WASTEWATER RECLAIMATION FOR HIGH QUALITY REUSE – A CASE STUDY IN HELENSVILLE

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ABSTRACT

Resource consent requirements, cultural views, public perception, advances in technology and affordability are driving the treatment of wastewater to a higher effluent quality standards moving ever closer towards drinking water quality.

Helensville wastewater treatment plant is located in the Rodney District and is currently serviced by a two stage oxidation pond system prior to tidal discharge into the Kaipara River. The oxidation pond system has reached the design capacity and requires an upgrade. Moreover, the resource consent is lapsed and Rodney District Council is currently preparing an application to renew the consent.

Genesis Energy have proposed a new power station in the Kaipara area near the existing wastewater treatment plant and have held discussions with Council regarding the potential to use the treated effluent from the upgraded wastewater treatment plant as a water source for boiler water, which is typically of a very high quality.

This re-use of the treated wastewater not only allows a reduction in treated effluent discharge to the Kaipara river but also means that development of a new source from the Kaukapakapa River is not required. This re-use of the treated effluent provides a sustainable output in terms of reducing waste produced and conserving clean freshwater sources for other uses.

While the timeframe required for the Power Station to obtain the resource consent and the negotiation between Genesis Energy and Rodney District Council is being undertaken, a treatment plant upgrade strategy has been developed. This strategy needed to provide a flexible design to ensure the Helensville wastewater treatment plant meets the needs of the ratepayers in the short term whilst allowing the potential for the re-use of treated effluent in the medium to long term.

A two stage upgrade approach has been proposed. The first stage is a low-cost upgrade to improve BOD_5 and TSS removal efficiency through implementing surface aeration and ultrafiltration (UF). The details of the second upgrade stage is subjected to future environmental monitoring and up to date population forecast. This may include the construction of a high rate activated sludge process to achieve biological nutrient removal and disinfection. The high quality effluent reuse requirement at the power station has also been taken into account in the plant upgrades.

This paper will cover the issues considered with developing the strategy, such as challenges with high quality water recovery and efficiency of design.

KEYWORDS

Effluent Reuse, Wastewater Treatment, Power Station

1 INTRODUCTION

In recent years, the treated effluent standards have been under an increasing scrutiny by the regulators and the public. This has resulted in tightening in discharge limits and driving the effluent quality ever closer to drinking water through implementation of extensive and often expensive plant upgrades. This study presents a case study of upgrading the wastewater treatment plant in Helensville to satisfy the community interests and achieve effluent reuse objectives at the same time.

Helensville and Parakai are two communities located in northwest Rodney. The wastewater is treated at a wastewater treatment plant (WwTP) located on a peninsula site on the true right bank within the Kaipara River. The treatment plant consists of two oxidation ponds operating in series and the treated effluent is discharged into the Kaipara River during outgoing tides.

The treatment plant site is approximately 2km northwest of Helensville and on the opposite side of the Kaipara River to Parakai. The properties surrounding the site are predominantly rural in character. Refer to Figure 1 below for the locality of the site.

Figure 1: Locality Diagram of Helensville Wastewater Treatment Plant

Wastewater from Helensville and Parakai is pumped to the treatment plant via separate rising mains. The oxidation ponds are designed to remove Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) and a discharge chamber regulates the effluent discharge from Pond 2 to the Kaipara River.

Figures 2 and 3 illustrate the existing ponds and the Kaipara River respectively.

Figure 2: Oxidation Ponds in Helensville Wastewater Treatment Plant (Pond 2 in the foreground)

Figure 3: Viewing of Kaipara River from the opposite side of the bank

2 CURRENT SIUTATION

2.1 PLANT PERFORMANCE

The oxidation ponds receive a daily wastewater flow between 700 and 850m³/day with storm flows peaking up to 5000m³/day. Table 1 below presents a summary of recent plant performance.

