ROTOTUNA RESERVOIR CONSTRUCTION – SECURING WATER FOR THE FUTURE

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ABSTRACT

Hamilton City's water distribution system consists of a single water treatment plant and distribution via a ring main system to eight reservoirs throughout the City.

In order to cater for current and future city growth, Hamilton City have invested $21m in a new 24Ml reservoir in Rototuna, which is anticipated to be completed by September 2017. In addition to facilitating city growth the new reservoir will provide significant benefits to network operation and resilience.

Geographically 95% of the current water storage is located on the western side of the city, with only one operational reservoir located on the eastern side. The city is therefore critically reliant on strategic river crossings to provide water to the east in emergency situations. The Rototuna Reservoir will provide some balance to the east/west storage.

A major strategic shift in the operation of the City water network is from the water treatment plant managing the demand of the city, to the treatment plant supplying reservoirs which will manage the demand by zones (Demand Management Areas). This change in operational philosophy will maximize reservoir utilization by allowing buffering of demand fluctuations and thereby alleviating the stress placed on the water treatment plant output rates.

This strategic shift changed the intended purpose of the reservoir pumphouse from simply supplying water at a steady head to the ring main, to supplying a primarily residential zone with a dynamic flow range of between 35l/s to 650l/s. This paper will focus on how the ranges of flow demands of a primarily residential zone were met, and the impacts of a strategic shift in how the network was operated after the design was completed.

This project faced challenges in the design phase including seismic requirements and geotechnical challenges, and the paper will also touch on Contractor led value engineering proposals, safety in design, and the twin bulk main design for reservoir filling and operational supply, including how to get water to the reservoir at the opposite end of the city from the Treatment Plant and at a high RL.

KEYWORDS

Reservoir, Network Strategy, pump design, water supply, safety in design

PRESENTER PROFILE

Lance Haycock has been with Hamilton City Council for 10 years, spending the last 7 Years as a Project Engineer in the City Development Project Team. Previously he enjoyed rallying a fully compliant rally car he built himself until rolling 9 times in the Possum Bourne Rally of NZ so now focuses on his family, as he isn't allowed another toy. He currently leads projects including the Rototuna Reservoir, Far Western Wastewater Interceptor, Rotokauri Swale Notice of Requirement and the Rotokauri Integrated Catchment Management Plan.

1 INTRODUCTION

Hamilton City's population is projected to grow rapidly from 160,000 in 2017 to 236,500 in 2046. The City is bisected by the Waikato River which flowing to the north. There is an almost equal balance of land area on the east and western sides of the river. The City's water treatment and supply network is rated as Aa according to the NZ Drinking Water Standards.

The land use of the City is primarily residential on the eastern side of the Waikato River with the majority of the City's industrial and commercial uses located on the western side. This creates a bias in demand during peak periods. It is noted that the recent Ruakura Structure Plan promotes significant additional industrial land use on the eastern side (e.g. Ruakura Inland Port)"

Geographically 95% of the current water storage is located on the western side of the city, with only one operational reservoir located on the eastern side. The city is therefore critically reliant on strategic river crossings to provide water to the east in emergency situations.

This reliance on strategic water crossings places the city at significant risk of its ability to provide water to the Eastern side of the city, should the crossings be compromised through a seismic event or pipe failure.

The Rototuna Reservoir was recommended in the 2002 report *2020 Water Supply Network Strategy Plan* in order to support the growth of the city and improve the storage bias between the eastern and western side of the city,. Land for this reservoir was purchased and designated in 2002.

A 24 megalitre reservoir was designed with an associated 2+1 pump house (2 operational and one standby) to facilitate the current network philosophy in 2010 with expectations to have the reservoir operational by 2012, However, with external factors such as the global financial crisis, fluctuating growth, and a conservative approach being taken by Council with respect to incurring debt large capital projects such as the reservoir were deferred.

By 2014 development and demand had continued to grow with the water to supply the Rototuna area being provided by Pukete Reservoir as an interim solution. The Pukete reservoir reached its operational limitations for supplying its geographic extents, so the Rototuna Reservoir implementation commenced.

