WASTEWATER REUSE FROM CONCEPT TO PLANT: RECYCLING AUCKLAND’S WASTEWATER FOR NON-POTABLE AND POTABLE APPLICATIONS

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ABSTRACT (500 WORDS MAXIMUM)

Auckland City, like many urban centres, faces significant water management challenges due to increasing population growth, climate change, and water scarcity risk. During 2020’s drought in Auckland, water scarcity was no longer a risk, but a reality. This posed an interesting challenge for the Central Interceptor project as it geared up to begin tunnelling - a very water exhaustive activity. Given the proximity of the tunnelling to the Mangere WWTP (Auckland’s largest wastewater treatment plant) it was proposed to build a wastewater reuse plant to help address this challenge. This plant’s aim was to treat wastewater and produce a high quality non-potable water (a.k.a. the fourth water) for tunnelling activities and other construction purposes. In parallel, it was proposed to run a pilot plant to treat the water to a potable standard.

Watercare’s Central Interceptor Project has funded and constructed a Reuse Water Plant (RWP) at Mangere Wastewater Treatment Plant. The RWP can produce 500 m^3/day of non-potable water for use in tunnelling operations and site activities. There is also the capacity to produce up to 30 m^3/day of potable water as a pilot for future use. This project marks the start of New Zealand’s fourth water.

The project approach divided the scope of works into 4 main packages: design (civil and process), construction, membrane supply, and MEICA (design and build). The selected treatment process comprises:

1. Chloramination followed by coagulation and screening.

2. Membrane ultrafiltration

3. Ultraviolet dosing

4. Chlorine dosing/contact to create non-potable water.

The pilot plant process design was developed with various options to allow diverse treatment capabilities. The supply water was membrane permeate from the main plant that can be treated with varying combinations of reverse osmosis, activated carbon, advanced oxidation, ultraviolet dosing, and chlorine contact. This variability allows for a greater trial and testing regime, as well as process

adaptability to ascertain what is required to turn Auckland's wastewater into potable water. As there are no current New Zealand standards for treating municipal wastewater the use of Australian QMRA exposure guidelines were used for the potable water section of the plant.

Severe droughts can be extremely challenging for water suppliers and users to respond to. The Watercare Central Interceptor team addressed this problem head on and faced the challenging prospect of going where no water supplier had gone before. Tackling water sustainability, lack of official guidelines, and roadblocks to water reuse is a significant step in the right direction for the betterment of New Zealand. Overcoming these challenges and sharing this journey with the industry will help pave a successful reuse water pathway that can be traversed by all.

KEYWORDS

Non-potable, Potable, Reuse water, Wastewater, Water treatment, Sustainability, New Zealand

PRESENTER PROFILE

Hamish Spence has over 6 years of experience in the water sector and is passionate about protecting New Zealand's water resources. As a Senior Project Engineer at Watercare Services Limited, Hamish is focused on delivering the Mangere Pump Station for the Central Interceptor project. He has been invited to speak at conferences and events across New Zealand and internationally and is an active member of the water industry.

INTRODUCTION

Around the world urban centres face significant water management challenges due to increasing population growth, climate change, and water scarcity risks. These issues will be exacerbated as time goes on and societies view on water usage will need to shift to help solve them. This mentality shift will be an on ongoing process and not without its own challenges.

During the 2020 drought in Auckland, the reality of this scarcity was brought to light for the whole of Auckland to see including one of its largest wastewater tunnelling projects. The Central Interceptor project decided the risk of being unable to tunnel due to lack of water was something that could not happen. This put into action a plan to create a resilient water supply for the Tunnel Boring Machine (TBM) comprising of three sources. The sources were potable water, non-potable and treated final effluent from the Mangere Wastewater Treatment Plant (MWWTP). The two former sources had existing infrastructure that could be repurposed making them fast to implement but the treatment of Mangere WWTP's final effluent was a blank slate.

Watercare is building a 14.7 km underground wastewater tunnel called the Central Interceptor (CI) from Māngere Wastewater Treatment Plant to Grey Lynn, central Auckland. The 4.5m diameter main tunnel is being dug by a large Tunnel Boring Machine called Hiwa-i-te-Rangi. Two smaller link sewers will intersect the main tunnel.

Ghella Abergeldie JV (GAJV) is delivering the project. Construction is taking place at 16 sites across Auckland and involves the excavation of 17 shafts and associated infrastructure. Around 500 staff are working on the $1.2b project, which is due for completion in 2026. It is the largest wastewater infrastructure project in New Zealand history and will leave a legacy of cleaner waterways by reducing around 80 per cent of wet-weather overflows in central Auckland by capturing combined stormwater and wastewater flows and sending them to Māngere Wastewater Treatment Plant for processing.

