WASTEWATER TREATMENT PLANTS - YOU CAN'T SWITCH THEM OFF FOR REPAIRS

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ABSTRACT (ARIAL, 11)

This paper discusses the challenges of undertaking major maintenance and repairs (R&M) on wastewater treatment plants (WWTPs). WWTP's operate 24 hours a day, seven days a week, 365 days of the year with no off season for undertaking R&M. Repairs and maintenance may not have been fully considered during the design. Furthermore later upgrades may have altered how maintenance and repairs can carried out or reduced the amount of redundancy originally built into the plant.

Considering R&M during the design phase is an essential part of the resilience of the plant. Careful planning and management of R&M activities, integrating these into the operation of the overall WWTP, is essential. There are four key techniques that are typically employed: 1) duplication of equipment, to allow part of a unit process to be taken off line, 2) isolation of individual items of equipment to allow safe access for R&M, 3) timing of the R&M, so that effects on treatment are minimised, and 4) holding of whole change out assemblies so that critical plant can be changed out quickly. Overlaid on top of these are health and safety considerations.

This paper uses a case study from the CWTP, the trickling filters.

KEYWORDS (ARIAL, 11)

Repairs, maintenance, trickling filter, health and safety

1 INTRODUCTION (ARIAL, 14)

The Christchurch Wastewater Treatment Plant (CWTP) treats wastewater from the city of Christchurch in New Zealand. The city has a population of approximately 350,000 people. The flow of wastewater from this population is not constant, it fluctuates throughout the day, with morning and evening peaks. Also, the daily volume of wastewater varies during the year, with typically higher daily flows during winter compared with the summer months. Regardless of these variations, the CWTP must continue to consistently treat the wastewater to remove contaminants and produce a treated wastewater that meets resource consent limits imposed by the local regional council with regard to odour and treated effluent.

The city of Christchurch, including the CWTP, was badly damaged in a series of significant earthquakes during 2010 and 2011. The network of underground pipes that convey untreated wastewater to the CWTP was also significantly damaged. This has resulted in increased flows to the treatment plant during periods of rain, with the cracked pipes allowing rainwater to leak in. Since these events, significant repairs have been undertaken to keep the CWTP operating within its resource consent limits. Whilst equipment has been off line, the CWTP have chosen to undertake maintenance where possible.

Over the past four years, there has been an on-going programme for repairs of earthquake damage at the CWTP. All of the main unit processes have required significant repairs. Running in parallel to this has been the on-going, regular maintenance programme at the CWTP. To minimise the disruption to the operation of the CWTP, the planning of maintenance activities has been coordinated with the on-going earthquake repair work. For the trickling filters, the maintenance activities have been scheduled to be carried out in tandem to the earthquake repairs, with different teams carrying out the separate packages of work.

This paper focuses on a single case study, the earthquake repairs and general maintenance of the CWTP Trickling Filter 1. We show that considering R&M during the design phase is an essential part of the resilience of the CWTP and that careful planning and management of R&M activities, is essential to ongoing operation of these facilities during major repairs. Four key techniques are discussed: 1) duplication of equipment, to allow part of a unit process to be taken off line, 2) isolation of individual items of equipment to allow safe access for R&M, 3) timing of the R&M, and 4) holding of whole change out assemblies so that critical plant can be changed out in a short period of time so that effects on treatment are minimised. Overlaid on top of these are health and safety considerations; all R&M must be carried out in a safe manner.

Figure 1 showing the CWTP Trickling Filters

2 TRICKLING FILERS CASE STUDY

2.1 BACKGROUND

To maintain sufficient treatment through the CWTP it was not possible to take both trickling filters off line at the same time and the trickling filters have to be taken off line separately, starting with Trickling Filter1. This involved inactivating the biomass through a process of starving and flushing. To achieve this, the trickling filter was partially isolated from the main treatment process. The trickling filter was only fully isolated when the biomass was completely inactivated. Isolation required closing valves and inserting manual slide gates at specific locations in the inlet and outlet pipes. Trickling Filter 2, which remained in operation took the full supernatant flow from the primary sedimentation tanks.

