LYTTELTON HARBOUR SCHEME - REMOVING WASTEWATER DISHARGES FROM A HARBOUR

Anthony Doherty (Jacobs), Matthew Sheppard (Jacobs)

ABSTRACT

The primary objective of the Lyttelton Harbour Wastewater project is to remove routine discharges of treated wastewater into Lyttelton Harbour. The project is an integral part of the Whaka-Ora Healthy Harbour Plan to restore the cultural mauri and ecological health of Lyttelton Harbour. This project removes the discharge of treated wastewater from Lyttelton Harbour and reduces the frequency and extent of wastewater overflows, resulting in an improvement of water quality within Lyttelton Harbour. This paper provides an overview of the scheme arrangement, operational philosophy, key challenges encountered and resolution of these challenges.

In 2009 Christchurch City Council (CCC) approved a joint working party recommendation to remove wastewater discharges into Lyttelton Harbour by pumping wastewater from Lyttelton, Governors Bay and Diamond Harbour to the Christchurch Wastewater Treatment Plant (CWTP) in Bromley. It was immediately obvious the project required significant capital investment. Consultation on the scheme, including public drop-in sessions, took place from September 2015 to March 2016.

Based on consultation feedback, a preferred approach was identified comprising the construction of submarine pipelines to convey untreated wastewater, approximately one metre under the seabed, from Diamond Harbour and Governors Bay to Lyttelton. Wastewater would then be pumped to CWTP through the existing road tunnel via a new pump station at Simeon Quay in Lyttelton.

The project is being constructed in four stages and is now near completion. The various elements of the scheme include:

- The construction of 7 km of submarine pipelines from Governors Bay and Diamond Harbour to Lyttelton
- Decommissioning and converting existing wastewater treatment plants at Governors Bay, Diamond Harbour and Lyttelton into pump stations with overflow storage
- A new high-head terminal pump station in Lyttelton to pump wastewater through the Lyttelton road tunnel
- The construction of a 2 km pressure main from the Lyttelton pump / storage facility to the terminal pump station
- The construction of a 2 km glass reinforced plastic (GRP) pipeline through the air shaft of the Lyttelton road tunnel

- The construction of a 5 km gravity pressure main with a control valve station and an above ground stainless steel pipeline section from the Lyttelton Tunnel to Pump Station PS15 in Woolston

There have been a number of design and construction challenges encountered on this project and many lessons learned over the six year journey. The paper describes the key engineering design challenges encountered on this project and the innovations developed by Jacobs and CCC to overcome these challenges, including:

- Development of low complexity pumping and storage arrangements
- Use of high-head progressive cavity pumps
- A design that includes a combination of pressure and gravity pipelines
- Design of control valve arrangements that provide straightforward operation
- Specific odour treatment to mitigate any potential negative impacts on local communities
- Design and installation of high-pressure pipework in the Lyttleton tunnel
- Design and construction of submarine pipelines across Lyttelton Harbour

A key construction challenge was the ground conditions presented by the loess soils of Banks Peninsula and the constrained nature of the majority of the pumping and storage facility sites. Our approach to address this challenge will also be highlighted.

KEYWORDS

Wastewater treatment and networks, wastewater overflow, Lyttleton wastewater

PRESENTER PROFILE

Anthony Doherty is an Associate Civil Engineer at Jacobs

Matthew Sheppard is Principal Water Consultant at Jacobs

1. INTRODUCTION

Wastewater from the catchments of Governors Bay, Diamond Harbour and Lyttelton has historically been conveyed to WWTP's in each catchment for treatment and discharge via marine outfalls to Lyttelton Harbour.

Christchurch City Council's (CCC) long term strategy to remove all wastewater discharges from the harbour resulted in the Lyttelton Wastewater Project to collect untreated wastewater from each of these catchments and convey it to Pump Station PS15 in Woolston, for onward transfer to the Bromley wastewater treatment plant (WWTP).

