Central Hawkes Bay District Council

Waipukurau & Waipawa Wastewater Treatment Plant Review

The Wastewater Specialists

Optimising your assets

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November 2017

FINAL

The Wastewater Specialists

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Executive Summary

Both the Waipukurau and Waipawa wastewater treatment plants (WwTPs) are single waste stabilisation ponds (WSPs), both of which were upgraded by Waterclean Technologies Ltd (Waterclean) between 2013 and 2015. The Waterclean upgrades divided each of the existing WSPs into three sections; a facultative pond, a nitrification zone, and a floating wetland zone. Tertiary treatment processes were also installed as part of the upgrades, including lamella clarifiers, sand filters, and UV disinfection. Despite these upgrades, neither the Waipukurau nor Waipawa WwTPs have achieved full resource consent compliance, in particular for ammonia. To achieve resource consent compliance, reliable, year-round nitrification is required to meet the median and 90-percentile ammonia resource consent conditions of 6 and 10 mg/L respectively.

An anaerobic pond and storm flow buffer facultative pond (SFBFP) were installed at the Waipukurau WwTP to pre-treat the raw wastewater prior to the modified WSP. These additional ponds were commissioned in May 2017, and resulted in the generation of significant quantities of hydrogen sulphide (H_2S) through the anaerobic pond.

The current populations of Waipukurau and Waipawa are approximately 4,000 and 2,000 respectively. CHBDC is expecting significant population growth to occur, with the projected 2048 populations being 5,500 and 2,700 for the two respective towns. In addition to municipal wastewater, both the Waipukurau and Waipawa WwTPs receive significant industrial wastewater loads. When taking into consideration industrial discharges, the current population equivalent (p.e.) wastewater loads treated by the Waipukurau and Waipawa WwTPs are approximately 11,000 and 3,750 respectively. This would increase further if each of the industries discharged the amount of wastewater flow and load permitted in their current trade waste agreements.

Significant stormwater inflow and infiltration (I&I) into the wastewater reticulation occurs in both towns. Based on pond discharge volumes, the wet weather peaking factors are approximately 8:1 for Waipukurau and 11:1 for Waipawa. Even allowing for skewing of the data due to rain falling directly onto the ponds, these peaking factors are considered to be very high. Stormwater I&I reduces the hydraulic retention time (HRT) through both WSP-based treatment plants, and a long HRT is required to achieve ammonia removal through modified WSPs. This stormwater I&I also results in peak flows exceeding the capacity of the tertiary treatment processes at both the Waipukurau and Waipawa WwTPs, resulting in partial bypass of effluent from the modified WSPs to discharge during significant wet weather events.

The combination of significant industrial wastewater loads, short HRT, cold pond temperatures in winter and high BOD concentrations entering the nitrification zone mean it is unlikely that a modified WSP would ever consistently achieve <6 mg/L ammonia at Waipukurau without much larger ponds.

The average HRT through the Waipawa WSP is longer than at Waipukurau, and industrial loads are not as significant. This has allowed the Waipawa WwTP to perform better than Waipukurau, although it still has not provided the required ammonia removal in winter. This is likely to be due

to the HRT being insufficient at winter pond temperatures, despite the additional treatment capacity theoretically provided by the Waterclean upgrade.

Table 1 and Table 2 summarise the likely ability of the existing Waipukurau and Waipawa WwTPs to achieve compliance with current resource consent conditions.

Table 1: Can the existing Waipukurau WwTP achieve Resource Consent Compliance?

Parameter	Current Flow & Load[(1)]	Future Flow & Load[(1)]
Flow, m^3/d	Marginal	Marginal
$cBOD_5$, mg/L	Yes	Yes
TSS, mg/L	Yes	Yes
Ammonia, mg/L	No	No
Soluble Reactive Phosphorous (SRP), mg/L	Yes	Yes
E. coli, cfu/100mL	Yes	Yes
pH	Yes	Yes

Table 2: Can the existing Waipawa WwTP achieve Resource Consent Compliance?

Parameter	Current Flow & Load[(1)]	Future Flow & Load[(1)]
Flow, m^3/d	Marginal	Marginal
$cBOD_5$, mg/L	Yes	Yes
TSS, mg/L	Yes	Yes
Ammonia, mg/L	No	No
SRP, mg/L	Yes	Yes
E. coli, cfu/100mL	Marginal	Marginal
pH	Yes	Yes

To reliably and consistently meet the conditions of the existing resource consents, we recommend that wastewater from both Waipukurau and Waipawa should be treated using activated sludge (AS)-based technology, either at individual or a combined WwTP. Rough order cost estimates for AS-based WwTP for Waipukurau and Waipawa indicate the cost would be between $11.9 M and $20.2 M.

[1] Providing additional lamella, sand filter and UV capacity is installed to effectively treat the PWWF, or stormwater I&I is significantly reduced so peak flows are within the hydraulic capacity of these tertiary treatment processes

While further WSP-based processes, and/or other enhancements, could be added to the Waipawa WwTP, further modifications would come with a higher risk of failure and would still likely cost in excess of $1 M.

On the basis of this review, we recommend:

- Undertaking further investigations to identify the most cost-effective option to treat wastewater from both Waipukurau and Waipawa using activated sludge-based technology.
- Optimising the existing Waipukurau WwTP, with the most important modifications being:
  a) addition of more mechanical aeration in the SFBFP.
  b) improving the performance of the lamella tube settlers by optimising the recently-added polymer dosing.
- Optimising the existing Waipawa WwTP by:
  a) improving the performance of the lamella clarifier, potentially through the addition of polymer after coagulation.
  b) desludging the pond, if necessary and if possible, noting it may not be possible to remove sludge from under the BAS and floating wetlands.
- Engaging with industries regarding:
  a) the future of the Waipukurau and Waipawa WwTPs.
  b) the likely cause(s) of excessive foaming at the Waipukurau WwTP.
  c) the potential impact of specific Trade Waste discharges on each WwTP.
  d) likely future changes to the discharge activities or operations undertaken on each site to gain an understanding of likely future capacity required to treat trade wastes.
- Reviewing volumes and characteristics of landfill leachate discharged into the Waipawa WwTP, and performance of other WwTPs, to determine whether other WwTPs could more effectively treat some or all of this leachate load.
- Reviewing maintenance schedules for critical items such as the UV disinfection systems.
- Reviewing raw wastewater and trade waste sampling locations and methodologies to ensure that representative samples are being collected.

1 Introduction

The Waipukurau and Waipawa wastewater treatment plants (WwTPs) are not currently meeting resource consent conditions, in particular the requirements for ammonia. To achieve resource consent compliance, reliable and consistent ammonia removal down to <6 mg/L is required at both plants.

Both the Waipukurau and Waipawa WwTPs were upgraded by Waterclean Technologies Ltd (Waterclean) between 2013 and 2015, dividing each of the existing waste stabilisation ponds (WSPs) into three zones; a smaller facultative pond, a nitrification zone, and an area of floating wetlands. This did not provide reliable, year round ammonia removal through either WwTP. In 2017, an anaerobic pond and storm flow buffer facultative pond (SFBFP) were added before the existing, modified facultative pond at Waipukurau. Monitoring to date suggests this has not improved ammonia removal, and has also resulted in the generation of significant amounts of hydrogen sulphide (H_2S).

In September 2017, Council passed the following resolution:

> *THAT a report on the appropriateness of the Waipukurau and Waipawa wastewater treatment systems and their ability to meet current resource consent requirements is presented to the Finance and Planning Committee by the end of November.*
>
> *The scope of the report should include:*
>
> - *ALL resource consent requirements for both systems,*
> - *Capacity to deal with current residential and trade-waste demands,*
> - *Capacity to deal with projected growth requirements under the draft Urban Growth Strategy (with reference to the economic projections in the draft LTP),*
> - *Outline of potential capital investment required to address issues identified.*
>
> *Results of the report will be used to inform the current Long Term Plan design and for working with potential external funders of capital works.*

Central Hawkes Bay District Council (CHBDC) has commissioned The Wastewater Specialists (twws) to undertake a review of the Waipukurau and Waipawa WwTPs to address the scope of work identified in the Council resolution. This report details the results of our investigations, and makes recommendations for both short-term and long-term improvements to the Waipukurau and Waipawa WwTPs.

2 Waipukurau WwTP

2.1 Resource Consent Conditions

The Waipukurau WwTP discharges treated effluent to the Tukituki River under Hawkes Bay Regional Council (HBRC) resource consent numbers DP030231Wc and DP030859Ac. The resource consent expires on 30 September 2030. The numerical conditions of the consent are outlined in Table 3.

Table 3: Waipukurau WwTP Consent Conditions

Parameter	Median	90-percentile
Flow, m^3/d	2,200	4,000
$cBOD_5$, mg/L	20	30
TSS, mg/L	30	50
Ammonia, mg/L	6	10
Soluble Reactive Phosphorous (SRP), mg/L	0.25	0.5
E. coli, cfu/100mL	800	4,000
pH	6.5 – 8.5	

2.2 Original Facultative Pond

The original facultative pond is approximately 25,000 m^2 in area (2.5 ha)[(2)]. With an average depth of 1.5 m, the volume of the facultative pond is approximately 37,500 m^3.

At a typical Ministry of Works (MoW, 1974) loading rate of 84 kg biochemical oxygen demand (BOD_5)/ha.d, the original facultative pond had a treatment capacity of approximately 210 kgBOD_5/d. More recent work by Duncan Mara suggests appropriate facultative pond loading rates are temperature dependent, and significantly higher loading rates are possible at temperatures of 20°C (Mara, 2003; Mara, 2008). However, CHBDC monitoring indicates the temperature of the Waipukurau pond drops to <10°C during winter, and at such cold temperatures the MoW loading rate remains appropriate.

It should be noted that the loading rates recommended by MoW and Mara are intended to provide BOD removal only, not nitrification (conversion of ammonia to nitrate). Therefore, even if the loading onto the facultative pond was within MoW and Mara guidelines, it would be unlikely that reliable year-round ammonia removal would be achieved.

2.3 Waterclean Upgrade

The Waterclean upgrade partitioned the original facultative pond into the following three areas:

[2] NIWA (2017)

- Pond Section 1; Facultative pond (1.13 ha), with 4 x 3kW of supplementary aeration.
- Pond Section 2; Nitrification zone (0.78 ha), using biological attachment surface (BAS) media, with a total of 8kW of supplementary aeration (2 x 3kW surface mounted Reliant Lagoon Master aerators, 1 x 2kW blower with diffused aeration).
- Pond Section 3; Floating wetland zone (0.55 ha).

The Waterclean proposal (Waterclean, 2012) groups these modified pond sections into two stages; Oxidation Pond with Aeration (facultative pond), and Floating Treatment Media (FTM) (BAS plus floating wetland).

In addition, lamella tube settlers and recirculating sand filters were installed after the modified pond to provide tertiary filtration, with ultra-violet (UV) disinfection after filtration. The design hydraulic capacity of each of these three treatment processes is shown in Table 4, as quoted by the equipment suppliers. It should be noted that treatment process performance generally deteriorates towards the upper-end of their theoretical treatment capacity. In combination these processes have sufficient capacity for dry weather flows and average flows, but they do not have sufficient capacity to treat wet weather flows.

Table 4: Waipukurau Tertiary Treatment Capacity

Treatment Process	Hydraulic Capacity	Source
Filtec lamella tube settlers	2,400 m^3/d	Ewen, 2017
Toveko sand filters	5,760 m^3/d	Gunn, 2017
Berson UV system	3,480 m^3/d	Schrader, 2017

The Waterclean design for Waipukurau was to treat a BOD load of 240 kg/d in the FTM section of the ponds (Waterclean, 2012). The Waterclean proposal did not state the total design BOD load, i.e. what BOD load would be removed through the facultative pond, prior to the 240 kg/d BOD loading onto the FTM.

The majority of the Waterclean upgrade was installed in 2014, with the lamella tube settlers added in 2015.

2.4 Recent Additions

An anaerobic pond and SFBFP were recently added to the Waipukurau WwTP, prior to the modified WSP. These additional ponds, commissioned in May 2017, have the following approximate dimensions:

- Anaerobic pond; Area 1,875m^2, depth 4m, volume 7,500m^3
- SFBFP; Area 8,900 m^2, depth 1.2 – 2.2m, minimum volume 10,700m^3. 2 x 3kW of mechanical aeration (Reliant Lagoon Masters) were installed in the SFBFP as part of the upgrade

In addition, new inlet screens were installed in 2016.

The design flow path through the current Waipukurau WwTP is as shown in Figure 1.

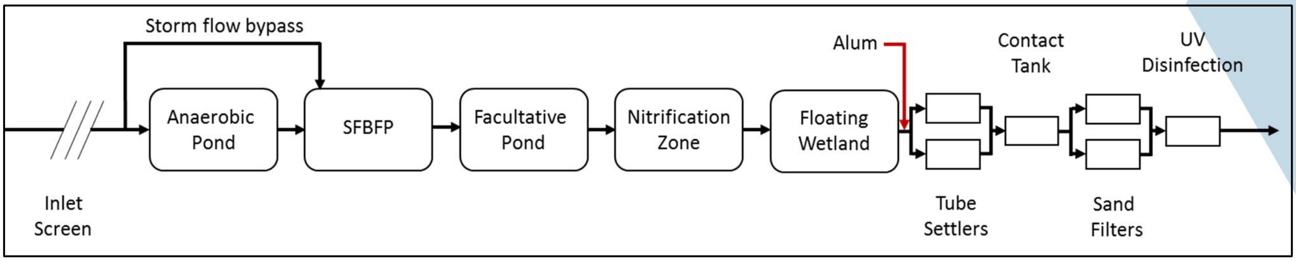

Figure 1: Waipukurau WwTP Current Design Process Flow Diagram

Note, following the addition of the lamella tube settlers prior to the sand filters, the contact tank is effectively redundant. While it is still in use, it serves no function and can be decommissioned.

2.5 Wastewater Flow and Load

2.5.1 Measured Raw Wastewater Characteristics

Between December 2013 and January 2015, 24-hour time-proportional composite samples of the raw wastewater entering the Waipukurau WwTP were collected on a monthly basis. The results of this monitoring are summarised in Table 5.

Table 5: Waipukurau WwTP Raw Wastewater Characteristics

	TSS, mg/L	$cBOD_5$, mg/L	Ammonia, mg/L	Total N, mg/L	SRP, mg/L	Total P, mg/L
Maximum	438	253	68	83	4.9	7.6
Average	154	117	33	49	3.2	5.3
Median	108	135	28	46	3.4	5.1
"Typical"[3]	220	220	25	40	-	8

Data in Table 5 suggests the TSS and BOD in the raw wastewater arriving at the Waipukurau WwTP are low in comparison to typical domestic wastewater, but the ammonia and total nitrogen concentrations are about as expected. Given the significant industrial discharges, the low TSS and BOD concentrations are surprising, and suggest this data may not be representative.

In addition, minimal influent monitoring has been undertaken since January 2015, and Trade Waste monitoring data suggests the industrial load has increased significantly since January 2015. Therefore, the data in Table 5 is not considered to be representative of current raw wastewater characteristics.

[3] Typical concentration of medium strength domestic wastewater (Metcalf & Eddy, 1991)

2.5.2 Measured Discharge Flows

Raw wastewater flow is not measured coming into the Waipukurau WwTP, but discharged flows are measured. With a WSP-based treatment plant, discharged flow rates differ from raw wastewater flow rates due to rain falling directly on the ponds, seepage, evaporation from the ponds, and hydraulic buffering provided by the ponds. However, we have found that the 10-percentile discharged flow rate from WSP-based WwTP's gives a reasonable indication of dry weather flow (DWF).

The daily discharge volume from the Waipukurau WwTP over a 3½ year period is shown in Figure 2, indicating that the DWF is approximately 1,320 m^3/d. Figure 2 also indicates that significant stormwater inflow and infiltration (I&I) enters the WwTP, although a portion of this will be due to rain falling directly onto the ponds rather than entering the plant through the reticulation. For example, based on an overall surface area of 3.54 ha, a 10 mm rainfall event would result in the addition of 354 m^3 of rainwater to the Waipukurau WwTP.

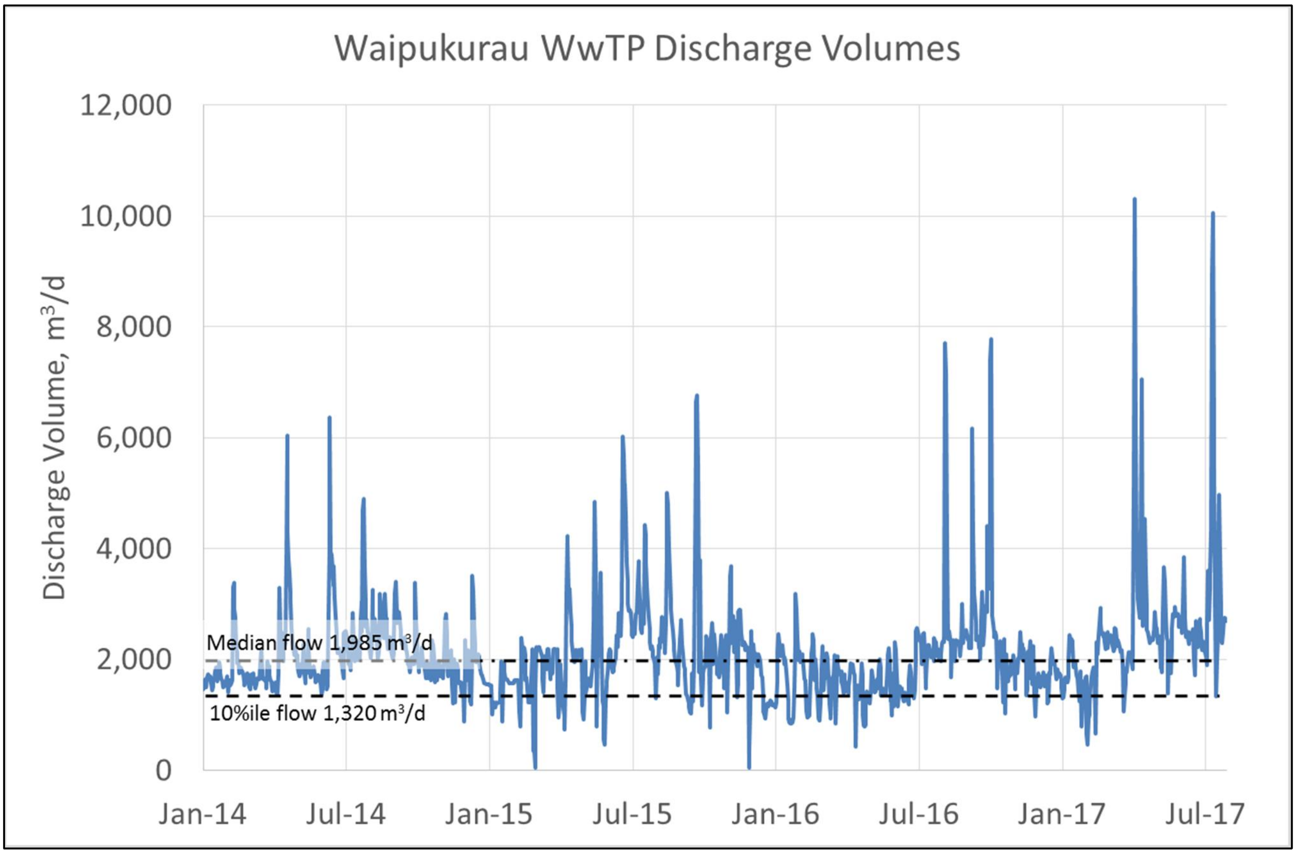

Figure 2: Waipukurau WwTP Discharge Volumes

Generally the volume of treated effluent discharged to the Tukituki River is within the median and 90-percentile daily volumes permitted by the resource consent of 2,200 and 4,000 m^3/d respectively. However, with 2017 being a particularly wet year for much of New Zealand, the median daily volume discharged in the period 1st July 2016 to 30th June 2017 did slightly exceed the permitted volume. This is shown, along with data for the preceding two years data, in Table 6.

Table 6: Summary of Waipukurau Discharge Volumes

Consent Period	Median, m^3/d	90-percentile, m^3/d
1st July 2014 to 30th June 2015	1,974	2,844
1st July 2015 to 30th June 2016	1,816	2,749
1st July 2016 to 30th June 2017	2,242	2,928
Resource consent conditions	*2,200*	*4,000*

2.5.3 Domestic Wastewater Contribution

The current population of Waipukurau is approximately 4,000. CHBDC is expecting significant growth, with the population expected to reach 5,000 by 2028, and 5,500 by 2048 (Thrush, 2017). Industry-standard per capita volumes and contaminant loadings can be used to estimate the current and future domestic wastewater flow and load. The results of such estimations are shown in Table 7.

Table 7: Estimated Waipukurau Domestic Wastewater Flow and Load

Parameter	Per Capita Contribution[4]	Domestic Contribution	
		Current	Projected 2048
Flow	250 L/head.d	1,000 m^3/d	1,375 m^3/d
TSS	90 g/head.d	360 kg/d	495 kg/d
$cBOD_5$	80 g/head.d	320 kg/d	440 kg/d
Total Nitrogen	13 g/head.d	52 kg/d	72 kg/d
Total Phosphorous	3 g/head.d	12 kg/d	17 kg/d

2.5.4 Industrial Wastewater Contribution

CHBDC undertake routine monthly Trade Waste monitoring on the following four significant industries discharging into the Waipukurau WwTP:

- Ovation (including Pasture Petfoods)
- NNNZ Casings
- Lowlan Plant Hire

[4] Metcalf & Eddy (2003)

- Medallion Petfoods

Time-proportional or grab samples are collected from each of the four industries at least once per month, and discharge volumes are either measured directly or estimated based on water consumption. This provides some understanding of wastewater flows and loads from each of these major industrial dischargers.

Based on results of Trade Waste monitoring undertaken in the period August 2016 to July 2017, the wastewater loads contributed by the four industries are as shown in Table 8.

Table 8: Waipukurau Trade Waste Contributions

	Ovation + NNNZ[5]		Lowlan		Medallion		Total	
	Average	Max	Average	Max	Average	Max	Average	Max
Flow, m^3/d	154	204	1	13	11	19	166	236
TSS, kg/d	84	216	0.8	3.8	2.6	6.9	87	227
$cBOD_5$, kg/d	295	562	1.0	7.0	4.3	8.1	300	577
Total N, kg/d	45	82	0.2	1.6	0.5	1.5	46	85
Total P, kg/d	4.4	9.4	0.1	0.5	0.0	0.1	4.5	10

However, we note that these industries are generally discharging less flows and loads of Trade Waste than permitted by their current Trade Waste permits. Table 9 summarises the flows and BOD loads that the four industries are permitted to discharge under their current Trade Waste permits.

Table 9: Waipukurau Trade Waste Contributions

Industry	Permitted Flow, m^3/d	Permitted $cBOD_5$, mg/L	Permitted BOD load, kg/d	Population Equivalent, p.e.
Ovation	850	500	425	5,300
NNNZ	100	3,000	300	3,750
Lowlan	18	800	14	180
Medallion	80	1,250	100	1,250
Total	***1,048***		***839***	***10,480***

[5] Separate monitoring of the Ovation and NNNZ discharges commenced in July 2017. Based on data from July to October 2017, Ovation contribute approximately 55% of the BOD load from these two industries on average, and NNNZ 45%.

A visit to Ovation and NNNZ on 15th November 2017 suggests it may be possible to reduce the impact of these Trade Waste discharges on the Waipukurau WwTP by:

- NNNZ changing the type of acid used for pH correction prior to their dissolved air flotation (DAF) from sulphuric acid to an acid which doesn't contain Sulphur (e.g. nitric acid or hydrochloric acid). The purpose of this change is to reduce the potential for H_2S formation in the anaerobic pond.
- NNNZ pH-correcting after the DAF to raise the pH (ideally to neutral 7.0) prior to discharge. Currently the pH of the NNNZ discharge is approximately 4. The CHBDC Trade Waste Bylaw (CHBDC, 2008) requires the pH to be between 6 and 9 at all times.
- Chemical conditioning of the Ovation wastewater using acids, coagulants and/or polymers to improve the performance of the existing "saveall" treatment process.
- Replacing the "saveall" at Ovation with a more effective treatment process(es).

2.5.5 Total Estimated Wastewater Dry Weather Flow

Based on a current average domestic wastewater flow of 1,000 m^3/d (from Table 7), and an average total Trade Waste discharge of 166 m^3/d (from Table 8), the total estimated Waipukurau DWF is 1,166 m^3/d. This is in reasonable agreement to the 1,320 m^3/d deduced from Figure 2.

2.5.6 Total Wastewater Load

From the estimated domestic wastewater load and measured industrial loads, the average total daily load requiring treatment at the Waipukurau WwTP for each month over a 5-year period is shown in Figure 3, along with 2028 and 2048 projections. This confirms the Trade Waste discharges add a significant load to the Waipukurau WwTP, and this industrial load appears to be increasing. Based on the available monitoring data, the peak month population equivalent (p.e.) wastewater load in the 5-year period shown in Figure 3 was approximately 11,000, in February 2017. The peak day p.e. is likely to be higher still.

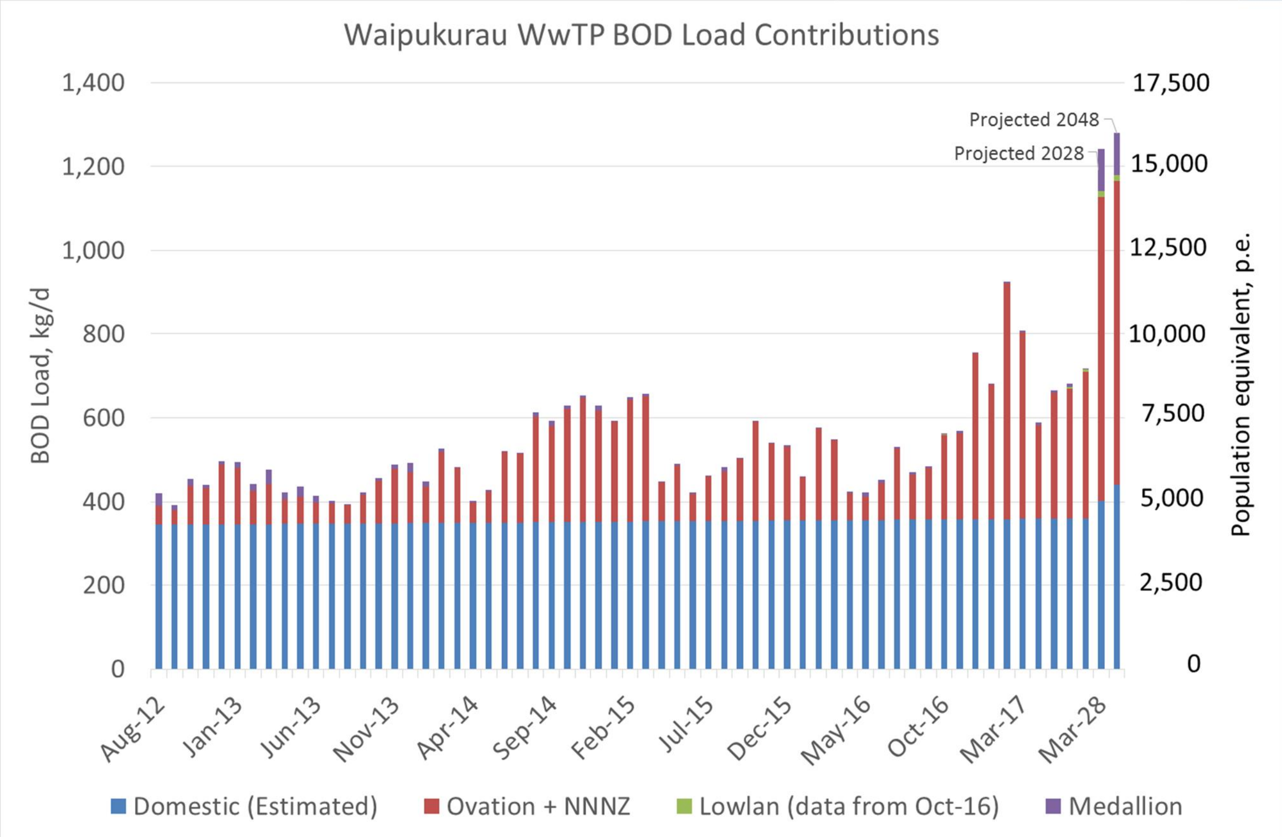

Figure 3: Waipukurau BOD Load August 2012 – July 2017

Note: The 2028 and 2048 projections assume each of the four major industries discharge the maximum wastewater flow and BOD load permitted under their existing Trade Waste agreements

It is important to note that it is critical that the raw wastewater flows and loads are accurately understood to be able to design a WwTP to provide effective treatment.

