Mangawhai CWWTP Options Report Peer Review

Executive Summary

Kaipara District Council (KDC) operates the sewerage assets for the Mangawhai area which includes sewerage reticulation, Community Wastewater Treatment Plant (CWWTP) and a transfer pipeline to the Lincoln Downs farm. The Lincoln Downs Farm is commonly referred to as Browns Farm.

The current CWWTP includes a cyclic activated sludge (CASS) process followed by filtration and chlorine disinfection. Sludge produced from the plant is dewatered on site.

Beca Hunter H2O was engaged to undertake a peer review of the upgrade options for the CWWTP. WSP previously had explored treatment options and recommended a membrane bioreactor (MBR) process with reuse on the nearby golf course. The MBR process was selected as it could produce a class A effluent required for unrestricted reuse.

Since this time a project team led by SCO consulting has been developing the overall upgrade strategy. The strategy has evolved with class A effluent being beneficially reused on the golf course. Excess effluent in winter or wet weather is planned to be discharge at a new location with a new resource consent and with some being directed to the current Browns Farm irrigation system. This will provide more operational flexibility in low irrigation demand and high flow periods.

A plant capacity assessment was undertaken to assess when the upgrade needed to occur. The current plants capacity will be exceeded by summer of 2024. There is a significant driver to address the capacity in the short term.

For the class A reuse option WSP restricted the review to one option. However, Class A can be provided in other processes configurations. Two alternative options were considered along with the MBR option which included:

- **CASS.** Expanding the existing CASS activated sludge process with extra CASS units to meet capacity combined with a downstream class A system including ultrafiltration, ultraviolet and chlorination disinfection.
- **Continuous**. Continuous activated sludge process with gravity clarifiers combined downstream with a downstream class A system including ultrafiltration, ultraviolet and chlorination disinfection. The current CASS reactors would be converted to continuous bioreactors.

For both the CASS and continuous options the inDense system was considered as a sub option. This system is used to improve the performance of systems which rely on gravity settling in the activated sludge reactor.

Of the two additional options CASS with in Dense was the preferred approach. It was less complex and used less energy and is more likely to meet the immediate capacity restriction in 2024. Therefore, the CASS option was assessed in more detail and its capital cost assessed independently by Alta.

WSP estimated the MBR option previously to be $34.5 M by 2026. Alta's estimate was $23.5 M by 2026 for the CASS option which represented a considerable saving. An assessment of key operating costs (power, chemicals and key replacement items) indicates the CASS option was 65% of the cost the MBR approach.

Based on a consideration of each option it was considered the CASS upgrade approach with inDense represented the most optimal approach as it:

- Reuses most of the plant infrastructure and is a well proven technology that is well known to KDC.
- Represents capital and operations cost savings.
- Does not present significant construction risk. The bioreactors structures required are already in place.
- Can be staged with progressive roll out of extra capacity and does not produce stranded assets. The CASS option is more flexible to have capacity added quicker to handle the imminent lack of capacity by 2024. The other options involve significant works which will require more time and it is likely capacity will be exceeded before the option is ready.

- Has the lowest construction commissioning risk and hence capital cost risk. There is no major change to how the process operates. The other options require significant additional recycles and process units on a small brownfield site.

Based on the operating and capital savings and other factors described above it is recommended the CASS option with inDense be adopted.

Contents

Tables

Tables

Glossary of Terms

ADWF	Average dry weather flow
BOD	Biochemical oxygen demand over 5 days
COD	Chemical oxygen demand
DO	Dissolved oxygen
EBPR	Enhanced biological phosphorus removal
CWWTP	Community wastewater treatment plant
MLSS	Mixed Liquor Suspended Solids
NH_3-N	Ammonia as nitrogen
NO_3	Nitrate
NO_2	Nitrite
TKN	Total Kjeldahl nitrogen which is the ammonia and organic nitrogen only
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
LRV	Log reduction value
PAO	Polyphosphate accumulating organisms
PE	Persons equivalent
PO_4-P	Phosphate as phosphorus
KDC	Kaipara District Council
NOx	Oxidised nitrogen (nitrate + nitrite) as nitrogen
SRT	Solids retention time
SVI	Sludge volume index
UV	Ultraviolet
WAS	Waste activated sludge

1 Project Overview

1.1 Background

Downer operates the Community wastewater treatment plant (CWWTP) for Kaipara District Council (KDC) which treats sewage from the towns of Mangawhai heads and Mangawhai. The treated effluent is pumped to a farm commonly referred to as Browns farm for land discharge through an irrigation system. The Mangawhai CWWTP catchment area experiences a large influx of tourists during the Christmas and New Year's period with the treatment plant beginning to exhibit symptoms of capacity exceedance during these peak tourist periods.