Table 1: Recent Performance Data Summary of Helensville WwTP

Parameters	Consent Limits[1]	January 05 – April 08 Effluent Data	
		Median	95^{th} percentile
BOD_5 (mg/L)	20	28	48
TSS (mg/L)	30	72	152
Dissolved Oxygen (mgO/L)	5	7.6	16.4[2]
pH	-	7.8	8.7
NH_4N (mgN/L)	-	22	35
NO_3N (mgN/L)	-	1	2
NO_2N (mgN/L)	-	0	0.4
TP (mgP/L)	-	6.2	10.8
Enterococci (/100ml)	-	860	9460

Note:

1. Consent specifies maximum values.
2. The measurement values marked with "*" are expected to be affected by algal cells.

As presented in the table above, the current performance typifies a municipal oxidation ponds system which removes most of the influent BOD_5 and suspended solids. It does not reduce nitrogen and phosphorus to any significant extent.

The current resource consent, which lapsed in 1999, specifies maximum discharge limits of Biological Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) of 20 and 30mg/L respectively. This is considered to be a very stringent effluent standard for pond systems, and the ponds currently do not meet the conditions.

A marginally higher effluent BOD_5 concentration (~28mg/L) indicates that organic over-loading in the ponds may have occurred. A comparison between the current BOD_5 loading rate and the typical recommended loading rate shows that the current BOD_5 loading is approximately 195kg/ha.day^{-1}, which exceeds the recommended loading rate in winter conditions of 100kg/ha.day^{-1}.

2.2 CURRENT EFFECTS ON THE RECEIVING ENVIRONMENT

Rodney District Council (RDC) commissioned a number of investigations to examine the effects of the discharge on the receiving environment, namely Kaipara River and Kaipara Harbour.

Kaipara River and estuary are often used for a range of recreational activities, including contact uses such as kayaking, swimming, water-skiing, boating and sailing as well as low contact activities like walking, cycling, running and shellfish gathering.

The water quality survey on the receiving environment (DSL, 2007) indicated that the effluent discharge has "no measurable effect" on the water quality of Kaipara River as the general water quality in the river is predominantly affected by the upstream agricultural run-off resulting in elevated concentrations of turbidity, suspended solids, microbial indicators and nutrients.

The Quantitative Microbial Risks Assessment (QMRA) undertaken by NIWA indicated that whilst the effluent discharge from the treatment plant has no measurable impact on the river quality, improving the efficacy of pathogen and virus removal at the treatment plant will reduce the infection risk of the full-contact recreational water users and consumers of raw shellfish.

3 FUTURE DEMANDS

Helensville, is one of the high growth centres in the Rodney District and its population is expected to increase from 3800 to 8500 in the next 40 years. This significant population growth will require a substantial increase in infrastructure capacity including wastewater treatment.

Table 2: Population Growth and Projected Wastewater Flows in Helensville & Parakai Catchment

Year	Population	Average Dry Weather Flow (m^3/d)
2006	3813	750
2011	4211	926
2016	4275	941
2021	5238	1152
2025	5800	1276
2036	7278	1601
2051	8491	1868

As presented in Table 2 above, the wastewater flow required for treatment from the Helensville and Parakai catchment will reach 1,300m^3/day by 2025 and 1,900m^3/day by 2051, and hence an expansion of the treatment process will be required.

4 IDENTIFYING THE WATER SOURCE FOR THE POWER STATION

Genesis Energy has proposed a new combined cycle power station in the Kaipara area near the Helensville wastewater treatment plant. Steam is used to drive turbines for electricity generation and this provides an opportunity of potential effluent reuse as make-up the boiler feed water. It is estimated that the water demands at the power station will range from 300 to 700m^3/day.

Genesis Energy in conjunction with their Consultants have examined a number of water source options for the boiler water make-up:

1. Brackish/Saline water from the Kaukapakapa River
2. Drinking water from the water treatment plants
3. Groundwater sources
4. Treated effluent from the Helensville Wastewater Treatment Plant

High quality water source is often required to prevent any potential detrimental effects on the turbines and the overall operation of the plant plants. Availability and consistent flow are also crucial.

