# A HEALTHY DOSE OF FIBRE – TWO CASE STUDIES OF FIBREGLASS PUMP STATIONS IN MARLBOROUGH

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## ABSTRACT

Use of fibreglass (or glass-reinforced plastic, GRP) is becoming more widespread in wastewater conveyance. Particularly in the case of GRP submersible pump stations, there is potential to provide significant benefits in corrosion resistance, reduced construction times, less extensive and safer site works and overall project cost savings. By fabricating the structures in a factory environment and delivering near-complete units to site, "plug-and-play" installations are not just a pipe dream.

This paper provides two case studies of GRP pump stations in sewer networks within Marlborough. In one, a GRP pump station has replaced an existing concrete pump station conveying corrosive winery wastewater. It provided the secondary benefits of requiring a simple, yet seismically-resilient, foundation and delivery to meet a tight commissioning deadline based on the grape harvest. The project was completed early and under-budget. In the other, preliminary design of an upgrade to the Picton sewerage system had proposed reinforced concrete structures built-*in situ* for the pump stations. Subsequently, with confirmed reduced flows, and accounting for post-earthquake learnings from Christchurch, the design was re-visited. This generated a radical solution, incorporating GRP pump stations. A triple pump station at the terminal site has been replaced with three individual GRP units within the same footprint as the originally-proposed concrete structure. At another, the site footprint has been much reduced, providing less visual impact and disruption to neighbours. Capital savings of over $1Million have been estimated, while reducing the construction programme by months.

## KEYWORDS

**Fibreglass, glass-reinforced plastic (GRP), wastewater pump stations, resilience, reduced capital cost, cost-efficiency, safety, corrosion resistance**

## 1 INTRODUCTION

For the last 50 years or so, large-scale wastewater conveyance in New Zealand has conventionally involved concrete structures: both sewer pipes and lift pump station structures. Large pipes have been in reinforced concrete (RC), whereby concrete pipe is manufactured with an internal skeleton of wire reinforcement, combining concrete's compressive strength with the wire reinforcement's tensile strength. Asbestos cement (AC) pipes were also used for a period in the late 1960s – mid 1980s before the health risks of asbestos were identified. More recently, as manufacturing processes have improved and raw material costs have reduced, thermoplastics such as polyvinyl chloride (PVC-U) and polyethylene (PE) have become increasingly cost-competitive for piping systems; up to around 450mm diameter for PVC-U and around 900mm diameter for PE (and even larger for ribbed profile PE pipes). RC pipes typically remain more cost-effective at larger diameters. Thermoplastic pipes are produced by heating, melting and either extruding or spirally-winding the mix into the required tubular shape, prior to cooling. Another form of plastic; thermoset plastic, in the form of glass-reinforced plastic (GRP), commonly known as fibreglass, is also becoming more widely used in the water industry, particularly as an alternative to RC in larger pipe diameters. These pipes are formed by fibreglass sheets being laid in a mould and set in a resin, analogous to the reinforcing wire in RC pipes. Relative advantages and disadvantages of RC and the various plastics are shown in Table 1.

*Table 1: Comparison of materials for sewer piping*

| | Advantages | Disadvantages |
|---|---|---|
| *Reinforced Concrete (RC)* | • Good corrosion resistance<br>• Widely available<br>• High strength<br>• Good load supporting capacity | • Requires careful installation to avoid cracking<br>• Heavy<br>• Susceptible to attack by hydrogen sulphide and acids when pipes are not coated |
| *Thermoplastics (inc. Polyvinyl Chloride (PVC-U) and Polyethylene (PE))* | • Very lightweight<br>• Easy to install<br>• Economical<br>• Good corrosion resistance<br>• Smooth surface reduces friction losses<br>• Long pipe sections reduce infiltration potential<br>• Flexible | • Susceptible to chemical attack, particularly by solvents<br>• Strength affected by sunlight unless UV protected<br>• Requires special bedding and backfill |
| *Glass-Reinforced Plastic (GRP)* | • High strength<br>• Lightweight<br>• Corrosion resistant<br>• Smooth surface reduces friction losses | • High material cost<br>• Brittle (may crack); requires careful installation<br>• Requires special bedding and backfill<br>• High installation cost |

Table details largely derived from US EPA's Wastewater Technology Fact Sheet – Pipe Construction and Materials (EPA 832-F-00-068, Sept. 2000)

A notable feature of GRP pipes is that, because of their method of manufacture, the pipe moulds can be relatively simply adapted to create cylindrical pump station chambers. In so doing, GRP structures, manufactured off-site, can provide an alternative to RC structures which are required to be built-*in situ* because of their much greater mass. This application forms the subject of this paper.

Two case studies are examined; the upgrade of the Vernon Street sewage pump station in Blenheim and two pump station sites forming part of a sewerage upgrade being undertaken in Picton. Both projects have been designed and project managed by consultant CH2M Beca Ltd (Beca) for Marlborough District Council (MDC), the local authority for the north-eastern district of New Zealand's South Island. Blenheim and Picton are the two largest population centres in the district. The Vernon Street project is complete and fully operational. At the time of writing, detailed design of the Picton project is complete and the tender process is underway for both the construction contract and the fabrication of the pump stations. Construction will be undertaken over approximately the next 12 months. In a sense, the use of GRP pump stations at the Vernon Street site can be considered a pilot trial for the larger and more complex Picton Sewerage Upgrade.

An underlying theme of this paper is resilience. Since the Christchurch earthquakes of 2010 and 2011, the term has been at the forefront of designers' minds, specifically in relation to the effects of seismic events. Previously, although engineers had taken account of seismic events in designs, it was often without any real experience or understanding of what actually happens to underground infrastructure in an earthquake. The SCIRT (Stronger Christchurch Infrastructure Rebuild Team) alliance was established in 2011 with the stated purpose of "creating resilient infrastructure that gives people security and confidence in the future of Christchurch". Since then, a number of technical papers have been produced on the learnings from SCIRT, such that we now have a significant body of literature and design experience that can be applied in future designs both within and beyond Christchurch.

The term ‘resilience’ is not easy to pin down; ‘bouncing back’ is a common colloquial definition. In relation to our working environment, the UK Water Industry Research organisation offers: “resilience in the water industry can be defined as the ability of an asset or asset system to continue to withstand or to recover from the effects of an exceptional event such that acceptable service levels are maintained and/or restored quickly” (UKWIR Resilience Planning: Good Practice Guide - Summary Report, 2013). Although not stated, a key point is that resilience does not necessarily equate to massive, immensely strong, structures. By way of examples from nature, kelp in a rocky surf zone can be considered just as resilient as a massive kauri tree in a forest. Incorporating resilient features was a fundamental element of the two Marlborough pump station projects; without resorting to concrete bunker-like structures.

