DALDY STREET OUTFALL

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ABSTRACT (500 WORDS MAXIMUM)

To install the largest pipe laid in New Zealand, five metres deep, through contaminated ground, and under tidal conditions was a challenge in itself. To do this whilst precluding entry into the trench during installation seemed like too great an opportunity to miss. Plain sailing for the Wynyard Edge team!

As a variation to the Americas Cup infrastructure project, this critical element of work involved installation of 510 metres of 3.5 metre diameter HDPE pipe, under tidal conditions. Key to the success of the project was the innovative temporary works specifically designed for the challenging conditions - installation of a cutter soil mixed retaining wall to support the excavation, the installation of concrete cradles to support the ends of each pipe in the excavated trench, supporting the cradles on inflated grout bags under water, and sinking the lightweight pipes below the rising / falling tide.

More importantly, the whole process was designed to preclude entry into the trench during installation, a huge safety benefit. The pipeline also included a new featured outfall with a darkened, patterned face blending it in with the surrounding basalt breakwater. The project was completed on time, under budget and incident free with a delighted Client - the innovative temporary works being critical to its success.

KEYWORDS

Drainage, ground stabilisation, contamination, tidal conditions, innovation

PRESENTER PROFILE

David is an accomplished civil engineer with over 35 years' construction industry experience in New Zealand and the UK spanning the transport, water, utilities, and civil infrastructure sectors. He led the development and relocation of Daldy Street Outfall as part of the America's Cup 36 works.

INTRODUCTION

Auckland Council's Healthy Waters division owns and maintains Daldy Street Outfall, which discharges approximately one third of Auckland CBD's stormwater into Wynyard Basin, the location for several AC36 syndicate bases. Tranquillity of Wynyard Basin was a functional requirement of AC36, and the outfall would have compromised this requirement.

The existing discharge point was at the junction of Wynyard Wharf and North Wharf, adjacent to the old SeaLink facility. A decision was taken to extend the pipeline along the full length of Brigham Street, discharging water into Waitematā Harbour via a new outfall structure.

Figure 1 – extension of Daldy Street Outfall

With construction of AC36's infrastructure underway, in particular the new syndicate bases on Wynyard Point, it became apparent that any relocation of the pipeline would need to be undertaken concurrently. As such, Daldy Outfall was added to the scope of AC36. An outline design was developed, target cost agreed, and a variation issued for the additional works.

The project involved a technically challenging ground stabilisation system and installation of what is believed to be the largest diameter pipe ever laid in New Zealand through contaminated land and in tidal conditions – all delivered in the middle of AC36 construction and to extremely tight timescales.

WEA's engineering, temporary works, and construction teams worked collaboratively to develop a highly technical solution which removed the need for entry into the trench. Overall, the team delivered a safe, sustainable, and cost-effective solution for Auckland.

1 DISCUSSION

1.1 INTRODUCTION

1.1.1 Wynyard Point

Wynyard Point is a peninsular on the north west corner of Wynyard Quarter, Auckland CBD, that was reclaimed 100 years or so ago from the Waitematā Harbour. The area is bounded by Brigham Street to the east and Hamer Street to the west. A basalt breakwater was constructed around its perimeter, a concrete seawall cast on top, and then infilled with excavated arisings (from the early CBD development) and hydraulic fill / dredged arisings (from the sea). Once capped off, the area was developed as an industrial site, with gas works, fuel storage tanks etc occupying the site. The ground has substantial quantities of hydrocarbons, fuel oils, asbestos, 'blue billy' (by product from gas works), scrap steelwork and various other obstructions. Work carried out for ground stabilisation and pipe installation was therefore considered a dirty zone involving the use of disposable overalls / gloves / air monitoring.

1.1.2 Relocation

The Daldy Street Outfall discharges into Wynyard Basin at the south east corner of Wynyard Point, adjacent to the old SeaLink ferry terminal. Scope for the AC36 project, amongst other things, required the need for tranquillity in Wynyard Basin and the possibility of storm water overflows into the Basin, from the Daldy Street Outfall, were considered undesirable. The outfall had to be relocated and following investigation of several possible locations, the northern tip of Wynyard Point was selected – this involved the extension of Daldy Street outfall some 510 metres along the entire length of Brigham Street. The new outfall would discharge directly into the Waitematā harbour, maintaining tranquillity of Wynyard Basin. Furthermore, with the obvious clash between Daldy St and AC36's syndicate bases, the only viable solution was for the WEA to execute the works directly as a variation to the AC36 contract, thus managing the interface with AC36 works. The outline design was developed, target cost provided and ultimately agreed, and a variation issued for the additional works.