In the time between design in 2010 and the need for the reservoir a number of critical events had occurred that impacted the design and performance of the reservoir, these included; the Christchurch earthquake, the Health and Safety at Work Act, Network Operation Philosophy, and the Waikato Expressway.

This paper will discuss the impacts of these events and the impacts and actions taken to address them.

2 HAMILTON CITY'S STRATEGIC NETWORK OPERATION

2.1 OVERVIEW OF STRATEGIC OPERATION

2.1.1 CURRENT OPERATIONAL PHILOSOPHY

Hamilton City Council (Council) is moving away from an operational philosophy where sole Water Treatment Plant (WTP) treats water drawn from the Waikato River and supplies consumers directly via the reticulation network and as well as refilling reservoirs for storage.

The current approach has vulnerabilities, for example, a total power failure at the WTP would prevent water being pumped into the network. The reservoirs would then be expected to provide continued service to consumers by gravity, albeit with a limited storage reserve.

The current configuration also relies heavily on the WTP to absorb daily and seasonal pressure fluctuations from the network demand.

The 2020 Water Supply Network Strategy Plan (Zhang, Boyte 2002) highlighted the above deficiencies.

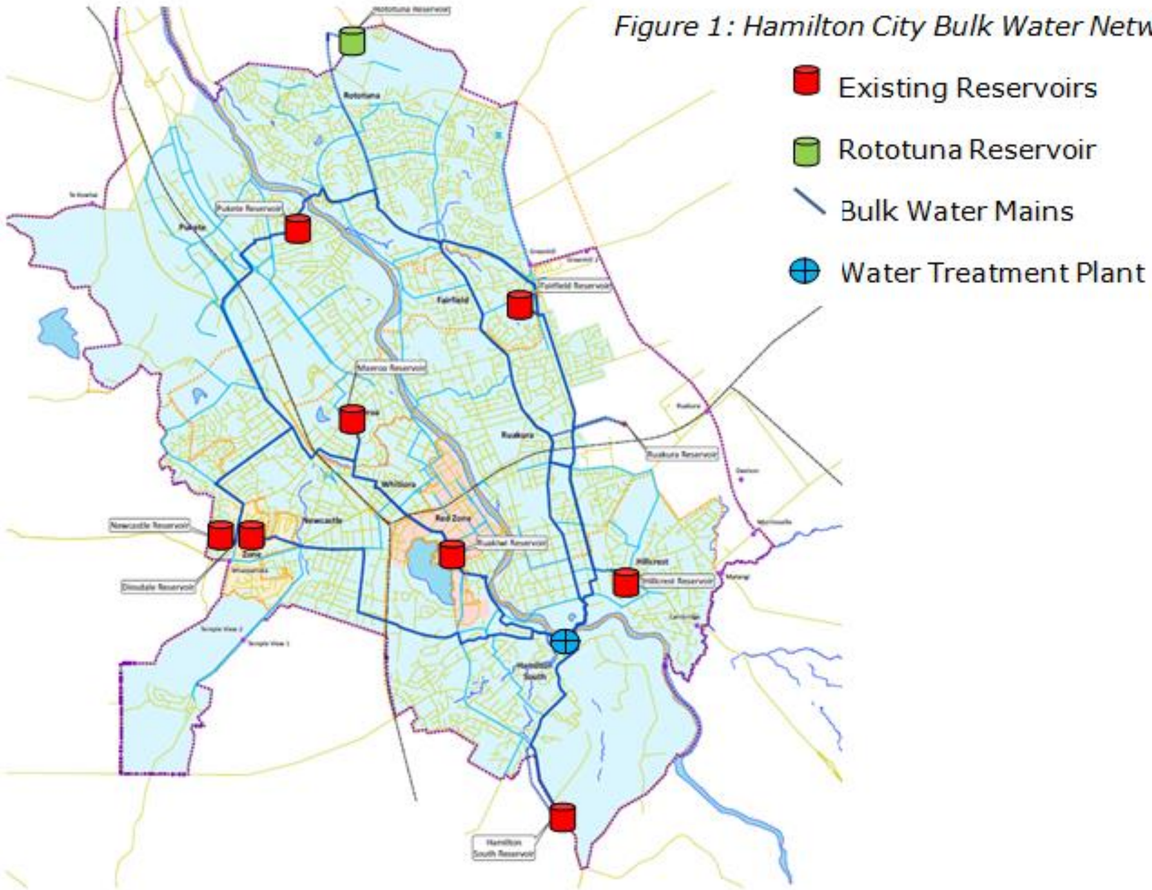


Figure 1: Hamilton City Bulk Water Network

2.1.2 NETWORK CHALLENGES

As well as treating water and managing the demand fluctuations of the city the WTP is has to push water from the south of the city nearly 12 km north including to elevated locations. With rapid population growth in the north elevated areas started to experience pressure and flow levels of service (LOS) issues.

Further complications arise as a consequence of the bias in water demands from the western to the eastern side of the river caused by an unequal allocation of residential, industrial and commercial land uses. Security of supply risks emerge for the eastern side because that side reliant on strategic bulk water mains crossing over the Waikato River and only two of the eight reservoirs are on that side of the city.

During peak demand periods over summer, LOS complaints would be common in the raised areas and the northern parts of the city. At some peak demand periods, water pressures were so strained new gas hot water califonts were not receiving enough pressure to activate, with some new developments were forced to install temporary booster pumps stations to improve pressure in the northern areas.

In response to these issues the Rototuna Reservoir and Demand Management Areas (DMA's) philosophy was approved for implementation.