Therefore, the Reuse Water Plant (RWP) was given the green light, to be built on the MWWTP. The plant was planned to be a multipurpose dual membrane plant (UF (Ultra Filtration) & RO (Reverse Osmosis)), whose primary purpose was to treat final effluent to a nominated standard for construction water.

The water produced by the plant was to be allocated initially to assist in the tunnel boring activities and construction needs of the Central Interceptor project (New Zealand's largest wastewater infrastructure project). After the project no longer needed the water, it was to be used for the chemical make-up water at MWWTP. To meet the needs of the project and the MWWTP, the plant would need to produce 500 m^3/day of non-potable water.

To benefit from this plant as much as possible a secondary side stream pilot plant was added. This pilot plant's aim was to demonstrate the various treatment steps required to produce safe potable water equivalent to current drinking water standards. The design capacity for the pilot plant was set to produce up to 30 m^3/day of potable water.

This paper outlines the process to complete this task and the challenges faced whilst constructing and operating New Zealand's first RWP fed from municipal wastewater.

Water is precious to every New Zealander and Watercare and Jacobs alike, would like to protect it. This type of plant is a first for New Zealand and uses proven technologies that have been developed worldwide for this specific application. Jacobs was able to meet the needs of their client Watercare and provide a high-level design and specification for this plant. We want this plant to attract interest from the wider construction industry, as it has the potential to initiate change and expand to other construction sites if we share our learnings.

THE GOAL

The primary goal of this RWP was to initiate a step change in the industry and to reduce footprint for Watercare and its Central Interceptor Project. The main driver of this plant was to minimise the use of potable water across the Mangere Pump Station (MPS) construction site, and to assist in the tunnelling operations of Hiwa-i-te-Rangi (CI's Tunnel Boring Machine).

Another main aim of the RWP was to provide resilience to the water supply for the CI tunnelling operations during a time of water scarcity in Auckland. The tunnelling operations use approximately 250 m3/day for tunnelling and other construction activities. These activities include washdown of sites, truck washes and flushing the TBM tunnel. This consumption was the target flow for the overall design of the reuse treatment plant and the main driving design constraint.

Additionally, If the TBM could not be supplied water (due to drought or other means) the potential for significant project delays, costs, and damage to the TBM would be a very real occurrence. In addition to this main aim there were a series of supplementary goals that we added to maximise value from the delivery of the construction plant.

As the future is less and less certain with greater challenges faced each year. Long term water scarcity is a topic that has arisen in various project and company meetings. Supplementary goals were developed to understand and learn new technologies and treatments for the for the Watercare's operational teams. These goals not only served as a case study to show it could be done but also how it would be done and what needs to be factored in if this plant was to supply thousands.

SUSTAINABILITY GOALS

We had various sustainability goals to meet with the overall CI project and water consumption was one of these. By reducing our potable water consumption, we improved the overall project impact, reducing the waste of clean potable water.

The CI project is a sustainable frontier in construction projects around New Zealand, leading the way in innovative and sustainable practices. Producing recycled water for construction is becoming more common around the world, with major factors such as water scarcity playing a big role.

Generating reuse water for construction is a Watercare sustainable initiative reducing both the volume of treated effluent being discharged into the bay, but also reducing the reliance on the potable water network for its needs within construction. It also represents the wider opportunities for Watercare protecting our precious resource and looking at alternatives such as reuse for uses within the MMWTP, specifically for non-potable uses.

THE HOW

The approach is to build a RWP that is cost-effective and replicable. This would allow an estimate of future reuse water treatment plants that would be built, but also includes potential downsides with this approach.

With the design it was up to Jacobs to complete the detailed earthworks, civil and building design. The MEICA (Mechanical, Electrical, Instrumentation, Controls and Automation) portion was preliminary designed by Jacobs with the detailed design completed by H20 Engineering.

For the construction, two trusted contractors were utilised that specialised in treatment plant construction. These two main contractors were Cassidy Construction and H20 Engineering. Cassidy was contracted to cover the earthworks, civil construction, and overall building construction. H20 Engineering had the remainder of the works with mechanical, electrical, instrumentation, control, and automation to be completed.

Once constructed the commissioning, operation and handover were completed in conjunction with the Central Interceptor Delivery Team and H20 Engineering.

DESIGN

To achieve the demand of the TBM (250 m3/day), the water source needed to be assessed with regards to treatment potential and capacity. As Jacobs consultancy was working on the Central Interceptor it was a natural progression to call upon their expertise and background with wastewater reuse for potable and non-potable uses.

