SMART PRESSURE SEWER AND THE DEVELOPMENT OF SOUTH WEST CHRISTCHURCH

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ABSTRACT

The South West area of Christchurch is experiencing rapid residential growth and development, partially as a result of the Canterbury earthquakes. To enable the development of land in this area for an additional 5,000 houses the Christchurch City Council needed to provide suitable wastewater infrastructure. The area zoned for residential development borders a large flood management basin which has high ground water levels and poor ground conditions. A conventional gravity wastewater system with deep pipes and a below ground wet-well pump station was not suitable. This paper presents the solution and discusses some of the design and construction challenges, and the lessons learned along the way.

A smart pressure sewer system was chosen for the area because of its resilience, suitability for the ground conditions, and ability to be developed in stages. Iota's OneBox smart system was selected as it provides the benefit of being able to manipulate the flows delivered to the receiving pump station. At the start of the development, coordination of the pumps provides a flushing flow through the pipeline. As development progresses the system can be operated in a peak shifting mode to reduce the peak flow from the catchment, reducing the size of rising main required for full development. The lower infiltration expected from a pressure sewer system when compared to a gravity system, and the reduced emergency storage requirement all resulted in a smaller pump station and sewer network.

Due to high ground water and the flood prone nature of the area the receiving pump station building was able to be situated well above the 200-year flood level and was designed with an above ground wet-well tank to provide a cost-effective design when compared to a traditional gravity sewer pump station.

Construction of the $12M scheme is now complete and included installing 6.3 km of wastewater rising main, upgrades to an existing pump station, and a new 120 l/s pump station. Construction of the scheme was not without its challenges. This paper outlines the South East Halswell Wastewater project and the smart pressure sewer technology. Focus is given to the key lessons learned on this project.

KEYWORDS

Smart pressure sewer, pressure sewer system, flow management

PRESENTER PROFILE

Helen Barclay is a Senior Water Engineer at GHD with over 12 years' experience. She was the Engineer's Representative for the construction of the South East Halswell Sewer Scheme and GHD's Design Manager for the project.

1 INTRODUCTION

The South West area of Christchurch includes the Southern and Eastern parts of the suburb of Halswell. The area is experiencing rapid residential growth and development, partially because of the Canterbury earthquakes. To enable the development of land in this area for an additional 5,000 houses, the Christchurch City Council (Council) needed to provide suitable wastewater infrastructure.

Council engaged GHD to design upgrades and extensions to their wastewater network. These improvements intended to achieve the following two main outcomes:

- to extend the wastewater trunk main network to enable previously un-serviced areas to be developed for residential and retail purposes, and
- to relieve pressure on existing catchments currently experiencing wet weather capacity problems by diverting wastewater to an alternate catchment with sufficient capacity.

Preliminary options for achieving these outcomes were previously considered and reported upon in 2014 (Jacobs SKM, 2014). This work concluded that a pressure sewer system with individual on-site tanks and pumps was the most appropriate means of servicing the development area.

Council engaged Iota Services, a division of South East Water in Melbourne to provide hydraulic modelling. Iota has developed a control panel called OneBox for managing individual pressure sewer system pumps. A small control panel is located on each property with a pressure sewer pump and allows remote real-time monitoring and control of individual sewer pumps. The smart controller has the ability to minimise peak flows by:

- locating the source of infiltration by identifying properties that show increased pumping frequency during wet weather events,
- reducing the diurnal peak flow to a target of up to 1.5 times the average dry weather flow from households by spreading out pump runs throughout the day,
- preventing spill during power outage recovery by controlling the number of pumps that operate simultaneously and prioritising those closest to spilling.

Other benefits include:

- meeting required self-cleansing velocities in catchments still developing by coordinating household pressure pumps to run simultaneously,
- smoothing out peak flows to maximise the efficiency of downstream infrastructure,
- real-time information provided through integration into the SCADA network,
- providing on site storage in the event of a power failure and allow controlled recovery from such an event,
- allowing control of flows from the catchment during a storm event to prevent downstream overflows,
- controlling pumping to allow for maintenance.

