OKARA PARK PUMP STATION UPGRADE

E W Thorn and F Richter Opus International Consultants Limited

ABSTRACT

Many sewer pump stations in New Zealand are reaching the point where significant upgrading is required either because of their age or due to insufficient capacity.

This paper looks at the upgrades that were made to one such station in Whangarei.

The problems and solutions addressed in this paper include:

- Design of the construction sequence to enable continued safe operation of the station
- Increasing the suction pipes between the wet well and drywell from 300mm diameter to 600mm diameter
- Fitting pumps into the drywell when the pumps are nearly as high as the drywell itself
- Installing a second rising main into the existing station
- Safe operation of pumps when the wetwell was significantly smaller than desirable
- And many other details that are made more difficult by the limited space in the existing station and the need to keep the existing station operational at all times.

The pump station and rising mains are now fully operational. The station can now pump more than twice its original flow rate and has less kW's of pumps installed. Overflows from this pump station as a result of insufficient pump capacity should no longer occur.

KEYWORDS

Wastewater Pump Station, VSD, Okara Park

1 INTRODUCTION

1.1 THE SITE

Until 1967 sewage from Whangarei flowed to a large septic tank at Okara Park, from which the treated effluent flowed to the Whangarei Harbour. In 1966/67 a pump station was built on the site to pump flow to a new treatment plant about 1.6 km away in Kioreroa Road. The pump station was connected to the treatment plant with a 600 mm diameter reinforced concrete rising main. The pumping station had a separate wet well where the incoming sewage entered and a drywell in which the pumps and valves were installed. It had four J. J. Lee Howl pumps installed, two of 60kW, and two larger pumps of 100kW. The pump station had a claimed maximum pump capacity of 570l/s, however the actual maximum capacity was probably less than this figure.

Photograph 1: Original pump station building

1.2 PUMP UPGRADE

In 1990 the two smaller pumps were replaced with two 250 kW pumps, installed on the original suction pipework. The fluid velocities in the inlet pipework were about 8 m/s which was the likely cause of cavitation problems that the pumps suffered from. Opus measured the actual capacity of the pump station at 630 l/s with these pumps installed prior to any upgrading works.

Photograph 2: Original pump station dry well

1.3 TREATMENT PLANT

The Whangarei Wastewater Treatment plant serves a population of about 48,000 and includes additional flows from commercial and industrial areas. The average daily flow reaching the treatment plant is 20,000m^3/day (230 l/s). Of this flow about 80% is pumped to the treatment plant from Okara Park Pump Station.

1.4 INLET PIPELINE

The maximum flow rate from the gravity line feeding into Okara Park pump station is about 1,100 l/s. Prior to the commencement of the upgrade this was 470 l/s more than the pump station capacity. Overflows from the station to the harbour were common. Whangarei District Council wished to upgrade the station to, as far as practically possible, eliminate overflows from the station.

2 UPGRADE OPTIONS

2.1 GENERAL

The initial requests from the council were for investigation of upgrading options for both the pump station and the rising main for flows of up to 2,600 l/s or about four times the existing pump station capacity. It became obvious at an early stage that flows of that magnitude would not be possible without the construction of a new pump station. The client brief was then amended to upgrading the pump station to the maximum flow possible within the confines of the existing structure.

2.2 FLOWS

Flows into Okara Park pump station are less than 100 l/s for 10% of the time and less than 300 l/s for 90% of the time. Any upgrade had to not just cope with peak flow rates but also had to be able to cope with these lower daily flow rates.

2.3 UPGRADE OR BUILD NEW

At an early stage rough order estimates were made of the comparative costs of building a new pump station or upgrading the existing structure. The existing building is a drywell / wetwell station made of reinforced concrete, with a concrete building with brick facing above. The building appears to be structurally sound.

The site has sufficient space available for the construction of a new pump station. The area of land available however contains the original septic tank that served as Whangarei's treatment plant before the construction of the pump station and treatment plant. The condition of the tank was not known. An attempt was made to pump out the tank and the sludge that still remains in it, but the costs of the operation were more than the client was prepared to pay and there were concerns that the tank might fail if it were to be emptied.

The initial cost estimates suggested that the cost of construction of a new pump station would cost in the order of $1M more than upgrading the existing pump station.