2.5.7 Potable Water Supply

In an attempt to validate the estimated wastewater flows, daily wastewater volumes are compared with potable water production in Figure 4. This shows the potable water production greatly exceeds wastewater volumes. While we understand that some dwellings in Waipukurau are serviced by potable water but not reticulated wastewater, the discrepancy in Figure 4 suggests potable water losses may be high, and large volumes of potable water are being used to water gardens, lawns or recreational areas in summer.

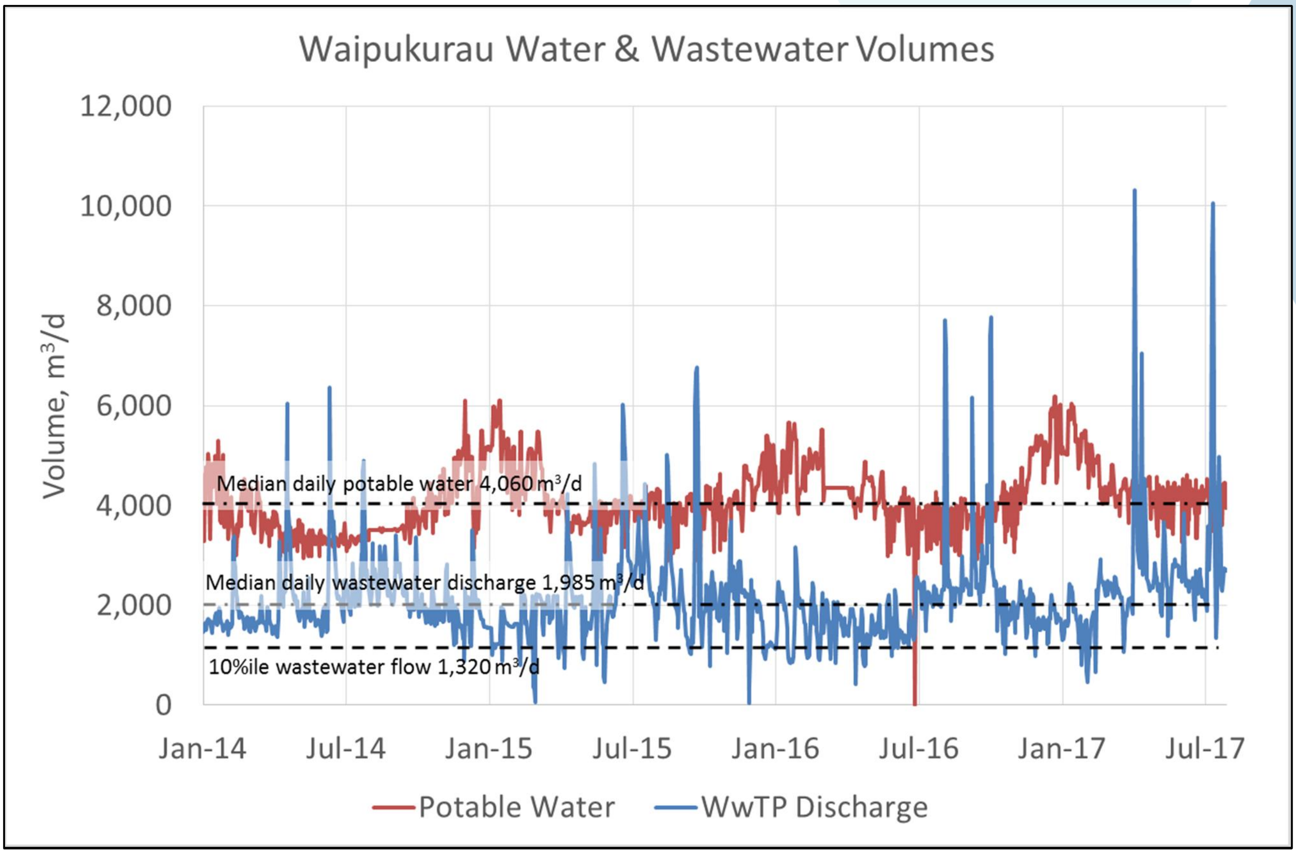

Figure 4: Waipukurau Water & Wastewater Volumes

3 Current Performance - Waipukurau

3.1 Treated Effluent Quality

The current performance of the Waipukurau WwTP for the contaminants with conditions specified in the resource consent is shown graphically in the following sub-sections. However, with the anaerobic pond and SFBFP only recently brought on-line, little data is available to determine the actual performance of the Waipukurau WwTP in its current configuration. Therefore the “current” performance discussed in the following sub-sections mainly details the effluent quality achieved after the Waterclean upgrade but before the most recent additions.

3.1.1 Total Suspended Solids

Between 2014 and early-2017, the discharged effluent comfortably met the resource consent requirements for TSS. However, through the middle of 2017, effluent TSS concentrations increased considerably, as shown in Figure 5. This increased effluent TSS is considered likely to be due to deterioration in performance of the lamella tube settlers.

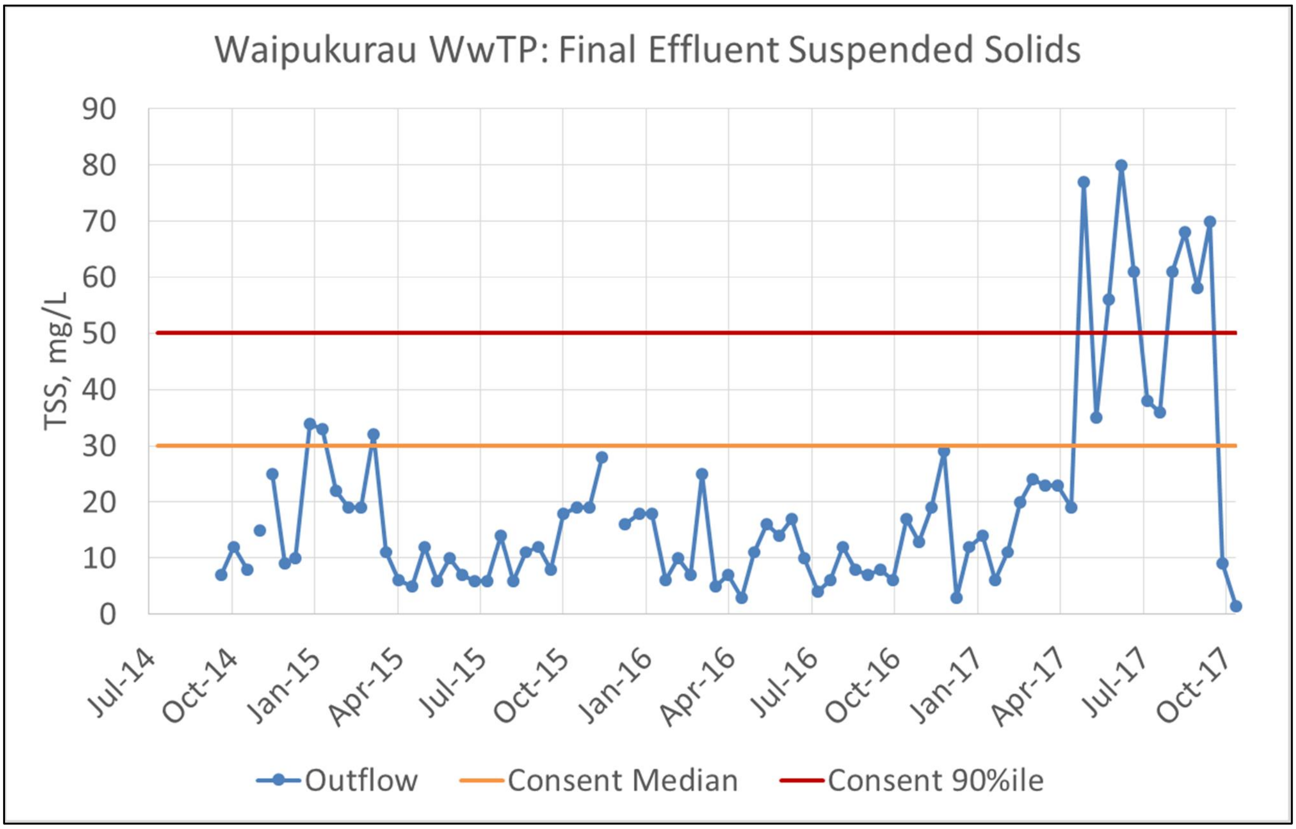

Figure 5: Waipukurau WwTP Final Effluent TSS, 2014-2017

3.1.2 BOD

As shown in Figure 6, the BOD concentration in the treated effluent is generally well within the resource consent requirements, although the performance deteriorated through 2017. This increased effluent BOD occurred at the same time as effluent TSS increased, suggesting that the recent higher BOD concentrations are due to solids breakthrough, rather than due to the discharge of soluble BOD.

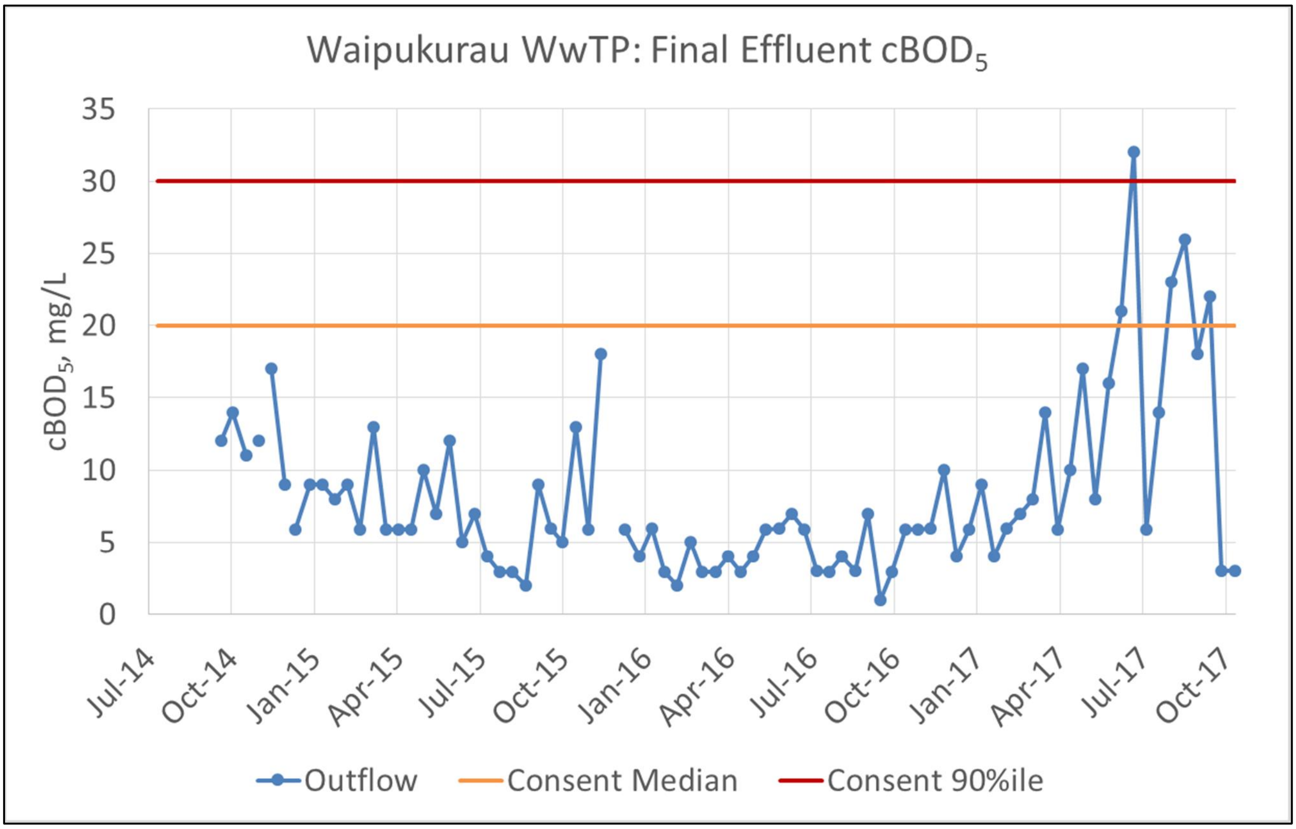

Figure 6: Waipukurau WwTP Final Effluent $cBOD_5$, 2014 - 2017

3.1.3 Ammonia

To achieve the resource consent requirements for ammonia of 6 mg/L as a median and 10 mg/L as a 90-percentile, reliable year-round nitrification (conversion of ammonia to nitrate) is required. Figure 7 suggests that little, if any, nitrification has occurred through the Waipukurau WwTP over the past three years.

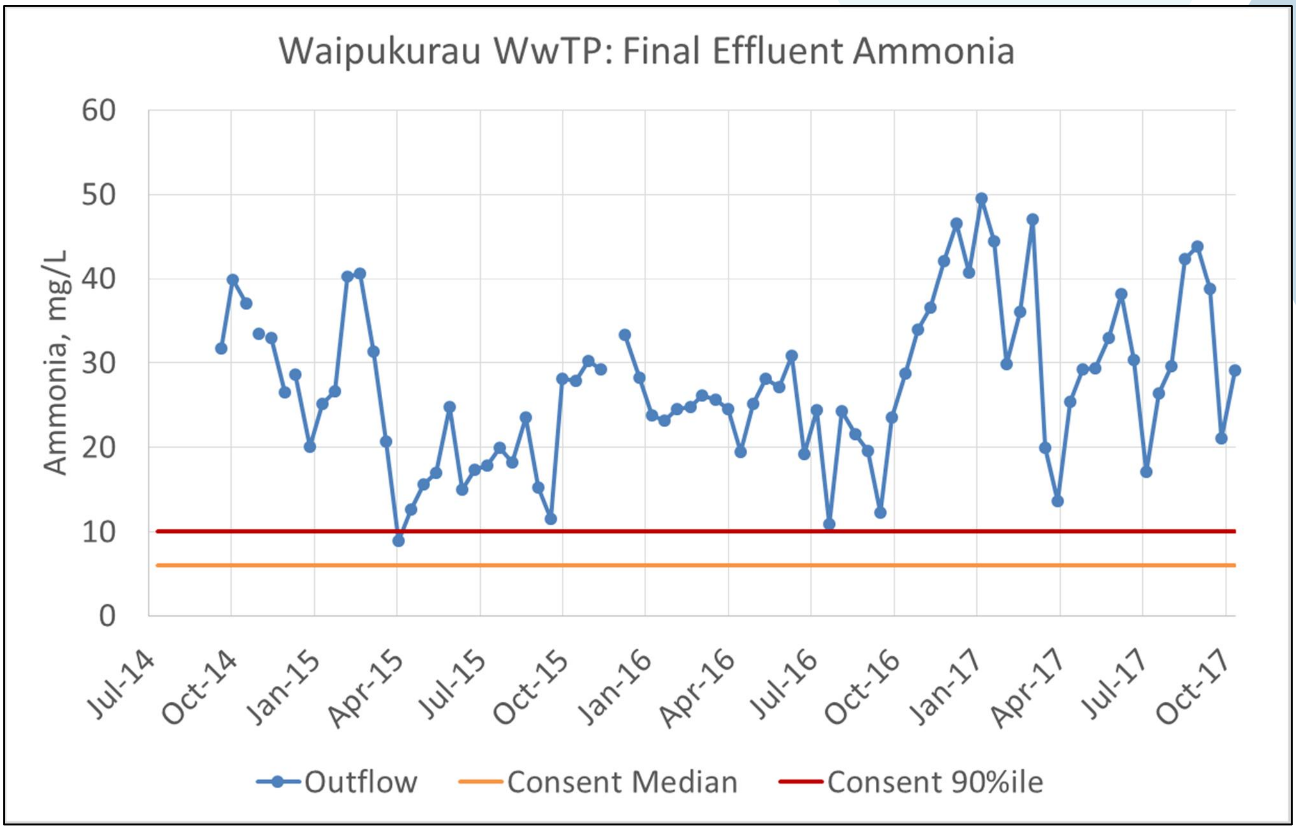

Figure 7: Waipukurau WwTP Final Effluent Ammonia, 2014-2017

3.1.4 Soluble Reactive Phosphorous

A high level of SRP removal is necessary to achieve the resource consent requirements, and alum is dosed prior to the lamella tube settlers to coagulate the SRP into flocs which can then be removed through the tube settlers and the sand filters. As can be seen in Figure 8, after the lamella tube settlers were installed to reduce the solids loading onto the sand filters, the discharge has generally complied with the SRP resource consent conditions, although with some exceptions.

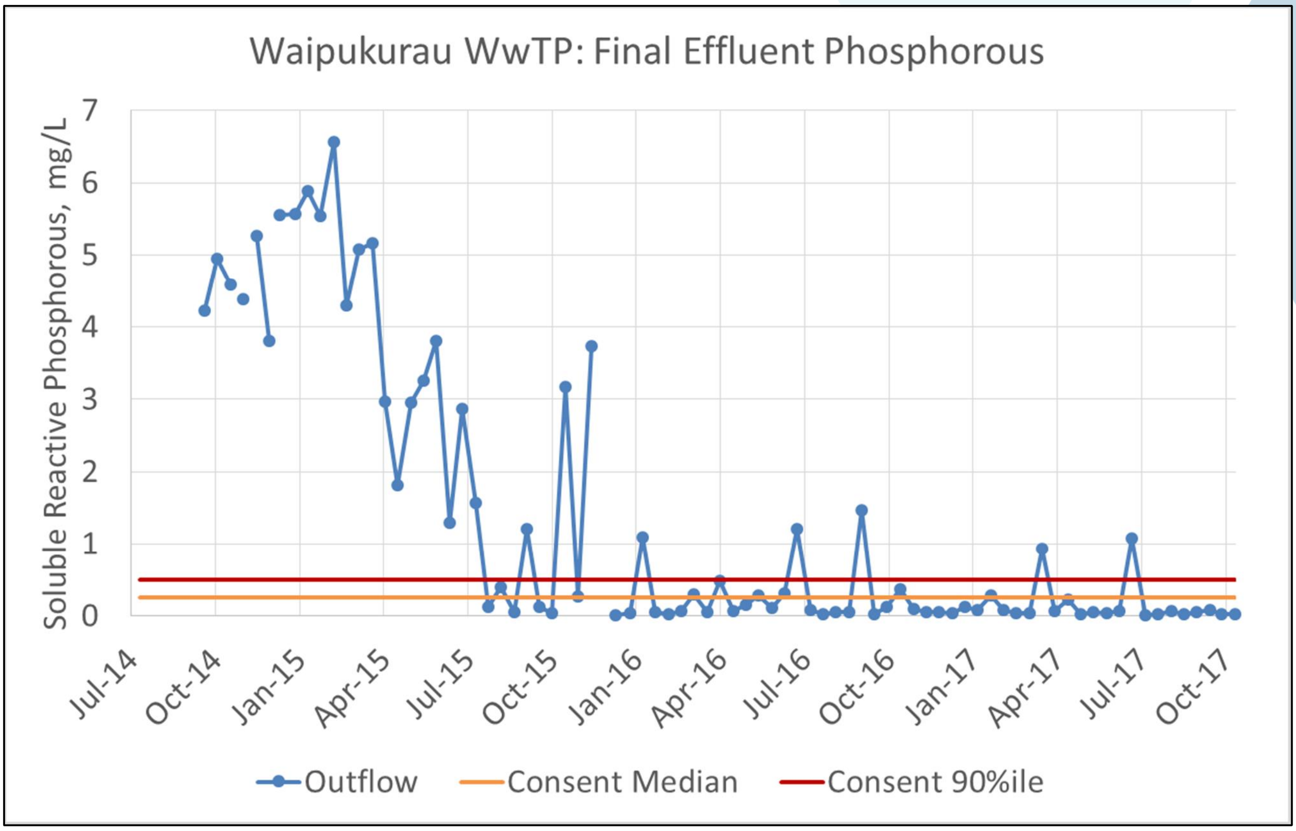

Figure 8: Waipukurau WwTP Final Effluent SRP, 2014-2017

3.1.5 Indicator Organisms

UV disinfection systems require low effluent TSS and high effluent UV transmittance (UVT) to effectively inactivate microorganisms. Therefore, for the UV system at Waipukurau WwTP to work well, the alum dosing, lamella tube settlers and sand filters must all perform well. It is our understanding that the UV system at Waipukurau WwTP is designed for a minimum UVT of 60% (Schrader, 2017). We note that a value of 60% UVT is very high for a minimum design UVT, although with coagulation and tertiary treatment this may be achievable. More common minimum design UVTs are 45 to 50% for a secondary treated wastewater. A minimum design UVT of 60% increases the risk of insufficient *E. coli* inactivation through the UV system.

The TSS breakthrough from the sand filters that has occurred through 2017, shown in Figure 5, would be expected to impact on the performance of the UV system. *E. coli* concentrations shown in Figure 9 suggest that this expected performance deterioration has occurred, with the concentration of *E. coli* in 5 of the 15 final effluent samples collected between May and October 2017 exceeding the 90-percentile resource consent condition.

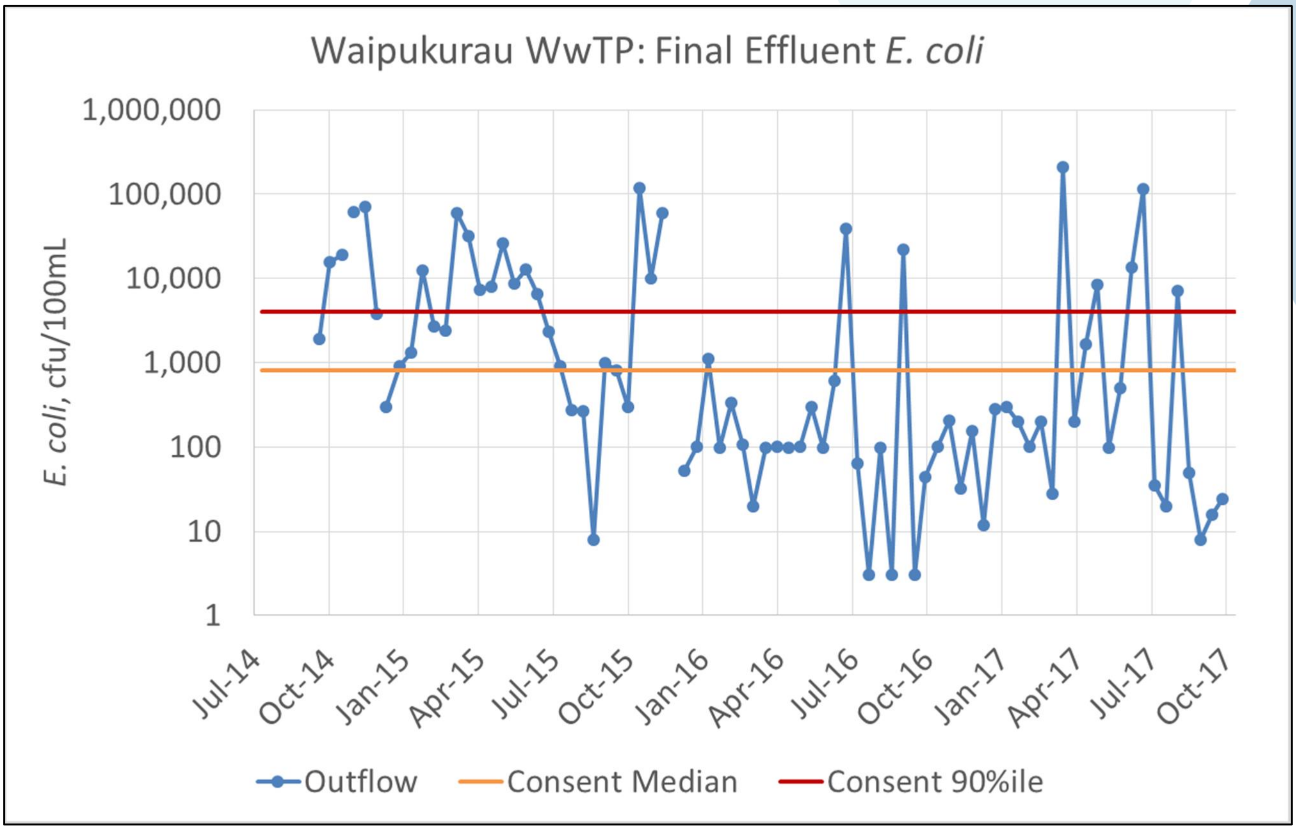

Figure 9: Waipukurau WwTP Final Effluent E. coli, 2014-2017

3.1.6 pH

Figure 10 shows that the pH of the discharge from the Waipukurau WwTP has been within the range stipulated in the resource consent range of 6.5 to 8.5 for the past three years.

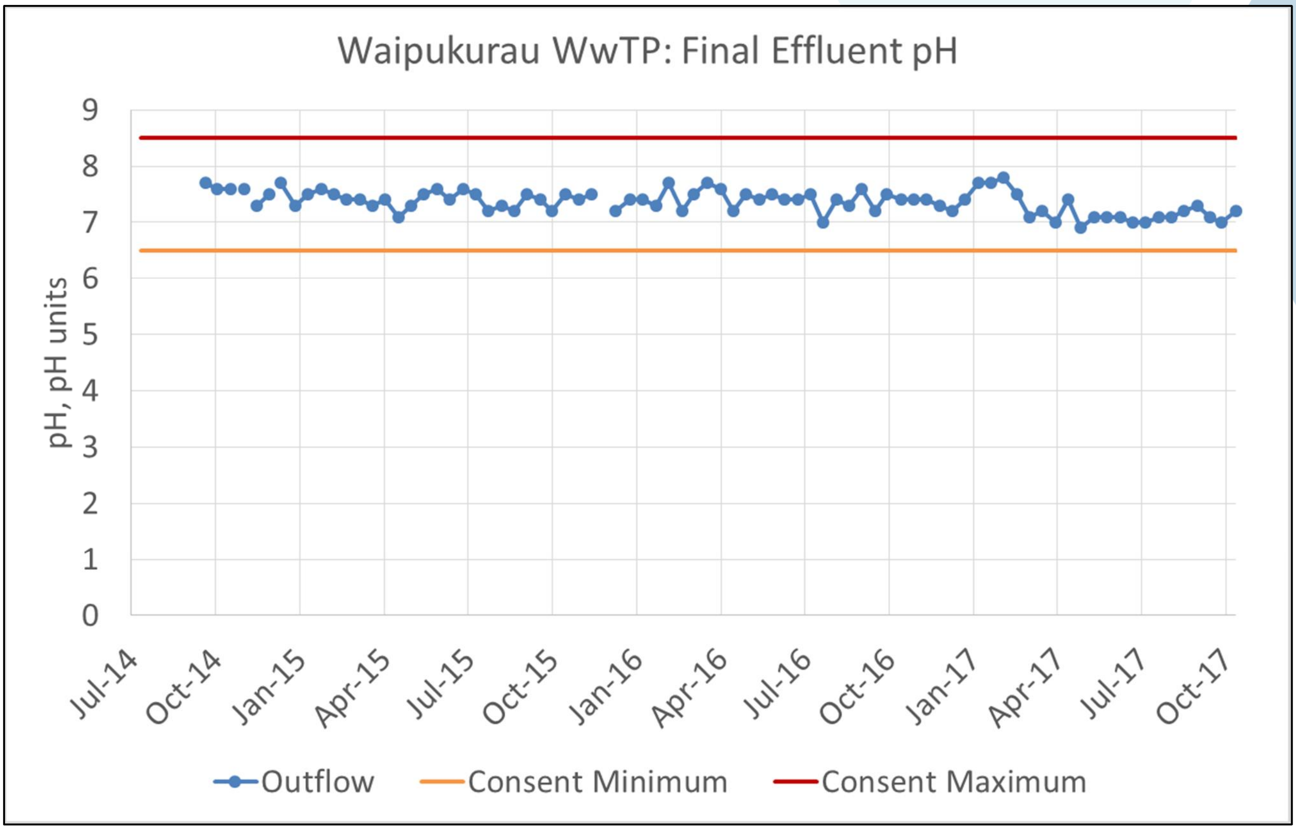

Figure 10: Waipukurau WwTP Final Effluent pH, 2014-2017

3.2 Operational Issues

3.2.1 Odour

It is our understanding that odour has long caused concerns at the Waipukurau WwTP, but the community has generally been accepting of these odour issues while CHBDC has worked through the various upgrades. CHBDC keep a register of odour complaints which dates back to December 2006. More complaints than usual were received in December 2016, with the complaints register noting that the oxidation pond level was low at that time with Contractors removing debris from aerators.

In June 2017 CHBDC started an odour survey. As a result of the odour survey, more frequent complaints have been received since June 2017. We understand the following changes have occurred in recent months which could have contributed to the increased odour complaints, both before and after the odour survey commenced:

- The pressure vessel and pump at the Ovation WwTP failed in December 2016.
- NNNZ started production in late 2016, and brought their DAF treatment process on line in March 2017.
- The anaerobic pond and SFBFP at the Waipukurau WwTP were brought on line in May 2017.

While a range of different odours have been reported, the most objectionable has been a "rotten egg" odour that is characteristic of H_2S.