2.1.3 PROPOSED OPERATIONAL PHILOSOPHY

The proposed operational philosophy that Council is currently implementing is to decouple the WTP from the network and create DMA's. Each DMA will eventually be supplied by a reservoir dedicated to that area.

Each reservoir will be supplied via a ring main with a dedicated fill and feed bulkmain to allow for simultaneous fill of the reservoir and feeding of the network. With the WTP only supplying reservoirs via a dedicated bulkmain system, a flat line of operational performance can be achieved as the reservoirs provide a 'buffer' for the zone during peak periods.

This flat line operation of the WTP has a number of benefits including improving efficiency of the WTP performance, increase flexibility for maintenance planning, reducing wear on the pumps operation and reducing pressure fluctuations and inconsistencies in the network.

2.1.4 NETWORK CHALLENGES FROM PHILOSOPHY SHIFT

A key risk to the implementation of the Rototuna Reservoir was the impact the reservoir would have on the network itself. It became apparent during the transition to the reservoir becoming operational that because the surrounding area was not yet configured to create a DMA that the reservoir would have negative effects on the WTP ability to service the City. This is because the WTP would be operating at capacity during peak demand times to supply the un-DMA network, but with the Rototuna Reservoir coming online outside of a DMA the WTP would now be asked to fill an additional 24 million litre reservoir at a high RL in an area it was already known to have pressure issues in peak demand periods.

In response to this risk of the following actions were taken:

- The program for creating the DMA zones was advanced to alleviate the network demand from the WTP and increase the efficiency on the network as a whole; the more DMA's that are implemented the the closer the WTP could operate as a flat line output.

- The duplication of the bulk mains to the Pukete Reservoir (which currently feeds the Rototuna area) was installed to allow dedicated Fill and Feed operations. This was fast tracked to give the Rototuna Zone additional resilience to peak demand periodsby alleviating the WTP.

- A booster pump was provided for in the Rototuna Reservoir Dedicated Bulk Water Main design which would allow for a booster pump to be used to increase the pressure to fill the reservoir. This would only be required in the unprecedented situation of 3 consecutive days of peak demand exceeding 90 million litres for the city from the WTP. A average demand is about 45 million litres.