2.4 MAIN CONSTRAINTS

2.4.1 WETWELL SIZE

The wetwell was adequately sized for the original design capacity of the pump station, but was smaller than desirable for the proposed increased flows

2.4.2 DEPTH OF DRY WELL

The shallow depth of the existing dry well was the most significant factor limiting the maximum flow that the station could be upgraded to. However, given that the size of the wetwell was also marginal, even if larger pumps could have physically been installed, little if any more flow could have been pumped.

2.4.3 RISING MAIN SIZE

The existing rising main was not capable of taking more flow than it was already. The rising main had originally been constructed with reinforced concrete, rubber-ring jointed pipe. About half of it had already been replaced with PE due to failures in the concrete pipeline. Increasing the pressure to get more flow through the existing pipeline was likely to cause further pipeline failures.

Any increase in rising main diameter would have to continue into the pump station as the existing pipework inside the pump station was not adequate for the proposed flows.

2.4.4 KEEPING THE STATION OPERATIONAL DURING THE UPGRADE

The upgrade works had to be able to be undertaken with only very brief night time shutdowns for any required cut-ins. Most of the works would need to take place while the station continued to operate.

2.4.5 SUCTION PIPE SIZE

The size of the suction pipework for the larger pumps was significantly smaller than required and new connections into the operational wetwell would need to be installed.

2.5 THE SOLUTIONS

2.5.1 CHOSEN SOLUTION

The chosen solution was to install four new pumps in the existing dry well and to construct a new rising main to serve the larger two pumps.

Dry mounted submersible pumps were used so that if for any reason the dry well floods the pumps will still operate.

The existing pipework within the station was used for the two smaller pumps and new pipework, both inlet and outlet, was installed for the two larger pumps.

2.5.2 DEPTH OF DRY WELL

PUMPS

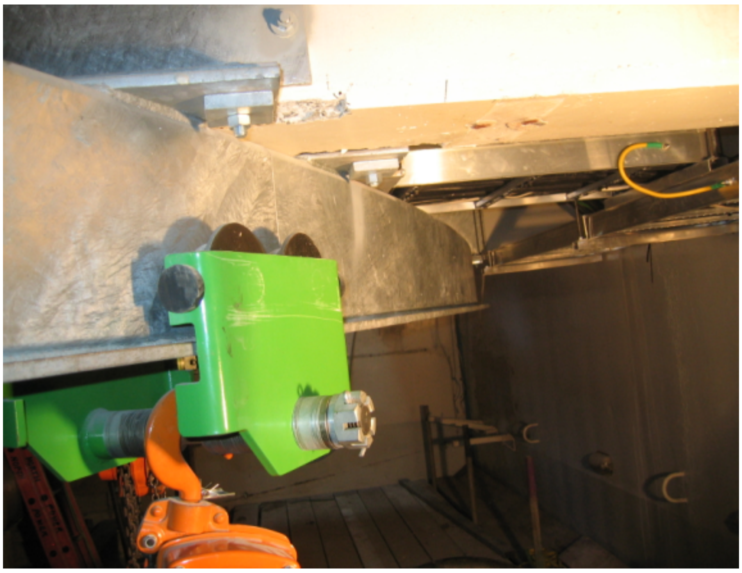
The selected pumps were chosen not just for their adequate performance but also because they were shorter by a few cm than the other pump manufacturers could provide. But even with the more squat pumps a number of other measures were necessary to enable the pumps to be installed. These included:

- Cutting the suction pipework flanges slightly into the pump station floor to gain about 1cm.
- Using eccentric reducers on the connection from the suction pipework to the pump flange to keep the pump inlet as low as possible.

Photograph 3: Eccentric taper and flanges cut into floor

- Using a box section for the lifting beam to enable a shallower beam section

Photograph 4: Curved box section lifting beam



- Sourcing a chain winch with the smallest possible minimum operating depth.
- Curving the lifting beam so that the 250kW pumps can be lifted around the end of the smaller pumps and do not have to be lifted over the top of them.

