# HASTINGS WASTEWATER OUTFALL MAXIMUM LIFE VS MINIMUM SPEND

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## ABSTRACT

Hastings Wastewater Treatment Plant discharges treated effluent to the Hawke Bay via a 3km long outfall pipeline constructed in the early 1980's. This outfall is a critical element of the treatment plant as the historic beach discharge and short outfall are no longer acceptable to the community other than in an emergency situation.

Shortly after its commissioning, there were issues with the outfall and several significant repairs were required. This paper outlines the historic issues, the repairs undertaken, the condition investigations, rehabilitation carried out recently and further works planned to maximise the life of the overall asset whilst minimising expenditure.

A recent innovative external FRP pipe repair method for a short land based section of highly corroded concrete pipe was developed to allow the outfall to remain operational, whilst working in with the timing of low tide and minimum treatment plant flows to allow works to be completed. Repairs to a section of steel pipe and the full replacement of the ocean diffuser are also detailed in the paper.

The approach of targeted condition investigations, investment in repairs and renewal of specific outfall components is expected to significantly extend the overall economic life of the outfall system.



## KEYWORDS

**Ocean Outfalls, Diffuser Replacement, External pipe repair, Condition assessment**


## 1 INTRODUCTION

This paper outlines the components of the Hastings Wastewater long ocean outfall, historic condition investigations and repairs, and the more recent condition investigations, assessments, repair and renewal works that have been completed or are underway.

Prior to the long outfall construction, wastewater from the site had been discharged from a short outfall, approximately 50 metres offshore, since 1960. Prior to that wastewater had been discharged directly to the sea between the Tukituki and Clive Rivers in Hawke Bay. The short outfall was decommissioned in 1992 however is still partially in place for emergency use and is connected by a bypass channel from the treatment plant.

To avoid overflows to the beach or within the plant, the long outfall is required to remain operational at all times, other than for short duration shutdowns that can be accommodated with storage in the main inland trunk sewers conveying wastewater to the plant. Additionally, the pipeline alignment is in most part below sea level. These factors make any condition investigation, repair or renewal works difficult and potentially expensive.

The current long outfall was designed by engineers from the City of Hastings and was constructed by McConnell Dowel.

The treatment plant receives separated industrial wastewater for final milliscreening and domestic wastewater which is treated through biological trickling filters. The domestic plant was commissioned in 2009. Both streams are combined at the Outfall pump station on site.

*Photograph 1: Beach and Short Outfall – Damaged in recent storms*

## 2 LONG OUTFALL COMPONENTS

The long outfall was commissioned in 1981 and extends approximately 3,000 metres offshore into Hawke Bay. The outfall has been described in the four distinct components that have different materials and/or operating conditions affecting asset deterioration and life:

- Manifold – Steel Pipe Section
- Land Based Concrete Pipe
- Submarine Concrete Pipe
- Fibreglass Diffuser.

A schematic of the outfall with the layout and lengths is shown in Figure 1 below.

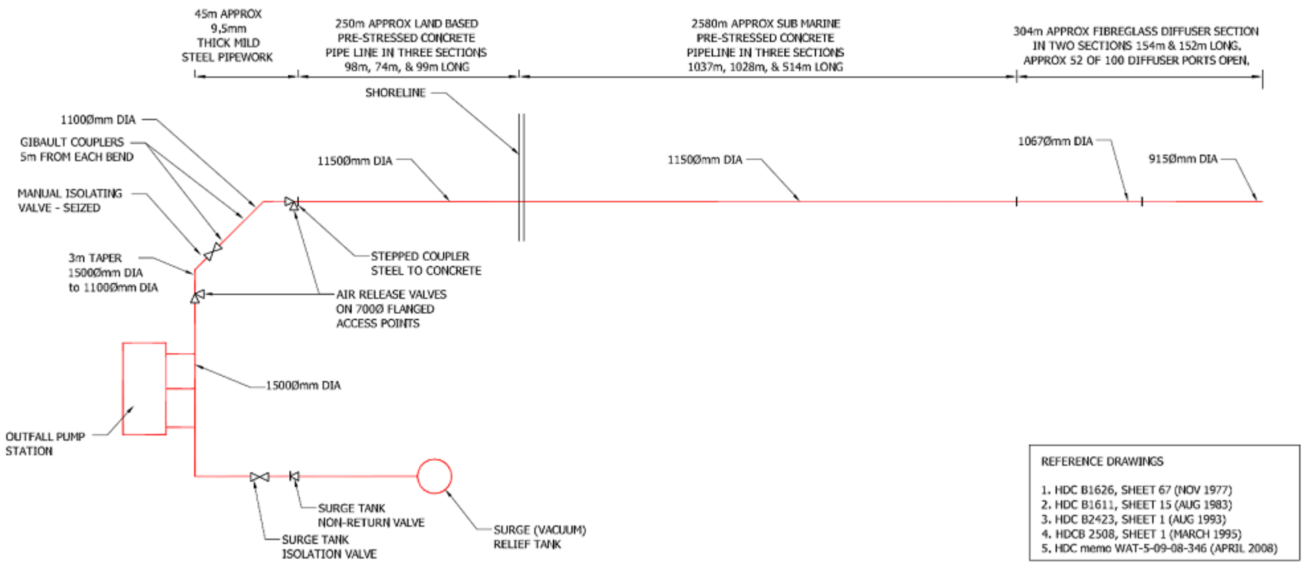


*Figure 1: Outfall Schematic*

The following sections describe the outfall components as well as historic condition investigations and repairs that have been carried out prior to 2012.

## 2.1 MANIFOLD SECTION

The "manifold section" is a steel pipeline with flange connections to the three pumped discharge pipes from the treatment plant outfall pump station. The length of the manifold is approximately 45 metres and includes:

- 15m (approx.) 1500mm diameter section before a 45 degree bend,
- 1100mm isolating valve (seized open) and a 30m (approx.) straight section,
- further 45 degree bend then a 3m straight section with a stepped gibault coupling connecting to the concrete outfall pipe.

The manifold pipe is fabricated from 9.5mm mild steel, with a protective coating. The details of the protective coating have not been confirmed, however it is likely to be some form of epoxy paint. A 16m high vertical surge pipe was initially constructed on one of the flanges, however when the outfall pumps were replaced this surge pipe was replaced in 1993/1994 with a vacuum relief tank arrangement and two air relief valves. A separate air relief valve is located on the pump side of the station isolation valve.