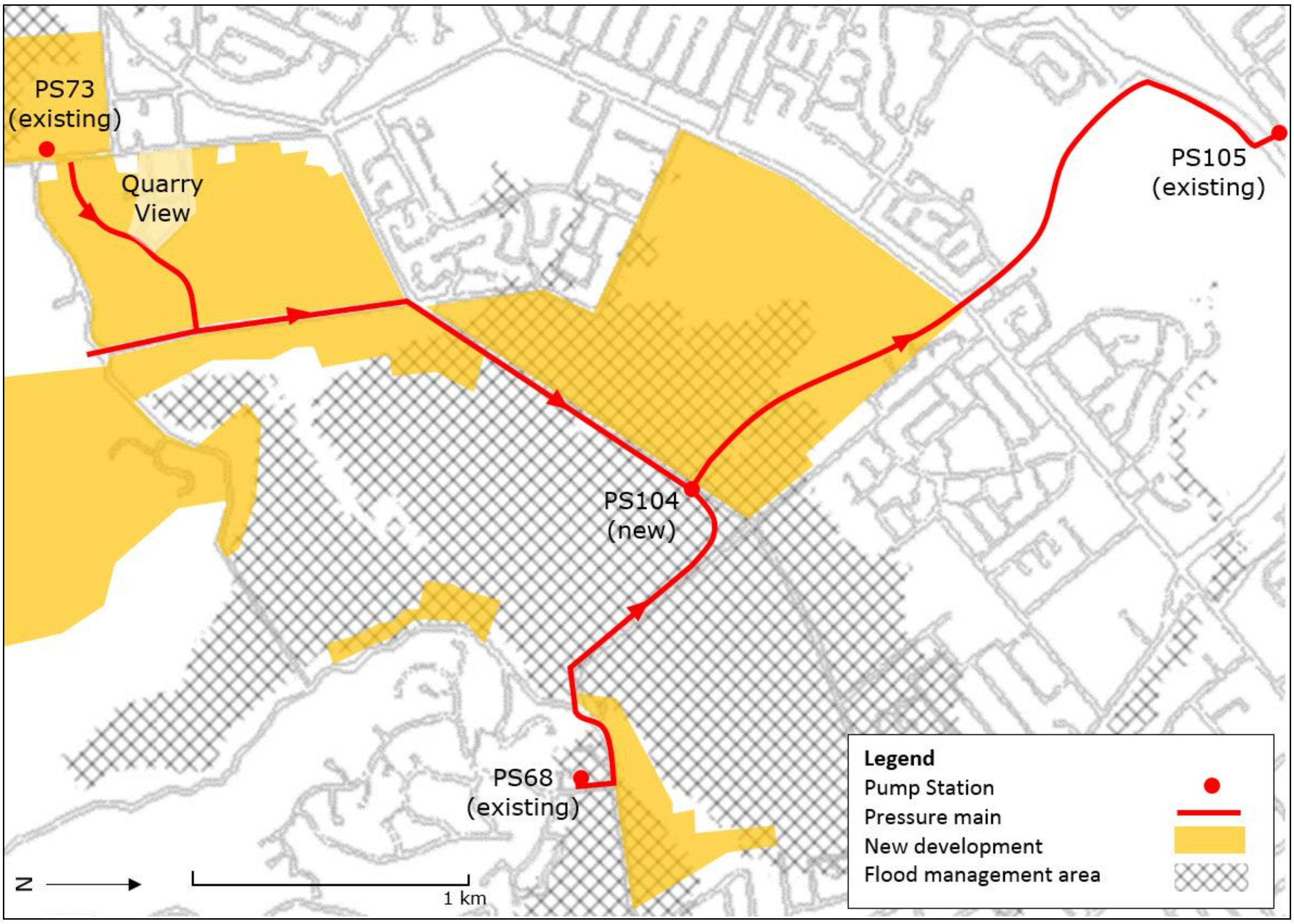
This project involved the design and construction of the pressure mains and pump station into which the pressure sewer network will connect to allow for new development.