Jacobs created a high-level preliminary design, that determined the process requirements and identified the main equipment, electrical instrumentation and the building and civil works for the project and the plant. The design and drawings including P&IDs were handed over the different contractors, Cassidy Construction and H20 Engineering respectively.

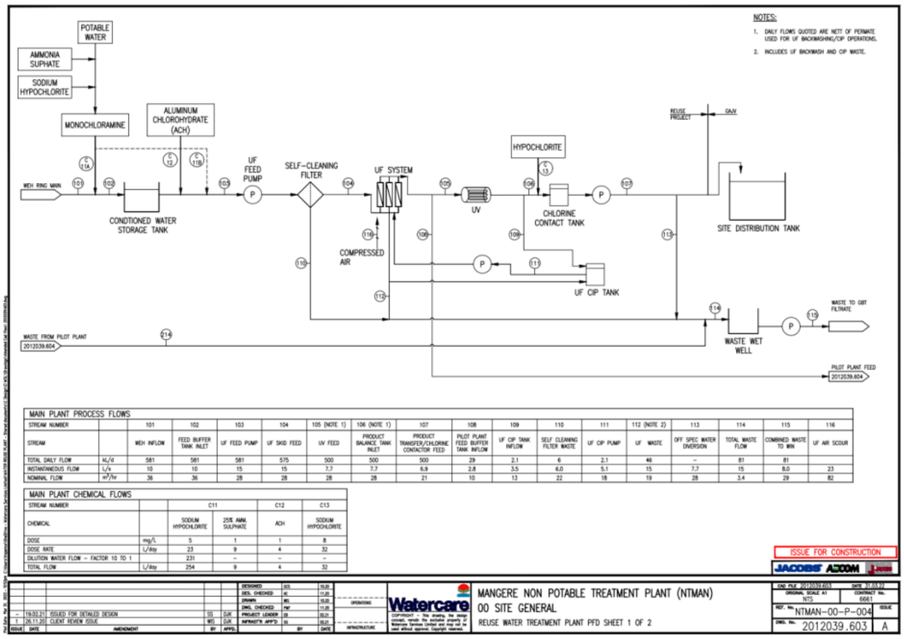

Figure 1: Process flow diagram of the main RWP.

The civil works (Cassidy Construction) was completed under a separate contract specifically for the civil structural works, which included the building supply and installation of services in and around the building at the MWWTP. It was important that the civil contractor worked closely with the MEICA contractor to ensure that terminations and other interfaces were aligned and agreed, allowing for complete handover that complied with the design and specifications.

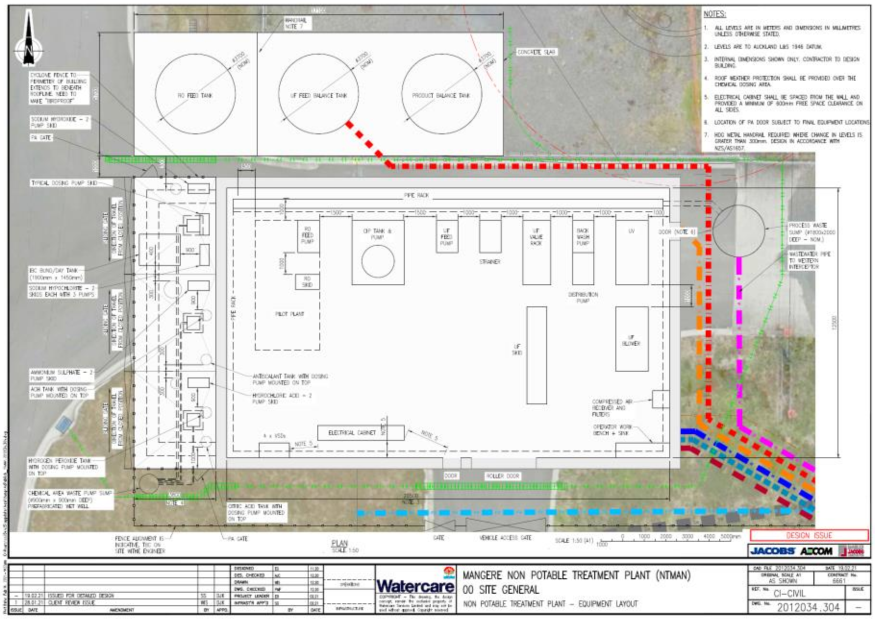

Figure 2: Overall equipment and services layout drawing.