From our site visits, the following parts of the overall Waipukurau WwTP are considered to be either potential or current sources of odour:

- Inlet screens, due to the screening chutes and bins being uncovered.
- Anaerobic pond outlet channel, due to high H_2S concentrations in the effluent from the anaerobic pond.
- SFBFP, due to release of H_2S when the anaerobic pond is in operation, or raw wastewater odours when the raw wastewater is diverted straight to the SFBFP.
- Modified WSP due to low dissolved oxygen (DO) concentrations, in particular the floating wetlands.
- Lamella tube settlers, due to release of H_2S as the effluent weirs over.
- Sand filters, due to release of H_2S as the effluent weirs over. At the time of our site visits, the filter shed was the most notable point source of H_2S-like odours.
- Concrete drying beds.

Since June 2017, the HBRC H_2S monitoring truck has been stationed on the Waipukurau WwTP site, between the SFBFP and Mt. Herbert Road. This records airborne H_2S concentrations at 10-minute intervals. However, because the monitoring truck is in a fixed position, the ability of this instrument to measure airborne H_2S is strongly influenced by wind direction and speed. When predominantly northerly winds are blowing, H_2S from the WwTP is blown towards the monitoring truck, but southerly winds blow any odours past the walkway along the flood embankment, and over the Tukituki River.

Measured airborne H_2S concentrations between 24th June and 25th September 2017 are shown in Figure 11.

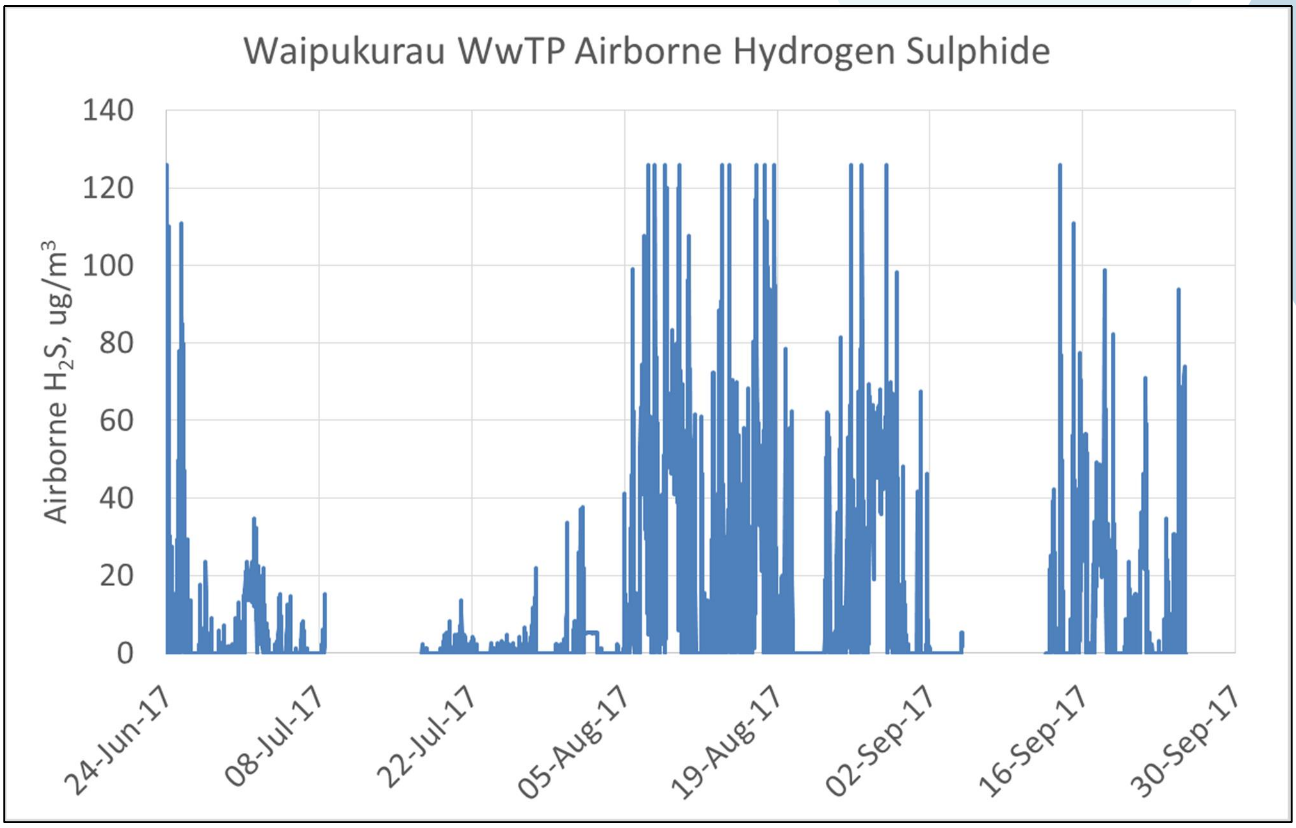

Figure 11: Waipukurau WwTP Measured Airborne H_2S

Note: The recording tape "stuck" between 8th and 17th July, and again between 5th and 12th September, with the same concentration recorded for each 10-minute interval in these periods. This data is excluded from Figure 11.

DO monitoring in the SFBFP in August and September 2017 indicated that DO concentrations were typically 0.2 to 0.3 mg/L, which is very low for a WSP process. DO concentrations >1 mg/L are generally effective at controlling H_2S odours because the sulphides are oxidised to thiosulphate, sulphate and sulphur at such DOs (WEF, 2007).

To reduce airborne H_2S and odour complaints, the following approaches were sequentially instigated between June and November 2017:

- Ferrous chloride was dosed into the anaerobic pond outlet channel from 23rd June 2017 to 11th August 2017. While this initially helped to reduce the H_2S concentrations, it also had the unexpected adverse effect of producing fine black precipitates which flowed through into all subsequent treatment processes.
- Calcium ammonium nitrate (CAN) and sodium nitrate were dosed into the anaerobic pond outlet channel and directly into the SFBFP from 18th August (ongoing) to provide an oxygen source to break down the H_2S. This has not been particularly effective, although jar tests have indicated that if very large quantities of sodium nitrate were added, H_2S destruction would occur.

- Taking the anaerobic pond out of service, and diverting raw wastewater directly into the SFBFP on 23rd August 2017. This changed the nature of odour of the SFBFP from a strong H_2S odour to a raw wastewater odour, although data in Figure 11 suggests this did not reduce airborne H_2S concentrations.
- The following additional aeration was installed in the SFBFP:
  - 2 x 6 kW "Aquarators" were installed on 6th October 2017. While Aqua Infrastructure, the suppliers of the Aquarator, claim the Aquarator provides a high oxygen transfer efficiency, this has not been verified.
  - On 27th October 2017, KlipTank installed a total of five of their proprietary venturi aeration systems, two "Megajets" and three "Klipjets", mounted on a pontoon, fed by a portable diesel pump. Due to noise concerns, this is generally run between the hours of 07:00 and 19:00 only. It is our understanding from discussions with KlipTank that the oxygen transfer efficiency of this venturi system has been measured at 0.14 kg O_2/kWh when aerating dairy effluent (Curtis, 2017), and KlipTank estimate the installed Megajets and Klipjets would provide approximately 5.7 kg O_2/hr (Martin, 2017). Based on this reported efficiency when measured in dairy effluent, the standard oxygen transfer rate (SOTR) of this venture aeration system is unknown.
- Redirecting raw wastewater back to the anaerobic pond to reduce the BOD load to the SFBFP on 31st October 2017.
- Recirculation of algae-laden effluent from the Facultative Pond back into the SFBFP on 2nd November with the intention of providing additional oxygen through algal photosynthesis. This resulted in a loss of algae through the whole system.

Even with the additional aeration in the SFBFP and BOD reduction through the anaerobic pond, the DO in the SFBFP has remained low, typically still 0.2 to 0.3 mg/L, and there has been no noticeable reduction in odours.

The fact that DO concentrations are still low in the SFBFP indicates that additional oxygen is still required in the SFBFP, either in the form of mechanical aeration or sodium nitrate. Providing adequate DO concentrations are being achieved in the facultative pond, it may be possible to move some aeration from the facultative pond into the SFBFP.

3.2.2 Stormwater Inflow & Infiltration

As shown previously in Figure 2, while the median discharge volume from the Waipukurau WwTP is approximately 2,000 m^3/d, the peak daily discharge is much higher. This is due to stormwater I&I into the wastewater reticulation, and due to rain falling directly onto the ponds. The WSPs provide some buffer storage capacity, however when this buffer capacity is exceeded flows in excess of approximately 2,400 m^3/d flow from the modified WSP outlet directly to the discharge manhole, bypassing the tertiary treatment processes. Therefore, the effective process flow diagram for the Waipukurau WwTP is as shown in Figure 12. Partial bypass of the lamella tube settlers, sand filters and UV disinfection system increases the risk of resource consent non-compliance for TSS, BOD, SRP, and *E. coli*.

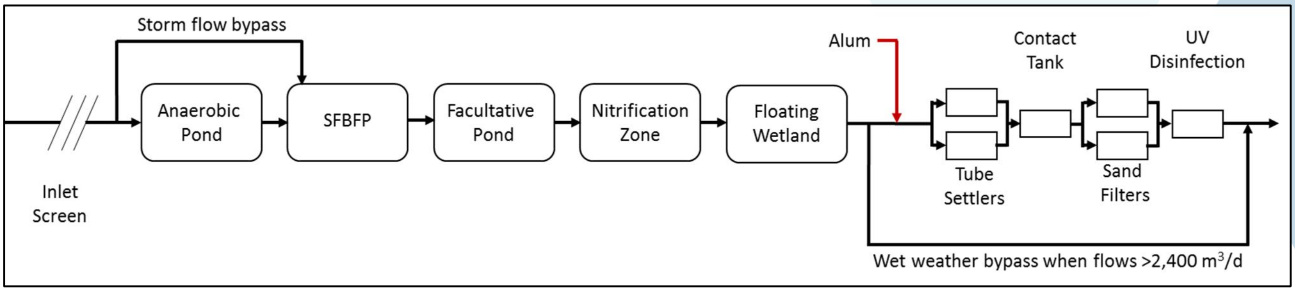

Figure 12: Waipukurau WwTP Actual Process Flow Diagram

3.2.3 High Sand Filter Solids Loading

As detailed in Section 3.1.1, the TSS concentration in the treated effluent has been increasing in recent months. From our observations on site, the poor performance of the lamella tube settlers are considered likely to have contributed significantly to these increasing effluent TSS concentrations. As shown in Figure 13, significant floc carry-over was occurring from the lamella tube settlers in August and September 2017. This would have been placing a high solids loading onto the recirculating sand filters, with such high solids loading likely to reduce the performance of this process. High solids loading to the sand filters also increases the risk of the sand filters becoming blocked.

Figure 13: Solids Carry-Over from Lamella Tube Settlers at Waipukurau WwTP

3.2.4 Foaming

It was evident from our visits to site that foam is generated through many stages of the Waipukurau WwTP. This foam has the potential to cause nuisance by blowing beyond the site boundaries during higher winds, and may cause public concern due to its visibility both on site and at the point of discharge. This foam appears to be a chemical foam, rather than a biological foam, because the foam is white and unstable. Some examples of the foaming observed at the Waipukurau WwTP are shown in Figure 14.

a) On the Nitrification Zone

b) At the sand filters

c) In the final effluent manhole

d) At the point of discharge

Figure 14: Foaming at Waipukurau WwTP

We understand from CHBDC that foaming at the Waipukurau WwTP has reduced in recent weeks (Thrush, 2017).

4 Expected Performance - Waipukurau

The following sub-sections estimate the expected average performance of the current Waipukurau WwTP, including the anaerobic pond and SFBFP, assuming that sufficient aeration is provided in each aerobic treatment process to maintain DO concentrations of >2 mg/L. These estimations are based on the estimated average and peak raw wastewater characteristics outlined in Table 10. These raw wastewater estimations are based on measured Trade Waste characteristics between August 2016 and July 2017, estimated domestic wastewater contributions, and a longer term average discharge flow rate of 2,130 m^3/d.

Table 10: Estimated Waipukurau Raw Wastewater Characteristics

Parameter	Average		Peak	
	Load, kg/d	Concentration[6]	Load, kg/d	Concentration[6]
TSS	447	210 mg/L	587	276 mg/L
$cBOD_5$	620	291 mg/L	897	421 mg/L
Total nitrogen	98	46 mg/L	137	64 mg/L
Total phosphorous	16	7.5 mg/L	24	11.3 mg/L
E. coli, cfu/100mL		10,000,000		

4.1 TSS

WSP systems are not effective at removing TSS because a well-functioning WSP converts soluble BOD into TSS in the form of algae. Therefore, the TSS concentration in effluent from traditional WSPs can be as high as 150 g/m^3 during summer when algal growth rates are at their highest, and considerably lower during winter. According to NZWWA (2005), the average TSS concentration in effluent from one- and two-pond WSP-based WwTP's are 50 and 40 g/m^3 respectively.

The Waipukurau WwTP includes add-on treatment processes designed to reduce TSS concentrations in the treated effluent through the following mechanisms:

- Outlet shading by floating wetlands, to reduce algal growth at the end of pond
- Lamella tube settlers, to settle coagulated solids
- Sand filters, to filter remaining TSS

Optimised chemical coagulation and sand filters after WSPs can be expected to achieve effluent TSS concentrations <10 mg/L (Ratsey, 2016). Therefore, the Waipukurau WwTP can be expected to achieve treated effluent TSS concentrations of <10 mg/L when effluent flow rates are within the design capacity of the lamella tube settlers and sand filters. However, wastewater flow rates during wet weather exceed the capacity of these tertiary treatment processes, resulting in partial bypass from the end of the modified WSP to the discharge manhole. When this bypass is

[6] At average annual flow rate

occurring, increased TSS concentrations in the treated effluent can be expected. Historical performance suggests that it should still be possible to achieve the TSS resource consent conditions even when part of the WSP effluent is bypassing tertiary treatment during wet weather.

4.2 BOD

Organic loading rates of 0.1 to 0.2 kgBOD/m^3.d are considered appropriate for anaerobic ponds operating under New Zealand conditions (WaterNZ, 2017). The average organic loading rate of the anaerobic pond at the Waipukurau WwTP is 0.08 kgBOD/m^3.d, so is at the conservative end of recommended design guidelines.

Table 11 summarises expected BOD removal rates through anaerobic ponds, with BOD removal being a function of temperature.

Table 11: BOD Removal through Anaerobic Ponds (Mara, 2003)

Temperature, ^oC	Volumetric loading, g/m^3.d	BOD Removal, %
<10	100	40
10 - 20	20T - 100	2T + 20
20 - 25	10T + 100	2T + 20
>25	350	70

Where T = temperature, ^oC

At minimum and maximum Waipukurau pond temperatures of 10 and 20^oC respectively, Table 11 suggests a BOD removal rate of between 40 and 60% could be expected through the anaerobic pond, depending on season.

Providing sufficient dissolved oxygen (DO) is available, BOD removal through facultative ponds can be estimated using the BOD removal equations from Mara (2003). The relevant equations are shown below as Equation 1 and Equation 2.

Equation 1: $$L_e = \frac{L_i}{1+k_{1(T)}\theta_f}$$

Where: L_e = BOD concentration in pond outlet, g/m^3

L_i = BOD concentration in pond inlet, g/m^3

$k_{1(T)}$ = first order rate constant at temperature, T (minimum monthly average pond temperature)

θ_f = hydraulic retention time (HRT), days

The temperature-adjusted first order rate constant in Equation 1, $k_{1(T)}$, is calculated from Equation 2, also from Mara (2003), with $k_{1(20)}$ being 0.3 d^{-1} for facultative ponds.

Equation 2: $$k_{1(T)} = k_{1(20)} \times 1.05^{(T-20)}$$

It should be noted that Equation 1 and Equation 2 relate to the removal of soluble BOD (sBOD) through WSPs. As WSPs convert soluble BOD into particulate BOD in the form of algae, the total (unfiltered) BOD in WSP effluent would be expected to be higher than that predicted through Equation 1 and Equation 2. However, at Waipukurau WwTP, the lamella tube settlers and sand filters would be expected to remove the majority of the particulate BOD along with the TSS.

Based on the above equations, the current Waipukurau WwTP would be expected to achieve average treated effluent sBOD concentrations of <10 mg/L providing sufficient aeration is installed where required. The calculations used to estimate the achievable effluent BOD and aeration requirements are included in Appendix A, and discussed further in Section 10.1.2. With such low sBOD concentrations, average effluent total BOD concentrations of <10 mg/L can also be expected after optimised chemical conditioning and sand filtration (Ratsey, 2016). However, when wastewater flow rates exceed the capacity of the tertiary treatment processes, increased effluent BOD concentrations are likely to occur. Historical performance suggests that it should still be possible to achieve the BOD resource consent conditions even when part of the WSP effluent is bypassing tertiary treatment during wet weather.

We note that measured effluent BOD concentrations following the Waterclean upgrade are less than predicted using the above equations. This suggests the effective first order rate constant, $k_{1(20)}$, is higher than 0.3 d^{-1} for Waipukurau. This may be due to the installation of both aeration and BAS media in the Waipukurau pond. A $k_{1(20)}$ value of 0.5 d^{-1} provides a better fit with actual performance data.

4.3 Ammonia

Anaerobic ponds do not provide ammonia removal. In fact ammonia concentrations generally increase through anaerobic ponds as more complex nitrogen species are broken down into ammonia. Therefore the 46 mg/L estimated average total nitrogen concentration in the raw wastewater will likely result in similar ammonia concentrations entering the SFBFP.

The most often quoted equations for estimating ammonia removal through conventional WSPs are those developed by Pano & Middlebrooks (1982), shown as Equation 3 (for temperatures up to 20°C), and Equation 4 (for temperatures over 20°C). Pano & Middlebrooks' equations assume the majority of ammonia removal is through volatilisation.

Equation 3: $$C_e = \frac{C_1}{\left\{1+\left[\left(\frac{A}{Q}\right)(0.0038+0.000134T)exp\left((1.041+0.044T)(pH-6.6)\right)\right]\right\}}$$ *(up to 20°C)*

Equation 4: $$C_e = \frac{C_1}{\left\{1+\left[5.035\times10^{-3}\left(\frac{A}{Q}\right)\right]\left[exp\left(1.540\times(pH-6.6)\right)\right]\right\}}$$ *(over 20°C)*

Where: C_e = ammonia concentration in the pond outlet, g/m^3

C_i = ammonia concentration in the pond inlet, g/m^3

Mara (2003) suggests that ammonia removal may be more significant than predicted by the Pano & Middlebrooks (1982) equations at high (~40 to 80 days) hydraulic retention time (HRT) due to nitrification. However, even with the addition of the anaerobic pond and SFBFP, the overall HRT of the Waipukurau WwTP is only ~22 days at average flow, therefore the Pano & Middlebrooks equations may be appropriate given that significant nitrification would not normally be expected at such a short HRT.

The Pano & Middlebrook equations do not, however, consider the additional nitrification capacity that may be provided by fixed growth processes such as the BAS system installed at Waipukurau WwTP.

NIWA (2017) reviewed Waterclean's design calculations for the Waipukurau BAS system and concluded that:

- Insufficient aeration is currently installed in the BAS zone to achieve full nitrification.
- The internal surface area of the BAS material would likely become clogged by biofilm, reducing the effective media surface area available for nitrifying bacteria.
- Nitrification rates at the winter pond temperatures experienced at Waipukurau (<10^{o}C) may be lower than those assumed by Waterclean.

We agree with NIWA (2017)'s general conclusion that the BAS zone is unlikely to provide the required level of nitrification to achieve the ammonia resource consent conditions. We note that the relatively high BOD concentrations entering the BAS zone are likely to encourage the growth of heterotrophic bacteria on the BAS media, thus out-competing nitrifying bacteria.

Therefore, considering that minimal nitrification is expected to be achieved through the Waipukurau WwTP, using the Pano & Middlebrooks (1982) equations we estimate summer (20^{o}C) and winter (10^{o}C) ammonia concentrations in the treated effluent of 37 and 40 mg/L respectively at average annual flow rates. These are in reasonable agreement with the predictions made by NIWA (2017) of 28 and 34 mg/L in summer and winter respectively, and the actual Waipukurau WwTP performance in recent years of between 10 to 50 mg/L ammonia in the final effluent.

4.4 Soluble Reactive Phosphorous

The Waipukurau WwTP includes several mechanisms for the potential removal of phosphorous from the wastewater, including:

- Assimilation into algal biomass.
- Removal of particulate phosphorous through settlement and filtration.
- Coagulation of SRP into flocs, and subsequent removal through settlement and filtration.

To achieve the resource consent conditions of 0.25 and 0.5 mg/L SRP as median and 90-percentile values respectively, the key mechanism at Waipukurau is coagulation through alum addition, and removal of the resulting flocs through the lamella tube settlers and sand filters.

Coagulation of SRP into flocs using either aluminium or iron-based coagulants is a resilient method of phosphorous removal. Quite simply, if the alum (or ferric) dose rate is increased, so the SRP concentration in the treated effluent will fall. Therefore, providing the alum dosing is optimised, the SRP concentration in the treated effluent from the Waipukurau can be expected to be within resource consent requirements when operating within the design capacity of the tertiary treatment processes. However, when wet weather results in the partial bypass of effluent from the outlet of the modified WSP to the discharge manhole, elevated SRP concentrations are likely to occur in the final effluent. Historical performance suggests the SRP resource consent conditions are unlikely to be met when part of the WSP effluent is bypassing tertiary treatment during wet weather.

4.5 Indicator Organisms

The general industry-adopted equations for predicting *E. coli* removal through WSPs are those provided by Marais (1974), as shown in Equation 5 and Equation 6.

Equation 5: $$N_e = \frac{N_i}{1+k_{B(T)}\theta}$$

Where: N_e = *E. coli* concentration in the pond outlet, cfu/100mL

N_i = *E. coli* concentration in the pond inlet, cfu/100mL

$k_{B(T)}$ = first order rate constant at temperature, T

Equation 6: $$k_{B(T)} = 2.6 \times 1.19^{(T-20)}$$

Providing minimal short-circuiting is occurring through the three zones of the modified WSP, Equation 5 and Equation 6 suggest that *E. coli* concentrations in the range of 1,000 to 10,000 cfu/100mL can be expected leaving the Waipukurau pond system.

An appropriately sized and operated UV disinfection system can be expected to achieve at least 2 $\log_{10}$ (99%), and more likely 3 $\log_{10}$ (99.9%), reduction in indicator organisms, providing the disinfected effluent is treated to a secondary effluent quality, is relatively low in TSS, and has an adequate UVT. Data in Figure 15 indicates the UV system at Waipukurau has achieved expected performance at times, but this has not been consistent.

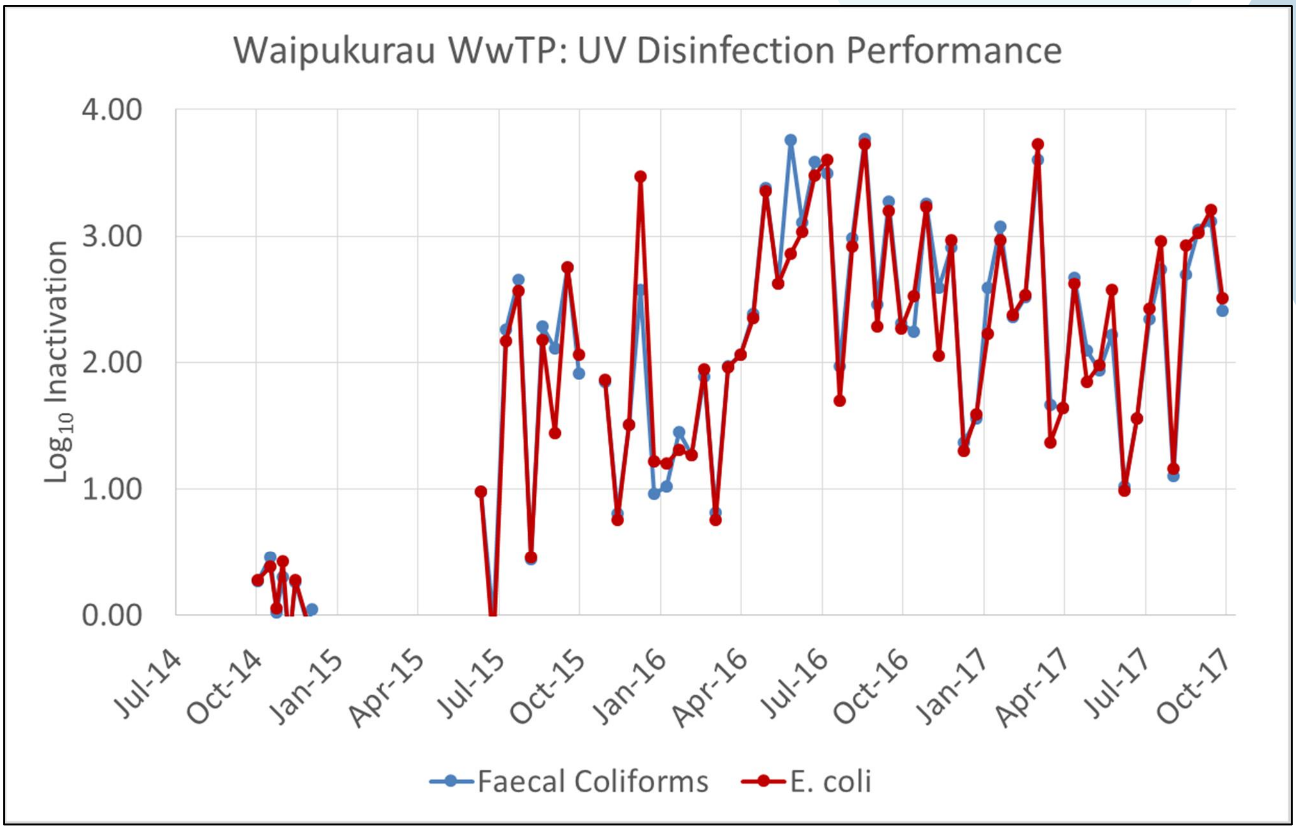

Figure 15: Waipukurau WwTP UV System Performance

Providing the lamella tube settlers and sand filters are being operated effectively (optimised chemical conditioning, operating within hydraulic capacity, optimised sludge withdrawal) producing an effluent with low TSS and high UVT, and necessary maintenance has been undertaken on the UV system (lamp replacement, sleeve cleaning, wiper replacement etc), it should be possible to achieve at least 2.5 $\log_{10}$ *E. coli* removal through the Waipukurau UV system. Therefore the median *E. coli* resource consent condition of 800 cfu/100mL should be easily achievable up to flow rates of approximately 2,400 m^3/d. However, when wet weather flows result in partial bypass of the tertiary treatment processes, significant increases in treated effluent *E. coli* concentrations are likely to occur. Based on historical *E. coli* concentrations in the modified WSP effluent, this is likely to result in resource consent non-compliance for *E. coli*.

5 Waipawa WwTP

5.1 Resource Consent Conditions

The Waipawa WwTP discharges treated effluent to Bush Drain, a tributary of the Waipawa River, under HBRC resource consent numbers DP030232Wb and DP030860Ab. The resource consent expires on 30 September 2030. The numerical conditions of the consent are outlined in Table 12.

Table 12: Waipawa WwTP Consent Conditions

Parameter	Median	90-percentile
Flow, m^3/d	1,300	1,500
$cBOD_5$, mg/L	20	30
TSS, mg/L	30	50
Ammonia, mg/L	6	10
Soluble Reactive Phosphorous (SRP), mg/L	0.25	0.5
E. coli, cfu/100mL	800	4,000
pH	6.5 – 8.5	

5.2 Original Facultative Pond

The original facultative pond is approximately 22,700 m^2 in area (2.3 ha)(7). With an average depth of 1.5 m, the volume of the facultative pond is approximately 34,000 m^3.

At a typical Ministry of Works (MoW, 1974) loading rate of 84 kgBOD/ha.d, the original facultative pond had a treatment capacity of approximately 190 kgBOD/d. More recent work by Duncan Mara suggests appropriate facultative pond loading rates are temperature dependent, and significantly higher loading rates are possible at temperatures of 20^{o}C (Mara, 2003; Mara, 2008). However, CHBDC monitoring indicates the temperature of the Waipawa pond drops to <10^{o}C during winter, and at such cold temperatures the MoW loading rate is appropriate.

It should be noted that the MoW and Mara loading rates are to provide BOD removal only, not nitrification. Therefore, even if the loading onto the facultative pond was within MoW and Mara guidelines, it is unlikely that reliable year-round ammonia removal would be achieved.

5.3 Waterclean Upgrade

The Waterclean upgrade partitioned the original facultative pond into the following three areas:

- Pond Section 1; Facultative pond (1.42 ha). A Reliant Lagoon Master aerator has recently been installed to replace the old 12kW vertical shaft aerator.

[7] Based on measurements from GoogleMaps

- Pond Section 2; Nitrification zone (0.54 ha), using BAS media, with 3 x 2.2kW surface mounted Whitley brush-type aerators installed by Waterclean. Two of these brush aerators have since been replaced with Reliant Lagoon Master aerators.
- Pond Section 3; Floating wetland zone (0.31 ha).