2 SCHEME OVERVIEW

The proposed development areas to be served by the new South East Halswell Wastewater Scheme are shown in Figure 1 along with the pressure trunk main alignment. The new system will carry flow from the new catchments to a new pump station (PS104) as well as taking flows from an existing pump station (PS68) catchment to Pump Station 104. From this point the wastewater is pumped to Pump Station 105 (PS105).

The area also includes a large flood management area. This is shown hashed in Figure 1. Within this area required floor levels have been calculated based on a modelled one in 200-year flood event with an allowance for 1.0 m sea level rise and 400 mm freeboard.

Figure 1: South East Halswell Wastewater Scheme Overview



3 HYDRAULIC DESIGN

The hydraulic design of the pressure sewer catchments for the development areas was undertaken by Iota Services. Iota developed a dynamic hydraulic model of the South East Halswell catchment with the proposed development modelled using a generic grid development. This permitted several scenarios to be modelled.

Optimal pipe diameter and on-site storage tank sizes were established by running several flow scenarios. The performance of the established pipe sizes was checked against several other flow scenarios, and whether self-cleansing velocities could be obtained.

3.1 PEAK FLOW SHIFTING

Peak flows and pressures were modelled under a scenario of full development with no control over peak daily flows. The results showed that for full development the morning peak flow arriving at Pump Station 104 under normal operation with no flow control is 85 l/s (Iota Services, 2015).

Peak flow shifting occurs by utilising the additional storage in the tanks and spreading out the pumping. The smart controller ensures that those pumps that are closest to spilling go first. The modelling showed that when peak shifting control is applied the peak flow reduces by a third to 54 l/s.

3.2 POWER OUTAGE RECOVERY

For hydraulic design, the scenario that causes the greatest peak flow and that typically dictates pipe size selection is recovery from a long duration power cut. In this situation the on-property tanks are likely to be their fullest, so the ability to balance out the peak demand is the most compromised. The smart controller limits the peak flow during power outage recover by limiting the number of pumps operating simultaneously and prioritising pumping to those tanks that are the most compromised.

For a 24-hour power cut recovery, two different on-site tank sizes were modelled; the standard 700 litre tank and larger non-standard 890 litre tank. For the larger on-site tank size, the modelling showed that there was no difference in the peak flow that arrived at the pump station under normal operation and after a power cut when there is no control on the pumps. There was also no change in the pipe diameters recommended.

The benefit of the larger tank occurs when peak shifting control is implemented. The peak flow after a power cut for the 890 l tanks with peak shift controlling is one third of the flow that would occur with no controls in place. For the smaller tanks the peak shifting control reduces the flow to two thirds of the flow that would occur with no controls in place.

The reason for the difference is the ability for the larger tank to buffer flows when recovering from a power cut. For the South East Halswell catchment due to availability and the additional cost of the non-standard larger tanks, the standard 700 L tanks were chosen for the catchment.

3.3 FLUSHING FLOWS

The smart controller allows for coordinated pumping of the individual pumps to create a flushing flow to increase the flow to ensure that scouring velocities are achieved. This is particularly useful during the initial period of residential development when there are few properties connected.

Within the existing development there are approximately 30 properties built at Quarry View Subdivision that currently operate a pressure sewer system. These properties have recently had Iota OneBox smart control panels installed and will provide an initial base flow for Pump Station 104 with co-ordinated control to create a flushing flow.

At the scoping stage of the project twin pressure mains were proposed to allow the incremental development of the catchment. The smaller pipe would be used during the initial development phase to reduce issues with long retention times and solids settling in the pipeline. The modelling showed that twin pipes were not required as a flushing flow can be provided by coordinating the flow from these existing properties, reducing costs for the Council.