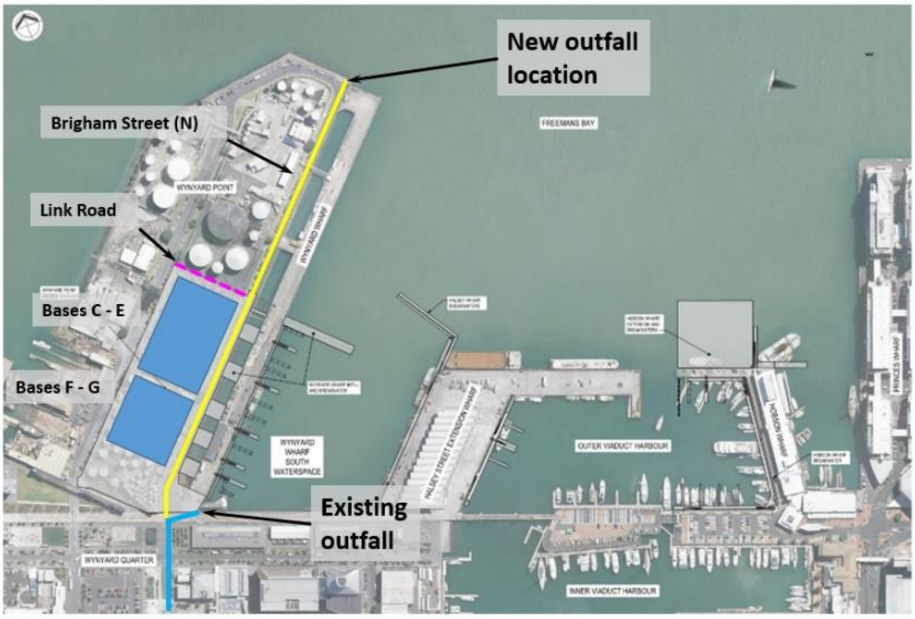

Figure 2 – extension of Daldy Street Outfall

1.1.3 Site investigation

The first step of the design process was to initiate a detailed programme of geotechnical investigation. The focus of this was to determine the location and extent of the basalt breakwater along the eastern edge of Brigham Street, the location and extent of an old haul road believed to be formed along the back of the basalt breakwater, the physical properties of the backfill material used to construct Wynyard Point, contamination levels, information on water levels, integrity of the existing seawall, and anticipated construction loadings. Additionally, information relating to utility services was collected – this revealed a major issue with a fire-fighting water main which would need to be diverted / relocated several times during the construction phase in order to maintain a firefighting provision for the adjacent Stolthaven tank farm and Wynyard Wharf.

1.2 DESIGN

1.2.1 Pipe design

Analysis by the hydraulics team quickly identified that a pipe diameter of at least 3,000 mm would be required. The existing pipeline in Daldy Street was 2,700 mm diameter with little / no fall due to the reclaimed land within which it was laid. Furthermore, there existed very little driving head to flush the pipe, and with it being so close to the harbour, the pipe was subject to tidal flows. The maximum diameter concrete pipe available in New Zealand was 3,050mm (concrete) with an effective length of 2,700 mm – this would have complicated the connection detail and slowed the laying process down considerably. In addition, nearly 200 number pipes would be required, thus adding to the carbon footprint associated with manufacture and subsequent delivery into the CBD.

The final design landed on a 3,000mm pipe for the upstream half of the extension, and a 3,500mm pipe for the downstream half, and with concrete not being a viable option, an HDPE solution was pursued. The main advantage of HDPE pipe is that it is made from an extruded rectangular section (wound onto a mandrel) with the rectangular section effectively producing a void within the pipe wall - this makes it extremely light, whilst remaining very strong. Additionally, it is extremely flexible, with manhole sections, lateral connections and an expansion piece all capable of being factory produced. The pipe could be supplied in 15 metre lengths which would greatly assist in the installation process, speed up production, and provide a better Health & Safety solution.