The CWTP is subject to stringent Resource Consent Conditions for odour and treated wastewater characteristics. Significant consideration was given to the development and planning of a robust and effective procedure for taking Trickling Filter 1 off line. From prior experience, the consequence of poor execution would be significant malodourous discharge negatively affecting the local residents for a significant period of time.

Maintenance of the internal components of the trickling filters requires each trickling filter to be taken off-line separately. This is a significant undertaking as it takes several weeks to take each trickling filter off-line and as a result maintenance typically occurs once a decade. Thus, when earthquake repairs became necessary for the CWTP trickling filters, it was decided that internal maintenance should be undertaken at the same time. This created a potential for extra hazards, with both Contractor's staff and CWTP Operations staff working in the same space at the same time.

The full extent of earthquake damage to the trickling filters could not be fully assessed while they were in operation. Only external assessments had been undertaken and any earthquake damage that manifested internally had not been observed. The likely value of internal damage was the subject of discussion between CCC and its insurers. An assessment of the earthquake damage to the internal structure of the trickling filters while they were off line was important to help both parties reach a position for the insurance claim for this asset.

This added to the complexity of the project, and hazards to be managed, with engineering specialists entering the trickling filter to inspect for earthquake damage.

Carrying out the repairs and maintenance of the trickling filter was a complicated undertaking, involving the coordination of three separate sets of activities:

1) Maintenance activities by site operations staff

2) Earthquake repairs by a contractor

3) Earthquake damage assessments by engineering specialists

2.2 MAINTENANCE BY SITE OPERATIONS STAFF

In order to undertake the R&M, the trickling filter was taken off line. However, as the treatment process taking place inside the trickling filter is biological, taking a trickling filter off line is challenging. In order to be taken off line, the biomass inside the trickling filter must be inactivated (i.e. killed). If this inactivation is undertaken incorrectly there can be significant negative environmental effects, particularly the discharge of highly offensive odours emanating from the dying biomass. Such a discharge had happened in the past, causing a significant nuisance to people living in Christchurch and resulted in many complaints. To avoid this, the inactivation of the trickling filter was carefully planned. The biomass was slowly and systematically inactivated, through a series of carefully planned step changes to the process. These changes involved cycling between flushing and starving the biomass for periods of time until the biomass was fully inactivated. This inactivation took over two weeks to achieve.

Once off line Trickling Filter 1 was isolated by closing valves, and installing slide gates to block off pipes and ducts. When maintenance staff entered the trickling filter the first action was to install safety equipment, to protect people from harm and equipment from damage. This included installing temporary steps and walkways as shown in Figure 2.