As with the Waipukurau WwTP, the Waterclean proposal (Waterclean, 2012) groups these modified pond sections into two stages; Oxidation Pond with Aeration (facultative pond), and FTM (nitrification zone plus floating wetland).

In addition, a lamella clarifier and recirculating sand filters were installed after the modified pond to provide tertiary filtration, with UV disinfection after filtration. The design hydraulic capacity of each of these three treatment processes is shown in Table 13, as quoted by the equipment suppliers. It should be noted that treatment process performance generally deteriorates towards the upper-end of their theoretical treatment capacity. In combination these processes have sufficient capacity for dry weather flows and average flows, but they do not have sufficient capacity to treat wet weather flows.

Table 13: Waipawa Tertiary Treatment Capacity

Treatment Process	Hydraulic Capacity	Source
Lamella clarifier	1,680 m^3/d	Svedala (undated)
Toveko sand filters	2,880 m^3/d	Gunn, 2017
Berson UV system	1,632 m^3/d	Schrader, 2017

The Waterclean design for Waipawa was to treat a BOD load of 112 kg/d in the FTM section of the ponds (Waterclean, 2012). The Waterclean proposal did not state the total design BOD load, i.e. what BOD load would be removed through the facultative pond, prior to the 112 kg/d BOD loading onto the FTM.

The majority of the Waterclean upgrade was installed in 2013, with the lamella clarifier added in 2015.

The current design flow path through the Waipawa WwTP is as shown in Figure 16.

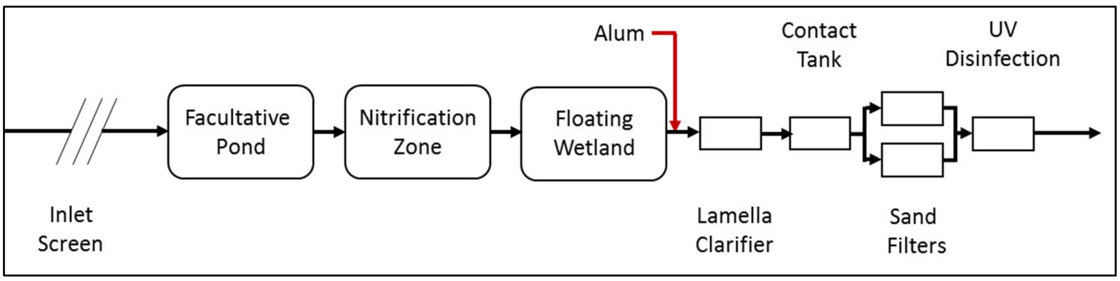

Figure 16: Waipawa WwTP Current Design Process Flow Diagram

Note, as with the Waipukurau WwTP, following the addition of the lamella clarifier prior to the sand filters, the contact tank is effectively redundant. While it is still in use, it serves no function and can be decommissioned.

5.4 Wastewater Flow and Load

5.4.1 Measured Raw Wastewater Characteristics

Between December 2012 and December 2014, 24-hour time-proportional composite samples of the raw wastewater entering the Waipawa WwTP were collected on a monthly basis. The results of this monitoring are summarised in Table 14.

Table 14: Waipawa WwTP Raw Wastewater Characteristics (December 2012 to December 2014)

	TSS, mg/L	$cBOD_5$, mg/L	Ammonia, mg/L	Total N, mg/L	SRP, mg/L	Total P, mg/L
Maximum	782	203	75	84	11.0	12.4
Average	173	86	26	37	5.0	6.9
Median	130	74	26	34	4.8	6.4
"Typical"	220	220	25	40	-	8

Data in Table 14 suggests the BOD and TSS in the raw wastewater arriving at the Waipawa WwTP is weak in comparison to typical domestic wastewater, but the ammonia and total nitrogen concentrations are about as expected. Given the significant industrial discharges, the low BOD and TSS concentrations are surprising, and suggest this data may not be representative.

Since the beginning of September 2017, a 24-hour time-proportional composite sample of the raw wastewater entering the Waipawa WwTP has been collected at least once per week. The results of the first 15 sample sets are shown in Table 15, suggesting the raw wastewater is higher strength than the 2012 to 2014 monitoring indicates. Even so, the median TSS and BOD concentrations are noticeably weaker than typical raw domestic wastewater, again suggesting this data may not be representative.

Table 15: Waipawa WwTP Raw Wastewater Characteristics (September to October 2017)

	TSS, mg/L	$cBOD_5$, mg/L	Ammonia, mg/L	Total N, mg/L	SRP, mg/L	Total P, mg/L
Maximum	1,530	492	57	75	-	12.9
Average	308	117	33	46	-	6.1
Median	114	72	33	45	-	5.5
"Typical"	220	220	25	40	-	8

5.4.2 Measured Discharge Flows

Raw wastewater flow has historically not been measured coming into the Waipawa WwTP, but discharged flows are measured. With a WSP-based treatment plant, discharged flow rates differ from raw wastewater flow rates due to rain falling directly on the ponds, seepage, evaporation from the ponds, and hydraulic buffering provided by the ponds. However, we have found that the 10-percentile discharged flow rate from WSP-based WwTP's gives a reasonable indication of DWF.

The daily discharge volume from the Waipawa WwTP over a 3½ year period is shown in Figure 17, indicating that the DWF is approximately 500 m^3/d. Figure 17 also indicates that significant stormwater I&I enters the WwTP, although a portion of this will be due to rain falling directly onto the ponds rather than entering the plant through the reticulation. Discharge flows in 2017 have been consistently high, presumably due to increased I&I and rain falling directly onto the pond as a result of the very wet year experienced in much of New Zealand.

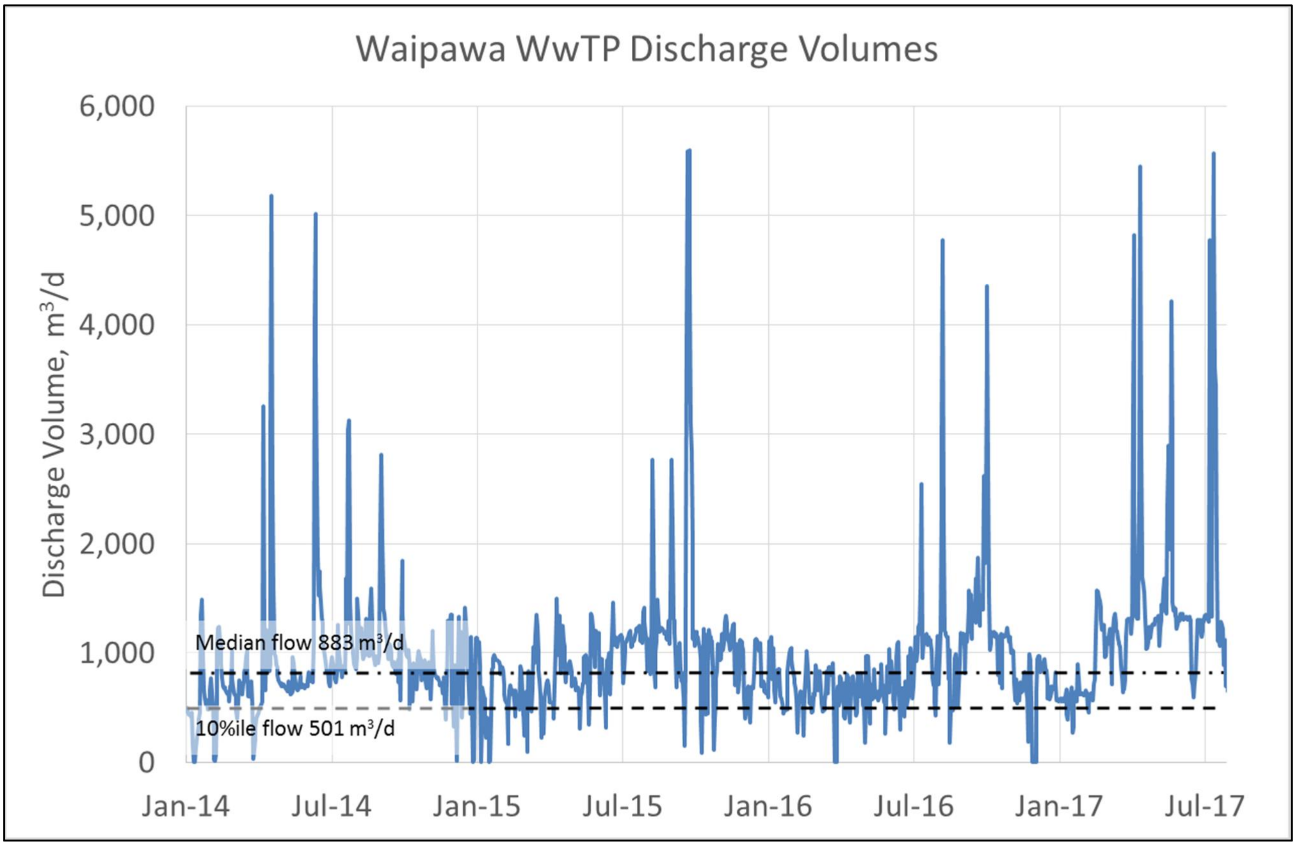

Figure 17: Waipawa WwTP Discharge Volumes

Generally the volume of treated effluent discharged to the tributary of the Waipawa River is within the median and 90-percentile daily volumes permitted by the resource consent of 1,300 and 1,500 m^3/d respectively. However, with 2017 being a particularly wet year, the 90-percentile daily volume discharged in the period 1st July 2016 to 30th June 2017 did exceed the permitted volume. This is shown, along with data for the preceding two years data, in Table 16.

Table 16: Summary of Waipawa Discharge Volumes

Consent Period	Median, m^3/d	90-percentile, m^3/d
1st July 2014 to 30th June 2015	870	1,250
1st July 2015 to 30th June 2016	820	1,219
1st July 2016 to 30th June 2017	1,122	1,567
Resource consent conditions	*1,300*	*1,500*

5.4.3 Domestic Wastewater Contribution

The current population of Waipawa is approximately 2,000. CHBDC expect considerable growth to occur, with projected 2028 and 2048 populations of 2,500 and 2,700 respectively (Thrush, 2017). Industry-standard per capita volumes and contaminant loadings can be used to estimate the current and future domestic wastewater flow and load. The results of such estimations are shown in Table 17.

Table 17: Estimated Waipawa Domestic Wastewater Flow and Load

Parameter	Per Capita Contribution	Domestic Contribution	
		Current	Projected 2048
Flow	250 L/head.d	500 m^3/d	675 m^3/d
TSS	90 g/head.d	180 kg/d	243 kg/d
$cBOD_5$	80 g/head.d	160 kg/d	216 kg/d
Total Nitrogen	13 g/head.d	26 kg/d	35 kg/d
Total Phosphorous	3 g/head.d	6 kg/d	8 kg/d

5.4.4 Industrial Wastewater Contribution

CHBDC undertake routine monthly Trade Waste monitoring on the following two significant industries discharging into the Waipawa WwTP:

- Farmers truckwash
- Stephensons truckwash

Time-proportional or grab samples are generally collected from each of the two industries once per month, and discharge volumes are either measured directly or estimated based on water consumption. This provides some understanding of wastewater flows and loads from these two major industrial dischargers.

Based on results of Trade Waste monitoring undertaken in the period August 2012 to July 2017, the wastewater loads contributed by the two truck washes is as shown in Table 18.

Table 18: Waipawa Trade Waste Contributions

	Farmers		Stephensons		Total	
	Average	Maximum	Average	Maximum	Average	Maximum
Flow, m^3/d	33	66	46	66	79	132
TSS, kg/d	44	125	46	125	90	250
$cBOD_5$, kg/d	16	43	22	44	48	87
Total N, kg/d	4	12	7	18	11	30
Total P, kg/d	0.9	2.5	2.1	5.9	3.0	8.4

However, we note that these industries are generally discharging less trade waste, and at lower concentrations, than are permitted by their current trade waste permits. Table 19 summarises the flows and BOD loads that the two industries are permitted to discharge under their current trade waste permits.

Table 19: Waipawa Trade Waste Contributions

Industry	Permitted Flow, m^3/d	Permitted $cBOD_5$, mg/L	Permitted BOD load, kg/d	Population Equivalent, p.e.
Farmers	90	800	72	900
Stephensons	80	1,450	116	1,450
Total	***170***		***188***	***2,350***

We also understand that landfill leachate is tankered to the Waipawa WwTP, with up to 60 m^3/d permitted (Bothwell, 2017). While we have not reviewed recent characterisation data for this leachate, we note that landfill leachate is often concentrated, and can contain high concentrations of ammonia, typically between 500 and 1,000 mg/L. This could, therefore, add a considerable ammonia load to the Waipawa WwTP. Landfill leachate can also contain tannins, which can reduce the effectiveness of UV disinfection.

2.2.6 Total Estimated Wastewater Dry Weather Flow

Based on a current average domestic wastewater flow of 500 m^3/d (from Table 17) and an average total trade waste discharge of 79 m^3/d (from Table 18), the total estimated Waipawa DWF is 579 m^3/d. This is in reasonably good agreement to the 501 m^3/d deduced from Figure 17.

5.4.5 Total Wastewater Load

From the estimated domestic wastewater load and measured industrial loads, the average total daily load requiring treatment at the Waipawa WwTP for each month over a 5-year period is shown in Figure 18, along with the projected 2028 and 2048 loads. This indicates the trade waste discharges add some load to the Waipawa WwTP, but this is not currently as significant as received at the Waipukurau WwTP. However, at 3,750, the current equivalent p.e. is still significantly higher than the domestic population. The 2028 and 2048 projections in Figure 18 assume the two truck washes discharge the volume and load permitted in their current trade waste agreements. If they did discharge this permitted flow and load, it would result in a very significant load increase to the Waipawa WwTP.

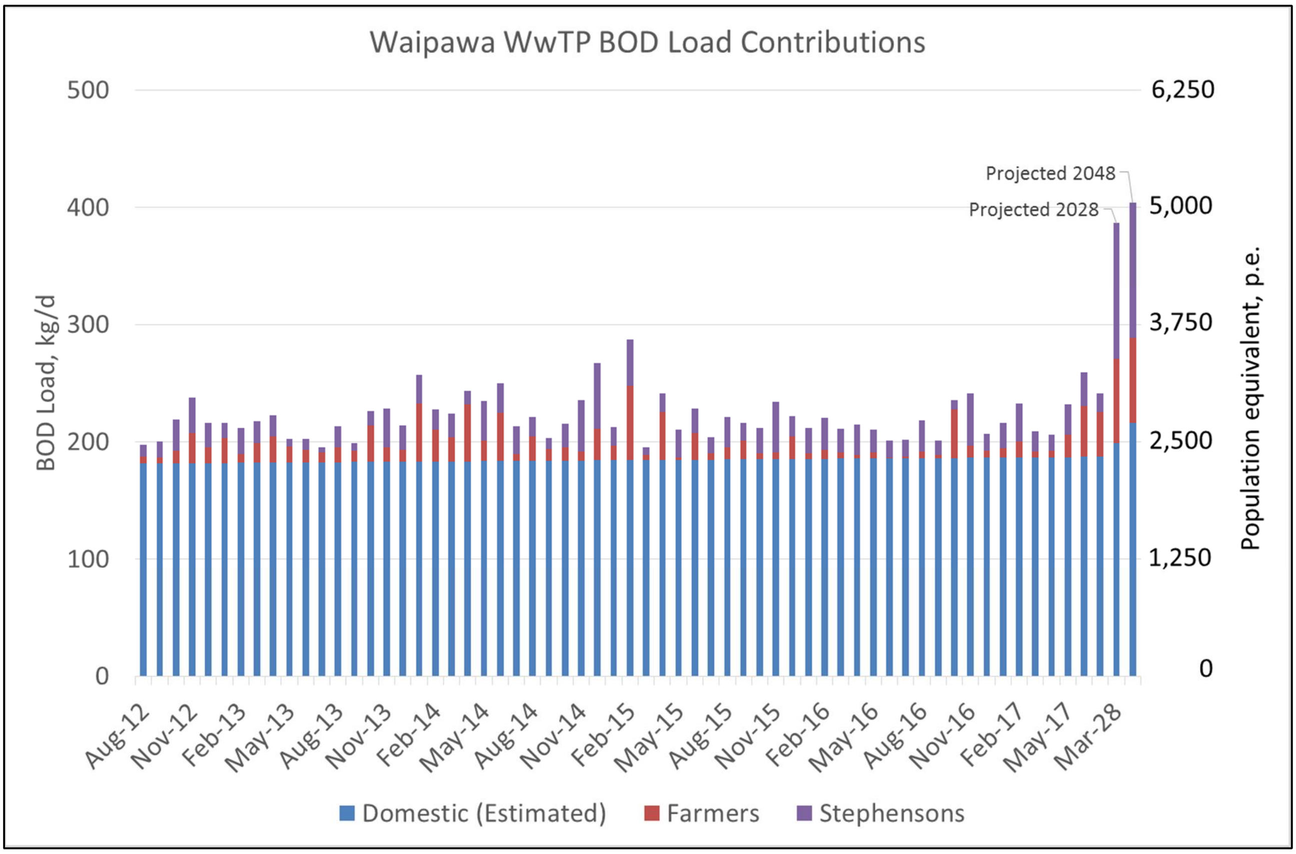

Figure 18: Waipawa BOD Load August 2012 – July 2017

It is important to note that it is critical that the raw wastewater flows and loads are accurately understood to be able to design a WwTP to provide effective treatment.

5.4.6 Potable Water Supply

In an attempt to validate the estimated wastewater flows, daily wastewater volumes are compared with potable water production in Figure 19. This shows the potable water production greatly exceeds wastewater volumes. However, the Waipawa supply also supplies Otane as well as Waipawa, and we understand that some dwellings in Waipawa are serviced by potable water but not reticulated wastewater. Therefore, the significance of this difference between volumes of potable water and wastewater is unknown.

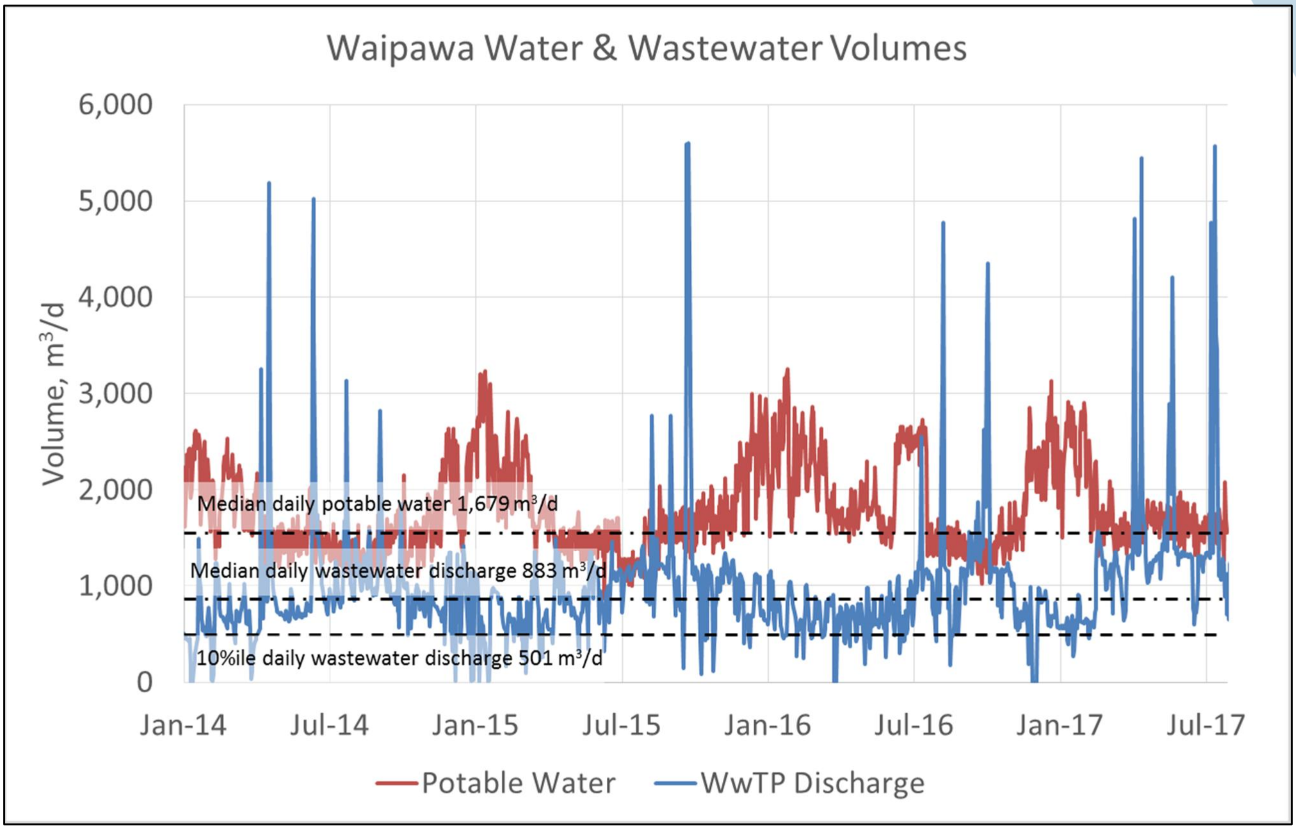

Figure 19: Waipawa Water & Wastewater Volumes

6 Current Performance - Waipawa

6.1 Treated Effluent Quality

The current performance of the Waipawa WwTP for the contaminants with conditions specified in the resource consent is shown graphically in the following sub-sections.

6.1.1 Total Suspended Solids

Figure 20 shows that the Waipawa WwTP has met the TSS resource consent requirements over the past three years.

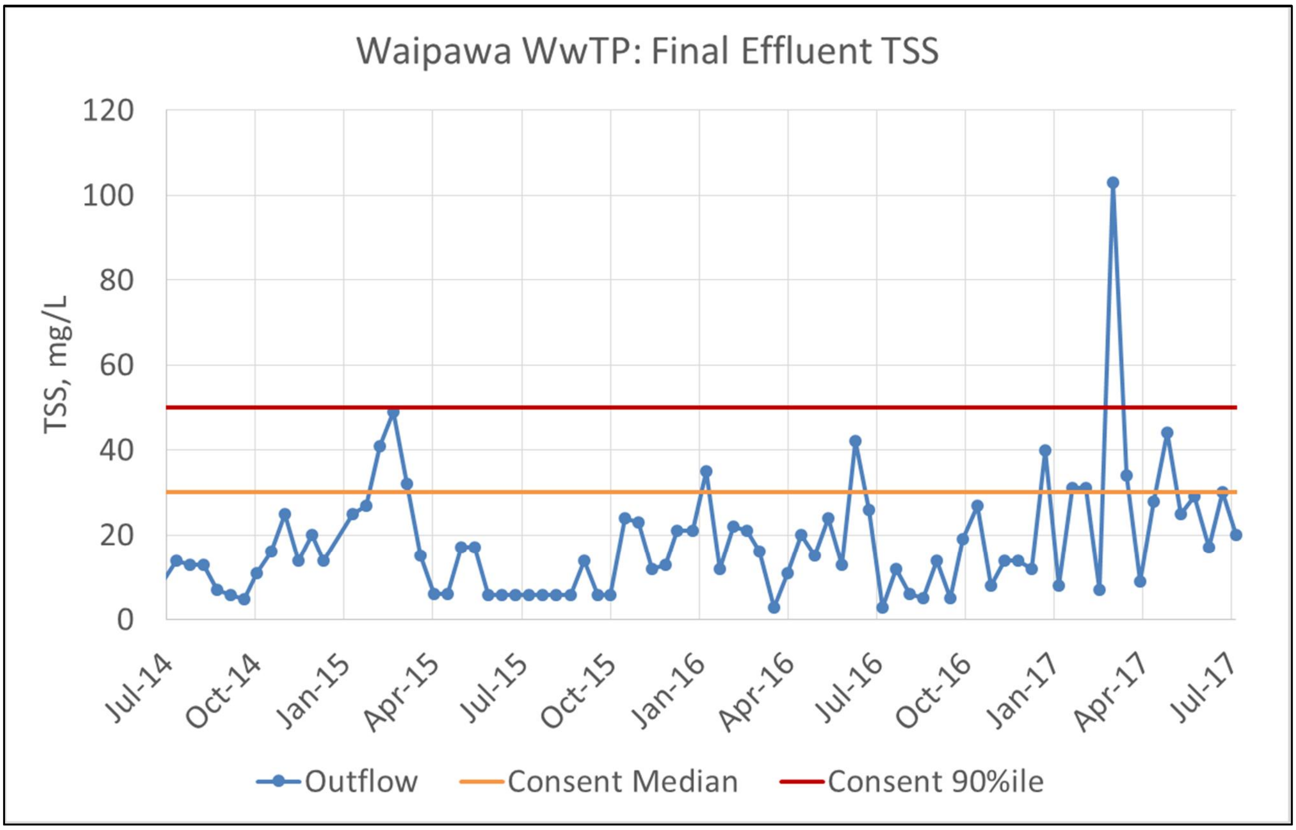

Figure 20: Waipawa WwTP Final Effluent TSS, 2014-2017

6.1.2 BOD

Figure 21 shows that the Waipawa WwTP has comfortably met the $cBOD_5$ resource consent requirements over the past three years.

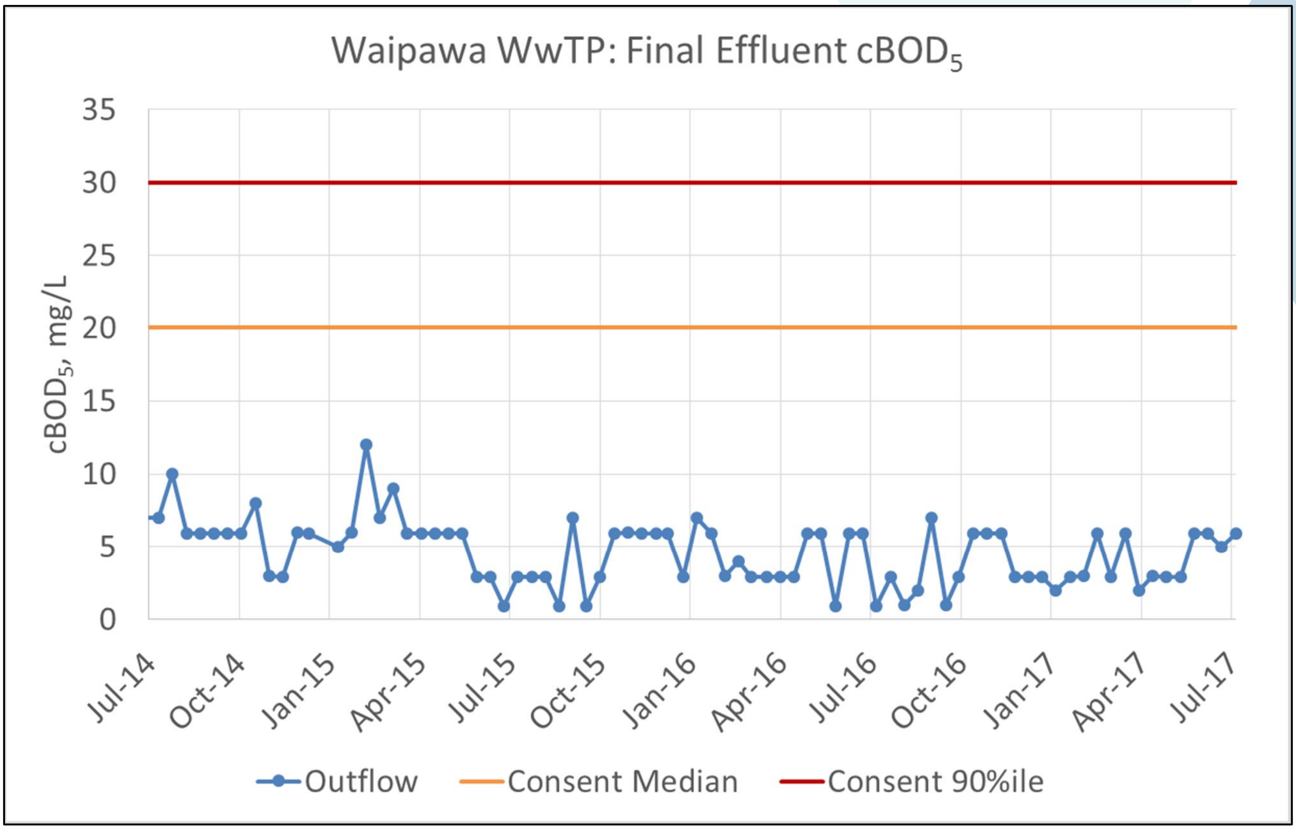

Figure 21: Waipawa WwTP Final Effluent $cBOD_5$, 2014 - 2017

6.1.3 Ammonia

In the 2014/15 and 2015/16 summer periods, the Waipawa WwTP achieved the ammonia resource consent requirements. However, as shown in Figure 22, the WwTP did not achieve sufficient ammonia removal during the corresponding winter periods. In addition, since June 2016, the ammonia resource consent conditions have not been met under either summer or winter conditions.

