OPTIMISING EXTENDED AERATION AT NARRUNG ST STP WAGGA WAGGA

Jason Creed, *Water Reclamation Team Leader,* Wagga Wagga City Council
Chase McAlister, *Treatment Plant Operator, Wagga Wagga City Council*

Abstract

This project focuses on optimising the performance of an Extended Aeration Biological Nutrient Removal (BNR) plant using the Orbal process—an oxidation ditch configuration designed in the 1970- 1980 for efficient nitrogen removal and used extensively in China. The plant features a 7 ML Orbal basin with an average influent flow of 3 ML/day and is one of only two Orbal systems currently operating in Australia, making it a rare and valuable case study for the industry.

The Orbal system, known for its concentric channel layout and long retention times, provides stable sludge characteristics and process resilience. Achieving consistent biological nutrient removal under varying conditions requires careful control of aeration, internal recycles, and sludge age. Using a combination of process modelling, on-site monitoring, and collaborative input from both operators and operations support, several optimisation strategies are being implemented. These include:

- **Data Collection & Baseline Assessment:** Historical performance data were reviewed to identify trends, performance gaps, and seasonal impacts on nutrient removal.
- **Process Monitoring:** Real-time monitoring of dissolved oxygen (DO), oxidation-reduction potential (ORP), and mixed liquor characteristics was implemented to better understand zone-specific performance.
- **Aeration and Recycle Optimisation:** DO setpoints were refined, and internal recirculation rates were adjusted to improve nitrogen removal and minimise energy use.
- **Sludge Age Management:** Sludge wasting routines were revised to optimise microbial populations and to try and improve biological phosphorus uptake.
- **Operator-Operations Support Collaboration:** Routine reviews and feedback sessions were conducted to ensure practical viability and sustained optimisation outcomes.

This multi-pronged strategy enabled the legacy Orbal plant to evolve into a more efficient, BNR-optimised system without requiring major structural upgrades. With the appropriate processes in place the plant achieved more consistent nutrient removal performance and reduced energy use by up to 20%.

This study highlights how targeted process control and operator engagement can enhance the efficiency and reliability of complex BNR systems like the Orbal, offering practical guidance for similar facilities striving to meet tighter regulatory standards.

1.0 INTRODUCTION

The Narrung Street sewage treatment plant is located in Wagga Wagga NSW. The plant consists of two different processes combining at the tertiary stage for common discharge/reuse these are, the sequential batch reactors (SBR) and an extended aeration biological nutrient removal plant (Orbal) that is designed to treat in total 17.5 ML average dry weather flow per day.

The Continuous Extended Aeration Biological Nutrient Removal plant, also known as the Orbal process, is an oxidation ditch configuration with secondary clarifiers, that was designed in the 1970's for efficient nitrogen removal and is similar to a process that is used extensively in China.

The plant features a 7 ML Orbal basin, with a design flow of 7.3ML average dry weather flow per day and with a current average influent flow loading of 3 – 3.5 ML/day. It is said to be one of only two Orbal systems currently operating in Australia, making it a rare and valuable case study for the industry.

The Narrung Orbal Ditch consists of three (3) concentric concrete channels. The channels are identified as the centre (No.1) with four aeration shafts and 2 directional mixers, the inner (No.2) with 6 aeration shafts and the outer (No.3) with 10 aeration shafts and a total of 200 discs across the Orbal. The channels are 6 meters wide and 4 meters deep with a straight channel length of 22m.

From the centre of the Orbal, the mixed liquor (MLSS) enters a distribution box where it is split into two secondary clarifiers. The Clarifiers are 20m in diameter and 4m deep with flat floors utilising sludge box and scrapers suspended from the rotating bridge with a 1.2ML capacity each.

Biological Nutrient Removal (BNR) is a critical aspect of modern wastewater treatment, driven by increasingly stringent environmental regulations aimed at limiting nitrogen and phosphorus discharges into sensitive waterways. In conventional BNR systems, distinct anaerobic, anoxic, and aerobic zones are used to facilitate the sequential removal of phosphorus and nitrogen through microbial processes such as enhanced biological phosphorus removal (EBPR), nitrification, and denitrification.

The Orbal process is uniquely suited to BNR due to its concentric-channel configuration, which allows for the creation of distinct biological environments within a single reactor footprint. Through controlled aeration and internal recirculation, the system supports the growth of diverse microbial communities capable of removing nutrients efficiently. Its long sludge age also enhances nitrification stability, while the inherent flexibility of the system allows for real-time process adjustments in response to influent variability.

Despite its foundational strengths, the legacy Orbal system—commissioned in two stages in 1978 and 1982—was not originally designed with modern BNR optimisation strategies in mind. As such, the existing infrastructure required careful analysis and adaptation to meet current effluent targets and operational efficiency goals. This necessitated a detailed review of hydraulic performance, aeration efficiency, sludge age control, and carbon availability from trade waste and residential inflows.