Kaukapakapa River

The Kaukapakapa River is an estuarine water with considerably high salinity and solids levels. Moreover, the characteristics of this water source is highly variable.

An extensive treatment will likely be required to raise the quality of this water source to the standard suitable for feeding the boilers. The treatment will probably include a conventional water treatment process of the saline raw water followed by microfiltration and reverse osmosis.

Moreover, the high salinity of this water source will result in a low water recovery through the reverse osmosis system. Hence, treating this water source was considered to be difficult and expensive.

Drinking Water

Potable supply from the Helensville water treatment plant is a good quality water source for supplementing the water needs at the power station. However, using drinking water for the power station will result in direct competition for scarce freshwater source in the area with domestic water demand. Hence, keeping the drinking water for potable consumption is preferred by the community and Rodney District Council.

Groundwater

There are a number of groundwater sources in the area; some of which are saline or brackish and they are less suitable as a water source to the power station for the reasons similar to the Kaukapakapa River.

Moreover, the freshwater water source for potable use in the Helensville area is limited and there have been studies examining new water sources to meet the future demands. One of the options is developing groundwater source to supplement current sources. Developing groundwater bores or springs to supply water to the power station will have a competing interest to the local community for gaining access to quality freshwater for potable use.

Therefore, it was concluded that groundwater is not a suitable water source for the power station.

Reclaimed Treated Effluent

The treated effluent from the Helensville Wastewater Treatment Plant is an alternative water source for the power station. The advantages of using the treated effluent include:

- Consistent volume and flow – the current average dry weather flow is 750m³/day compared with the water demand at the power station of 300-400m³/day for the initial years.
- Better water source quality than abstracting brackish/saline water in the Kaukapakapa River;
- Reduction in effluent discharge volume – a small volume of treated effluent will be lost through evaporation in the power station;
- A separate discharge consent is not required – the return stream from the power station can be pumped back to the wastewater treatment plant for discharge;

Moreover, reclaiming treated effluent from the Helensville WwTP as the water source for the power station avoids the abstraction of difficult water sources such as the Kaukapakapa River and have a potential competing interest with the community for freshwater access.

Table 3: Evaluation Summary of the Power Station Water Sources

	Suitable Volume & Quality	Not Compete with Community Interests (e.g. drinking water)	No Separate Discharge Consent Required
Abstracting from the Kaukapakapa River	x	✓	x
Drinking Water	✓	x	x
Ground Water	?	x	x
Effluent Reuse from the Helensville WwTP	✓	✓	✓

Based on the reasons above, Genesis Energy and Rodney District Council have been discussing the details of implementing effluent reuse from the Helensville wastewater treatment plant at the power station. Whilst the discussion is ongoing, Rodney District Council is preparing an upgrade strategy of the wastewater treatment plant with this effluent reuse opportunity in mind.

5 UPGRADE STRATEGY

Below describes the upgrade strategy proposed for Helensville Wastewater Treatment Plant.

5.1 UPGRADE DRIVERS

As presented in Section 2 to 4, the issues facing at the Helensville Wastewater Treatment Plant are:

- Organic overloading in the oxidation ponds – this results in an elevated BOD_5 concentrations in the pond effluent;
- The resource consent has lapsed;
- Non-compliance to the current resource consent conditions – the current consent conditions are difficult to comply, especially for oxidation pond systems like Helensville;
- Improving the efficacy of pathogen and virus removal is desirable given contact recreational activities in the river and estuary;
- Significant growth forecasted in the area – this would require an increase of the treatment plant capacity.
- Possible effluent reuse opportunity at the proposed power station

Therefore, a suitable treatment plant upgrade strategy will deliver the following objectives:

- Increase plant capacity to meet future demands;
- Improve compliance with the resource consent conditions;
- Improve pathogens and virus removal;
- Affordable to the community and ratepayers;
- Compatible with possible high-quality effluent reuse opportunity at the power station.