This deterioration in performance with regard to ammonia is considered likely to be due to one or both of the following factors:

- High rainfall in 2017, resulting in reduced HRTs.
- Clogging of the BAS media, reducing the surface area for nitrifying bacteria to grow on.

Both of these are discussed further in Section 9.1.1.

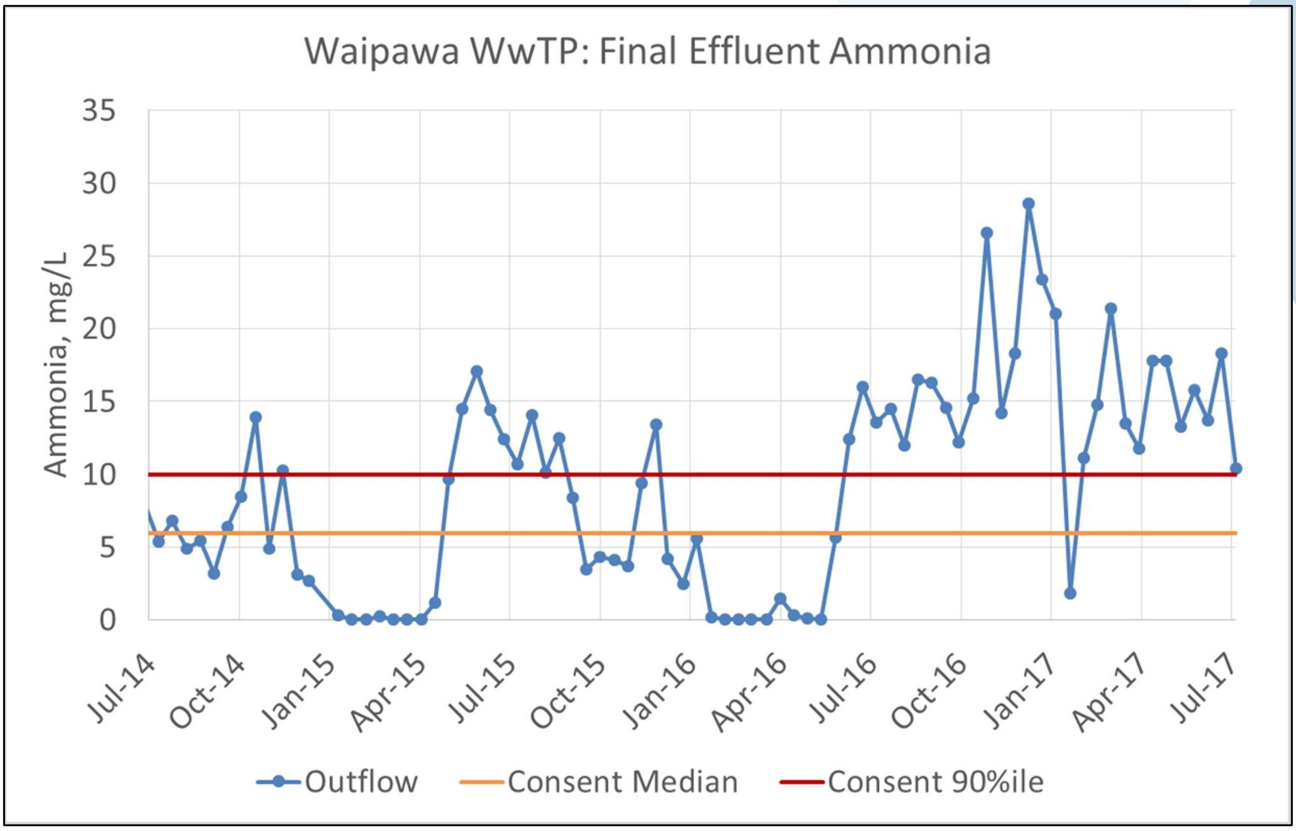

Figure 22: Waipawa WwTP Final Effluent Ammonia, 2014-2017

6.1.4 Soluble Reactive Phosphorous

After the lamella clarifier was installed to reduce the solids loading onto the sand filters, the discharge has generally complied with the SRP resource consent conditions, although with some exceptions. This is shown in Figure 23. The intermittent exceedances of the 90-percentile resource consent condition of 0.5 mg/L are considered likely to be due to a combination of the following two factors:

- Sub-optimal alum dosing at times.
- Wet weather flows resulting in a partial bypass of the tertiary treatment processes.

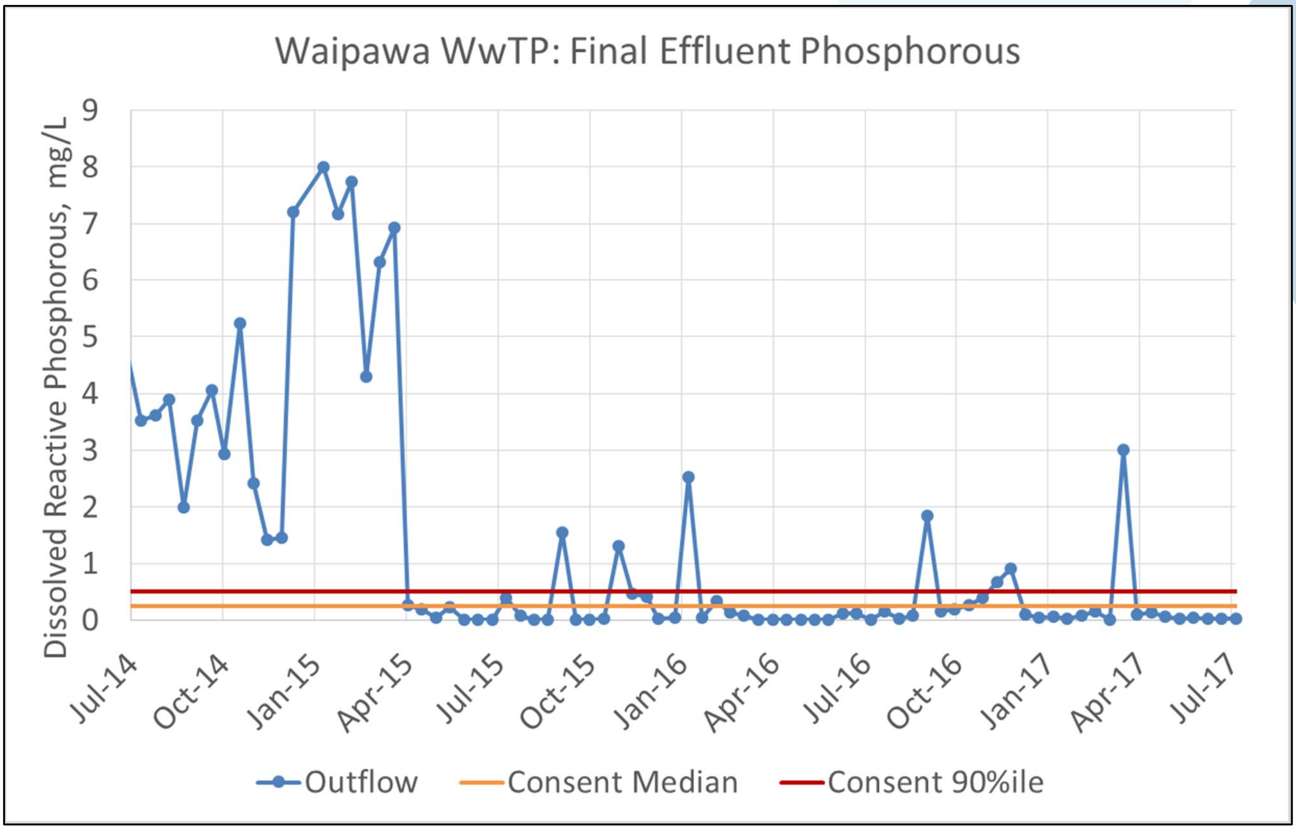

Figure 23: Waipawa WwTP Final Effluent SRP, 2014-2017

6.1.5 Indicator Organisms

Figure 24 indicates the Waipukurau has struggled to achieve the *E. coli* resource consent conditions over the past three years. This is considered likely to be due to a combination of the following factors:

- Sub-optimal alum dosing at times.
- Marginal sizing of the UV disinfection system.
- Partial bypass of the tertiary treatment processes during peak flows.

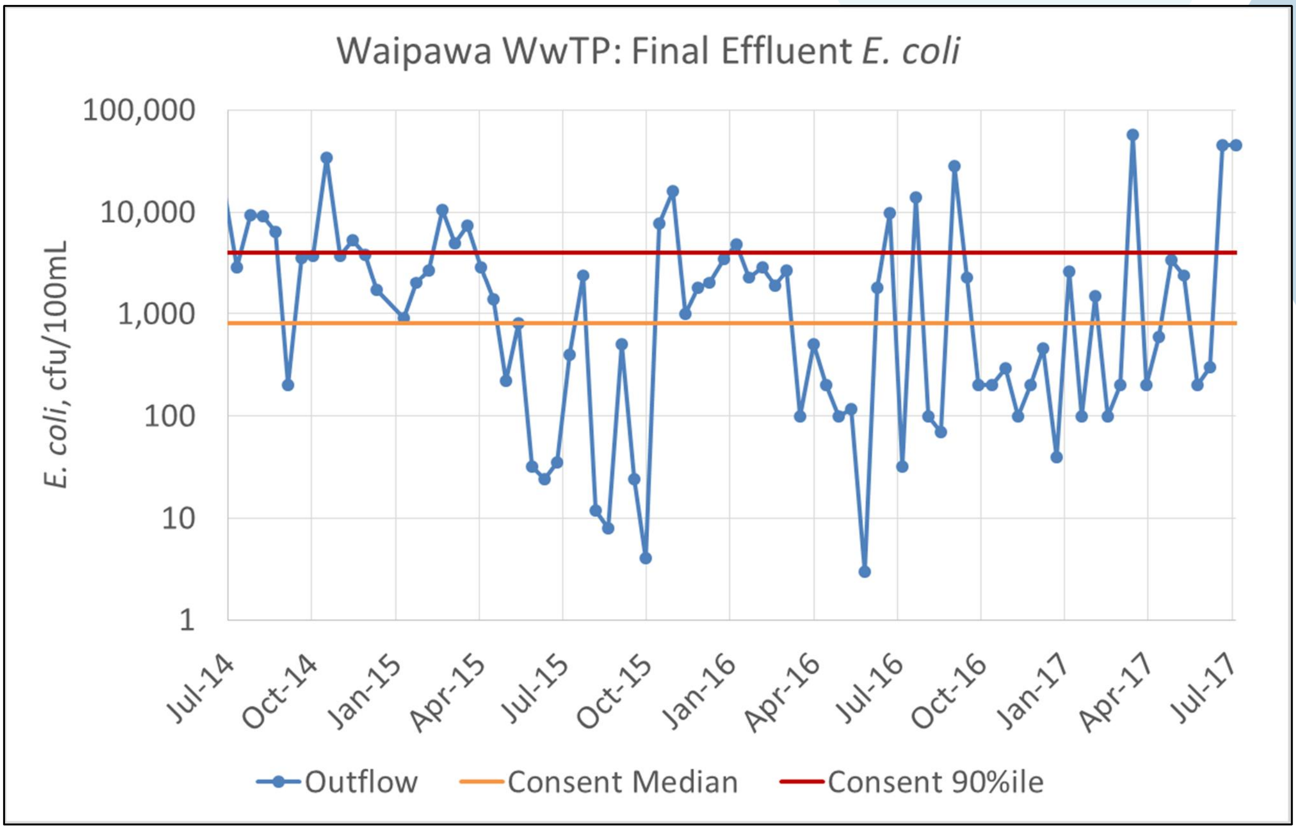

Figure 24: Waipawa WwTP Final Effluent E. coli, 2014-2017

6.1.6 pH

The pH of the effluent discharged from the Waipawa WwTP over the past three years is shown in Figure 25. This shows the pH of the discharge has generally been within the resource consent range of 6.5 to 8.5, although it did drop below the minimum permitted pH in May and June 2016. It is our understanding this drop in pH was due to the change in coagulant from alum to ferric. When the adverse effects on pH were noted and understood, the coagulant was changed back to alum.

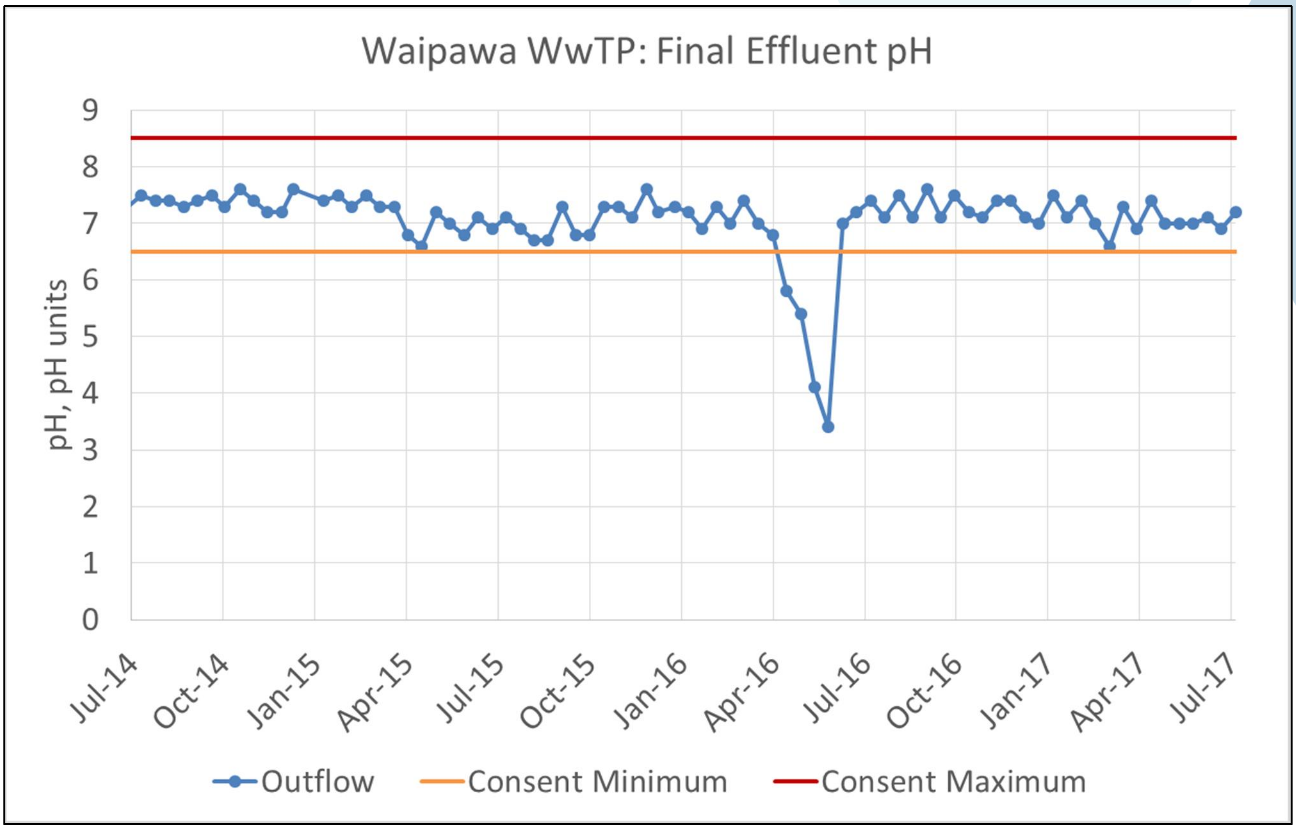

Figure 25: Waipawa WwTP Final Effluent pH, 2014-2017

6.2 Operational Issues

6.2.1 Stormwater Inflow & Infiltration

As shown previously in Figure 17, while the median discharge volume from the Waipawa WwTP is approximately 900 m^3/d, the peak daily discharge is much higher. This is due to stormwater I&I into the wastewater reticulation, and due to rain falling directly onto the ponds. The WSP provides some buffer storage capacity, however when this buffer capacity is exceeded flows in excess of approximately 1,400 m^3/d flow from the modified WSP outlet directly to the discharge manhole, bypassing the tertiary treatment processes. Therefore, the effective process flow diagram for the Waipawa WwTP is as shown in Figure 26. Partial bypass of the lamella clarifier, sand filters and UV disinfection system increase the risk of resource consent non-compliance for TSS, BOD, SRP, and *E. coli*.

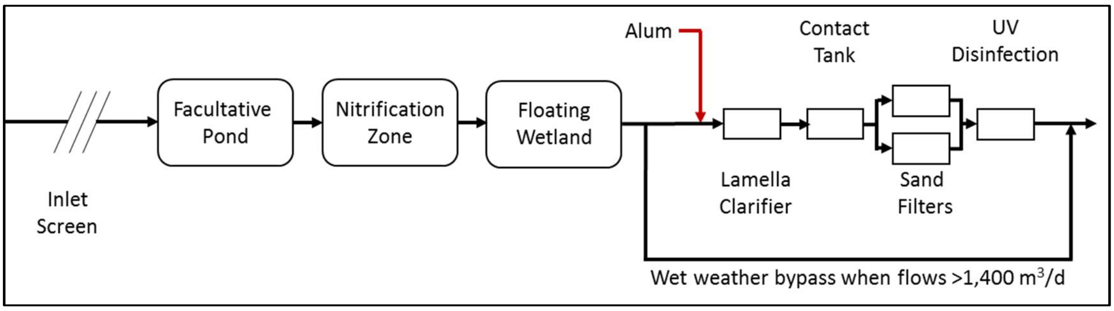

Figure 26: Waipawa WwTP Actual Process Flow Diagram

6.2.2 Sludge Accumulation

Recent work at the Waipawa WwTP suggests a significant amount of sludge appears to have accumulated in some parts of the modified WSP (Crawford, 2017). Accumulated sludge impacts on WSP performance in two ways:

- reducing the pond volume available for treatment, thus reducing the HRT and treatment capacity.
- as organic material in the sludge breaks down anaerobically, nitrogen, in the form of ammonia, and phosphorous, in the form of SRP, are released from the sludge. This increases the load onto the WwTP, and can reduce the quality of treated effluent.

7 Expected Performance - Waipawa

The following sub-sections estimate the expected average performance of the current Waipawa WwTP, assuming that sufficient aeration is provided in each aerobic treatment process to maintain DO concentrations of >2 mg/L. These estimations are based on the estimated average and peak raw wastewater characteristics outlined in Table 20, and the same methods used for estimating the performance of the Waipukurau WwTP outlined in Sections 4.1 to 4.5. These raw wastewater estimations are based on measured Trade Waste characteristics between August 2016 and July 2017, estimated domestic wastewater contributions, and a longer term average discharge flow rate of 990 m^3/d.

Table 20: Estimated Waipawa WwTP Raw Wastewater Characteristics

Parameter	Average		Peak	
	Load, kg/d	Concentration[8]	Load, kg/d	Concentration[8]
TSS	270	273 mg/L	430	434 mg/L
$cBOD_5$	208	210 mg/L	247	249 mg/L
Total nitrogen	37	37 mg/L	56	57 mg/L
Total phosphorous	9	9 mg/L	14	14 mg/L
E. coli, cfu/100mL		10,000,000		

7.1 TSS

The Waipawa WwTP can be expected to achieve treated effluent TSS concentrations of <10 mg/L when effluent flow rates are within the design capacity of the lamella clarifier and sand filters. When wastewater flows exceed the capacity of the tertiary treatment processes, the partial bypass of effluent from the modified WSP to the discharge manhole will likely result in a deterioration in effluent quality. However, historical performance suggests this is unlikely to impact on resource consent compliance for TSS.

7.2 BOD

The current Waipawa WwTP would be expected to achieve average treated effluent sBOD concentrations of <10 mg/L providing sufficient aeration is installed where required. The calculations used to estimate the achievable effluent BOD and aeration requirements are included in Appendix A, and discussed further in Section 10.1.2. With such low sBOD concentrations, average effluent total BOD concentrations of <10 mg/L can also be expected after optimised chemical conditioning and sand filtration (Ratsey, 2016).

When wastewater flows exceed the capacity of the tertiary treatment processes, the partial bypass of effluent from the modified WSP to the discharge manhole will likely result in a

[8] At average annual flow rate

deterioration in effluent quality. However, historical performance suggests this is unlikely to impact on resource consent compliance for BOD.

As with our review of the Waipukurau performance data, the Waipawa WwTP has achieved lower BOD concentrations entering the BAS zone than our modelling predicts. Therefore, as with Waipukurau, the effective first order rate constant, $k_{1(20)}$, appears to be higher than the standard facultative pond value of 0.3 d^{-1}. This suggests the installation of BAS media and aeration is increasing the rate of BOD breakdown beyond what would be expected to be achieved in a standard WSP.

7.3 Ammonia

Using the Pano & Middlebrooks (1982) equations, we estimate summer (20^{o}C) and winter (10^{o}C) ammonia concentrations in the treated effluent of 28 and 31 mg/L respectively at average annual flow rates. These are in reasonable agreement with actual Waipawa WwTP performance over the past year of between 10 to 30 mg/L ammonia in the final effluent. However, treated effluent ammonia concentrations of <1 mg/L were achieved in the 2014/15 and 2015/16 summer periods, indicating that additional ammonia removal is being achieved through nitrification, at times, when sufficient HRT and DO is available for the given temperature.

7.4 Soluble Reactive Phosphorous

Providing the alum dosing is optimised, the SRP concentration in the treated effluent from the Waipawa can be expected to be within resource consent requirements when flow rates are within the design capacity of the lamella clarifier and sand filters. When wastewater flows exceed the capacity of the tertiary treatment processes, the partial bypass of effluent from the modified WSP to the discharge manhole will likely result in exceedance of the SRP resource consent conditions.

7.5 Indicator Organisms

As discussed in Section 4.5, an appropriately sized and operated UV disinfection system can be expected to achieve at least 2 $\log_{10}$ (99%), and more likely 3 $\log_{10}$ (99.9%), reduction in indicator organisms, providing the disinfected effluent is treated to a secondary effluent quality, is relatively low in TSS, and has an adequate UVT. However, data in Figure 27 indicates the UV system at Waipawa has generally not been able to achieve this level of performance.

This historical poor performance of the UV system at Waipawa may be due to a combination of the following factors:

- Flow rates being towards the upper-end of the design capacity of the UV system of 1,600 m^3/d.
- High design UVT of 60%.
- Sub-optimal chemical conditioning at times.
- Insufficient maintenance of the UV system.

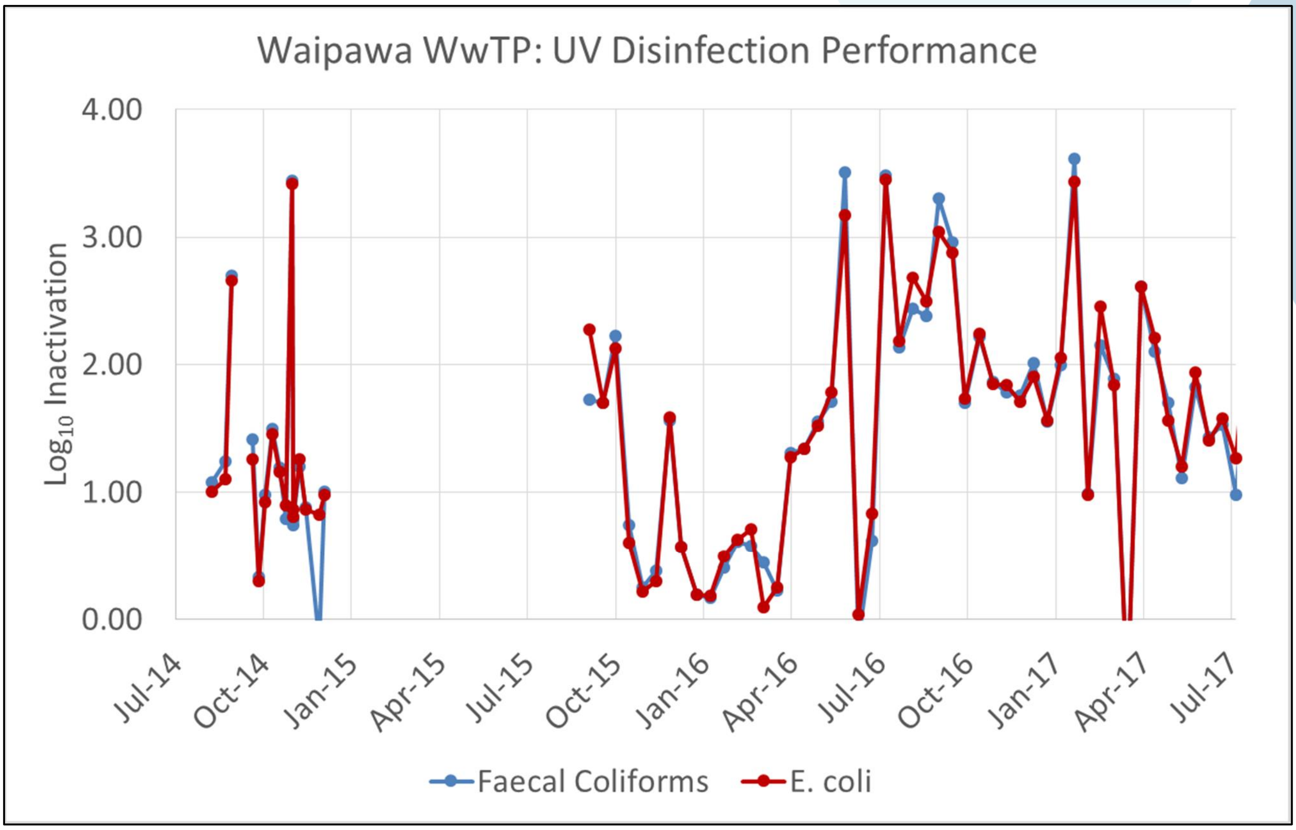

Figure 27: Waipawa WwTP UV System Performance

Providing the lamella clarifier and sand filters are being operated effectively (optimised chemical conditioning, operating within hydraulic capacity, optimised sludge withdrawal) producing an effluent with low TSS and high UVT, and necessary maintenance has been undertaken on the UV system (lamp replacement, sleeve cleaning, wiper replacement etc), it should be possible to achieve at least 2.5 $\log_{10}$ *E. coli* removal through the Waipawa UV system. However, historical performance suggests this may not be possible. Further investigations are required to better understand the historical poor performance of the UV system at Waipawa WwTP.

In addition, when wet weather flows result in partial bypass of the tertiary treatment processes, significant increases in treated effluent *E. coli* concentrations are likely to occur. Based on historical *E. coli* concentrations in the modified WSP effluent, this is likely to result in resource consent non-compliance for *E. coli*, even if the UV system is effectively disinfecting the post-sand filter effluent.

8 Expected Performance Summary

The Council resolution required a report on the appropriateness of the Waipukurau and Waipawa wastewater treatment systems and their ability to meet current resource consent requirements. Table 21 and Table 22 summarise the ability of the existing Waipukurau and Waipawa WwTPs to achieve resource consent compliance at current residential and Trade Waste demands, and projected growth.

Table 21: Can the existing Waipukurau WwTP achieve Resource Consent Compliance?

Parameter	Current Flow & Load[9]	Future Flow & Load[9]
Flow, m^3/d	Marginal	Marginal
$cBOD_5$, mg/L	Yes	Yes
TSS, mg/L	Yes	Yes
Ammonia, mg/L	No	No
SRP, mg/L	Yes	Yes
E. coli, cfu/100mL	Yes	Yes
pH	Yes	Yes

Table 22: Can the existing Waipawa WwTP achieve Resource Consent Compliance?

Parameter	Current Flow & Load[9]	Future Flow & Load[9]
Flow, m^3/d	Marginal	Marginal
$cBOD_5$, mg/L	Yes	Yes
TSS, mg/L	Yes	Yes
Ammonia, mg/L	No	No
SRP, mg/L	Yes	Yes
E. coli, cfu/100mL	Marginal	Marginal
pH	Yes	Yes

[9] Providing additional lamella, sand filter and UV capacity is installed to effectively treat the PWWF, or stormwater I&I is significantly reduced so peak flows are within the hydraulic capacity of these tertiary treatment processes

9 Improvement Options – Long Term

As summarised in the previous section, the existing treatment plants can be expected to meet some of the consented effluent quality parameters (BOD, TSS, pH). If additional tertiary treatment capacity (lamella clarifiers, sand filters, UV disinfection) is installed and tertiary treatment processes are optimised, resource consent compliance for SRP and *E. coli* can also be expected. However, the existing Waipukurau and Waipawa WwTPs cannot be expected to meet the resource consent conditions for ammonia.

Therefore, the improvement options discussed in the following sub-sections focus on ammonia removal. While this section focuses on ammonia removal, consideration should also be given to likely future resource consent conditions when assessing upgrade options. For example, the current Waipukurau and Waipawa WwTP resource consents don't include conditions on other forms of nitrogen, such as total nitrogen or nitrate, but it is possible that limits could be placed on such contaminants in future resource consents.