The original scheme (Jacobs SKM, 2014) also included the diversion of the Pump Station 73 catchment to Pump Station 104 via another new pump station. As part of the hydraulic modelling, it was identified that the pressure sewer system could be adequately designed without this diversion. This was based upon the smart controller flushing cycle using the existing pressure pumps at Quarry View to achieve initial self-cleansing velocities and the conclusion that there were not sufficient benefits to warrant chasing retention time reductions. As a result, the final design did not include any changes to the existing Pump Station 73 and saved Council from the expense of building an additional pump station.

4 PUMPS STATION DESIGN

The new Pump Station 104 location is on Council owned land within a flood management area. This required a unique design.

4.1 ABOVE GROUND WET-WELL

Due to ground conditions and the risk of flooding a standard pump station with a below ground wet-well would be difficult to construct and maintain. For these reasons an above ground pump station with a separate wet-well tank was designed.

The above ground design has significant hydraulic advantages for both the pressure sewer catchment and Pump Station 68 operation as it provides a high-level discharge point and prevents most of the pressure mains in the catchment from draining. Maintaining a fully primed system helps minimise odour generation by reducing the amount of sewerage exposed to air. Reducing air entrapment also helps to maximise pump efficiency and ensure self-cleansing velocities.

Other advantages of the above ground design are:

- The fill required to bring the pump station above the 200-year flood level could be engineered to minimise differential ground movement as opposed to expensive foundation design such as piling.
- There was no requirement for thick concrete walls and base or tie down works to prevent flotation.
- Improved construction safety through design as the construction method did not require working in a sheet piled excavation, reducing the need for work in confined spaces.
- A tank suitable for the corrosive inflows from the pressure sewer catchment was readily available at a reasonable cost when compared to a concrete wet-well.