# 2 VERNON STREET SEWAGE PUMP STATION

## 2.1 BACKGROUND

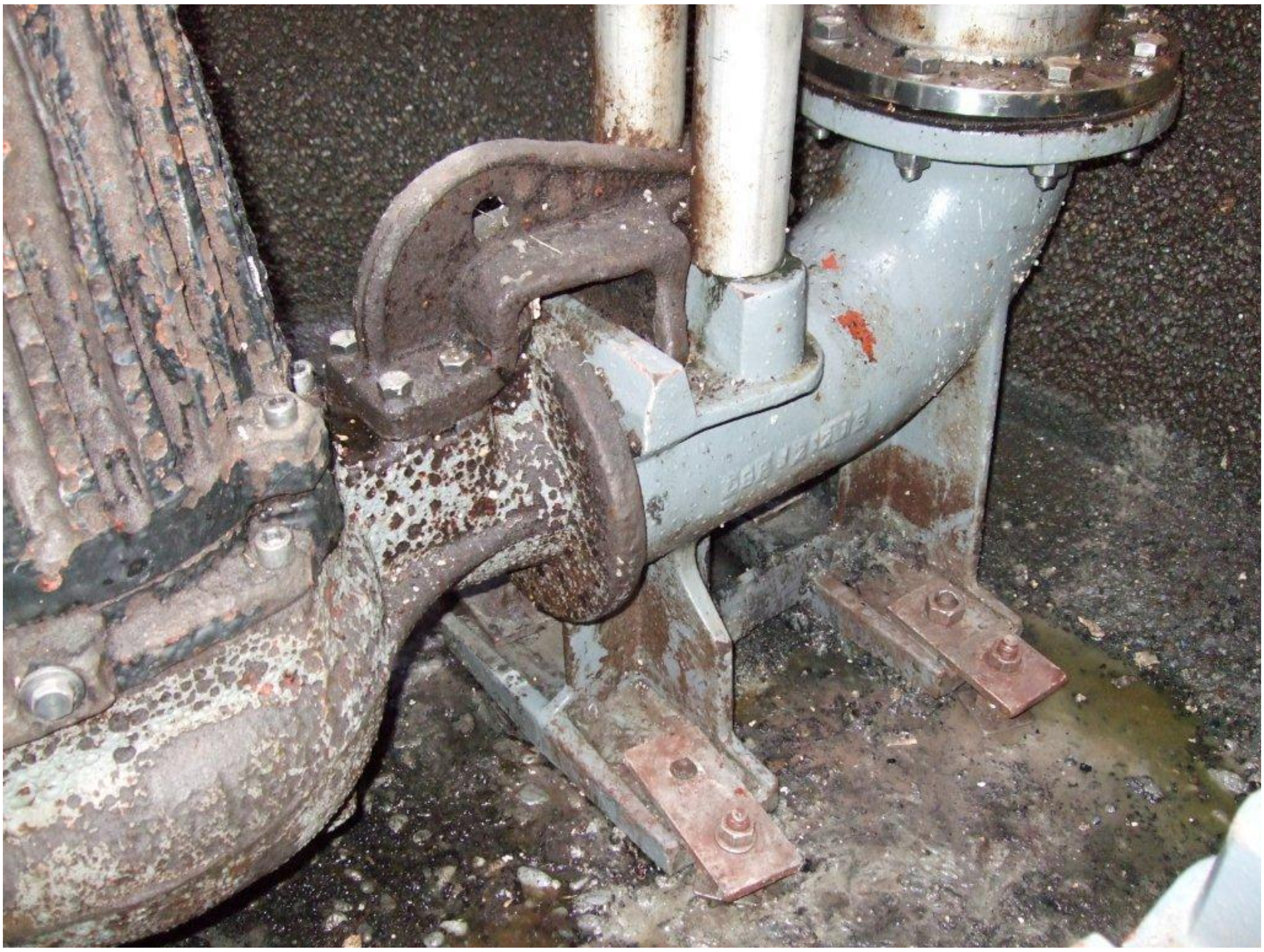
Marlborough District Council’s (MDC) Vernon Street sewage pump station is located within the Riverlands Industrial Estate, immediately to the east of Blenheim. It pumps a combination of sewage and industrial wastewaters received from a gravity catchment within the industrial estate as well as from the nearby smaller Vernon Street South Pump Station. The pump station discharges to the Blenheim Industrial Sewage Treatment Plant (STP) through a pressure main shared with other pump stations.

The previous pump station was constructed in the mid-1990s and had been upgraded in 2005. It comprised a wet well fitted with two 18.5kW submersible pumps operating in a duty/assist configuration, a separate valve chamber and an electrical switchboard enclosed in a weatherproof cabinet.

Continued growth within the industrial estate, particularly related to the wine industry, required upgrade of the pump station. This entailed replacing the wet well and valve chamber to accommodate three submersible pumps in duty/assist/standby configuration. The new wet well and valve chamber were to be installed adjacent to the existing structures, with new connecting piping between the existing inlet and outlet pipes. MDC required that the two existing pumps and existing valves be re-used, in combination with one new matching pump (directly purchased by MDC) and associated valving.

A critical design element was the need for the new wet well and equipment to resist the corrosive effects of the acidic winery wastewater. The previous concrete wet well and pumps had suffered considerable damage as a result of these acidic conditions, as clearly evidenced in Photograph 1 of the surfaces of the nearby Vernon Street South Pump Station. Other key project requirements were to avoid disruption to the Industrial Estate users, both during and following construction activities, and to commission the pump station prior to the grape harvest in early March 2015.

*Photograph 1: Corrosion of pump and concrete wet well at the nearby Vernon Street South Pump Station*



Flow and pH records during the 2013 and 2014 grape harvests (March – April) are summarised in Table 2. Note that pH is only measured at the inlet to the Blenheim Industrial STP, where it regularly falls to below 4.5 during the vintage, with measurements as low as 3.5 having been recorded on occasion. The industrial wastewater will have been buffered and diluted with other flows, albeit mainly other industrial discharges, before it reaches the measurement point. This suggests that the wastewater from the industrial discharges would tend towards the lower end of the measured range. Previous epoxy coating of the pump surfaces by MDC appears to have prevented further damage to the pumps themselves and a corrosion-resistant paint coating was required from the pump manufacturer for the new pump.

*Table 2: Vernon Street Pump Station wastewater flow and pH summary characteristics*

| **Parameter** | **Value** |
|---|---|
| Pump station median flows during vintage (March – April) | 1100 – 1200m³/d |
| Pump station typical flows outside vintage (May – February) | 300 – 400m³/d |
| Maximum design flow | 105 l/s |
| Typical pH during vintage (measured at the Blenheim STP) | 4.5 |

Following MDC tendering of the design, consenting, contracting and construction management services in mid-2014, Beca was selected to provide these services, commencing in mid-June 2014, with construction management sub-contracted to Marlborough Management Services (MMS).

## 2.2 WET WELL OPTIONS

Options for the wet well materials and construction methods were considered early; even during the bid stage. The three considered were:

- a conventional bespoke built-*in situ* RC structure, measuring approximately 2.5m (L) x 2.5m (W) with a wall thickness of 400mm;
- a structure comprising stacked pre-cast 3.5m-diameter RC manhole ring elements, requiring design of only the wet well base and covers; and
- a proprietary GRP wet well of 3.5m-diameter with attached valve chamber.