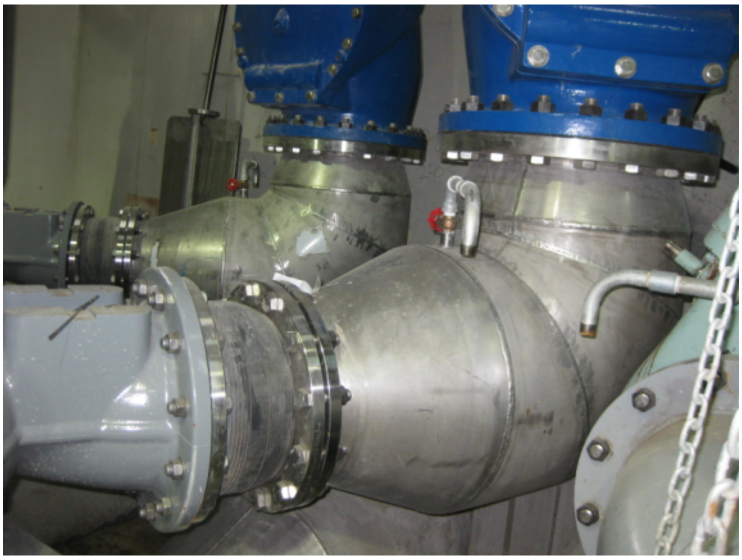
Even with all of the above the 250kW pumps only clear the floor by about 2cm.

DISCHARGE PIPEWORK

New discharge pipe was installed to serve the two larger pumps. The space available to install the second rising main within the station made it necessary to specifically design every taper, bend and tee. The bends and tapers were combined into one fitting to enable them to be built shorter; it was also necessary for the bend radius to be less than desirable because of the limited space.

The discharge pipework had to be installed clear of the existing rising main to allow the station to remain operational while the new pipework was being installed.

Photograph 5:Discharge Bends off pumps



2.5.3 WETWELL SIZE

The size of the wetwell was less than desirable. A number of potential solutions were investigated.

MAKING THE WETWELL WIDER

A wider wetwell would have enabled the wetwell hydraulics to be improved significantly. However it was found that the existing wetwell is built very close too and possibly hard against, the old septic tank that treated the sewage prior to the pump station being built.

Investigation of the old septic tank revealed a buried structure, about 2,000m^3 in volume. It was mostly full with water with a thick layer of old sludge in the base.

The use of part of the tank for storage or increased wetwell storage is still a future possibility but was not pursued as part of this project.

PIPELINE AROUND THE PUMP STATION

It would be feasible to lay a pipeline from the existing inlet on the western side of the pump station around the drywell to the eastern side, breaking into the other end of the wetwell, thus creating a wetwell fed from both ends.

Although possible, this solution would have been difficult and had significant risks. The pipeline would have been about 6m to invert and laid very close to the toe of a 3.5m high retaining wall. It is likely that the power supply to the pump station would have to be temporarily relocated while a power transformer and associated cables were moved to allow the pipeline to be installed below their current location.

The risks of all options to improve the wetwell were considered to be too high for the benefits they promised and no major upgrading of the inlet pipes was undertaken.

Minor wetwell improvements were made by the removal of obsolete screening equipment and replacement of the inlet penstock.

NET POSITIVE SUCTION HEAD

The net positive suction head (NPSH) is a measure of the amount of positive head that pumps require to avoid cavitation problems. Generally as the pump flow rate increases the NPSH required also increases. If the pump station had been designed for the flows that we were proposing the dry well and the wet well would both have been deeper and the NPSH problem would have been less.

Because of the NPSH restrictions the larger pumps are speed-controlled so that their maximum speed increases as the depth of water in the wet well increases.

PUMP INLET PIPEWORK

The existing inlet pipework serving the larger pumps was 300mm diameter; with proposed flows of up to 630 l/s through a single pump this pipework was too small. (The inlet velocity would have been close to 9m/s.) NPSH was a significant constraint; and the larger the pipework, the less the NPSH problem. The inlet pipework to the larger pumps was increased to 600mm diameter.

The new suction pipework required the wet well wall to be cored with a 710mm hole and the new pipes threaded in and then turned around in place. The annulus between the outside of the suction pipe and the wetwell wall was then sealed with a "Link-Seal" modular seal. This seal allowed the full water pressure to be placed on it as soon as the seal was tightened and no time had to be allowed for curing. The coring and the insertion of the new suction had to occur during a full station shut down at night. A window of only 4 hours between 12am and 4am was available for the cut in, leaving a contingency of 1hr before the station would have started overflowing. The two suction lines were replaced on separate nights as the available station shutdown time was not sufficient to safely do both in one shutdown.