The MEICA works was also awarded to a separate contractor (H20 Engineering), which included managing the interface between the civil contractors as well as the equipment supply contractors and the control supply contractors. There was also components of design required from the contractor, equipment procurement and supply, as well as commissioning start-up as well as handover activities.

The equipment supply that mainly consisted of the Ultrafiltration (UF) and Reverse Osmosis systems were awarded to SUEZ, other equipment was issued to the MEICA contractor, who worked in parallel to install and commission the UF system.

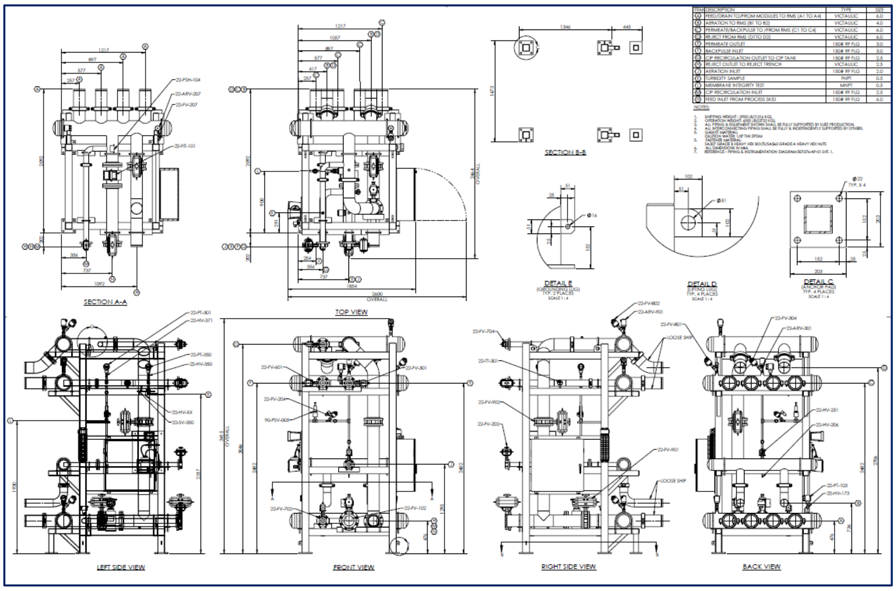

Figure 3: Ultra Filtration Membrane Skid Assembly

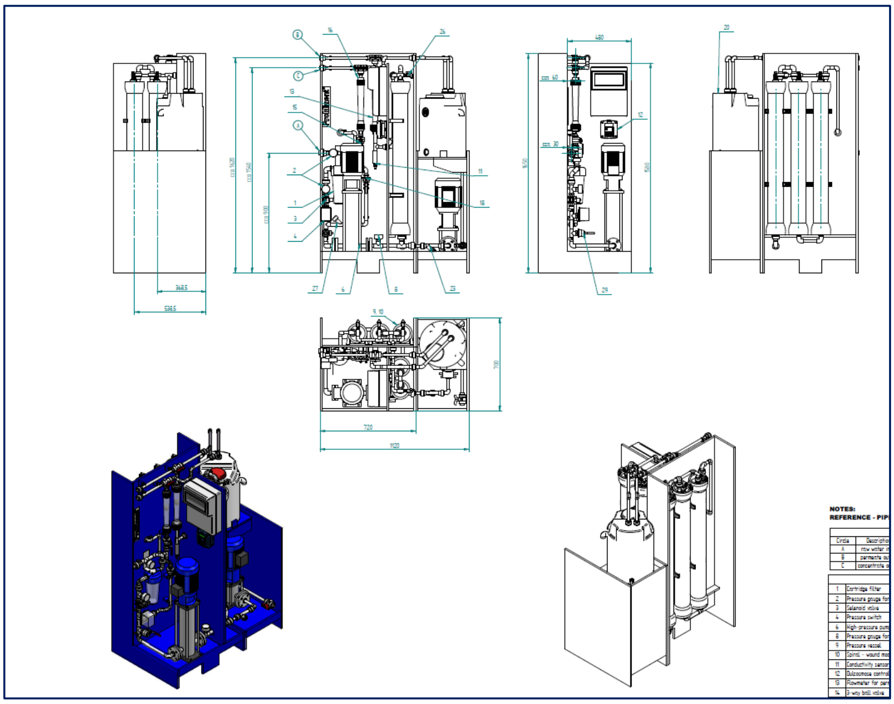

Figure 4: Reverse Osmosis Membrane Skid Unit

PRELIMINARY DESIGN

Jacobs completed an assessment of the options available to Watercare to use recycled water from the MWWTP for construction water. It was decided that the plant will include a mainstream treatment train to provide the required construction water and a side stream pilot plant, that is able to demonstrate potable grade water treatment.

