CONTAINERISED WASTEWATER TREATMENT PLANTS HELP KEEP AUCKLAND'S GROWTH SUSTAINABLE

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ABSTRACT

Due to rapid population growth in the greater Auckland region, existing infrastructure in many areas is approaching capacity. In this project, wastewater treatment capacity in Warkworth, Waiheke Island, and Clarks Beach were increased by adding containerised membrane bioreactor (MBR) treatment plants in parallel with the existing facilities.

This paper reviews the benefits and challenges of this approach, presenting learnings from the design and build process along with operational results.

As all three sites discharge treated water to surface waters, MBRs utilising a Modified Ludzack-Ettinger nutrient removal process were selected. Acetic acid dosing was provided as a supplemental carbon source to achieve a higher level of nitrification-denitrification. The Waiheke site also has particularly tight phosphorus discharge consent limits so aluminium sulphate dosing was incorporated into the design to achieve this.

The main benefits of this innovative containerised approach included:

- Compact plant, compatible with the very limited space constraints of both Warkworth and Waiheke Island
- Modularity and standardisation of design
- Construction off-site in controlled workshop conditions with shipping of a largely complete plant to Waiheke Island saved time and cost on island
- One of the two treatment trains installed at Warkworth will be relocated to Waiheke Island to further boost capacity once the overall Warkworth site is decommissioned in 5-years time
- The other Warkworth treatment train can be held as a rapid-response portable emergency treatment plant or relocated to a future site
- The speed of construction achievable off-site, enabled the Waiheke plant to be operational before the island's population swelled from approximately 9,000 to over 45,000 over the Christmas break
- The MBR process provided a high level of flexibility over a wide range of loading conditions

Building the plants into the footprint of 40' shipping containers presented two main design challenges:

- Significant space constraints in the plant room decreasing ease of access for maintenance of some equipment
- High cost of converting shipping containers to robustly engineered water tanks

In order to provide commonality of design for operators who also operate Waiheke Island, the Clark's Beach plant was constructed using the same modular containerised approach.

For the subsequent Meremere MBR plant, the same process design was executed using in-ground concrete tanks and a separate plant room due to lower overall cost of this method and no need to allow for future relocation of this plant.

The performance of these plants exceeded expectations with treated water qualities as low as, <1mg/L BOD_5, <1mg/L Suspended Solids, <1CFU/100mL *E.Coli.* and <2mg/L Total Inorganic Nitrogen being repeatedly achieved.

For remote locations and islands where on site construction is disproportionally expensive, the benefits of the containerised construction approach were found to out-weigh the disadvantages.

The MBR process was shown to be a robust and effective means of achieving very high quality treated water for discharge to the most sensitive receiving environments. In most other cases, an approach without containerisation would be more practicable.

KEYWORDS

MBR, Modular, Containerised, Membrane Bioreactor, design and build.

PRESENTER PROFILE

Dr. Matt Savage is a founding director of Apex Environmental and has 15 years experience designing, building and optimising membrane bioreactors. He is a Chartered Professional Engineer with a Ph.D. in industrial wastewater treatment who is passionate about the implementation of new technologies and finding novel solutions for difficult wastewater treatment problems.

INTRODUCTION

In post-earthquake New Zealand, shipping containers have become a ubiquitous part of the landscape, serving functions ranging from building reinforcement and safe transit corridors for pedestrians, to housing banks and cafes.

Figure 1: Christchurch Container Mall[1]

Figure 2: Shipping Containers prop up the Cathedral of the Blessed Sacrament, Christchurch[1]

Shipping containers are strong and corrosion resistant due to the ribbed Corten construction. Corten is a steel alloy that forms a stable oxide layer upon weathering. Like aluminium, the layer of oxide on the surface protects it from further corrosion rather than flaking off and spreading like rust in normal mild steel.

Shipping containers are also, by definition, easily transportable, standardised and widely available, with the entire global transport infrastructure built around the movement of these units.

For this reason, when called to provide four relocatable, modular side stream treatment plants for Watercare that had to be built in a very short time frame and delivered to three different sites, one of which is difficult to access, containerising the plants was an obvious option to consider.