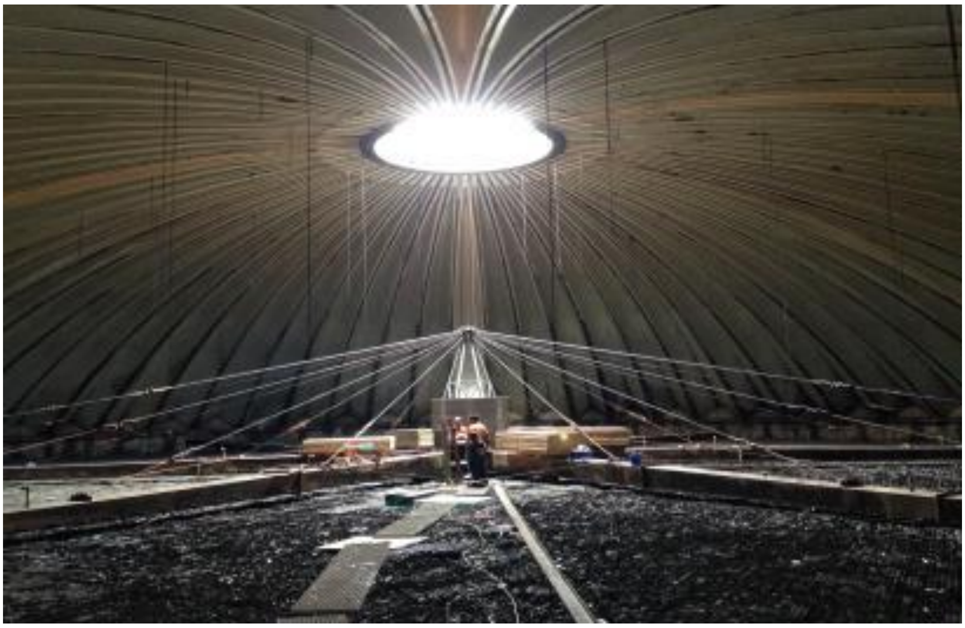

Figure 2 showing the inside of Trickling Filter 1, during R&M

The main R&M task was to dismantle the large rotary distributor and replace the bottom bearing. The distributor comprises a large central column that rotates on a bearing. Attached to this central column are six distributor arms that carry the wastewater and discharge it evenly along their length so that it rains down on to the media

The R&M included checking and repairing tie rods that hold the distributor arms onto the central column. The central column on the distribution tower was dismantled and R&M carried out as required. Finally the large bearing was removed and replaced. On completion of the R&M, the large rotary distributor column and distribution arms were reinstated.

2.3 EARTHQUAKE REPAIRS BY CONTRACTOR

Repairs were undertaken on the trickling filter by a contractor under a NZS 3910 contract. These repairs were predominantly civil engineering works and involved, repairing damaged concrete work and pipes.

Damaged concrete plenums were demolished and replaced with new precast concrete plenums. Damaged air ducting was removed and replaced with new ducting. There was significant cracking to the concrete (see Figure 3), in particular the lower section of the trickling filter, beneath the trickling filter media. All of these cracks were repaired in situ, using epoxy resin.

Figure 3 showing typical cracks in CWTP Trickling Filter 1

R&M was also undertaken on pipework and ducting associated with the trickling filter. Much of the pipework is buried and needed to be excavated for the R&M to be carried out. Like many WWTP's the CWTP has significant amount of underground services including wastewater pipes, water pipes, air ducts, and electrical cable ducts. This means that any excavations must be carefully planned with existing underground services accurately located prior to commencing. For the trickling filter project the key underground service to locate was an 11kV power cable, located very close to some of the damaged underground pipework.

This 11kV power cable is part of a ring main and presented a significant safety risk. The 11kV ring main had been completed just prior to the Canterbury Earthquakes and was installed as part of a programme to provide the plant with an N-1 power supply. This improvement initiative has provided many benefits since installation. The relevant section of the ring main was shut down for these works. Hydroexcavation using high pressure water was used, rather than a digger, to minimise the risk of damaging this cable. Hydro excavation is now used extensively in Christchurch for service location due to the greatly reduced risk of damage to underground services. The 11kV power cable was rerouted during the project to enable sufficient space for the pipework repairs to be carried out safely. Figure 4 shows the location of the 11kV power cable.

Figure 4 showing the location of the 11kV power cable.

2.4 EARTHQUAKE DAMAGE ASSESSMENTS BY ENGINEERING SPECIALISTS

Engineering specialists carried out assessment of the internal structure for earthquake damage. An important zone for investigation was the lower section of the trickling filter, below the media. External assessments had identified evidence of earthquake damage and internal assessment was required to investigate the extent of this damage.

Once the trickling filter was off line high pressure water spray was used to clean the dead biomass off the concrete and expose the concrete surface. This area was identified as a confined space and strict protocols were put in place to manage entry to and exit from this area. Maintaining adequate ventilation during the cleaning and earthquake damage assessments was essential as was staying in constant radio contact with the spot man at the door (good confined space procedures).

