Technical Memorandum.

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From	Louis Ortenzio, Sylvia Chia
Subject	Porirua WWTP Effluent Ammonia Investigation
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1 Introduction

The Porirua Wastewater Treatment Plant (WWTP) is currently exceeding its effluent total ammoniacal nitrogen (TAN) concentrations. It has had several effluent TAN exceedances since May 2024 such that a Monitoring and Technology Review Report must be commissioned as defined in Condition 35 of the Coastal Discharge Permit consent conditions WGN200229 [36816]. Lutra is commissioned by Wellington Water (WWL) to perform an investigation on the ammonia effluent at the Porirua WWTP.

1.1 Objectives

This report has the following objectives:

- Conduct a compliance assessment on Porirua WWTP.
- Provide an operational review on the lack of nitrification in the oxidation ditch.
- Provide recommendations including operational adjustments and available technologies (if necessary) to re-establish nitrification.

1.2 Reference documents

This document should be read in conjunction with the following documents:

- Porirua WWTP Ammonia Nitrogen Removal Memo (Veolia, 2024)
- Porirua WWTP Influent Characterization Sampling Campaign Results (Stantec, 2022)
- Porirua Wastewater Treatment Plant Coastal Discharge Permit consent conditions WGN200229 [36816] (GWRC, 2024)
- Nutrient Control Design Manual (EPA, 2010)
- Dimensioning of Single-Stage Activated Sludge Plant (ATV-DVWK, 2000)

2 Compliance Assessment

Table 1 shows the Resource Consent WGN200229 [36816] for the Porirua WWTP, which commenced in August 2024, defining new conditions regarding Total Ammonia Nitrogen (TAN) monitoring and its effluent limits. The related conditions are as follows:

Table 1 – Porirua WWTP's Resource Consent Conditions (GWRC, 2024)

Consent Conditions	Descriptions
9A	The consent holder shall on at least one occasion each week, on a normal working day, obtain a representative 24-hour flow-proportioned composite sample of the wastewater from the location identified in accordance with condition 6. This sample shall be analysed for Total Ammonia Nitrogen.
30B	If the annual process model re-run predicts that the concentration of total ammonia nitrogen in the treated wastewater will exceed the threshold in condition 33 (b) within 5 years, then within 3 years the consent holder shall complete a project to design and commit funding for a WWTP upgrade or improvement intended to maintain the concentration of total ammonia nitrogen within the threshold in condition 33 (b). Notes: 1. For the purpose of this condition, 'design' means designed to a level of detail that would enable construction or implementation without the need for further design to be undertaken. 2. The option designed under condition 30B will be considered as part of the Monitoring and Technology Review process under condition 33 (b), if such a review is triggered by the concentration of total ammonia nitrogen in wastewater samples.
33	The monitoring and technology review and report required under conditions 31 and 32 shall be completed and submitted to the Manager for certification that it complies with the requirements of conditions 31 and 32: a. Within 12 calendar months of the ecological survey reports, required under condition 29, being submitted to the Manager; and b. Within 9 calendar months of the concentration of total ammonia nitrogen exceeding 6 g/m^3 in more than 5 of 26 consecutive wastewater samples required to be collected and analysed under condition 9A.
35	Notwithstanding the scope of the review set out in condition 31, if the monitoring and technology review is undertaken in response to the concentration of total ammonia nitrogen in the treated wastewater, then it shall be limited to the consideration of the adverse effects of the total ammonia nitrogen and the technological options or other methods which may be available to reduce those adverse effects.

A 24-hour flow-proportioned composite sample of the final effluent at Porirua WWTP has been collected weekly and analysed for TAN by a third-party contractual laboratory (see Figure 1). The data trend shows a significant increase in TAN concentrations that occurred in May 2024, exceeding the threshold stated in Condition 33(b). This condition specifies that the concentration of TAN should not exceed 6 g/m³ in more than 5 out of 25 consecutive wastewater samples required to be collected and analysed under Condition 9A.