Previously KDC engaged WSP to conduct an options assessment to investigate the best approach to address the capacity constraints at Mangawhai CWWTP. The findings from this investigation were that the plant will reach capacity between 2025 to 2028 depending on growth. Their preferred upgrade option was to convert the cyclic activated sludge (CASS) reactors to a membrane bioreactor process (MBR) to meet the Victorian EPA guideline for water recycling. This involved conversion of the CASS reactors to continuous reactors and installation of an immersed membrane reactor.

Since this time a project team led by SCO consulting has been developing the overall upgrade strategy further. The strategy has evolved with class A effluent being beneficially reused on the golf course. However, excess effluent in winter or wet weather is planned to be discharge at a new location with a new resource consent and with some being directed to the current Browns Farm irrigation system. This will provide more operational flexibility in low irrigation demand and high flow periods.

1.2 Project Purpose

KDC have engaged Beca HunterH2O in collaboration with SCO to undertake a peer review of the WSP options assessment prior to further design development. This report will develop and compare treatment options and present the potential risks with each option. A capacity review and suggested way forward will also be presented which will be compared to the preferred option from WSP's options report.

1.3 Overview of Plant

Mangawhai is in the KDC area and the operations are managed by Downer. The operations contract consists of management of the treatment plant and the effluent discharge to Browns Farm. The treatment plant consists of the following treatment systems:

- Inlet Screening via sieve screens with capacity up to 160 L/s.
- Two CASS reactors configured as follows:
  - A hydraulically mixed selector and air mixed anoxic zone which is 22% of the volume of each CASS reactor. The third zone is a large open rectangular structure with diffused aeration installed over the entire floor area.
  - Diffused aeration and blower system to provide aeration to the anoxic (periodic) and third zone of the CASS.
  - Wasting is conducted during the settle phase via a waste pump.
  - A 4.4 m decant weir is used to decant clear effluent to the intermediate storage tank
  - Each CASS operates based on a cycle. The total cycle length is typically 4 hours consisting of 120 minutes react (aerobic), 60 minutes settle, 55 minutes decant and 5 minutes idle time prior to restarting the cycle.
- Decant storage tank that collects decanted effluent from the CASS reactors and pumps decanted effluent to the pressure filters.
- Four pressure filters with dual media with a capacity of 6.5 L/s/filter.

- Liquid chlorine is dosed into the filtered effluent to provide disinfection prior to being pumped to Browns Farm for irrigation.
- Waste sludge is collected in the sludge holding and is dewatered using a rotary drainage deck and belt filter press. The flocculant for dewatering is liquid polymer.
- A balance tank the same size as a CASS reactor.

A new balance tank and screen system has been constructed in 2022 and recently commenced commissioning in April 2023. Up to 100 L/s from the catchment is directed a new sieve screen. The balance tank is to enable the plant to periodically receive higher instantaneous flows. The balance tank is of identical dimensions to the other two CASS reactors. This tank could be readily converted to a CASS reactor if needed.

As part of Downer's operations contract there is a requirement to manage the effluent discharge at Browns Farm. This report is limited to an options assessment of the CWWTP only.

1.4 Overview of Key Issues

The catchment area for Mangawhai CWWTP experiences highly variable population loadings. During the Christmas holiday peak period the population in Mangawhai can be 3.5 times higher than then non tourist off peak period. Based on a capacity assessment conducted as part of this project, the plant's capacity will be exceeded in the summer of 2024. Exceedance of the capacity can cause the decant to draw solids into the decant storage tank and cause excessive backwashing of the filters or complete bypass.

WSP noted in their report that capacity is exceeded between 2025 to 2028 depending on growth.

1.5 Basis of Design

The section below outlines the key design basis for both influent and effluent. All options were assessed against these criteria.

1.5.1 Population and Flow Growth

In 2021 WSP undertook sewage quality testing from 20/12/21 to 16/1/22 to assess the load over the peak tourist period and to develop the design basis for the plant. This report included population projections. The population projections were prepared for the Mangawhai sewerage catchment by Formative and adopted by WSP. The projections are shown in Table 1. WSP combined this information in their basis of design report. These projections included a new care home and commercial area.

Formative and WSP developed flow projections based of connection projections using following basis:

- Off peak 1.33 PE/connection and 201 L/PE/d
- Peak tourist 4.88 PE/connection and 113 L/PE/d

The flow projections are provided in Table 1. These projections have been adopted for this options study.

Table 1 – Mangawhai Population and Flow Growth Projections by Formative

Year	Total PE		Dry Weather Flow (m³/d)		Peak Wet Weather Flow (L/s) 5 x peak dry weather flow
	Off Peak	Peak	Off Peak	Peak	
2021	3,193	11,751	813	1,333	77
2023	4,191	14,014	769	1,564	90
2028	5,597	18,032	1,045	2,051	119
2033	6,741	21,774	1,255	2,471	143
2038	7,609	24,665	1,414	2,793	162
2043	8,266	26,849	1,534	3,037	176
2048	8,662	28,170	1,607	3,184	184
2051	8,900	28,963	1,650	3,272	189
Ultimate 2051	9,164	29,777	1,695	3,362	195

1.5.2 Sewage Loads

We adopted the following sewage loading per PE to calculate the influent load over time to the CWWTP:

- Chemical oxygen demand (COD) 125 g/PE/d.
- Total Kjeldahl nitrogen (TKN) 12 g/PE/d.
- Total phosphorus (TP) 2.3 g/PE/d.
- Inorganic suspended solids (ISS) 8 g/PE/d.