2.1.5 RESERVOIR CHALLENGES DUE TO THE PHILOSPHY SHIFT

As the design of the reservoir began some five to seven years prior to beginning the shift in operational philosophy, some elements of the reservoir design and intended operation had to fundamentally change to adapt to the expected operational LOS, for example the reservoirs original intent was act as a storage facility and to subsidise flow and pressure to the network during emergency events or peak demand periods with the WTP to supply and pressurize the network.

The reservoir will now take over the daily operational supply, pressure and storage functions from the WTP,. This absorbs the network demands of the network on the WTP.

Several alterations were made to adapt to the new demands placed on the reservoir by the change in philosophy, these included :

- Changing the design outputs of the pumps from 101 litres/second peak with a 2+1 pump arrangement, to a flow range of 30 to 650 litres/second which required 7 pumps with different and overlapping ranges.

- Adjusting the number of pumps in response to the flow range needed to supply the primarily residential Rototuna area which has a high peak day time demand and extremely low night time demand.

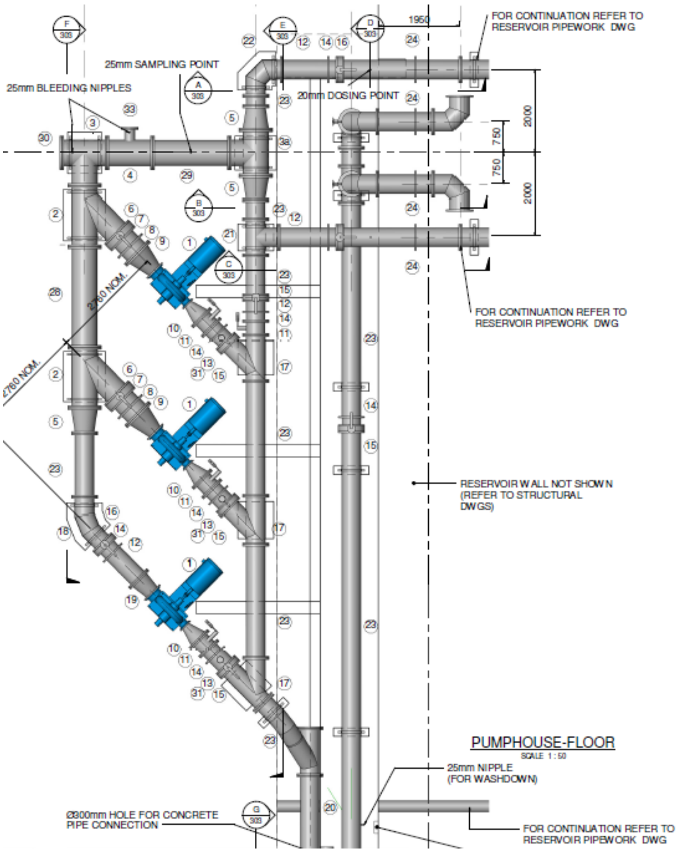
- More than doubling the size of the pumphouse to accommodate an additional four pumps. Refer Figure 2

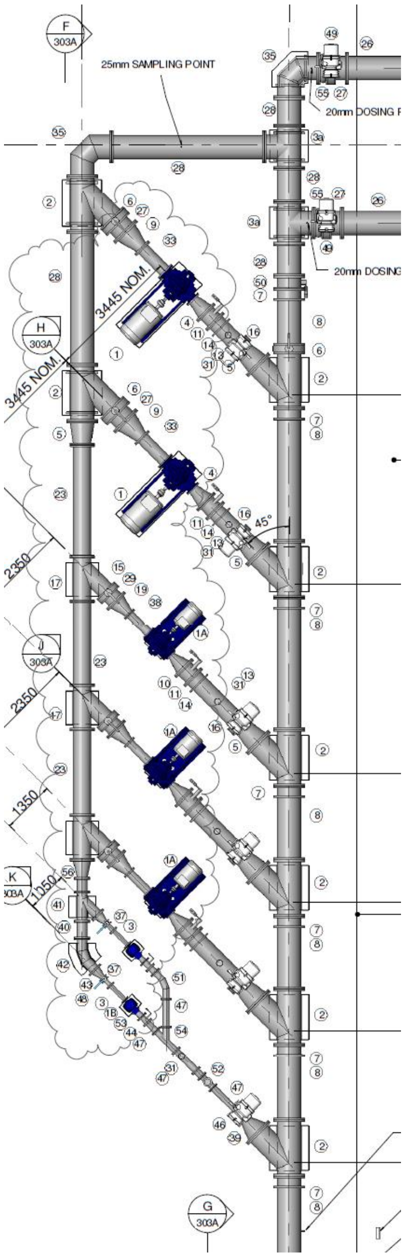
- Providing pumps with Variable Speed Drive (VSD) to meet the new pump design profile with a consequential increase in the electrical room footprint.