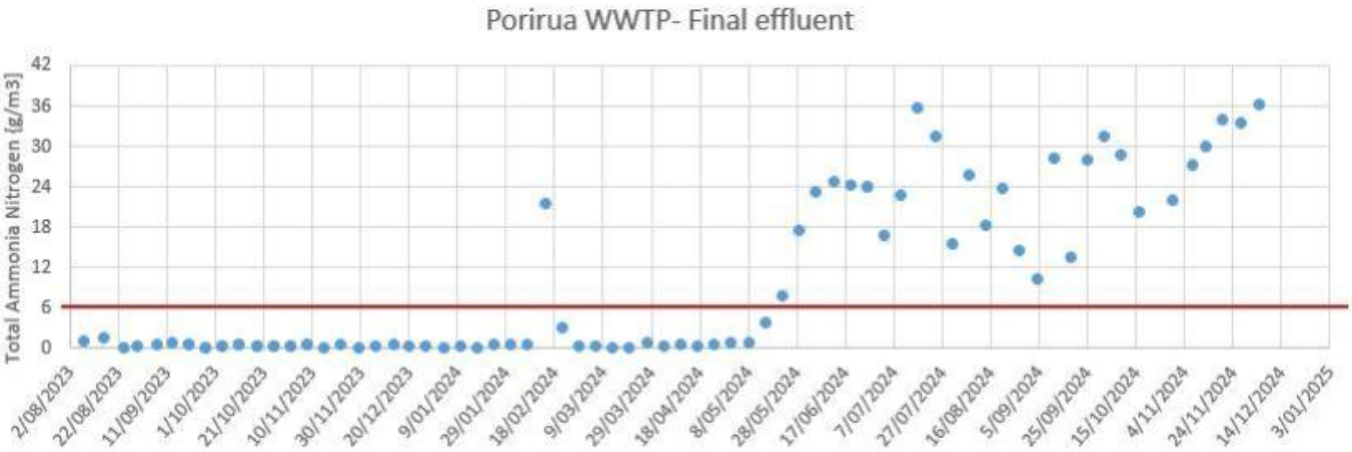

Figure 1 – Effluent TAN Concentrations at Porirua WWTP from August 2023 to December 2024 (Veolia, 2024)

The WWTP influent is analysed monthly for TAN (see Figure 2). As part of the investigation, the inlet TAN concentrations were examined. Data collected since January 2023 indicate an average TAN concentration of 32 g/m³. No notable increase in inlet concentrations was observed since May 2024 that could explain the rise in effluent concentrations.

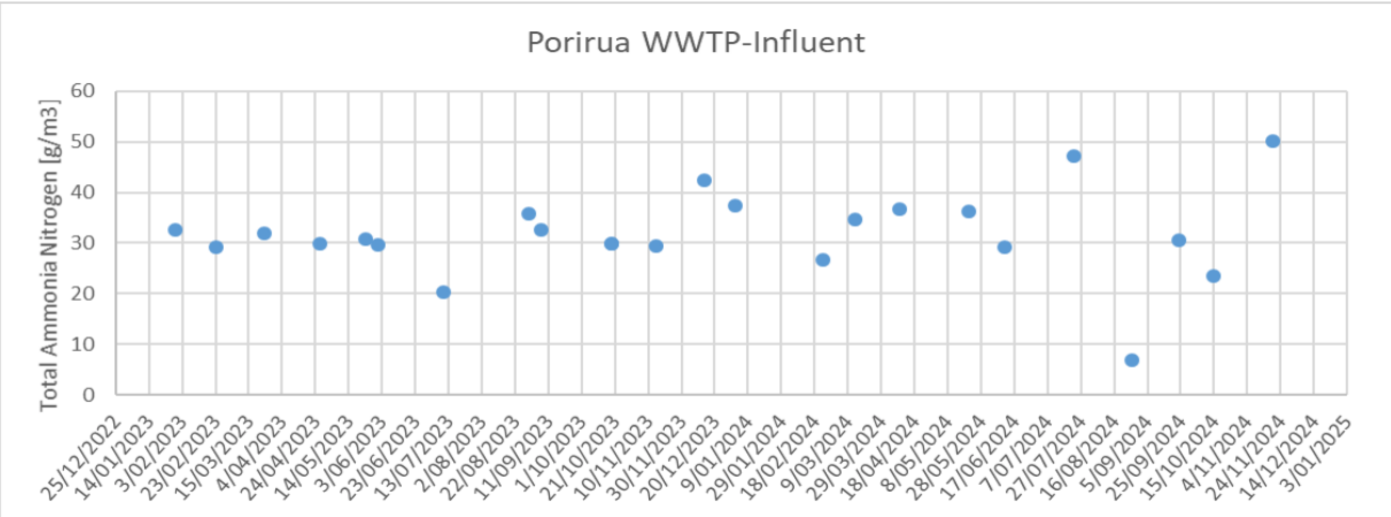

Figure 2 – Influent TAN Concentrations at Porirua WWTP from December 2022 to December 2024 (Veolia, 2024)

3 Operational Review

3.1 Timeline

Table 2 outlines the changes made to the process and state of effluent TAN exceeding effluent limits.

Table 2 – Timeline of Process Changes and TAN Exceeding Effluent Limits

Timeline	Process Changes
February 2024	Diffuser cleaning.
28th May 2024	Ammonia concentrations exceeded effluent limits.
September/October 2024	Thickener optimisation. The thickener optimisation allowed for more efficient dewatering by providing a higher and more consistent thickened waste activated sludge (TWAS) during dewatering by changing the wasting schedule and method.
Mid December 2024	DO setpoint increase. DO control currently looks at the C and D dissolved oxygen (DO) probes, averages them together, and compares to an operator adjustable setpoint.

3.2 Oxidation Ditch Layout

Figure 3 provides a plan view of the oxidation ditch, highlighting the DO probe locations. Aeration control in the oxidation ditch is managed by averaging the DO readings from probes C and D to maintain a specified setpoint which sits around 1.2 to 1.4 mg/L of DO across 2024. Probe A is located just upstream of any aeration.