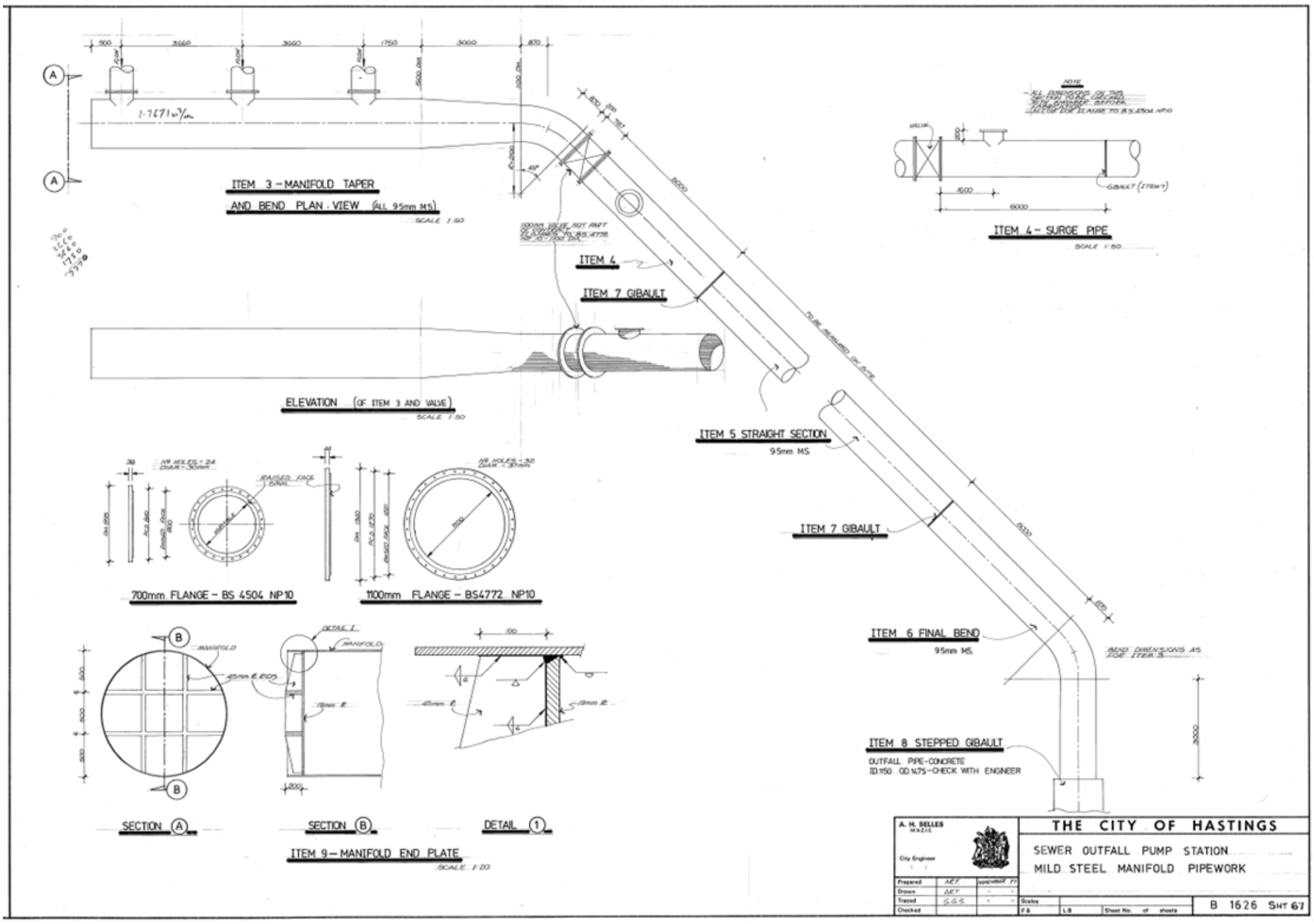


*Figure 2: Manifold Pipework Detail*

The manifold has required several repairs since commissioning:

a) 1992 a leak in the base of the manifold required emergency repair by plugging with steel wedge, welding in place, grinding off then welding a steel plate over. Measurements of the steel using an ultrasonic thickness meter indicated that the steel thickness was between 7.4 and 8.4mm.

b) 2005 a leak was found in the stepped gibault coupler between the steel and concrete sections. This was repaired by welding and then encasement with concrete.

c) 2006 a leak was found in the soffit of the upstream end of the 1500mm diameter manifold and it was found that the steel at that point was very thin due to internal corrosion. The thickness, measured using ultrasonic measurement, was between 3.0 and 6.0mm in several top sections and between 8.0 and 10.0mm on the side sections.

   Steel plate, rolled to the pipeline diameter, was welded to the crown of the manifold. The full length of the manifold was exposed with the exception of the service road and plate was welded where the measured loss of wall thickness was significant.

## 2.2 LAND BASED CONCRETE PIPE

The concrete pipeline consists of 2410mm length sections of 1150mm diameter reinforced concrete pipe. Two layers of 6mm hard deformed reinforcing wire at a 50mm pitch providing circumferential reinforcing over 12 equally spaced 5mm longitudinal wires. The reinforcing wires are located on each side of twelve post tensioning ducts, which are concentrated on the sides of the pipe section (2 o'clock to 4 o'clock and 8 o'clock to 10 o'clock approximately). The pipeline sections are post tensioned with 12 polyethylene covered prestressing strands tensioned to 40,000 lbs. The internal concrete cover appears to be 25mm to the internal reinforcing layer and the external concrete cover is approximately 55mm to the external reinforcing layer. The pipes detail is shown in Figure 3 below.

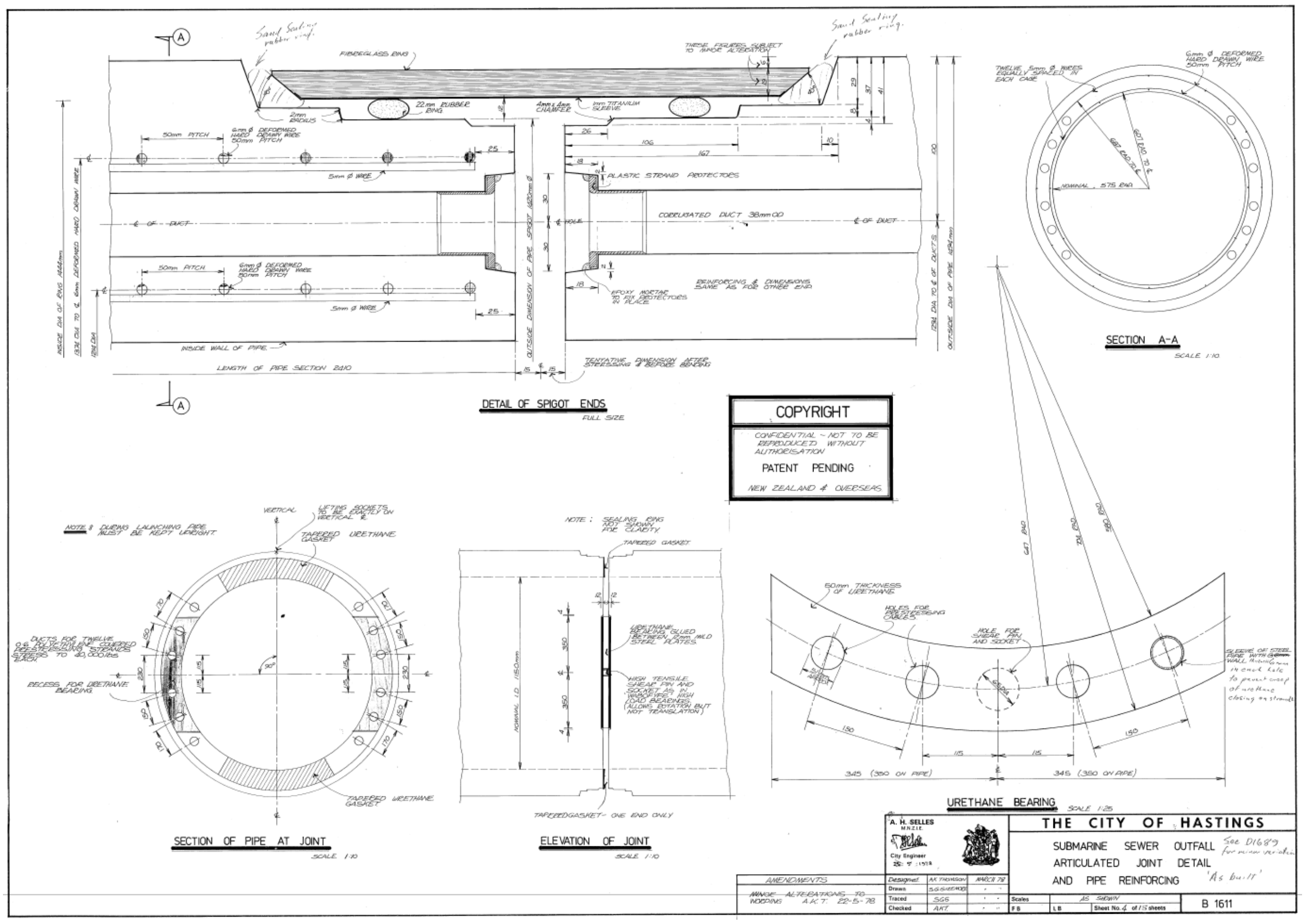


*Figure 3: Pre-stressed Concrete Pipe Detail*

The land based section of the concrete pipe has also suffered some internal corrosion damage to the soffit and joints. A leak was discovered from this pipe in July 2007 from the top of the pipe at a joint. A short longitudinal crack was also found on the crown of the pipe at the 12 metre point, and when a core section was taken the thickness of the core confirmed that the soffit of the pipe was severely corroded.

Repairs to the cracked section of the pipe were carried out in 2007 by placing custom made large stainless steel straps over a linotex rubber underlay, refer to Photograph 2 below.