A HAZOP (Hazard and Operability study) was completed and hosted by Jacobs, including Jacobs Process expertise, Watercare, CI personnel as well as the MEICA contractor and SUEZ.

The basis of design involves the RWP to treat the Water High-Pressure Effluent (WEH), which has been through its' tertiary treatment and has been supplied from the MWWTP. With the main objective of this plant to exhibit recycled water in New Zealand. The mainstream treatment of this plant is designed to produce construction water for the CI tunnel project for 5 years at rate of 0.5 MLD. The secondary side stream treatment has been designed to produce potable grade water at a rate of 0.03 MLD.

The process and water compliance were designed in accordance with the Australian guidelines for Water Recycling (2006) with QMRA compliance. This came as New Zealand did not have a standard for water recycling or the production of construction water.

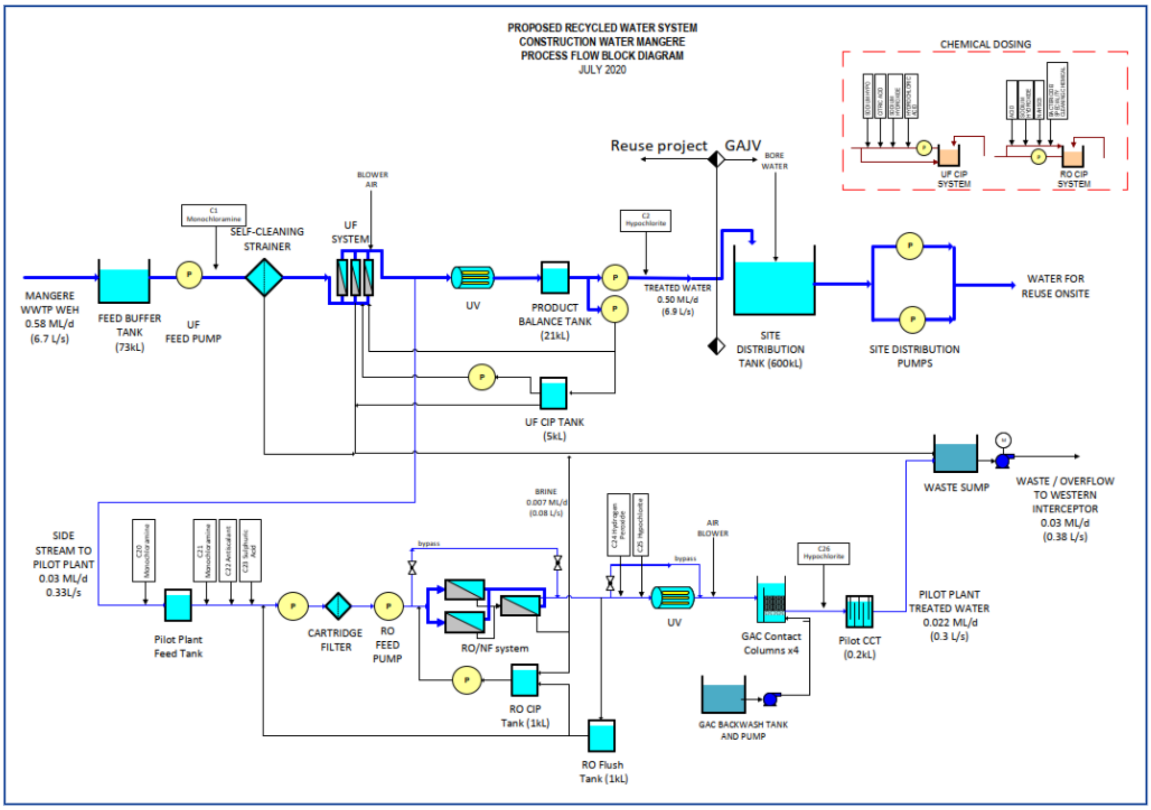

Figure 5: Process Flow Diagram for the construction water and potable water streams of the RWP

DETAILED DESIGN

The IFC (Issued for Construction) design package was designed by Jacobs. The sampling regime of the final effluent was rigorous and detailed in the final design to help determine any unknowns that might exist. It included the treatment of final effluent, which can be challenging. Jacobs entered the design process with a philosophy that was to provide as much treatment resilience as possible.

Detailed design was solely completed by H20 Engineering with their expertise in mechanical fit-out and electrical wiring this allowed for a very streamlined design and build process. The H20 team utilised various design tools and coupled that with industry experience to develop a well-rounded detailed design. This detail design was shared with the project management team for review of any key issues or questions raised and then actioned into construction.

