DON'T TEAR DOWN THIS WALL – RENEWAL OF A U SHAPED SEWER

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ABSTRACT

A condition inspection on an ageing trunk main in Porirua identified a high level of microbial induced corrosion on the pipeline with pipe soffit deteriorating and reinforcing exposed.

An options assessment was undertaken to determine the most effective method to renew or replace this 675mm wide x 1000mm high U shaped sewer which runs through a residential area including beneath private properties. The considered options had to minimise any reduction in the capacity of the sewer with a requirement to maintain maximum hydraulic capacity.

Cured in Place Pipe (CIPP) lining was selected as the most suitable methodology for the renewal. Large diameter manholes were installed along the mains to allow access for the structural liner installation.

Issues encountered on site included; a pipe cutter obstruction occurring in small diameter sections of the line, a heavy rain event which consequently caused trench washout and the distinctive odour of styrene through the CIPP curing process.

Installation of the U-shaped main liner resulted in some longitudinal fins and invert wrinkling occurring. The contractor was required to undertake manual entry to remove the majority of the fins. As health and safety holds a vital role within site function, this part of the project required an extensive amount of planning and preparation. The results proved to be successful with majority removal of the fins, however, some invert wrinkling remains. These are currently being monitored to ensure no loss of performance of the pipeline. This experience proved to be beneficial as lessons were learnt and recorded for future large diameter unconventional shape lining projects.

Despite the contingencies that were encountered on site, all parties involved maintained a high level of interaction and communication. Wellington Water, Stantec and Pipeworks ensured the job was completed within the capacity that met budget and customer requirements. The project was completed with minimal inconvenience to the local community and no complaints were recorded.

KEYWORDS

Pipeline Design, Trenchless Technology, U-shaped Sewer

PRESENTER PROFILE

Andrew Owen is a results focused intermediate engineer whose career at Stantec has involved investigation, design and the construction monitoring of network upgrades. He enjoys the challenges of these mostly urban works and the interactions with clients, contractors, residents, stakeholders and other consultants to ensure good solutions and happy communities.

Steve Hutchison is the Chief Advisor, Wastewater at Wellington Water who has worked in the water industry for 22 years. His work involves all facets of wastewater engineering at Wellington Water.

1 INTRODUCTION

In October 2014, Stantec was approached to tender the sewer renewals forward plan for the Porirua City Council (PCC). This was a process that assessed the wider network and evaluated it on a CCTV assessment which involved investigating pipe condition, age, material and the consequences that could occur should a pipe fail or be removed from operation. This analysis was valuable for determining which areas of the network were in need of maintenance and renewal, with several sections of main identified as needing to be replaced. This included a 520m section of sewer main which forms part of the original trunk main in Titahi Bay.

The 520m of trunk main in Titahi Bay included a downstream section of pipe with a non-standard profile. Whilst the upper 210m section of the main was a standard circular pipe, being DN900mm reinforced concrete (RC) pipe, the downstream 310m section was built as a U-shaped channel with a flat soffit and a rounded invert. This section of the trunk main is 1000mm high and approximately 685mm wide.

