

Asset Optimisation Saves Operating Costs and Defers Capex

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The following provides a taste of the presentation, "Tauranga Waste Water Treatment Plants – The 10 Year Journey of Asset Optimisation," which will be presented by Rainer Hoffmann, Chief Process Engineer, MWH Global at the Water New Zealand 2013 Conference. It presents the outcomes from a long period of participation in optimising the assets at both Chapel Street and Te Maunga Waste Water Treatment Plants to meet the projected wastewater treatment capacity for the city.

Introduction

The Tauranga City Council (TCC) owns and operates two wastewater treatment plants (WWTPs) namely Chapel Street and Te Maunga. The treated wastewater from the Chapel Street WWTP is pumped to the Te Maunga Wetlands and the treated wastewater from the Te Maunga WWTP gravitates through a separate oxidation pond and wetland in series. The outflow from the two wetland systems is combined upstream of the outfall pump station from where it is pumped via a pipeline and diffuser arrangement into the ocean.

In order to provide additional treatment capacity to meet projected population increases and improved treatment capability to meet new effluent discharge consent requirements, the Tauranga City Council (TCC) needed to implement a development programme for their two WWTPs, namely Chapel Street and Te Maunga.

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The following traverses the journey from inception to completion and highlights some of the challenges and smart solutions implemented to provide redundancy and treatment security, and defer capital investment by maximising the use and performance of existing assets at the two operational WWTPs.

MWH Global carried out feasibility studies and prepared Design Statements for development programmes at the two WWTP's and

project managed and designed over twenty project work packages over a period of 13 years, to implement the agreed development programme. The implementation works were staged to match increasing capacity demands and the coming into effect of new consent discharge conditions, to enable project implementation to fit within "live" plant operational constraints, to match funding availability, and to allow the progressive refinement of follow-on designs based on the commissioning outcomes from project packages which had been implemented at an earlier stage of the programme.

The process optimisation studies and capacity investigations at both WWTPs clearly showed that major capital works can be shelved by following an optimisation route which maximises the use and performance of existing assets.

Chapel Street WWTP Optimisation

The over-riding objective for the design of the WWTP's development was to optimise the use and performance of the existing assets and achieve the required treatment outcomes at minimal capital and operating cost.

The optimisation strategy which was implemented considered the following key factors:

- Plant Item Effectiveness;
- System De-Bottlenecking;
- System Integration and Operational Security

The effectiveness of individual plant items was assessed against the required performance, reliability and other specified development outcomes. Options for improvement were considered, including modifications to the item itself or to its "support infrastructure" such as power supply or controls. An example was the 50 percent increase in treatment capacity of the Contact Stabilisation Tank (CST) at Chapel Street WWTP, as a result of upgraded diffusers and improved air distribution piping and aeration control. This improvement in effective treatment capacity within the existing process unit meant that the previously-planned construction of an additional CST was able to be shelved.

Opportunities to improve the overall effectiveness of connected system elements by removing the limitations or restrictions which existed between them were identified and assessed. These "bottlenecks" were often severely limiting the performance of the downstream elements.

Examples of "de-bottlenecking" which resulted in allowing the downstream elements to operate much more effectively include replacement of the flow distribution chamber and piping to the primary sedimentation tanks at Chapel Street WWTP, and provision of new larger influent piping to the oxidation ditch at Te Maunga WWTP. These improvements enabled the downstream process units to operate at their maximum performance levels and helped defer the construction of additional process units to handle the expected plant loads.

Options for improving the reliability and security of operation, and for maintaining operation in the event of process unit failure, were identified and evaluated so as to maximise the use of existing assets within each plant and between both plants. The objectives were to:

- Provide adequate operational redundancy;
- Reduce the risk of overall system outage and the potential for consent non-compliance; and
- Minimise the construction of major new standby process units (for example, bioreactors and clarifiers)

Examples of optimising the use of existing assets to provide adequate operational security include the investigative works on the Chapel Street CST (to reduce tank structural uncertainty to an acceptable level), provision of bypass system extensions at Chapel Street WWTP, and the addition of an emergency bypass connection between

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the Chapel Street effluent pipeline and the Te Maunga WWTP. These measures making integrated use of existing assets avoided significant investment in additional standby capacity.

The first stage of upgrade for Chapel Street WWTP was implemented in 2002 by replacing the existing coarse bubble aeration with fine bubble dissolved aeration (FBDA) system, including an advanced dissolved oxygen control system, and providing increased hydraulic capacity through the plant which resulted in power savings of about 20 percent. The optimisation study identified several opportunities to increase the existing treatment capacity of 16,300 m³/d to 25,000 m³/d in stages.

