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DELIVERING INNOVATIVE INFRASTRUCTURE TO PROVIDE A CLEANER AND SAFER ENVIRONMENT FOR OUR COMMUNITIES

Abstract

Each day, Watercare handles around 378,000,000 litres of Auckland wastewater. In doing this, Watercare manages and minimises the impact of their operations on the environment and embeds sustainability into their business.

The Kohimarama wastewater pump station which services a dense urban suburb overflows approximately 8 times per year into the Kohimarama Beach, via a local stream. To improve water quality in the receiving watercourse and comply with Watercare's Network Discharge Consent for overflows and provide for population growth, Watercare invested NZ\$11.5M in new infrastructure.

This paper will demonstrate how Watercare, MWH and Tonkin+Taylor (Designers) and Fulton Hogan (Contractor) worked collaboratively to deliver innovative and cost-effective infrastructure whilst minimising the impact on the local community, mitigating project risks, complied with consent requirements and consistently scored a '1' (highest) for environmental audits during construction. The site was a multipurpose environment used for recreational and public activities. This project is showcased as one of engineering excellence.

Engineering innovation delivered multiple savings including a New Zealand 'first' with the design and installation of the Biogest® vacuum flushing system. This is a proprietary self-cleaning facility to keep the tank free sewage debris.

Authors' details

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Key words

Wastewater storage tank, pump station, overflow, Biogest®, vacuum flushing, Deep Soil Mixing, DSM

Introduction / Background

Watercare Services Limited

Auckland (North Island, New Zealand), is the largest populated area in the country with Auckland Council being the local authority for the region. One of seven Council Controlled Organisations (CCOs), Watercare delivers significant services on behalf of the Council.

Watercare provides water and wastewater services to around 1.4 million people in the Auckland region. It has an obligation to upgrade its systems to provide for future growth while ensuring compliance with regional regulations. Watercare has implemented an asset renewal programme and new infrastructure works across the Auckland region over a number of years to continuously meet such requirements.



Figure 1: Location of Auckland Globally

The issue

The coastal residential suburb of Kohimarama, located to the east of Auckland city, requires wastewater services provisions for future growth. During significant wet weather events, the Kohimarama Wastewater Pump Station overflows into the Kohimarama Stream directly to Kohimarama Beach, via the upstream Combined Sewer Overflow (CSO). Overflow volumes range from 100 – 2,500 m³ per event and occur due to insufficient storage at the pump station. Previous studies have indicated that the frequency and volume of overflow events will steadily increase as a result of planned area growth, unless additional conveyance capacity or storage is provided. These CSOs were in breach of Watercare's Network Discharge Consent and adversely affecting the river water quality in the Kohimarama Stream.

The project's objective was to provide additional storage for population growth and reduced overflows, thereby providing a safer and cleaner environment.

Project location

The tank site was located at Madills Farm, a recreational reserve surrounded by dense urban housing, used for various sporting codes throughout the year, and popular amongst dog walkers, runners, and cyclists.



Figure 2: Location of Auckland within New Zealand



Figure 3: Site Locality Map

Design approach

Via a competitive tender process, MWH New Zealand Limited (MWH) was appointed by Watercare in August 2011 to undertake the preliminary and detailed design of the proposed Kohimarama Storage Tank and associated branch sewer upgrades.

Tonkin + Taylor (T+T), subconsulting to MWH, provided geotechnical services. Watercare independently engaged a number of other consultants, to assist the Resource Consent application process.

Designed and constructed key elements included a 3,500m³ concrete underground circular storage tank with a Biogest® vacuum flushing system, approximately 20 metres in diameter and 16 metres deep; 425m of DN750 concrete sewer; manholes; branch sewers; and revised overflow arrangement.

Construction

The total cost of the upgrade was NZ\$11.5M inclusive of investigation, design, construction, and commissioning. Following a competitive tender process, Watercare awarded Fulton Hogan (FH) a NZS3910 contract with a 72 week delivery period. Construction commenced in April 2014 and the overall project was delivered on-time and within the approved capital budget. The new system has been commissioned and is functioning well.



Figure 4: Madills Farm Reserve before Construction

Outcome

The additional storage has enhanced system capacity for future growth and helped reduce overflows, ensuring that Watercare complies with its regulatory requirements. Overall the upgrade provides a safer and cleaner environment.