The three sites varied significantly in their existing treatment technologies with Warkworth employing an oxidation ditch with an Actiflow for handling peak wet weather flow, Owhanake on Waiheke Island being a sand filter treatment system, and Clarks Beach being a combination aerated facultative pond with sand filtration.

Each site was facing unique challenges with regards to compliance but all had reached the limit of their ability to handle increasing loads due to population growth.

At all sites, the objective was to treat a portion of the incoming raw water flow to a very high standard, while maintaining enough feed to the existing treatment system to maintain stable biological performance. This enabled the blended treated water from both treatment systems to maintain compliance while still handling storm flows through the traditional processes on site in-order to minimise the size of membrane bioreactor required.

THE CHALLENGE

WARKWORTH

The Warkworth Sewage Treatment Plant (STP) already used two different types of treatment along with sludge digestion and mechanical dewatering. The plant is nearing the end of its service life and is required to treat high levels of wet weather flow. Any additional treatment plants at this site therefore need to be highly automated as the operators already have a high workload operating this and surrounding treatment plants.

Approximately five years after completion of this project, the Warkworth STP is to be replaced by a new centralised treatment plant at Snell's Beach. The new 250m^3/day treatment plant at Warkworth was therefore to be constructed as two entirely independent treatment trains that could easily be relocated to different sites when Warkworth is decommissioned.

The level of treatment required at Warkworth was very high with the key design parameter of the plant being the need to achieve a total nitrogen level in the treated water of < 4mg/L.

The final challenge at the Warkworth site was real estate. The existing plant occupies a site on the banks of the Mahurangi River with very little space available for additional treatment. Unless a sufficiently compact plant could be developed, there was a very real prospect of the treatment plant needing to be built in the site's car park.

Figure 3 Warkworth STP

OWHANAKE

Situated on a hillside a short walk above the Matiatia Bay ferry terminal on Waiheke Island, the standout challenge of expanding the Owhanake STP was access. With construction on the island being notoriously expensive and the long supply and logistics chains potentially slowing down progress, there was a clear incentive to complete as much of the construction as possible off-island.

This treatment plant is also only attended occasionally, so the automation of an advanced membrane bioreactor plant needed to be comprehensive and robust.

While there is actually a lot of land available on this site compared to that required, the available flat land suitable for construction was largely taken up by existing sand filters.

The Owhanake site needed to achieve a high level of phosphorus removal to < 2mg/L along with reduction of nitrogen to TN < 15mg/L, NH_4-N < 2mg/L. While these targets would not generally be considered difficult to achieve, highly seasonal inflow quantity and quality with BOD_5 peaking at over 3,000mg/L and TKN in the feed peaking at over 400mg/L, resulted in significant challenges in maintaining this level of performance.

Figure 4 Owhanake STP - Existing site

CLARKS BEACH

The Clarks beach site was one of the easiest to address as access was straight forward and there was plenty of space available for the upgrade works.

The key design parameter for this site was to achieve total inorganic nitrogen (TIN) of < 5mg/L.

While there was initially no requirement to make the Clarks beach relocatable, this was changed late in the design process to provide consistency for operators working between the different sites, and to provide flexibility for future reuse of the plant elsewhere if required.

One more unusual design and construction challenge of the Clarks Beach site was the construction taking place immediately adjacent to a golf course fairway – immediately in the firing line of a gentle slice off the No. 10 tee.

Figure 5 Clarks Beach STP

THE SOLUTION

CONTAINERISATION

In order to provide ease of relocation, modular construction, and minimise construction and install time on site, the solution selected was to containerise the treatment plants. This allowed construction and pre-commissioning of the plants to be largely completed in a workshop environment prior to dispatch to site.

For the three 125m^3/day treatment plants for Warkworth and Owhanake, one 40’ high cube container was converted into an anoxic and aerobic reactor, and a second 40’ container was converted into a second stage anoxic reactor, membrane tank, and plant room.

For the Clarks Beach site which required less nitrogen removal but double the flow, one entire 40’ high cube container was converted into an aeration tank whilst a second 40’ high cube container was converted into an anoxic tank and membrane tank. A separate 20’ container was used as the combined plant room and Motor Control Centre (MCC).

