (high pressure).

The RO Cartridge Filters are horizontal pressure vessels fitted with 5-micron string-wound cartridge filter elements (2.5-inch diameter, 40-inch length). The filters act as a safeguard to prevent particulate matter or construction debris from being pumped to the RO membranes. The RO Cartridge Filters are equipped with downstream and upstream pressure indicating transmitters (PIT), which measure the differential pressure drop across the filter elements during operation and determine when to replace the cartridge filter elements.

The RO Feed Pumps are located downstream of the RO Cartridge Filters, and pump directly into the RO system at high pressure. The variable speed RO Feed Pumps provide the required feed pressure for the RO system to produce the design permeate flow under varying operating conditions including flow, feedwater TDS, temperature and membrane age.

The RO system is designed as a single-pass, three-stage configuration. The design recovery of the RO system is 85 percent. The RO elements are thin-film composite, spiral-wound type, and each element is 200mm in diameter by 1,016mm in length. The RO pressure vessels (modules) are multi-port side entry type, with a maximum operating pressure of 450 psi. There are 1,470 RO elements in each skid and a total of 5,880 elements in the entire system.

Figure 2: General Schematic of RO System Stages

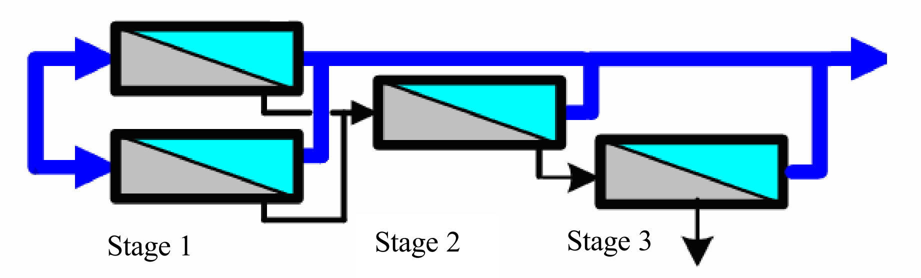


Figure 2 presents a general schematic of an RO skid staging and illustrates the feed, permeate, and concentrate flow paths. At the Luggage Point AWTP the concentrate from Stage 3 of each RO skid is fed to an energy recovery turbine (ERT), hydraulic turbocharger-type, which transfers the majority of the energy in the Stage 3 concentrate to the Stage 3 feed. This reduces overall energy consumption by boosting the concentrate pressure between Stages 2 and 3.

2.6 UV / ADVANCED OXIDATION

The UV / AO system contributes to the multi-barrier approach attaining a 4 log removal of Bacteria and Virus and >4 log removal of Cryptosporidium and Giardia.

The process is a chemical-physical process that effectively removes the following micro-contaminants that may not be removed by the RO

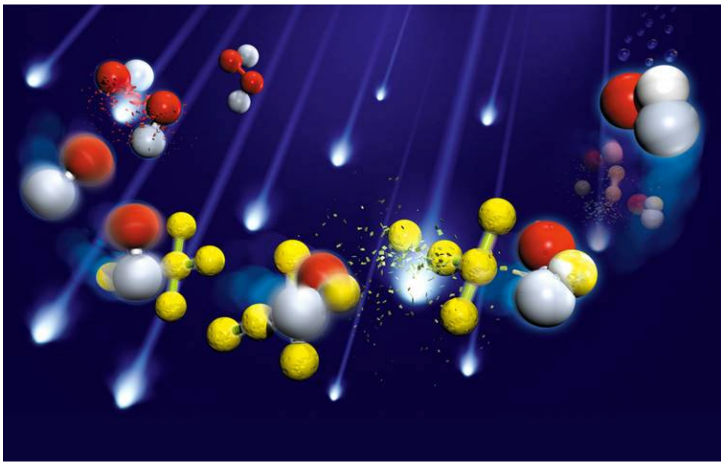
- NDMA and other Nitrosamines (and other DBPs)
- 1,4-Dioxane and other solvent compounds
- Pesticides and Herbicides
- Taste and odour causing compounds and algal toxins
- Endocrine-disrupting compounds (EDCs)
- Pharmaceutical and personal care products (PPCPs)
- Synthetic organic chemicals and volatile organics (SOCs and VOCs)

Photograph 6: Trojan UV PHOX

Three main methods of destruction work together in the UV/AOP process are Photolysis by UV light, Oxidation by hydrogen peroxide (H_2O_2) and Oxidation by OH (which is formed through the photolysis of H2O2 by the UV light). The hydroxyl radical formed through the photolysis of H_2O_2 is one of the most powerful oxidants and reacts rapidly with organic constituents in the water.

A significantly higher dose of UV light is used compared with UV that is utilised for disinfection only. The disinfection of any remaining pathogens is achieved in the UV/AOP process. Many micro-pollutants are broken down directly by this large dose of UV light.

