Lessons in reservoir building

This is a précis of a paper by Lance Haycock from Hamilton City Council and Johan Meintjes from Opus.

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 invested $21 million in a new 24-megalitre reservoir in Rototuna, which was completed by September this year. In addition to facilitating city growth the new reservoir will provide significant benefits to network operation and resilience.

Geographically 95 percent of the city's 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. 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. So, the Rototuna Reservoir is designed to provide some balance to the east/west storage.

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 35 litres per second to 650 litres per second.

This project faced challenges in the design phase including seismic requirements and geotechnical challenges, and how to get water to the reservoir at the opposite end of the city from the treatment plant and at a high RL.

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, and land for this reservoir was bought and designated in 2002.

A 24-megalitre reservoir was designed with an associated two-plus-one pumphouse (two 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 was started.

In the time between design in 2010 and 2014 a number of critical events occurred that impacted the design and performance of the reservoir. These included the Christchurch earthquakes, the Health and Safety at Work Act, Network Operation Philosophy, and the Waikato Expressway.

A key risk to the implementation of the Rototuna Reservoir was the impact the reservoir would have on the network itself.

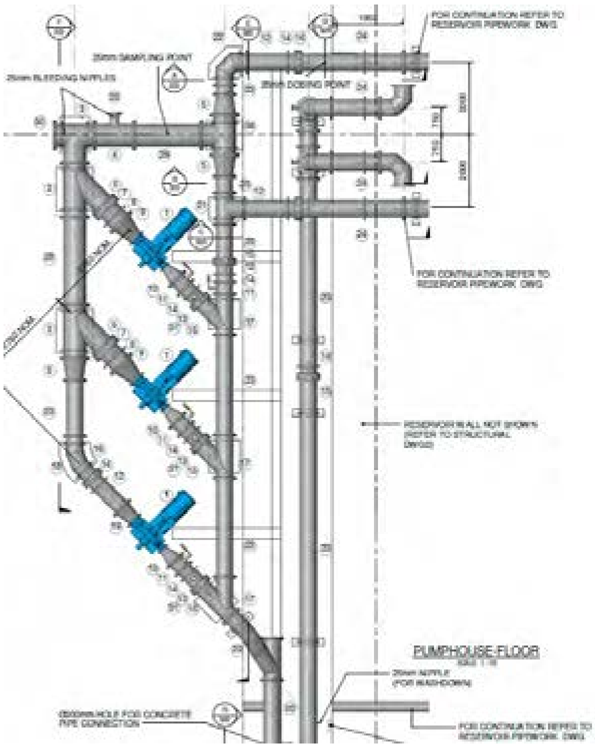
It became apparent during the transition to the reservoir becoming operational that, because the surrounding area was not yet configured to create a DMA, the reservoir would have negative effects on the WTP's ability to service the city. This is because the WTP would be operating at capacity during peak 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 in which it was already known to have pressure issues in peak demand periods.

In response to this risk, the following actions were taken. The programme for creating the DMA zones was advanced to alleviate the network demand from the WTP and increase

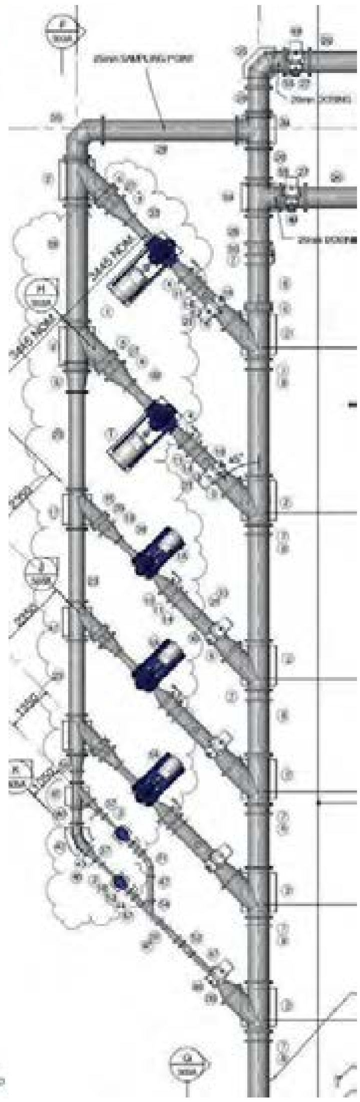
Hamilton City Bulk Water Network

- Existing Reservoirs
- Rototuna Reservoir
- Bulk Water Mains
- Water Treatment Plant