- Altering the Designation to accommodate the increase in the pumphouse footprint.

While redesigning the pumps and pumphouse, Council recognized and took the opportunity to review the entire reservoir design against the findings of the recently implemented Health and Safety at Work Act 2015, It was specifically measured against the Safety in Design aspects of the four phases of the operational life cycle; construction, operation, maintenance and demolition. With this revision some improvements around operational and maintenance safety were made such as, access space between manifolds/pumps, a two tonne overhead gantry for lifting pumps and pipework and a handrail/guardrail system around the roof structure.

Figure 2 : Comparison of original pump design to the new pumphouse aligning with the new operational philosophy.





Original Pumphouse Manifold Design

Revised Pumphouse Manifold Design

3 PROJECT CHALLENGES

3.1 DESIGN PHASE

3.1.1 GEOTECHNICAL AND SIESMIC CHALLENGES

Findings from a geotechnical investigation "Rototuna Reservoir Geotechnical Factual Report", revealed coarse silt to fine sand with loose to medium density and ground water being located at 18m depth. Analysis of these results concluded:

- Potential levels of differential settlement were unacceptable for the structure and mitigation measures would be required.
- Even though the soil types were prone to liquefaction, due to the depth of ground water it was considered low.

Without mitigation ground settlement was anticipated to range between 200mm & 800mm across the site.

A review of the original assessments and designs were undertaken to take advantage of the learnings from the Christchurch earthquakes.

Further to the above challenges, a separate New Zealand Transport Agency (NZTA) Designation for the Waikato Expressway applied to an adjoining property. This roading project proposed to make an 18m cut on the eastern boundary of the Rototuna Reservoir to form an underpass to enable the existing road to pass above (Kay Road). This 18m cutting was at a safe slope with no engineering structure (retaining wall) as support. This represented a significant unknown risk to the Reservoir in a seismic event.

To mitigate seismic risk and differential settlement two options were available:

1. Preloading the site to a target consolidation target over a period of 12 months.
2. Installing pile foundations to enable almost immediate construction start.

At the time of considering these options, time was not a key driver as this was planned as a 'just in time' delivery, therefore option 1 Preloading was selected due to its significant cost savings and time flexibility in the program.

The alternative to preload was the use of extensive pile foundation design using two screw piles raked at 3° to 4° to a depth of 15m to 21m at each of the 60 locations with an estimated cost of $2.6 million.

The preferred option of preload which required approximately 12,500m³ of material to place a 1.4t/m³ load, compacted and monitored with a settlement target achieved within 12 months was approved. This equates to a 4.5m high load of material placed on the entire footprint of the reservoir. A blue/brown rock was selected due to is cost and was placed and compacted over a 6 week period.

By the time the placement of the preload was scheduled to commence, development pressures had increased and options of accelerating the program were being reexamined. This resulted in increasing the load to 1.65t/m³ or 6.2m high and installation of wick drains which should reduce the program to nine months duration.

Acknowledging the learnings from the Christchurch Earthquake around liquefaction and the neighboring 18m cut for the Waikato Expressway, approval to proceed with the additional load to accelerate the program was given on the basis of the following:

- Liquefaction risk had been canvassed in a technical memo from OPUS 'Rototuna Reservoir PreLoad Design Considerations – Liquifaction Analysis', confirming that there are no requirements for pile foundations in regard to liquefaction due to low (deep) ground water levels.