Whilst the sectional concrete structure would be cheaper and simpler to construct than a bespoke RC structure, it is not possible to obtain a Producer Statement (PS1) when using multiple manhole rings for other than their design purpose. Also, the stacked concrete rings would present challenges in relation to both effective application of protective coating and robustness in the event of seismic events. For these reasons, this option was not considered further in this application. A comparison of the key features of the two other options is provided in Table 3.

*Table 3: Comparison of wet well construction options*

| | **Advantages** | **Disadvantages** |
|---|---|---|
| *Glass-reinforced Plastic (GRP)* | Minimises on-site construction time and dewatering costs | Requires transport from the North Island; large structure for transportation (particularly for ferry crossing of Cook Strait) |
| | Material is resistant to damage from the acidic wastewater | Circular shape requires larger volume of wet well (although this has the benefit of reducing depth) |
| | Lightweight, yet can accommodate a similar level of ground movement to RC structures, requiring less ground improvement for an equivalent working volume | Limited number of suppliers |
| *Reinforced Concrete (RC)* | Use of rectangular shape allows for a smaller structure (although requires base benching) | Acidic wastewater requires protective coating to the concrete or on-going chemical dosing to neutralise |
| | Widely used construction material and techniques opens the procurement to a wider supplier base | Concrete coating is likely to require periodic replacement over the life of the pump station |
| | | Very heavy structures, requiring thick walls; can be problematic in confined sites |
| | | Long construction period in confined space |

Chemical dosing to neutralise the wastewater was considered as an alternative to using corrosion resistant materials and/or protective coatings on vulnerable materials, but was discounted due to the level of control complexity that would be required, the health and safety risks associated with hazardous chemical dosing and handling, as well as the on-going operational cost in labour, chemicals and dosing equipment maintenance.

A cost-comparison of the two options was carried out; indicating that the capital cost for a cast-*in situ* RC structure would be approximately $190,000 whilst that for a pre-fabricated GRP structure would be approximately $155,000. These costs assumed excavation and sheet piling are similar (and so were excluded) and internal fit-out has been excluded from both options.

On the basis of the inherent corrosion resistance and the lower cost, the GRP option was selected for integration into the project design.

## 2.3 PUMP STATION DESIGN FEATURES

Having confirmed the GRP option, the various design features are summarised in the following paragraphs.

In order to accommodate three pumps and provide increased wet well capacity, the wet well diameter was increased from the original 2.3m to 3.5m, while its base was lowered by approximately 250mm from the existing, so that the wet well height was 5.0m, providing some increased wet well capacity and improving the seismic resilience of the facility. Benching has been provided to minimise quiescent areas in the base of the wet well that may otherwise accumulate settled material.

The design of the pump station uses a valve chamber (3m-diameter and 2m-deep) conjoined to the wet well, housing the discharge valves from the three pumps. This has the advantage of occupying less space on site and improving seismic performance. Attaching the valve chamber to the wet well eliminates the potential for differential settlement between structures and reduces the number of pipe penetrations in the structures that could break due to ground movement.

One of the significant differences between the RC and GRP construction options is that the GRP structure can be constructed to close tolerances in a well-controlled factory environment and transported to site as a complete unit. In doing so, the duration of open excavation and dewatering is minimised. Typically, the wet well can be lowered into place and secured in a single day. Although excavation and backfill requirements are similar to a concrete structure, time on site is saved in constructing formwork and placing reinforcement. This provides a safer working environment, with less time required for workers in a confined space excavation.

Previous studies had assessed the site as having a high liquefaction potential during both Serviceability Limit State (SLS) and Ultimate Limit State (ULS) seismic events. Anticipated settlements are summarised in Table 4.

*Table 4: Anticipated vertical seismically-induced settlements at the Vernon Street Pump Station site*

| ***Design Limit State Earthquake*** | **Anticipated Global Settlement (mm)** | **Vertical Differential Settlements across Structure (mm)** | **Vertical Differential Settlement Between Ground Surface and Base of Pump Station (mm)** |
|---|---|---|---|
| *SLS* | 180 | 90 | <25 |
| *ULS* | 300 | 150 | 50 |

To accommodate the potential seismic settlement, the following design features have been provided:

- The wet well invert has been lowered by 150mm and the last length of inlet pipe over-steepened by a similar amount to allow for the anticipated differential settlement between the inlet pipe and the base of the wet well (i.e. settlement of pipe within the non-improved ground beyond that underlying the wet well) in a significant seismic event. Analysis indicates that only 50mm is expected, with the larger installed offset providing a margin against model uncertainty;
- Flexible pipe connections have been provided at the interface with the wet well structure; and slack has been provided in the cables connecting to the pump station, to allow for seismic settlement. Gibault joints have been provided for the pressure pipe connects to provide an easy-to-repair ‘fuse’ if differential settlement exceeds the capacity of the pipe or jointing system;
- Minor rotation of the pump station ($<3^{o}$) during a significant earthquake could occur; unlikely to affect the mechanical performance of the pump station. Some elements, such as the concrete surface slab, may need to be replaced if this rotation occurred;
- To resist uplift forces on the wet well under liquefied conditions, the design of the pump station base slab has been extended beyond the footprint of the wet well.

The GRP wet well is secured to a cast-*in situ* RC base slab; in this case, with dimensions of 5.5m x 5.5m and 400mm thick. Attachment detailing is based on the wet well manufacturer’s requirements. The ‘over-sized’ concrete base compared to the wet well diameter acts both as a foundation and a counter to buoyant forces through the addition of mass and as an anchor acting against the surrounding backfill.