5.2 UPGRADE OPTIONS CONSIDERED

Rodney District Council has commissioned a number of investigations to upgrade the Helensville wastewater treatment plant and wastewater servicing options and the following options were considered:

1. Upgrade existing pond with disc filters / drum filters followed by UV disinfection
2. Upgrade existing ponds with additional capacity followed by ultrafiltration (UF)
3. Construct a high-rate activated sludge process with biological nutrient removal (BNR) followed by UV disinfection
4. Effluent disposal via land
5. Relocate the existing ponds to a new location / Pumping sewage to a treatment plant elsewhere

Pond Upgrade with Disc Filters and Drum Filters followed by UV Disinfection

This option will entail installation of drum filters/disc filters downstream of the final pond and the filtered effluent will be treated with UV disinfection prior to outfall discharge. This is considered to be the least expensive option. Drum filters and disc filters are often used as a tertiary treatment downstream of activated sludge or trickling filter processes for solids removal.

However, this option does not address the capacity increase requirement and there are potential operational and performance issues associated with the drum filters / discfilters in this application.

Due to algal solids in the pond effluent, the filter media in the disc filters and drum filters could become blinded (clogged) resulting in reduction in throughput and deterioration in effluent quality. Furthermore, the effluent quality is unlikely to be suitable as a water source for boiler water at the power station.

Therefore, this option is not considered to be suitable.

Pond Upgrade with Additional Capacity followed by Ultrafiltration (UF)

This option will consist of installing additional surface aerators to supplement the assimilative capacity in the ponds and the pond effluent is treated by an ultrafiltration system prior to outfall discharge.

Whilst the existing process configuration will be maintained in this option, the installation of surface aerators will allow the treatment plant to cope with the increase in organic loads and the ultrafiltration (UF) unit will reduce total suspended solids, pathogens and virus in the final effluent, resulting in an improvement of compliance with the resource consent conditions and higher quality of effluent.

The key advantage of this option is that it is a low-cost upgrade and is affordable by the ratepayers.

In order to satisfy the high quality required for boiler feed water at the power station, the pond effluent will be further treated by a microfiltration and reverse osmosis at the power station. The permeate from the reverse osmosis units will then be treated by a demineralisation plant before it is used as the make-up boiler water. Moderate nutrient concentrations in the effluent may result in potential breakthroughs in the microfiltration and reverse osmosis processes. However, this is subjected to further investigation by the suppliers.

High-Rate Activated Sludge with Biological Nutrient Removal (BNR) followed by UV disinfection

A membrane bioreactor (MBR) plant upgrade, which is a variant of activated sludge process, was considered. This option will entail building a membrane bioreactor (MBR) system with a modified Ludzack-Ettinger (MLE) configuration. As the membrane acts as a physical barrier for the suspended solids and pathogens to pass through, downstream UV disinfection may not be required.

Under this option, the existing oxidation ponds will be used as a flow balance storage pond and sludge lagoons while part of the mangrove area adjacent to the pond embankment will be reclaimed for constructing the new bioreactor tanks and ancillary equipment.

This option is considerably more expensive in terms of capital and operating costs associated with a BNR plant. BNR removal is not required at this stage as the current receiving environment studies do not indicate any noticeable effect of the discharge on the receiving environment.

This BNR option may still occur in later stage if the future receiving environment monitoring results indicate higher level of nutrient removal is required or this option is implemented as part of the power station requirement.

The final effluent from this option will need further treatment to meet the required quality for boiler feed water at the power station. The treatment processes will be similar to the ones described for the previous option (pond aeration & UF).

Effluent Disposal via Land

A number of land-based disposal options were considered and the assessment concluded that the costs and the land availability making these disposal options unlikely to be feasible and affordable. Moreover, the effluent discharge has no measurable impacts on the Kaipara River.