Social Aspects

Stakeholder management

During the design phase, Watercare consulted with the following stakeholders:

- The Ōrākei Local Board
- Auckland Council including Parks
- Auckland Transport
- Various sporting bodies using Madills Farm
- Round the Bays organisers
- Local residents
- Various interest groups
- Schools
- Motorists
- Watercare's Service Delivery team, responsible for owning and operating the wastewater network.

Ōrākei Local Board

Watercare consulted with the Local Board to discuss wastewater issues facing the region and alternative solutions. The Board fully supported the proposed initiative to upgrade the wastewater infrastructure and maintained an active interest throughout the project.

Construction traffic management

Madills Farm is bordered by two major collector roads to and from Auckland City carrying a two-way traffic volume of 6,400 vehicles per day.

During detailed design, the MWH team undertook an extensive traffic impact study, with the recommendations successfully implemented through a construction traffic management plan.

Round the Bays

Round the Bays is a major public running and walking event held at Madills Farm every year in March. Watercare examined the programme and site layout for this event during detailed design to mitigate potential construction conflicts. Watercare identified any areas unavailable for public access during the event and advised organisers. This information was also included in the construction contract and all tenderers advised of their responsibilities during the event.

During discussions with the organiser, it transpired that the proposed storage tank location was usually their VIP carpark. This news involved re-designing the tank roof to accommodate these vehicle loadings in future. The event was held successfully with no issues.

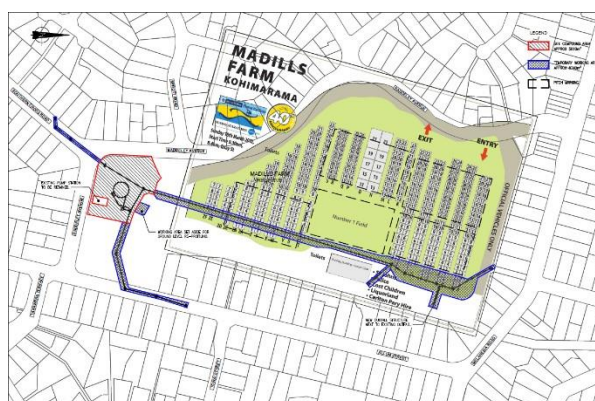


Figure 5: Round the Bays overlay on project site

Public consultation

The detailed design process included an open evening to share project information with the community. This comprised project information displays, question and answer bulletins, and maps describing the proposed works. This event elicited community concerns, which helped in structuring the project implementation plan.

Construction across sports fields

Part of the proposed DN750 pipeline crossed a sports field at Madills Farm. After consultation with Auckland Council, a construction window from August 2014 to March 2015 was identified as the period of least disruption to the sporting activities. This requirement was specified within the construction contract.

Property condition surveys

Pre and post-construction condition surveys were undertaken, by an independent Chartered Professional Structural Engineer, on surrounding properties that were most likely to be affected by the construction works. This was to understand if any adverse effects resulted from construction activities.

Community engagement

Watercare organized artwork produced by the St Heliers Bay Primary School to be displayed on the 2.4m high tank site perimeter fence. This gesture was well received by the community.

During construction, Watercare organized an open day for the community to view the 18 metre deep tank excavation. The event included a project information presentation, an engineered viewing platform, a barbecue, and face painting. Community members showed great appreciation for this rare opportunity.

Watercare released newsletters to the community informing them about progress.

Unforeseen conditions

Construction work involved installation of a DN750 pipe along the Southern side of Madill's farm. While temporarily removing a park bench to facilitate construction, a community member notified team members that her husband was buried there.

A plaque on the bench spoke of the memory of a deceased person but no records existed as to the man's ashes having been buried beneath. Construction work was ceased upon the discovery. The man's family members took charge of the urn and a local vicar blessed the site before construction work recommenced.

A key learning taken from these events is that if a memorial plaque is found in the proximity of a

construction site, it is beneficial to research prior to excavation to confirm no interments exist.



Figure 6: Kohimarama Creek

Design / Technical Aspects

Following an extensive options analysis, Watercare concluded that providing additional network storage in the form of a new 3,500m³ storage tank was the most effective means to provide system capacity for future growth and reducing CSO discharges to the environment. The options for siting the new storage tank were limited to Madill's farm reserve due to the location of the existing sewer outfall.



