Abstract

The Christchurch earthquake sequence of 2010/2011 resulted in widespread liquefaction and a dramatic increase in inflow and infiltration into the sewage network. Large quantities of grit were carried into the Christchurch Wastewater Treatment Plant (CWTP) both immediately after the earthquakes and later during high rainfall events.

While the CWTP continued to operate throughout, the five grit removal tanks and seven associated primary sedimentation tanks at the CWTP were frequently overwhelmed by the volume of grit coming into the plant. Grit carried over into downstream parts of the process where it accumulated, shut down plant and caused damage to equipment.

A review of options to improve the plant focused initially on vortex grit traps, as the default modern technology option for improving grit capture performance. However there were concerns about construction risks and uncertainty around the response of vortex grit traps to shock loads of grit.

Instead a resilience project emerged based on optimising the existing asset by decoupling the grit tanks from the primary sedimentation tanks.

This paper describes how simple and innovative adaption of the existing plant and structures improved operational flexibility, resilience and the ability to cope with high grit loads, while minimising both operational and construction risk, and capital cost.

Keywords

Grit removal, plant modification, resilience, wastewater treatment

Introduction

The Christchurch Wastewater Treatment Plant (CWTP) in Bromley, Christchurch treats approximately 200,000 m³/day of wastewater from urban Christchurch. The plant comprises primary sedimentation, trickling filters solids contact process, secondary clarification and 230 hectares of oxidation ponds for disinfection prior to discharge through an ocean outfall. Grit is removed via five grit removal tanks, which are connected directly to Primary Sedimentation Tanks (PSTs). This system was designed to remove up to 5 tonnes of grit per day. During the 2010/11 earthquake sequence significant liquefaction occurred across the city resulting in large flows of silt laden water entering the broken sewage network. This wasn't a one off event – because every time there was a high rainfall event more silt and grit was carried into the sewage network.

It was expected that this situation would continue for a number of years as seismic activity in the region continued and network repairs were completed, making operation of the grit tanks highly problematic in the immediate future. Recognising this, Christchurch City Council (CCC) initiated a project to investigate options for improving grit removal performance. The preferred option from this round of investigations was to replace the existing grit tanks with vortex grit traps. Vortex grit traps offered a step change in grit
removal performance, as well as some improvement in resilience to shock loads. This option was accepted and design commenced.

However part way through the design process CCC revisited the drivers for the project and decided to put a hold on the vortex grit trap concept and progress a simpler modification to the existing structures to achieve the improved operation and resilience to peak grit load the plant needed. The simpler option offered a similar level of grit removal performance and capacity to the existing plant operation, but a substantial improvement in resilience and a reduction in capital cost over the original project.

This paper describes how the project was adapted by a shift in focus from performance and capacity improvements to increased resilience. This change in focus resulted in CCC deciding on a simple and more cost effective adaption of their existing plant to improve resilience of the grit removal process at CWTP.

**Existing Grit Removal and The Effect Of The Earthquakes**

The Christchurch Wastewater Treatment Plant (CWTP) has five grit tanks of the aerated chamber type. Wastewater influent to the treatment plant passes through a screening process before entering the five grit tanks. The current flow path of the CWTP can be seen in schematic form, in Figure 1. Three of the grit tanks date back to the original plant installation in 1959 with each grit tank dedicated by direct connection to a corresponding Primary Sedimentation Tank (PST). When the CWTP was extended in 1971, two new grit tanks were installed to serve four new PSTs; each new grit tank being connected to two PSTs.

![Figure.1 Current Treatment Plant Flow Schematic](image)

(normal flow paths shown with broad arrows, optional flow paths in single-line arrows)
Grit is pumped out from the bottom of the grit tanks, passed through one of two grit separators and collected in grit bins. Prior to the Christchurch earthquakes, the 1.5 m$^3$ grit bins were being emptied once every 12 hours, having typically filled to approximately 1 m$^3$ volume. At its peak following the earthquakes of 2010/2011, the bins were being emptied seven times within 12 hours (a 700% increase), often having already overflowed before being emptied. The source of the additional grit load was liquefaction material washing into the sewerage network. It was mainly liquefaction material (small diameter) rather than grit (larger diameter) that entered the solids process.

The amount of liquefaction sand and grit settling in the tanks often overwhelmed the tank solids extraction systems. This resulted in a build-up of material over the entire floor of the grit tanks, in time filling the tanks with 2 to 3 m depth of grit and liquefaction sand. During this time the grit removal pumps blocked frequently. It is thought that the grit and sand built up to a point where it would slip from the pile and cover the extraction piping, thereby choking the grit pumps completely.

Overall grit volumes went from 2 m$^3$/day pre-earthquake to an estimated 50 – 100 m$^3$/day after the earthquakes. Now 5 years later it has settled at approximately 2.5 m$^3$/day. In response to these ongoing process and operational issues, a project was initiated to investigate how best to improve the performance of grit removal at CWTP.