The overall scheme arrangement for the Lyttelton Wastewater Project is presented schematically in Figure 1 below:

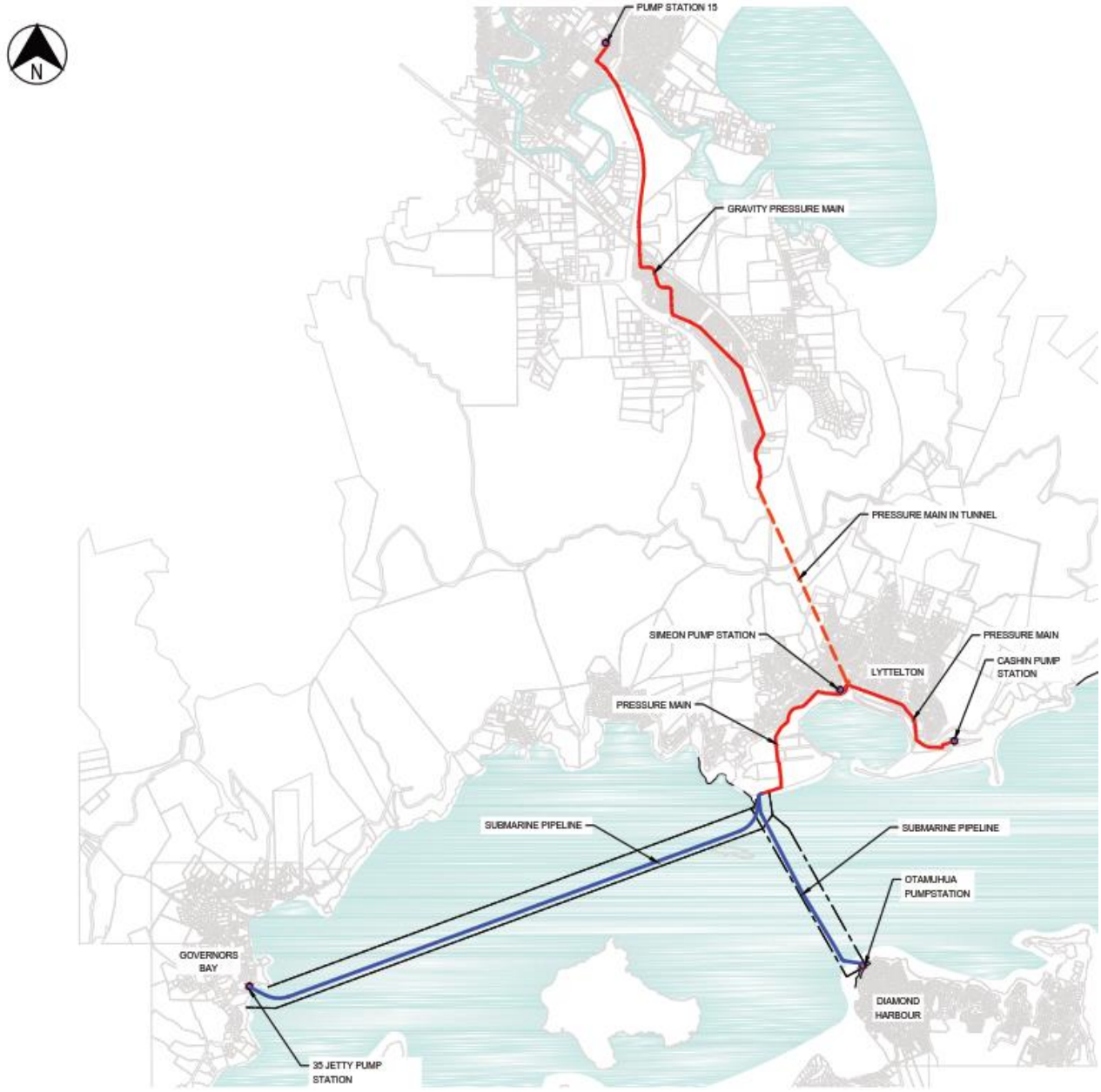

Figure 1: Scheme Arrangement

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- The construction of a 2 km pressure main from the Lyttelton pump / storage facility to the terminal pump station
- The construction of a 2 km glass reinforced plastic (GRP) pipeline through the air shaft of the Lyttelton road tunnel
- The construction of a 5 km gravity pressure main with a control valve station and an above ground stainless steel pipeline section from the Lyttelton Tunnel to Pump Station PS15

Construction of all the pipework is complete.

Pump stations at Diamond Harbour, Governors Bay and Lyttelton are complete and commissioned, only now requiring finishing works to overflow storage and general site works.