Figure 7: Kohimarama tank site - after

Watercare required the design to leave no lasting negative effect on the reserve and to be low impact in terms of the public perspective, eliminating any new aboveground structures or features. Balancing this requirement with the physical ground level requirements was challenging and required protecting shallow structures with functional infrastructure and the subtle re-profiling of ground levels to conceal structures.

For example, the hydraulic capacity requirements for the outfall pipes required twin DN600 outfall pipes. The pipes were limited by the Kohimarama Stream bed level and

thus the pipe soffits were close to ground level. Working closely with MWH, Watercare assisted in developing a unique speed table (hump) for a pipe protection solution that allowed the outfall pipes to be installed while maintaining a usable roadway and all parking areas in the park.



Figure 8: Completed speed table to protect pipes and allow bus access

Design efficiencies

Retaining the existing pumping station wet well increased the overall storage volume in the system; further reducing the theoretical overflow frequency to the stream.

The new storage tank was set at the optimum levels for efficiency. Energy was saved by allowing 13% of the tank's stored volume to be drained back into service under gravity without the need for pumping.

Key assets were future proofed by incorporating easily installed future upgrades. The new Sanitary Sewer Overflow (SSO) chamber, the final structure in the system prior to the overflow, is a simple rectangular structure with an internal overflow weir. This SSO chamber was designed to facilitate easy, cost-effective future modifications allowing for the addition of a powered mechanical screen, further improving the discharge quality to the stream.

MWH designed the new storage tank to produce no odour emissions, being mindful of the project's impact on the local community. This was achieved by including a self-cleaning facility to keep the tank free of sewage debris, minimising odours. The vacuum flushing system by Biogest® was selected.

The vacuum flushing system operates by creating an elevated column of water held in the tank's central column. The water column is created by using a vacuum pump to create a partial vacuum and by using the earth's

atmospheric pressure to push the water level in the centre column upwards. To flush the tank, the partial vacuum is released (broken) using an innovative vacuum diaphragm valve that instantaneously allows full atmospheric pressure back into the centre column, allowing the elevated column of water to be discharged rapidly back into the tank, cleaning the tank floor.



Figure 9: Innovative Biogest® Vacuum Diaphragm Valve

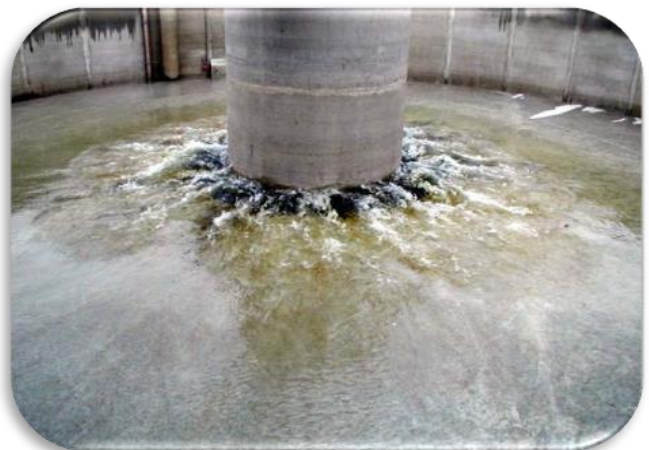


Figure 10: Vacuum Column Flushing Release (Step 5)

Structural components

The Kohimarama Storage Tank is formed with reinforced precast concrete wall panels with cast in situ stitch joints, radially aligned single tee precast concrete roofing panels supported on the perimeter wall and central column, and a structural floor slab with tension anchors and a 600mm thick benching overlay. The central column is formed using a precast concrete pipe outer shell and a glass reinforced plastic (GRP) internal lining with a reinforced concrete infill.

The tank walls are designed as hinged-base and free-top structural elements with imposed loading resisted by circumferential compression. Limitation on excavations and imposed buoyancy loading necessitated the use of

grouted tension anchors into the underlying rock to limit the demands on the structural floor slab. The single tee precast concrete roofing panels act as simply-supported elements designed to resist the imposed loading from possible overhead heavy vehicle movements.

The central column provides support to the tank roof and also serves as a reservoir for storing the liquid used in the flushing operation. The imposed axial loading and flexural bending demand on the central column are resisted by the precast concrete pipe and reinforced concrete infill. The GRP lining acts as a membrane to seal the area.