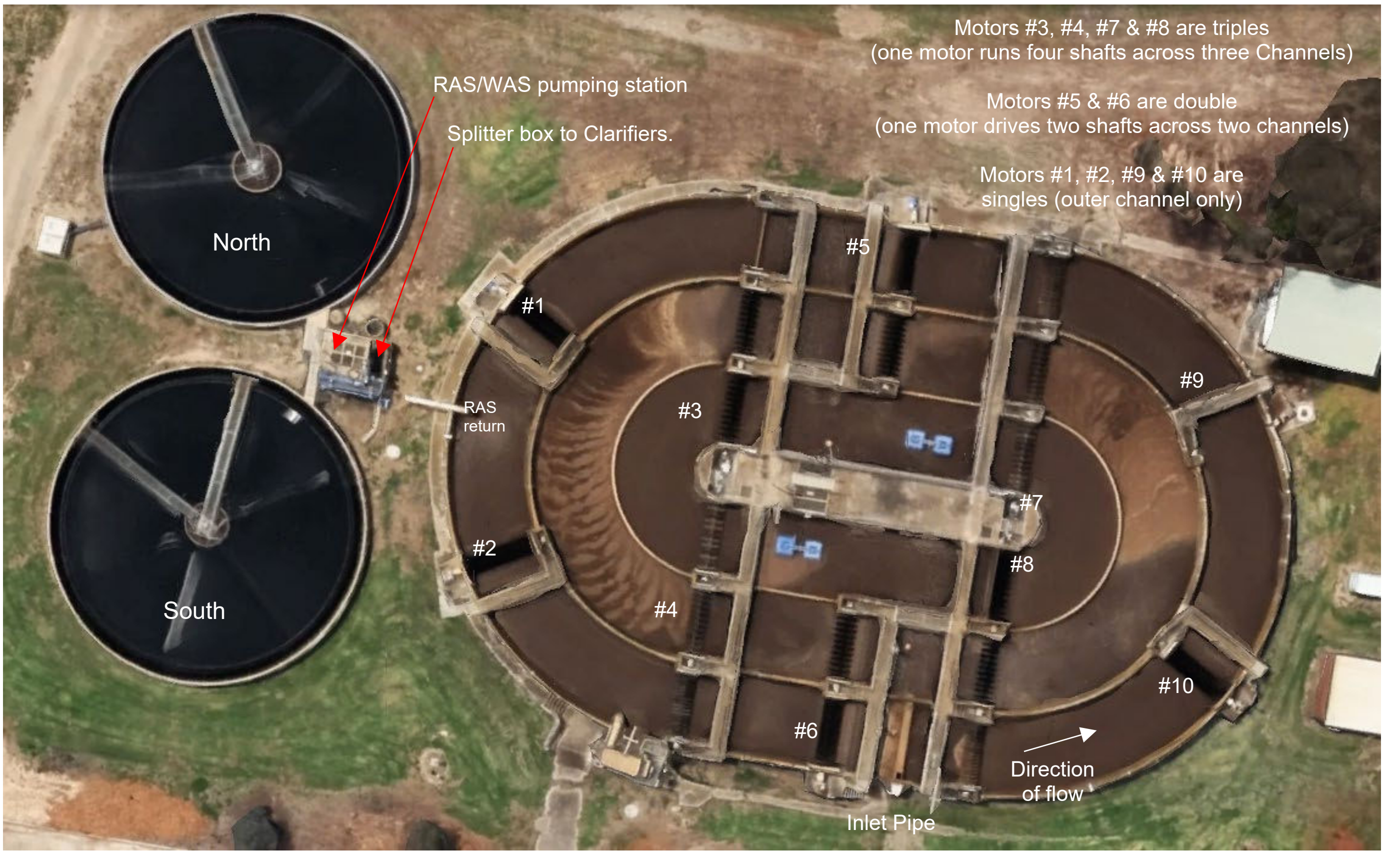

Figure 1 – Orbal Aeration Overview

Methodology:
The optimisation approach combined process modelling, historical data analysis and hands-on operational insights. The key steps included:

- **Data Collection & Baseline Assessment:** Historical performance data were reviewed to identify trends, performance gaps, and seasonal impacts on nutrient removal.
- **Process Monitoring:** Real-time monitoring of dissolved oxygen (DO), oxidation-reduction potential (ORP), and mixed liquor characteristics was implemented to better understand zone-specific performance.
- **Aeration and Recycle Optimisation:** DO setpoints were refined, and internal recirculation rates were adjusted to improve nitrogen removal and minimise energy use.
- **Sludge Age Management:** Sludge wasting routines were revised to optimise microbial populations and to try and improve biological phosphorus uptake.
- **Operator-Operations Support Collaboration:** Routine reviews and feedback sessions were conducted to ensure practical viability and sustained optimisation outcomes.