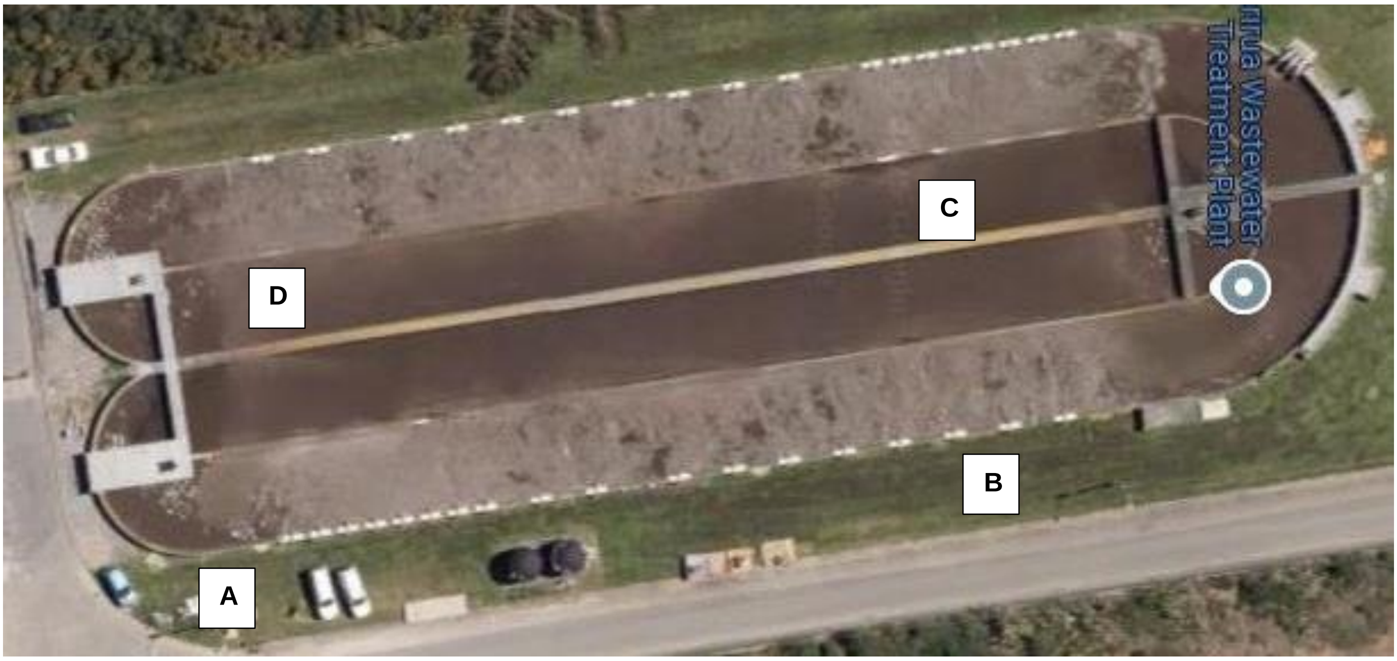

Figure 3 – Porirua WWTP Oxidation Ditch with Indicative Probes Locations

3.3 Alkalinity and pH

Table 3 presents data from a sampling campaign conducted by Stantec from 23rd of March to 5th of April in 2022. There is no recorded data for MLSS and temperature for this campaign.

Table 3 – Mean Alkalinity and pH of Porirua WWTP from March 2022 to April 2022 (Stantec, 2022)

Parameter	Unit	Influent	Oxidation Ditch	Final Effluent
Alkalinity	mg $CaCO_3$/L	207	104	87
pH	-	7.1	-	-
TKN	mg/L	57.2	-	4.1
TAN	mg/L	35.6	-	1.26
NO_3-N	mg/L	<0.005	-	1.41

The results of the sampling campaign indicate the following:

- The Porirua WWTP was fully nitrifying and providing almost complete denitrification.
- Sufficient influent alkalinity is available to support significant nitrification. Full nitrification is achievable if there is adequate alkalinity credit gained through denitrification.
- pH is such that nitrification should not be inhibited.

3.4 Nutrient Concentrations

To achieve effective biological wastewater treatment, a minimum BOD, nitrogen, and phosphorus ratio of 100:5:1 should be maintained. The results from Veolia's sampling program conducted up to 2024 shows that the nitrogen portion of this ratio has significantly increased compared to COD and phosphorus throughout the years (see Figure 4).