These align with the values noted in the WSP basis of design report. Slightly different parameters have been used (i.e. COD and ISS and opposed to BOD and TSS) which better align with the requirements of process models. However, they are equivalent to the values WSP adopted.

There is no monitoring available to know what type of organics are present in the sewage. Therefore, typical domestic sewage values were used for the key COD and TKN fractions which are outlined below:

- Fraction of COD which is biodegradable and particulate = 0.2
- Fraction of COD which is unbiodegradable and soluble = 0.07
- Fraction of COD which is biodegradable and soluble = 0.15
- Fraction of TKN which is unbiodegradable and soluble = 0.03

1.5.3 Approach to Assessing Load Impacts over the Peak Tourist Period

To better understand the peak tourist load, Beca Hunter H2O undertook an extensive testing regime from late 2022 to early 2023. This supplemented a similar shorter review of sewage loads by WSP over 2021 to 2022. This assessment identified there is a sharp increase in load over Christmas as outlined in Table 1. However, the load is not constant and occurs for a short period and tails off in January. The results from the two sampling periods are provided in Appendix A.

The data collected to date is not comprehensive and does not cover the full tourist period. However, it provides a good basis for understanding the high load periods between Christmas and early January. To estimate the load over the whole holiday period where concentration data is not available, we have produced estimates of the concentrations for periods where data is not available. The values chosen were based on a review of available data.

While the load is high over Christmas to early January period (up to 3.5 times load increase per day), the load increase is not sustained. Activated sludge processes operate over a long solids retention time (SRT) of 15 to 20 days and short-term load increase don’t often have a major impact. This presents a challenge to assess the required size of any bioreactor. Steady state modelling approaches often used in plant design will overestimate the infrastructure size as they assume the loading is constant over many SRT periods. To overcome this, we used the Biowin dynamic simulator and modelled the sludge production to enable us to size the activated sludge process. This was undertaken at an initial 20-day SRT entering the peak period. As the load increased the SRT setting was reduced to 15 days which is acceptable for ammonia removal at the higher temperatures in December and January. This modelling indicated the plant sludge inventory increase would be in the range 1.4 to 1.7 times the level prior to Christmas. The more recent and extensive sampling in 2022 to 2023 indicated the sludge increase could be much lower near 1.3 times.

All options were sized based on a sludge inventory increase in the activated sludge plant in the order 1.5 times the off-peak inventory.

It is recommended sewage sampling continue next holiday period and extend from Christmas day to the end of the holiday period (late January). This will ensure the plant is appropriately sized based a good understanding of how the peak loads are presented to the plant over time.

1.6 Effluent Quality

Mangawhai CWWTP currently has a resource consent discharge agreement with the parameters detailed in Table 2. The resource consent notes the plant shall include a granular filtration system and disinfection system. The filtration system must be designed to remove helminths.

The requirements of the consent are outlined in Table 2. The average is based on the last 6 results. The median and 90%ile is based on the last 12 results.

Table 2 – Mangawhai CWWTP Resource Consent Discharge Parameters

Parameter	Units	Median	Average	90th Percentile
Group A – Weekly Sampling				
E. coli	MPN/100 mL	10		100
Total Dissolved Solids (TDS)	mg/l		500	
Total Nitrogen (TN)	mg/l		30	
Total Phosphorous (TP)	mg/l		15	
Total Suspended Solids (TSS)	mg/l		10	
Carbonaceous Biochemical Oxygen Demand (cBOD)	mg/l		10	

1.7 Future Effluent Quality Limits

The Browns Farm irrigation fields are nearing capacity, the plan is to produce a class A effluent and reuse it on the Mangawhai Golf Club in future. Class A allows for unrestricted use of effluent. Excess effluent in wet weather or colder months may need to be discharged to the estuary with a new consent.

It is likely the nutrient levels will need to be lower than the current consent for both golf course sustainable use and estuary discharge. Estuary discharge may need to be significantly lower (i.e. < 5 mg/L TN) and require an additional treatment process at the CWWTP or processes such as artificial wetlands at the golf course prior to discharge.

We have assessed the options based on meeting an average TN of less than 10 mg/L and a degree of biological phosphorus removal (~ < 3 mg/L) as it is acceptable for irrigation. The CWWTP can be designed for a much lower median TN of 3 mg/L which is considered the limit of technology, however this presents capital cost challenges and it increases the complexity of operation.