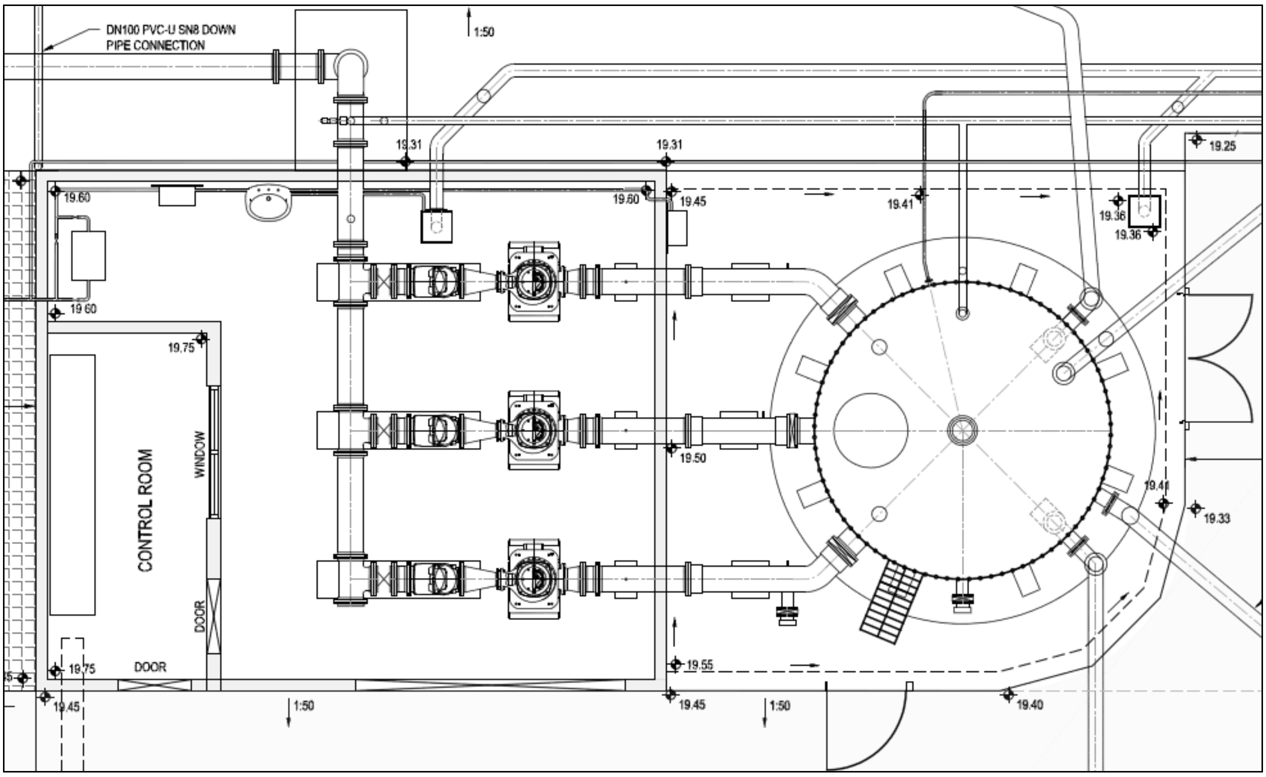
4.1.1 PUMP ARRANGEMENT

Two options for the pumping arrangement were investigated; using either standard centrifugal wastewater pumps or progressive cavity pumps.

A key disadvantage of using progressive cavity pumps is that they are physically long and would require a larger building to accommodate the pumps, macerators and valves than centrifugal pumps. Macerators would be required to protect the pumps from debris that could make its way through the gravity fed Pump Station 68 catchment.

Standard centrifugal pumps were chosen, operating as either duty/assist/standby or duty/duty/standby. The pumps selected were three Flygt N 3202 HT454 30 kW pumps in the arrangement shown in Figure 2.

Figure 2: PS104 Pump Station arrangement



The selection of the pumps for pump station 104 was a balance between the required design duty, the variables in the system curve over time (varying friction losses from a clean or fouled pressure main, as well as future direct connections into the rising main) and the restrictions in the pressure main diameter to provide sufficient tractive shear stress for scouring and stripping slime. To meet these requirements the pump curves were matched to the system curve for both one pump and two pump operations.

4.1.2 PRESSURE MAIN SIZING

The pressure main was sized to minimise sediment deposition, slime formation, and retention time. A recommended minimum tractive shear force to strip slime is 4 N/m^2. At the peak inflow to Pump Station 104 of 108 l/s the maximum pipe diameter for slime stripping is approximately 335 mm (internal diameter) and at the design duty flow of 130 l/s (including 20% allowance for pump degradation as per Council's requirements) the maximum pipe diameter for slime stripping is approximately 360 mm.

A pressure main with an internal diameter of approximately 300 mm was considered to provide the best compromise between pumping head (approximately 34 m), velocity sufficient to strip slime, and retention time in the pressure main. A DN400 PN16 PE100 pipe with an internal diameter of 320 mm was specified.

5 CONSTRUCTION

Construction of the $12 M scheme including new pump station, pump station upgrades, and 6.3 km of trunk mains commenced in November 2016 with Fulton Hogan as the main contractor. The works were completed in April 2018 (Figure 3).

Figure 3: PS104 nearing completion

The construction was not without its challenges.

Delays in finalising easement agreements through greenfield areas meant that pipeline construction commenced at the end of the summer and as winter approached the ground conditions became more difficult.

Two stream crossings were required for the DN400 rising main from Pump Station 104. Trenching through the waterways was avoided by using pipe ramming techniques in these two locations. Significant dewatering and other peripheral works were required to enable these work, with the peak dewatering and treatment flow estimated at 70 to 90 l/s.

In another location excavations for the pipeline works breached the confining layer over artesian water, flooding the site. This breach was at a single dewatering well point established 2.6 m below ground level. To rectify this issue an engineered capping of bentonite clay and back fill was placed, followed by targeted grout and bentonite injection. Council and GHD suspect an old tree root system intersected both the pipeline works and the artesian confining layer.