Relocating the Treatment Plant

Relocating the ponds to another location was investigated and discounted because of much higher costs associated with the alternative location, loss of existing infrastructure/assets and extension of reticulation rising mains. This option is also discouraged because the discharge currently has no measurable impacts on receiving environment and the cost of relocating the wastewater treatment plant is difficult to justify.

Option of conveying the wastewater to another catchment for treatment and disposal was also considered but it has been discounted because of similar reasons above. Moreover, conveying the wastewater out of the Helensville catchment will be against the objective of meeting the potential effluent reuse opportunity at the power station.

Upgrade Options Evaluation Summary

Table 4: Evaluation Summary of the Helensville Wastewater Treatment Plant Upgrade Options

Options	Increase Plant Capacity	Resource Consent Compliance?	Affordable Option?	Suitable for Effluent Reuse at the Power Station
Drumfilters + UV	X	X	✓	X
Aeration + UF	✓	✓	✓	✓ (To be confirmed, but can be upgraded)
BNR AS Plant	✓	✓	X	✓
Effluent Land Disposal	X	X	X	X
WwTP Relocation	✓	✓	X	✓
Pump to a treatment plant elsewhere	-	-	X	X

The upgrade option of additional surface aeration followed by ultrafiltration has been selected as the preferred option as it satisfies most of the upgrade objectives.

The upgrade for the Helensville WwTP will be undertaken in two stages. The first stage will include additional surface aeration followed by ultrafiltration and this stage has a design horizon up to 2025.

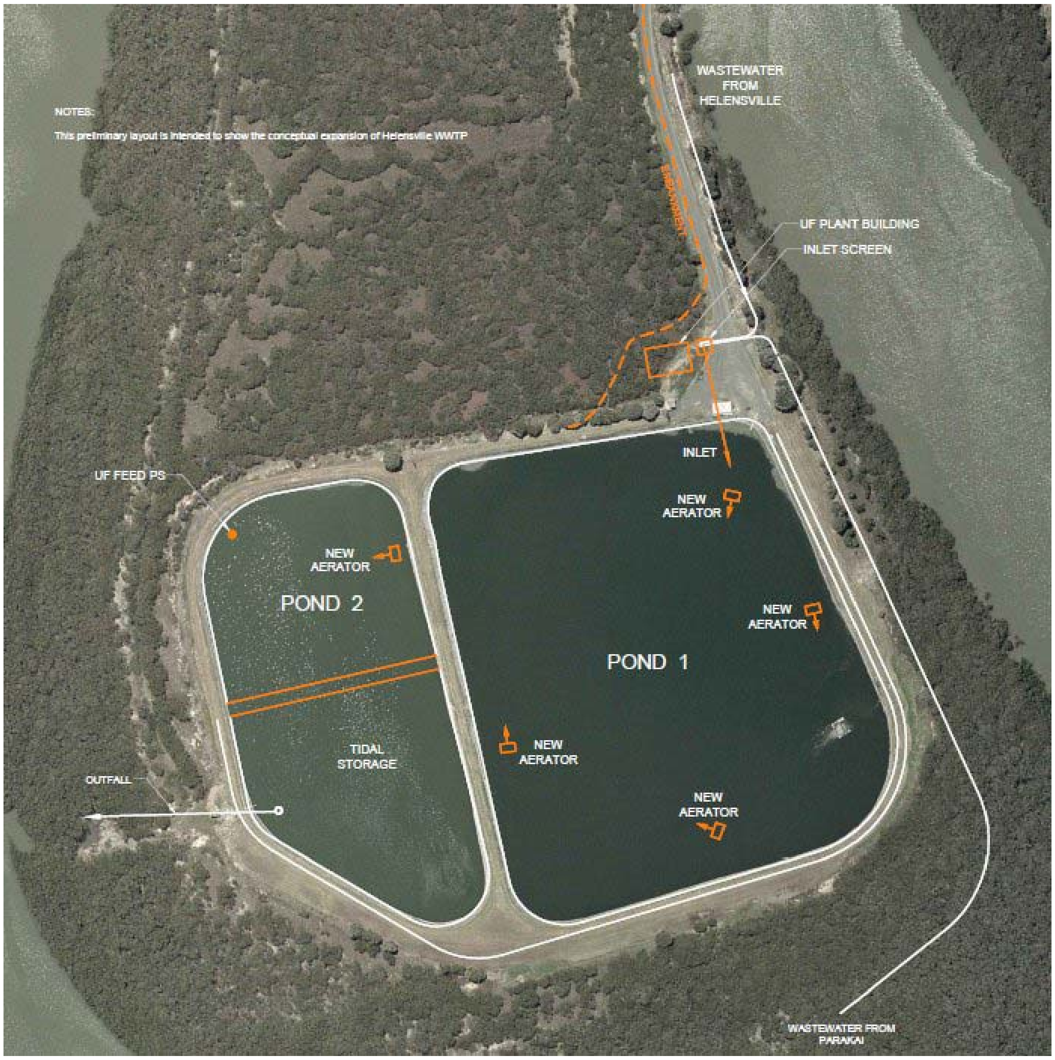
The BNR upgrade option is currently not preferred because it is outside the affordability of the community. This option may still be a possibility in next stage (2025-2051) if the future receiving environment monitoring indicates higher level of nutrient removal is required or a higher quality of effluent in terms lower nutrient concentration is desired by the power station.