2.5.4 RISING MAIN

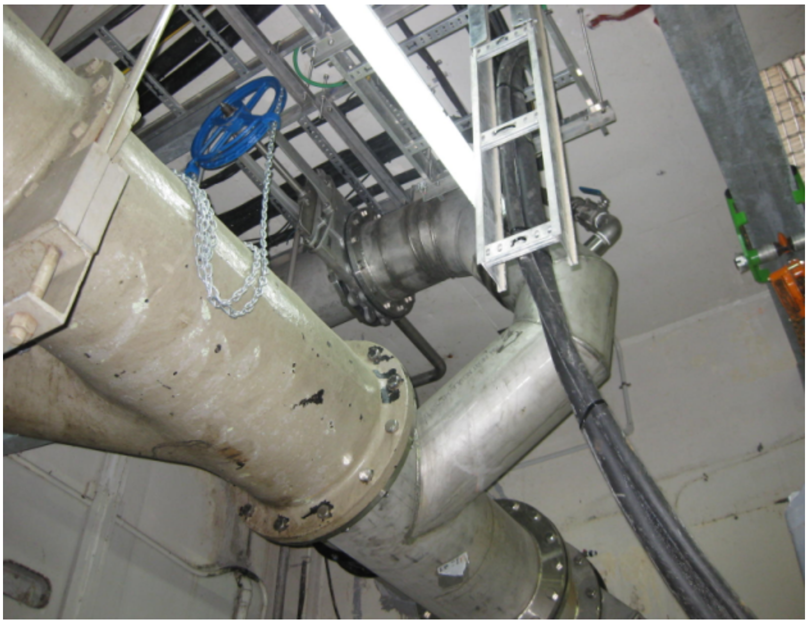
The existing rising main was already at its maximum capacity. It was originally a 1,600m long 600mm diameter RCRRJ pipe, which had suffered from a number of failures. In 2002 385m of the pipeline was replaced with a DN630 SDR21 polyethylene (PE) pipe. A further 330m of pipeline was replaced with PE in 2008. Increasing the pressure to get more flow though the existing pipeline was not a viable option. The pipeline would almost certainly have failed if the pressure in the pipeline was increased significantly.

A new duplicate DN800 PE100 SDR13.6 rising main was designed and installed from the pump station to the treatment plant. For most of its length the rising main follows a different route from the existing rising main, which lessens the risk of one single event causing the failure of both rising mains.

Photograph 6:Rising main under construction

For general day to day operation the two larger pumps pump through the newer, larger rising main and the two smaller pumps pump to the old rising main. A cross connection between the two mains within the pump station enabled the flow from all pumps to be diverted to one rising main if required.

Photograph 7:Cross connection between rising mains



During the connection of the new rising mains into the pump station it was found that a short length of the original concrete rising main was still operational between the station and the road. This was clearly a potential weak link in the system and was replaced with PE.

2.5.5 PUMPS

The client initially wished the station to be upgraded to pump significantly more flow than the existing gravity pipeline to the station can deliver. If this had been done there would have been problems with the low flows that occur for much of the time. With the small wetwell, even with running the pumps at low speeds, they still would have had to start and stop frequently.

A number of pump and rising main options were investigated and the final chosen pumps were two Flygt NT3306/665 (curve 53-670, 445mm impeller) dry-mounted submersible pumps with 75kW motors and two Flygt NT3312/835 (curve 53-670, 585mm impeller) dry-mounted submersible pumps with 250kW motors.

The two smaller 75kW pumps can each pump about 270 L/s (Range 225 – 325 L/s) in to the older rising main or, with both pumps running on a duty/assist basis, they can pump up to about 380 L/s (range 335 – 475 L/s).

The two larger 250kW pumps can each pump about 630 L/s (range 530 – 670 L/s) into the new rising main. This is about the same flow as the four previously installed pumps could pump if all were operating together. With both 250kW pumps running on a duty/assist basis, they can pump about 950 L/s (range 800 – 1,020 l/s). Again the exact flow is dependent on wetwell level and pipe friction.