Figure 11: Vacuum Pump and Control Valves



Figure 12: CSO Chamber under construction



Figure 13: Tank Centre Column Showing PC Wall Panels and Roof Beams

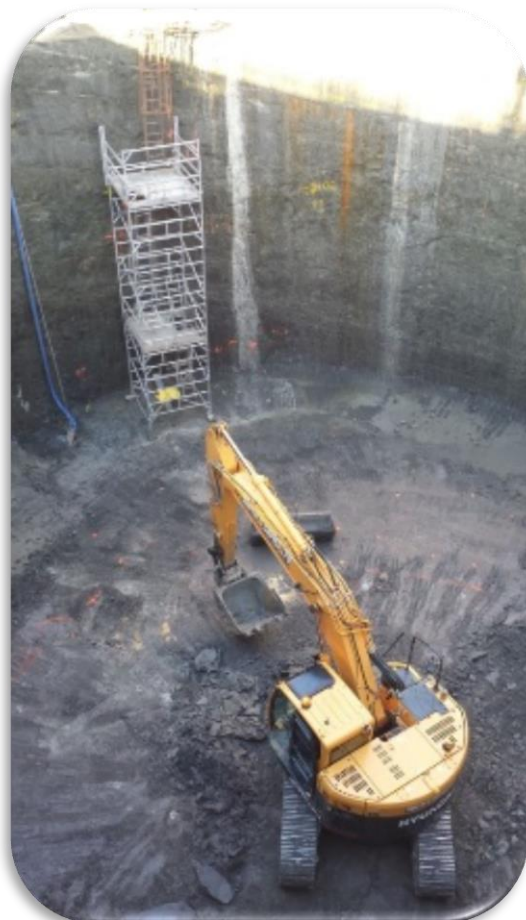
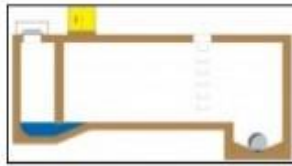


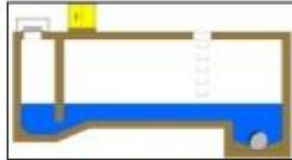
Figure 14: Excavation of ECBF rock

Flushing system description



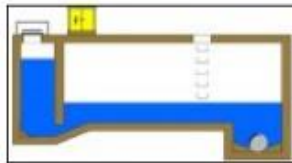
Flushing system, step 1

Both the tank and flushing chamber are empty



Flushing system, step 2

The storm begins. Combined sewage and rainwater spill into the storage chamber and rises above the siphon level of the inlet to the flushing system.



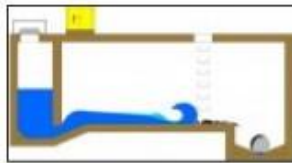
Flushing system, step 3

The vacuum pump starts automatically drawing water from the storage chamber into the flushing chamber till the maximum level in the flush chamber is reached.



Flushing system, step 4

The storm subsides and the storage chamber empties leaving sludge and other sewage related debris on the chamber floor. The level in the flushing chamber is still held under vacuum.



Flushing system, step 5

Once the tank is empty the flushing sequence starts automatically. The vacuum seal is broken and a large volume of water surges from the flushing chamber driving all of the solids from the chamber floor

Figure 15: Biogest® 5 Step Vacuum Flushing Description

- 💧 No submerged moving parts, all parts serviceable without entering the tank.
- 💧 No separate water supply required, flushing with storage water (rain- and sewage water).
- 💧 High cleaning performance (pot. energy of up to 7 m water head).
- 💧 Optimal flushing result, even on very long lanes and little slope.
- 💧 Full flushing action even after small spills (most rain events).
- 💧 Potential for a separate "dry" flush with external water supply (dry climates).
- 💧 Flushing lane width up to 10 m with only one System.
- 💧 The use of the system is independent of the tank geometry.
- 💧 Low energy consumption (about 1,5 kWh per flushing).
- 💧 Completely automatic operation, prepared for a remote control System.
- 💧 No maintenance within the tank for greater health and safety.
- 💧 Minimal maintenance (oil change).
- 💧 Excellent quality – low whole of life cost.

Figure 16: Biogest® 5 Step Vacuum Flushing Description

Geotechnical design considerations

Madills Farm Reserve is located within a flat valley floor formed in the weak sedimentary rocks of the East Coast Bays Formation (ECBF). The valley floor overlies a former stream gully, which was infilled with alluvium and estuarine sediments approximately 18,000 years ago. The site was lifted a further 1-2m by the placement of fill around 1959.