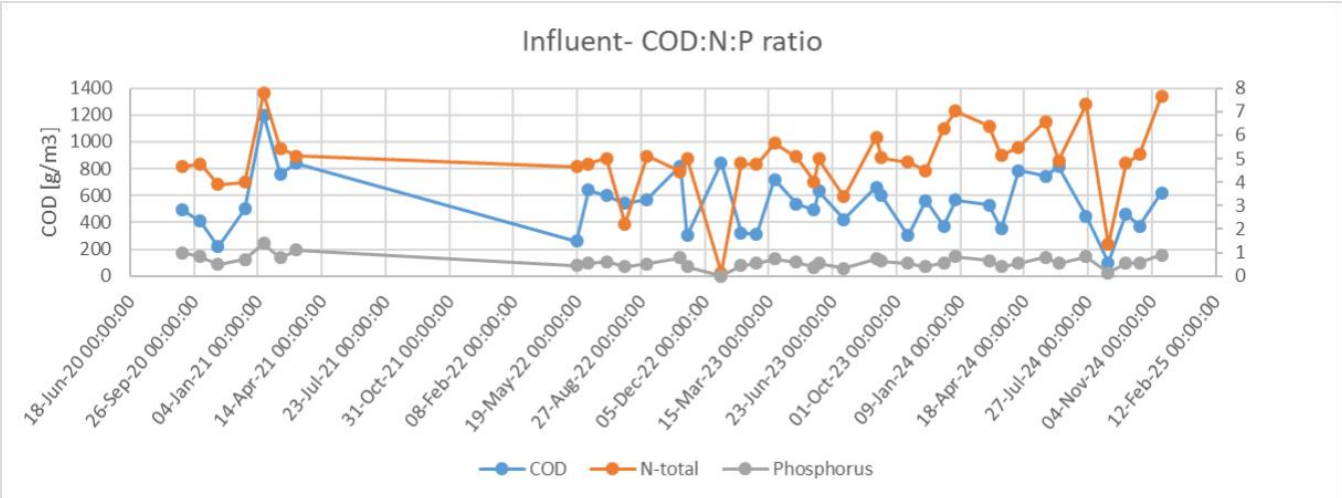

Figure 4 – Trends for COD, Total Nitrogen and Phosphorus Concentrations from June 2020 to December 2024 (Veolia, 2024)

Data from Stantec in 2022 (Table 4) indicates that the BOD: Nitrogen: Phosphorus ratio was approximately 100:23:2 in 2022. The proportion of N and P are above 5 and 1 respectively, which indicates nutrient limitation is not an issue for the Porirua WWTP to achieve BOD removal and nitrification.

Table 4 – Mean COD, $CBOD_5$, Nitrogen and Phosphorus Concentrations from March 2022 to April 2022 (Stantec, 2022)

Parameter	Unit	Influent	Ratio
COD	mg/L	644	-
$CBOD_5$	mg/L	248	100
TKN	mg/L	57.2	23
TP	mg/L	5.87	2

3.5 Dissolved Oxygen (DO) Concentrations and Profile

Figure 5 shows the oxidation ditch DO concentrations extracted from Infrastructure Data (ID) in the past 12 months. The average DO readings for Zones A, B, C, and D are 0.33, 0.85, 1.4, and 1.2 mg/L, respectively.