- Once settlement targets are achieved, piles would not be required (i.e. no 'risk' of failure requiring piling).

- Intervening in the preload process part way through before settlement targets are achieved to change to a pile foundation method would not reduce the piling design requirements or costs because the piles would still need embedment into solid compacted sand layer found at 15m+.

- OPUS designed the Expressway slope and have managed the safe slope limit with the Rototuna Reservoir in place, however, onsite measures need to be taken to ensure no undermining of this slope occur. Ie saturation of the soils from a leak in the reservoir, all points raised has been accommodated in the design.

3.1.2 DESIGNATION CONSTRAINTS

The designation was confirmed December 2002. The Designation conditions required the immediate installation of screen planting around the full boundary of the reservoir property to offer some screening of the 60m x 60m x 8m high concrete structure located on top of a prominent ridge line.

At the time of construction this screen planting had reached 6m-8m in height and was well established. Unfortunately at the time of Designation, no consideration had been given to the constructability in the construction phase of the reservoir, or the contours of the existing site and the influence this would have on a design.

The screen planting created a significant site constraint with construction, vehicle maneuverability and also safety. These constraints effectively arise from impacts on sightlines entering and exiting and limited turning space for large vehicles inside the site with large plant (cranes, trucks) active.

The approved site layout plan that was part of the Designation became a challenge to achieve as it seemed to have been developed without adequate recognition of the sites contours. This is evident as the pump house is identified on a 1:4 slope which posed serious constructability issues and cost implications.

An alteration to the Designation was sought to improve the site layout by placing the pump house against the reservoir and allowing for some screen planting to be removed to improve site entry and exit. Once construction was completed this screen planting would be reinstated.

Figure 3 shows the original proposed site layout for the reservoir, originally anticipated to be constructed in two stages (2x 12mega litre tanks) to deliver storage in a 'just in time' phasing. However development demand increased at such a rate the reservoir was built as one unit.

Note the location of the propose vehicle park and the pumphouse and the revised design location in Figure 4. These were relocated due to the steep contours as discussed above.

Figure 3: Initial Site layout

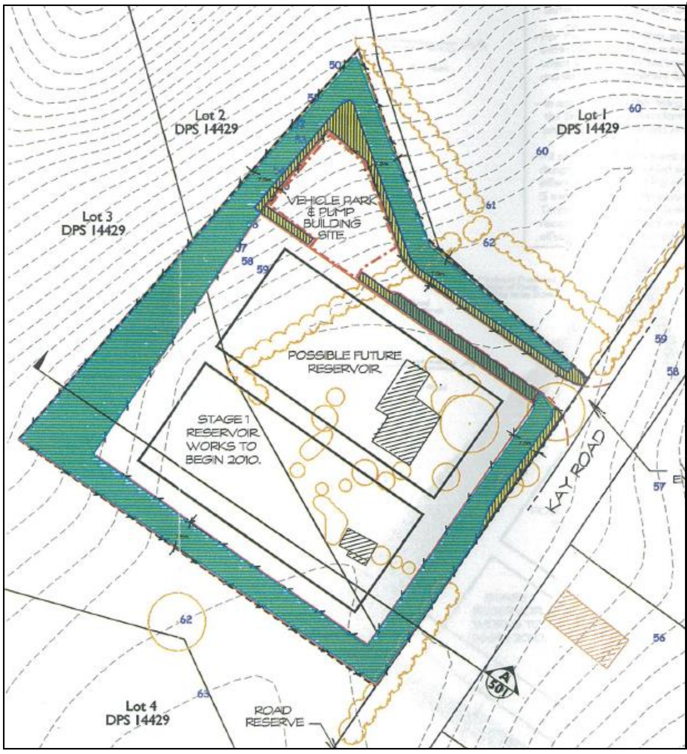
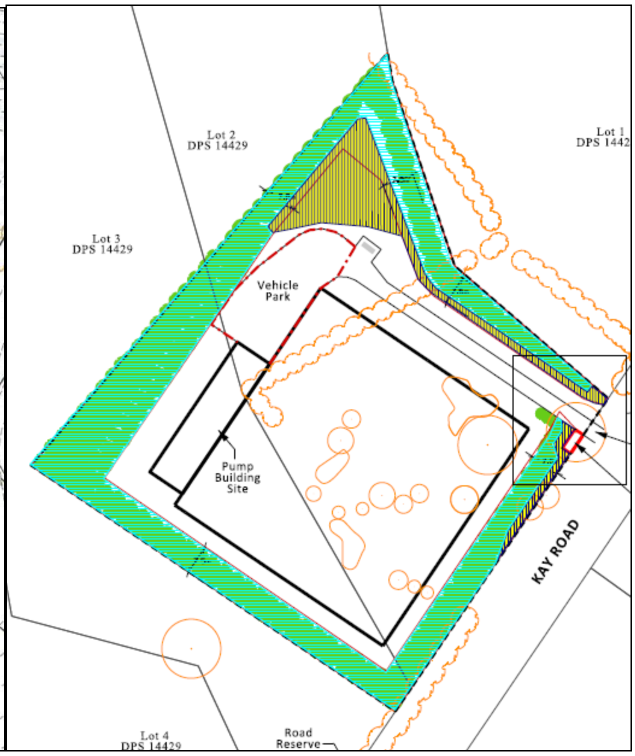