*Photograph 2: Concrete Pipe Repair Bands*

During the 2007 repair work an internal inspection was undertaken. By using low tide and low flow periods it was possible to float a small waterproof camera 60 metres down the pipeline. The camera revealed visible corrosion of the soffit from about 10 metres into the pipe, with the crack seen at 12m, significant reinforcing showing at 16m and the corrosion reducing from 18 metres. The corrosion appeared to be about 200-300 mm wide. Joints at 22m, 32 m and 40m showed some corrosion at high points within and adjacent to the joint.

The mechanism of hydrogen sulphide corrosion of concrete pipes is well documented and is not discussed here. Ideally the pipeline would be maintained full however the designed profile does not achieve this at all times. The Hastings District Council (HDC) treatment plant operators have noted that due to a large flow reduction in 1986 the operating level in the pipeline would have lowered and increased opportunity for corrosion. The new air valves were also leaking in 1994 and were reportedly closed for about 6 months, which is likely to have further exacerbated the potential for corrosion. More recently, biological trickling filters have been commissioned for the domestic waste stream and this should have reduced the level of hydrogen sulphide generation from the domestic portion of the effluent stream.

## 2.3 SUBMARINE CONCRETE PIPE

The submarine section of the concrete pipe is constructed from the same pipe sections as described above, to a distance 2594m from the 1978 shoreline. The construction methodology was to assemble tensioned “strings” of pipeline on land, which were then floated out to sea and sunk into a trench with a nominal 400mm cover.

The jointing system between pipe sections is a custom designed 330mm wide by 19mm thick fibreglass joint with a 1mm internal titanium sleeve layer. The joint compresses 22mm rubber rings on each spigot end and there is a secondary rubber ring on each end of the fibreglass joint. A 30mm/50mm tapered urethane bearing system provides for movement between pipe sections. A maximum joint deflection of $2^{o}$ was designed to allow for launching and sinking into position. A detail is shown in the previous section, reference Sheet 4 of B1611.

The jointing system between pipe strings is detailed below and includes a grouting between an outer and inner sleeves around an anchor pipe section at the end of each pipe string.

At least one joint (between pipe strings) has failed since the commissioning of the long outfall. This was reportedly discovered by a diver during preparations for some dye testing on the outfall. It was not confirmed which joint this was, but the repair methodology was reportedly by concrete encasement.

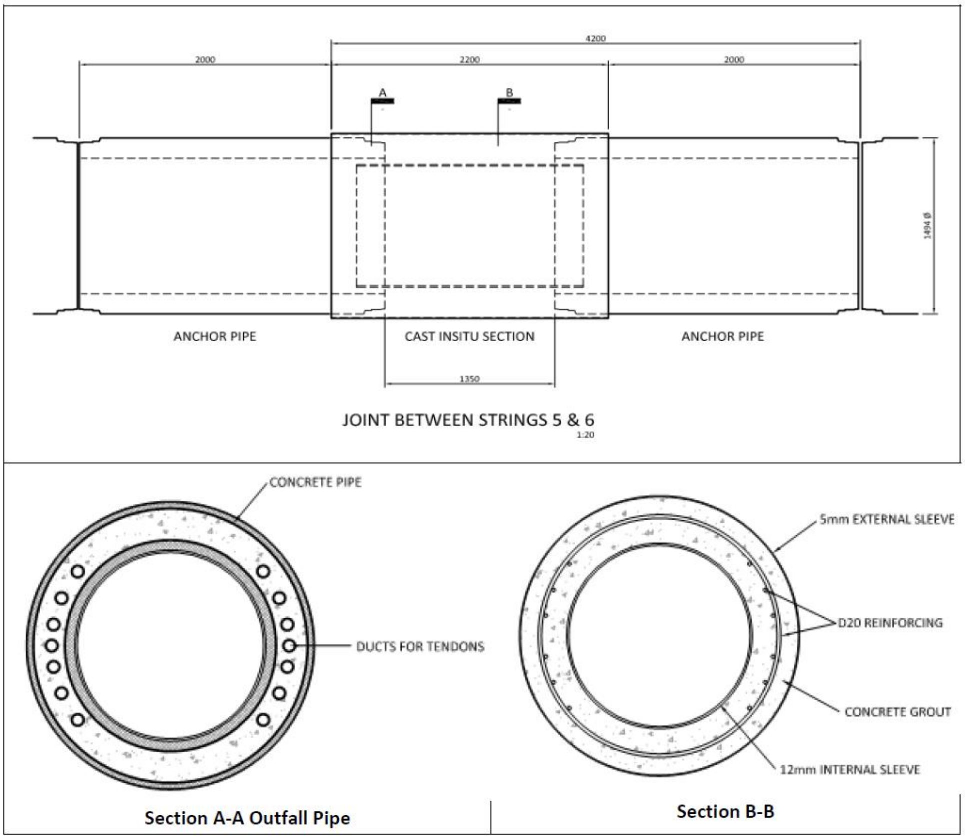


*Figure 4: Joint Between Post Tensioned Pipe Strings*

## 2.4 FIBREGLASS DIFFUSER

A 304 m fiberglass diffuser section is joined to the pre-stressed concrete pipeline. The diffuser pipeline is located on the seabed, and is held in place by ballast “wing” sections on each side of the pipeline filled with iron sands and is strapped in some areas to buried anchor blocks. Approximately 52 of the 100 diffuser ports are open. A drawing of the diffuser section including repair work is shown in Figure 5 below.

Construction details from repairs made in 1992 and 1995 include repairs to two joints and repairs to two breaks in the diffuser pipe. One of the breaks had a vertical displacement of greater than 150mm.

The diffusers are condition surveyed by divers on an annual basis. The 2012 survey noted that several sections of the pipeline are showing changes to the surface texture. There was also leakage at some pipe joints, with scour that was repaired with sandbags. The report noted that it is “difficult to quantify the amount or existence of any degradation in the seabed conditions and water column visibility”, with the inspections based on touch.

The overall impression from the reports is that the diffuser section is reaching the end of its design life and the divers have noted signs of significant wear during their more recent inspections. A GPS survey has concluded that the diffuser section alignment was not in a straight line as designed. The 2012 inspection recommendation was that pipeline replacement should be considered as considerable realignment and remedial work would be required to correct the existing leakage problem.

No comment on the condition of the ballast wings was noted in the inspection reports.