If required additional process can be added to each plant option to improve TN and TP removal. In the case of TN this can be modifications to the MBR and continuous reactors or a bolt on Moving Bed Bioreactor (MBBR) process. Alum or iron salts can be added to the existing options to remove phosphorus in the reactors to 1 mg/L median with no impact on capacity.

It is considered to have greater community acceptance to use constructed wetlands to polish effluent if needed for discharge. If this approach is used additional processes the CWWTP will not be required.

1.7.1 Class A Requirements and Recommended Technology Approach

The project has adopted the requirements of the Victorian EPA guidelines for water recycling. This effluent reuse class allows for unrestricted reuse. The requirements are summarised in .

Table 3 – Class A Victorian Health Guidelines Effluent Quality Requirements

Requirement	Class A
E. Coli median (CFU/100 mL)	<1
BOD median(mg/L)	<10
TSS median (mg/L)	<5
pH range	6 - 9
Turbidity median (NTU)	<2
Virus Log Removal	5
Protozoa Log Removal	3.5
Bacteria Log Removal	4

A key requirement of guidelines is the whole process is to meet certain log reduction values (LRV's). LRV's are values given to each unit operation and represent the number of 10 fold reductions (i.e. 1 log = 10 times reduction and 2 log = 10 x 10 = 100 times reduction).

Three pathogens are nominated which include bacteria, protozoa and viruses. Treatment technologies remove each pathogen differently. Table 4 outlines what can be practically expected from each unit operation. The likely total LRV for two options involving membrane and granular media filtration are presented in this table.

To meet the class A LRV requirement a minimum of filtration, UV and chlorination is required. UV is required in combination with filtration and chlorination as it has an ability to easily inactive protozoa. Whereas membrane filtration and chlorination alone cannot meet the LRV for protozoa together.

Granular media filtration can struggle to achieve LRVs without significant investment in monitoring and control. LRVs can be claimed for protozoa if strict turbidity limits are met which can be hard to achieve. For example, a 2.5 log LRV for protozoa is possible with a 90%ile turbidity of < 0.3 NTU. For viruses the LRVs are typically low.

It is likely activated sludge processes with granular media filtration combined with UV and chlorination will struggle to reliably meet the class A LRV requirements. However, ultra-filtration (UF) membranes processes with either MBR or tertiary membranes, UV and chlorination will readily meet the Class A requirement. Therefore, the options in this report only considered ultrafiltration as the filtration barrier.

From our experience the capital cost of membrane versus granular media options is similar. Adopting a membrane approach provides superior LRV removal overall for a similar cost.

Table 4 – Typical LRV's for Unit Operations

Process Treatment Stage	LRV Virus	LRV Protozoa	LRV Bacteria	Comment
Bioreactor	0	0	0	Validation required to claim LRV- Likely 0.5 Bacteria.
MBR (Mixed Liquor)	1.5	2	4	MBR Can claim the listed LRV's however, can also challenge test to claim more if required.
Granular media filtration (Current Operation)	0	0	0	Requires validation testing to claim protozoa or virus LRVs
Pressure Filtration (UF)	1.5	2	4	This covers both tertiary pressure membranes.
Chlorination	4	0	4	Maximum possible claim under Victorian guidelines. This can readily be achieved with free chlorination of filtered effluent.
UV Disinfection	0.5	3.5	3.5	In line with UV dose as specified by suppliers to meet cryptosporidium removal. Higher doses can be used to target greater removal at much higher cost
Total LRVs for Process Configurations versus Class A Requirement				
MBR/Tertiary Membranes + UV+ chlorine	6	5.5	11.5	Exceeds compliance requirements
Granular Media Filter + UV + chlorine	4.5	3.5	7.5	Possible compliance issues with viruses.
Required Victorian Guideline Class A Requirement	**5.0**	**3.5**	**4**	

1.7.1 Helminth Removal

Helminths are a parasitic worm that can infect animals exposed to irrigated with effluent. Processes that can remove the helminth ova (i.e. eggs) are required by the consent and most reuse guidelines where animals graze on irrigated land. The Victorian EPA guidelines recommend 4 log removal of helminths. The consent does not specifically quote a removal value, just the filters must remove helminths.

Adoption of ultrafiltration will provide effective removal and ensure this requirement is met if reuse continues to occur at Brown's Farm.

In some options below bypass of the Class A filtration system is expected to occur in wet weather. If treated flows which bypass filtration occur and the effluent is irrigated with animal present, additional helminth barriers are recommended. For Browns Farm it is recommended 25 days (allowed in the Victorian guidelines) of pond storage be used prior to irrigation. This will mean some volume in the current dam will need to be reserved for helminth removal.

Helminth removal is not considered necessary for the golf course reuse. However, it will be achieved as the recommend class A filtration system (UF membranes) will meet the 4-log removal requirement.