2.5 R&M RESILIENCE

2.5.1 CHALLENGES OF CWTP R&M

The ability to undertake R&M is a key aspect of any WWTP design. Unlike manufacturing factories there is no "off season" shut down period for carrying out R&M. Indeed, WWTP's must operate 24 hours a day, seven days a week, 365 days of the year to meet the needs of the communities that they serve.

The four key techniques that are typically considered when designing WWTPs are:

a) Duplication of equipment, to allow part of a unit process to be taken off line. The CWTP trickling filter process includes duplicate trickling filters normally operating parallel

b) Isolation of individual items of equipment to allow safe access for M&R. At the CWTP each trickling filter can be isolated and the full flow routed to either the trickling remaining in services, or bypassed.

c) Timing of the M&R, so that effects on treatment are minimised and can be managed through process modifications.

d) Holding of change out assemblies so that critical plant or components can be replaced in a short period of time reducing the duration of process interruptions.

Overlaid on top of these is health and safety. The safety of people, equipment, and the environment must be considered before and during any R&M activities.

Forward planning prior to taking the tricking filters off line was critical to the success of this project

2.5.2 R&M TIMING

The trickling filters at the CWTP are hydraulically limited, particularly in winter. In Christchurch in winter there is more rainfall and the ground water level is higher. With the earthquake damage to the underground wastewater pipe network, there is significant ingress of water into the wastewater pipework. This results in a higher volume of lower concentration wastewater arriving at the CWTP for treatment and a higher flow through the trickling filters. At these higher flows both trickling filters are required to be in operation.

During the summer months the flow of wastewater through the CWTP is lower. In the driest summer months (December through to March) it is possible to have only one trickling filter in operation and still achieve adequate wastewater treatment. For this reason the trickling filter repairs were scheduled for the summer months of January through to March. Through careful planning (discussed in Section 2.5.4) repairs were successfully carried out within this timeframe.

Relying solely on dry summer weather was considered high risk. Christchurch can have significant wet weather events in the middle of summer. In a summer storm event (high rainfall), a single trickling filter would struggle to treat the full wastewater flow. Thus back-up plans were put in place to actively manage the wastewater treatment.

2.5.3 PROCESS MODIFICATIONS

The operation of the solids contact tanks was changed. Normally this unit process operates in two parallel trains; one for each trickling filter. Instead the solids contact tanks were temporarily reconfigured so that the wastewater flowed through the tanks in series. This facilitated floc formation by making full use of the solid contact tank volume and improved solids settling in the down-stream clarifiers.

Operating a higher flow through a single trickling filter can increase biomass sloughing and result in a smaller biomass particle being sloughed off. These smaller particles make floc formation problematic (in the solid contact tanks) and as a result the floc can be difficult to separate in the clarifiers. This can result in excessive biomass being carried out to the polishing ponds, adversely affecting the pond performance and resulting in significant malodorous discharges and potential breach of resource consents. To mitigate this, flocculent dosing equipment was put on standby and a suitable polymer flocculent was sourced. This flocculent dosing system was used during the project to improve the performance of the solids contact tanks.

In a high rainfall event, it was likely that some primary effluent from the primary sedimentation tanks would be by-passed around the secondary treatment (trickling filters, secondary contact tanks, and clarifiers), and be diverted directly to the polishing ponds. This partially treated wastewater would have higher concentration of contaminants which, in turn, could negatively affect the pond performance and result in significant malodorous discharges if DO in the ponds is allowed to drop too low. To mitigate this, a chemical dosing system, using hydrogen peroxide, was put on standby. This dosing equipment would be used to dose hydrogen peroxide directly into the bypassed wastewater, increasing the oxygen concentration of the wastewater, and thereby boosting the performance of the ponds. This back-up chemical dosing system was not used during the project.