Figure 2: Removing Mounds of Liquefaction Sand from Grit Tanks Post Earthquake
Initial Options Investigation For Improved Grit Removal Performance

The options investigation started with a review of the existing structures, flows and loads. The purpose of the investigation was to identify an upgrade that would meet the following objectives:

- Optimal grit separation and removal to a specified grit particle size
- Increase in grit removal capacity
- Process flexibility – de-coupling of the grit tanks from the primary sedimentation tanks (PSTs) where possible.
- Redundancy for both normal operation and in the event of major earthquake-induced grit ingress.
- Flow path flexibility to allow for channel maintenance
- Resilience during seismic events
- Reliability both of the process units themselves and the associated equipment
- Optimised cost - both capital and on-going operational and maintenance costs

The investigations found that the existing grit tanks were inherently susceptible to short circuiting and grit could be expected to carry through the existing system in any event. A review of various options concluded that a series of modifications to Grit Tanks 4 and 5 would eliminate the issue of short circuiting through these grit tanks. In addition in order to achieve a peak hydraulic capacity of 7.5 m$^3$/s while retaining grit tank functionality and providing the required level of redundancy, it was proposed to install two bespoke vortex grit traps which maximise the use of the available space within the footprint of the existing Grit Tanks 1 to 3.

Vortex grit traps are widely accepted as the best modern solution to efficient grit removal. Vortex type grit traps are generally proprietary equipment and rely on a defined circular type flow pattern within the trap, which in turn creates a velocity profile within the tank to promote the separation of the grit. A rotating paddle is installed in the trap to maintain the correct rotational velocity of the wastewater within the cylinder and create an upward centre flow roll current sweeping grit deposition on the floor towards the centre. The heavier grit is deposited closest to the centre of the trap where it falls by gravity into a holding basin from which it can be pumped at intervals.

The capital cost of the project was estimated to be approximately $6 million and the project required a complex staging plan to be put in place to manage the construction works.

The Change in Focus from Performance to Resilience

While the technical complexity, magnitude of likely impact on operations and capital cost of the vortex grit trap project had always been recognized, when the ongoing continuous high grit loads did not eventuate, the project team re-evaluated the need to take on such risks.

It was also determined that increasing the grit removal performance at the grit tank stage would significantly increase the operating costs to CWTP. Central to this economic analysis, was the higher cost involved in disposing of grit or grit and screenings to landfill, compared with reuse of the grit as a dried biosolids component. In other words, because of beneficial reuse of the biosolids from the plant, there were economic disincentives to take the grit out. Therefore, a client decision was made to maintain the existing grit removal performance so that some of the grit was removed further downstream with the biosolids, thus reducing disposal costs.

The project focus now turned to how to adapt the existing system to be more resilient to shock grit loads, how to decouple the grit tanks from the primary sedimentation tanks to improve operational flexibility, and how to upgrade the grit removal pumps and separators to provide the ability to receive grit from all grit tanks concurrently.

The upgrade of the grit handling facilities also needed to provide improved contingency measures, for future seismic events, in the
form of increased resilience to large grit load post-earthquake. The revised objectives of the proposed upgrade(s) became to:

- Increase the grit handling and separation capacity to cope with peak grit loads arriving in a 6\(m^3\) inflow event.
- Increase the process flexibility by enabling grit tanks to be taken out of service without loss of primary settlement capacity.
- Upgrade the separators to provide for the ability to accept all grit trapped from more than one tank at a time.
- Introduce flow path flexibility and isolation to allow for grit tank and channel maintenance.
- Improve resilience during seismic events, where possible within the scope of works.
- Optimise cost - both capital and on-going operational and maintenance costs.

By removing the vortex grit traps from the project scope and designing for flows of 6 \(m^3/\text{day}\) rather than a future flow of 7.5 \(m^3/\text{day}\) the capital cost of the project was able to be reduced significantly at a time when cash flow and project funding within the city was being tightly controlled.

**Decoupling The Grit Tanks**

To achieve grit tank de-coupling the creation of a new transverse channel was proposed. Due to a provision in the original plant layout this channel could be formed from an existing space located beneath a service trench in between the grit tanks and PSTs. The channel was of sufficient size such that any one tank could be taken out of service without affecting operation of the other tanks. Isolation gates fitted to the grit tanks and PSTs would facilitate flow paths into and out of the channel.

Figure 3: New Transverse Channel for Grit Tank Decoupling
Upgrade Of Grit Separation

The grit tanks have a total of twelve grit pumps for removing grit from the bottom of the tank; two for each of grit tanks 1 to 3, and three for each of grit tanks 4 and 5. Each pump on grit tanks 1 to 3 serves three sumps, while each pump on grit tanks 4 and 5 serves only one sump. The current grit pumping system was split in two (GTs 1 to 3 and GTs 4 and 5) with only one pump running in each system at all times, and sequencing through each grit tank in turn. In the grit tanks 1 to 3 sequence there is a further sub-sequence in which each pump draws from each of the three sumps within each grit tank in turn.

There were two grit separators (also referred to as grit washers or grit classifiers), one for each of the two systems. Each has a separate feed line with a normally closed cross-connection. They discharge into separate grit bins, but the separated effluent has a combined return.