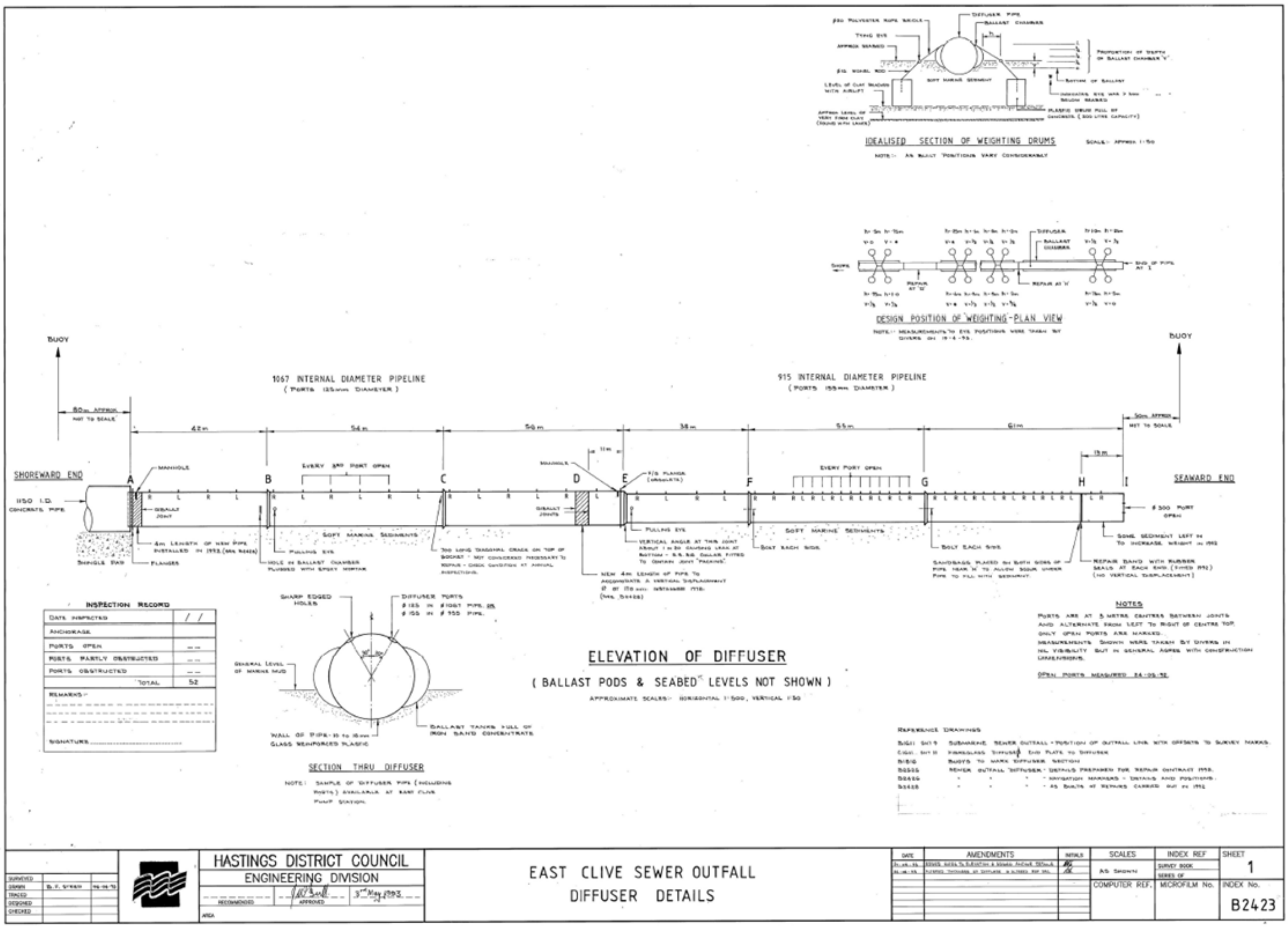


*Figure 5: Fibreglass Diffuser Detail Including 1992 Repairs*

# 3 RECENT CONDITION INVESTIGATIONS

With Council budgeting for full replacement of the outfall pipeline by 2026, a condition investigation and assessment project was advanced in late 2012. Based on a review of the history and discussions with HDC staff at that time the key issues with the outfall pipeline, in order of priority, were:

1. Internal corrosion of the soffit of the steel manifold
2. Internal corrosion of the soffit of the land based concrete pipeline
3. Damage to the fiberglass diffuser section
4. Reduced integrity of the couplings between post-tensioned concrete pipeline strings
5. Structural integrity of the submarine concrete pipeline and joints

To date investigations and remedial works have focused on items 1 to 3, with further inspections planned in the future for items 4 to 5. The following sections provide a description of the issues and short-term condition inspections carried out over the last 4 years.

## 3.1 STEEL MANIFOLD SECTION

Further external measurements of the steel manifold thickness were undertaken to confirm the extent of corrosion. This required excavation of the top half of the manifold pipeline section and cleaning of the pipeline surface for a detailed thickness survey using ultrasonic measuring devices.

Due to the uncertainty of the manifold condition hydro-excavation of the manifold was carried out to expose the pipe. Excavation was made down to half height. This was partly to prevent undermining of the pipe and was a practical depth as groundwater was encountered at around half height.

*Photograph 3: Exposed Steel Pipeline*

SGS were commissioned to undertake the ultrasonic thickness inspection. The survey was not able to distinguish between the 2006 installed 8mm cover steel plate and the underlying original pipe. The only conclusion that could be drawn was that the full thickness of the 2006 repairs was still intact. One of the 1 metre long repair plates on the 1500mm manifold was 10mm thickness. It is presumed that this plate was placed over the section of manifold that was cut out in the 2006 repairs. A small area around the 3” air relief stub pipe was found to have significant loss of pipe thickness, down to 3.8mm at the lowest point.

During the excavation the air relief valve by the pump station building was found to be leaking. This valve was removed and replaced. Two small leaks through the 2006 repair plates were found at the north end of the 1500mm manifold section and repaired.

Rolled steel plate held on site was welded around the air release pipe. A steel plate was also welded to the crown of the pipe under the road, where a localized area of corrosion down to 7.7mm was found. Although the remaining steel was considered satisfactory the patch was provided for added strength.

The minimal deterioration observed in the six years since the previous repairs were made suggests that with ongoing maintenance the steel manifold should have a remaining life in the order of 20 years.

Future maintenance required in the medium term may include additional repairs to the crown of the pipe if hydrogen sulphide corrosion continues. These external repairs can be readily made to the steel manifold. External corrosion is likely to become the limiting factor in the medium term. Internal erosion has not been investigated to date, and while it may seem to be a low risk with the grit removal provided at the treatment plant this assumption should be verified in future condition inspections. The rubber ring seals on the gibault joints may require maintenance or replacement in the medium term. This could become apparent if there is future ground movement on this section of pipeline as the elasticity of the rubber will have reduced over time.

## 3.2 LAND BASED CONCRETE SECTION

The extent of corrosion in the concrete pipe had not been measured since emergency repairs were made to the concrete pipe in 2007. The primary means of inspecting this corrosion would be by internal CCTV inspection, however CCTV is qualitative. A quantitative inspection, using laser and/or sonar equipment, would be more useful. Previous internal inspections had been undertaken at low tide and cannot be undertaken during the seasonal higher industrial flow peak between February and April.

Ideally, direct measurement of the concrete strength and reinforcing steel integrity would be taken however this is a much more difficult (and expensive) operation due to the need to keep the pipe in operation. Future investigation and assessment of the extent of corrosion or deterioration is to be carried out.

An initial trial inspection was undertaken by Drain Surgeons Ltd in May 2013 to 100m distance using sonar. However the sonar inspection was inconclusive on the extent of any corrosion.

A laser profile was obtained in November 2013 to a 50m distance, at which stage the water level was too high to record. An extract from the laser profile report is shown in Figure 6 below. In summary, the inspection showed the first five pipe lengths had corrosion along the entire soffit and the sixth, eighth; ninth, twelfth and fourteenth pipes had at least 50mm corrosion at the upstream end. The depth of corrosion was reported as up to 161mm in the concrete pipes which have a maximum wall thickness of 174mm and minimum wall thickness of 133mm at the joints.