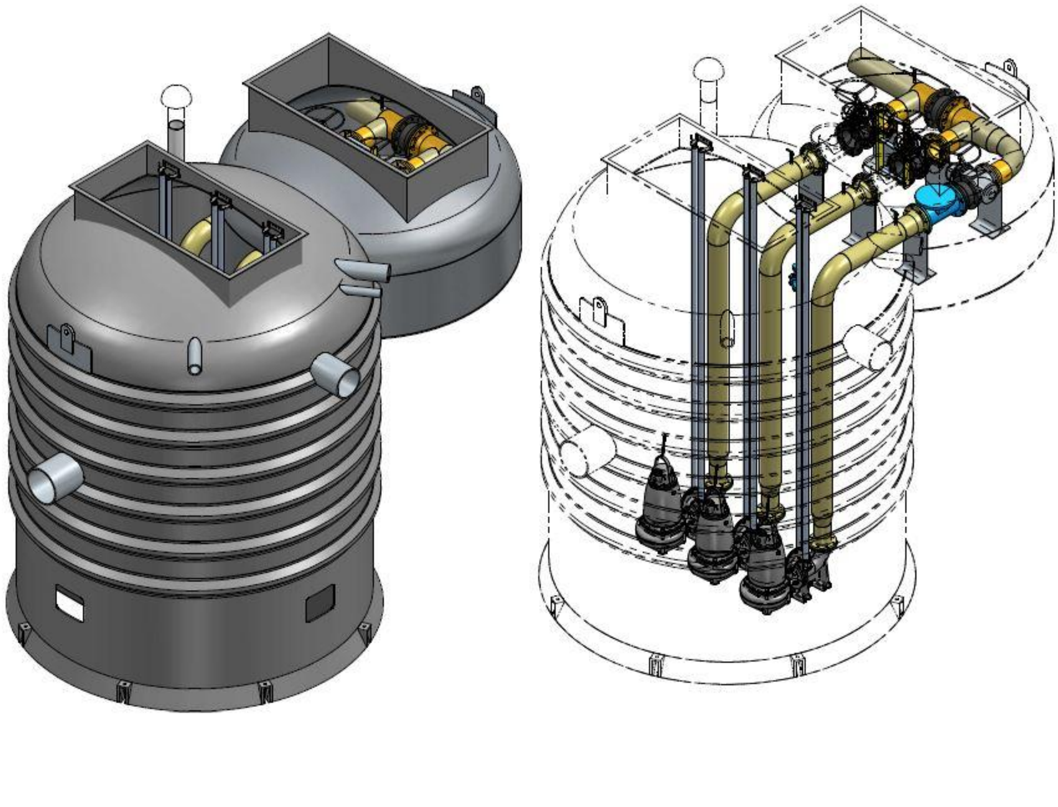
To reduce the effects of liquefaction, the design includes a 500mm-thick layer of hardfill below the wet well, extending 0.25m beyond the base slab wings. The excavation around the wet well has been backfilled with a minimum 1.25m width of hardfill. This reduces the effects of liquefaction on the performance of the pump station chamber. The backfill beneath the valve chamber extends to approximately 1.0m below the floor, with a flowable fill pumped in between, to minimise the potential for differential settlement or rotation of the structure.

## 2.4 PROCUREMENT AND CONSTRUCTION

The other key decision that contributed to a successful project outcome was to separate the wet well procurement from the main construction contract. This option was only made possible due to the preceding decision to select the GRP wet well option; neither of which had been envisaged by MDC at the time of tendering. Separating out the wet well procurement allowed the two contracts to run in parallel, rather than having a single construction contractor procure the wet well, following award of the construction contract; effectively, the two contracts being in overlapping series. With the hard deadline of the grape harvest in early March, it is unlikely that either (a) building a RC structure on site, with an anticipated 4 – 6-week construction period, or (b) procuring the construction contract and a GRP pump station via a single contractor, with a significant lead time for wet well fabrication, would have achieved this deadline.

The two separate contracts were managed by Beca, using MDC contract documents. Following specimen design, the wet well contract was tendered in early September 2014 to selected specialist proprietary GRP wet well fabricators, with the contract awarded to Maskell Productions Ltd in mid-October 2014. Fabrication methodology is a critical aspect of the strength and resilience of a GRP wet well. The full structural loading calculations were provided with the tender documents, enabling Maskell to engineer a suitable glass fibre and resin mix, along with the wall thickness, for fabrication. Without divulging commercially sensitive information, the GRP walls are 18mm thick, with integral ribs providing structural rigidity. Isometric sketches of the supplied wet well are shown in Figure 1. The contract specified a commissioning date of no later than 6 March 2015, requiring the wet well delivery to be in mid-February 2015. The main construction contract was tendered in mid-September 2014 to invited civil construction contractors and the contract was awarded to Crafar Crouch Construction Ltd in late October 2014.

*Figure 1: Isometric views of the Vernon Street GRP Pump Station (provided by Maskell Productions Ltd)*



Not only can the GRP wet well structure be pre-fabricated, it can be pre-fitted with most mechanical items before transportation to the installation site. In this case, the wet well supply contract required that the pump guiderails and duckfoot bends, valve chamber valves, piping and access ladder, be purchased and fitted into the GRP structure (as illustrated in Figure 1). Based on good experience at SCIRT, McBerns safety access covers were also specified.

During the contract period, careful attention was paid to both co-ordinating the delivery of the wet well so that it arrived in timely fashion when the base was ready for the installation, and making sure that the base slab hold-down points aligned with the wet well base connections. In the event, the wet well was delivered, from Auckland to Blenheim (including the ferry crossing of Cook Strait), on the back of a low-loader vehicle on the due date of 11 February 2015. Similarly, the unit was able to be lifted off the vehicle, straight onto the slab base, with the hold-down points lining up precisely. The off-loading manoeuvre is illustrated in Photograph 2.

Once bolted down to the base slab, the remaining work was straightforward to complete. Essentially, the excavation was backfilled, pumps were installed, piping connected and electrical connections were made. The pump station was commissioned over the weekend of 28 – 29 February 2015, without issue, and has been in full use since, with the old pump station now demolished.

Total cost for the contract works, including wet well supply, was approximately $485,000.

*Photograph 2: The wet well and conjoined valve chamber being off-loaded from the low-loader vehicle onto the prepared base at Vernon Street Pump Station, Blenheim*

# 3 PICTON SEWERAGE UPGRADE PUMP STATIONS

## 3.1 BACKGROUND

MDC is in the process of upgrading the existing trunk sewer network in Picton. The upgrade extends between Waikawa and the Picton Sewage Treatment Plant (Picton STP), being undertaken through a project known as the 'Picton Sewerage Upgrade'. The primary purpose of the upgrade is to increase the network's capacity. In so doing, the objective is to significantly reduce, although not completely eliminate, overflows of untreated sewage to waterways and the coastal marine area in Picton. This, in turn, will reduce health risks and environmental impacts associated with untreated sewage overflows.

Trunk gravity sewers and pressure mains, totalling approximately 3.3km in length, are being replaced, along with replacement of existing sewage pump stations and marine outfall in Picton Harbour. In addition to the increase in network capacity, basic sewage treatment will be provided for a proportion of the flows, received during wet weather events, which exceed the capacity of the new terminal pump station site at Dublin Street. The part-treated storm flows will discharge to the marine outfall. All the new facilities are sized to meet future design flows and wet weather events to the year 2130.