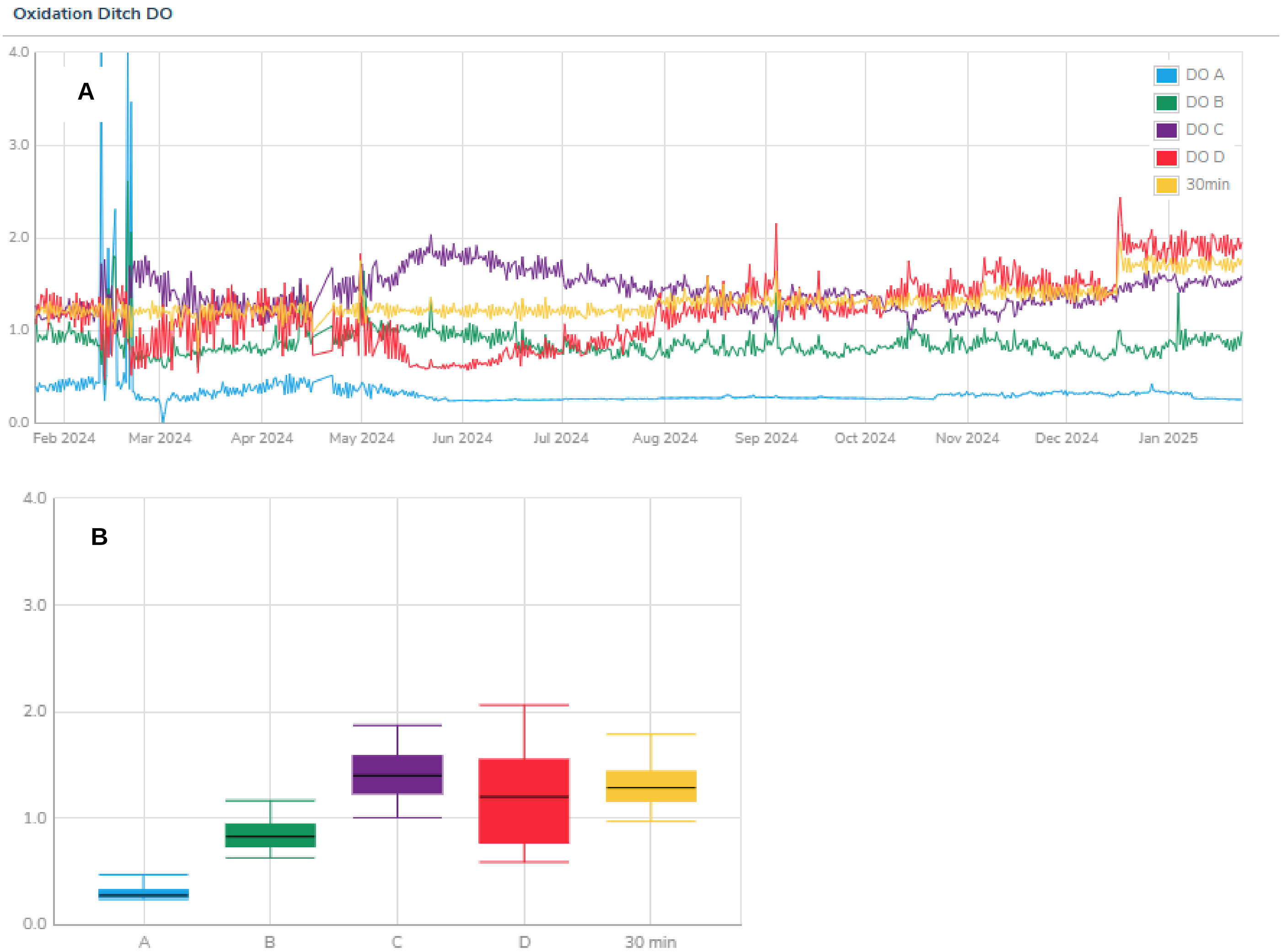

Figure 5 – A: Line Graph of DO Concentrations from ID; B: Box Plot of DO Concentrations from ID (February 2024 to January 2025)

A DO profile reading was conducted by WWL on the 21st of January 2025. The DO measurements taken from the outer pass of the oxidation ditch at 12-meter intervals are shown in Figure 6. The data indicates that less than half of the oxidation ditch aerobic volume meets the operating DO range of >0.5 mg/L and remains aerobic.

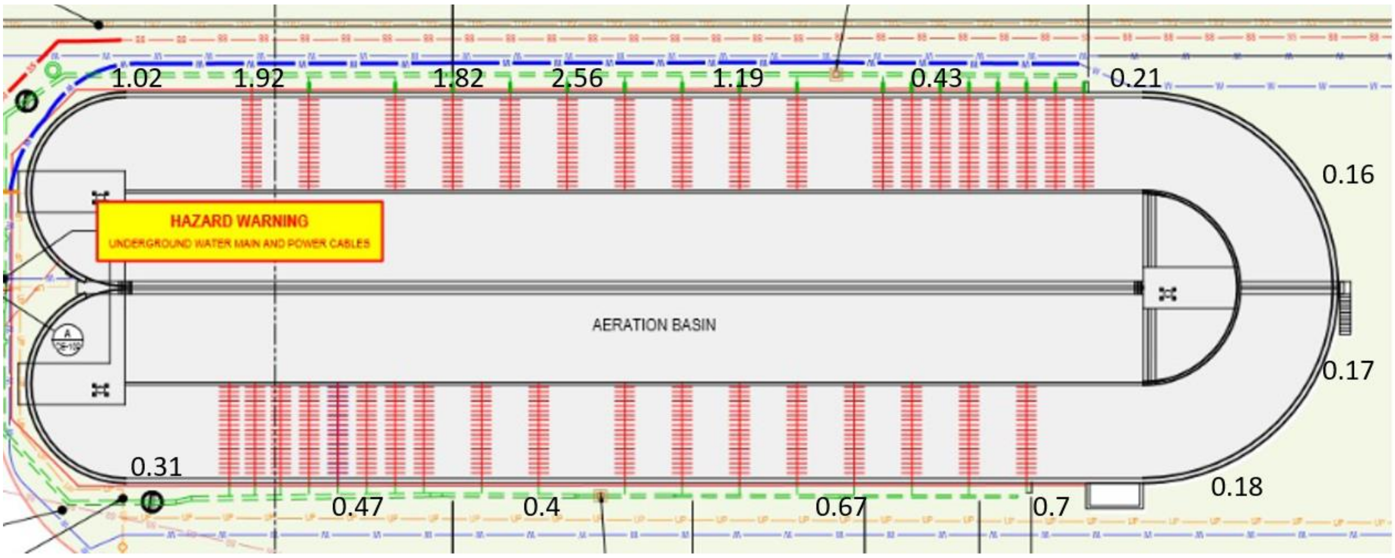

Figure 6 – DO Profile along the Oxidation Ditch on the 21st of January 2025 (WWL, 2025)

3.6 Solids Retention Time (SRT) and Aerobic SRT

SRT is an operational parameter used to quantify the retention time for biomass particles. Aerobic SRT is the amount of time that biomass spends in the aerobic phase before being wasted from the system. Aerobic SRT is particularly important for nitrification as nitrifiers have a relatively slower growth rate compared to some bacteria and microorganisms. Because of this slower growth rate, nitrification systems are typically designed and operated with an aerobic SRT with an applied safety factor to ensure stable and sustainable nitrification under steady state and potentially adverse conditions such as inhibiting chemicals, diurnal pollutant peak loads, wet weather flows, etc.