Following numerous discussions, an order was placed with Uponor with fabrication done in their Thailand factory. After a 10-week fabrication programme, the pipes were transported by ship and delivery made directly into Wynyard Wharf, adjacent to Brigham Street. 200 truck journeys into Auckland’s CBD had been avoided, providing a more desirable environmental solution.

Figure 3 – HDPE pipe arrives from Thailand

A key feature of the pipeline design was the connection detail between adjacent pipes. A mechanical connection between pipes of this size was not possible, so a concrete cradle / saddle arrangement was designed with macalloy bars used to effectively clamp the sections together. A strip of EVA was detailed across the joint to maintain as good a seal as possible – not essential but seen as good practice.

1.2.2 Stabilisation

Initial stages of design concentrated on the ground support required for the 5 m-deep excavation. With the basalt breakwater running along the eastern edge of the proposed trench, traditional double row sheet piling was not an option. A second option of providing a single row sheet pile (to the landward side) and tying back proved unworkable as the strength of the reclaimed land would not support any type of tie-back or anchor.

The preferred option soon became an in-situ mass stabilisation, formed by mixing grout with the existing ground, effectively forming a low strength 'concrete' mix. The concept was to treat the full 12 metre width of Brigham Street, then to dig through the treated ground to lay the pipe. However, a trial of the method failed due to a lack of penetration through the fill – the equipment was not powerful enough. The design would have to be re-thought.

At this stage we sought advice from an international ground engineering expert who introduced the team to the "Cutter Soil Mixing" (CSM) method. The method utilises a powerful drill rig, with cutter heads mounted on a kelly bar, which are driven into the ground – grout is injected behind the cutter heads as they descend, mixing the grout with the in-situ ground – similar to the initial mass stabilisation method, just more powerful. The treated panels produced are 2.4 m long and 1.0 m wide (plan area of cutter head) and can be installed as deep as the kelly bar.

Figure 4 – CMS methodology

This methodology was adopted and the ground stabilisation developed. The completed design utilised four abutting rows of CSM panels running the entire length of Brigham Street. The CSM block would support the ground to the west of the excavation during pipe excavation / install. Furthermore, the mixing of existing ground with grout reduced the volume of excavation, and consequently the volume of contaminated material, to dispose off-site – a more sustainable solution.

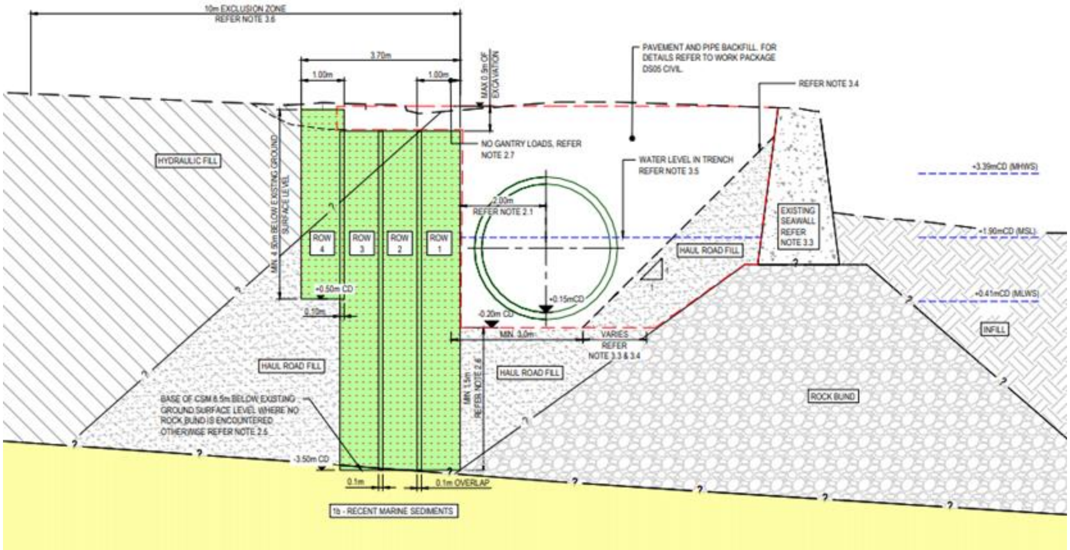

Figure 5 – section through CSM design

1.2.3 Structures

Having completed the design of the pipe and ground stabilisation for its installation, the structures team completed the design of the following elements:

- Outfall structure
- Upstream connection into existing pipe (North Wharf)
- Manholes / lateral connections.