Figure 4: Revised site layout



As part of constructing a concrete reservoir a number of staged large scale pours were required, the largest of which was the two stages of the floor pours totaling 1900m³.

To deliver 950m³ of concrete in one pour would require two concrete pump cranes working from 5am to 4pm constantly. With the site being constrained for access, a standard reach of concrete pump trucks could not access the back edge of the foundation, therefore two long reach pump cranes were used (one 44m and one 52m reach) to reach the extents of the foundation on the first pour, with a third standing by in reserve.

The workability for the second pour of the slab was further constrained due to nearly half the site being closed from the first concrete pour. This forced the contractor to be creative in placing the concrete. This was achieved with a double over pump, where concrete was delivered to a pump crane, which pumped it over the screen planting and site cabins to a second pump crane which then pumped the concrete in place on the footing (refer Photo 2)This allowed a third pump crane to be located close to the site entrance and deliver the concrete the second pump crane would be placing. This meant on this pour we had four pumps onsite, three pumping and a standby.

Photo 1: First pour of 950m³ showing two concrete pump cranes

Photo 2: Second pour of 950m³ showing the over pump configuration

3.1.3 CONTRACTOR LED VALUE ENGINEERING

The successful tenderer (Hawkins Infrastructure) proactively developed value engineering options with Council and the OPUS design team. The three major options considered were:

1. Disposal of preload material
2. Post Tension Slab
3. Pre-casting off site.

<u>Preload Removal</u>
Discussions with NZ Transport Agency and their Alliance team constructing the Waikato Expressway provided a solution to the removal of the 12,500m³ of preload from the site prior to the construction of the reservoir. As part of the enabling works for the Waikato Expressway they would need material suitable for the construction of haul roads through their sites.
The solution for both parties was for Councils team to relocate the reservoir preload material onto the Expressway site at no charge. This saved the reservoir project $480,000 and the Expressway team material and transport costs.

<u>Post Tension Slab</u>
Moving from a concrete mass foundation to a Post Tension Slab was proposed by the Hawkins Team after developing the design with their Structural team and OPUS. This change in design resulted in a reduction in concrete volume of 640m³ and reduced the reinforcing required by 240 tonnes. This saved the contract nearly $360,000 in net project costs once all overheads and other costs were accounted for.

Additional non-financial benefits included the reduction in cold joints in the floor slab. Under the original option the floor slab was to be poured in 6 individual sections which would result in two cold joints in each tank. With the Post Tension Slab option this was significantly reduced as the only joint between the two concrete pours, each being 950m³, would be located under the central wall dividing the tanks.