A resource consent renewal application based on this upgrade strategy is being prepared at the time of writing.

5.3 DESCRIPTION OF UPGRADES

As presented in Section 5.2, an upgrade strategy has been conceived and the plant upgrades have been staged to balance the requirements of environmental protection, economics and potential opportunities of effluent reuse. Refer to Figure 4 below for a schematic diagram of the proposed Stage 1 plant upgrades.

Figure 4: Helensville WwTP Plant Upgrades Layout Schematic Diagram



5.3.1 STAGE 1 UPGRADES

The Stage 1 upgrade will increase the plant capacity to meet the projected demands in 2025.

Inlet Screen

A new inlet screen system is installed in the southeast corner of Pond 1 to remove gross solids (>3mm) in the incoming sewage to minimise accumulation of solids and debris in the pond.

Pond Aeration Upgrade

The oxidation ponds are retained as the main secondary treatment process for the Helensville WwTP, in which Pond 2 will be partitioned into two separate cells. One of the cells acts as the secondary oxidation pond receiving pond effluent from Pond 1 and the effluent will be lifted to a ultrafiltration (UF) system for further treatment. The other cell in Pond 2 receives the permeate from the UF system and provides a storage between the tidal discharge period.

As presented earlier, the oxidation ponds require supplementary aeration to increase treatment capacity to cater for additional future loads. The addition of surface aeration will provide more consistent BOD_5 removal and some reduction of ammoniacal nitrogen.

Ultrafiltration Installation

A new UF system will be installed in a small reclaimed area adjacent to the embankment of Pond 1. The small pore size in the UF system (~0.04um) allows the membrane modules acting as a physical barrier to prevent solids and pathogens to pass through. Virus reduction will also be achieved.

Tidal Discharge

The permeate from the UF system will be temporarily hold in the tidal storage cell in Pond 2 before being discharged during outgoing tides.

5.3.2 FUTURE UPGRADES (STAGE 2)

The future upgrade stages will be dependent on the following factors and requirements including:

- Future population growth (beyond 2025)
- Future reviews of the effects on the receiving environment
- Effluent Reuse in Power Station

Flow Monitoring

The Stage 1 upgrade is designed for a daily flow of 1280m³/day or 5800 people. The design capacity is expected to be adequate until 2025 where the renewed resource consent expires.

Flow monitoring will provide an indication when the design capacity of the upgrade has been reached.