Approximately 55-60% of the oxidation ditch volume and SRT has the potential to be aerobic based on diffuser coverage. However, the DO profile in Figure 6 indicates that less than 50% of the intended oxidation ditch aerobic volume can currently be considered aerobic (DO >0.5 mg/L).

To determine the SRT, thickened WAS is used instead of regular WAS, as it represents the solids being removed from the activated sludge system. WAS can be recycled back to the oxidation ditch via the overflow at times when dewatering is not being executed. The graph below illustrates the total SRT and aerobic SRT. A sensitivity analysis evaluates the impact of aerobic zones on the aerobic SRT. Aerobic SRT (4/4) represents the aerobic SRT of the oxidation assuming

55% of the total oxidation ditch volume is aerobic (diffuser coverage and effluent bend). As the number of aerobic zones decrease, the aerobic SRT also decreases.

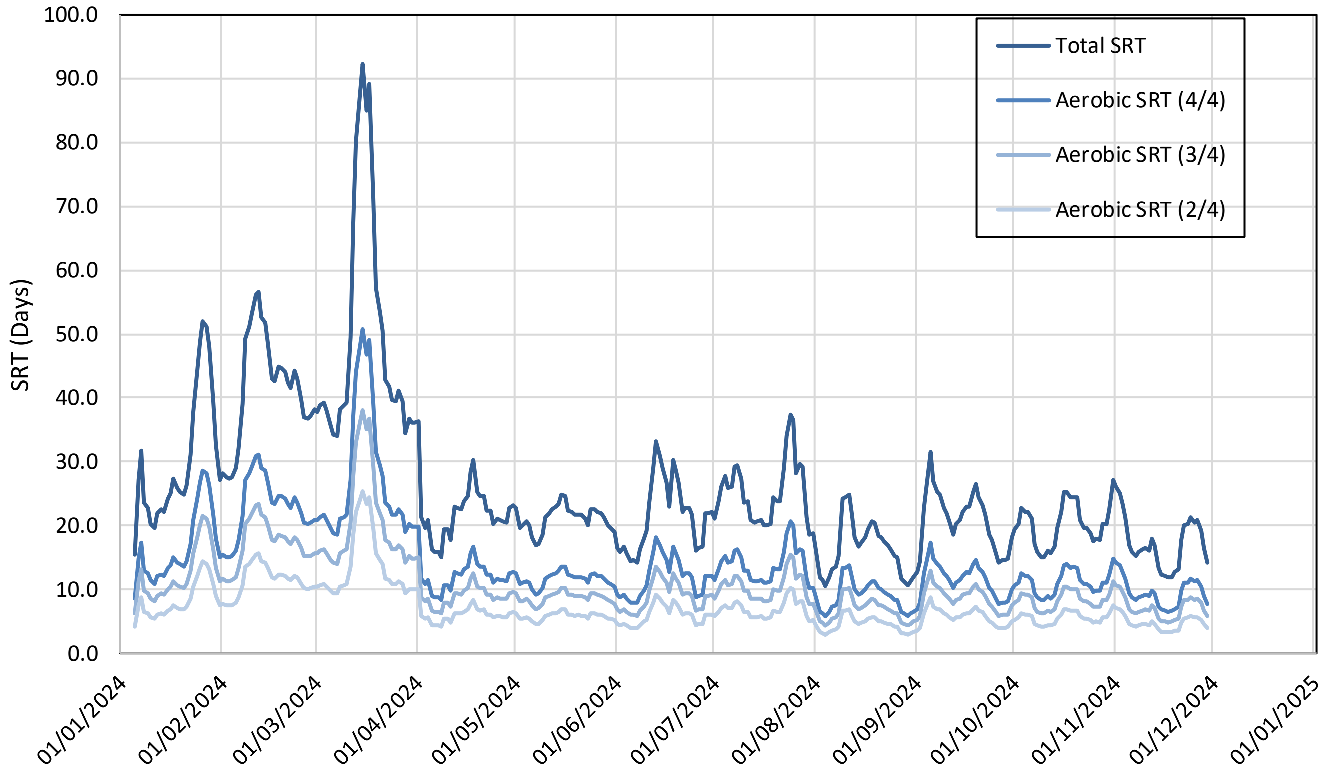

Figure 7 – SRT of Porirua WWTP Calculated by Lutra (January 2024 to December 2024)