9.1 Further Modifications

A plethora of upgrade technologies are being promoted within New Zealand to enhance the performance of WSPs. Ratsey (2016) collated a summary of these technologies. Few of the available upgrade technologies focus on achieving enhanced ammonia removal. Those that are promoted for ammonia removal are summarised in the following sub-sections.

It must be stated that modifications to WSPs to enhance ammonia removal are still reliant on natural treatment processes. While natural treatment processes have advantages such as lower operational costs, they also come with disadvantages, in particular a lack of control. This increases the risk of WSP modifications not achieving the required level of ammonia removal, as CHBDC have experienced with modifications of the Waipukurau and Waipawa WwTPs to date.

Therefore, while further modifications to the existing Waipukurau and Waipawa WSP-based WwTPs are possible, the risks of pursuing such options should be considered carefully.

9.1.1 Attached Growth Media

The theory of attached growth media for enhanced nitrification in WSPs appears to be sound, however the New Zealand experience of this technology has been less favourable. In theory, by providing sufficient media surface area for nitrifying bacteria to grow on, and by providing sufficient oxygen for the bacteria to nitrify the ammonia to nitrate, it should be possible to achieve low effluent ammonia concentrations.

The Waterclean BAS process is one type of attached growth process available in New Zealand. The most widely adopted alternative is the AquaMat system, for which Brickhouse Technologies is now the New Zealand agent. Several WSPs in New Zealand have been upgraded with AquaMats over the past decade or so, including Te Kauwhata, Raglan, Matamata and Whatuwhiwhi. The performance of WSPs upgraded with AquaMats in New Zealand has been variable, although consistently low effluent ammonia concentrations were achieved at Te Kauwhata in the first few years after upgrade to AquaMats technology.

To put the challenge of attempting to achieve reliable, year-round nitrification at the Waipukurau and Waipawa WwTPs using attached growth media into context, Table 23 compares some key parameters of the Waipukurau, Waipawa and Te Kauwhata WwTPs.

Table 23: Comparison of Waipukurau, Waipawa and Te Kauwhata WwTPs

Parameter	Waipukurau	Waipawa	Te Kauwhata
Average daily flow, m^3/d	2,130	988	700
Significant industrial load?	Yes	No	No
Average BOD load, kg/d	620	208	175
Minimum winter pond temperature, ^oC	7	7	9
Overall WSP area, ha	3.3[(10)]	2.3	1.5
Average depth, m	1.5	1.5	2.0
Overall WwTP volume, m^3	47,000	34,000	30,000
Average overall HRT, days	22	34	51
Modified WSP loading, kgBOD/ha.d	94[(11)]	90	117
Installed BAS surface area, m^2	26,660[(12)]	12,800[(12)]	17,800
BOD loading per BAS surface area, $gBOD/m^2$	12	16	10
Duty blower capacity, Nm^3/hr	140	140	560
Duty blower capacity, Nm^3/m^2 BAS.d	0.13	0.26	0.76

In comparison to Te Kauwhata, the Waipukurau BAS zone is operating at a colder winter temperature, a considerably shorter hydraulic retention time (HRT), a higher BOD loading per attached growth surface area, and with considerably less aeration than the Te Kauwhata AquaMats system. Therefore, it is no surprise that the Waipukurau WwTP is performing so poorly with regard to ammonia removal. Of these, the much shorter HRT is considered likely to be the most significant obstacle to reliable ammonia removal.

In comparison, the Waipawa WwTP is generally operating at a longer HRT than Waipukurau, and with greater aeration per BAS surface area. This combination of factors likely explains the better historical performance of the Waipawa compared with Waipukurau. The significant impact of stormwater I&I on HRT through the Waipawa WwTP in 2017 is considered likely to be a key reason why the ammonia removal observed in summer 2014/15 and 2015/16 was not repeated in the summer of 2016/17. This is shown in Figure 28. At shorter HRTs, there is simply not enough time

[10] Including SFBFP
[11] Assuming 50% BOD removal through the anaerobic pond
[12] Waterclean (2012)

to either maintain a population of nitrifying bacteria in the treatment plants, or for the nitrifiers to break down the ammonia.

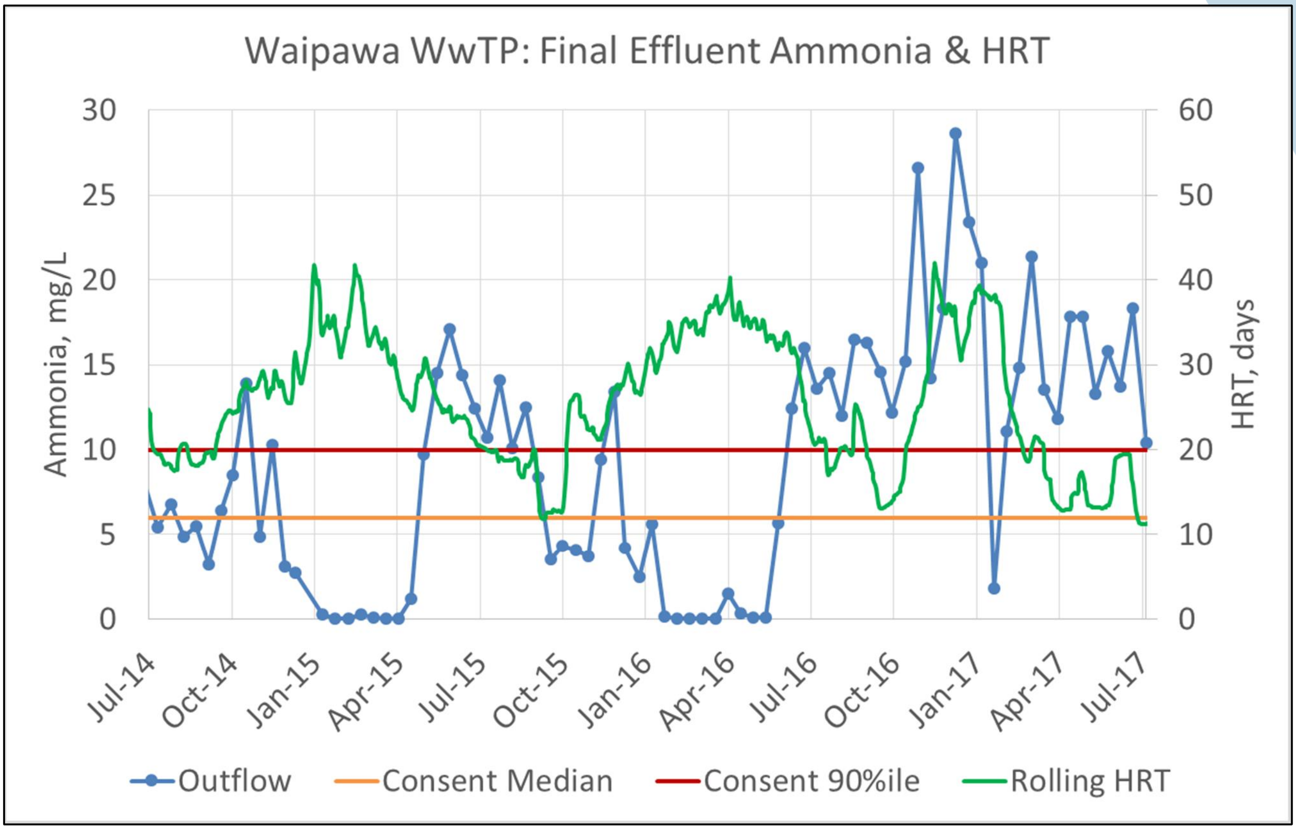

Figure 28: Waipawa WwTP Final Effluent Ammonia and HRT

It is possible that clogging of the BAS media may have also contributed to the deterioration in ammonia removal at Waipawa in the summer of 2016/17. The design of BAS systems, and other attached growth treatment processes, generally relies on both external and internal media surface area being available for microorganisms to grow on. If the BAS media becomes clogged and the internal surface area is no longer available for active biomass, the effective surface area reduces by a factor of 10. In turn, the treatment capacity is considerably reduced.

In attached growth treatment processes such as trickling filters, submerged aerated filters or, to a lesser degree, AquaMats, kinetic energy is provided by the movement of either liquid and/or air across the media surface. This movement encourages "sloughing" of the biomass. Sloughing is the removal of dead biomass from the surface of the media, enabling the regrowth of active biomass. In the Waterclean BAS system, the BAS curtains are closely spaced, and minimal mixing energy is provided. Therefore, this reduces the potential for sloughing of old biomass to occur, increasing the likelihood of media clogging.

As discussed in Section 4.3, the relatively high pre-BAS BOD concentrations would be expected to encourage the growth of heterotrophic bacteria on the BAS media. Growth of heterotrophic bacteria would accelerate clogging of the media.

Suppliers of attached growth media products may still claim to be able to effectively meet the Waipukurau and Waipawa resource consent conditions for ammonia. Given the New Zealand experience, both in Central Hawkes Bay and elsewhere, we consider further attached growth modifications to be a high risk option.

9.1.2 Bio-domes and Bio-shells

Bio-domes and Bio-shells (Bio-domes), shown in Figure 29, are additional attached growth modifications promoted for use in WSPs. Originally from the USA, Bio-domes are now offered in New Zealand by Marshall Projects, however we are unaware of any operational Bio-dome installations in NZ at this time.

While, as with BAS and AquaMats, the theory behind Bio-shells appears to be sound, we are concerned that this technology would likely retain the unpredictability of other attached growth WSP modifications. Therefore, we consider further modification of the Waipukurau or Waipawa WwTPs using Bio-domes or any other attached growth process to be a high risk option.

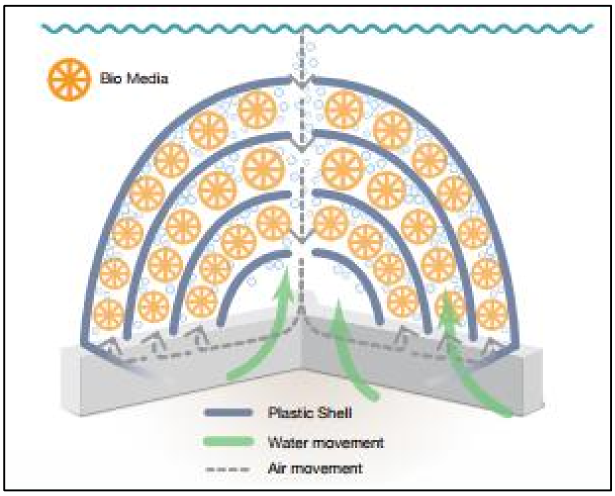

Figure 29: Bio-dome (WCS, undated)

9.1.3 Nitrifying Filters

The concept of upgrading WSPs with nitrifying filters is similar to the use of attached growth media to enhance nitrification. Nitrifying filters typically use a rock media, although a plastic media could be used. As with a BAS-type process, the media provides a surface area for nitrifying bacteria to grow on, thus enhancing the nitrification capacity.

Nitrification filters can be either within the confines of existing WSPs, or external constructions. When constructed within existing WSPs, a portion of the WSP effluent is sprayed over the surface of rocks which can be located on existing pond embankments. However, Archer & O'Brien (2004) concluded that while such nitrifying filters can increase nitrification during summer, unrealistically large areas of rock filters would be required to provide effective nitrification during cooler winter temperatures.

Externally constructed nitrifying filters are essentially low rate trickling filters (TF). A portion of the WSP effluent is distributed over the surface of the TF, and is returned to the pond after it has passed through the TF. The result, known as the PETRO® process, is shown in Figure 30.

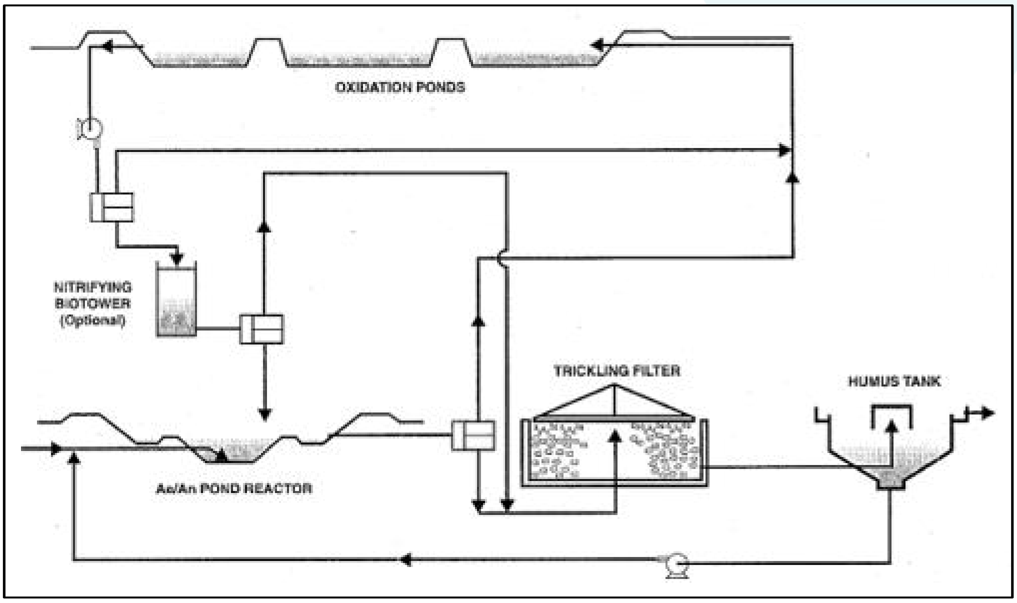

Figure 30: PETRO® Process Schematic (Shipin et al. (1998))

Reported performance of the Petro® process in South Africa has been good (Shipin *et al*. (1998)) and, like the BAS-type process, the theory appears to be sound. We would, however, be concerned that a PETRO® process would not reliably achieve the necessary year-round nitrification at the low winter temperatures experienced in Waipukurau and Waipawa. This would also not address the potential for the existing modified WSPs to generate odours.

9.1.4 BioFiltro

The BioFiltro treatment process is a vermifiltration (worm-based) process which Clutha District Council (CDC) have installed to polish effluent from several of their WSP systems. The mechanism for ammonia removal through a BioFiltro plant is the same as through a BAS-type process or a nitrifying filter; additional surface area is provided for nitrifying bacteria to grow on.

Performance of the CDC BioFiltro systems with regard to ammonia removal has been variable, although the most lowly-loaded of these installations does achieve consistent effluent ammonia concentrations of <6 mg/L (Ross, 2016). This suggests that a BioFiltro process could be added to the Waipukurau and/or Waipawa WwTPs, however the footprint of a BioFiltro process would be much larger than a PETRO® process. As with the PETRO® process, BioFiltro would not address the potential for the existing modified WSPs to generate odours.

9.1.5 Alternative Aeration Systems

Aqua Infrastructure, the New Zealand manufacturer and supplier of the Aquarator, suggest the Aquarator can enhance nitrification in WSPs (Okan, 2017). If, as claimed by Aqua Infrastructure, the Aquarator provides greater oxygen transfer efficiency than other aerators, this has the potential to increase DO availability in WSPs. Increased DO availability does not necessarily translate to enhanced nitrification. Heterotrophic bacteria have the first use of DO in aerobic wastewater treatment processes to break down BOD. After the oxygen demand for BOD removal has been satisfied, then nitrifying bacteria may be able to utilise any remaining DO to convert ammonia to nitrate. Our modelling of BOD removal through the Waipukurau WwTP, shown in Appendix 1, suggests it is unlikely to be possible to break down the BOD quickly enough through the anaerobic pond, SFBFP and facultative pond to allow nitrification to occur in the BAS zone. In addition, the reduced winter HRTs resulting from significant stormwater I&I in Waipawa also makes it unlikely to be able to achieve reliable nitrification, even with additional aeration.

9.1.6 Alternative Products

CHBDC have recently been approached by a range of suppliers offering solutions to the reported issues at Waipukurau WwTP. These include:

- BioBrew
- Sustainable Infrastructure Solutions
- AlgaeEnviro

The products offered by each of these suppliers are discussed in the following sub-sections. An additional alternative product, the dosing of nitrifying bacteria to the WSP, is also discussed.

9.1.6.1 BioBrew

BioBrew are a New Zealand-based company that produce fermentative bacteria through a multi-stage fermentation process. They propose dosing approximately 1,000 L of their product into the Anaerobic Pond at Waipukurau. Their aim would be to change the biology in the Anaerobic Pond from putrescent to fermentative, and believe this may significantly reduce H_2S concentrations in the Anaerobic Pond outlet (Pearson, 2017). If the product was effective, they would expect to see a significant reduction in H_2S within a week. If no improvement occurred within this timeframe, they consider it unlikely it would do so. From discussions with BioBrew, it is possible that the loading onto the SFBFP may increase if the product does effectively reduce H_2S, which may exacerbate the current overloading of the SFBFP.

While we are not familiar with this technology, we consider it unlikely that significant reductions in odour would be achieved by dosing this product into the Anaerobic Pond. Even if it did significantly reduce odour issues, it would not be expected to reduce treated effluent ammonia concentrations.

9.1.6.2 Sustainable Infrastructure Solutions

From the information supplied we understand Sustainable Infrastructure Solutions (SIS) are an Australian-based company, who provided case studies from South African WwTPs. The main two products offered are “RemediaTOR” enzyme formulation, and a proprietary aeration system (HEADs).

From a brief review of the information provided, the RemediaTOR enzyme formulation appears to be a similar product to that offered by both Parklink and EcoTabs in New Zealand. Suppliers of enzyme formulations claim their products accelerate the breakdown of organic sludge by solubilising organic material bound up in solids/sludge, making the molecules more available to naturally occurring bacteria. Some suppliers, such as SIS, add the enzymes directly, while others add a mix of microorganisms conditioned to produce the enzymes.

Historically there has been little hard data available to back up suppliers claims regarding the effectiveness of enzyme technology, with suppliers typically using visual comparisons to "demonstrate" the effectiveness of their products. Recently we have been involved in a project which suggests such enzymes can accelerate the breakdown of sludge in WSPs in some circumstances. However, such accelerated sludge breakdown has resulted in a deterioration in treated effluent quality, as would be expected if the product works as the suppliers claim. RemediaTOR, or similar products, would not be expected to either reduce odours or effluent ammonia concentrations at the Waipukurau WwTP.

As discussed in Section 3.2.1, the odour issue at Waipukurau is believed to be primarily due to low DO concentrations in the SFBFP. Even with the addition of more mechanical aeration, it has not to date been possible to raise DO concentrations in the SFBFP, with the DO concentration generally being 0.2 to 0.3 mg/L. DO concentrations >1 mg/L are expected to eliminate the odour problems through oxidation of the odorous compounds. Therefore, more aeration is required in the SFBFP. SIS's HEADs aeration system is one of many options to provide more aeration in the SFBFP, although we are not familiar with the HEADs aeration system so cannot comment on its likely efficiency. Aeration system suppliers generally claim the oxygen transfer efficiency of their products is superior to other systems. Generally suppliers are not able to provide sound evidence to support such claims.

While the HEADS aeration system, or other aeration systems, would be expected to reduce odours providing adequate DO concentrations can be achieved in the SFBFP, achieving aerobic conditions in the SFBFP is not expected to significantly reduce ammonia concentrations in the treated effluent at Waipukurau.

9.1.6.3 AlgaeEnviro

AlgaeEnviro are also Australian-based, and supply a product called "Diatomix". From the information provided, the aim of Diatomix appears to be to promote the growth of green algae, thus suppressing the growth of blue-green algae (cyanobacteria). High algal concentrations can be beneficial to WSP processes because they provide oxygen through photosynthesis. AlgaeEnviro also claim that nutrients assimilated into algal biomass are then moved up the food chain to be removed from the wastewater.

Waipukurau does not have a blue-green algae issue. It is considered unlikely that addition of Diatomix into the SFBFP could provide sufficient DO to effectively break down the BOD load aerobically. Therefore, dosing Diatomix is not expected to reduce odours. It would also not be expected to reduce ammonia concentrations in the treated effluent.

9.1.6.4 Nitrifying Bacteria Addition

While CHBDC have not been approached by suppliers of nitrifying bacteria, such suppliers do exist in New Zealand, including Parklink and Environmental Leverage. The concept of adding nitrifying bacteria to WSPs is to provide a population of nitrifying bacteria that wouldn't naturally establish due to insufficient HRT. This population of nitrifying bacteria can then, theoretically, convert ammonia to nitrate through nitrification.

Addition of nitrifying bacteria at Waipukurau is unlikely to effectively reduce effluent ammonia concentrations to within resource consent requirements due to:

- The high residual BOD concentration in the facultative pond. The nitrification of ammonia to nitrate will only happen after most of the BOD has been broken down.
- The cold winter temperatures in the WSPs at Waipukurau. Environmental Leverage have indicated in previous discussions that it is extremely difficult to maintain a nitrifying population at WSP temperatures <10^{o}C, even with supplementary additional of nitrifying bacteria.

9.2 Activated Sludge

"Activated sludge" (AS) is a generic term given to a group of suspended growth treatment processes that include, amongst others, sequencing batch reactors (SBRs), membrane bioreactors (MBRs), oxidation ditches, and extended aeration plants. "Activated sludge" refers to the biomass, comprising bacteria, protozoa and small animals, which develops in the treatment process.

One of the key differentiating factors between AS processes and modified WSPs is the complete separation of HRT and solids retention time (SRT), or sludge age, in the activated sludge process. This allows an AS process to be operated at a sludge age which enables nitrifying bacteria to remain established in the biomass, all year round. A sludge age of at least 8 to 10 days is typical for a nitrifying AS plant. By maintaining a nitrifying biomass, treated effluent ammonia concentrations from a nitrifying AS plant are comfortably <6 mg/L, and typically <1 mg/L.

While AS processes can reliably provide a higher overall level of treatment than WSP-based plants, they do have disadvantages. These disadvantages include:

- Increased power requirements for aeration and pumping.
- Poorer *E. coli* and other indicator organism removal. This can, however, be mitigated through installation of a larger UV disinfection system.
- The generation of waste activated sludge (WAS) which requires removal and processing on a continual basis.
- More complex operation, which requires more skilled and more frequent Operator input.

However, as well as providing reliable ammonia removal, AS processes can provide other advantages. These advantages include:

- Lower effluent TSS concentrations and less reliance on the tertiary filters.
- Low effluent total nitrogen and nitrate concentrations, if configured for nitrogen removal.

- Low effluent phosphorous concentrations, if configured for phosphorous removal as well as nitrogen removal.
- Greater Operator control of the treatment process.

Much of the existing Waipukurau WwTP could likely be incorporated into an AS-type plant. While further optioneering and preliminary design would be required to determine the most appropriate activated sludge system for Waipukurau, one option may be as follows:

- Retain the existing inlet screens.
- Install a new grit removal system.
- Convert the Anaerobic Pond to an SBR, although the fact that this pond doesn't currently have gas relieving underdrains would require remediation.
- Use the SFBFP as a post-SBR buffer pond, although this may require a pumped decant from the SBR. Again, retrofitting of gas relieving underdrains would likely be required.
- Install new pumps to pump from the post-SBR buffer pond to the lamella tube settlers and/or the sand filters.
- Retain the lamella tube settlers and/or existing sand filters for tertiary filtration, with chemical conditioning, although additional filtration capacity may be required.
- Retain the existing geobags for dewatering the reject flow from the lamella tube settlers and/or sand filters.
- Retain the existing UV system for disinfection, however it may be necessary to upgrade the UV system to achieve reliable disinfection.
- Install a new dewatering system for dewatering the WAS which would be produced by an activated sludge process.
- Create a biosolids monofill in the existing facultative pond for dewatered sludge storage. However, this may be a risky option due to the history of odours at the Waipukurau WwTP and the proximity of neighbours.

9.3 Trade Waste Control

Trade Waste dischargers contribute a significant wastewater load to both the Waipukurau and Waipawa WwTPs. The estimated average contribution of the major industries to the two WwTPs for the 12 months to July 2017 is shown in Table 24. This is based on the estimated current domestic loads presented in Sections 2.5.3 and 5.4.3, and the industrial flows and loads presented in Sections 2.5.4 and 5.4.4.

Table 24: Industry Contribution to Wastewater Flow and Load (August 2016 to July 2017)

	Flow (DWF)	TSS	BOD	TN	TP
Waipukurau	13%	18%	46%	44%	25%
Waipawa	12%	30%	17%	27%	30%

Therefore, while industries only contribute 12 to 13% of the DWF to the Waipukurau and Waipawa WwTPs, they contribute a far higher percentage of the contaminant loads. At Waipukurau, industries contribute nearly half of the average total contaminant loads requiring treatment. If the industries discharged their maximum consented flows and loads, this percentage contribution would be higher still. This demonstrates the significance of industrial discharges on both the Waipukurau and Waipawa WwTPs.

Irrespective of the treatment processes used at the Waipukurau and Waipawa WwTPs in the future, the wastewater flow and load discharged by industries will impact on the overall cost of treatment. This, in turn, will impact on the per unit rate for treatment charged by CHBDC to the trade waste dischargers. For example, the current unit rate of $1.96 per kg nitrogen discharged into the Waipukurau network will likely increase in the future, particularly if activated sludge technology is adopted. Similarly, other unit rates will also likely increase. With such increases in trade waste charges, it may become more cost effective for industries to undertake further pre-treatment on site, thus reducing the load discharged to the WwTPs. The most appropriate pre-treatment option for each industry will be site specific.

In Waipawa, the two significant trade waste dischargers are both truck washes, which contribute a significant proportion of the total wastewater load. Simple pre-treatment of truck wash wastes can remove large quantities of TSS and associated nitrogen and phosphorous. Figure 31 shows such a screen set up at a truck wash in the Waikato.

Figure 31: Truck Wash Screening

On its own, reducing wastewater loads from industries is unlikely to result in resource consent compliance being achieved at either Waipukurau or Waipawa.

9.4 Stormwater I&I

I&I of stormwater and/or groundwater into the wastewater reticulation in both Waipukurau and Waipawa significantly increases wastewater volumes requiring treatment. This was shown earlier in Figure 4 and Figure 19. The ratio between peak wet weather flow (PWWF) and DWF at Waipukurau and Waipawa is approximately 8:1 and 11:1 respectively, although these are based on pond outflows so may be somewhat skewed due to rain falling directly onto the ponds. These are considered to be very high peaking factors. A reasonably tight gravity wastewater reticulation system would be expected to have a peaking factor of approximately 3:1.

The impact these peaking factors have on the HRT through the WwTPs is very significant, in particular for Waipawa. The Waipukurau average HRT of 22 days is relatively short for a WSP-based WwTP, so it is considered unlikely that the current Waipukurua WwTP would reliably achieve any significant nitrification. However, at average daily flow, the HRT through the Waipawa WwTP is notably longer, at 34 days. At an HRT of 34 days, an appropriately designed and operated modified WSP could be expected to provide some nitrification, as suggested by the performance of the Waipawa WwTP in the 2014/15 and 2015/16 summer periods. As discussed in Section 9.1.1, the significantly reduced HRTs due to high rainfall and subsequent stormwater I&I are considered likely to be a contributing factor to the high effluent ammonia concentrations in the summer of 2016/17. Historical performance of the Waipawa WwTP suggests that significant tightening of the sewer reticulation network may improve ammonia removal through the existing Waipawa WwTP, at least during summer. During colder winter temperatures, reliable ammonia removal is still unlikely to be achieved.

Stormwater I&I, and rain falling directly onto the WSPs, also results in discharge flow rates exceeding the capacity of the tertiary treatment processes at both Waipukurau and Waipawa WwTPs. This results in the partial bypass of post-WSP effluent to the discharge manhole during significant wet weather events. This partial bypass increases the risk of exceeding the resource consent conditions for TSS, BOD, SRP and *E. coli*.

9.5 Alternative Effluent Disposal

The cost implications of upgrading and/or replacing the existing Waipukurau and/or Waipawa WwTPs with activated sludge plants that would provide reliable year-round ammonia removal are significant. Therefore, CHBDC requested consideration be given to alternative effluent disposal methods. The resource consents for Waipukurau and Waipawa stipulate low treated effluent ammonia concentrations because the current discharges are to river, and ammonia is toxic to aquatic life at relatively low concentrations. If treated effluent were to be irrigated to land, effluent ammonia concentrations may not be so critical. Nitrogen and phosphorous are essential nutrients required for plant growth. Therefore, an appropriately designed and operated irrigation scheme can provide nutrient uptake into crops, although leaching of nitrogen to groundwater, in the form of nitrate, is a significant concern with effluent disposal schemes.

HBRC owns a total of 196 ha of land which was purchased for irrigation of treated effluent and has been planted with Eucalypt trees. Of this 196 ha, 164 ha is deemed to be irrigable (CPG, 2009), with 103 irrigable hectares in the vicinity of the Waipukurau WwTP, and 61 irrigable hectares in the vicinity of the Waipawa WwTP.