Receiving Environment Monitoring

The planned Stage 1 upgrades will allow better compliance with the resource consent limits (BOD_5 <20mg/L, TSS < 30mg/L) and improvement in effluent quality (pathogen and virus removal).

Whilst the proposed plant upgrades are not designed to achieve significant nutrient removal because of no measurable impact is currently detected, Rodney District Council plans to undertake periodic review of the effects on the receiving environment (the Kaipara River and the Kaipara Harbour) after the upgrades. If the findings indicate a significant increase of nutrient removal is required at the treatment plant, the Stage 2 upgrade will incorporate biological nutrient removal. Otherwise, a capacity upgrade will be undertaken.

Effluent Reuse in Power Station

As the discussion between Genesis Energy and Rodney District Council is ongoing and the financial contributions are being negotiated, the proposed Stage 1 upgrades have been based on attaining a capacity increase and an improvement of resource consent compliance. No allowance has been made in the Stage 1 plant upgrade to drastically reduce the nutrient concentrations in the final effluent.

A more detailed assessment of the suitability of using the reclaimed effluent from the upgraded plant at Helensville WwTP will be undertaken once the negotiation is complete and an agreement is signed. The Stage 1 upgrades can be easily be retrofitted in the Biological Nutrient Removal (BNR) option should this be required by the power station.

Nonetheless, a flexible plant design upgrade philosophy proposed for the Helensville WwTP facilitates plant upgrades for additional capacity and improved effluent quality without burdening the ratepayers in the short term while enabling re-use of treated effluent in medium to long term.

5.4 DESIGN FLEXIBILITY

The proposed upgrades for the Helensville Wastewater Treatment Plant not only ensure better compliance with the resource consent limits (BOD_5 <20mg/L, TSS < 30mg/L) and improvement in effluent quality (pathogen and virus removal), but also being flexible in terms of future upgrades to meet the future demands from population growth, possible more stringent discharge quality and effluent reuse.

Flexible to Provide Sound Environmental Protection

This is achieved by continuing receiving environment monitoring to assess the effects of the discharge after the plant upgrades. The proposed Stage 1 upgrades are flexible to be incorporated into a BNR configuration should this be required in the future.

Flexible to Meet the Future Growth

This is achieved by providing a process configuration in Stage 1 that can be adaptable into a number of process configurations to increase the plant capacity in the future. Plant capacity can be further increased by providing more surface aeration, or employing more advanced configurations such as fully-mixed aerated lagoons and pond-based activated sludge process.

As the projected population increase between 2025 and 2051 is less certain, it is important to keep the option "open" at present.

Flexible to Effluent Reuse

This is achieved by providing a process configuration which can be adaptable to produce an effluent quality suitable to water reuse at the power station as the negotiation and discussion to utilise the treated effluent from the Helensville WwTP is ongoing.

The proposed plant upgrade strategy for the Helensville Wastewater Treatment Plant offers a flexible pathway to satisfy the increasing infrastructure requirements (more capacity and resource consent compliance) while the effluent reuse opportunities can also be realised without significantly burdening the ratepayers.

6 CONCLUSIONS

The proposed upgrade strategy of the Helensville Wastewater Treatment Plant ensures a synergy between the infrastructure demands from the growth pressure in Helensville and the opportunity of effluent reuse at the proposed power station by setting out a flexible plant upgrade regime.

The proposed upgrades will be undertaken in two stages. The oxidation ponds will be equipped with surface aerators and ultrafiltration to increase its capacity and treated effluent quality in terms of solids and pathogens removal during the first stage. The potential reuse of reclaimed effluent from the Helensville WwTP in the power station as a water source for boiler make-up water has been taken into consideration when developing the plant upgrade strategy.

The proposed upgrade strategy has demonstrated that a flexible approach is essential to satisfy the community requirements (e.g. capacity, resource consent compliance and economics) and capture the potential of treated effluent reuse opportunities.

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