40’ high cube containers were used as these provided the necessary depth for the submerged SINAP flat sheet membrane modules used.

The reactor tanks were structurally reinforced with 100mm Rectangular Hollow Section (RHS) welded to the outside of the containers and tie-rods across the internal width of the containers to minimise wall deflection when full.

Each container was then blasted and fully glassed inside with vinyl-ester fibreglass to provide a durable, chemical resistant water-tight vessel.

The use of a separate 20’ container segregated into separate MCC and Plant rooms, rather than compressing this into one end of a 40’ container like the previous sites, significantly improved both operability and maintainability of the resulting plant.

Figure 6 Structural Reinforcing and Fibre Glassing of Containers

Containers were then fitted out with all pumps, pipework, aeration equipment etc and pre-commissioned prior to being dispatched from the workshop to site.

Figure 7 Assembled plant nearing completion at workshop prior to being dispatched to site

Dry commissioning, clean water commissioning and leak testing were all carried out in the controlled workshop environment prior to dispatching the plants to site.

SITE WORKS

While workshop-based construction of the treatment plants was underway, site works, including foundations, site pipework and site electrical infrastructure was completed, so that upon completion of the treatment plants, they could be sent immediately to site for installation.

At Warkworth, due to the constraints on available real estate, the treatment plant was built on strip footings over a seldom used skip cleaning bay previously used to wash out skips from the sludge dewatering system.

Figure 8 Strip footings for the two treatment plant trains at Warkworth

At Owhanake, two of the sand filters that would be made redundant by the new plant were decommissioned and replaced by foundations for the MBR, and support equipment such as waste sludge tanks and chemical IBCs and to provide a fully contained chemical unloading bay.

Figure 9 Owhanake site works awaiting container delivery

At Clarks beach, significantly more space was available so a larger concrete pad for the treatment plant was provided, complete with chemical unloading bay and bulk acetic acid storage for carbon source dosing. An essential feature of the

Clarks Beach site was a 5m high fine mesh fence to prevent operators and critical elements of plant being struck by golf balls.

Figure 10 Clarks Beach site showing installed plant and 5m high golf ball barrier

DELIVERY AND INSTALLATION

After construction of the plant and site works were completed, the containerised plants were delivered to site for site wiring and process integration to be completed. The plants were then commissioned and made operational.

One of the most significant challenges with site installation was access to the remote Owhanake site via a steep dirt track.

Figure 11 Delivery trucks negotiating the track to the Owhanake site

Figure 12 Container installation at the Owhanake site

FINISHED PLANT PERFORMANCE

WARKWORTH

Once stable biological conditions were established in the Warkworth plant, the treatment performance achieved exceeded expectations with total nitrogen levels of <4mg/L regularly being achieved.

Figure 13 Completed Warkworth MBR plant wrapped around an existing site shed to make optimum use of limited space available