Following this event, the pipeline installation design was reviewed to assess if it was still appropriate for the challenging ground conditions likely to be encountered for the remaining sections of pipe. Eventually the decision was made to delay construction of the difficult section of the pipeline until the following summer when the ground conditions were much improved. Several alternative construction methodologies were considered in case of ground conditions deteriorating further. These included geo-grid systems, alternative wrapped raft options and compacted sub-foundations of coarse aggregates pressed into soft ground at the bottom of the excavations. Construction then continued in summer with agreed variation rates, and alternative construction methods "pre-approved" by the client.

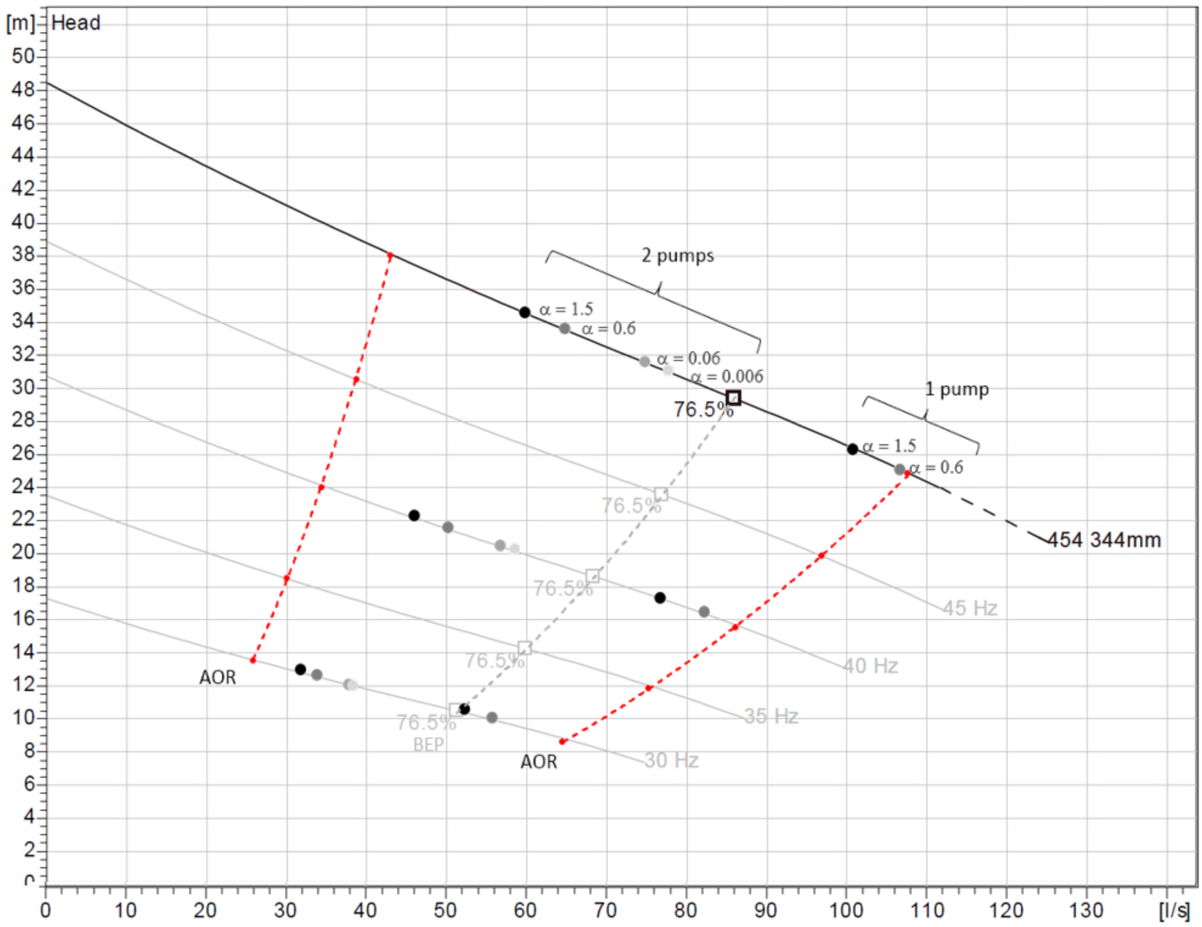
Raft foundations were required for extensive lengths of trunk main where scala-penetrometer results showed the bearing capacity was less than the Council's requirement of 50 kPa. The geotechnical testing undertaken at the design stage was sufficient to identify that this may be required, but insufficient to quantify the extent of the potential difficulties. More extensive geotechnical testing along the pipe route is recommended for future projects in areas with similar ground condition.