1) Outfall Structure

This was designed to blend in with the existing basalt breakwater at the northern end of Brigham Street. Due to the tidal nature of the installation, in-situ concrete was not considered as a viable option so pre-cast units were developed as the preferred solution. The headwall was split into 5 segments, following the sloping face of the breakwater. However, the shape of each unit precluded transportation from the pre-cast yard (due to size constraints), so each unit was constructed from a pair of pre-cast wall units, connected together on site with an in-situ base unit.

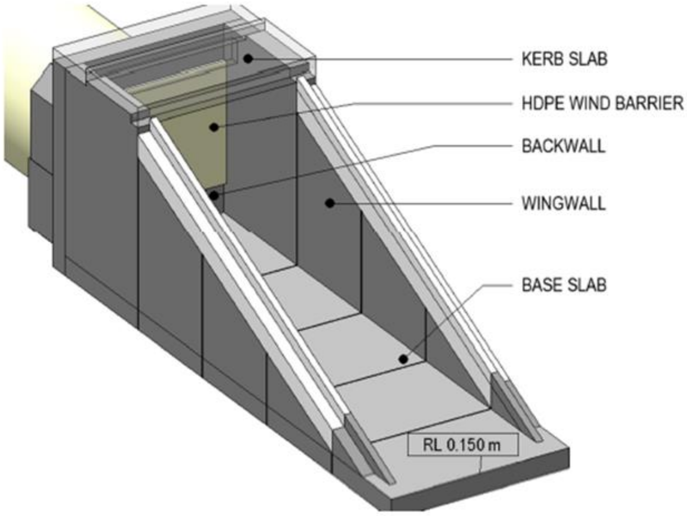

Figure 6 – headwall structure

The Client expressed a desire to blend the headwall in with the existing breakwater. To satisfy this requirement, the concrete panels were coloured with an 8% (by binder volume) black oxide additive, and the wall units given a profiled finish to replicate a rock pattern.

Figure 7 – patterned feature to pre-cast walls

Following installation of the pre-cast ‘U’ sections within the breakwater, an in-situ pour was detailed to tie the units together, at the top, out of the tide. The structure was completed with the introduction of a flap valve across the pipe outfall, designed to discourage kayakers / adventurous children entering the pipe and reduce the risk of prevailing winds blowing unwanted gases back up the pipe.

2) North Wharf Connection

The existing Daldy Street pipeline runs northwards along Daldy Street, terminating at a point where it meets the northern edge of North Wharf. The wharf is a 100-year-old reinforced concrete structure constructed with columns, beams, cross bracing, and a 200 mm thick deck slab atop. When Wynyard Point was developed (infilled) the existing outlet had no point of discharge and the solution was to break a hole in the side of the pipe and divert the flow along a newly formed channel – see red arrow below. That arrangement has been in place for many years.

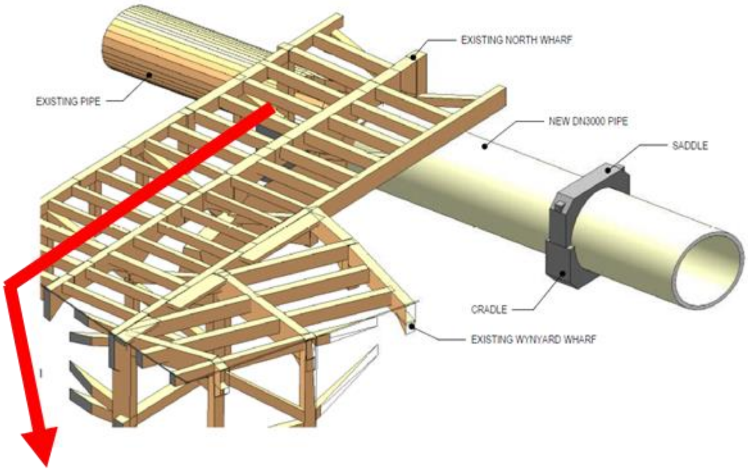

Figure 8 – connection at North Wharf

Access to the existing outlet is therefore possible, albeit difficult. A survey team was able to complete a laser survey under the wharf and undertake a detailed survey of the existing pipe at the intended point of connection. From this survey, a detailed model of a transition piece was made, to connect into the existing pipe, and move the new alignment away from other columns of the existing wharf structure.