The subsurface conditions at the tank location therefore comprised a mix of cohesive soils, silty sands, and silty clays overlaying ECBF highly weathered rock. Groundwater levels were found typically 1-2 m below ground level.

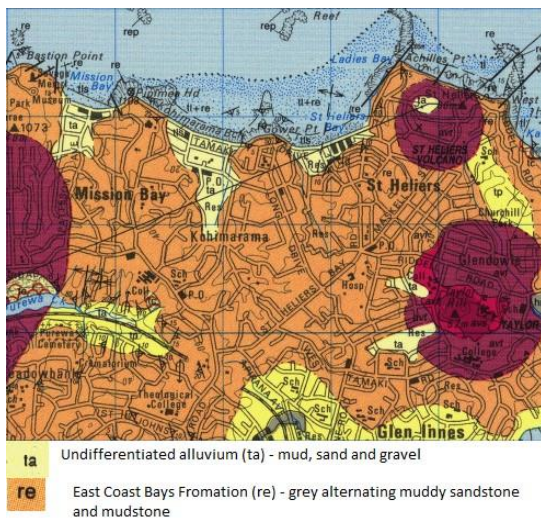


Figure 17: The geology of the site

The key geotechnical design and construction considerations for the project were:

- **Detailed geotechnical investigations** - to assess soil and rock depths, strengths and consistency and groundwater levels
- **Groundwater** – control of groundwater both during construction (inflows and potential drawdown effects) and long term (design for uplift pressures of approximately 180kPa on the underside of the tank).
- **Temporary retention** – for support of saturated alluvial/estuarine soils and ECBF rock
- **Permanent retention** – design of the tank walls for active hydrostatic and seismic pressures acting on the tank walls
- **Excavation** - of the ECBF rock
- **Monitoring** - possible groundwater drawdown related settlements using piezometers and a range of survey monitoring pins located around the site

The detailed geotechnical investigations comprised

multiple machine drilled boreholes, including one inclined borehole to assess the orientation of bedding planes within the ECBF rock. This information was used to confirm the extent and nature of structural retention required for excavating up to 12 m through rock.

A key geotechnical risk was the control of groundwater inflows through the upper soils (top 5-6.5m of the excavation). The design team needed to prove that any dewatering of the soils and the ECBF rock would have a negligible effect on the surrounding environment (residential dwellings, pump station & creek), in order to satisfy the recent Proposed Auckland Unitary Plan (PAUP) rules.

Detailed seepage analyses demonstrated that the effects of the excavation could be constrained locally to around 20 m from the tank perimeter by minimising the inflow of groundwater through the upper soils but accepting full dewatering of the ECBF rock during construction. T+T proposed open excavation through the ECBF rock as a suitable excavation methodology, with due consideration to the bedding and rock mass defects investigated for the tank construction.



Figure 18: Site Works Commence with Installation of DSM Columns

Wire mesh, supported by short rock bolts into the rock, was used to provide a safe working environment for staff working at the base of the excavation.

Strand anchors, embedded approximately 20 m below the underside of the tank, were used to provide resistance to buoyancy pressures (up to 180 kPa). The anchors were installed from the base of the excavation and tested up to 150% of design working load to prove capacity.

The FH led construction team proposed an innovative alternative to the proposed piling for temporary support of the upper soils and control of groundwater inflows; by the installation of multiple rows of overlapping deep soil-mixed columns (DSMs), extending through the upper soils and nominally into the weathered ECBF rock. This was ultimately one of the key differentiators for the FH lead team.

Construction Innovations

Deep soil mixed columns

Construction of the storage tank required a hole excavation of 24m diameter and 18m deep. The Resource Consent imposed limitations on construction vibration and noise due to the location of the project within a residential area.

FH successfully used DSM columns for excavation wall stability. DSM columns were made by mixing existing soil with high strength grout in situ to create low strength columns, which work very well in compression. The design for the tank included two rows of secant columns with a 1m key into the ECBF around the entire perimeter and an additional secant row around half the perimeter where the 400T crane worked from; this provided the additional necessary support for the lifts. DSM column depths ranged from 4.5-7m below ground level to achieve the key into the ECBF.