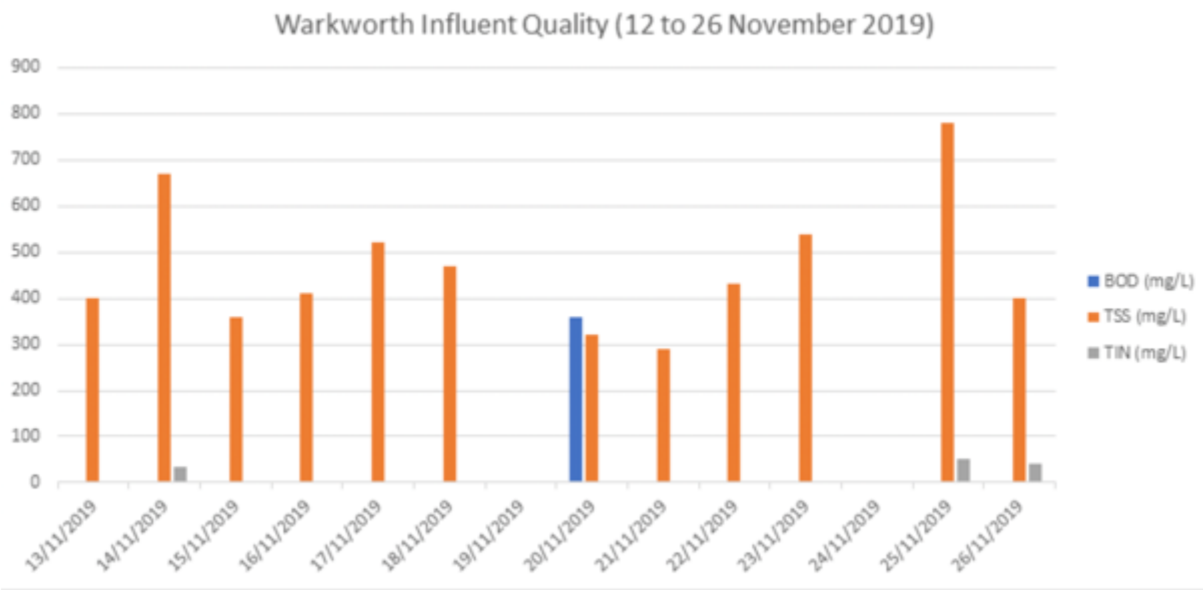

Figure 14 Warkworth influent quality

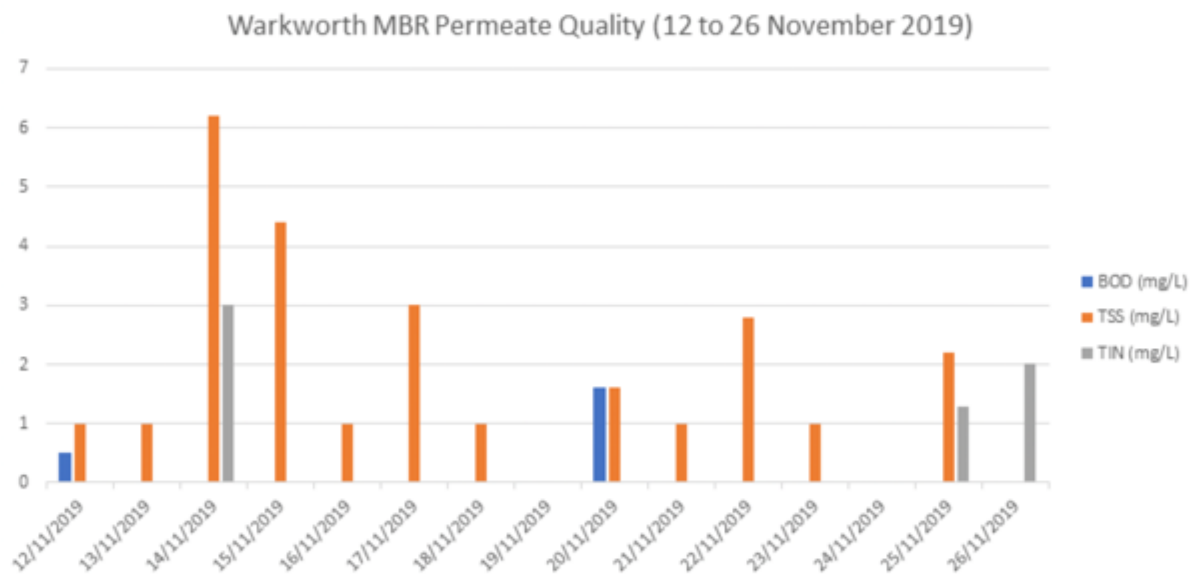

Figure 15 Warkworth treated water quality

OWHANAKE

The Owhanake plant provided a very high level of nutrient removal even under extremely high loads from the network.