Results/Discussion:
What was the big changes made:

- Changes to the Aerations/mixing cycles to find a better balance of dissolved oxygen transfer and mixed liquor suspension throughout each channel, whilst still achieving the critical stages of the process, being anaerobic and aerobic.
- Two secondary clarifiers operating without compression zones or were adjusted to create a good balance between clarified effluent and the sludge blanket (compression zones). This was conducted to optimise the biomass separation for improving returned activated sludge (RAS) rates.
- Improved biological phosphorous removal along with nitrification and denitrification process and reduction in overall volume returned, while still maintaining the same biomass required for RAS rate.
- Changes in Influent have been one of the hardest things to control with data showing increasing variability in quality, this requires more investigation into the trade waste received and better control of trade waste operations.

1. Nutrient Removal Performance

Following the implementation of revised aeration control and internal recirculation strategies, total nitrogen (TN) removal improved, with effluent TN concentrations reducing to a more stable level during dry weather flow conditions. Total phosphorus (TP) levels also saw improved stability in the biological uptake, giving more control to meet our current discharge limits of 0.6mg/L. This was achieved without the addition of external carbon sources and reduced phosphorus precipitation, reducing Ferrous usage by approximately 20% and a reduction of Alum at the tertiary filters by approximately 35% and highlights the improved biological function of the system.

2. Aeration Efficiency and Energy Savings

One of the most significant gains came from improved dissolved oxygen (DO) management. Prior to this exercise DO was controlled by starting and stopping all Motors each hour based of the ammonia results from the previous day's grab sample. By mapping DO profiles across the three concentric channels and aligning aerator/shaft motor control with biological demand, the plant reduced the number of motors and time each shaft spent running and avoided over-aeration in low-demand zones. These changes led to a reduction in energy use associated with aeration, representing one of the most cost-effective outcomes of the optimisation process.

3. Sludge Stability and Process Resilience

With better control of sludge age and a more consistent solids retention time (SRT), the mixed liquor showed greater stability and improved settleability. Operators noted reduced instances of filamentous outbreaks and improved sludge volume index (SVI) values, contributing to a more predictable secondary clarifier performance. With a more predictable and consistent Return Activate sludge (RAS), typically at around one, to one and a half times MLSS returning from the clarifiers saw a reduction in overall pumped volume returning to the Orbal, this dropped from 9ML/day, to just 4ML/day whilst also decreasing the theoretical RAS flow from an unachievable rate of 8 times inflow to just 0.88 times inflow. Mechanical wear and power savings were also seen with a reduction from three pumps to typically one.

4. Operator Engagement and Practicality

A key success factor was the active involvement of operational staff throughout the optimisation process (Ongoing). Their on-the-ground observations and familiarity with the plant's behaviour proved vital in identifying subtle issues, validating data trends, and trialling process adjustments safely. This collaborative approach not only enhanced outcomes but also helped build internal capability for ongoing optimisation.

5. Limitations and Opportunities

While the existing infrastructure supported significant improvements, certain limitations remain. The system's original design lacks inbuilt online monitoring points for key parameters such as nitrate and orthophosphate, limiting the ability to automate feedback loops. Future opportunities should include upgrading instrumentation, integrating SCADA-based control strategies, Identified the need for greater flexibility in set points and independent operation of each zone.

What was the outcome of these changes:

- Change to aeration meant reduced run times on motors – saving in maintenance, power, replacements of equipment
- Refined dissolved oxygen transferred around the channels rather then just having everything on, achieving better nutrient removal
- Achieved phosphorous reduction through biological process which resulted in a reduction in chemical usage
- Created a better-quality effluent with less pin flock from the clarifiers which in turn reduced chemical usage in the tertiary filters and number of backwashes.
- Created greater knowledge and understanding of the BNR process across the operations team working collaborative together.

6. Challenges faced along the way

- Changing operational thoughts from doing what is the norm to trying new approaches, created some anxiety with unknow operational changes occurring.
- Making too many changes at once and not being able to determine what went wrong because too many changes were made at once.
- Making too big a change – for example – the quality was good for period 10 days but mixed liquor was higher then desired. Reduced too rapidly, causing a rise in nitrates, phosphorous along with changes to RAS/Was cycles.
- Operational patience to let the change take place and wait for an outcome
- Over reaction to today's results before giving the changes time to even out and making sure tomorrows are on the right path – can take days to get an outcome.
- inconsistencies in sewage/trade waste inflows where and are still an ongoing issue, highlighting the need for better regulation across the network.