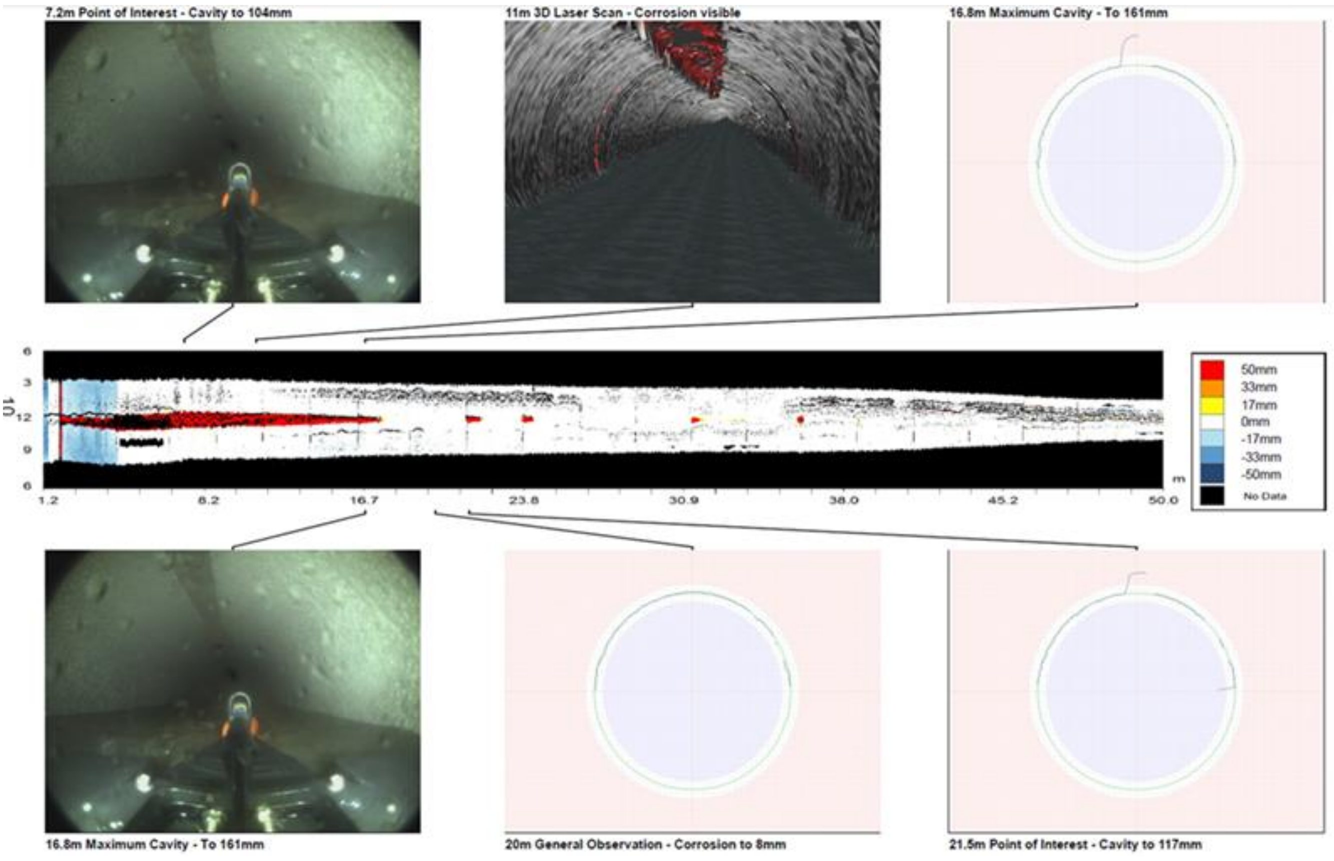


*Figure 6: Extract from Laser Profiling report*

A quantified assessment of the concrete loss profile was subsequently requested and a data file of corrosion width (as a chord) and depth is summarised in Figure 7.

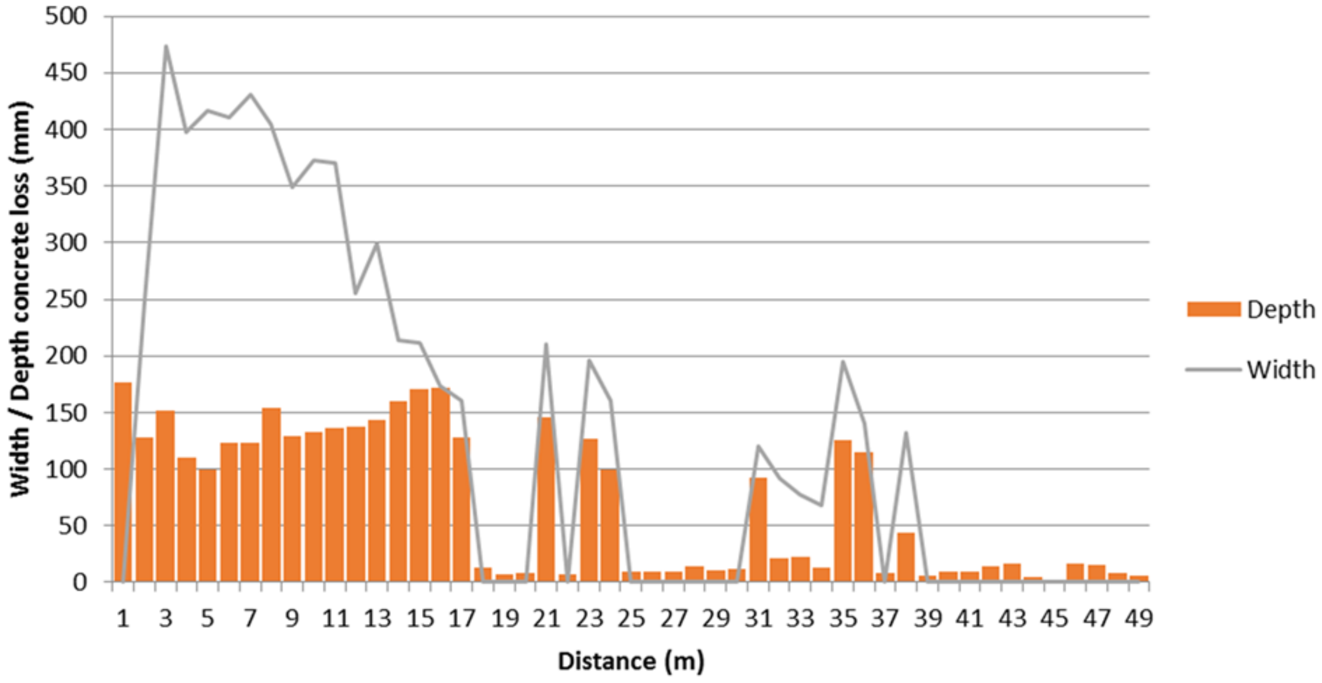


*Figure 7: Width and depth of pipe wall loss (13 November 2013)*

The laser profiling indicates that significant corrosion has continued to occur in the soffit of the intermittently full pipeline section since 2007. It appears that corrosion is initiated in joint areas where hydrogen sulphide can accumulate and be trapped allows for biofilm growth, creating a "corrosion slot" that continues to widen and extend along the length over time. Velocities at normal pumped rates are not high enough to limit the biofilm growth and corrosion can continue with the intermittent full pipe conditions.

Additional repairs were required urgently as additional failures could be expected with corrosion to full wall thickness for at least 20m of the pipe. Refer to Section 5 for details of the options considered and the works constructed.

Future investigations are required to review wider corrosion and condition of the pipe including:

- Further laser profiling to monitor the extent of "corrosion slot" in width and length along the pipeline.
- Assessment of general external concrete deterioration with core samples taken to for testing of wall thickness, reinforcing wire condition and concrete strength.
- Assessment of post tensioning wires condition and corrosion

## 3.3 FIBREGLASS DIFFUSER SECTION

As noted above it is "difficult to quantify the amount or existence of any degradation in the seabed conditions and water column visibility." The dive inspections are based on touch and gaining more detailed information in these conditions is very difficult.

Major maintenance or replacement of the diffuser has been recommended by the inspection reports in the short term. The FRP appears to be deteriorating at the joints through moisture ingress and this seems to be increasing over time with the joints roughening in texture. This degradation is most probably water ingress due to strain on the pipe causing delamination of the FRP layers. It is likely that this is a consequence of stress at the joints caused by mis-alignment during construction however ongoing movement in the marine environment could be contributing to this.

Intrusion of saline water has been observed in the outfall, which is expected at lower flows and will reduce the efficiency of the diffuser as the effluent will not be evenly discharged.

FRP is generally regarded to be a suitable material for marine applications, as it is chemically stable and durable when installed within its design parameters. Performance evaluation of FRP is more complex than more conventional materials due to the variability in the material properties which can vary due to the different types of resins, fibres and manufacturing methodology that can be used.

Some of the damage types for FRP include, delamination (surface / deep / full), porosity / voids, edge damage, impact damage and cracking.

FRP pipe manufacturing facilities undertake deflection, axial and hoop/circumferential load testing on pipe samples, however those tests are not practically possible to undertake on an in-situ marine outfall and are generally considered destructive tests as they have potential to damage the FRP.

As the diffuser is not a sealed pipe it would be possible to obtain samples of the diffuser by cutting small sections of the pipe out for above ground inspection. Samples from the suspected delaminating joint ends could be compared to samples collected from the diffuser ports.

Non-destructive methods for testing FRP material above ground are well established. However the site conditions that the diffuser is in clearly place severe limitations on the condition inspection options. With regard to visual inspection, the divers have stated that it is possible to take photographs using a water line to displace sediment laden marine water, however the cost involved in obtaining such photographs is likely to be high. Other more sophisticated techniques are generally used in the aeronautical industry and are unlikely to be suitable for marine application.

### 3.4 PIPELINE SECTION COUPLINGS

A fiberglass coupling was used between the six post tensioned concrete pipeline sections. This appears to be a custom made detail, so the expected performance of these couplings is difficult to assess. The fact that at least one joint has failed indicates that a condition inspection will be required at some stage in the future. The environmental consequence of these failures would be lower, however the marine location for 5 of the 7 couplings would make any repair much more difficult.