During construction of the DSM columns, vehicle movements in and out of site were minimised, with only one truck per day to supply the dry binder required, thus minimising the effect on the local community.

The DSM columns were successful during construction in the following ways:

- The maximum decrease in the upper groundwater level of 1m was less than predicted; the alert and alarm levels defined in the PAUP conditions of consent.
- The groundwater level in the ECBF rock decreased to the predicted elevations.

- Measured settlement around the perimeter was less than the predicted alert and alarm levels defined in the PAUP conditions of consent.
- A maximum lateral deflection of the capping beam of the DSM column 'ring' of 10mm (typically less than 5mm) was recorded around the excavation perimeter.



Figure 19: Tank excavation showing soil columns on perimeter

Thus the excavation progressed quickly and effectively without additional mitigation and construction contingency measures (e.g. re-injection of groundwater). Programme and cost were reduced.

Positioning of crane pads / lifting

Early and detailed planning allowed for the lifts to proceed adjacent to the 18m deep excavation, with the tank walls constructed in precast sections.

Panel lifting involved a fully rigged 400t mobile crane at capacity sitting at the top of the excavation; with planning completed by site personnel, an independent lift planner, and lift planners from the crane company.

All other lifts were completed by a 90t tracked crane that was onsite for the duration of the project. Loading generated by this was also considered for the temporary works but were not as significant as the 400t mobile.

Sediment controls

To ensure effective sediment control, FH limited the volume to be controlled and ensured that all sediment generated on site met consent requirements. The DSM columns helped reduce the initial groundwater inflow estimate of 10L/s by approximately 35%.

Concrete haul roads with designated site entry and exit points (including wheel wash) were maintained throughout the project. All stockpiles were stabilised, reducing the amount of flows requiring treatment.

FH, in collaboration with Southern Skies Environmental Consultants, conducted testing and treatment of site water for pH and turbidity to confirm discharge was acceptable to Council.

The site achieved the highest scores from Council environmental audits throughout the project.



Figure 20: Precast wall panel and crane lift pad

Public communication

FH and Watercare jointly produced regular letter drops during construction to keep local residents informed of the project. These letters included a 0800 number that went directly to the FH Project Manager to respond to queries. Watercare and FH worked jointly with key residents from neighbouring properties who had a special interest in the project, to ensure a 'no surprise' approach.

Base construction and roof beams

The design incorporated an in situ reinforced base slab that was tied into ground anchors. Wall panels were cast offsite and transported with special attention to the requirements of moving an 18m x 2.7m panel weighing approximately 32t through a residential area. The panels were stitched together with in situ pours completed in two lifts using twin layers of hydrophilic bead to ensure water

tightness. The roof was constructed using angled single T-beams with a topping slab.

Water ingress testing

The tank is predominantly dry with inflows only during severe weather events. Due to this, the water tightness testing was completed using an "outside in" method. Post completion of the perimeter walls, the groundwater was allowed to recharge at a maximum of two meters per day to identify any potential leak paths from within the tank.

Backfilling of the annulus

This was a high health and safety risk due to the restricted area between the walls and excavation edge. Watercare approved the use of carefully selected sand to be saturated for compaction, in lieu of placing persons or plant into this confined space.

GRP liner and offsite testing

The central vacuum column was constructed using a GRP liner, in situ reinforced concrete, and manhole risers. The GRP liner was constructed locally and tested offsite in a vacuum by charging it with water then opening a valve at the base with the top sealed, allowing the water level to drop, thus placing the liner under vacuum.

Testing and commissioning

FH led commissioning the mechanical and electrical components; a specialist from Biogest® in Germany attended. Biogest® staff assembled the diaphragm valve, installed the vacuum pump, and assisted electrical subcontractors in wiring the flushing system into the main pump station control board and commissioning the system. The diaphragm valve held a 4m column of water for 24 hours - the acceptance criteria for successful commissioning of the system.

Ensuring all code and standards between the supplier and installation countries are equivalent was a challenge of commissioning as the Biogest® product being used in New Zealand for the first time; for example, the flushing system wiring colours were not compliant with New Zealand standards. This was noticed and addressed well before installation.

Other items successfully commissioned on the job included two sump pumps and a scavenger pump located at the base of the storage tank, along with a range of telemetry and instrumentation.