Whilst these construction challenges involved some variation cost to the project they demonstrated the benefits of a pressure network in this area. A traditional gravity sewer would have necessitated deeper excavations and the construction of deep pump station wet-wells. By being able to keep trenching excavations shallow (generally less than 2.0m) and following the general contours of the surface, significant construction costs and risks were removed.

6 COMMISSIONING

During commissioning the pipeline commenced operation in a clean, unfouled state with fresh water and minimum friction losses. In this state it was found that at 50 Hz the pumps operated slightly outside of the Allowable Operating Range (AOR) that the pump manufacturer would provide warranty for. Figure 4 shows the Flygt allowable operating range for the pump selected for a range of operating frequencies, along with the operating points for varying α values (where α is the scaling coefficient, $k_s = \alpha V^{-2.34}$ and V is velocity).

Figure 4: PS104 pump curve for Flygt N3202 pump with AOR



The hydraulic design was carried out on the basis that the pressure main was fouled. The pipe friction was calculated, and initial pump selection made using a scaling coefficient value of α = 0.6 (ks of 0.3 mm) as per Council's Infrastructure Design Standard (IDS) Part 6 for pipes in average condition.

Under commissioning conditions with the new pipe and clean water, for the pumps to operate within the AOR, the pumps needed to operate in a duty/duty/standby configuration. With two pumps in operation the achieved flow at commissioning of 153 l/s was much closer to the best efficiency point. This was equivalent to a scaling coefficient value of α = 0.006 (ks of 0.003 mm). The options of increasing the head by slightly closing a valve or utilising the variable speed drive (VSD) to reduce pump output were considered. These were not Council's preference. It was therefore recommended that two pumps are operated together initially to ensure they are within the AOR. This could be reviewed once the pipeline was receiving sewage and had become fouled.

Whilst the issue could be overcome with duty/duty/standby operation, and an option to move to duty/assist/standby operation in future years as the pipeline fouls, this case demonstrated some of the challenges and risks around designing pump system for an extremely wide range of operating conditions. The selection of a pressure sewer system meant that a reasonable operating range could be achieved, reducing the cost and complexity of the same pump station in a gravity sewer catchment.

7 CONCLUSIONS

The following conclusions were made over the course of this project:

- The ability for a smart pressure sewer system to provide a flushing flow removed the need for a dual pipe line, reducing costs to the Council.
- A pressure sewer system allowed for an above ground pump station design, reducing the costs further.
- Large on-site pressure sewer tanks were not selected as there was not sufficient benefit to the trunk main sizing to warrant their use.
- When choosing pumps the clean unfouled state of the new pipework should be considered to ensure the pumps can operate within the allowable operating range initially.
- The construction challenges encountered demonstrated that the selection of a pressure sewer system that enabled the collector mains to remain shallow and follow the general contours of the land had significant construction costs advantages over a traditional gravity system.
- Due to reduced peak wet weather flows from a pressure sewer catchment when compared to a gravity catchment the selection of a pressure sewer system meant that a reasonable pump operating range could be achieved, reducing the cost and complexity when compared to the same pump station in a gravity sewer catchment.

REFERENCES

Jacobs SKM (2014) *South East Halswell Wastewater Strategy Development Report* prepared for Christchurch City Council

Iota Services (2015) *South East Halswell Pressure Sewerage Project - Design Basis and Hydraulic Assessment Report*, prepared for Christchurch City Council.