Available condition inspection techniques to inspect these buried couplings are limited. Dye testing has been undertaken in the past and could be used again. This would only locate relatively large leaks however minor leaks should not affect the integrity of the pipeline (i.e. a leak large enough to result in scour should be detectable with dye testing).

### 3.5 SUBMARINE PIPELINE

The submarine pipeline is not known to have any condition problems, so condition inspection has not been a high priority. A typical life expectancy of a concrete marine pipeline should be in the order of 70 years, however this pipeline detail is unique and more detailed analysis of the components and corrosion or failure mechanisms is proposed to inform the appropriate condition investigations. The obvious failure mechanisms include failure of the polyurethane joints, failure of the post tensioning wires, corrosion of the concrete or corrosion of the reinforcing wire.

Available condition inspection techniques for outfall pipelines are limited. The length of the outfall is well beyond any conventional or readily available CCTV equipment, so an acoustic based condition inspection may be required. The technology to undertake acoustic inspections is very specialized and likely to be brought in from overseas, e.g. the “SmartBall” from Pure Technologies in Australia.

The technology to undertake non-destructive in-situ condition inspection is even more specialized than the acoustic inspections and is not currently available in New Zealand, e.g. the “PipeDiver” from Pure Technologies which can measure reinforcing wire integrity but is primarily designed for pre-stressed pipes.

## 4 CONCRETE PIPE REPAIR

### 4.1 INTERNAL REPAIR OPTIONS

The options for internal repair are severely limited by the operational need to keep the outfall pipe on-line, except for short shut downs. This is a resource consent requirement and it would be very difficult to obtain short term consent for repair if there is another technically viable option available.

The major limitations with internal rehabilitation are surface preparation and working conditions. Typically, for a corroded sewage pump station wet well for example, the corroded concrete will be removed using high pressure water blasting prior to coating. In this case the remaining concrete is so thin, and there is so little reinforcing likely to be unaffected by corrosion, that removal of the residual concrete would present an unacceptably high risk of breaking through the remaining concrete shell. There are also significant health and safety issues that would need to be considered for this type of confined space work.

There are various commercial products available however they all have limitations and are unlikely to be suitable as a structural repair with the working condition and access limitations in this case. Protection of the corroded soffit would arguably benefit the long term life of the pipe however it would not have provided a complete solution and was not considered further.

Several techniques are available for "trenchless" renovation, including Cure In Place Pipe (CIPP), spiral wound PVC and slip-lining. CIPP and spiral wound PVC have limitations for pressure pipes for the 23m operating pressure required and are generally not considered for pressure pipes. In addition, CIPP would require a dry pipe for insertion.

Slip-lining was considered technically possible however the temporary works required in this situation to keep the outfall in operation had considerable consent compliance risk.

## 4.2 EXTERNAL REPAIR / RENOVATION

Due to the limitations around keeping the pipe in service an external repair was considered likely to be the lower risk approach. From previous work in this pipe it was known that there is potentially a high seasonal groundwater table at the site which would require dewatering.

Previous emergency repair work undertaken in 2007 involved the installation of **multiple stainless steel clamps** around the pipe. The main concern of this methodology would be ensuring a water tight solution for between clamps, requiring a suitable underlay with sufficient durability and strength for the pressure loading. The 2007 repair clamps were placed close to each other with a sheet rubber underlay to provide a water-tight overlap between clamps. This would be acceptable at an isolated leak, at a joint, for example, however if the internal concrete continues to corrode then there will potentially be exposure for long lengths of the soffit that would limit the effectiveness of this approach.

The other difficulty with this approach would be supporting the pipes during the clamp placement. Although the post tensioning will provide some rigidity the pipe is flexible through the rubber ring joints. The rubber rings will have a limited amount of flexibility, particularly as the pipe was installed over 30 years ago so the rings will have a reduced elasticity with the passing of time. The pipe would require support similar to the reinforced concrete bandage option below.

**Reinforced concrete encasement** is an established technique for concrete pipe repairs. The Hutt Valley Main Outfall Pipeline has had over 30 "concrete bandages" constructed at historic joint leaks, although internal seals are now used. The stepped coupler between the steel and concrete sections was cast in a concrete block in the 2007 repair work and there was no evidence of settling when that block was uncovered in the February 2013 manifold inspection.

The underneath of the pipe would need to be excavated in stages to minimise any settlement of the pipe. A water-tight seal could be obtained using suitable concrete mix and water-stop detailing. A capping layer of corrosion resistant material would need to be placed over the top of the pipe to protect the concrete encasement from further corrosion.

There would be some risk of settlement for the mass of concrete and a risk of cracking at the junction of the rigid pipe section and the "flexible" concrete section.

ConTech, an experienced repair contractor engaged for work at the Hastings treatment plant, had previously suggested to HDC that a **FRP wrap** over the crown of the pipe would provide sufficient restraint for the internal pressure. While FRP would provide tensile strength for pressure loading the resistance to ground loads would require compressive strength reinforcement.

## 4.3 REPLACEMENT PIPELINE

The main issue replacing the pipeline would be that a temporary diversion of effluent would be required through the short outfall. This diversion would be for several days at a minimum and possibly several weeks. There are also significant works required to re-commission the short outfall.

As the pipeline is post tensioned the entire first 98 metre pipe string would need to be replaced. There is a high degree of uncertainty in whether a resource consent could even be obtained for this work, as from an RMA perspective there are reasonable alternatives available.

## 4.4 OPTION SELECTION

The options considered are summarised in Table 1 below. Option 1, FRP wrap was selected for repair of the pipe due to overall lowest risk and cost considerations. This option did have some residual medium risk but also had the highest level of flexibility for future works.

| Option | Scope of work | Comments | Risks |
|---|---|---|---|
| 1- FRP external wrap | Excavate pipe to half height<br>Water-blast surface<br>Base layer product (SikaGard 62 impregnated in FRP), multiple layers of FRP, 1.8m wide<br>Reinstate with reinforced concrete capping layer above wrapped pipe | Minimises excavation<br>Protection of top of pipe probably required as FRP has different stiffness to concrete | Some technical uncertainty of sealing over or underneath existing stainless steel straps/bands<br>Less proven repair methodology and some risk of future leaks requiring repair if joint sealant is not successful |
| 2- Reinforced concrete encasement | Dewater ground and excavate below pipe invert<br>Excavate and cast reinforced concrete support under pipe joints<br>Excavate and cast reinforced concrete encasement around entire pipe diameter, 40m length approx. | Proven repair technique for joint encasement however not commonly used over full lengths of pipe | Settlement of encased (rigid) section could place stress on the outfall pipe at interface.<br>Movement of existing pipe during construction work could result in leaks from rubber ring joints |
| 3- Slip line HDPE | Fabricate new valved bend in steel manifold ("Y" section), including new man access port.<br>Temporary shutdown to install "Y" section.<br>Slip line HDPE through "Y section" during temporary shut down<br>Seal ends of HDPE in place<br>Grout HDPE pipe in place | Installation of the proposed "Y" section would need to be carefully planned operation to ensure outfall back in service without overflow.<br>Reduction in diameter would reduce flow capacity of outfall slightly<br>Would provide a flexible solution with longer design life than above repair options. | The two temporary shut downs required are complex and have significant risk of overflowing wastewater due to limited holding time in network.<br>Internal work required to seal pipe in place (H&S risk). |
| 4- Replace with HDPE | Lay 98m of 1300 OD HDPE pipe in trench adjacent to existing pipe.<br>Divert pumped effluent to short outfall<br>Connect new pipeline | This would provide the most resilient outcome for this section of the outfall. | Resource consent may not be obtained for work to proceed<br>Connections from manifold and to outfall will be difficult items to construct under time pressure (to limit diversion time). |

*Table 1: Land Based Concrete Pipe Repair Concept Options*

## 4.5 CONSTRUCTION

Construction of the repair wrap had a number of risks and uncertainties due to the unknown extent of "breakthrough" corrosion through the pipe wall or at joints. Excavations to expose the pipe were advanced on a staged basis to expose only limited extent of the top of the pipe, during part full flow conditions. Contingency plans were prepared to manage the possibility of a pipe or joint failure during excavations and repairs.

Generally works in the worst corrosion areas were restricted to coincide with the low diurnal plant flow and low tide to allow opening of cracked/corroded sections.