Commissioning of the Simeon Quay Pump Station is currently underway. Once this commissioning is complete and Simeon Quay Pump Station is operational, works can commence to decommission the Lyttelton WWTP.

2. DISCUSSION
2.1 SCHEME COMPONENTS

The scheme components are described in general below:

Governors Bay Transfer Pump Station – PS0629 - 35 Jetty Pump Station

A new wastewater pumping station and conversion of existing clarifier to an overflow wastewater storage tank at the Governor's Bay WWTP site, with a raw wastewater pump capacity of 15 L/s and overflow storage of 350 m^3. Two progressive cavity pumps and macerators in a duty/standby configuration in an open-air pump station, stainless steel extension to existing concrete treatment tank, stainless steel above-ground wet well. All electrical cabinets and controls installed within the existing building.

A permanent emergency standby generator and fuel tank under a canopy cover, with capacity to power the new pump station plus the existing Jetty pump station and construction of a new pressure main and emergency generator power supply for the Jetty Pump Station.

Diamond Harbour Transfer Pump Station – PS0630 - Otamuhua Pump Station

A new wastewater pumping station and conversion of the existing clarifier to an overflow storage tank at the Diamond Harbour WWTP site. Pump capacity of 40 L/s and overflow storage of 700 m3.

Two dry-mounted submersible centrifugal pumps in a duty/standby configuration in an open-air pump station, stainless steel extension to existing concrete clarifier treatment tank, stainless steel above-ground wet well.

A permanent emergency standby generator and fuel tank under a canopy cover, with capacity to power the new pump station.

Lyttelton Transfer Pump Station – PS0628 – Cashin Pump Station

A new wastewater pumping station and overflow storage tank and conversion of the existing boat clarifier to a second overflow storage tank at the Lyttelton WWTP site, with pump capacity of 65 L/s and a combined overflow storage of 2100 m^3.

Two dry-mounted submersible centrifugal pumps in a duty/standby configuration in an open-air pump station, stainless steel primary overflow storage tank (700 m^3), modification to existing concrete treatment tank as secondary storage (1400 m^3), stainless steel above-ground wet well

Permanent emergency standby generator and fuel tank under a canopy cover, with capacity to power the new pump station and the upgraded lift pump station.

Simeon Quay Pump Station – PS0631 – Simeon Pump Station

A new wastewater pumping station at a new site on Simeon Quay immediately to the west of the southern tunnel portal, with pump capacity of 120 L/s. Installation of three progressive cavity pumps in a duty/assist/assist configuration and provision for a future fourth pump to provide additional redundancy, in a concrete pump station building with a below-ground concrete wet well, 2 x 10 m^3 air bladder surge mitigating pressure tanks, odour treatment and provision of a permanent emergency standby generator and fuel tank, with sufficient capacity to power the new pump station at a capacity of 80 L/s.

Submarine Pressure Mains

High density polyethylene (HDPE) pressure mains from landfalls at Diamond Harbour and Governors Bay pump stations, 5000 m and 1800 m long respectively, to a valve chamber at Naval Point.

See Photographs 1 and 2 below taken during the launch of the Governors Bay submarine pipeline:

Photograph 1: Launch of Governor Bay Submarine Pipeline

Photograph 2: Governor Bay Submarine Pipeline String

Onshore Pressure Mains

High density polyethylene pressure mains from Diamond Harbour and Governors Bay pump station manifolds to connect with the submarine pipelines, 35 m and 15 m long respectively, in single pipe trench.

HDPE pressure mains, 1200 m long each, from the submarine pipeline terminal valve chamber at Naval Point to a new manhole on the DN375 gravity sewer in Simeon Quay, approximately 200 m west of the Simeon Quay Pump Station, buried in road in common pipe trench.

HDPE pressure main from Lyttelton pump station to Dublin Street/Norwich Quay junction, 1075 m long, buried in road in single pipe trench.

Ductile Iron (DI) pressure main from PE termination at Dublin Street to Simeon Quay Pump Station, 200 m long

Ductile Iron (DI) pressure main, with short section of Stainless steel, from Simeon Quay Pump Station to southern tunnel portal, 150 m long, buried in road in common pipe trench.