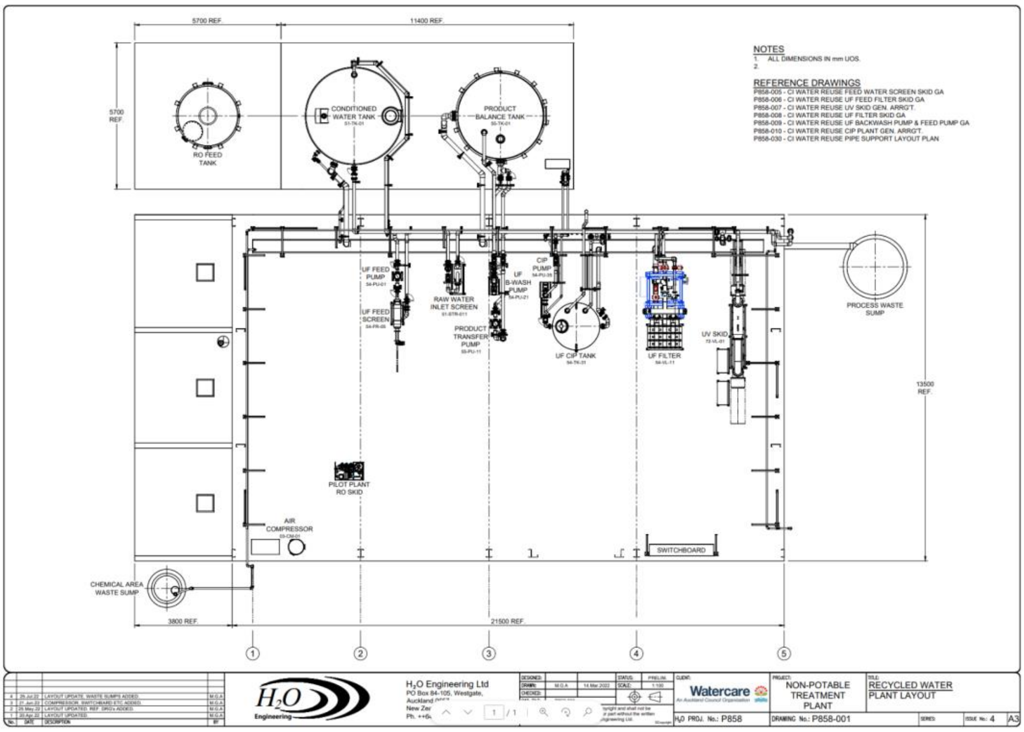

Figure 6: Detailed RWP process equipment layout and piping design

THE BUILD

The building of the treatment plant was separated into two disciplines with the civil construction being completed first and then the MEICA works being completed afterwards. The RWP plant is located approximately 50 meters away from the CI Pump station and is separated by the blue fence. Within the MWWTP it is situated near the Gravity Belt Thickener building.

CIVIL

The civil contractors were tasked with the preliminary site establishment, foundation works, concrete slab, and the installation of the building. There were several additional scope activities that the contractor was responsible for such as drainage, external tank slabs, fencing etc. Daily site reports, recording progress, any issues or design queries were kept by Watercare, these were invaluable during the claim and payment process.

Figure 7: Drone photo overview of RWP building slab and tank slabs.

Figure 8: Construction progress of building and tank slab formwork

MECHANICAL, ELECTRICAL, INSTUMENTATION, CONTROL AND AUTOMATION (MEICA)

Once the building was fully erected, the MEICA contractors started moving in with equipment delivered to site once available. First the layout of the plant was marked out, per the process drawings provided. An electrical sub-contractor was on hand to install all the cables once all the major mechanical equipment had arrived and was positioned.

The Ultrafiltration membranes were installed later in the build, with a SUEZ representative arriving from Australia to assist in the installation and initial pre-commissioning. WSL and the MEICA contractors were involved in this space and assisted in the installation works. The Ultraviolent units also arrived later and were installed with assistance from the manufacturers Trojan, along with the initial pre-commissioning checks and tests. With all pre and testing commissioning covered in a separate commissioning report.

Figure 9: Trojan UV install.

COMMISSIONING

Commissioning of the RWP involved collaboration with the MEICA contractors, WSL commissioning, project, and process engineers, as well as additional help from Jacob's process expertise. The commissioning came with a lot of challenges that were very unexpected.

Overall, it was an enlightening commissioning process due to the complexity of the water composition and the impact weather seasons, and MWWTP maintenance that was completed on the water entering the reuse treatment plant, that affected the variability of the incoming source water.