Figure 16 Completed Owhanake MBR plant located on the previous site of two of the sand filters

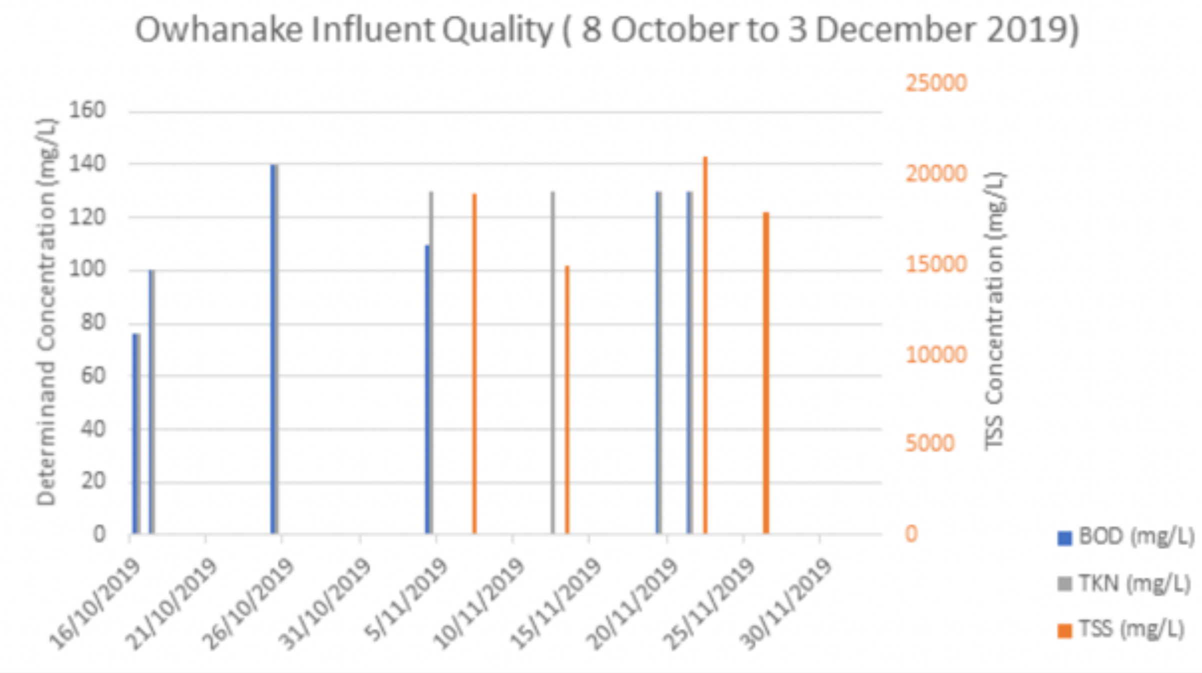

Figure 17 Owhanake influent quality

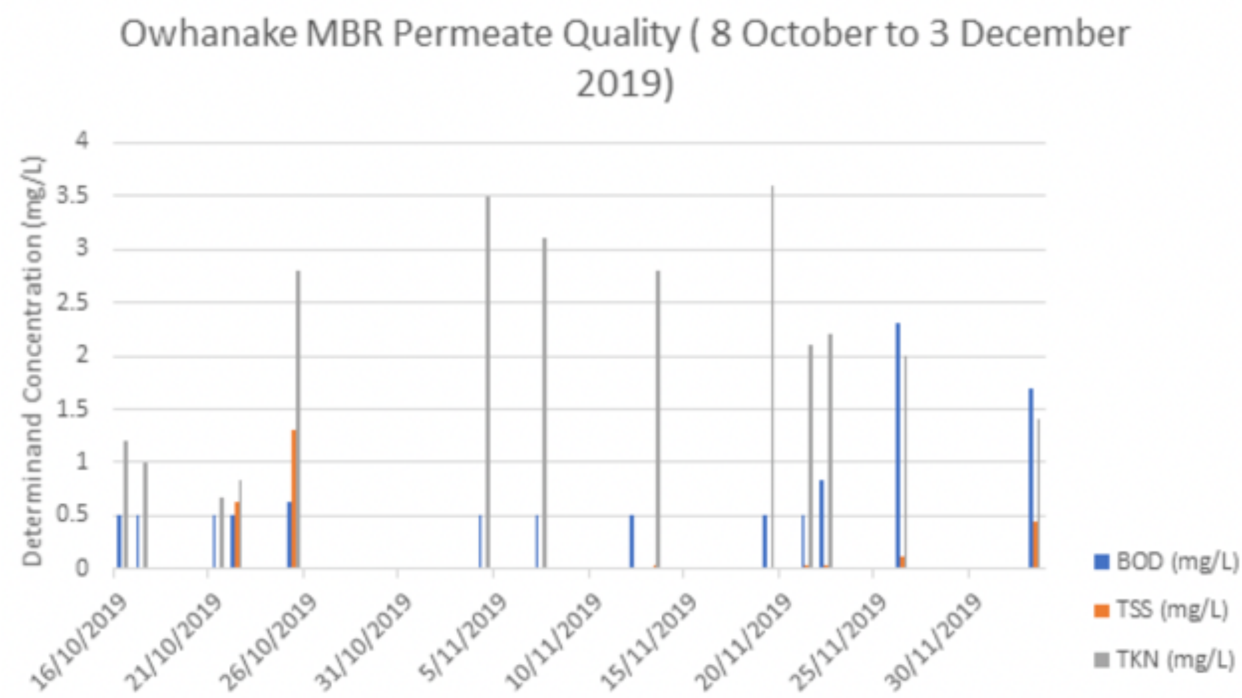

Figure 18 Owhanake treated water quality

CLARKS BEACH

The Clarks beach plant incorporated learnings from the previous two sites including a significantly more spacious plant room and a simplified biological process due to the lower level of treatment required. Despite the simplified process with only one anoxic stage, a very high level of treatment was achieved by this plant.