GRP pressure main from end of ductile iron pipe through the Lyttelton Tunnel to the northern tunnel portal, 2200m long, supported from tunnel roof and walls.

HDPE with DI sections pressure main from northern tunnel portal to PS15, 4600 m long, buried in road and paddock in a single pipe trench, directional drilled crossing of the Heathcote River and flow control valve chamber located in Alport Place.

See Photograph 3 below showing the preparation for horizontal directional drilling under the Heathcote River:

Photograph 3: DN355 PE100 pipe string being positioned prior to the horizontal directional drill under the Heathcote River

2.2 DESIGN APPROACH

The general design philosophy adopted for the project has been to achieve the following:

- Prioritise achieving reliable and safe operation
- Adopt a consistent design approach at all pump stations including:
    - Utilise elevated or pressurised inflows to achieve gravity flow into and out of overflow storage and avoid internal pumping
    - Provide generous wet well capacity to minimise frequency of use of overflow storage tanks and associated need for wash-down
    - Re-use existing treatment tank assets where practical and cost effective to do so
    - Use open-air pump sets to reduce built footprint on space constrained sites
- Identify future upgrade approaches for pump station sites, consider the difficulty of future implementation and marginal cost to implement now, incorporate now if sensible or design to accommodate future upgrades
- Identify infrastructure items that could possibly be deferred if design flows are found to be conservative, where they can be efficiently and easily be constructed in future

2.3 STAKEHOLDER INPUTS

During the design development stage of the project stakeholder interactions that were specifically considered included:

- Rapaki Iwi - Ngati Wheke – As an outcome of several hui, the following design elements were agreed to be provided to mitigate the risk or impact of submarine pipeline rupture:
    - Use of HDPE pipe, buried in the seabed and with rock armoured in areas of risk of damage, with pipe pressure rating increased above that otherwise required for operational duty and hydrostatic testing undertaken prior to installation and again prior to commissioning (originally proposed)
    - Provide non-return valves at submarine pipeline landfalls to prevent drainage of pipes on shore in the event of a submarine pipe rupture (developed through consultation)
    - Provide a method for periodic pressure testing during operation and incorporate periodic pressure testing into operation and maintenance plans (originally proposed)
    - Increase the volume of storage provided at Governors Bay to reduce the frequency of environmental overflows beyond once in 2-years due to the heightened environmental sensitivity in this area (developed through consultation)
    - Pump shut-down on pressure loss (originally proposed)

  Adoption of these mitigation measures resulted in Ngati Wheke submitting in support of Resource Consent applications for the project.
- NZTA – Identification of NZTA design requirements including tunnel fire heat loads, operational access requirements for the pipeline, need for design review by NZTA appointed consultant and preparation and packaging of works to be incorporated into the Tunnel Fire Safety Upgrade Project Contract Documents. Conformance with

these requirements resulted in gaining of NZTA agreement to the tunnel pressure main design and incorporation of design into their Tunnel Fire Safety upgrade project.

- LPC - Identification of extent of dredging required for the proposed cruise ship terminal development alongside Cyrus Williams Quay required adjustment of the Diamond Harbour submarine pipeline alignment and landfall location on Cyrus Williams Quay, plus agreement to the location of pipeline entry to LPC land and terms and conditions that were incorporated into project contract documents relating to construction on LPC land.
- LPC – Identification of preferred location for pipeline access into and alignment within LPC land and worker security approval and physical works method processes, resulted in gaining of LPC acceptance of design.
- Orion – The Terminal Pump Station general arrangement required movement of several buried 11kV power lines was discussed and accepted. Power supply provisions for all other sites were discussed and confirmed.
- CCC Parks & Recreation – Review of preliminary master plan for the Naval Point Recreation Area, including yacht club and public slipways, identified the potential for service conflicts and resulted in moving the Governors Bay submarine pipeline alignment and landfall location further southwards to reduce future site development constraints.
- Kiwi Rail – The need for rail crossings into and within Lyttelton Port required interaction with Kiwi Rail technical and processing teams to gain a “Grant of Right” for all crossings. See Photograph 4 below taken during construction of a rail crossing:

Photograph 4: Construction of pipeline under KiwiRail tracks

2.4 DESIGN CHALLENGES

2.4.1 LOW COMPLEXITY OVERFLOW AND STORAGE ARRANGEMENT

Governors Bay, Diamond Harbour and Lyttelton Overflow Storage design involves the use of flow splitter boxes, using internal overflow weirs to direct overflows from wet-well to overflow storage tank and when storage is exceeded, from overflow storage tank to the environment.