Once exposed and stabilised the pipeline was protected from the weather within a temporary enclosure constructed from scaffolding with a plastic wrap. The enclosure included windows to allow for ventilation and gas monitoring was provided during works, but no issues were encountered with gas monitoring within the workspace.

In the area of the existing stainless steel bands, installed in 2007, there were areas of breakthrough corrosion of the concrete wall to the surface. These required additional repair stages during low level periods to install preformed GRP patches shaped to the diameter of the pipe that were adhered with Sikdur 31 CF and the bands reattached whilst the repair cured. Refer to Photograph 5 below.

The design wrap layers were then able to be installed over top to create a continuous repair over a length of approximately 40m. Refer to Photographs 6 and 7.

The design allows for the soffit to continue to corrode to a width of 800mm with a protective lining underneath the structural FRP wrap. However the existing rubber ring joints would not provide an effective seal with the soffit of the pipe corroded and the repair wrap did not extend to the full circumference of the pipe, so sealing at each of the joints was required.

*Photograph 5: GRP patch in area of "breakthrough" Corrosion at a Pipe Joint*

Sealing of joints proved to be difficult with each joint having two spigot pipe ends with rubber rings. These were sealed in stages (refer to Figure 8) and over the structural area of the FRP wrap by:

a) cleaning out the annulus between the concrete, rubber ring and the fibreglass joint band

b) placing Sikaflex Tank within the edge of the joint

c) drilling injection holes and installing Sikaboom to seal the top and bottom of the area to be sealed

d) injecting Sika Injection-201 into the circumferential annulus between the existing rubber ring, the Sikaboom top and bottom seal and the Sikaflex Tank joint edge seal

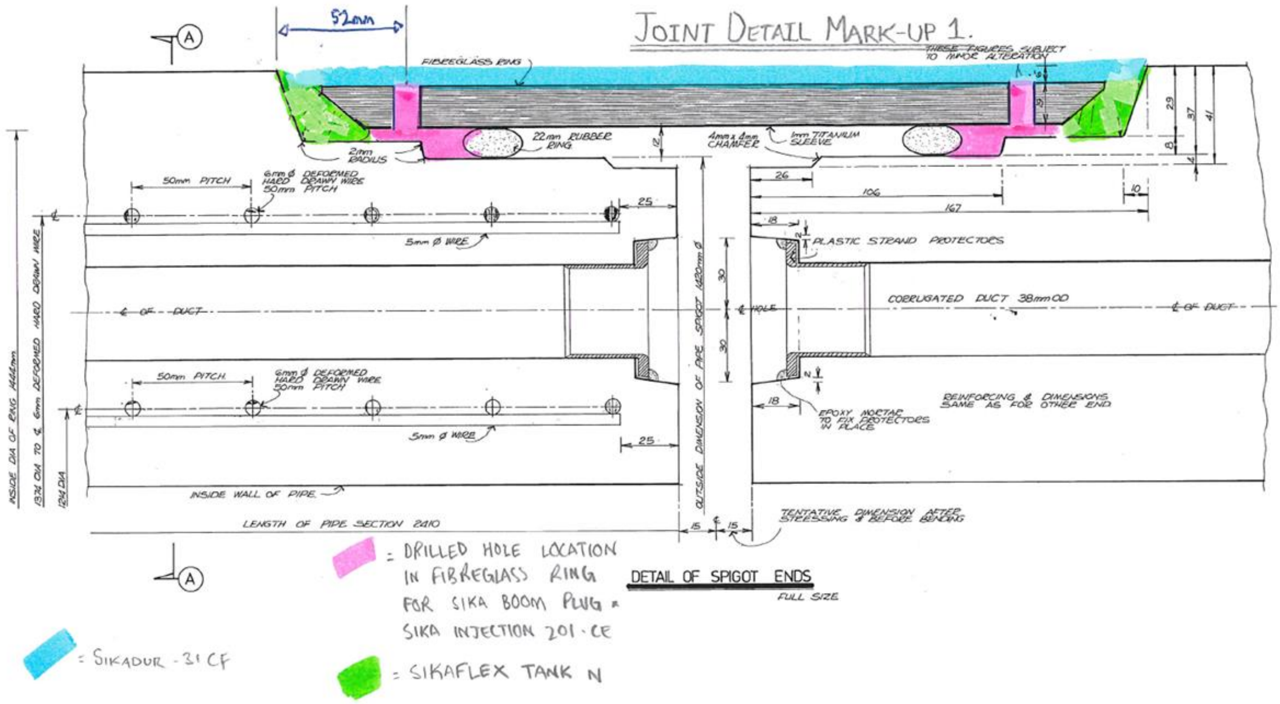


*Figure 8: Joint Sealing*

*Photograph 6: Repaired pipe with FRP wrap and Steel Reinforcing Prior to Spray Concrete*

# 5 DIFFUSER REPLACEMENT

## 5.1 ISSUES

### 5.1.1 DESIGN AND CONSTRUCTION ISSUES

Several modifications were made to the original diffuser design during construction, most notably the cutting of the two sections of pipe into six sections. These joints were formed with FRP spigot and socket sections welded to each cut face to permit the pipe sections to be joined in-situ.

The diffuser wall thickness appears to be variable. The sample of diffuser on site at the treatment plant had a wall thickness measured between 10 and 12 mm. The design life of the diffuser was understood to be 30 years. Design life of FRP marine outfalls is variable, however it is generally capable of a minimum of 50 years.

Marine environments are inherently difficult construction zones for both physical works and contract duration. Historical records note that for this project the time initially set for completion doubled and costs blew out from a budget $4.5M to a final $11.3M (1981 dollars).

### 5.1.2 SITE CONDITIONS

The diffuser is located in approximately 13 metres of water depth.

Records from the 1992 repairs indicate that the sea bed consists of soft marine sediment (mud) around the pipe, with a clay layer present approximately 1.5m below the sea bed and a very firm clay layer approximately 0.5m deeper, as indicated by lancing.

The predominant swell in Hawke Bay is from the south so the long outfall is relatively sheltered. However, the site is exposed to east or north-easterly swells, which will present the most difficult design conditions for restraint of the diffuser.

### 5.1.3 CURRENT CONDITION

Review of the 1992 repair records and recent condition inspections suggest that there were two main issues with regard to the current condition of the diffuser:

1. Leaking from the joints that is scouring the supporting sea bed
2. Deterioration of the FRP material

The first issue is primarily of consequence if the leak undermines the diffuser pipe and that under-mining then develops and results in a pipe failure under storm conditions. To prevent undermining of the pipe sandbags have been placed on a regular basis (during annual inspections) to fill in any scour holes that have developed at the joints.

The second issue is around possible delamination or swelling of the FRP pipe material appears to be restricted or at least focused at the joints, however the site conditions make this difficult to verify. The delamination will severely reduce the integrity of the FRP at that location.

## 5.2 REPAIR, UPGRADE OR REPLACEMENT OPTIONS

Three concept options were considered and these are described in the following sections.

### 5.2.1 REPAIR AS REQUIRED

One option for ongoing use of this diffuser is to “repair as you go”, with a task plan reviewed annually based on divers inspection, including replacement of sand bags at scour points and installing repair bands or replacing sections as required.

The major risk of this approach is a blow-out of the ageing pipeline resulting in limited diffusion of the effluent while a repair or replacement was arranged. A reactive replacement would most probably be at a higher cost as construction would have to be fast tracked and would not have the same level of checks and balances as a planned replacement. Also, the seasonal conditions may be unfavourable, resulting in longer construction time and associated cost, depending on the urgency at the time. Replacement section(s) could be designed and fabricated and held in stock to mitigate these issues to some extent.

Although there are commercially available FRP repair products that can be used underwater (e.g. wharf pile structural wrapping) there is limited experience in using these. As they are most probably unsuitable for the low visibility and moderately deep site conditions that the outfall diffuser is located in they have not been considered further.

### 5.2.2 UPGRADE KNOWN DEFECTS

From the limited information available, the diffuser pipe lengths may still be in good condition, with the exception of several of the joints, joints B, C, E, F and G. On this basis, an upgrade to the joint sections and holding down system could be a viable option to extend the life of the existing diffuser.