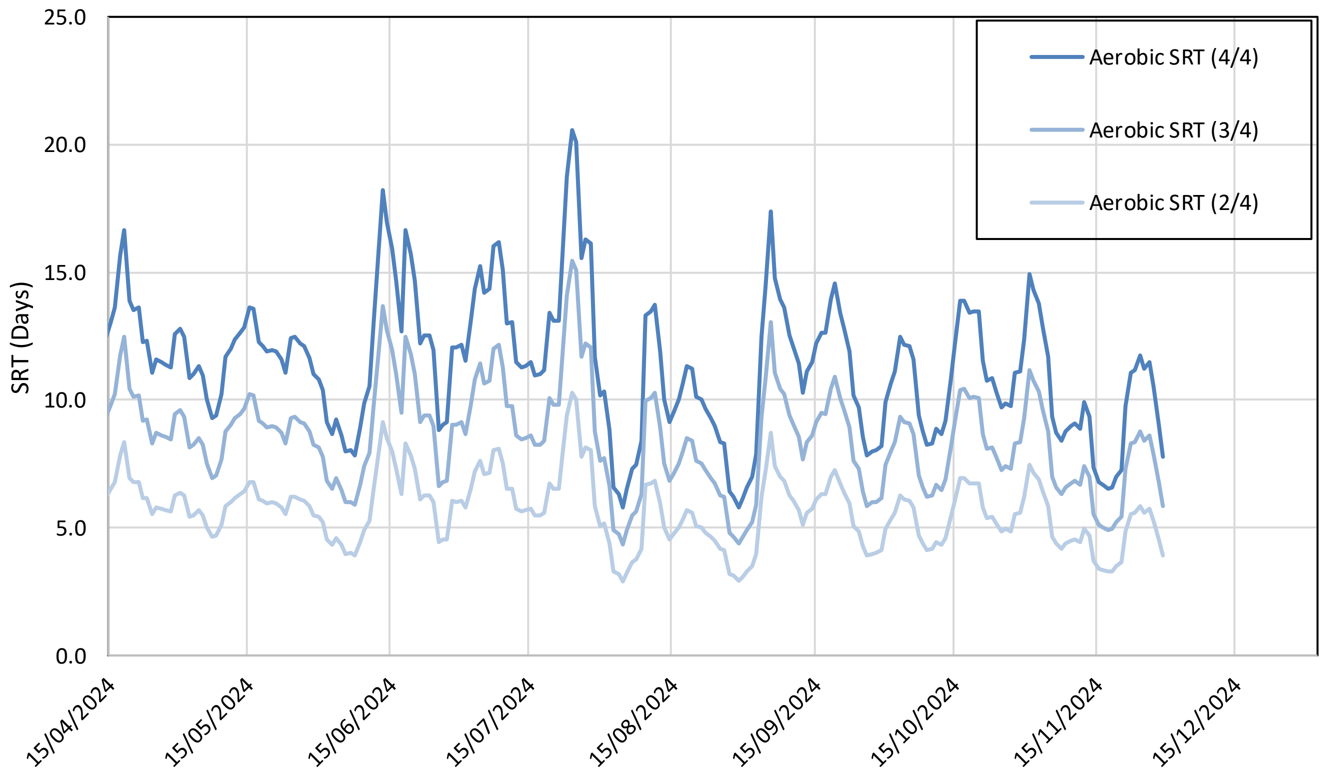

Figure 8 – Aerobic SRT of Porirua WWTP (April 2024 to December 2024)

4 Analysis

4.1 Estimated Required Aerobic SRT

The target operating range for aerobic SRT is determined using two methods: the Monod Kinetics approach and the ATV 2000 method to support nitrification while mitigating the potential for washout, overloads, etc

4.1.1 Aerobic SRT calculated via Monod Kinetics

The following Monod Kinetics equations are adapted from the Nutrient Control Design Manual (EPA, 2010). Table 5 shows the calculated SRT for the system assuming several constants and temperature correction factors.

$$\mu_{AOB} = \mu_{max,AOB}\left[\frac{S_{NH}}{S_{NH}+K_{NH}}\right]\left[\frac{S_o}{S_o+K_{o,AOB}}\right]-b_{AOB} \qquad \text{Eq. 4-6}$$

$$\mu_{NOB} = \mu_{max,NOB}\left[\frac{S_{NO}}{S_{NO}+K_{NO}}\right]\left[\frac{S_o}{S_o+K_{o,NOB}}\right]-b_{NOB} \qquad \text{Eq. 4-7}$$

Where:

μ_{AOB} = Specific growth rate of ammonia-oxidizing bacteria, g VSS/g VSS – d
μ_{NOB} = Specific growth rate of nitrite-oxidizing bacteria, g VSS/g VSS – d
$\mu_{MAX,AOB}$ = Maximum specific growth rate of ammonia-oxidizing bacteria, g VSS/g VSS - d
$\mu_{MAX,NOB}$ = Maximum specific growth rate of nitrite-oxidizing bacteria, g VSS/g VSS – d
bAOB = Specific endogenous decay rate of ammonia-oxidizing bacteria, g VSS lost/g VSS – d
bNOB = Specific endogenous decay rate of ammonia-oxidizing bacteria, g VSS lost/g VSS – d
S_{NH} = NH^+_4 – N concentration, mg/L
K_{NH} = Half-velocity coefficient for NH^+_4 – N, mg/L
S_o = DO concentration, mg/L
$K_{o,AOB}$ = Half – velocity coefficient for DO for AOB, mg/L
S_{NO} = NO^-_2 – N concentration, mg/L
K_{NO} = Half – velocity coefficiency for NO^-_2 – N, mg/L
$K_{o,NOB}$ = Half – velocity coefficient for DO for NOB, mg/L