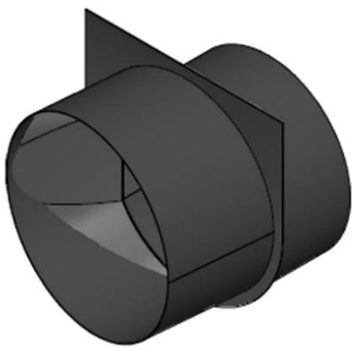

Figure 9 – stainless steel transition piece

3) Bend / manholes / lateral connections

Due to the existing kink in Brigham Street, a 24-degree bend was detailed at Chainage 45 to replicate the existing alignment.

In addition, a maintenance requirement of the pipeline was access for periodic inspection / cleaning. Clearly there is access at the outfall (at flap valve) and, additional to this, two manholes were detailed; one at the bend and one at the mid-point of Brigham Street. No ladders were detailed to discourage unauthorised entry.

As the Daldy pipeline design developed, the drainage for AC36 syndicate bases was completed, and lateral connections for these outlets were catered for in the Daldy design.

To Uponor’s HDPE pipeline order, we therefore added a 24-degree bend, two manhole sections, and all lateral connections. These were all factory made / fitted and delivered with the main pipeline into Wynyard Wharf.

1.3 INSTALLATION

Working alongside the detailed design team, our engineering team devised and developed the temporary works schemes required for the installation of the permanent works. Collectively, the permanent and temporary works teams produced a robust, innovative, engineered solution for installation. The key feature of the pipeline installation was that man entry into the trench was precluded, due primarily to safety concerns regarding the depth and tidal conditions. All pipe installations were carried out from existing ground level, thus protecting the workforce.

1.3.1 CSM

The CSM installation works were sub-contracted to Wagstaff Piling, from Brisbane. They mobilised their equipment from Australia and set up their plant on the new Link Road verge, central to the new pipeline.

Following the extensive GI work, it was clear that there would be many obstructions within the ground that could hamper progress. With this in mind, the Alliance set up an attendant team (excavator and labour) to initially dig a guide trench for each panel, then clear any obstructions if encountered. This proved to be a great benefit as the ground was littered with redundant steel pipes, scrap steel, chains, an old ship’s boiler and propeller – as shown below.

Figure 10 – ship's boiler and propeller

The phasing of the work had to dovetail in with progress on the AC36 syndicate bases and infill bridges. By careful planning and integration with the other teams, we were able to maintain progress on site, without delay to any party.

Figure 11 – CSM rig in operation

Five months after commencing work, and 959 CSM panels and 13,000m^3 of treated ground later, the CSM works were successfully completed.

In order to monitor the behaviour of the CSM panels during excavation for the pipeline, inclinometers were installed at regular intervals along the length of the pipeline. Concerns related to a horizontal displacement of the panels during excavation, which in turn would lead to a vertical deflection behind the panels, which could lead to differential settlement of Stolthaven's fuel tanks. These concerns were never realised and the CSM walls behaved well, with horizontal displacements typically less than 10 mm.

1.3.2 Excavation

With ground stabilisation in place well in advance, excavation for the pipeline could commence.

A 47-tonne excavator was selected for the 5 m-deep excavation. This was a compromise between digging power, reach, swing radius, and ground bearing pressure on the existing road / seawall.

The tidal range of the adjacent harbour runs between pipe invert and pipe crown – with the porous breakwater alongside, it was thought that water would always be present within the excavated trench, typically following the tide – this proved to be the case.

Excavation of the trench would follow the vertical face of the installed CSM panels (row 1) to the west, and the seawall / basalt breakwater to the east. Control therefore centred around the depth of dig, which would always be under water. To assist with this 'blind' dig, a GPS sensor was fitted to the excavator and formation of the trench bottom controlled electronically. At each cradle position, a slight over dig was required to take the thicker cradle – the GPS catered for this. Excavation was completed to 100 mm below the underside of the concrete cradles (used to support the pipe).