The five joints requiring attention include the four spigot/socket joints and the transition piece. The highest priority are joints B and C on the 1067 pipe, as they provide the initial diffusion and would allow for reasonable diffusion even if the end piece of the diffuser was compromised. Ideally these would be cut out and replaced, but to allow the diffuser to continue operating, these could be encapsulated with a new FRP collar, made in two sections and at least 1 metre in length. The lower section should be close fitting to avoid future scouring and the top section could be vented to allow leaks from the existing joint to safely discharge to the ocean. The collar should be made sufficiently stiff to allow tie down points to be attached to screw anchors on each corner. Each collar would need to be custom made from careful site measurements of the joint.

The major risk for the upgrade concept would be ongoing deterioration of the FRP diffuser pipe and a more detailed “touch” inspection of the diffuser pipe for evidence of the extent of delamination should be undertaken if this approach is chosen. Construction costs are very difficult to estimate and uncertain with further investigation needing to be done to scope this concept.

### 5.2.3 REPLACEMENT CONCEPT

Although FRP is still used for marine intakes and outfalls, currently preferred material for ocean outfalls is high density polyethylene (HDPE). Discussions with one FRP supplier indicate that HDPE is generally a more cost effective material for outfalls 1 metre diameter and less.

A replacement diffuser would most likely be constructed from HDPE pipe, with flexible “duckbill” type non-return valves for the ports to improve diffusion and with concrete support blocks secured to the sea bed by screw anchors. Construction costs are estimated in the order of $3M for a 300m long HDPE diffuser.

### 5.2.4 RISKS

While there are a number of risks with each of the three options, the “repair as required” and “upgrade” options have a reasonable likelihood of failure within the short to medium term which could result in an undiffused discharge occurring. The consequence of such failure includes potential environmental, cultural and social impacts. The scale and nature of these impacts would relate to the nature of any failure of the diffuser and the practicality and timing of repairs. A major failure could result in undiffused discharge occurring for many months.

A failure of the diffuser, with its known condition issues, is expected not be viewed favourably by stakeholders. Overall the diffuser is a critical element in the wastewater system that is located in an adverse working environment. The prudent approach is to have an asset that is in good condition with low likelihood of failure and no significant condition or performance issues.

### 5.2.5 PREFERRED OPTION

Due to the uncertainties and the risks noted above full renewal of the outfall diffuser was recommended to be completed within the next 5 years, prior to 2018.

In the interim though there is a need to continue to monitor and potentially implement reactive repairs including sandbag placement and/or joint wrapping. Details for repairs will need to be confirmed depending on annual inspection findings.

## 5.3 REPLACEMENT DESIGN

The replacement diffuser design has been advanced on the basis that the existing diffuser continues to operate until the new diffuser has been constructed. Only short shutdown windows are available and will be required to allow the switch over and "cut-out" of the existing FRP pipe from within the proposed Wye Fitting and provision of a blank flange. Refer to Figure 9 below.

A design life of 50 years has been used for the diffuser. HDPE pipe and fittings have been used where practical with sacrificial anodes provided for protection of steel fittings to achieve this design life.

Lateral stability is provided by piled connections and blocks to hold the diffuser pipe place, as the marine sediments at the site have minimal shear strength, offer little friction resistance and become close to fluid in high sea-state conditions.

The diffuser has been designed to achieve 100 to 1 dilution within a 100m mixing zone at peak pumped flows. Diffuser ports with duckbills to prevent ingress of seawater and marine sediment with shroud protection are provided at 5m centres staggered each side.

Marine work includes staged installation of the support clamp and pipes to the existing concrete pipe, installation of the wye fitting around the pipe and steel bend with pile supports. The design provides for maximum on-shore fabrication and construction with the diffuser pipe string able to be launched and floated out to position then sunk in a controlled manner, to minimise stresses on the pipe, into place on a prepared sea bed base, connecting to the steel pipework.

## 5.4 CONSTRUCTION

A construction contract has been awarded with construction planned to be carried out from September to December 2016.

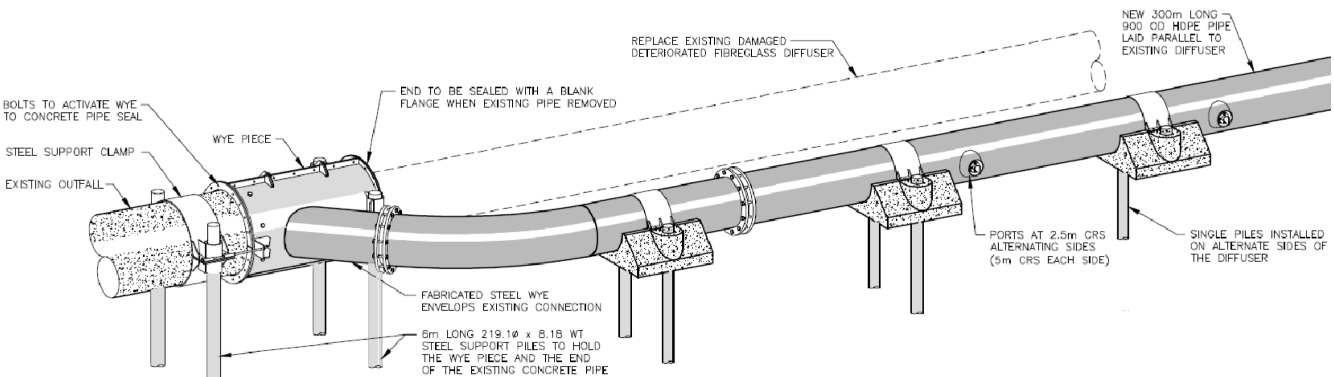


*Figure 9: Schematic of Diffuser Replacement*

# 6 RENEWAL PLANNING

Maintaining critical assets is an ongoing challenge for many communities. In this case Hastings District Council has chosen a combination of repair and replacement for discrete parts of the asset, with known condition issues or failure risks, in an effort to optimise investment while meeting a level of service appropriate to community expectations.

In 2012 the economic life of the outfall had been conservatively assessed at 50 years with full replacement programmed for 2026 (46 years after installation) at an estimated cost of approximately $40M. The recent condition investigations and repairs completed and renewal works proposed over the 5 year period 2012 to 2017 are expected to effectively extend the economic life for the overall outfall pipeline considerably.

Completed/Proposed Investigations and Repair/Replacement works for 2012 to 2017 cost is summarised below:

- Steel pipe repair $0.05M
- Concrete pipe repair $0.25M
- Diffuser replacement $2.5M

Total $2.8M

Consideration of outfall components, known issues and potential high risk elements as detailed in this paper gave comfort that the timing for full replacement of the outfall was significantly further into the future, and at or outside the 30 year planning horizon (2045). This timing lines up with current discharge permits for the wastewater treatment plant utilising the outfall, and allows further investment to be optimised with changes in technology or approach for wastewater management in Hastings District.

Further investigations and assessments are proposed in the following 5 year period (2017 to 2022) for some elements or components of the outfall, that at present are considered low risk, including:

- Condition of each of the cast-insitu joints between post-tensioned pipe strings
- Condition and potential failure of the post tensioning wire or fittings
- Concrete condition and possible corrosion of the reinforcing wire of submarine pipes.
- Condition of joint elements (rubber rings, urethane bearings)

Ongoing inspections and assessments will continue into the future for some components or elements of the outfall.

# 7 CONCLUSIONS

The elevation of the steel manifold and upstream end of the concrete outfall pipeline are at levels that mean full flow does not occur at all times and allows for biogenic $H_2S$ corrosion to occur, Significant corrosion has occurred and it is uncertain over what period that the corrosion occurred.

Historic construction, settlement, erosion and movement issues have continued to cause issues and potential high risks for future performance of the diffuser which is to be replaced in 2016/17.

Majority of the length of the outfall (3km) is a submarine concrete pipe that is approximately 35 years old and expected to be in relatively good condition with potentially 35 years or more remaining life.

Targeted investigations, repair and renewal work is being undertaken to provide the maximum life of the asset with optimised expenditure.

## ACKNOWLEDGEMENTS

We wish to acknowledge the following for their valuable input in the investigations, designs and construction of the various aspects and assistance with preparation of this paper.

Bob McWilliams, Wastewater Treatment Plant Manager, Hastings District Council

Steve Hutchison, Wellington Water (formerly MWH)

City Care

Greenfield Diving Services

OCEL Consultants

New Zealand Diving and Salvage

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