Additional upgrades were implemented from 2004 to 2012 to increase hydraulic and treatment capacity and reduce operating and maintenance costs which included:

- Increased raw sewage pumping capacity for peak flows
- Improved screenings capture of influent wastewater
- Reduced hydraulic restrictions between inlet works and primary sedimentation tanks
- Improved control of balancing tank operation
- Increased final effluent pumping capacity
- Installation of a new screenings facility
- Construction of a bypass system
- Installation of a new biogas cogeneration facility
- Installation of a new waste activated sludge thickening facility
- Installation of hydraulic mixing system in anaerobic digesters

The aerial view of the Chapel Street plant layout is provided below to demonstrate the restricted nature of the site and the proximity to commercial development on the adjoining predominantly eastern boundaries.

Figure 1 – Aerial view of the Chapel Street WWTP¹



Figure 2 – New pipework to feed the primary settling tanks, and removing plant bottle-necks has increased hydraulic capacity

The By-Pass system at the Chapel Street WWTP provides the facility to by-pass peak wet weather flows in excess of 750 L/s and an extreme wet weather flow in the order of 1,000 L/s, whilst still meeting the conditions of the Resource Consent.

The Resource Consent allows, under extreme wet weather conditions, for secondary treated disinfected wastewater to be discharged directly to the harbour. This was achieved by diverting the peak wet weather flows from the Flow Balancing Tank past the CST and clarifiers, and connecting the Chapel Street Plant effluent using the rising main to the Te Maunga Wetlands.

This diversion ensures that only disinfected secondary treated wastewater is discharged into the harbour. The bypass control was programmed to divert flows at specific setpoints to protect secondary treatment processes under these conditions. The bypass strategy also allowed the CST to be taken out of service for maintenance without compromising the ocean outfall water quality.

Te Maunga WWTP Optimisation

The Te Maunga WWTP provides wastewater treatment for the domestic, commercial and industrial communities from the Mount Maunganui and Papamoa catchments. The industrial chemical oxygen demand (COD) load to the plant is about 13 percent of the total incoming load. Whilst the industrial component is not large, the composition and the variable nature of the trade wastes posed several operational issues and have historically been attributed to being the cause of the instability and variable performance of the treatment process. The main issue with the plant related to periodic loss of nitrification and poor settleability of the sludge due to high levels of filamentous bacteria in the biomass.

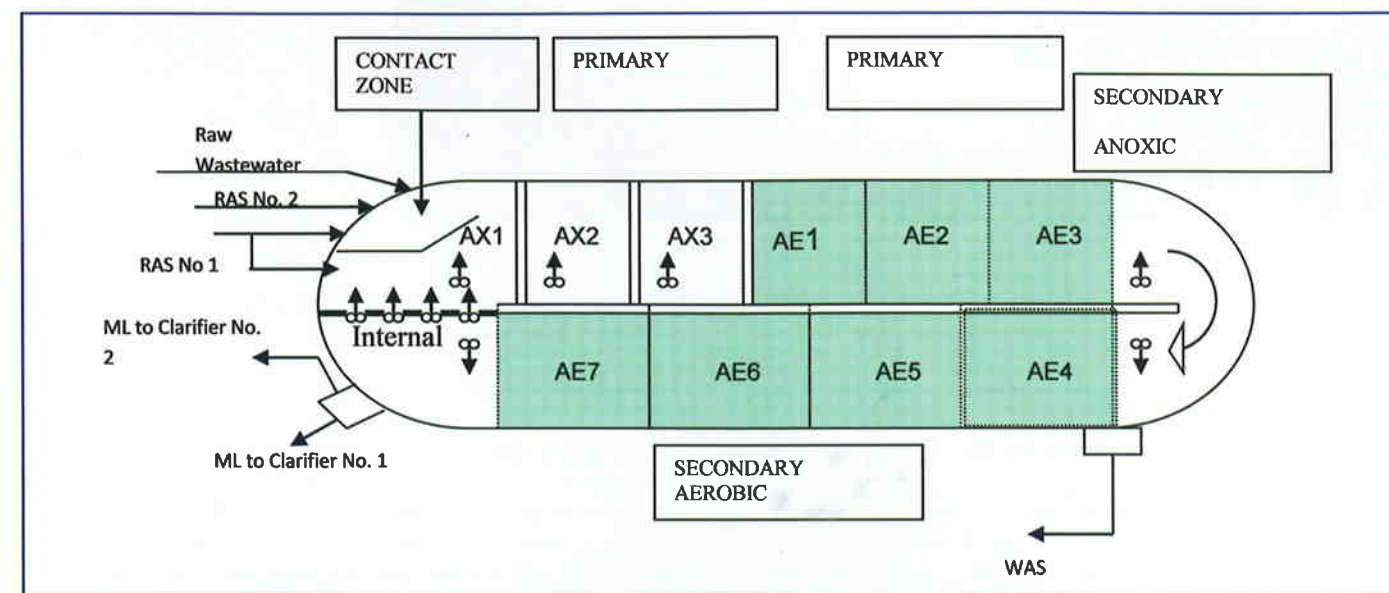
The original bioreactor consisted of a single oxidation ditch, configuration rated at 9,000m³/d, with fine bubble aeration and slow speed vertical shaft mixers to maintain an internal recycle rate of 100 to 200 times average daily flow (ADF) to achieve nitrification and denitrification.