Several reviews of effluent disposal to land for Waipukurau and Waipawa have been undertaken. The amount of land required for sustainable effluent irrigation varied from reviewer to reviewer, as summarised in Table 25.

Table 25: Summary of Irrigable Area Required

Reviewer	Waipukurau	Waipawa	Source
CPG	196	75	CPG, 2009
Good Earth Matters	200 - 420	100 - 140	GEM, 2009
URS	200	58	GEM, 2009
Duffills	210	83	GEM, 2009
HBRC Eucalypt Plantations	103	61	CPG, 2009

Therefore, these reviews suggest that the amount of land purchased by HBRC and planted in Eucalypts is insufficient for sustainable effluent irrigation for Waipukurau and Waipawa. In addition, the suitability of the HBRC land has been questioned due to relatively steep slopes and the soil types (GEM, 2009).

Despite the limitations of the existing HBRC-owned land, irrigation of treated effluent to land is still a potential alternative option, and requires consideration.

9.6 Summary of Long-Term Options

The most reliable long-term option to provide year-round ammonia removal for both Waipukurau and Waipawa is AS-based treatment. This is a low risk but high cost option.

Given the short HRT through the Waipukurau WwTP, the significant industrial wastewater contributions, and the resulting high wastewater loads, AS is considered to be the only viable option for Waipukurau.

A higher risk but potentially viable option for Waipawa is further modification of the existing WSP-based WwTP. For this to be a viable option, the following would likely be required:

- Very significant reductions in stormwater I&I into the wastewater reticulation.
- Reduction in wastewater loads from industries.
- Construction of an additional modified WSP-based process or processes, such as attached growth media (BAS/AquaMats/Bio-domes) or BioFiltro.
- Proactive operation and maintenance (O&M) to maintain low sludge levels in the WSP and adequate aeration.

9.7 Preferred Long-Term Option

Given CHBDC's and the wider New Zealand experience with the unpredictability of modified WSPs, our preferred long-term option to provide reliable ammonia removal for both Waipukurau and Waipawa is AS-based treatment. This is a low risk but high cost option.

9.8 Cost Estimates

Beca has undertaken rough order cost estimates for the following options:

- Conversion of the existing Waipukurau WwTP to a SBR-based AS plant.
- Construction of a new AS-based WwTP at Waipawa.
- Construction of a new AS-based WwTP at Waipukurau to treat wastewater from both Waipawa and Waipukurau, including necessary pumping and reticulation.
- Construction of a new AS-based WwTP at Waipawa to treat wastewater from both Waipawa and Waipukurau, including necessary pumping and reticulation.
- Effluent disposal to land.

These rough order cost estimates are presented in Table 26.

Table 26: Rough Order Capital Cost Estimates (Crawford, 2017)

	Waipukurau	Waipawa	Combined
Separate new or modified AS-based WwTPs	$8.6 - $11.6 M	$5.2 - $8.0 M	$13.8 - $19.6 M
Combined AS-based WwTP at Waipukurau			$11.9 - $20.2 M
Combined AS-based WwTP at Waipawa			$11.9 - $20.2 M
Effluent disposal to land			$36 M

It should be noted that these costings are rough order cost estimates, with significant uncertainties in all of the cost estimates. These rough order cost estimates are provided to give CHBDC indicative costs associated with the different options. For the preferred option or options, more detailed and robust cost estimates should be undertaken, including capital cost (Capex), operational cost (Opex), and net present value (NPV) costs. Operational costs associated with activated sludge-based WwTPs are considerably higher than for modified WSPs.

Cost estimates have not been undertaken for further modifications to the current WSP-based WwTP at Waipawa, but such costs would still exceed $1 M and would come with a higher risk of failure. To put the likely cost of further WSP modifications at Waipawa into context:

- Contract price for 2014 Waterclean modifications at Waipawa was $2.1 M.
- 2012 estimate for supply and installation of BioFiltro at Waipawa was $1.85 M.

In deriving the rough order cost estimates shown in Table 26, Beca made the following key assumptions:

- Rough order costs are based on a population flow and BOD load only, with reference to historical rates and no appreciable design analysis undertaken.
- For Waipukurau the upper and lower numbers represent different population equivalents, one based on flow and the other based on load.
- Key treatment plant components have been estimated using data for similar components from previous jobs with all historical costings indexed forward to 2017 values.
- Option 3a assumes the Waipawa flow is routed via the highway and bridges to a new plant at the Waipukurau site.
- Greenfield site 3b assumes two river crossings and a reasonably direct route from each existing to the new WwTP.
- Contract preliminary and general (P&G) costs; 15%
- Fees & Council costs; 18%
- Land Price; $20,000/ha
- Gross land area required for irrigation disposal is 2 x the net area requirement
- Allowable irrigation rate is assumed to be 30mm/week for 8 months/year

- Risk and Uncertainty contingency applied; 40%

Cross checks for treatment plant options have been made using a nomograph of historical full build treatment plant costs.

10 Waipukurau Improvement Options – Short Term

The short-term options discussed in the following sub-sections would not be expected to significantly reduce ammonia concentrations in the treated effluent, but they would address the operational issues outlined in Section 3.2.

10.1 Odour

10.1.1 Odour Prevention

10.1.1.1 Inlet Screens

The recently installed inlet screens discharge captured screenings into an uncovered chute, which then fall down into an uncovered bin. This is shown in Figure 32. Even after washing, screenings removed from wastewater have the potential to generate objectionable odours, so it is good practice for screenings chutes and bins to be covered. This can be as simple as capturing screenings in a sealed bag. The location of the inlet screens along Mt. Herbert Road, close to neighbours, increases the risk of any odours from this process being deemed objectionable by members of the public.

It is our understanding that the screenings chutes and bins are to be covered.

Figure 32: Waipukurau WwTP Inlet Screens

10.1.1.2 SFBFP

As mentioned in Section 3.2.1, since the anaerobic pond and SFBFP have been brought on line, the DO in the SFBFP has typically been low (0.2 – 0.3 mg/L). This is much lower than the DO concentration required to oxidise H_2S and maintain aerobic conditions (>1 mg/L). Providing aerobic conditions can be maintained in the SFBFP, it should be possible to treat H_2S-laden effluent from the anaerobic pond in the SFBFP without generating objectionable odours. Tests on site have confirmed that when sufficient oxygen was provided in the form of sodium nitrate, H_2S concentrations in the post-anaerobic pond effluent could be reduced to low levels.

The amount of oxygen required to maintain aerobic conditions in the SFBFP is a function of several factors, including raw wastewater load, performance of the anaerobic pond, HRT in the SFBFP (which is influenced by both raw wastewater flow rates and SFBFP level), and temperature. These, along with the difficulty of accurately determining the AOTR for any type of mechanical aeration system, make it difficult to estimate the amount of aeration capacity required to achieve adequate DO residuals.

However, estimations of the aeration capacity required to maintain aerobic conditions in the SFBFP have been made using the following assumptions:

Average wastewater flow rate	2,130 m^3/d	
Raw wastewater BOD load	Average 620 kg/d	Maximum 886 kg/d[13]
Pond temperature	Winter 10°C	Summer 20°C
BOD removal in the anaerobic pond	Winter 40%	Summer 60%
BOD rate constant in WSP at 20°C	0.3 to 0.5 d^{-1}	
BOD rate constant in SFBFP at 20°C	0.5 to 0.8 d^{-1}	
SFBFP surface area	8,927 m^2	
SFBFP level	Minimum 1.2 m	Maximum 2.2 m
kgO_2 required per kgBOD removed	1.2	
AOTR	0.6 kgO_2/kWh	
Oxygen produced by algae	None[14]	

On the basis of the above assumptions, estimations of the amount of aeration required to maintain aerobic conditions in the SFBFP range from 12 kW (average load, minimum SFBFP depth, summer, $k_{1(20)}$ of 0.3 d^{-1}) to 36 kW (maximum load, maximum SFBFP depth, summer, $k_{1(20)}$ of 0.8 d^{-1}).

If further assumptions are made that the peak wastewater load occurs in summer (February 2017 is the peak trade waste load month to date) when the level in the SFBFP is more likely to be low, the estimated aeration requirement in the SFBFP is 20 kW ($k_{1(20)}$ of 0.3 d^{-1}) to 25 kW ($k_{1(20)}$ of 0.8 d^{-1}).

If the SOTR claimed by the manufacturers of the Reliant Lagoon Master aerator of 2.3 kg/kWh is accurate, this would approximately halve the estimated required aeration power in each of the above scenarios. However, we note that when the anaerobic pond was brought on line in winter 2017 with 6 kW of aeration installed in the SFBFP, the aeration was insufficient to maintain aerobic conditions in the SFBFP. This suggests the SOTR of the Reliant Lagoon Master aerator in the Waipukurau SFBFP is unlikely to be as high as claimed by the Manufacturer.

If it is not possible to install sufficient mechanical aeration in the SFBFP to maintain aerobic conditions, supplementary oxygen sources such as sodium nitrate can also be used. Based on the above assumptions regarding oxygen transfer efficiency, one 25kg bag of 100% sodium nitrate (containing 56% oxygen) would provide roughly the same amount of oxygen as 1kW of aeration

[13] Based on CHBDC's trade waste monitoring, the peak industrial load to date was the month of February 2017, with the average daily BOD load being 886 kg/d in that month. Note that the peak day BOD load is likely to be higher still.
[14] The assumption has been made that no significant algae growth will occur in the SFBFP due to the relatively short HRT (5 days) at average annual flows and low SFBFP operating level. Therefore, all oxygen must be provided by mechanical aeration. Any oxygen provided by algal photosynthesis would be a bonus.

running for 24 hours. Therefore, it is estimated that, say, 17 kW of mechanical aeration in the SFBFP, supplemented with 8 bags of sodium nitrate per day, would be expected to maintain aerobic conditions in the SFBFP at times of peak BOD load based on $k_{1(20)}$ of 0.8 d^{-1}.

10.1.1.3 Facultative Pond

Providing sufficient oxygen can be provided in the SFBFP to maintain aerobic conditions, and using the assumptions detailed in Section 10.1.1.2, the load to the old, modified WSP would likely range from 70 to 200 kgBOD/d at current population and historical peak industrial load.

This equates to a BOD loading rate of 30 to 80 kg/ha.d on the entire 2.46 ha area of the modified WSP, or 60 to 180 kg/ha.d on the 1.13 ha of actual Facultative Pond (removing the area used for BAS and floating wetlands). Therefore the loading rate to the facultative pond is still likely to exceed the MoW (1974) guideline of 84 kgBOD/ha.d for much of the time, and there is therefore still the potential to generate objectionable odours from the old WSP. Continued operation of the existing 2 x 3kW Reliant Lagoon Master aerators will, however, do much to negate potential odour generation at this stage of the process, particularly if algal growth occurs in this pond.

10.1.1.4 Nitrification Zone

Providing adequate aeration is provided through the SFBFP and facultative pond, the BOD load entering the nitrification zone under likely scenarios is estimated to be between 20 and 80 kgBOD/d. The total of 8 kW of aeration currently installed in the nitrification zone should be more than adequate to maintain aerobic conditions in this zone, and should provide some residual DO to pass through into the floating wetland zone.

10.1.1.5 Floating Wetland Zone

Providing adequate aeration is installed through the SFBFP, facultative pond and nitrification zone, the BOD load entering the floating wetlands under likely scenarios is estimated to be between 7 and 40 kgBOD/d. While this is a relatively low loading, no aeration is provided in the floating wetland zone, either through mechanical aeration, or from algal growth or transfer from the air, due to the shading in this zone. Therefore it is considered possible that anaerobic conditions could continue to occur in the floating wetland zone. Having residual DO passing through to the floating wetland zone from the nitrification zone will help maintain aerobic conditions in the floating wetland zone, however anaerobic conditions may still occur.

Odour release is unlikely to occur from the floating wetland zone due to the covering, however anaerobic effluent passing through to subsequent treatment processes (lamella tube settlers, sand filters) could still result in H_2S release at these latter stages.

Removal of the floating wetlands and/or covered sections in between the floating wetlands is an option, and this could create aerobic conditions at the end of the modified WSP. At the Franz Joseph WwTP, pond health appeared to improve when the covered sections were removed (Crawford, 2017).

10.1.1.6 Lamella Tube Settlers and Sand Filters

If the post-floating wetland zone effluent is anaerobic when it reaches the lamella tube settlers and sand filters, the cascading of effluent over weirs at both of these processes provides an opportunity for the release of H_2S into the air. At the time of our site visits, the sand filter building was the most obvious point source of H_2S. While provision of sufficient aeration to maintain aerobic conditions through the SFBFP, facultative pond, and nitrification zone will increase residual DO concentrations, the effluent could still go anaerobic through the floating wetland zone where no aeration is provided and there is no wind action possible over the water surface. As discussed in the preceding section, removal of sections of the floating wetlands may help to create aerobic conditions in this zone, reducing the potential for H_2S release through the lamella tube settlers and sand filters.

As shown in Figure 33, the sand filter building is open at both ends, so any odour can escape out of the building. When a southerly is blowing, this odour is blown straight on to the footpath which runs along the flood embankment.

Figure 33: Waipukurau WwTP Sand Filter Building

One option is to seal the building to prevent odours escaping, however this would require forced air ventilation to maintain a safe working environment in the building, and treatment of the removed air. Given that odours should not be generated at this part of the process if the effluent is truly aerobic (e.g. from an AS plant), then sealing the building and treating the extracted air may not be the most cost-effective short term solution.

10.1.1.7 Drying Beds

The concrete drying beds, shown in Figure 34, are used to thicken the occasional septage tanker load and waste produced on the Waipukurau WwTP site, including screenings. These wastes are discharged into the uncovered beds, and free liquid drains through the beds into the adjacent concrete channel. From the concrete channel, the filtrate is pumped up to the geobags along with the sand filter reject.

At the time of our site visit, the concrete drying beds were not generating a noticeable odour and, given their location well away from Mt. Herbert Road, are therefore not considered to be a high odour risk.

Figure 34: Waipukurau WwTP Concrete Drying Beds

10.1.2 Odour Destruction

Maintaining aerobic conditions through the SFBFP, facultative pond and nitrification zone will reduce the potential for odour generation from the site. However, if it is not possible to install sufficient aeration to maintain aerobic conditions, and/or if H_2S release still occurs at the lamella tube settlers and sand filters, misting chlorine dioxide around the perimeter of the areas of site generating odours is an option.

Chlorine dioxide oxidises wastewater odours such as H_2S and mercaptans, converting them to non-odourous compounds. Therefore, misting chlorine dioxide around odourous parts of the plant provides a barrier to the odour leaving site. While feasible, misting chlorine dioxide around the whole of the Waipukurau WwTP would be costly. However, misting chlorine dioxide between the sand filter building and the walkway would be relatively cost-effective, if the post-floating wetland effluent remains anaerobic. Ixom, one of the New Zealand suppliers of chlorine dioxide has indicated there are no health and safety (H&S) concerns regarding its use (Drinkwater, 2017), however we are waiting for evidence from Ixom to support this.

10.2 Increased Resilience

Jar tests undertaken on site by Ixom on 4th September 2017 indicated the performance of the lamella tube settlers could be improved through the addition of polymer, after coagulation. Ixom's jar tests suggested an optimal alum dose of 110 mg/L, slightly higher than the 80 mg/L being dosed at the time, and a Crystalfloc B610 polymer dose rate of 0.2 to 0.4 mg/L (Bottrill, 2017). Ixom also suggested moving the alum dose point to after the lamella feed pumps but prior to the non-return valves, and dosing the polymer into the previous alum dosing point.

Effective coagulation and flocculation is expected to significantly improve the performance of the lamella tube settlers, providing they are operated at an appropriate flow rate. Filtec, the suppliers of the tube settlers, have confirmed that each of the two lamella tube settlers has a design capacity of 50 m^3/hr (14 L/s), and that performance can be expected to deteriorate when operated close to this maximum design capacity (Ewen, 2017).

CHBDC has recently made the Ixom recommended changes to chemical dosing, and early indications suggest a considerable improvement in lamella tube settler and sand filter performance has been achieved. Considering these changes, the current flow path through the Waipukurau WwTP is as shown in Figure 35.

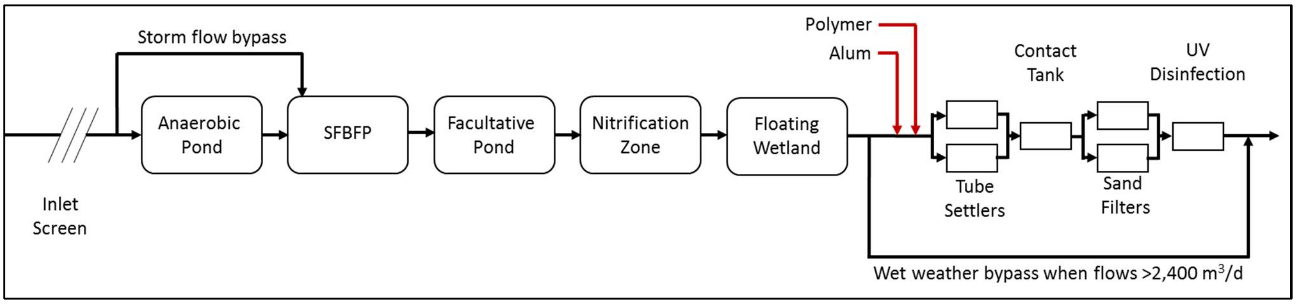

Figure 35: Current Waipukurau WwTP Process Flow Diagram

10.3 Trade Waste Control

This review has identified that Trade Waste discharges add a significant wastewater flow and load to both the Waipukurau and Waipawa WwTPs, and potentially contribute to some of the operational issues. It may be possible to reduce the impact of these Trade Waste discharges through changes on individual sites, such as:

- NNNZ and Ovation using less foaming chemicals, or different chemicals, to potentially reduce foaming at the Waipukurau WwTP.
- NNNZ using an alternative acid (i.e. nitric acid or hydrochloric acid) instead of sulphuric acid to reduce the discharge of Sulphur to the Waipukurau WwTP.
- NNNZ adjust the pH of the treated effluent (ideally to neutral 7.0) prior to discharge.
- Chemical conditioning of the Ovation wastewater (e.g. using coagulants and/or polymers) to improve performance of the "Saveall".

- Alternative treatment process(es) to treat the Ovation wastewater.

10.4 Maintenance

Data in Figure 15 suggests the performance of the Waipukurau UV system has been inconsistent. While elevated TSS concentrations and/or low effluent UVT may have contributed to this inconsistency, it is possible that insufficient maintenance may also be a contributing factor. We understand that, while Downs Group are generally contracted to undertake maintenance on the UV system, this is done on an ad hoc basis rather than having a formal contract in place to ensure that necessary maintenance is undertaken to schedule (Gunn, 2017). We also understand that inorganic fouling of the quartz sleeves has been observed in the past (Schrader, 2017). The automatic wiping system would not be expected to remove inorganic fouling, and it is generally necessary to undertake periodic manual cleaning with dilute phosphoric acid to keep the sleeves clean.

10.5 Foam

10.5.1 Foam Prevention

Given the foam appears to be a chemical foam rather than a biological foam, it is likely due to a compound, or compounds, present in the raw wastewater. Providing more aeration through the SFBFP may help to break down any such compounds, however given the presence of foam through the whole of the Waipukurau WwTP, foam may still occur even with additional aeration.

Many types of chemicals could cause foam, including surfactants and detergents. It is considered unlikely that sufficient quantities of such chemicals could be discharged from a domestic residence, so the suspected chemicals are more likely to come from one of the main industrial dischargers. It is our understanding that Ovation and NNNZ both use high foaming detergents to assist with washdowns; Magnafoam at Ovation, and HC Foam Clean at NNNZ. It is possible that one or both of these products are contributing to the foaming at the Waipukurau WwTP. If these compounds are the cause of foaming at the WwTP, it is possible that the products are being over-dosed by one or more of the industries.

The most appropriate laboratory test to undertake in the first instance is the methylene blue active substances (MBAS) test. This tests for anionic surfactants, including detergents. Eurofins ELS offer this analysis with a limit of detection (LOD) of 0.1 mg/L. Including MBAS analysis on trade waste samples will give an indication which, if any, of the four main industries are discharging significant quantities of such substances.

10.5.2 Foam Destruction

If it is not possible to prevent the foaming, an alternative option is to break foam down using chemicals. A range of anti-foaming agents are available, and are commonly used to reduce foaming in effluent discharge from several industrial WwTPs in New Zealand. Chemical suppliers such as Ixom would be able to supply anti-foaming chemicals.

11 Waipawa Improvement Options – Short Term

The short-term options discussed in the following sub-section would not be expected to result in full resource consent compliance being achieved at Waipawa, but would allow the existing WwTP to perform to the best of its ability.

11.1 Additional Aeration

The BOD removal calculations, included in Appendix A, indicate that up to 16 kW of aeration may be required in the Waipawa facultative zone, depending on the extent of algal growth. The more algal growth, the more oxygen is provided by the algae through photosynthesis. The average HRT through the facultative zone of some 20 days would be expected to provide sufficient HRT for algae to remain established in the pond. This algal growth reduces the estimated aeration requirements to 6 kW. Sufficient aeration should be installed in the facultative pond to ensure that aerobic conditions are maintained.

A 3 kW Reliant Lagoon Master aerator has recently been installed in the facultative zone to replace the 12 kW vertical shaft aerator that was previously operational. Ongoing monitoring will determine whether sufficient aeration is now installed in the facultative zone, or whether additional aeration is required.

11.2 Optimised Tertiary Treatment

The Waipawa WwTP has not consistently met the SRP or *E. coli* resource consent conditions. While this is likely to be partly due to the hydraulic limitations of the tertiary treatment processes, resulting in partial bypass during peak flows, and the capacity of the UV system, it may be possible to improve consent compliance by optimising the tertiary treatment processes.

As discussed in Section 10.2, early indications are that dosing polymer after alum addition has improved the performance of the lamella tube settlers at Waipukurau. Similar improvements to chemical conditioning at Waipawa may be possible, and should be investigated.

11.3 Sludge Removal

If, as indicated by recent work on site, a significant amount of sludge has accumulated in the Waipawa WSP, removal of this sludge will provide additional treatment capacity. However, removal of this sludge may be difficult due to the main sludge accumulation appearing to be beneath the BAS curtains. In the first instance, a sludge survey should be undertaken to determine the extent of this sludge accumulation.

11.4 Landfill Leachate

Tankered discharge of landfill leachate into the Waipawa WwTP will be increasing the ammonia load, and could be reducing the UVT of the treated effluent. It may be more appropriate to discharge some, or all, of this leachate to other WwTPs that may be better placed to treat this additional load.

11.5 Maintenance

Data in Figure 27 suggests the performance of the Waipawa UV system has been inconsistent. While elevated TSS concentrations and/or low effluent UVT may have contributed to this inconsistency, it is possible that insufficient maintenance may also be a contributing factor. We understand that, while Downs Group are generally contracted to undertake maintenance on the UV system, this is done on an ad hoc basis rather than having a formal contract in place to ensure that necessary maintenance is undertaken to schedule (Gunn, 2017). We also understand that inorganic fouling of the quartz sleeves has been observed in the past (Schrader, 2017). The automatic wiping system would not be expected to remove inorganic fouling, and it is generally necessary to undertake periodic manual cleaning with dilute phosphoric acid to keep the sleeves clean.

12 Additional Considerations

12.1 Raw Wastewater Sampling

Unusual raw wastewater characteristics were noted for both Waipukurau and Waipawa during this review. As discussed in Sections 2.5.1 and 5.4.1, the total nitrogen concentrations measured in the raw wastewater entering both the Waipukurau and Waipawa WwTPs were similar to a typical medium strength wastewater. However, the BOD and TSS concentrations were lower than a typical medium strength wastewater. The majority of the TN in raw wastewater is present as ammonia, which is soluble. TSS is insoluble, and a significant proportion of the BOD is associated with the TSS. Therefore it is considered possible that current sampling of the raw wastewater is not representative, with TSS potentially being under-represented in the samples. This could occur if heavier solids are settling out prior to sampling.

12.2 Alum Dosing Control

Data presented in Figure 8 and Figure 23 indicate that occasional spikes in treated effluent SRP have historically occurred at both Waipukurau and Waipawa WwTPs. These spikes will be due to insufficient alum dosing for the given effluent characteristics and flow rates. It may be possible to optimise alum dosing through the use of on-line measurement and feedback control. For example, the Palmerston North WwTP uses an S::CAN to provide a surrogate measurement for phosphorous which is used to control coagulant dosing. The control logic for this is provided by Lutra (www.lutra.com).

13 Recommendations

13.1 What to do about ammonia removal?

The resource consent conditions require consistent ammonia removal down to <6 mg/L. Ammonia concentrations in the treated effluent over the past three years have ranged from 10 to 50 mg/L at Waipukurau WwTP, and 0 to 30 mg/L at Waipawa. While suppliers may claim that alternative pond-based technologies are available which can achieve reliable nitrification, the reality is that performance of such technologies is generally inconsistent and unpredictable. Therefore, further modifications to the existing WSP processes are considered unlikely to reliably achieve the required effluent ammonia concentrations, particularly at Waipukurau. The lower loadings at Waipawa may provide more scope for further upgrades with WSP-based technologies, however this would be a considerably higher risk option.

Our recommendation to provide reliable, year-round ammonia removal is AS-based treatment for both Waipukurau and Waipawa.

Recommendation 1: Undertake further investigations to identify the most cost-effective option to treat wastewater from both Waipukurau and Waipawa using activated sludge-based technology.

13.2 Can the current Waipukurau and Waipawa WwTPs meet all resource consent conditions?

13.2.1 Waipukurau

While in theory it should be possible to achieve reliable ammonia removal through an attached growth-type system, due to the following factors we consider it unlikely that such a system will provide the required level of treatment at Waipukurau:

a) Even with the recent addition of the Anaerobic Pond and the SFBFP, the overall HRT through the Waipukurau WwTP is approximately 22 days at average flow. This is a short HRT for a modified WSP to achieve reliable nitrification when winter pond temperatures are <10^{o}C.

b) Even with additional aeration in the SFBFP and facultative pond, the BOD concentration entering the nitrification zone is considered likely to be too high to allow nitrifying bacteria to establish on the BAS media. This has likely clogged the media, reducing the available surface area for biomass growth.

c) Industrial wastewater loads appear to be increasing, and the industries are permitted to discharge considerably higher flows and loads under their existing trade waste agreements.

d) Significant population growth is expected in Waipukurau. This will further increase the wastewater flows and loads.

e) The New Zealand experience of modifying WSPs to achieve low effluent ammonia concentrations is checkered, even in WwTPs with higher HRTs and more robust design and installation.

In addition, the hydraulic capacity of the tertiary treatment processes (lamella tube settlers, sand filters, UV system) is insufficient. Discharge flow rates >2,400 m^3/d bypass tertiary treatment which could result in breach of the TSS, BOD, SRP and/or *E. coli* resource consent conditions.

13.2.2 Waipawa

As with Waipukurau, while in theory it should be possible to achieve reliable ammonia removal through an attached growth-type system, due to the following factors we consider it unlikely that such a system will provide the required level of treatment at Waipawa without significant additional investment:

a) Stormwater I&I into the Waipawa reticulation is very significant. Following the heavy rains in 2017, the theoretical HRT reduced to approximately 10 days. Nitrification is very unlikely to be achieved through a modified WSP at such a low HRT.

b) The BOD concentration entering the nitrification zone is considered likely to be too high to allow nitrifying bacteria to remain established on the BAS media.

c) Significant population growth is expected in Waipawa. This will further increase the wastewater flows and loads.

d) The New Zealand experience of modifying WSP's to achieve low effluent ammonia concentrations is checkered, even in WwTP's with higher HRT's and more robust design and installation.

In addition, the hydraulic capacity of the tertiary treatment processes (lamella clarifier, sand filters, UV system) is insufficient. Discharge flow rates >1,400 m^3/d bypass tertiary treatment which could result in breach of the TSS, BOD, SRP and/or E. coli resource consent conditions.

13.3 What changes or additions would you recommend?

13.3.1 Waipukurau WwTP

We do not recommend making further changes or additions to the Waipukurau WwTP to try to improve ammonia removal. Any such changes would almost certainly bring further disappointment and cost money that is better spent on a permanent, reliable solution.

However, the following changes are suggested to improve the short-term performance of the existing Waipukurau WwTP, reduce the potential for odours from the site, and reduce foaming:

- Cover the inlet screen chutes and bins, as proposed.
- Install additional aeration in the SFBFP to consistently achieve a DO concentration of >1 mg/L. It is estimated that a total of 20 to 25 kW of aeration will be required to achieve this.

If it is not possible to provide sufficient mechanical aeration, this can be supplemented with sodium nitrate.

- Run all available aeration in the old, modified WSP, including the sub-surface aeration in the nitrification zone.
- Optimise the recently modified chemical dosing to the lamella tube settlers and sand filters which added polymer dosing after coagulation.
- Continuing to work with trade waste dischargers to eliminate the foaming issues, and/or dose a suitable anti-foaming agent into the final effluent manhole to reduce foaming at the point of discharge to the Tukituki River.