Another non-financial benefit was an environmental. With the Post Tension Slab design using less concrete and steel it reduced the overall project carbon footprint in materials and with less vehicle movements to deliver the concrete and steel.

<u>Off Site Concrete Pre-casting</u>
Due to the physical constraints of the site posed by the screen plantingthe team needed to be creative in how the site operated. Initially the design methodology looked to use a poured insitu structure. This concept was dismissed early because the formwork needed would essentially require closing the site from additional works.
Hawkins moved instead towards pre-casting components off site to improve site efficiency. This had the advantage of improved QA control, consistency in product replication, and program efficiencies through concurrent works and safety.

This was a cost neutral alternative, however it offered non-financial benefits to the programme by improving safety, reducing the onsite works and storage needs, and improving overall workability on site. This made it a worthwhile value engineering option

3.1.4 SAFETY IN DESIGN

During the finalisation of the design phase, the new Health and Safety at Work Act (HaSAWA) became active. Although the project had gone through a Safety in Design (SiD) Review which had already been completed, a further SiD was held to reflect on the changes. A key outcome of the changes was the consideration of the Health and Safety of workers through the life of the assets operation.

Initially a caged ladder was deemed appropriate for access to the roof of the reservoir. This was identified as a potential safety issue for staff access. Once it was understood the frequency of access, the number of times it would be accessed during the assets life, that the cost to install a set of stairs to the roof instead of a ladder system would only be $38,000 (equateing to $32 per access), it was a straightforward decision to install a stairway instead.

Some simple improvements for mitigating risk were were identified for the pumphouse, for example the fluorescent tube lighting located on the roof 8m from the floor of the pumphouse floor. This provided significant risk and cost during bulb replacement. For this reason the lights were relocated to the walls and changed to LED type which removed both access risk and frequency of replacement.

Lessons learnt from other reservoirs were to consider the accessibility and ability to remove the heavy pumps and gearboxes. In response the pump house was designed on a single level and in an open plan to enable a 2 tonne electric gantry crane to be located over all components. This meant the components could easily be moved to the garage door forebay where a vehicle could be positioned to recieve the component lowered onto it with absolutely no lifting required from staff.

An 'at level' safety hatch was located on each of the two reservoir water tanks to provide access for plant and equipment that would be used during an internal inspection, wash-down or maintenance task. This hatch was 800mm in diameter and designed to be used as a stretcher retrieval point in an emergency in lieu of lifting an injured person 8m up to the roof hatch.

During construction of the reservoir a handrail system the full length of the roof perimeter was added to the design reflecting the standard requirement of 5m each side of an access point. After understanding the future maintenance and inspection requirements of the roof seals, and the potential maintenance and repairs required over the asset life, the $50,000 cost to improve overall safety was reduced to just $41 each inspection. This was a missed opportunity as a temporary handrail system was in place by the contractor for edge protection during construction. If this had been considered earlier additional savings would have been achieved as the permanent solution would have negated the need for temporary edge protection.

4 CONCLUSIONS

The change in operational philosophy of a cities water network or the construction of a water reservoir of this size are not activities frequently undertaken by local authorities in New Zealand.

A change in operational philosophy although well thought through and extensively modelled over a number of years, is predominantly a theoretical activity, and once challenged with the need of certainties to inform detailed design can result in overly conservative assumptions of network performance. This can be challenging to manage; especially when trying to manage risk of supply to customers, however, by becoming comfortable with the approach the information is derived from, an element of certainty can be derived from the model outputs.

The extensive time difference between construction of a project of this nature, or even the time between planning and execution of a project like this, can mean any lessons learned from the last build are either forgotten, poorly documented or not relevant to current standards. To overcome this flexibility and experience is essential to identify and respond to these challenges in delivering a product that the Council's Asset and Operations Teams find acceptable.

Having experienced designers and competent contractors that openly communicate also added to the success of this project. All parties were willing to understand all proposals and assess each on their merits without being protective of their respective roles.

Under estimating a blue sky suggestion without further investigation may develop into a missed opportunity which could save the project time, money and/or improve safety.

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