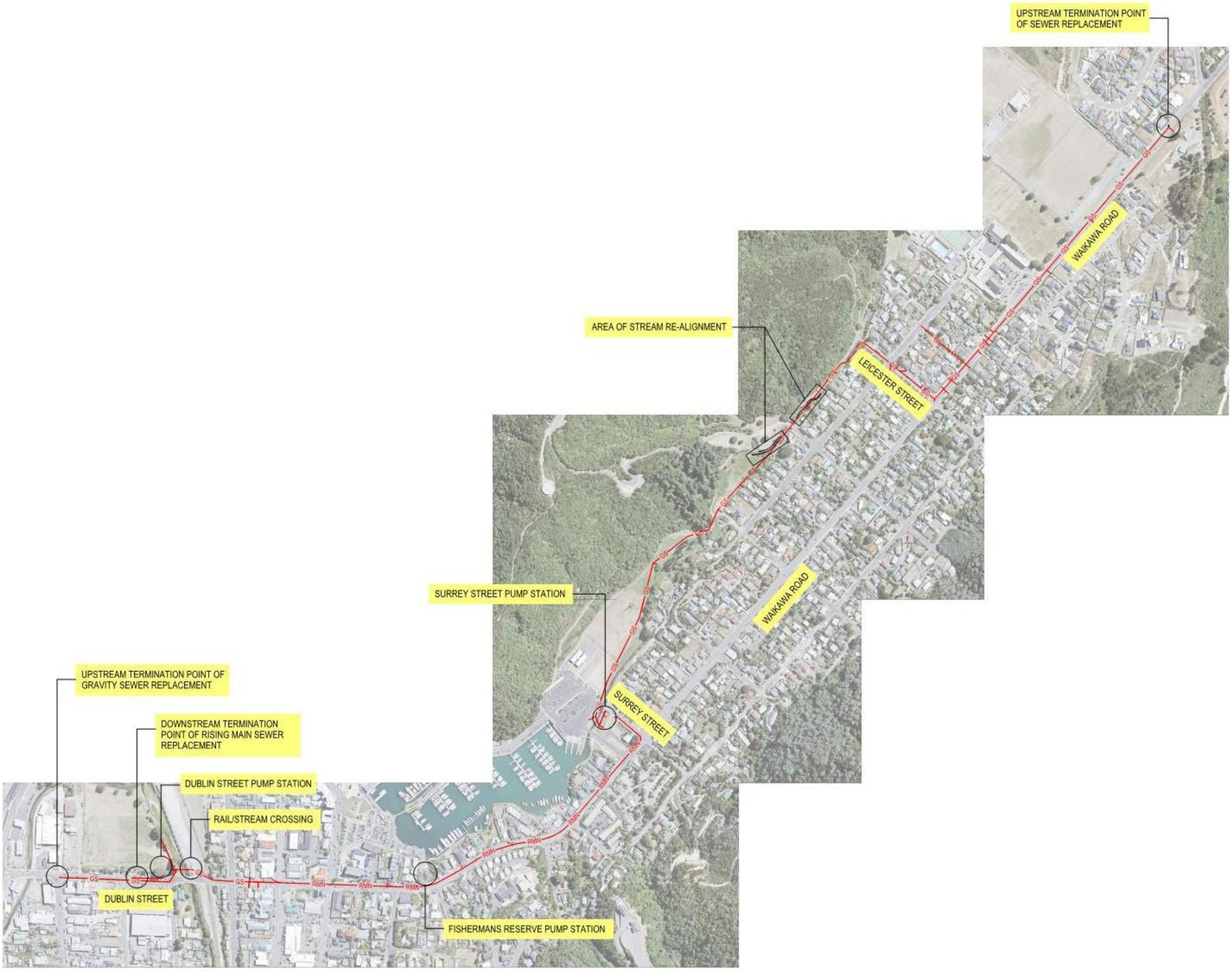
Beca won a competitive tender to provide consultancy services to MDC for the design, consenting, tendering and contractor management, construction monitoring and commissioning for the upgrade. Following appointment in January 2011, preliminary design was completed in August 2011. To meet MDC's budgetary programme, the upgrade has been split into four stages. Stage 1; the replacement discharge landline and marine outfall, was commissioned in December 2012. Resource consent applications were then lodged for the remaining construction and operational activities, with consents being granted in early to mid-2014. Detailed design for Stages 2 and 3 commenced in late 2014. These two stages, being the subject of this paper, comprise the following elements:

- **Stage 2:** Design, construction and commissioning of a new sewage pump station at Dublin Street, approximately 50m from, and replacing, the existing Dublin Street Pump Station. The new Pump Station site comprises a number of elements:
  - a Main Pump Station, being the network's terminal pump station, transferring sewage to the Picton STP for treatment;
  - a Bypass Pump Station, operating intermittently in receiving flows in excess of the capacity of the Main Pump Station;
  - a Bypass Treatment Facility (BTF) where flows from the Bypass Pump Station will be screened and disinfected with ultraviolet (UV) light to achieve partial treatment;
  - an Outfall Pump Station receiving the partially-treated sewage from the BTF for pumped discharge to the marine outfall in Picton Harbour.
- **Stage 3:** Design, construction and commissioning of the following elements:
  - a new sewage pump station at Fishermans Reserve and sewage overflow storage facility, adjacent to the location of, and replacing, the existing Fishermans Reserve Pump Station;
  - a new sewage pump station at Surrey Street, immediately adjacent to, and replacing, the existing Surrey Street Pump Station;
  - a new replacement rising main from Fishermans Reserve;
  - a new replacement gravity main into Surrey Street, along with a new replacement rising main out of it.

An overview location plan of the Stages 2 and 3 Upgrade is shown in Figure 2.

The Stage 4 elements; replacement pump stations at the two upstream sites at Beach Road and Waikawa Wharf and associated sewers, are scheduled for design in 2017/18 and construction in 2018/19.

*Figure 2: Overview location plan of the Picton Sewerage Upgrade (Stages 2 and 3)*




## 3.2 PRELIMINARY PUMP STATION DESIGN

At the preliminary design stage, the three pump stations associated with Stages 2 and 3 were proposed to be constructed as follows:

- Dublin Street Pump Station – a single combined RC structure, encompassing all three separate wet wells and an interconnecting overflow channel, measuring approximately 8.0m (L) x 10.5m (W) x 7.5m (D), including provision for 500mm-thick external walls and floor slab. It assumed construction utilising a caisson structure. In addition, valve chambers for the Main Pump Station and Outfall Pump Station measured approximately 3.5m (L) x 3.0m (W) x 3.5m (D), and 5.0m (L) x 4.0m (W) x 3.5m (D) respectively;
- Surrey Street Pump Station – a RC wet well structure, measuring approximately 6.2m (L) x 7.5m (W) x 6.7m (D), including provision for 500mm-thick external walls and floor slab. The valve chamber was designed as a separate RC structure; measuring 3.6m (L) x 5.7m (W) x 2.7m (D). Construction was designed to be staged such that the new pump station was built adjacent to the existing, before effecting the changeover, then demolishing the existing, with that area then used to install the required odour biofilter;
- Fishermans Reserve Pump Station – a small packaged GRP pump station, of 1.2m diameter and 4.2m depth, with separate concrete valve chamber, measuring 2.75m (L) x 2.0m (W) x 2.6m (D).

A notable feature is that the redevelopment of the Surrey Street Pump Station attracted considerable interest when the Notice of Requirement for a new designation over the site was publicly notified in late 2013. The resulting designation imposed tight restrictions on the appearance, bulk and height of the proposed buildings and the site landscaping.

## 3.3 DETAILED PUMP STATION DESIGN

Between completion of preliminary design in 2011 and commencement of detailed design in 2014, additional population projections and hydraulic modelling indicated certain significant reductions in design flows. The combination of these reduced design flows, as well as the intervening period having coincided with the post-earthquake Christchurch environment, provided both a challenge and an opportunity. On one hand, certain elements of the design needed to be scaled back to account for the reduced flows. On the other, the SCIRT learnings, along with the local experience from the Vernon Street installation, were able to be incorporated into the design. Rather than simply tweak the design, a more radical concept was developed. Much of the preliminary design was effectively discarded, with GRP wet wells incorporated into the design for all three Dublin Street pump stations and the Surrey Street Pump Station. More minor changes were incorporated into the smaller Fishermans Reserve site, which had already been based on GRP design. Summary details of the changes are shown in Table 5.