Although the existing reactor channel can be considered a plug type system, the high internal recycle resulted in a system that is completely mixed. Notwithstanding the geometry of the oxidation ditch (continuous channel without partitions) it was considered appropriate to provide partitions in the existing ditch so that the anoxic zones become separate reactors and also provide controlled internal recirculation for overall process stability.

The proposed modifications to the oxidation ditch had to consider the continued operation of the 'single train' oxidation ditch during the construction period to ensure that a good quality effluent was maintained. TCC allowed short term (a few hours) shut downs for ties-ins and other construction related works.

The first anoxic zone of the biological nutrient removal (BNR) process is now preceded by an underated selector (previously aerated) to increase the food to mass ratio to create environmental conditions that promote the growth of floc forming bacteria.

Figure 3 – Aerial view of the Te Maunga WWTP



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Figure 4 – Schematic layout of bioreactor

“The optimisation of the performance of the existing oxidation ditch meant that increased load could be treated without the significant cost of an additional process unit.”

The advanced aeration control system was designed to control the amount of air to maintain a constant level of oxygen concentration in the seven aeration zones.

The aeration system consists of three control loops for control of blower air, dissolved oxygen and blower pressure. The return activated sludge (RAS) pumps are variable speed driven and the rate of return flow is set as a percentage (70 percent) of the incoming raw wastewater flow which is operator adjustable. The control system for the RAS pumps has also been provided with a minimum setpoint to ensure that settled mixed liquor from the clarifier is recycled at a specified rate under all incoming flow conditions.

The internal recycle pumps have been selected to provide a minimum internal recycle rate four times the average daily incoming flow. The selection of the number of pumps depends on the actual daily incoming flow.

The optimisation of the performance of the existing oxidation ditch meant that increased load could be treated without the significant cost of an additional process unit.

Chapel Street WWTP Operational Experience

The installation of the automatic aeration control system has achieved process stability and the dissolved oxygen (DO) concentration remains constant around the setpoint.

Significant energy savings have been achieved by controlling the amount of air according to the oxygen demand and maintaining a constant level of oxygen concentration in the contact zones.

The plant has been operating with the new diffuser and improved dissolved oxygen control system since October 2002 and the average power saving on the blower system is in the order of 48 kW/h. The overall site power usage has dropped by 10 percent and can be attributed largely to the more efficient aeration system. The power saving on the aeration system is about 30 percent.

The installation of the new screens equipment, which consisted of band screens with 5mm opening screen face, has made big changes to the plant operational activities:

- The pre-treatment tank was previously cleaned out monthly; this is now scheduled for six monthly cleaning
- The aerated grit pump clogged regularly; this hasn't required cleanout or inspection for the last six months
- Regular cleaning of screenings from the primary settling tanks is no longer required
- Reduction of rag accumulation in pumps in general and the anaerobic digesters has occurred, requiring less disruption to treatment processes and less labour inputs

The blowers were repaired and maintained a number of years ago and there has been no further problems experienced with the blower operation. The change from coarse to fine bubble diffused aeration improved aeration control a great deal, while the observed benefit was that the treated wastewater quality was much more consistent.

The treated wastewater pumped from Chapel Street WWTP is no longer disinfected with the UV disinfection system, as the effluent is pumped to the Te Maunga wetlands as shown in Figure 2. This results in a significant electrical power saving and annual lamp replacement cost. The 2005 annual power costs were about \$44,000, with annual lamp maintenance costs of \$58,000, amounting to an annual \$102,000 total operating cost, or approximately \$120,000 annual savings in present day terms.

The UV system is only operated when treated wastewater is likely to be discharged to the harbour. The change in flow path as a result of the final effluent pump upgrade together with the installation of the new by-pass pipe lines has allowed an improved and lower environmental impact on the harbour, while reducing the operating costs for disinfection of the order stated above.

The bypass system was tested up to 900L/s during the 23 July 2012 wet weather event and the setpoints checked and adjusted to suit the new bypass pipework arrangement. The bypass strategy has allowed the UV system to be shut down unless required during an extreme wet weather event (as discussed above). Only two events have initiated a discharge of treated wastewater to the harbour.