REUSE PLANT

The bulk of the pre-commissioning involved, checking the pipework was connected to the right lines, ensuring all valves were operational and were as per the P&ID. Ramping up and down the pumps in the plant, manual checks on the filters, UF system and the UV systems. Other process pre-commissioning involved jar testing, calibrating all the chemical dosing pumps, and water sampling to ensure the theoretical treatment design was effective. Supplier commissioning was completed for the UF and UV systems, by Suez and Trojan respectively. Site representatives came to site and were available on call if additional testing was required.

After the plant was pre-commissioned and cold commissioned on water, the hot commissioning could commence. Hot commissioning was carried out step by step to allow sufficient problem solving at each process area. Starting at the front of the plant the raw water was introduced into the system and treated. This operation was monitored over hours, days and then weeks to ensure process compliance and water quality parameters were met. During this time snags and various other issues were resolved and/or investigated to determine root causes.

Once we had been operational for over two weeks consecutively without major issues with enough water quality data, we began exporting to the tunnel boring machine supply tank. This transition was the final hot commissioning test for the plant where it would automatically fill the tank as the TBM consumed the water.

PILOT PLANT

The pilot plant commissioning was a complete copy of the main reuse plant as it had similar process units but with a much lower flow. Following the same process, the pilot plant was brought online and produced water to waste for over two weeks as the proving period. After this period, it was handed over to the water reuse team at Watercare for trial testing to be completed.

THE RESULTS

Once fully operational the CI construction management team was solely responsible for operating the plant whilst it feed the TBM. During this time very little issues were found with the plant that couldn't be resolved by the CI team.

The RWP can be remotely controlled, this feature was extremely helpfully during the commissioning and operation phases. The purpose of the overall control module is to manage the starting and stopping of the process areas during a plant start up and shutdown. Each process area is enabled and disabled from a sequence that ensures the plant never operates in such a way as to produce non-compliant water. It also provides control over the raw water flow setpoint, adjusting it to the available plant capacity, calculated from individual process area capacities. It allows the operators and engineers to check on the status of the plant and adjust what may be required to run the plant efficiently.

H20 engineering did support instrumentation verification and other long-term snags that arose although these weren't a common occurrence.

After the TBM no longer needed the RWP the plant was handed over to the MWWTP process team so that they could practice operation and understand the water it was producing as well as the control interface before using it as chemical make-up water.