The significant geotechnical hazards posed to the pump stations and associated infrastructure have been identified as lateral spread, seismic settlement and both hydrostatic and seismic buoyancy. Anticipated settlements are typically somewhat less than those for the Vernon Street site. The recommended foundation solution incorporated into the detailed design for all pump station sites comprises (a) an extended base slab with minor ground improvement provided by excavation of soils with liquefaction potential, and (b) replacement with granular hardfill to provide lateral support and limit buoyant uplift. Vertical effects of liquefaction are mitigated by founding the pump stations within the non-liquefiable soils beneath. This pragmatic low to moderate-cost engineering solution improves resilience and performance. Flexible pipe materials and connections, along with geogrid reinforced gravel rafts beneath shallow foundations also improve the seismic performance. The pump stations are expected to be serviceable following a SLS design event, while for a significant earthquake, minor to moderate damage will be sustained. Following a ULS design earthquake, if pump station functionality is lost, it is expected that it could be reinstated within a period of days to weeks.

The design features of the Dublin Street and Surrey Street pump station sites are discussed in the following sub-sections (the Fishermans Reserve installation is not discussed due to its small scale and similarity to the original design).

*Table 5: Summary comparison of the preliminary and detailed design features of the Picton pump station sites*

<table>
<tr><th colspan="2"></th><th colspan="2">Preliminary Design Stage</th><th colspan="2">Detailed Design Stage</th></tr>
<tr><th colspan="2"></th><th>Structure</th><th>Flow (l/s)</th><th>Structure</th><th>Flow (l/s)</th></tr>
<tr><td rowspan="3">Dublin Street P/S site</td><td>Main P/S</td><td rowspan="3">Single combined RC structure with three wet well compartments, linked by inlet overflow channels. Separate RC valve chamber</td><td>130, two pumps</td><td rowspan="3">Three separate GRP wet wells fed by a GRP inlet chamber, with gravity overflow ports at different levels. Above-ground discharge valving</td><td>130, two pumps</td></tr>
<tr><td>Bypass P/S</td><td>440, three pumps</td><td>260, two pumps</td></tr>
<tr><td>Outfall P/S</td><td>260, two pumps</td><td>260, two pumps</td></tr>
<tr><td colspan="2">Surrey St P/S</td><td>RC wet well with separate RC valve chamber</td><td>370, three pumps</td><td>GRP wet well with conjoined valve chamber</td><td>205, two pumps</td></tr>
<tr><td colspan="2">Fishermans Reserve P/S</td><td>GRP wet well with separate RC valve chamber</td><td>15, two pumps</td><td>GRP wet well with conjoined valve chamber</td><td>18, two pumps</td></tr>
</table>

### 3.3.1 DUBLIN STREET PUMP STATION SITE

Although only the Bypass Pump Station has seen a reduction in design flows, and a consequent change from a 3-pump wet well to a 2-pump wet well, the opportunity was taken to re-consider the entire layout for all three pump stations. Now, the design comprises three separate GRP pump stations, within approximately the same footprint as the original massive concrete structure, linked by a separate GRP Inlet Chamber. The preliminary design and detailed design pump station layouts are shown in Figures 3 and 4 respectively.

*Figure 3: Dublin Street Pump Station site plan layout at preliminary design stage (wet wells and inlet channel structure in the centre and discharge valve chambers to the left)*

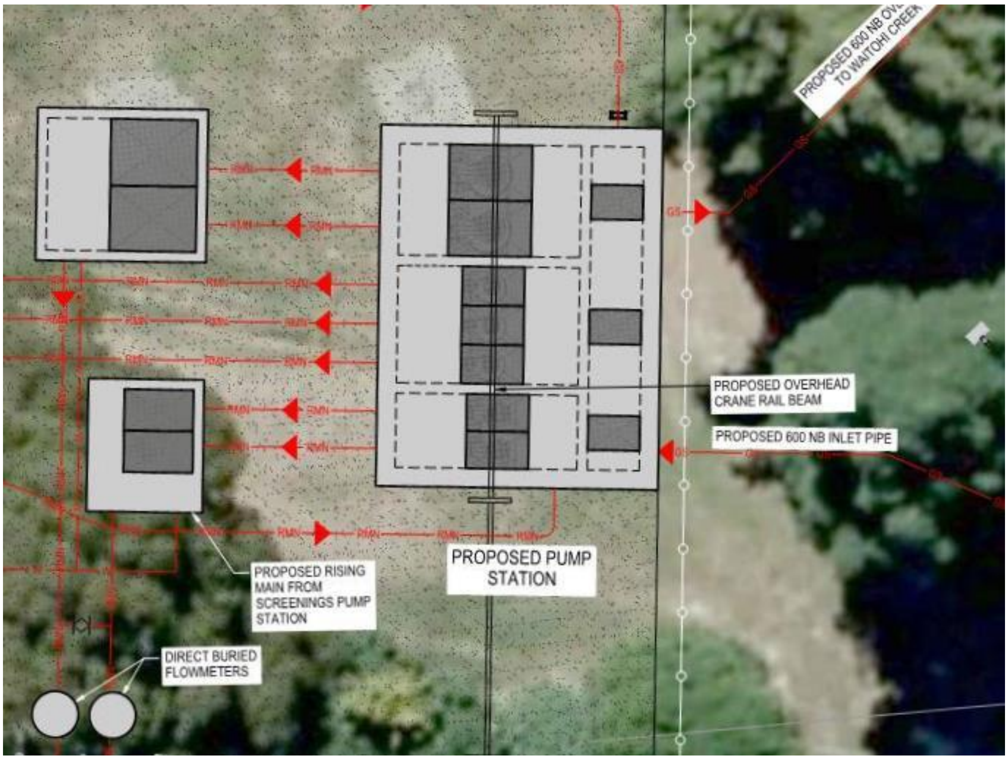
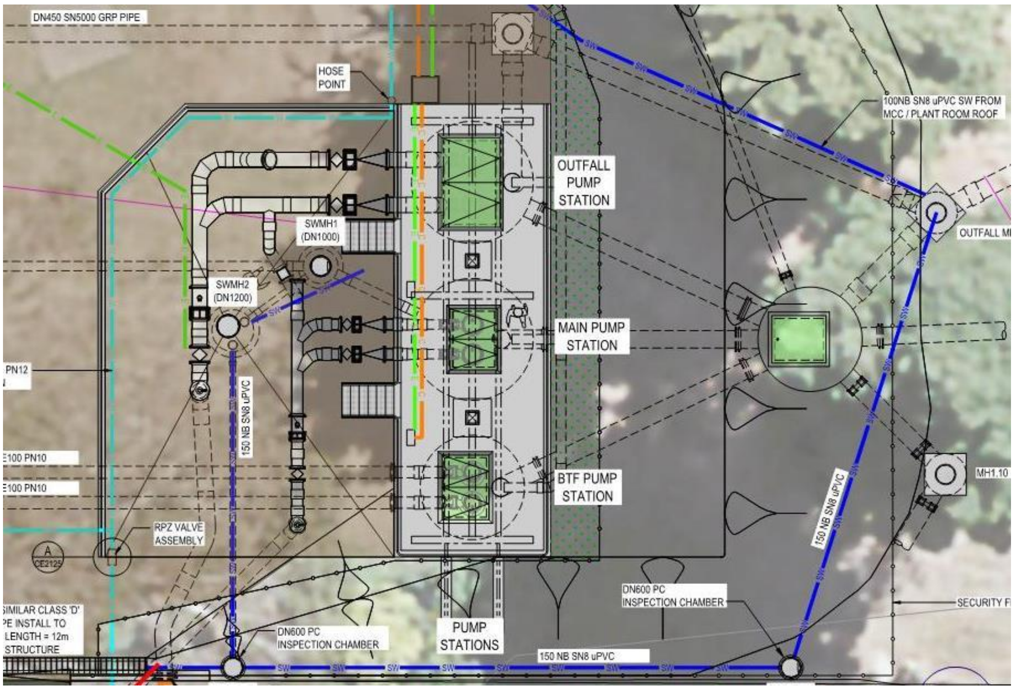