Figure 19 Clarks Beach MBR plant by night

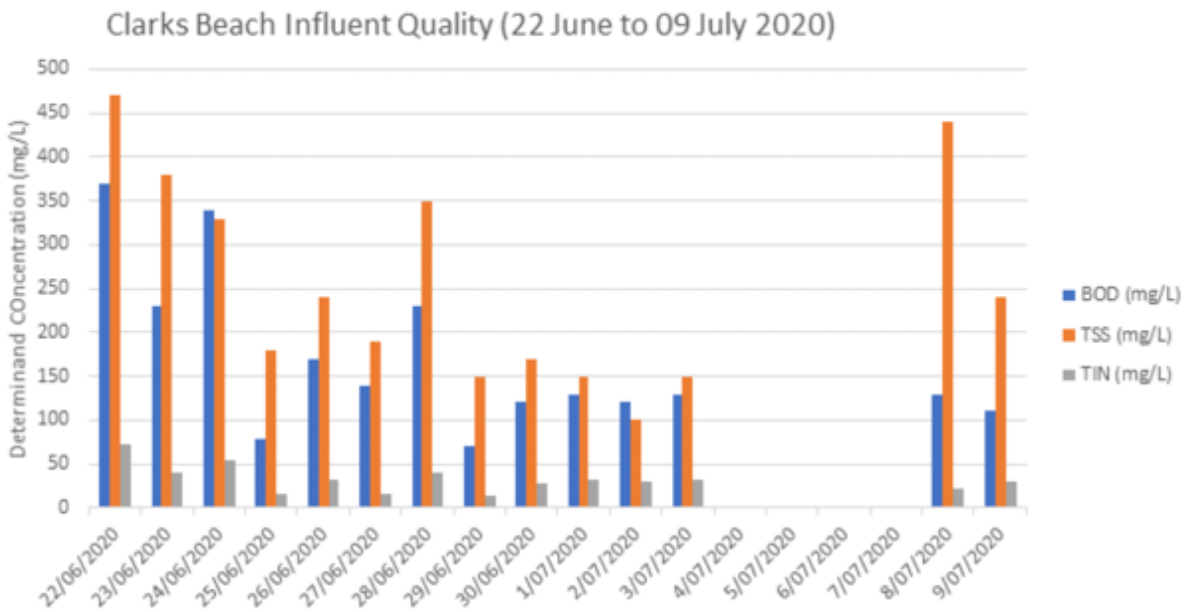

Figure 20 Clarks Beach influent quality

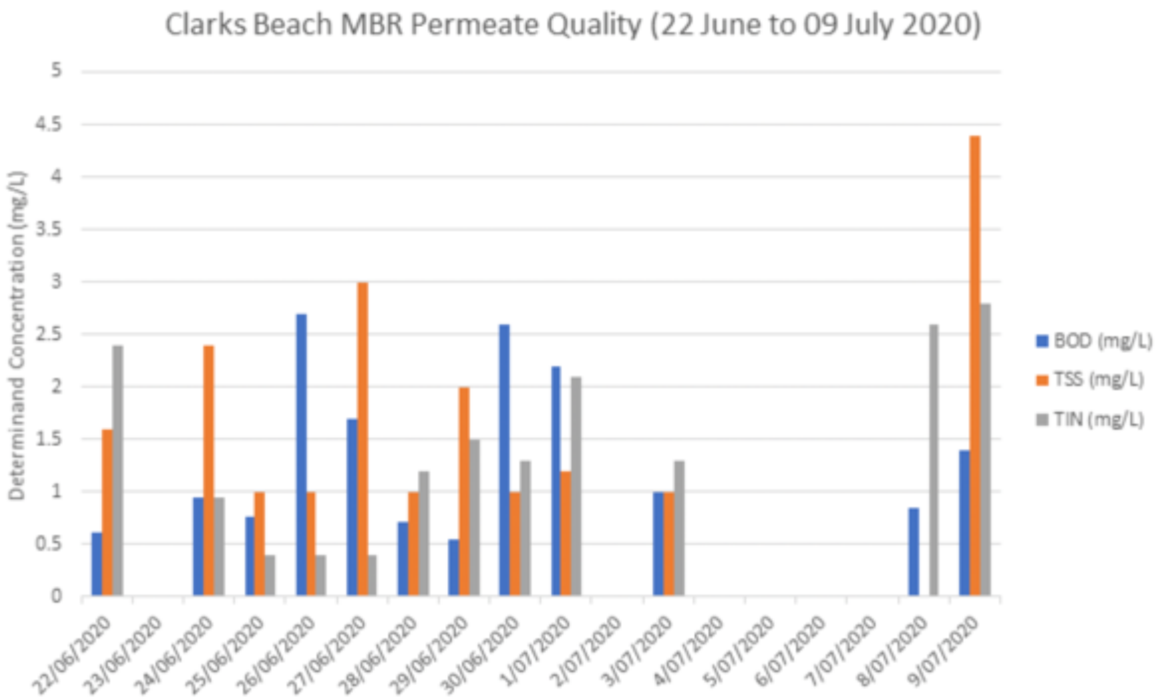

Figure 21 Clarks Beach treated water quality

CONCLUSIONS

Three containerised membrane bioreactors were designed, built and installed for side-stream treatment of influent at traditional sewage treatment plants to boost treatment capacity and improve consent compliance.

The containerised approach provided an accelerated construction time and the MBR process provided a very high level of treatment.

Whilst positive outcomes were achieved in terms of treatment and construction time, the cost of converting shipping containers into robustly engineered watertight process vessels was disproportionate to the gains made.

Advantages of the approach were:

- Fast construction time
- Excellent health and safety management due to workshop-based fabrication, assembly, and initial commissioning
- Ease of transport
- Modular design allowing for commonality of spares, and operation between the plants
- Relocatable design that can be used elsewhere if no longer required on current site
- Significantly accelerated construction on a remote island site
- Compact footprint

Disadvantages of this approach were:

- High cost
- Very compact plant room is not optimised for ease of maintenance
- Extensive enabling works are still required on site to interface with site infrastructure and supporting equipment
- Whilst extensive wet pre-commissioning can be completed in the workshop prior to delivery, full recommissioning is required once the system is installed and connected to site and all supporting infrastructure.

After reviewing these pros and cons, when a similar system was required at a 4th site in Meremere (currently under construction) where there was easy access and no need to relocate the plant in the future, a more traditional approach using concrete in-ground reactor tanks and fabricated stainless steel membrane tanks was followed.

Figure 22 Meremere MBR Plant currently under construction

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REFERENCES

1. Liz Macdonald, Christchurch container mall tenants scatter as six-year-old 'temporary' community ends, *Stuff* 31 Jan 2018