Health and Safety

Contractor's staff members undertook a Watercare health and safety induction prior to commencing work on site. Watercare conducted regular health and safety audits on site during construction and ensured that FH observed other Watercare health and safety requirements.

New mining regulations came into effect three days prior to closure of construction tenders; tank excavation became classified as a mine.

FH and Watercare engaged with Worksafe NZ to ensure the works were delivered with acceptable compliance of these regulations.

Gas monitoring was managed using a mine entry format with continuous monitoring in different sections and levels of the tank excavation to confirm air quality.

The project also engaged with the local fire brigade and trialled an emergency evacuation. This exercise highlighted the following key areas to be addressed:

- The fire brigade was unable to identify the site fire warden on arrival to site. Going forward, all persons onsite wore orange hi-viz jackets; yellow hi-viz for the fire warden or site manager for easy identification.
- Fire wardens in breathing apparatus struggled to fit down ladders with safety cages so staged access was provided to the excavation area.
- If a man-cage on the crane had not been available, an access fire team would be required, taking approximately an hour to arrive. Thus, an operator and working crane were available anytime while works were in the excavation for the remainder of the project.

Project Management

Whilst the project was programmed using Microsoft Project, the implementation of Last Planner® meetings by FH during the construction phase made a significant contribution to keeping the project on track.

Conclusion

The new Kohimarama storage tank was successfully commissioned and integrated into Watercare's wastewater network. This tank helps manage high flows due to population growth within the catchment up to year 2051 and ensures the overflow frequency complies with Watercare's Network Discharge Consent. The overall project was completed within Watercare's scope, quality, time, and budget requirements.



Figure 21: Showing Extent & Depth of Excavations Along With Forced Ventilation and Access Stairs



Figure 22: Overall site view during construction with GRP liner in tank center

Acknowledgments

The successful outcome of this project would not have been possible without the collaborative input of all stakeholders, local community and organisations, Auckland Council, and the staff of the Principal, Consultants, and Contractors.

References

The majority of information contained in this paper has been provided by numerous reports compiled for the project and team members who were closely involved in the project. It was decided not to provide specific references but the authors can provide further details if requested.

Authors' biographies



Mohamed Imtiaz is a Principal Engineer at Watercare. He is a Chartered Civil Engineer with over 30 years' engineering and management experience. Over the past 22 years he has managed a number of large and challenging public infrastructure projects in New Zealand. His experience includes management of planning, investigation, design, and construction phases of water and civil engineering projects; management of infrastructure capital works programmes; and stakeholder management and people management. He is the Watercare Project Manager for the Kohimarama Storage Tank and Branch Sewer Upgrade Project.

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Steve Shortt is MWH's Hamilton-based Principal Project Manager for Water and Waste. He has over 30 years' experience in civil engineering construction projects, asset management, operations and maintenance, design management, and project management. Steve has project-managed large capex programmes and has successfully completed several major projects in the Three Waters discipline areas. Over the past seven years within MWH, he has managed a number of civil infrastructure projects in Hamilton, Auckland, and Tauranga. These projects have covered all aspects of Three Waters Infrastructure, including project managing a number of water and wastewater modelling projects of similar magnitude. He has extensive experience and skills relating to establishing and diligently implementing project cost, time, and quality controls.

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Nick Speight is a Senior Geotechnical Engineer with Tonkin + Taylor based in Auckland. Nick has 16 years' experience in the management and supervision of geotechnical investigations, deep excavation, and deep foundation design and construction observation. Nick's geotechnical experience was gained on a wide range of projects, including major infrastructure projects, multi-storey commercial and residential towers with deep basements, cliff top residential properties, landslip remediation works, and land development projects. He has been responsible for the design of retention systems for deep basement, extending up to 17m below ground level. Nick's role on the Kohimarama Project was Lead Geotechnical Designer. He was responsible for management of all stages of investigations, detailed geotechnical design, groundwater related consenting, construction monitoring, and observation.

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Daniel McKessar is a Project Manager for Fulton Hogan specializing in Civil Projects. He has 10 years' experience in civil construction, project and operational management with a further six years' experience in height access construction management and maintenance. Daniel has worked on a complete range of projects specialising in piling, stabilizing, water and other multi-discipline construction. Daniel's role on the Kohimarama project was to oversee and manage all onsite works including the client and stakeholder relationships and construction management, including health and safety, programming, and commercial controls.

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