*Figure 4: Dublin Street Pump Station site plan layout at detailed design stage (wet wells in the centre, Inlet Chamber to the right and above-ground discharge piping to the left)*



Before proceeding with such a significant change to the design, Beca's quantity surveyors provided a cost analysis to estimate the cost-benefit of the GRP option to the project team. The analysis estimated savings of around $900,000 in using GRP wet wells, compared to the originally-proposed RC structure. Notably, this costing did not take account of any required ground improvements; which would have been more extensive for the more massive concrete structure. Besides the cost savings, there are the same site safety benefits, and commensurately larger construction time benefits, that were seen at Vernon Street, as previously discussed on Section 2.3.

The wet wells of the Main Pump Station and the Outfall Pump Station are both 3.5m diameter, while that for the Bypass Pump Station is 3.0m diameter. They are all some 6.3m tall (base to access hatch) and are positioned and bolted down on a common RC base slab, measuring 13.75m (L) x 5.5m (W); 400mm thick. All three pump stations incorporate McBerns pump station safety lids; having been well-received in SCIRT installations and that for Vernon Street. The working platform is elevated to achieve the required flood level protection. It has the secondary function of enabling the elimination of discharge piping valve chambers; utilising above-ground support of pipes and valves to facilitate easy access to fittings for operation as well as for repair/replacement in the event of seismic damage. The Christchurch earthquakes have demonstrated the benefits of above-ground access to damaged couplings.

### 3.3.2 SURREY STREET PUMP STATION SITE

With the design flows at the Surrey Street Pump Station site having reduced by approximately 45% since preliminary design, significant changes have been required for the pump station. Consequently, instead of three pumps in duty/assist/standby configuration, detailed design is on the basis of two pumps in duty/standby configuration. The now-proposed wet well is much-reduced in size at 3.5m in diameter and 6.8m deep, with a conjoined 3.5m diameter valve chamber, 4.25m deep. The pump station will be pre-fitted with guiderails, duckfoot bends, internal piping, complete with flanges and valves and will incorporates McBerns pump station safety lids. It will be bolted to a 5.5m (L) x 5.5m (W) RC slab, 400mm thick.

Through a combination of the reduced flows and the use of the smaller-footprint GRP wet well and conjoined valve chamber, the site layout has been able to be revised to achieve multiple benefits for construction time and cost, as well and for on-going operability. The reduced disruption during construction will be a significant benefit at this site where neighbour relationships will be key, as identified in Section 3.2. The preliminary design and detailed design site layouts are shown in Figures 5 and 6 respectively, with the main features summarised below:

- **Site positioning** – It is now proposed to compress the site, with the northern boundary moved approximately 8m to the south (i.e. set-back from the road), within the designated area. This is primarily to avoid the existing pump station and, hence, avoid staging of the works in building the biofilter over the existing pump station (once demolished). The change will reduce the construction period (i.e. reducing neighbour disruption) and position the structures further away from the properties on the other side of the road. The area in front (to the north) will be landscaped, both with plantings and provision of a slope up to the site;
- **Site elevation** – The original design was for the whole site, including access roadway, to be built up above the surrounding ground and above the existing public road, providing required flood protection. It is now proposed that only the pump station site proper will be elevated on a platform, while the site's access roadway will be elevated by only 400mm above the public road. This will facilitate pump removal directly onto flat-bed vehicles, whilst reducing the visual impact for neighbours. Heights will not exceed the threshold required by the site's designation;
- **Site access** – The access roadway will be re-oriented slightly to facilitate access for large vehicles if/when large, heavy, equipment needs to be lifted from the site. The original access configuration would be tricky to get a vehicle on to site, particularly considering the originally proposed slope up into the site. The site proper (i.e. pump station boundary) will remain in the same position;
- **Building positioning** – With the site being compressed to the southern end, the buildings will also be set well back from the road. The closest above-ground structures to the road will be the transformer and generator (approximately 8m from the road at its closest point), as opposed to the MCC Room in the original design (approximately 4m from the road at its closest point);

*Figure 5: Surrey Street Pump Station site plan layout at preliminary design stage*