2 Current Plant Capacity

A plant capacity assessment has concluded the plant will reach capacity in the Summer of 2024. The capacity is limited by how fast sludge can settle in the CASS. It needs to settle fast enough to avoid sludge being decanted. The high loading in the peak tourist period produces too high a solids concentration to allow effective settling.

Another concern is the sludge is bulking in nature. This can also slow the sludge settling rate. Bulking is measured using the sludge volume index (SVI) and has been historically high near 200 ml/g. Typically in most plants this is less than 150 ml/g. A separate plant audit report prepared by Beca HunterH2O addresses this issue and potential solutions to improve SVI.

3 Upgrade Options

3.1 Options Considered

The MBR option was the preferred option from the review of options completed by WSP. However, they only considered one class A option which was MBR. The filtration step needed for class A can be provided in other processes configurations other than MBR. Two alternative options were considered along with MBR which included continuing with the CASS approach and using the existing CASS reactors with gravity clarifiers. Both alternative options reuse most of the infrastructure onsite.

The three upgrade options that were considered included:

- **CASS.** The CASS activated sludge process (extra CASS units to meet capacity) combined downstream with ultrafiltration, UV and chlorination disinfection.
- **Continuous**. Continuous activated sludge process with gravity clarifiers combined downstream with ultrafiltration, UV and chlorination disinfection.
- **MBR**. Continuous activated sludge process with immersed membranes for activated sludge separation. This is knowns as the membrane bioreactor process (MBR). The MBR process is combined downstream with UV disinfection and chlorination disinfection.

For both the CASS and continuous options the inDense system was considered as a sub option. This system is used to improve the performance of systems which rely on gravity settling in the activated sludge reactor. The technology uses a series of hydro cyclones to select for denser floc forming bacteria. It relies on establishing biological phosphorus removal bacteria which produce denser bacteria. Overall, this process can significantly improve the sludge volume index (SVI) to values less than 90 ml/g. This ensures the sludge settles faster and increases the capacity of decant weirs or gravity clarifiers.

The inDense process is currently being trialled at Mangere WWTP and has significantly improved the SVI.

3.2 Configuration of Flows for each Option

The Class A processes (filtration, UV and chlorine) was sized for 2.5 x design peak ADWF. Note the sewage is designed to pass 5 x design peak ADWF to the plant. It has assumed the excess wet weather storm flow (above 2.5 times design peak ADWF) will receive secondary treatment follow by chlorine disinfection for CASS and continuous options only. This effluent which bypasses the Class A system will be suitable for grade B uses only such as Browns Farm or discharge.

CASS and continuous options can use either a storm cycle or solids contact bypass to treat storm flows and not change the size of the clarification system. This provides a degree of contact stabilisation with activated sludge at high flows. MBR cannot achieve this and either needs to bypass dilute sewage or provide membranes capable of treating all flows. In the case of MBR, membranes were provided for the full storm peak flow treatment.

3.2.1 CASS Option

3.2.1.1 Overview of the Option

In this option the upgrade is for continued operation of the existing CASS reactors and installation of new CASS reactors to meet capacity as detailed below in upgrade staging. The advantage of this option is that minor modifications can be made to the existing CASS reactors to increase capacity. In all options there has been a modification to increase the decant weir length from 4.4 m to 6 m to allow more process throughput. The increase in weir length increases the area of clear water zone under the weir which lowers the decant approach velocity. This enables the weir to handle more flow before sludge scouring occurs.

3.2.1.2 Staging of the CASS Upgrade

CASS options with and without inDense are presented in Table 5. The upgrade can be staged by progressively adding more CASS reactors which will provide more capacity as growth occurs. The staging is outlined below.

Table 5 – Staged Upgrade Capacities for the CASS Option

CASS		CASS with inDense	
Number of CASS Units	**Provides Capacity to**	**Number of CASS Units**	**Provides Capacity to**
2x CASS units (Current Operation)	2024 (2921 connections)	2x CASS units	2028 (3550 connections)
3x CASS Units + additional Sludge Balance Tank	2042 (5132 connections)	3x CASS Units + additional Sludge Balance Tank	2047 (5464 connections)
4xCASS Units	Ultimate (5672 connections)		

Conversion of the existing balance tank onsite to an extra CASS reactor will almost meet the ultimate capacity with inDense. This is a significant advantage for this option as it considerably reduces the construction of new major infrastructure on site.

Beca Hunter H2O's calculations agree with those presented in WSP's report of requiring four CASS reactors for 5000 connections. However, our modification of increasing the weir length will mean that three CASS units will meet 5000 connection capacity and 4 will meet the ultimate capacity at 2052.

Presented below are the staging steps for both CASS and CASS with inDense.

CASS Staging with inDense

If inDense is implemented the following upgrades are required in the following times:

1. Refurbish the existing CASS decant weirs to increase the length and implement inDense by the end of 2024.
2. Retrofit the existing balance tank as an extra CASS system and add the class A system (UF + UV+ chlorination) and construct the golf course pump station by 2028.
3. Construct a new CASS reactor by 2047.