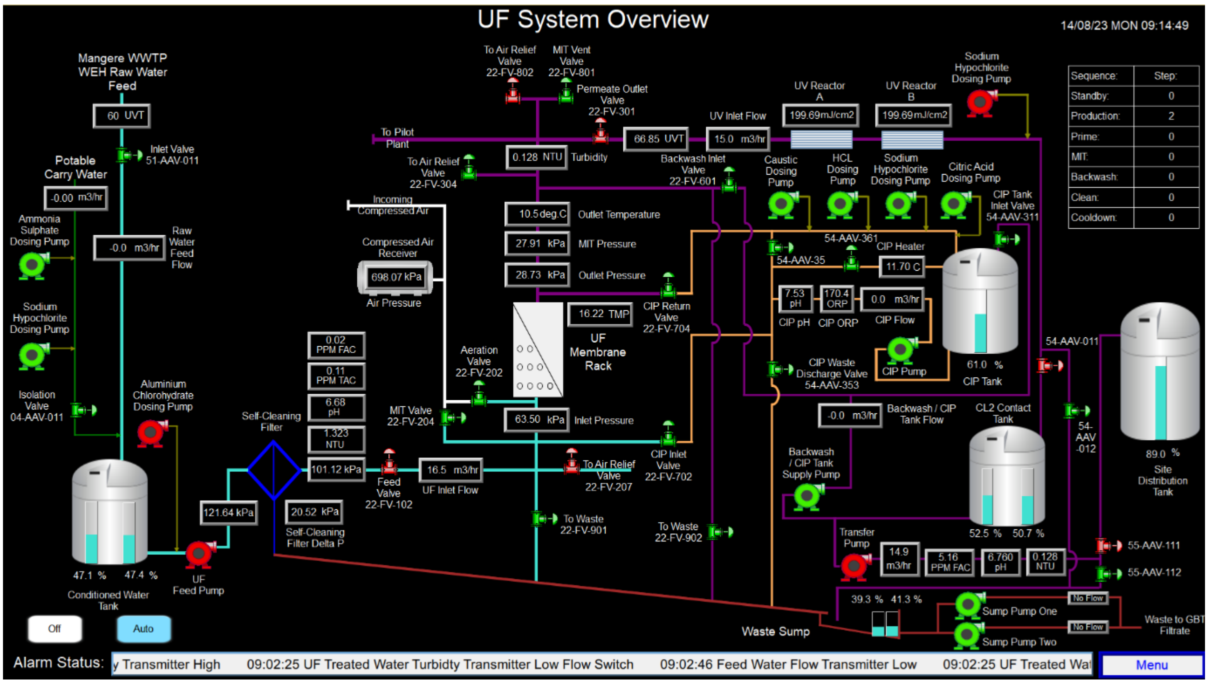

Figure 10: HMI Interface screen for RWP control and operation

LESSONS LEARNT

Constructing the RWP was by and large a very straight froward process. Using industry experts in their respective areas meant the civil, structural, mechanical, and electrical installation was done with great ease.

The major hurdles with the project were the unforeseen ground conditions, availability of sub-contractors, supplier provided packages, reuse of existing Watercare owned equipment, and extreme variability in the source water.

UNFORSEEN GROUND CONDITIONS

Throughout the project only one patch of bad ground was found in the excavation. However, due to its location this patch became very difficult to resolve. Additionally, as the design team were reviewing the proposed remedial methodology to find the best course of action the contractor was delayed, and ground conditions got worse due to weather. Eventually the issue was resolved, and the slab construction could continue. This issue is an ongoing one in New Zealand and seemingly is unavoidable. Mitigating this would've needed more geotechnical investigations however this was a very localised area of poor ground. To help speed the process a remedial methodology might've suited the project to allow faster turnaround of a solution.

AVAILIABLITY OF SUB-CONTRACTORS

For the software and control system portion of the RWP the sub-contractor completing the works for H20 did not have a robust team for which they could mobilise to complete the works. With only two individuals in the company and one of which was working on the plant at a time it meant the software package was significantly delayed. As well as this is meant fault resolution, commissioning and ongoing improvements were very difficult to get actioned as the labour resource was not available. Resolving this would have meant a larger control system implementation team that would've increased the capital cost but would've meant programme was met and less issues would've been faced. This is a good learning as future projects for reuse could benefit greatly from more streamlined contractor involvement.

SUPPLIER PROVIDED PACKAGES

Of the equipment at the reuse plant the key process equipment was all provided by external suppliers. The UV units were supplied by Trojan Technologies. The RO and UF membrane skids, and self-cleaning filters were provided by SUEZ (n.k.a Veolia). Finally, the Switchboard was provided by the electrical manufacturers. In each of these packages there were issues with integration into the overall system. This may have been missing parts, missing modules, incomplete orders etc. To ascertain the short comings and missing pieces was a challenge but the suppliers did assist where possible be it replacing parts or providing expertise. To resolve this in future it would require a lot of upfront investigation between the detailed designer and the suppliers to ensure the supplied equipment is compatible and the supplied materials are confirmed before shipment. This can be difficult as it does involve a lot of involvement increasing budget expenditure.

EXTREME VARIABILITY IN THE SOURCE WATER

During the design phase a lot of process resilience was built into the treatment stream that it seemed almost any challenge could be faced in the source water. However, during long term operation it was found that various amounts of chemical dosing was not required, and the chemical dosing limits were reached on numerous occasions. This was most prevalent with the requirement of large hypochlorite doses to achieve water compliance.

As the plants ammonia levels in the final water were found to be somewhat variable it was difficult to find an accurate and stable dose. Additionally, the turbidity of the effluent was very low at times so the loading on the membranes was minimal. However, as there were high dissolved solids it meant precipitation in the final water was a real issue when significant chlorine contact time was achieved.

CONCLUSION

Starting a new endeavour, it is easy to focus on the completion of the project or goal with blinders on. It isn't until the end that the possibility of what can now be created is realised. Setting out for the reuse plant the aim was to just achieve construction grade and potable grade water for use in the TBM and testing respectively. This focus then shifted to what else can be done with the water we've created and how best to utilise this source in Auckland.

Ideas that arose included creation of craft beer, educational tours, industry optioneering and workshops etc. These ideas are what make or break a successful new frontier in anything as creativity will be what Auckland and New Zealand needs going into a seemingly unknown and unpredictable future.

However, it can be said that the Reuse Water Plant (RWP) was an overall success with the goals and aims set out in the beginning being realised and achieved.

Its aim was to produce water for the TBM, prove that potable water can be produced and allow for the door to be opened to the possibilities of reusing final effluent for more than just ocean refilling.

With possible pilsners, stouts, future experts, and infrastructure being produced by this new enterprise it is an exciting and unknown point in the water industry of New Zealand. What other countries have already embraced New Zealand is likely to be next.