The existing ground excavated was extremely variable, with reinforced concrete sections (thought to be an old damaged wharf structure), steel pipes, steel rope, 'blue billy', pockets of hydrocarbons, basalt boulders and weak soils all encountered on a regular basis. At times, the water contained within the trench became very dirty / oily and environmental measures, such as plugging holes in the seawall, adding oil booms / silt socks within the harbour, pumping / sucking out to the treatment plant were instigated - this ensured that no environmental incidents occurred.

All excavated material was transported to the spoil handling area whereupon it was sorted and either disposed of off-site or mixed with cement to form mudcrete – this would later be used as backfill for the pipeline. Due to the contaminants found in Brigham Street, the site was deemed a dirty zone, hence the need for disposable paper overalls and gloves.

1.3.3 Pipe

After sufficient excavation had been completed, the first concrete cradle could be installed. With a minimum of 1 m of water always in the trench, inspection of the formation, and setting levels from within, was not possible. To overcome this, a steel gantry was utilised, spanning between the existing seawall and the CSM wall, to position each cradle.

Figure 12 – steel gantry in place

The pre-cast concrete cradles were prepared for installation – macalloy bars screwed into the top were used to suspend the cradle from a spreader beam above, and a grout bag strapped underneath. The spreader beam with cradle were positioned above the steel gantry and lowered down through a central opening. Lowering continued through the opening until the spreader beam sat on cross beams of the steel gantry. By careful surveying, the cradle was positioned and suspended off the steel gantry, at the correct chainage, off-set and reduced level.

Figure 13 – installation of concrete cradle

After a final survey check, a grout pump was connected to a hose on the grout bag, and approx. 2 m^3 of grout pumped into the bag, filling the void between the underside of the cradle and the formation below. Following an overnight initial set, the spreader beam and gantry were removed, leaving the cradle in its final, correct position.

With water levels typically higher than the top of the installed cradle, thus rendering it invisible, a survey frame was temporarily placed on top of the cradle to assist with surveying. Once set in place, the frame was removed.

Figure 14 – survey frame in place

Prior to installation, each pipe was laid on a preparation frame. The preparation included the removal of temporary 'spiders' welded across the open ends, to maintain pipe shape during transportation, and add water and air vents to the top of the pipe. By rotating the pipe on the frame, the need for 'working at height' was eliminated.

Figure 15 – preparation frame in use

Following preparation of the pipe, two lifting straps were wrapped around the pipe and connected to a bespoke spreader beam. The pipe was lifted from the preparation frame and lowered into the excavation between the next pair of cradles. However, as the pipe was lowered into the water, the buoyancy of the pipe would force the pipe to float. To overcome this, water was added through a central port on the crown of the pipe, which filled the helical annulus, venting at either end. This operation effectively tripled the weight of the pipe and allowed it to settle into the cradles below.

Figure 16 – HDPE pipe installation / sinking

With the pipe sunk into position, saddles were added to the pipe ends and bolted down to the cradles below. 2 additional saddles were also landed onto the pipe (at third points) which would prevent uplift during the next operation.

It was identified at an early stage, that laying pipe bedding under such a large diameter pipe would be extremely difficult. Added to this, it would be under tidal conditions rendering it virtually impossible. To this end, a flowable fill was specified, which would be tremmied in under water. The additional (temporary) saddles would prevent uplift of the pipe. A wooden staff, with laser target attached to the top, was used to check the height of flowable fill poured, the upper surface being approximately 1 m above invert and always below tide level.

The final stage of pipe laying was to backfill the remaining pipeline with mudcrete, produced in the spoil handling area by mixing selected excavated arisings with cement. The target strength of mudcrete was 1 MPa which was regularly exceeded. The mudcrete was returned to the pipeline area and placed by excavator bucket in regular layers.

The process of excavation, cradle install, pipe laying, flowable fill and mudcrete backfill continued on a cyclic basis along the entire length of the pipeline.

An additional feature of the temporary works design was purpose built ‘pigs’ which were installed in the first full pipe laid (of each diameter) and pulled through the sections of completed pipe. This had the effect of cleaning any detritus from the pipeline as installation progressed - this would negate the need for a final clean out on completion.