Photograph 7: Advanced Oxidation Pictorial



Approximately 80 percent of the dosed Hydrogen Peroxide passes the UV/AOX system and has to be removed by dosing Sodium Bisulphite. The dosing setpoint for the Sodium Bisulphite is based on the plant flow, the Hydrogen Peroxide dose, and the expected utilisation ratio. ORP transmitters prior to H_2O_2 dosing, and after the 5-minute partition in the Treated Water Storage Tank, are used to monitor the quenching of the Hydrogen Peroxide.

2.7 STABILISATION & CHLORINATION

The calcium carbonate precipitation potential (CCPP) is a water stability index that is used to provide a quantitative measure of the calcium carbonate deficit or excess of the water, giving a fairly accurate guide to likely extents of $CaCO_3$ precipitation. To achieve passive water (and a CCPP of 0 to -5 mg/L $CaCO_3$) calcium hydroxide and alkalinity are introduced by dosing a combination of Lime and Carbon Dioxide.

Flow from the UV / AO reactors is combined in a common header and is dosed with Lime and CO2. Following addition of these chemicals, the water flows through static mixers and then into a 5 minute Mixing Chamber before entering the treated water tank. Lime and CO2 are added to buffer the water, and achieve an alkalinity of 40mg/L (as CaCO3) and a hardness of 50 mg/L (as CaCO3). Carbon Dioxide is added to reduce the pH to meet the specification.

The amount of Lime to achieve the alkalinity requirement is calculated by the operator and input as a setpoint. Trim can occur automatically through use of the online alkalinity analyser. The relevant amount of CO_2 to achieve the CCPP requirement is determined by controlling the CO_2 dose to a pH setpoint. (The pH is used as an indirect setpoint for the CCPP.) The CO_2 dose is subject to PID control around the pH setpoint.

The stabilised water flows over a weir from the Mixing Chamber into the Treated Water Storage Tank main compartment. At this weir sufficient chlorine (Sodium Hypochlorite) is added to ensure that Breakpoint Chlorination is achieved. The water is then pumped to the Eastern Pipeline for distribution by the scheme operator.

2.8 CHEMICAL DOSING / STORAGE

A minimum of fourteen different chemicals are used across the site for treatment of the process stream, membrane cleaning, solids treatment, and chemical neutralisation. The majority of the chemicals are stored as liquids in bulk storage tanks or intermediate bulk containers (IBC). In addition to the liquid chemicals, there is Carbon Dioxide, stored as a liquefied gas, Lime and polyelectrolyte, both stored as bulk powders.

The design basis for all chemical systems is for the plant operating at a nominal production rate of 66 ML/d (as opposed to the maximum design flow of 70 Ml/d). The chemical requirements across the plant are based on the mass balances and the equipment supplier needs, such as the membrane cleaning chemicals. Storage vessel size is based on a minimum of 14 days of chemical storage at average chemical usage.

The following table gives a very general overview of the many and varied dosing pumps and systems likely to be encountered during day to day operation of the plant. There are too many chemical dosing systems to fully cover the subject in this paper.

Table 3: Chemical Dosing Pump Parameters

Chemical System	Dosing Point	Dosing Pumps	Minimum Dose Rate (L/hr)	Nominal Dosing Rate (L/hr)	Maximum Dosing Rate (L/hr)
Ferric Chloride	Rapid Mix / Clarifier	3	77	300	824
Sodium Hydroxide	MF Feed	2	12	151	437
	MF Cleaning	1		226	
	RO Cleaning	1		105	
	Neutralisation	1		206	
Aqueous Ammonia	Chloramination	2	3	14	18
Sodium Hypochlorite	MF Feed Strainer	2	14	108	161
	Product Water	2	6	122	215
	MF Cleaning System	2		167	
Sodium Bisulphite	Product Water	2	21	142	195
	Neutralisation	1		176	
	ROC de-chlorination	2	28	105	118
Hydrogen Peroxide	Product Water	4	3	10	14
Carbon Dioxide	Product Water	2	15	88	168
Antiscalant	RO pass 1	4	2	5	7
SLS	RO Cleaning	1		533	
Hydrochloric Acid	RO Cleaning	1		376	
Citric Acid	MF Cleaning	1		400	
EDTA	RO Cleaning	1		1307	
Sulfuric Acid	Neutralisation	1		400	
	MF Cleaning	1		400	
Polymer	Centrifuge	2	227	720	1650
Lime	Product Water	2	284	1556	2658

3 CONCLUSION

By necessity water recycling on a large scale is a reality in South East Queensland. The Luggage Point AWTP is just one of four large plants that have been designed and built to provide purified recycled water to industrial, agricultural and indirect potable reuse should the need arise in the future.

It is unlikely that cities in New Zealand will ever need to build recycling plants on this scale to satisfy water shortages. However as discharge consents become more stringent, and our concern for their effect on the environment grows, perhaps it is more likely that advanced treatment plants will become more common.

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