CASS Only Staging

For CASS only the following upgrades are required in the following times:.

1. Refurbish the existing CASS decant weirs to increase the length and retrofit the existing balance tank as a new CASS reactor by the end of 2024.
2. Add the class A system (UF + UV+ chlorination) and construct the golf course pump station by 2028.
3. Construct a new CASS reactor by 2042.

The staging and site footprint requirements for this upgrade are presented below in Figure 1.

Figure 1 – CASS Staging and Footprint Diagram

3.2.2 Continuous Option

In this option the operating level of the CASS reactors will be set at the current top water and a fixed weir established. The internals of the reactor will be modified, and the size of the unaerated zone extended. The aerobic part of the reactor would aerate continuously, and mixed liquor would flow over the fixed weir to settle and separate in two new circular clarifiers. This option requires construction of 2x 20 m diameter clarifiers to separate solids. Return activated sludge (RAS) from the clarifiers will be pumped back and evenly split to each bioreactor.

It is proposed to operate this process in solids contact mode in wet weather. This involves bypassing flows above 3 times peak average design flow to a flocculation zone with sludge post the reactor and then through the clarifiers. This approach provides effective storm treatment of high flows up to 5 x peak average design flow.

Like the CASS option this option would benefit from implementation of inDense with a reduction in clarifier size from 20 to 17 m diameter being the major impact. The upgrade stages are presented below in Table 6.

Table 6 – Staged Upgrade Capacities for the Continuous Option

Continuous (Clarifiers) 2 x 20 m diameter		Continuous (Clarifiers) inDense 2 x 17 m diameter	
Number of CASS units converted to bioreactors	**Provides Capacity to**	**Number of CASS units converted to bioreactors**	**Provides Capacity to**
2x CASS unit converted reactors and 2x 20 m Clarifiers	2039 (4874 connections)	3x CASS unit converted reactors and 2x 17 m clarifiers	Ultimate (5672 connections)
3x CASS unit converted reactors and 2x 20 m Clarifiers	Ultimate (5672 connections)		

This new option presented in Table 6 provides an opportunity to convert the current intermittent process to a continuous process reuse. The advantage of this option is no further signification bioreactor construction is needed as the balance tank can be converted to a reactor.

There is the option of constructing two smaller clarifiers now (2 x 16.3 m diameter) to further stage construction at the initial stage (i.e. 2 CASS reactor and 2 clarifiers). However, this brings forward the final upgrade significantly from 2039 to 2033 for only a minor change in clarifier size.

For this option two clarifiers required for the ultimate capacity need to be constructed at the start of the construction period. This would need to occur to promptly given the current plant's capacity is likely to be exceeded in 2024.

To deliver this option, the following stages are recommended:

1. Convert the existing balance tank as a new CASS reactor to allow for the existing CASS reactors to be converted. Refurbish the existing CASS decant weirs to increase the length.
1. Construct the clarifiers (as soon as practical).
2. Convert the existing CASS reactors to continuous reactors.
3. Add the class A system (UF + UV+ chlorination) and construct the golf course pump station by 2028.

The key disadvantage of this option compared to the CASS option is conversion of the current balance tank to a CASS reactor is required to provide capacity to construct the option. Later this CASS reactor will be redundant and be converted to a continuous reactor.

The staging and site footprint requirements for this upgrade are presented below in Figure 2.

Figure 2 – Continuous Staging and Site Footprint diagram

3.2.3 MBR

The supplier Du Pont worked Beca HunterH2O to develop a membrane solution for this option. The WSP options report showed the membrane system schematically, however no sizing information was provided. For this option to fully explore the complexity we sized the membrane trains with the supplier to enable us to position it on the site.

The MBR is very similar to the continuous option with the same bioreactor configuration used. The key differences are as follows:

- Finer screening to less than 2 mm is required included the need for grit removal prior to the bioreactor. A high level of redundancy of screening is required with a minimum of two screen recommended. Note only one is installed currently. This is a key warranty requirement for immersed membranes. They are subject to fouling and damage from screenings and grit that pass the inlet works.
- A much higher internal RAS flow is needed clear the immersed membranes of mixed liquor. The RAS needs to operate near 3 compared to 1 times inflow for the continuous process with clarifiers. This adds to the complexity of this option as a high flow return stream needs to be fed through a brownfield site to the current CASS structures.
- Separate to the current CASS reactor a smaller separate set of train reactor tanks needs to be constructed to house the immersed membranes. These trains need to be elevated above the current CASS reactor to ensure the trains do not overtop if the RAS pumping system fails.
- Six trains 5.1 m long by 4.1 m wide and 2.45 m deep are required for the ultimate capacity.
- A full standby generator is recommended to power the inlet works, bioreactor and membranes. This is recommended as the MBR processes will not fail safe hydraulicly on power failure and the reactor can overtop.