1.3.4 Sequencing

Against common practice, the installation of the pipeline commenced at the central point of the 500-metre extension, and headed in a southerly direction, thus clearing syndicate bases C, D and E in a timely fashion. The non-mechanical connection, symmetrical pipes, and a flat invert facilitated this. This enabled the AC36 finishing works to be completed and milestones associated with the project met. Installation continued as far as the North Wharf, stopping two pipes short of the connection point, which would be re-visited once the outlet was formed (see below). At this stage, laying returned to the central point (from where we had started) and headed in a northerly direction towards the outfall structure. Having made the final connection into the completed headwall (see below), the operation returned to the southern end to make the final connection into the existing point of outfall.

1.3.5 Outfall

As mentioned above, the shape and size of the outfall units precluded pre-casting in one unit.

To this end, the (patterned, blackened) wall sections were pre-cast in Busck's yard in Whangerei and transported down to site. On arrival on site, each pair of walls was set on a casting bed situated on Wynyard Wharf, alongside the new outfall position. An insitu base slab was cast between the walls to tie them together and form a 'U' shape section.

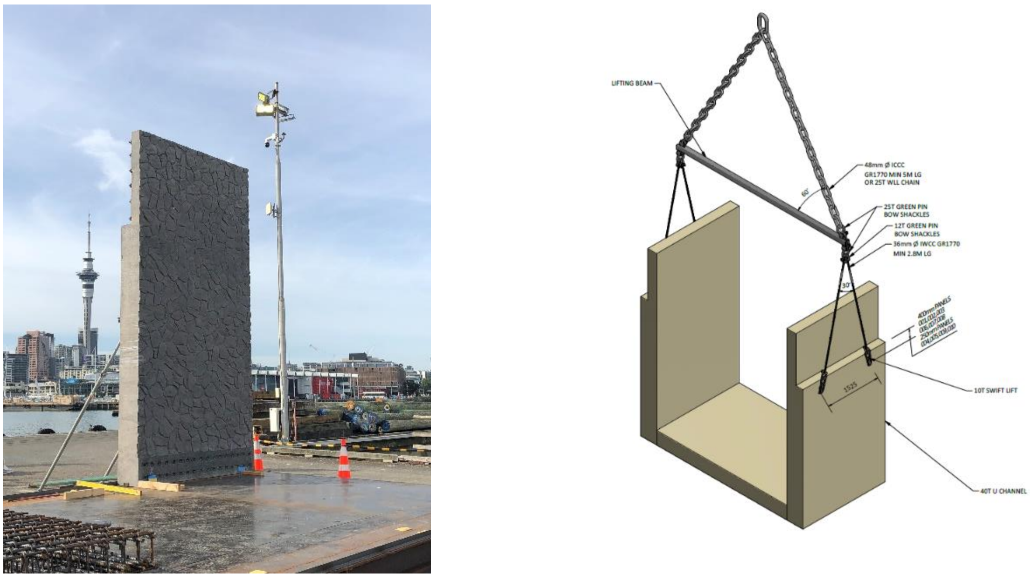

Figure 17 – pre-cast wall panels

Prior to the pipeline installation reaching the north part of Brigham Street, excavation commenced for the new outfall structure. Additional CSM panels had been installed to the rear of the outfall to allow a steepened back wall of excavation and sit the crane on to lift in the 'U' sections.

Excavation again utilised GPS to allow the correct formation level to be achieved, 1 m below lowest tide. Upon completion of excavation, a pre-fabricated steel frame was lowered into the excavation with diver assistance – the frame was fabricated with four adjustable legs (to set to the required level), scaffold poles with survey targets added (to assist positioning below water), and angled guides to assist landing the pre-cast sections (see below). Once positioned correctly, concrete was poured within the frame to within 50 mm of the top flange. A grout curtain was installed around the perimeter of the frame to contain the concrete within the frame, and a sliding screed rail was added to the frame to assist in screeding the concrete to the required level – a difficult operation for divers under water.

Figure 18 – headwall seating frame

With the seating frame set, and the pre-cast units completed, a 400-tonne mobile crane set up above the outfall structure and lifted each of the five 'U' sections into the water and onto the seating frame. The first (downstream) unit was set against a steel angle section to locate the downstream toe, and subsequent units lowered in and placed against the previous unit. With the five 'U' shaped units installed, the backwall sections were lifted in and bolted to the last unit, and the final cradle lifted in and bolted to the backwall, ready to receive the last pipe.