The flow splitter boxes enable fail-safe operation by removing the need for level sensing and valve actuation and allow flows to cascade from wet well to overflow storage tank to environment in the event of blockage, equipment failure or capacity being exceeded, without operational input or control. This also enables simple manual isolation of wet well or overflow storage tank if required for maintenance or other operational reasons.

See Figure 1 below for a schematic of the splitter box design:

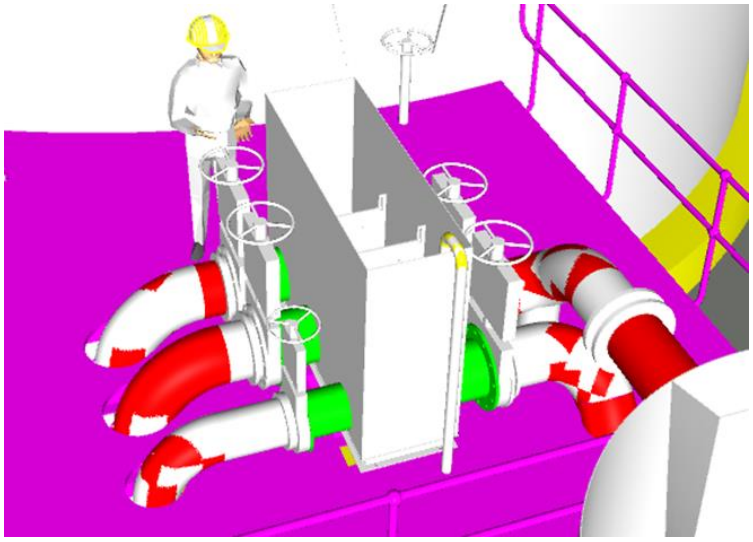


Figure 1: Splitter Box arrangement at the Diamond Harbour site

2.4.2 HIGH-HEAD PROGRESSIVE CAVITY PUMPS

Progressive cavity pumps were selected at the Governors Bay and Simeon Quay Pump Station sites due to the high pump pressures required at both these sites to achieve the flow velocities required to manage sedimentation and sliming.

Due to the potential for over-pressurisation when using progressive cavity pumps, pump station design incorporated pressure relief valves and rupture discs to provide additional protection of the pump discharge and pressure main piping.

A pressure rating of PN20 was selected for the Governors Bay submarine pipeline due to the potential for significant pressures achievable by the progressive cavity pumps. Similarly, a pressure rating of at least PN16 was selected for the Simeon Quay Pump Station pressure main directly downstream of this pump station.

Transient analyses were conducted for the discharge pipework for all pump stations. This identified that full vacuum conditions could form in the pressure main in the event of failure of the progressive cavity pumps at Simeon Quay Pump Station. To mitigate this risk, two 10 m3 air bladder surge vessels were incorporated on the Simeon Quay Pump Station pressure main. See Photograph 5 below of installed air bladder surge vessels.