Six MBR trains are required to provide flow turndown from peak flow (5 x peak tourist ADWF) to current minimum diurnal flow.

The bioreactor will be converted to a continuous reactor in a similar way to the continuous option with constant aeration. With MBR only two CASS reactors are required for the ultimate capacity. However, the existing balance tank will need to be converted to a bioreactor to enable it to be run as a MBR process so one other CASS reactor can be converted. The third CASS will not be required, however could function as a balance tank, or be converted to a bioreactor to provide further redundancy in future.

There is the potential to stage the membrane trains. Only 5 trains with membrane internals are required initially for loads up to 2038. With a further 6th train required after 2038. However, it is recommended the civil structure for the whole 6 trains be provided now. It will be very difficult to construct a separate small train in 2038 and integrate it with the plant.

A key challenge with the MBR trains is they will be position above the current bioreactors which are several meters above the ground. The floor of the MBR trains would be above the current ground level and require a raised structure with the floor some meters above ground level. This will present construction challenges.

In summary an MBR process while using much of the current infrastructure will require a major investment with most of the ultimate capacity required to be constructed now.

To deliver the MBR option the following upgrade staging is recommended.

1. Build the MBR trains, RAS, clean in place chemical dosing and new inlet works with fine screens and grit removal.
2. Convert the existing balance tank to a bioreactor for operation with the MBR trains.
3. Run on one bioreactor with the MBR and shut down both CASS reactors. Operations on one bioreactor is only recommended for the non-tourist period.
4. Convert on of the two CASS reactor to a bioreactor and connect it to the MBR process.
5. Add the class A system (UV+ chlorination) and construct the golf course pump station by 2028.

The staging and site footprint requirements for this upgrade are presented below in Figure 3.

Figure 3– MBR Staging and Site Footprint Diagram

3.3 Operations Cost Comparison

Key operating costs for each option (power, chemicals and limited maintenance items) have been developed to compare options. A summary is provided in .

Table 7 – Comparable Costs for Upgrade Options for Mangawhai CWWTP at 2033

		CASS	Continuous	MBR
OPEX Class A	Power ($0.2/kWh)	$118K/yr	$146K/yr	$159K/yr
	Chemicals (Disinfection and clean in place)	$24K/yr	$24K/yr	$33K/yr
	Maintenance and Replacements (Membranes, Diffusers, UV Lamp replacement)	$53K/yr	$54K/yr	$117K/yr
	Total	**$195K/yr**	**$223K/yr**	**$309K/yr**

The lowest operating cost is the CASS process. This is driven by the activated sludge process which has low energy use compared to the other two options which require more recycle pumping and other items in the case of MBR.

The MBR process represent the highest operating cost. This cost difference is due to the need to air scour the membrane trains and provide additional chemical cleaning. The clean in place requirements are higher for MBR then the UF membranes used for the other options. More chemical is required to be dosed into the larger volumetric trains of the MBR process.

All membranes have a finite life in the order of 10 years for all options considered. However, up to four times more membrane area is required for MBR due to its lower design flux need to treat all flows. Therefore, over a 10-year period the membrane replacement cost will be higher. This is reflected in the higher annualise maintenance cost below.

3.4 Recommended Approach and Capital Cost

Based on a consideration of each option and operations costs it was considered the CASS upgrade approach with inDense represented the most optimal approach as it:

- Reuses most of the plant infrastructure and is a well proven technology that is well known to KDC.
- Represents the lowest operations costs.
- Does not present significant construction risk. The bioreactors structures required are already in place. The balance tank has been designed with identical dimensions to the other CASS units.
- Can be staged with progressive roll out of extra capacity and does not produce stranded assets. The CASS option is more flexible to have capacity added quicker to handle the imminent lack of capacity by 2024. The other options involve significant works which will require more time and it is likely capacity will be exceeded before the option is ready.
- Has the lowest construction commissioning risk and hence capital cost risk. There is no major change to how the process operates. The other options require significant additional recycles and process units on a small brownfield site.

WSP estimated the MBR option previously to be $34.5 M by 2026. Alta was engaged by KDC to assess the cost of the CASS option. Their estimate was $23.5 M by 2026 which represented a considerable saving.

Based on the operating and capital savings and other factors described above it is recommended the CASS option with inDense be adopted.

4 Summary and Recommendations

Beca Hunter H2O was engaged to undertake a peer review of the upgrade options for the Mangawhai CWWTP. WSP previously had explored treatment options and recommended an MBR process, production of a class A effluent and reuse on the local golf course.

Since this time a project team led by SCO consulting has been developing the overall upgrade strategy further. The strategy has evolved with class A effluent being beneficially reused on the golf course. Excess effluent in winter or wet weather is planned to be discharge at a new location with a new resource consent and with some being directed to the current Browns Farm irrigation system. This will provide more operational flexibility in low irrigation demand and high flow periods.