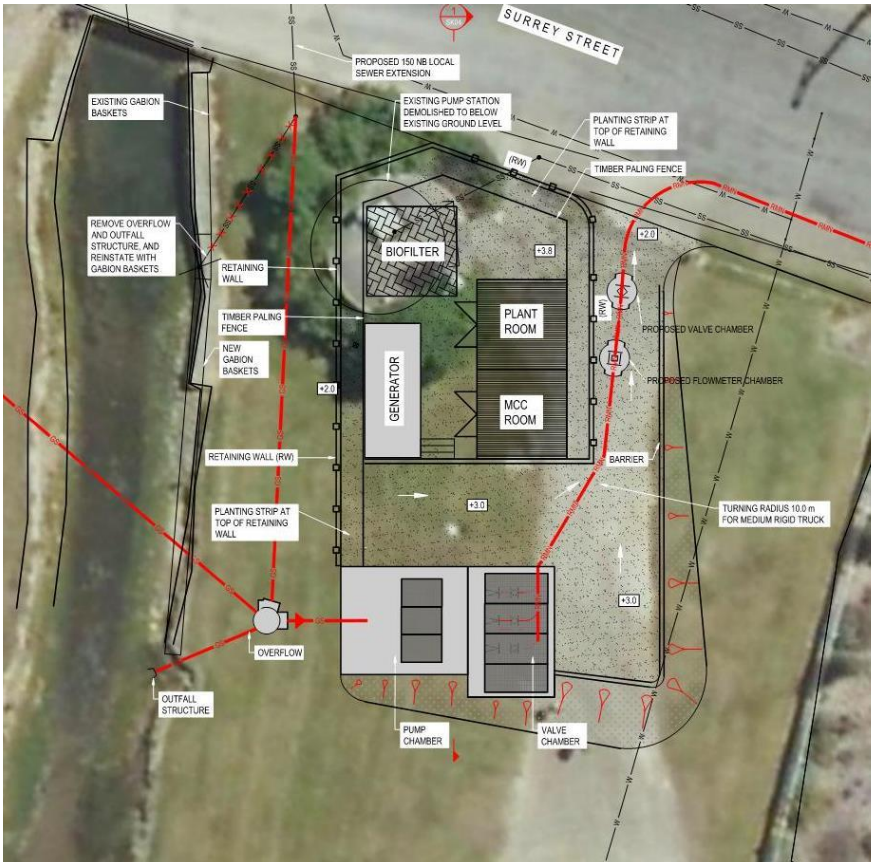
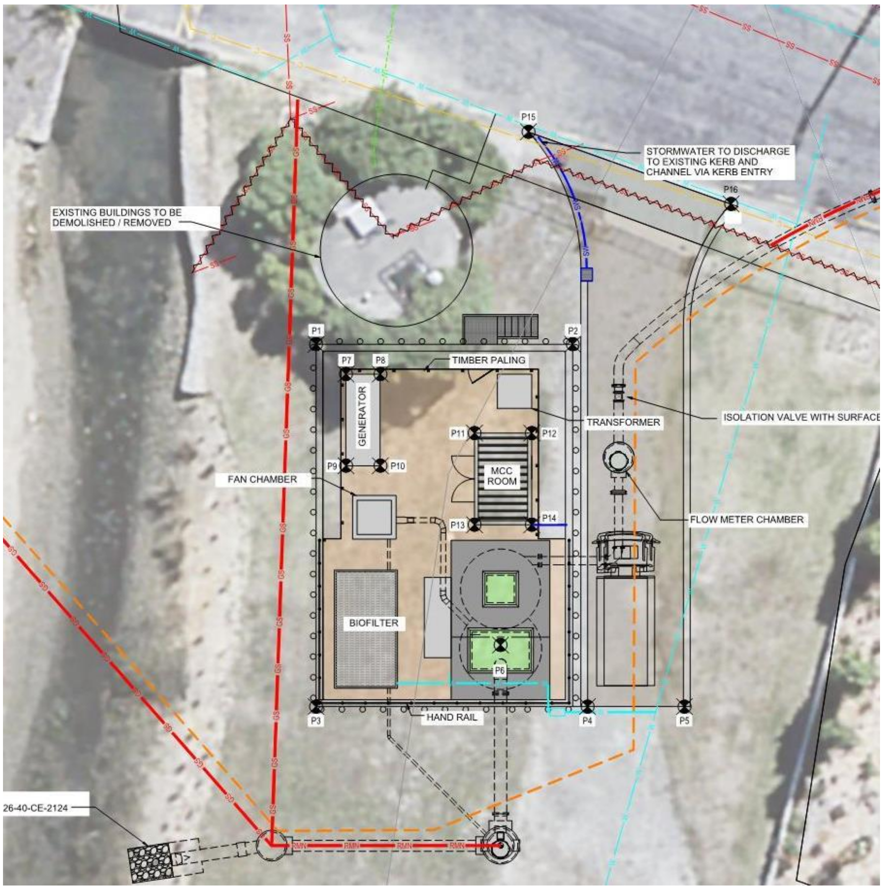



*Figure 6: Surrey Street Pump Station site plan layout at detailed design stage*



- **GRP pump station** – The pump station itself will be changed from a built-*in situ* RC structure to a GRP unit which will be fabricated off-site and craned into a prepared excavation with concrete base slab. This will reduce the pump station footprint and significantly reduce the construction time; both providing positive benefits for neighbours;
- **Landscaping** – The site's landscaping will essentially remain as shown on the original landscaping plan, taking into account the compression of the pump station site boundary which will increase the depth of plantings between the roadway and the pump station boundary to 6 – 10m.

### 3.4 CURRENT STATUS

Taken as a whole, the re-design of the three Picton pump station sites has generated estimated savings of over $1Million.

As noted in the Introduction, at the time of writing, detailed design of Stages 2 and 3 of the Picton Sewerage Upgrade is now complete. The tender process is underway for the construction contract, as well as the fabrication of the pump stations, along with other key items of equipment. Once contracts are let, it is expected that construction will be undertaken over approximately 12 months.

## 4 CONCLUSIONS

This paper has focused on the benefits of using GRP structures for new and replacement pump stations instead of conventional built-*in situ* concrete structures. Although the two case studies had different drivers, common benefits have been delivered. Being pre-fabricated in a factory environment, GRP pump stations can be produced to a high level of tolerance and can be pre-fitted with most mechanical equipment. Corrosion resistance is an inherent feature; eliminating the need for protective coatings or on-going chemical dosing that may be required with concrete structures. Site works and dewatering are much less extensive, with less time for construction staff to be working in confined space excavations and less neighbour disruption. Installation entails little more than off-loading the pump station, directly lowering it onto a pre-formed base, bolting it down at pre-marked hold-down points, back-filling, making the pipework connections and powering it up. For permanent underground municipal infrastructure, this is about a close as we can get to a plug-and-play installation. Moreover, significant cost savings have been demonstrated.

Resilience is a key consideration in our post-Christchurch earthquake design environment. The two case studies have demonstrated that, with a good understanding of the effects of seismic events on underground infrastructure, lightweight structures can be designed to be just as resilient, if not more so, than massive concrete structures.

On a more fundamental level, though, the two projects have been built around bold, yet smart, decisions made by the project teams to achieve best-for-project outcomes for the client.

In the case of the Vernon Street Pump Station, the key decisions were choosing a GRP pump station at the concept stage and then to separate the wet well procurement from the construction contract; neither of which had been considered by the client when the design was tendered. These decisions led to the project being delivered early of the tight deadline and under-budget, with the pump station commissioned seamlessly.

For the Picton pump stations, the key decision was in applying the post-earthquake learnings from SCIRT in Christchurch, going right back to concept design at the detailed design stage; effectively discarding much of the preliminary design, in coming up with a new, resilient design. Despite requiring some re-work, this decision has generated a significant reduction in capital expenditure, and will lead to a shorter construction timescale, as well as a less disruptive environment for neighbouring residents.

The projects demonstrate the value-add that design consultants can bring to bear on municipal infrastructure projects. With some additional design and project management work to co-ordinate separate fabrication and construction contracts, significant savings can be made in construction time and cost, as well as providing a safer working environment and less disruption for neighbours. Equally, the projects demonstrate the benefits of close working relationships between consultants and clients, and the pre-requisite mutual trust, in going beyond conventional solutions and being adaptable, if not resilient, in changing designs in the light of altered conditions. In doing so, cost-effective project delivery for our communities can be achieved.

## ACKNOWLEDGEMENTS

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