The co-generation of anaerobic digester methane using combined heat and power generation has realised a daily production of around 3,300kWh. This equates to 150kW of installed motor capacity which is about the same power requirement of the blowers. The cogen plant operates well using primary sludge with limited Thickened Waste Activated Sludge (TWAS). A portion of the TWAS is transported to the Te Maunga WWTP and treated with the raw wastewater in the bioreactor to avoid the operational control problems and ensure that power generation is maximised at the Chapel Street WWTP. In time, when funds are available, separate treatment of TWAS can be considered to further reduce the volatile solids in the anaerobic digesters to increase gas production.

Te Maunga WWTP Operational Experience

Since the upgrade, the performance of the plant has improved significantly in terms of nitrogen removal and settleability of the biomass.

The total nitrogen in the treated wastewater is consistently less than 10 mg/L and the settleability measured as SVI (sludge volume

index) is less than 150ml/g, whereas prior to the upgrade the SVI was higher than 250ml/g.

The treatment plant capacity was previously limited by the clarifier capacity due to the poor settling biomass, but with the improved settleability and an additional clarifier, considerably more clarification capacity has been created. The biological treatment plant capacity has been doubled by the upgrade.

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The additional diffusers and upgrading of the DO control system and new blowers with variable speed drive (VSD) control resulted in a reduction in daily airflow requirements, more stable and reliable operation and reduced maintenance and power consumption.

Te Maunga inlet works was also upgraded with fine screens with a similar improvement to the general plant operation. The plant is remotely operated from Chapel Street and with improved screenings capture rate, problems with clogging of the clarifier inlet well have been avoided and planned changes to the clarifier inlet well have been shelved. The Te Maunga WWTP has had no changes made to sludge wasting rates or aeration control for the last year and operates as an unmanned plant, providing a big reduction in labour input costs.

Integration of Both Plants

The additional benefit of the bypass strategy has been to allow the CST at Chapel Street WWTP to be isolated for planned maintenance and emergency events. In September 2012, the CST was prepared for maintenance and the primary settled wastewater was diverted to Te Maunga for full treatment. The CST was out of service for at least three weeks during the drain down, inspection and minor metalwork repair and strengthening that was required.

The plant performed as expected and Te Maunga WWTP operated at near upgraded design capacity levels, receiving 9,000 m³/d of normal flows with an additional flow of 16,000m³/d from Chapel Street. The organic load was about 90 percent of the upgraded Te Maunga WWTP design load and treated the water to the required consent quality without the need for additional oxygen. A temporary Vitox system was configured to be used under these conditions, but during this period the existing aeration system coped with the increased loads. If the load exceeds the plant capacity, then Vitox will add additional oxygen to achieve full treatment for a limited duration.

By employing the bypass upgrades, the consent conditions have not been breached during the extreme wet weather events or when a process unit has been taken off-line. This is a significant achievement with minimal investment in additional capital, but rather improved use of existing assets at both plants in a reconfigured fully integrated manner.

Conclusions

The successful plant optimisation upgrades at the Chapel Street and Te Maunga WWTPs demonstrate that there are opportunities at existing facilities to improve energy efficiency and optimise treatment and hydraulic capacities by maximising the use and performance of existing assets, thus reducing capital, operating and maintenance costs.

In summary the specific benefits achieved at the Chapel Street WWTP are:

- A 10 percent overall site power saving which equates to a 30 percent power saving on the aeration system
- Lower utilisation of blowers hence longer life expectancy of equipment
- Increased overall treatment capacity due to more efficient diffusers and automatic DO control
- Process stability and uninterrupted operation of the plant
- Increased hydraulic capacity by providing by-pass facilities
- Increased screenings capture
- Provision of treatment security
- Integration with Te Maunga WWTP
- Reduced labour and maintenance input

In summary the specific benefits achieved at the Te Maunga WWTP are:

- A 20 percent overall site power saving which equates to at least 30 percent power saving on the aeration system as reflected in lower airflow requirements
- Lower utilisation of blowers hence longer life expectancy
- Doubling the treatment capacity at significantly lower capital cost when compared to the construction of a second bioreactor and clarifier
- Improved effluent quality in terms of ammonia and nitrates with a total nitrogen concentration of less than 10 mg/L
- Improved settleability (SVI < 150 ml/g) of the biomass which creates additional settling capacity in the clarifiers which will match the bioreactor capacity and thus avoid the need for a third clarifier
- The commissioning of a second bioreactor has been deferred until 2019
- The provision of oxygen injection to increase treatment capacity
- Reduced labour and maintenance input

Acknowledgements

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Footnote

¹Aerial view courtesy of Google Maps