A plant capacity assessment was undertaken to assess when the upgrade needed to occur. The current plants capacity will be exceeded by summer of 2024. There is a significant driver to address the capacity in the short term.

For the Class A reuse option WSP restricted the review to one option. However, Class A can be provided in other processes configurations. Two alternative options were considered along with MBR option which included:

- **CASS.** Expanding the existing CASS activated sludge process with extra CASS units combined with downstream ultrafiltration, UV and chlorination disinfection.
- **Continuous**. Continuous activated sludge process with gravity clarifiers combined downstream with ultrafiltration, UV and chlorination disinfection. The current CASS reactors would be converted to continuous bioreactors.

For both the CASS and continuous options the inDense system was considered as a sub option. This system is used to improve the performance of systems which rely on gravity settling in the activated sludge reactor.

Of the two additional options CASS with inDense was the preferred approach. It was less complex and used less energy and is more likely to meet the immediate capacity restriction in 2024. Therefore, the CASS option was assessed in more detail and its capital cost assessed independently by Alta.

WSP estimated the MBR option previously to be $34.5 M by 2026. Alta’s estimate was $23.5 M by 2026 for the CASS option which represented a considerable saving. An assessment of key operating costs (power, chemicals and key replacement items) indicates the CASS option was 65% of the cost the MBR approach.

Based on a consideration of each option the CASS upgrade approach with inDense represented the most optimal approach as it:

- Reuses most of the plant infrastructure and is a well prove technology that is well known to KDC.
- Represents the lowest capital and operations cost.
- Does not present significant construction risk. The bioreactor structures required are already in place.
- Can be staged with progressive roll out of extra capacity and does not produce stranded assets. The CASS option is more flexible to have capacity added quicker to handle the imminent lack of capacity by 2024. The other options involve significant works which will require more time and it is likely capacity will be exceeded before the option is ready.
- Has the lowest construction commissioning risk and hence capital cost risk. There is no major change to how the process operates. The other options require significant additional recycles and process units on a small brownfield site.

Based on the operating and capital savings and other factors described above it is recommended the CASS option with inDense be adopted.

It is recommended sewage sampling continue next holiday period and extend from Christmas day to the end of the holiday period (late January). This will ensure the plant is appropriately sized based on a good understanding of how the peak loads are presented to the plant over time.

5 References

EPA Victoria, Victorian guideline for water recycling, Mary 2021

WSP, Mangawhai Community Wastewater Treatment Plant: Future Options Development, 2019

WSP, Mangawhai Community Wastewater Treatment Plant Growth Strategy: Basis of Design for Wastewater Treatment and Disposal, August 2022

Appendix A. Peak Period Sampling Results

WSP Sampling over 2021-2022 Christmas Period

Date	Flow (m3/d)	Rain' Mm/d	Concentration (mg/l) BOD	COD	TSS	NH_3	TKN	DRP	TP
20/12/2021	803	0	250	640	247	59.2	74	6.9	10
29/12/2021	1,274	1	550	1,400	628	85.5	116	9.4	13
1/01/2022	1,391	0	510	1,400	645	86	110	10	13
5/01/2022	1,079	0	530	1,600	667	87.3	116	9.4	14
12/01/2022	867	0	230	780	378	62.4	83.3	7.4	13
17/01/2022	777	0	400	1,200	475	75.8	96.2	8.7	13
24/01/2022	680	4.04	260	590	135	87.6	101	9.7	12
1/02/2022	670	3.535	270	970	300	78.5	92.1	8.4	11
14/02/2022	663	0		860	281	71.7	93.9	8	12
16/02/2022	618	0	310	1,300	500	47.5	74.7	12	19

Beca Hunter H2O sampling over the 2022-2023 Christmas Period

Date	Flow m3/d	Rain mm/d	Concentration (mg/L) cBOD	COD	TSS	NH3	TKN	TP
22/12/2022	810	0	200	570	142	57.6	74.2	9.04
23/12/2022	869	0	170	530	163	57.7	76.8	10.9
24/12/2022	982	0	210	630	169	61.4	82.9	10
25/12/2022	950	0	180	460	127	65.6	73.2	9.8
26/12/2022	1054	0	210	490	169	76	83.9	10.8
27/12/2022	1159	0	200	540	154	74.9	82.8	10.6
28/12/2022	1238	0	200	670	186	79.4	89.9	12.4
29/12/2022	1264	0	660	1600	700	104	135	19.6
30/12/2022	1368	0	310	940	621	46.4	82.6	12.5
31/12/2022	1421	0	180	650	155	70	75.2	10.7
1/01/2023	1319	0	200	590	169	78	79.3	10.3
2/01/2023	1232	0	510	1100	484	78.6	89.7	12.4
3/01/2023	1160	0	340	760	354	70.9	89.1	10.1
4/01/2023	1090	33	370	830	435	62.8	92.2	11.9