Figure 9 – Monod Kinetics Equation (EPA, 2010)

Table 5 – Calculating Aerobic SRT using Monod Equations

Parameter	**Unit**	**T= 15 ℃, DO = 1.5**	**T= 15 ℃, DO = 1.0**	**T= 20 ℃, DO = 1.5**
Max Nitrifier Growth Rate, μ_{max}	g/g/d	0.9	0.9	0.9
Half saturation Constant, K_n	mg/L	0.3	0.3	0.3
Half saturation Constant, K_{DO}	mg/L	1	1	1
Decay constant, k_d	per day	0.17	0.17	0.17
Safety Factor		2.0	2.0	2.0
Design Effluent NH_4	mg/L	1	1	1
Design Operating DO	mg/L	1.5	1.0	1.5
Temperature	℃	15	15	20
Max growth rate at temperature	per day	0.90	0.90	1.47
Net growth rate	per day	0.30	0.221	0.60
Minimum aerobic SRT	days	**3.3**	**4.5**	**1.7**
Design aerobic SRT	days	**6.7**	**9.0**	**3.4**

4.1.2 Aerobic SRT calculated via ATV 2000

The following Monod Kinetics equations are adapted from the Dimensioning of Single-Stage Activated Sludge Plant (ATV-DVWK, 2000). This version of the ATV method is more simplistic and takes into account fewer parameters. It assumes sufficient DO and full nitrification. Table 6 shows the calculated aerobic SRT for the system using this approach.

$$t_{SS,aerob,dim} = SF \cdot 3.4 \cdot 1.103^{(15-T)} \quad [d] \qquad (5\text{-}1)$$

Figure 10 – Equation for Calculating SRT via ATV's Approach (ATV-DVWK, 2000)

Table 6 – Calculating SRT using ATV Approach

Parameter	Unit	Value at 15℃	Value at 20℃
Max Nitrifier Growth Rate, μ_{max}	g/g/d	2.13	2.13
Safety factor		2.32	2.32
Low temperature	℃	15	20
Design sludge age	days	**4.95**	**3.03**

4.2 Porirua WWTP and Aerobic SRT

At a lower MLSS temperature of 15°C, the ATV method requires an aerobic SRT of 5 days, while the Monod kinetics method suggests a value closer to 7 days. Temperature has a significant influence on these requirements. In Porirua WWTP, the actual aerobic SRT has dropped to as low as 3.5 to 5 days when only half of the aerated zones are aerobic (see Figure 8). This value falls short of the required aerobic SRT estimated with the ATV and Monod kinetics methods at 15°C to sustain complete nitrification. The likelihood of low aerobic SRT resulting in nitrification loss is considered high at the Porirua WWTP.

It should be noted that warmer MLSS temperatures may temporarily restore nitrification as the nitrifier growth rate decreases significantly, the aerobic SRT will likely be insufficient to support consistent year-round nitrification.

A calculation has been made to determine the MLSS concentration required to meet a total SRT of 14 days.

- The average TWAS amount over the last three months (September to November 2024) is approximately 227 m^3/d, while the average total solids concentration is around 22,000 mg/L.
- For a 19,150 m^3 oxidation ditch, the required MLSS concentration is approximately 3,650 mg/L.
- This value is slightly higher than the MLSS concentration of around 3,500 mg/L or less, as advised by WWL, to prevent sludge carryover at peak flows due to suboptimal sludge settling. However, the sludge is currently settling well, suggesting that the plant may be able to sustain a higher MLSS concentration.

5 Recommendations

Lutra have the following recommendations based on this review:

- Target aerobic conditions across the oxidation ditch aerated zones and effluent bend and maintain a winter aerobic SRT of 7 days. The aerobic SRT can be reduced at higher MLSS temperatures. The following process is recommended in order:
    - Prioritize increasing DO in Zones A and B, with potential increases in Zone C as well. It is recommended that aeration drop leg positions be reviewed to try and shift airflow from D to other zones. Following this adjustment, consider increasing the DO setpoint for C and D. Adjustments to airflow distribution must be confirmed with visual inspection and DO profiling.
    - If DO concentration adjustments are insufficient to re-establish nitrification, consider slightly increasing the total SRT to enhance the aerobic SRT. A state point analysis should be considered depending on operating MLSS concentration and settling quality.
- Incorporate monthly influent monitoring for TKN, alkalinity, and pH along with the other parameters.
- Incorporate monthly effluent monitoring for alkalinity and pH along with the other parameters.

6 References

ATV-DVWK. (2000). *Dimensioning of Single-Stage Activated Sludge.*

EPA. (2010). *Nutreint Control Design Manual.*

GWRC. (2024). *Porirua Wastewater Treatment Plant Coastal Discharge Permit consent conditions WGN200229 [36816].*

Stantec. (2022). *Porirua WWTP Influent Characterisation Sampling Campaign.*

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