2.5.4 R&M PLANNING

Detailed planning was essential to the success of this project. With the range of people involved in this project, coordinating these inputs was critical to keeping people, plant/equipment and the environment safe. A comprehensive project programme was developed. This amalgamated the contractor's construction programme, and the operations staff maintenance programme, as well as the earthquake damage assessments. This was a useful tool for clearly demonstrating what activities were being undertaken, when, and by whom. Hazards associated with each achieved were then readily communicated around the project team, as discussed in Section 2.6.

This plan presented the duration of individual activities and clearly identified dependencies between different activities. The plan was not only a schedule of activities, it also contained information on equipment and parts that needed to be ordered. Lead times for equipment were incorporated, as was manufacturing times. This logistics planning successfully ensured everything was ready for R&M when it was needed.

The programme was a live document, particularly while the earthquake damage assessments were being undertaken. During this phase the programme was updated to show activities required to undertake these additional repairs.

This planning was also the first step in the development of the Job Safety Analysis, discussed in Section 2.6.

2.6 HEALTH AND SAFETY

Job Safety Analysis (JSA) was used to identify hazards to people and plant/equipment for the construction phase activities. A JSA is a systematic assessment of the individual tasks involved in a project or job. For each task the potential hazards were identified. The consequence and likelihood for each hazard was considered and from this the risk was assessed. Mitigation efforts then focused on the highest risks. Risks to not only people, but also the plant/equipment were considered during the preparation of the JSA. It was important to consider both the removal and reinstallation of equipment as separate tasks.

The CWTP has a Permit-to-Work (PtW) system and JSA's are required as part of the contractors PtW submission prior to commencing work. A separate JSA was undertaken by the site operations staff to identify hazards associated with their work and the overall project. A great many individual tasks were identified to carry out the trickling filter repairs and maintenance, which resulted in a large number of hazards being identified in the JSA. Most were assessed as low or very low risk.

JSA methodologies are not effective for identifying hazards to the environment. Safety in Design (SiD) methodology was used to identify and assess the hazards posed to the environment [Sterling]. Two main hazards to the environment were identified:

i. Malodorous discharges to air
ii. Inadequate treatment of the wastewater

Inadequate wastewater treatment is obviously linked to the generation of offensive odours.

3 CONCLUSIONS

During this project the CWTP Trickling Filter 1 was successfully taken off line for R&M and then returned to duty. The R&M was completed on time and on budget with no safety incidents. The operation of the WWTP was managed through careful planning and back-up plans were in place for wet weather events.

Considering process duplication, isolation during the design phase, combined with scheduling of the R&M works resulted in the successful and safely executed project. Trickling filter 1 was taken off line during a low flow period when all of the flow could be diverted for treatment. The trickling filter treatment system at the

CWTP was originally designed with two separate trickling filters, and the pipework designed so that each could be isolated independently for maintenance.

Timing of the R&M for a low flow period was an important part of managing the treatment risks. Process modifications were made and contingency plans put in place for managing the overall wastewater treatment.

Careful and detailed planning and active management of the project timeline facilitated the successful execution of this complex project. At times people from three different companies were on site, including CWTP R&M staff, contractor staff and Beca engineering specialists. The potential for conflict was managed through comprehensive planning that was clearly communicated to all involved.

JSA methodologies combined with SiD techniques proved to be effective tools to manage the complex health and safety risks on this project.

4 LESSONS LEARNED

The trickling filters R&M at the CWTP is only half way through, with Trickling Filter 2 scheduled to come off line for R&M next summer. Key lessons learned that will be applied to Trickling Filter 2 are:

- Prepare a detailed plan which links all of the activities being carried out by everyone involved.
- Undertake the repairs during the summer months when flows are typically low.
- Consider the worst case scenario and prepare back up plans.
- Schedule the underfloor cleaning for a single event.
- Include lead times for all parts and equipment into the project plan.

REFERENCES (Arial, 11)

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