The final stages of the headwall construction were to concrete around the outside of the seating frame to lock it in place, construct an in-situ tie beam to connect the tops of the wall panels together, and grout the void between the 'bedding' concrete and the underside of the units. This final operation was undertaken with divers and an intricate system of grout tubes / bleed valves to ensure the sea water below the units was fully displaced during grouting.

Upon completion of the headwall, the working space created during initial excavation was backfilled with basalt boulders, blending the new headwall into the existing breakwater. Furthermore, it allowed for excavation and laying of the penultimate and final pipes into the back of the completed structure.

1.3.6 North Wharf

To complete the Daldy Street Outfall extension, it was necessary to tie the newly laid pipeline into the existing pipe, under North Wharf. This followed completion of the pipeline downstream, in order to provide an outlet.

With ground stabilisation provided by the previously installed CSM panels, excavation commenced between North Wharf and the previously laid pipe – approximately 10 m in length. Excavation continued under North Wharf, including breaking through the existing retaining wall. Blinding concrete was laid as excavation progressed, as the flow of Daldy would soon pass over this area – environmental protection was thus afforded.

The stainless-steel transition piece (see above) was connected to the first HDPE pipe section, and the whole unit lowered over the edge of North Wharf at low tide, into a rope sling hung off the side of the wharf. With the weight of this combination pipe taken by the main hook on the crane, an auxiliary line was threaded through a hole in the wharf, directly above the connection point, and onto the end of the transition piece. As the tide came in the weight was taken off the crane as the pipe began to float.

At this point, the auxiliary line was hoisted, and the pipe section pulled into place under the wharf and into position – the stainless-steel transition piece fitting into the old outlet. At this stage, the annulus of the pipe was flooded, sinking the pipe into position. The seating cradle, unlike previous sections of installation, was fixed after the pipe had been installed.

The flow of Daldy pipeline immediately started to flow through this new pipe section, through a short 10 m section of excavation, then through the remaining pipeline previously installed. All that remained at this stage was to measure and cut the final pipe, place in the remaining gap and add the final pair of saddles to clamp in place. The final diversion of Daldy Street outfall had been completed.

1.3.7 Reinstatement

Following the completion of the diversion, all that remained was the reinstatement of Brigham Street which included a single carriageway road, swales to receive surface run-off (connected into the Daldy pipeline), a footpath and miscellaneous lighting, signing & marking. The final touch was to replace the five Pohutukawa trees removed to facilitate the works, with nine new trees added.

2 CONCLUSIONS

Early integration of design, temporary works, and construction teams enabled an innovative, effective, and safe system of design and installation to be developed. All of the complex elements of construction had never been undertaken by any of the site team – we were collectively pushing the boundaries of our knowledge.

As each design package was issued, a full understanding of design requirement and proposed installation method was gained. Construction Execution Procedures were developed alongside the design with input from design, construction, stakeholder, HSEQ representatives, owner representatives, and consenting teams.

Crucially, the design and installation method included a number of innovations:

- CSM ground stabilisation
- GPS controlled excavations
- Preclusion of man entry into the pipe excavation
- Steel gantry to support pipe cradles
- Use of steel survey frame
- Grout bags to set cradles
- A highly flexible pipe material - HDPE
- Possibly the largest pipe ever laid in New Zealand
- Pipe laying through tidal conditions
- Flooding of pipe annulus to allow sinking of pipes
- Flowable fill placement under water
- Use of mudcrete to reduce disposal
- Pre-cast elements to headwall
- Use of headwall seating frame under water
- Grouting of pre-cast units under water
- Installation of transition piece under North Wharf.

The team rose magnificently to the challenge and produced a combination of innovative temporary and permanent works solutions to eliminate many of the inherent risks associated with tidal pipeline installation. New technology was introduced from Australia to provide an innovative ground stabilisation scheme, the demand for which continues to grow within New Zealand.

Despite many challenges, the project was completed incident free, ahead of programme, under budget, and provided our client, with a quality product that has provided a legacy for Auckland.

ACKNOWLEDGEMENTS

- Healthy Waters - Client
- Panuku – land owner
- Stolthaven – tank farm tenant
- Ports of Auckland (POAL) – wharf operator
- Fire NZ
- Watercare – service diversions
- Wagstaff Piling – CSM installation
- Uponor – pipe supply
- Busck – precast cradles, saddles and headwall units