For the purpose of design a worst case grit inflow of $10 \times$ the average dry weather inflow was assumed; this equated to $24 \ \text{m}^3/\text{day}$ of grit. The minimum flow needed to convey this quantity of grit as a slurry could be met by the existing system and yet the existing system became severely blocked during the earthquake sequence. This implied that the failure of grit system during the earthquake sequence was primarily related to the flow and sequencing arrangement needed to maintain the grit sumps open and not blocked with grit, rather than the pumping capability itself.

To address this issue a scheme was devised whereby no new grit pumps were needed, but additional grit discharge lines were installed to allow more of the grit pumps to operate at any one time. This increased the frequency with which the grit sumps were pumped out, thereby reducing the likelihood of blockages during high grit loads. This also allowed each grit tank to operate as usual when the grit pipework for another grit tank was being cleaned, un-blocked, or reverse flushed.
The grit separators are limited by the amount of flow they can process, rather than the amount of grit they receive. Therefore, instead of doubling the number of separators, which would be costly and space intensive, grit concentrators have been introduced to reduce the flow to the existing separators, and a third separator of the same capacity installed. The separated effluent is redirected back to the PSTs while the grit concentrated flow is discharged directly into its corresponding separator. Additionally, both the concentrators and separators form another useful function of washing the grit of much of the attached organic matter. This reduces odour released off the separated grit, and returns the organic matter to the effluent treatment process path.

Figure 5 shows how the grit handling area will be reconfigured, with new equipment shown in red and the grit separators operating in a duty/duty/standby rotation.

**Grit Bin Handling**

The reconfiguration of the grit bin area provided the opportunity for CWTP operations staff to review how the dewatered grit was handled. Historically small blue bins have been used to collect the grit, and also rag from
the nearby screen room, and combine these in a larger red bin to be sent to landfill. This has now been revised to use the larger red bins only, and incorporate transfer conveyors so the two bins can be operated in a duty/standby configuration.

Benefits Of The Revised Focus

The revised upgrade project focus provided a means of improving grit removal resilience and flexibility without embarking on a technically and operationally complex and risky project. The new channels to achieve decoupling of the grit tanks from the PSTs could be formed within existing structures which minimised the time that plant needed to be taken out of operation. While the formwork for the new concrete structures was in places complex, and bespoke for each tank, the overall capital cost, technical complexity and duration of the work and each shutdown was much reduced.

As each grit tank and connected PST(s) were taken off line this provided the project and the site with the opportunity to complete other renewals work on the tanks, and undertake concrete remedial works and the application of protective coating to protect and extend the life of the structures.

The installation of new channels, new isolation gates, more pipework headers and increased redundancy means that in future not only operational flexibility will be improved, but the ability to take plant offline for both routine and non-routine maintenance will be greatly enhanced.

Conclusions

The Christchurch 2010/2011 earthquake sequence brought to light issues with the grit handling system at the Christchurch Wastewater Treatment plant, and initiated a project to improve the way the plant could cope with high grit loads. While the project started as a complex and costly capital project involving long shut downs, complicated staging and extensive demolition and build, the project team were able to adapt their approach and change focus part way through the project. By adapting the existing plant and structures, the project will achieve improved operational flexibility, resilience and the ability to cope with
high grit loads, while minimising both operational and construction risk and capital cost. This project is an example of innovative and relatively low cost resilience improvements targeted towards low risk but still able to cope with a high consequence event.

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Author Biography

Rae Stewart: Rae has over 20 years’ experience as a process engineer and project manager in the food and beverage and water and wastewater industry. Rae has been in Beca’s Christchurch Water team since 2011 during which time she has managed several large and complex projects including the CWTP Gas Engines Project and the Akaroa Water Supply Upgrade for Christchurch City Council, the Grovetown Sewerage Upgrade for Marlborough District Council and numerous Christchurch based earthquake repairs and renewals projects. Rae is currently the Programme Manager for projects at CWTP.

Greg Offer: Greg Offer is a project manager with an industrial background and 15 years’ experience in wastewater engineering design and project management. He is currently programme director for the Beca service agreement at Christchurch Wastewater Treatment plant and is involved in wastewater projects for a range of industrial and municipal clients around the South Island.

Graeme Wells: Graeme has worked in Central Government, Local Government and Private sector consultancy roles for 46 years, the last 28 with Beca specializing in the detailing and construction of wastewater treatment facilities. His experience is varied across a wide range of disciplines and industry sectors with approximately 30 years in the wastewater sector, both in design office and site roles. This includes work on seven digesters as well as other treatment plant structures. Currently Graeme is involved in numerous projects at the Christchurch Wastewater Treatment Plant in a design review and construction monitoring role.

Lee Liaw: Lee is a process engineer by training who has worked at the Christchurch Wastewater Treatment Plant for approximately seven years. Lee is Diploma qualified in wastewater treatment plant operation and is responsible for the efficient and effective operation of CWTP. He has recently taken up the role of Team Leader, Shift Engineers.