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

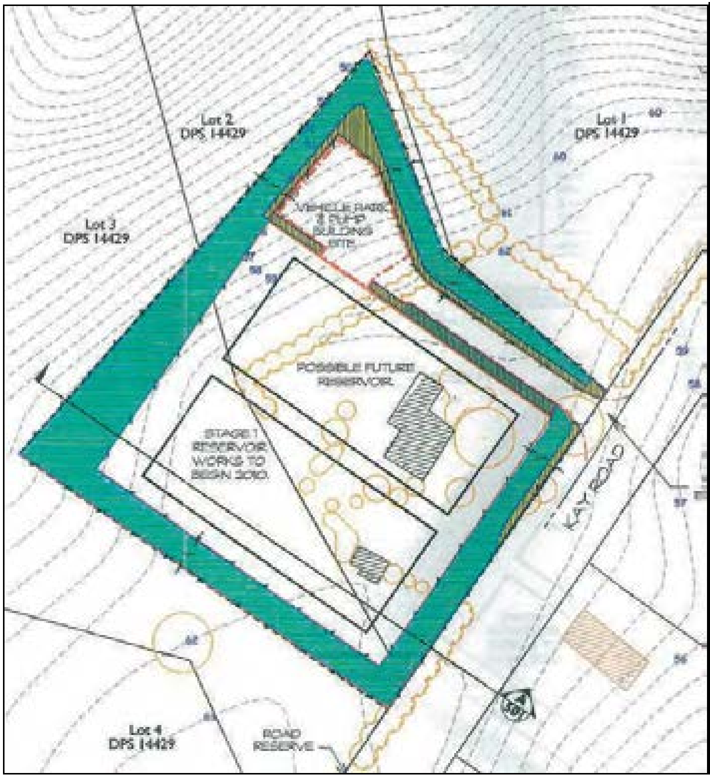


Original Pumphouse Manifold Design



Revised Pumphouse Manifold Design

Rototuna Reservoir



Initial site layout.

Revised site layout.

First pour of 950m³ showing two concrete pump cranes.

Second pour of 950m³ showing the over pump configuration.

the efficiency on the network as a whole; the more DMAs that are implemented 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 periods by 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 three consecutive days of peak demand exceeding 90 million litres for the city from the WTP. An average demand is about 45 million litres.

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 reservoir's original intent was to 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 pressurise the network.

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 per second peak with a 2+1 pump arrangement, to a flow range of 30 to 650 litres per second, which required seven pumps with different and overlapping ranges. It also involved adjusting the number of pumps in response to the flow range needed to supply the primarily residential Rototuna area which has a high peak daytime demand and extremely low night-time demand.

Other design alterations included more than doubling the size of the pumphouse to accommodate an additional four pumps; providing pumps with Variable Speed Drive (VSD) to meet the new pump design profile with a consequential increase in the electrical room footprint; and altering the designation to accommodate the increase in the pumphouse footprint.

A review of the original assessments and designs also took advantage of 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 18-metre cut on the eastern boundary of the Rototuna Reservoir to form an underpass to enable the existing road to pass above (Kay Road). This 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 this seismic risk and differential settlement two options were available: Preloading the site to a target consolidation target over a period of 12 months; or installing pile foundations to enable almost immediate construction to start. Preloading was selected due to its significant cost savings and time flexibility in the programme, which required about 12,500 cubic metres of material to place a 1.4t/m^3 load, compacted and monitored with a settlement target achieved within 12 months. This equated to a 4.5-metre high load of material placed on the entire footprint of the reservoir. A blue/brown rock was selected due to the cost and was placed and compacted over a six-week period.

By the time the placement of the preload was scheduled to commence, development pressures had increased and options of accelerating the programme were being re-examined. This resulted in increasing the load to 1.65t/m^3 or 6.2 metres high and installation of wick drains that was expected to reduce the programme to nine months duration.

Acknowledging learnings from the Christchurch earthquakes around liquefaction and the neighbouring 18-metre cut for the Waikato Expressway, approval to proceed with the additional load to accelerate the programme was given. Opus designed the Expressway slope and 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 occurs, ie, saturation of the soils from a leak in the reservoir, all points raised, has been accommodated in the design.

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 totalling 1900 cubic metres.

To deliver this amount 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 44 metres and one 52 metres 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. 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.

Construction

The successful tenderer was Hawkins Infrastructure, which developed engineering options with the council and the Opus design team. The three major options considered were: disposal of preload material; post tension slab; and pre-casting off site.

Preload removal

Discussions with the NZTA and its alliance team constructing the Waikato Expressway provided a solution to the removal of the 12,500 cubic metres 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.

So, the solution for both parties was for the council team to relocate the reservoir preload material onto the Expressway project site at no charge. Effectively, this saved the reservoir project $480,000 and the Expressway team material and transport costs.

Post tension slab

Moving from a concrete mass foundation to a ‘post tension slab’ was proposed by the Hawkins team after developing the design with its structural team and Opus. This change in design resulted in a reduction in concrete volume of 640 cubic metres 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 six 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 950 cubic metres, would be located under the central wall dividing the tanks.

Another non-financial benefit was environmental, such as fewer vehicle movements needed to deliver the concrete and steel.

Off-site concrete pre-casting

Due to the physical constraints of the site (posed by screen planting) the construction team needed to be creative in how the site operated. Initially, the design methodology looked to use a poured in-situ structure. This concept was dismissed early because the formwork needed would essentially require closing the site from additional works.

Instead, Hawkins moved pre-casting components off site, and this had the advantage of improved QA control, consistency in product replication, and programme efficiencies through concurrent works and safety.

This was a cost neutral alternative, however it proved a worthwhile engineering option that improved overall safety, reduced the onsite works and storage needs, and improved overall ‘workability’ on site.

Safety aspects

A key outcome of these 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, but was identified as a potential safety issue for staff access. Considering the frequency of access, the number of times it would be accessed during the assets life, and the cost to install a set of stairs to the roof instead of a ladder system would only be $38,000 (equating to $32 per access), it was a straightforward decision to install a stairway instead.

Some simple improvements for mitigating risk were identified for the pumphouse, such as the fluorescent tube lighting located on the roof eight metres from the pumphouse floor, which 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 pumphouse was designed on a single level and in an open plan to enable a two 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 receive 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 eight metres 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 five metres 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 put 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.

Conclusions

The change in operational philosophy of a city's water network or the construction of a water reservoir of this size are not activities frequently undertaken by local authorities in this country.

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 who 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.

Underestimating a blue sky suggestion without further investigation may develop into a missed opportunity that can save the project time, money and/or improve safety. WNZ