Photograph 5: Surge Vessels at the SIMEON QUAY PUMP STATION Site

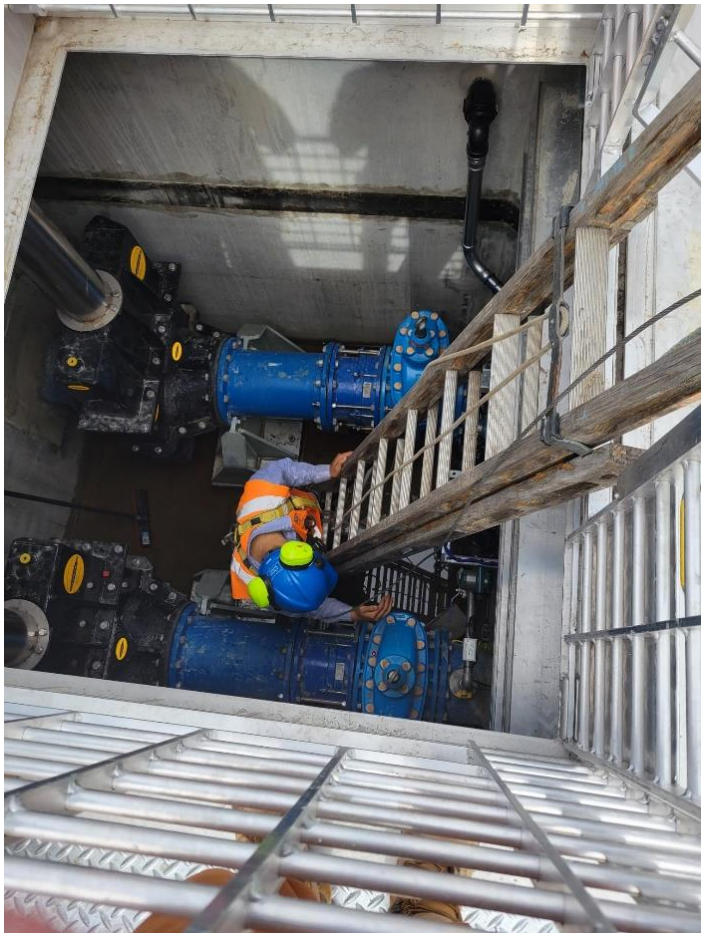
2.4.3 PRESSURISED GRAVITY MAIN AND VALVE CONTROL STATION

The pipeline from the Lyttelton tunnel to Pump Station PS15 has a static fall of approximately 60m, resulting in it behaving as a pressurised gravity main.

Hydraulic assessment identified that during routine dry weather operation and associated intermittent pump operation, flow velocities in the full sections of the pipe would be insufficient to maintain good scouring and cleansing. The design response was to introduce a valve control station that on valve closing enables filling of the pipeline and on valve opening achieves high-velocity scouring flows. Using this approach, peak scour velocities during dry weather operation increase from around 1 m/s to in excess of 2 m/s and the duration of flows above 1 m/s increase significantly.

The design of the control valve station has two electrically actuated pinch valves that operate in a duty/standby and it is located approximately 150m away and lower than the discharge location, to maintain a flooded outlet and back-pressure to mitigate the occurrence of cavitation at the pinch valves.

See Photograph 6 below of inside the valve control station:



Photograph 6: 2 no. Pinch Valves Installed Inside the Alport Place Buried Valve Chamber

The pressurised gravity main has been designed to be as hydraulically smooth as possible. One high point exists just prior to the Heathcote river crossing and an above ground air valve is located at this point.

The valve control station was designed to operate continuously with repeated valve close / open cycles and cycling the valve duty to share wear. During commissioning it has been observed that dry-weather diurnal peak flows achieve good scour velocities and that an intermittent scouring may be more appropriate, to reduce wear and extent asset life.

2.4.4 ODOUR TREATMENT

The long pumping distances result in high sewage age and increased likelihood of odour and the following odour devices have been incorporated into the scheme:

- Odour scrubber installed at Simeon Quay Pump Station, extracting air from the wet-well
- Biofilter constructed at the tunnel pressure main outlet, extracting air from the pressure main discharge location and from the pressure gravity main
- Armatec Green dome installed where the Governors Bay and Diamond Harbour pressure mains discharge into the existing Lyttelton gravity sewer networks

See Photograph 7 below of the biofilter:

Photograph 7: Biofilter Constructed above tunnel pressure outlet, for odour treatment at the discharge end of the tunnel pipeline

2.4.5 HIGH-PRESSURE PIPEWORK IN THE LYTTLETON ROAD TUNNEL

A GRP pipeline using double-bell couplings was selected and designed for installation inside the Lyttelton Tunnel, primarily due to the double-bell coupling joints being able to accommodate the challenging thermal variability and its relative light weight that simplified manual handling and installation within the confined tunnel working environment. The GRP can also achieve the high design pressures and has the ability to undertake field repairs.

The pipe has been suspended from the ceiling of the tunnel using steel pipe support brackets, including longitudinal thrust restraints at the ends and centre bulkheads, lateral restraint and pipe fixing every 4 pipe segments and simple hangers every other pipe section.