With all four pumps and two rising mains in operation the combined capacity of the pump station is 1,330 L/s (range 1,135 – 1,495 L/s depending on what assumptions are made.)

These pump flow rates compare to the maximum pump rate of less than 630L/s that could be pumped with the previously installed pumps and rising main. The new pumps have 50kW less capacity than the pumps they replaced, but pump more than twice the flow. The improvement is due to the installation of a second rising main and the poor performance of the original pumps. The poor performance was due to many factors but including incorrect impellors and high suction velocities, resulting in suction head loss and cavitation problems.

Photograph 8:New installed pumps

2.5.6 VSD DRIVES

VSD drives formed a very important component of the pump station upgrade. The existing station levels did not allow the pumps to be mounted as deep below the inlet level as would be desirable and this problem was made worse with the small volume of the wet well. This resulted in the suction head available being less than desirable and the pumps only being able to run at full speed when the wetwell level is 2.8m or more above the pump inlet level. (Overflow is 5m above pump inlet).

A careful check was made on inlet losses on the suction side of the pumps and on the NPSH required. The pumps are programmed so that they run at a particular speed depending on the depth of liquid in the wetwell. At low wetwell levels they can only run at low speed but as the wetwell fills they can run faster as more head is available on the suction side of the pumps. The smaller 75kW pumps have less NPSH required and can be run at full speed with only about 1m over the pump suction level.

Variable Speed Drives allow the pumps to ramp up to speed gradually. For much of the time the pump rate matches the inflow rate so that the flowrates are more consistent at the treatment plant and the friction losses and hence power costs are lessened. On shutdown the pumps ramp slowly down to lessen the effect of pressure surges.

2.5.7 CONSTRUCTION SEQUENCE

Considerable thought went into the exact construction sequence from the start of the design phase. Unlike most construction contracts a detailed construction sequence was included in the contract that the contractor could not alter without the Engineer's agreement. This was necessary as in many areas the detailed design would have had to change if the construction sequence had changed. The construction sequence was also in part aimed at lessening the risk of failure of the existing station during construction.

The construction sequence for example required that the new smaller pumps be replaced first with the station kept operational by using the larger pumps only. This was necessary as both the existing small pumps were in very poor condition and could not be relied on to continue operating while the larger new pumps were installed. Replacement of the smaller pumps first was also desirable as they could continue to pump via the existing rising main and at that time the new larger rising main was not completed.

2.5.8 POWER

The original switchboard was over 40 years old and was completely replaced. A full new Motor Control Centre was installed. A dual power supply has been provided to the station so that if the local circuit, which normally supplies the site, is out of action for any reason the power is automatically switched to the adjacent circuit.

The station originally had a standby generator. This was reconditioned. It has sufficient capacity to run both of the smaller pumps or one of the larger pumps. The generator cuts in automatically if both the power supplies fail. The pump flow available with the generator is approximately the same as the pump station capacity prior to the upgrade.

2.5.9 NEW STATION VERSUS UPGRADE EXISTING

The question is often asked; should you upgrade or build new? Upgrading costs are often difficult to estimate as working while keeping the station operational is difficult and working within the confines of an operational station is difficult. Upgraded stations always have some compromises that have to be accepted. Against this needs to be weighed the value of the existing infrastructure that can be retained.

In this case the council finished with an upgraded station that cost in the order of $1M less than a new station would have cost.

The saving of about $1M has to be weighed against the following risks and compromises

- Increased risk of overflows during the additional live cut ins that were required

- NPSH is effected by the wet well being shallower than desirable with consequential increased risk of cavitation in the pumps and pipework
- Slightly decreased pumping capacity for the same installed pumps due to shallow wetwell
- Dry well shallower than desirable, resulting in tight tolerances, tight bends and limited space for both construction and maintenance
- An older building that is likely to require more maintenance than a new building.

3 CONCLUSIONS

The sewage pump station at Okara Park has been upgraded to increase its pumping capacity from about 630 l/s to about 1,350 l/s. The new pumps installed to give this increased flow have less installed kW that the original installed pumps. This increased capacity is more than the capacity of the incoming pipelines, so overflows as a result of insufficient pump capacity should no longer occur. The works were all completed while keeping the existing pump station operational without any overflow occurring.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the Whangarei District Council, especially to Andrew Carvell, for the assistance that was given for this project.