Recommendation 2: Optimise the existing Waipukurau WwTP, with the most important modifications being:

a) addition of more oxygen in the SFBFP, either using mechanical aeration or through the addition of sodium nitrate.

b) improving the performance of the lamella tube settlers.

13.3.2 Waipawa WwTP

As with the Waipukurau WwTP, we do not recommend making further changes or additions to the Waipawa WwTP to try to improve ammonia removal. Any such changes may bring further disappointment and cost money that is better spent on a permanent, reliable solution.

However, the following changes are suggested to improve the short-term performance of the existing Waipawa WwTP:

- Install sufficient aeration in the facultative pond to maintain aerobic conditions. Providing good algal growth is achieved in the facultative pond, we estimate that approximately 6 kW of mechanical aeration would be required. Ongoing monitoring will determine whether the recently installed Reliant Lagoon Master aerator provides sufficient DO.
- Optimising performance of the lamella clarifier and sand filters. As demonstrated through the addition of polymer dosing after coagulation at Waipukurau, it may be possible to improve TSS removal through the tertiary treatment processes which, in turn, may improve UV disinfection performance.
- Undertaking a sludge survey to determine the extent of sludge accumulation and, if necessary, desludging the pond.

Recommendation 3: Optimise the existing Waipawa WwTP, with the most important modification being improving the performance of the lamella clarifier.

13.4 Should we throw it out and start again?

While it is considered unlikely that modified WSPs could reliably achieve the required year-round effluent quality, it is possible that much of the existing infrastructure at the Waipukurau WwTP could be incorporated into an upgrade to an activated sludge process. One such example could be as follows:

- Retain the existing inlet screens.
- Install a new grit removal system.
- Convert the anaerobic pond to an SBR, although the fact that this pond doesn't currently have gas relieving underdrains would require remediation.
- Use the SFBFP as a post-SBR buffer pond, although this may require a pumped decant from the SBR. Again, retrofitting of gas relieving underdrains would likely be required.
- Install new pumps to pump from the post-SBR buffer pond to the lamella tube settlers and/or sand filters.
- Retain the existing lamella tube settlers and/or sand filters for tertiary filtration, with chemical conditioning, although additional filtration capacity will be required.
- Retain the existing geobags for dewatering the reject flow from the lamella tube settlers and/or sand filters.
- Retain the existing UV system for disinfection, however it may be necessary to upgrade the UV system to achieve reliable disinfection.
- Install a new dewatering system for dewatering the WAS which would be produced by an activated sludge process.
- Create a biosolids monofill in the existing facultative pond for dewatered sludge storage, however the potential for odours would need careful consideration given the historical odour issues and proximity of neighbours.

13.5 Additional Recommendations

13.5.1 Discuss and limit trade waste discharges

Given the significant wastewater loads discharged by key Trade Waste dischargers in both Waipukurau and Waipawa, it is important to engage with these industries to understand their future intentions and requirements from CHBDC with respect to wastewater treatment. To design an activated sludge (or alternative) treatment process for Waipukurau and Waipawa, the design wastewater flows and loads must be clearly understood. Any significant industry discharging wastewater to the Waipukurau and/or Waipawa WwTPs has the potential to cause treatment problems, whatever technology is adopted. These discussions with industries should include consideration of:

- Industries current and likely future production levels and resulting wastewater flows and loads.

- Limits to permitted trade waste volumes and contaminant loads to ensure the overall flow and load discharged to the Waipukurau and/or Waipawa WwTPs does not exceed the plants design capacity.
- Future cost of wastewater treatment at the Waipukurau and/or Waipawa WwTPs, and therefore the likely trade waste charges per unit of flow, BOD, TSS (both inert and organic), nitrogen and phosphorous.
- The potential for industries to reduce their trade waste charges through installation of additional pre-treatment on site.
- Capital contributions from the main industries towards the cost of any WwTP upgrade.
- The structure of charging, to ensure that individual trade waste dischargers cannot disappear after having caused CHBDC to commit to substantial capital expenditure on their behalf.

It is important not to underestimate the potential complexity of such discussions with industries. For example, the future cost of wastewater treatment may influence the decisions of industries on future levels of production and potential pre-treatment options. Subsequent decisions by industries will, in turn, impact on the required design capacity of the WwTP, and the cost of both construction and operation.

Recommendation 4: Engage with industries regarding the future of the Waipukurau and Waipawa WwTPs.

13.5.2 Work closely with trade waste dischargers

It is likely that industrial discharges are contributing to some of the operational problems experienced at the Waipukurau and Waipawa WWTPs. For example, the foaming at the Waipukurau WwTP is considered likely to be due to discharge of excessive quantities of a cleaning product by one or more of the industries, and recent discussions with industries appears to have reduced the amount of foaming at the WwTP. By continuing to work closely with industries it may be possible to identify the cause of the foaming. Undertaking MBAS analysis on each trade waste discharge may be a useful screening tool.

The NNNZ discharge may be contributing to odours generated at the Waipukurau WwTP through the use of sulphuric acid as part of their on-site WwTP. It may be possible for NNNZ to use an alternative acid (i.e. nitric acid or hydrochloric acid) to achieve the same level of performance with their DAF.

Ovation may be able to improve the performance of their existing “saveall” by chemical conditioning the wastewater prior to treatment.

Recommendation 5: Work closely with industries to:

a) identify the likely cause of foaming at the Waipukurau WwTP.

b) reduce the amount of Sulphur discharged to the Waipukurau WwTP.

13.5.3 Review disposal of landfill leachate

The landfill leachate tankered into the Waipawa WwTP is likely to be adding a significant ammonia load, and could also be impacting on the efficiency of the UV disinfection system. It may be possible to discharge some, or all, of this leachate to an alternative WwTP to improve performance of the Waipawa WwTP.

Recommendation 6: Review leachate volumes and characteristics, and performance of other WwTPs, to determine whether other WwTPs would be better placed to treat some or all of the leachate.

13.5.4 Review UV system maintenance

The performance of the UV systems at both Waipukurau and Waipawa has been inconsistent. While this may be partly due to changing effluent characteristics, it is also possible that UV system performance could be improved through more regular, scheduled maintenance. In addition to routine maintenance such as lamp, wiper and sleeve replacement, periodic manual cleaning of the quartz sleeves is required using dilute phosphoric acid to remove inorganic precipitates.

Recommendation 7: Review routine maintenance of the UV systems (and other critical items)

13.5.5 Review raw wastewater sampling techniques

The measured TSS and BOD concentrations in the raw wastewater entering both the Waipukurau and Waipawa WwTPs are low in comparison to the total nitrogen concentrations. It is possible that current sampling techniques are not collecting representative samples of raw wastewater. For any further upgrade of the Waipukurau and Waipawa WwTPs to provide effective treatment, the raw wastewater flows and loads must be well understood.

Recommendation 8: Review raw wastewater sampling locations and methodologies to ensure that representative samples are being collected.

14 References

Archer, H & O'Brien, B (2004); *Nitrogen reduction improvements in waste stabilisation ponds*; Proceedings of the 2004 NZWWA Conference

Bothwell, K (2017); *Pers. Comm.*

Bottrill, F (2017); Letter to Steve Thrush dated 13th September 2017

CHBDC (2008); *Central Hawkes Bay District Council Bylaws: Part 23 – Trade Waste*

Crawford, J (2017); *Pers. Comm.*

Curtis, J (2017); *Pers. Comm.*

CPG (2009); From Bothwell, K (2017); *Pers. Comm.*

Drinkwater, D (2017); *Pers. Comm.*

Ewen, M (2017); *Pers. Comm.*

Good Earth Matters (2009); *Waipawa & Waipukurau STPs: Investigation of Land Disposal Options*; May 2009

Gunn, R (2017); *Pers. Comm.*

Mara, DD (2003); *Domestic Wastewater Treatment in Developing Countries*; Earthscan, London

Mara, DD (2008); *Waste Stabilisation Ponds: A Highly Appropriate Wastewater Treatment Technology for Mediterranean Countries*. In: Al Baz, I; Otterpohl, I; Wendland, C (eds) *Efficient Management of Wastewater: Its Treatment and Reuse in Water Scarce Countries*. Springer, Heidelberg, pp 113 – 123

Marais, GvR (1974), *Faecal Bacterial Kinetics in Waste Stabilisation Ponds*; Journal of the Environmental Engineering Division, American Society of Civil Engineers, v100, nEE1, pp119-139. In Mara, DD (2003); *Domestic Wastewater Treatment in Developing Countries*; Earthscan, London

Martin, P (2017); *Pers. Comm.*

Metcalf & Eddy (1991); *Wastewater Engineering: Treatment, Disposal, Reuse* (3rd Edition); McGraw-Hill

Metcalf & Eddy (2003); *Wastewater Engineering: Treatment & Reuse* (4th Edition); McGraw-Hill

MoW (1974); *Guideline for the Design, Construction and Operation of Oxidation Ponds*; Public Health Engineering Section, Ministry of Works and Development, Wellington, New Zealand

NIWA (2017); *Review of Waipukurau WwTP Upgrade*; Consultancy Report, March 2017

NZWWA (2005); *Oxidation Pond Guidelines* (Draft)

Okan, T (2017); *Innovative NZ aeration system enhanced ammonia removal and WwTP efficiency*; Proceedings of the 2017 WaterNZ Conference, Hamilton, NZ

Pano, A; Middlebrooks, EJ (1982); *Ammonia nitrogen removal in facultative wastewater stabilisation ponds*; J. Water Pollut. Control Fed, 54 (4), 2148

Pearson, D (2017); *Pers. Comm.*

Ratsey, H (2016); *Upgrading Waste Stabilisation Ponds: Reviewing the Options*; Proceedings of the 2016 WaterNZ Conference, Rotorua, NZ

Ross, P (2016); *Pers. Comm.*

Schrader, M (2017); *Pers. Comm.*

Thrush, S (2017); *Growing Central Hawke's Bay and having GREAT infrastructure to support smart growth*; Presentation to CHBDC Councillors

Shipin, OV; Meiring, PGJ; Rose, PD (1998); *PETRO® system: A low-tech approach to the removal of waste-water organics (incorporating effective removal of micro-algae by the trickling filter)*; Water SA, v24, n4, pp347-354

Svedala (undated); *Kiwipoint quarry lamella statistics*

Waterclean Technologies (2012); *Proposal to CHBDC for the upgrade of Waipawa & Waipukurau WwTP using granular media filtration and floating treatment media*

WaterNZ (2017); *Waste Stabilisation Ponds: Design and Operation*; Good Practice Guide (in development)

WCS (undated); *Keep your lagoons compliant at a cost you can afford*; Wastewater Compliance Systems promotional material

WEF (2007); *Operation of Municipal Wastewater Treatment Plants*; Manual of Practice No. 11 (6th Edition), Water Environment Federation

Appendix 1

BOD Removal and Aeration Calculations

The Wastewater Specialists

Optimising your assets

Waipukurau scenarios; Waterclean Upgrade					Less Likely Scenarios				
BOD Load (Ave/Max)	Ave	Ave	Ave	Ave	Max	Max	Max	Max	
Season (Summer/Winter)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Units
Average flow rate	2,130	2,130	2,130	2,130	2,130	2,130	2,130	2,130	m^3/d
Raw wastewater BOD load	620	620	620	620	886	886	886	886	kg/d
Temperature	10	20	10	20	10	20	10	20	^oC
$K_{1(20)}$	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	d^{-1}
$k_{1(temp)}$	0.18	0.30	0.18	0.30	0.18	0.30	0.18	0.30	d^{-1}
kg O_2 req'd / kg BOD	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
AOTR	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	kgO_2/kWh
Facultative Pond									
FP Area	11,300	11,300	11,300	11,300	11,300	11,300	11,300	11,300	m^2
FP Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FP HRT	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	d
BOD in FP effluent	251	183	251	183	359	262	359	262	kg/d
BOD removed through FP	369	437	369	437	527	624	527	624	kg/d
Aeration required	***31***	***36***	***31***	***36***	***44***	***52***	***44***	***52***	kW
Aeration required	***23***	***29***	***23***	***29***	***36***	***44***	***36***	***44***	***kW***
Nitrification (BAS) Zone									
BOD feed concentration	118	86	118	86	169	123	169	123	mg/L
Nit Zone Area	7,800	7,800	7,800	7,800	7,800	7,800	7,800	7,800	m^2
Nit Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
Nit Zone HRT	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	d
BOD in Nit Zone effluent	125	69	125	69	179	99	179	99	kg/d
BOD removed through Nit Zone	126	114	126	114	181	163	181	163	kg/d
Aeration required (for BOD only)	***11***	***9***	***11***	***9***	***15***	***14***	***15***	***14***	***kW***
Floating Wetland Zone									
BOD feed concentration	59	32	59	32	84	46	84	46	mg/L
FW Zone Area	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	m^2
FW Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FW Zone HRT	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	d
BOD in FW effluent	***34***	***15***	***34***	***15***	***49***	***21***	***49***	***21***	mg/L
BOD removed through FW Zone	52	37	52	37	74	53	74	53	kg/d
Oxygen required	62	45	62	45	89	64	89	64	kg/d

Waipukurau scenarios; Waterclean Upgrade					Less Likely Scenarios				
BOD Load (Ave/Max)	Ave	Ave	Ave	Ave	Max	Max	Max	Max	
Season (Summer/Winter)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Units
Average flow rate	2,130	2,130	2,130	2,130	2,130	2,130	2,130	2,130	m^3/d
Raw wastewater BOD load	620	620	620	620	886	886	886	886	kg/d
Temperature	10	20	10	20	10	20	10	20	^oC
$K_{1(20)}$	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	d^{-1}
$k_{1(temp)}$	0.31	0.50	0.31	0.50	0.31	0.50	0.31	0.50	d^{-1}
kg O_2 req'd / kg BOD	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
AOTR	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	kgO_2/kWh
Facultative Pond									
FP Area	11,300	11,300	11,300	11,300	11,300	11,300	11,300	11,300	m^2
FP Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FP HRT	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	d
BOD in FP effluent	180	125	180	125	257	178	257	178	kg/d
BOD removed through FP	440	495	440	495	629	708	629	708	kg/d
Aeration required	***37***	***41***	***37***	***41***	***52***	***59***	***52***	***59***	kW
Aeration required	***29***	***33***	***29***	***33***	***44***	***51***	***44***	***51***	***kW***
Nitrification (BAS) Zone									
BOD feed concentration	85	58	85	58	121	84	121	84	mg/L
Nit Zone Area	7,800	7,800	7,800	7,800	7,800	7,800	7,800	7,800	m^2
Nit Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
Nit Zone HRT	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	d
BOD in Nit Zone effluent	67	33	67	33	96	47	96	47	kg/d
BOD removed through Nit Zone	113	91	113	91	162	130	162	130	kg/d
Aeration required (for BOD only)	***9***	***8***	***9***	***8***	***13***	***11***	***13***	***11***	***kW***
Floating Wetland Zone									
BOD feed concentration	31	16	31	16	45	22	45	22	mg/L
FW Zone Area	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	m^2
FW Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FW Zone HRT	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	d
BOD in FW effluent	***14***	***5***	***14***	***5***	***21***	***8***	***21***	***8***	mg/L
BOD removed through FW Zone	36	22	36	22	52	31	52	31	kg/d
Oxygen required	44	26	44	26	62	38	62	38	kg/d

Waipukurau scenarios; Current Configuration					Less Likely Scenarios				
BOD Load (Ave/Max)	Ave	Ave	Ave	Ave	Max	Max	Max	Max	
SFBFP Depth (Max/Min)	Max	Max	Min	Min	Max	Max	Min	Min	
Season (Summer/Winter)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Units
Anaerobic Pond									
Average flow rate	2,130	2,130	2,130	2,130	2,130	2,130	2,130	2,130	m^3/d
Raw wastewater BOD load	620	620	620	620	886	886	886	886	kg/d
Temperature	10	20	10	20	10	20	10	20	^oC
BOD removal through A.P.	40	60	40	60	40	60	40	60	%
BOD removal through A.P.	248	372	248	372	354	532	354	532	kg/d
BOD load to SFBFP	372	248	372	248	532	354	532	354	kg/d
SFBFP									
$K_{1(20)}$	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	d^{-1}
SFBFP area	8,927	8,927	8,927	8,927	8,927	8,927	8,927	8,927	m^2
SFBFP depth	2.2	2.2	1.2	1.2	2.2	2.2	1.2	1.2	m
$k_{1(temp)}$	0.18	0.30	0.18	0.30	0.18	0.30	0.18	0.30	d^{-1}
SFBFP HRT	9.2	9.2	5.0	5.0	9.2	9.2	5.0	5.0	d
BOD in SFBFP effluent	138	66	193	99	197	94	276	141	kg/d
BOD removed through SFBFP	234	182	179	149	335	260	256	213	kg/d
kg O_2 req'd / kg BOD	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
AOTR	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	kgO_2/kWh
Aeration required	***20***	***15***	***15***	***12***	***28***	***22***	***21***	***18***	***kW***
Oxygen in sodium nitrate	56	56	56	56	56	56	56	56	% O_2
or sodium nitrate required	***502***	***390***	***383***	***320***	***717***	***558***	***548***	***457***	***kg***
	20	16	15	13	29	22	22	18	bags
BOD removed through AP & SFBFP	482	554	427	521	689	792	610	745	kg/d
Facultative Pond									
FP Area	11,300	11,300	11,300	11,300	11,300	11,300	11,300	11,300	m^2
FP Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FP HRT	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	d
BOD in FP effluent	56	19	78	29	80	28	112	42	kg/d
BOD removed through FP	82	46	115	70	117	66	164	100	kg/d
Aeration required	***7***	***4***	***10***	***6***	***10***	***6***	***14***	***8***	kW
Aeration required	***0***	***0***	***2***	***0***	***2***	***0***	***6***	***0***	***kW***
Nitrification (BAS) Zone									
BOD feed concentration	26	9	37	14	38	13	53	20	mg/L
Nit Zone Area	7,800	7,800	7,800	7,800	7,800	7,800	7,800	7,800	m^2
Nit Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
Nit Zone HRT	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	d
BOD in Nit Zone effluent	28	7	39	11	40	10	56	16	kg/d
BOD removed through Nit Zone	28	12	39	18	40	17	56	26	kg/d
Aeration required (for BOD only)	***2***	***1***	***3***	***2***	***3***	***1***	***5***	***2***	***kW***
Floating Wetland Zone									
BOD feed concentration	13	3	18	5	19	5	26	7	mg/L
FW Zone Area	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	m^2
FW Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FW Zone HRT	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	d
BOD in FW effluent	***8***	***2***	***11***	***2***	***11***	***2***	***15***	***3***	mg/L
BOD removed through FW Zone	12	4	16	6	17	6	23	8	kg/d
Oxygen required	14	5	19	7	20	7	28	10	kg/d

Waipukurau scenarios; Current Configuration					Less Likely Scenarios				
BOD Load (Ave/Max)	Ave	Ave	Ave	Ave	Max	Max	Max	Max	
SFBFP Depth (Max/Min)	Max	Max	Min	Min	Max	Max	Min	Min	
Season (Summer/Winter)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Units
Anaerobic Pond									
Average flow rate	2,130	2,130	2,130	2,130	2,130	2,130	2,130	2,130	m^3/d
Raw wastewater BOD load	620	620	620	620	886	886	886	886	kg/d
Temperature	10	20	10	20	10	20	10	20	^oC
BOD removal through A.P.	40	60	40	60	40	60	40	60	%
BOD removal through A.P.	248	372	248	372	354	532	354	532	kg/d
BOD load to SFBFP	372	248	372	248	532	354	532	354	kg/d
SFBFP									
$K_{1(20)}$	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	d^{-1}
SFBFP area	8,927	8,927	8,927	8,927	8,927	8,927	8,927	8,927	m^2
SFBFP depth	2.2	2.2	1.2	1.2	2.2	2.2	1.2	1.2	m
$k_{1(temp)}$	0.31	0.50	0.31	0.50	0.31	0.50	0.31	0.50	d^{-1}
SFBFP HRT	9.2	9.2	5.0	5.0	9.2	9.2	5.0	5.0	d
BOD in SFBFP effluent	97	44	146	71	139	63	209	101	kg/d
BOD removed through SFBFP	275	204	226	177	393	291	323	254	kg/d
kg O_2 req'd / kg BOD	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
AOTR	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	kgO_2/kWh
Aeration required	***23***	***17***	***19***	***15***	***33***	***24***	***27***	***21***	***kW***
Oxygen in sodium nitrate	56	56	56	56	56	56	56	56	% O_2
or sodium nitrate required	***589***	***437***	***484***	***380***	***842***	***624***	***691***	***543***	***kg***
	24	17	19	15	34	25	28	22	bags
BOD removed through AP & SFBFP	523	576	474	549	747	823	677	785	kg/d
Facultative Pond									
FP Area	11,300	11,300	11,300	11,300	11,300	11,300	11,300	11,300	m^2
FP Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FP HRT	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	d
BOD in FP effluent	28	9	42	14	40	13	61	20	kg/d
BOD removed through FP	69	35	104	56	98	50	148	81	kg/d
Aeration required	***6***	***3***	***9***	***5***	***8***	***4***	***12***	***7***	kW
Aeration required	***0***	***0***	***1***	***0***	***0***	***0***	***4***	***0***	***kW***
Nitrification (BAS) Zone									
BOD feed concentration	13	4	20	7	19	6	28	10	mg/L
Nit Zone Area	7,800	7,800	7,800	7,800	7,800	7,800	7,800	7,800	m^2
Nit Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
Nit Zone HRT	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	d
BOD in Nit Zone effluent	11	2	16	4	15	3	23	5	kg/d
BOD removed through Nit Zone	18	7	27	10	25	9	38	15	kg/d
Aeration required (for BOD only)	***1***	***1***	***2***	***1***	***2***	***1***	***3***	***1***	***kW***
Floating Wetland Zone									
BOD feed concentration	5	1	7	2	7	2	11	3	mg/L
FW Zone Area	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	m^2
FW Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FW Zone HRT	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	d
BOD in FW effluent	***2***	***0***	***3***	***1***	***3***	***1***	***5***	***1***	mg/L
BOD removed through FW Zone	6	2	9	2	8	2	12	4	kg/d
Oxygen required	7	2	10	3	10	3	15	4	kg/d

Waipukurau scenarios; Current Configuration						Less Likely Scenarios			
BOD Load (Ave/Max)	Ave	Ave	Ave	Ave	Max	Max	Max	Max	
SFBFP Depth (Max/Min)	Max	Max	Min	Min	Max	Max	Min	Min	
Season (Summer/Winter)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Units
Anaerobic Pond									
Average flow rate	2,130	2,130	2,130	2,130	2,130	2,130	2,130	2,130	m^3/d
Raw wastewater BOD load	620	620	620	620	886	886	886	886	kg/d
Temperature	10	20	10	20	10	20	10	20	^oC
BOD removal through A.P.	40	60	40	60	40	60	40	60	%
BOD removal through A.P.	248	372	248	372	354	532	354	532	kg/d
BOD load to SFBFP	372	248	372	248	532	354	532	354	kg/d
SFBFP									
$K_{1(20)}$	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	d^{-1}
SFBFP area	8,927	8,927	8,927	8,927	8,927	8,927	8,927	8,927	m^2
SFBFP depth	2.2	2.2	1.2	1.2	2.2	2.2	1.2	1.2	m
$k_{1(temp)}$	0.49	0.80	0.49	0.80	0.49	0.80	0.49	0.80	d^{-1}
SFBFP HRT	9.2	9.2	5.0	5.0	9.2	9.2	5.0	5.0	d
BOD in SFBFP effluent	67	30	107	49	96	42	153	71	kg/d
BOD removed through SFBFP	305	218	265	199	435	312	378	284	kg/d
kg O_2 req'd / kg BOD	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
AOTR	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	kgO_2/kWh
Aeration required	***25***	***18***	***22***	***17***	***36***	***26***	***32***	***24***	***kW***
Oxygen in sodium nitrate	56	56	56	56	56	56	56	56	% O_2
or sodium nitrate required	***653***	***468***	***567***	***426***	***933***	***669***	***811***	***608***	***kg***
	26	19	23	17	37	27	32	24	bags
BOD removed through AP & SFBFP	553	590	513	571	790	844	733	815	kg/d
Facultative Pond									
FP Area	11,300	11,300	11,300	11,300	11,300	11,300	11,300	11,300	m^2
FP Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FP HRT	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	d
BOD in FP effluent	14	4	22	7	20	6	31	10	kg/d
BOD removed through FP	54	26	85	43	77	37	122	61	kg/d
Aeration required	***4***	***2***	***7***	***4***	***6***	***3***	***10***	***5***	kW
Aeration required	***0***	***0***	***0***	***0***	***0***	***0***	***2***	***0***	***kW***
Nitrification (BAS) Zone									
BOD feed concentration	6	2	10	3	9	3	15	4	mg/L
Nit Zone Area	7,800	7,800	7,800	7,800	7,800	7,800	7,800	7,800	m^2
Nit Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
Nit Zone HRT	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	d
BOD in Nit Zone effluent	4	1	6	1	5	1	8	2	kg/d
BOD removed through Nit Zone	10	3	16	5	14	5	23	8	kg/d
Aeration required (for BOD only)	***1***	***0***	***1***	***0***	***1***	***0***	***2***	***1***	***kW***
Floating Wetland Zone									
BOD feed concentration	2	0	3	1	2	0	4	1	mg/L
FW Zone Area	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	m^2
FW Zone Depth	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m
FW Zone HRT	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	d
BOD in FW effluent	***1***	***0***	***1***	***0***	***1***	***0***	***1***	***0***	mg/L
BOD removed through FW Zone	2	1	4	1	3	1	6	1	kg/d
Oxygen required	3	1	5	1	4	1	7	2	kg/d

Waipawa scenarios; Waterclean Upgrade			
BOD Load (Ave)	Ave	Ave	
Season (Summer/Winter)	Winter	Summer	Units
Average flow rate	988	988	m^3/d
Raw wastewater BOD load	208	208	kg/d
Temperature	10	20	^oC
$K_{1(20)}$	0.30	0.30	d^{-1}
$k_{1(temp)}$	0.18	0.30	d^{-1}
kg O_2 req'd / kg BOD	1.2	1.2	
AOTR	0.60	0.60	kgO_2/kWh
Facultative Pond			
FP Area	14,200	14,200	m^2
FP Depth	1.5	1.5	m
FP HRT	21.6	21.6	d
BOD in FP effluent	42	28	kg/d
BOD removed through FP	166	180	kg/d
Aeration required	***14***	***15***	kW
Aeration required	***4***	***5***	***kW***
Nitrification (BAS) Zone			
BOD feed concentration	42	28	mg/L
Nit Zone Area	5,400	5,400	m^2
Nit Zone Depth	1.5	1.5	m
Nit Zone HRT	8.2	8.2	d
BOD in Nit Zone effluent	17	8	kg/d
BOD removed through Nit Zone	25	20	kg/d
Aeration required (for BOD only)	***2***	***2***	***kW***
Floating Wetland Zone			
BOD feed concentration	17	8	mg/L
FW Zone Area	3,100	3,100	m^2
FW Zone Depth	1.5	1.5	m
FW Zone HRT	4.7	4.7	d
BOD in FW effluent	***9***	***3***	mg/L
BOD removed through FW Zone	8	5	kg/d
Oxygen required	9	6	kg/d

Waipawa scenarios; Waterclean Upgrade			
BOD Load (Ave)	Ave	Ave	
Season (Summer/Winter)	Winter	Summer	Units
Average flow rate	988	988	m^3/d
Raw wastewater BOD load	208	208	kg/d
Temperature	10	20	^oC
$K_{1(20)}$	0.50	0.50	d^{-1}
$k_{1(temp)}$	0.31	0.50	d^{-1}
kg O_2 req'd / kg BOD	1.2	1.2	
AOTR	0.60	0.60	kgO_2/kWh
Facultative Pond			
FP Area	14,200	14,200	m^2
FP Depth	1.5	1.5	m
FP HRT	21.6	21.6	d
BOD in FP effluent	27	18	kg/d
BOD removed through FP	181	190	kg/d
Aeration required	***15***	***16***	kW
Aeration required	***5***	***6***	***kW***
Nitrification (BAS) Zone			
BOD feed concentration	28	18	mg/L
Nit Zone Area	5,400	5,400	m^2
Nit Zone Depth	1.5	1.5	m
Nit Zone HRT	8.2	8.2	d
BOD in Nit Zone effluent	8	3	kg/d
BOD removed through Nit Zone	20	14	kg/d
Aeration required (for BOD only)	***2***	***1***	***kW***
Floating Wetland Zone			
BOD feed concentration	8	4	mg/L
FW Zone Area	3,100	3,100	m^2
FW Zone Depth	1.5	1.5	m
FW Zone HRT	4.7	4.7	d
BOD in FW effluent	***3***	***1***	mg/L
BOD removed through FW Zone	5	2	kg/d
Oxygen required	6	3	kg/d

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