Due to the criticality of the road tunnel, the design of this pipeline was subject to external peer review.

See Photograph 8 below of the installed GRP tunnel pipeline:

Photograph 8: DN250 GRP Pipeline Installed inside the Lyttelton Tunnel

2.4.6 SUBMARINE PIPELINES ACROSS LYTTELTON HARBOUR

Submarine pipelines were installed with a minimum cover of 1m across the seabed and with additional rock gabion protection near landfalls and until the pipeline was buried within the landfall.

Trenching was undertaken by excavator on a barge and proving surveys undertaken prior to burial of the pipeline. The pipeline was weighted to provide slight buoyance when full of air.

Construction through the tidal floats at Governors Bay was challenging and required a combination of barge mounted excavation during high tides and tracked access on the tidal flats through the low tide.

Stringent water quality assessment was required for this phase of the project, with several months of sediment monitoring in advance of construction activities, sampling sites that moved with the construction area and some that provided background water quality data.

2.4.7 CLASHES WITH BURIED 11KV POWER CABLE

After design but prior to construction of the pressure gravity main from the Lyttelton tunnel, the local power distribution company Orion installed a new 11 kV power cable within the design corridor for the buried wastewater pipeline, requiring this section of pipework to be redesigned.

Due to topography, land access and spatial constraint, the final solution was using a DN400 SS316 above ground pipeline to minimise the extent of excavation required adjacent to the 11kV power cable.

Jacobs subsequent design incorporated the following features:

- Pressure pipework extending the tunnel pressure main to a new above-ground discharge chamber;
- Above-ground discharge chamber;
- Above-ground stainless steel pipework connecting the discharge chamber to the existing WP#4 PE buried pipeline; and
- Pipework connecting the discharge chamber to the biofilter pipework
- The pipe supports included the use of rock anchors fixed into the rock below

Hydraulic analysis of the discharge chamber arrangement was also conducted as part of this process to confirm the final configuration was hydraulically appropriate.

See Photograph 9 below for configuration of the DN400 SS316 above ground pipeline:

Photograph 9: DN400 SS316 above ground pipeline that was design and constructed to avoid the existing 66 kV buried power cable

2.5 CONSTRUCTION CHALLENGES

2.5.1 GROUND CONDITIONS ON SITE

During the construction of the Governors Bay site, it was found that the ground in the location of the new above-ground wet well was considerably different to expected from geotechnical investigations and consisted of highly variable fill material.

Sheet piles and universal columns were subsequently installed on site, covering the extent of the wet well slab.

Rock was also present during excavation works at Simeon Quay Pump Station and construction of the on-land pressure pipelines.

2.5.2 CONSTRAINED SITES AND UNDERGROUND SERVICES

The Simeon Quay Pump Station, Diamond Harbour and Governors Bay are all physically constrained, requiring good construction planning and sequencing.

The wastewater treatment plant sites remained operational throughout construction and required close interfacing with network operators City Care.

The Governors Bay sites was accessed of are shared use track popular with day-walkers and required close interfacing with the community and maintenance of walking access.

The Simeon Quay Pump Station contains 11kV and 66kV power cable on site, which were required to be worked around.

Pre-construction potholing of the road corridor in front of the Simeon Quay Pump Station identified that constructing the design alignment for three pressure mains arriving at site and one departing was not achievable without significant disruption of traffic for an extended period of time. Design changes were made to connect the Diamond Harbour and Governors Bay pressure mains to the Lyttelton gravity network upstream of the pump station to reduce the number of pressure mains to be laid to the pump station.

3. CONCLUSIONS

Construction of this complex project is near completion, with final commissioning of the Simeon Quay Pump Station and finishing of the overflow storage tanks and final sites works at Governors Bay and Diamond Harbour nearly completed.

Once Simeon Quay Pump Station is put into service, the Lyttelton WWT will be decommissioned, and treatment tank converted and connected as a second overflow storage tank and the overall scheme will become operational.

The design of pump stations and overflow storage will reliably prevent overflows of wastewater to the Lyttelton Harbour in all but extreme weather events or unforeseen failure of infrastructure and will be a major step towards improving the water quality of Lyttelton Harbour.

4. ACKNOWLEDGEMENTS

We would like to acknowledge Christchurch City Council and their project representatives.