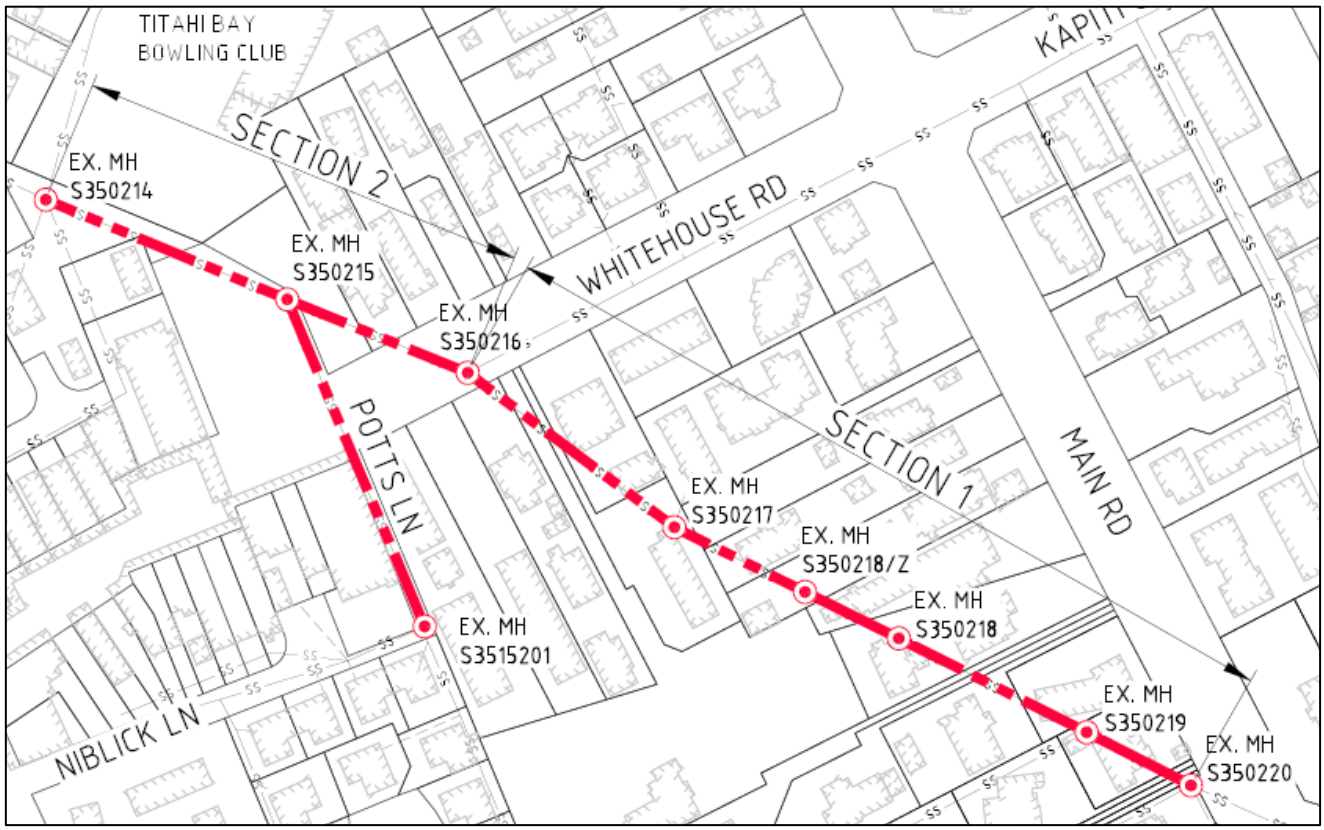
The condition of both lengths of sewer were poor and they also revealed signs of microbial induced corrosion. This is where concrete cover has been corroded to such an extent that the reinforcing bars had become exposed which could cause a number of issues to ensue.

The renewal also included a local sewer that branched off the trunk sewer. This section comprises of approximately 90m of DN150mm reinforced concrete pipe with a dip at the downstream end. The location of this section is adjacent to where it connected with the U-shaped sewer. This is referred to as the Potts Lane sewer.

The main was separated into two different sections as seen in Figure 1 below.

- Section 1: DN900 circular main
- Section 2: U-shaped pipe 1000mm x 685mm (including Potts Lane sewer)

Figure 1: Site Layout Plan



2 CURRENT FLOW AND FUTURE CAPACITY REQUIREMENTS

Although the trunk main was laid at a very shallow grade, it has capacity for up to 360L/s, which is significantly greater than the current peak flows. This was originally designed to convey all sewer flows from the greater part of the Porirua and northern Wellington City catchment; it is now only serving the local catchment which has approximately 1400 properties over 115 hectares. The calculated peak wet weather flow (PWWF) of the local catchment is 73L/s which correlates with flow monitoring completed on the alignment.

Since commissioning the main in 1950, a treatment plant in Titahi Bay had been commissioned in 1989 and a dedicated upstream pump station now diverts the catchment flows to the plant. As such, the renewal of the downstream trunk main was initially proposed to be slip lined with a 560mm OD PE100 pipe, suitably sized to manage the local flows with capacity to potentially develop the immediate catchment.

The idea of slip lining the main was later dismissed as an option for renewal. This was due to Wellington Water wanting to reduce and avoid any capacity loss through the pipeline. This provided the wider network with extra support should the rising main to the treatment plant be out of service for repairs or in an emergency situation.

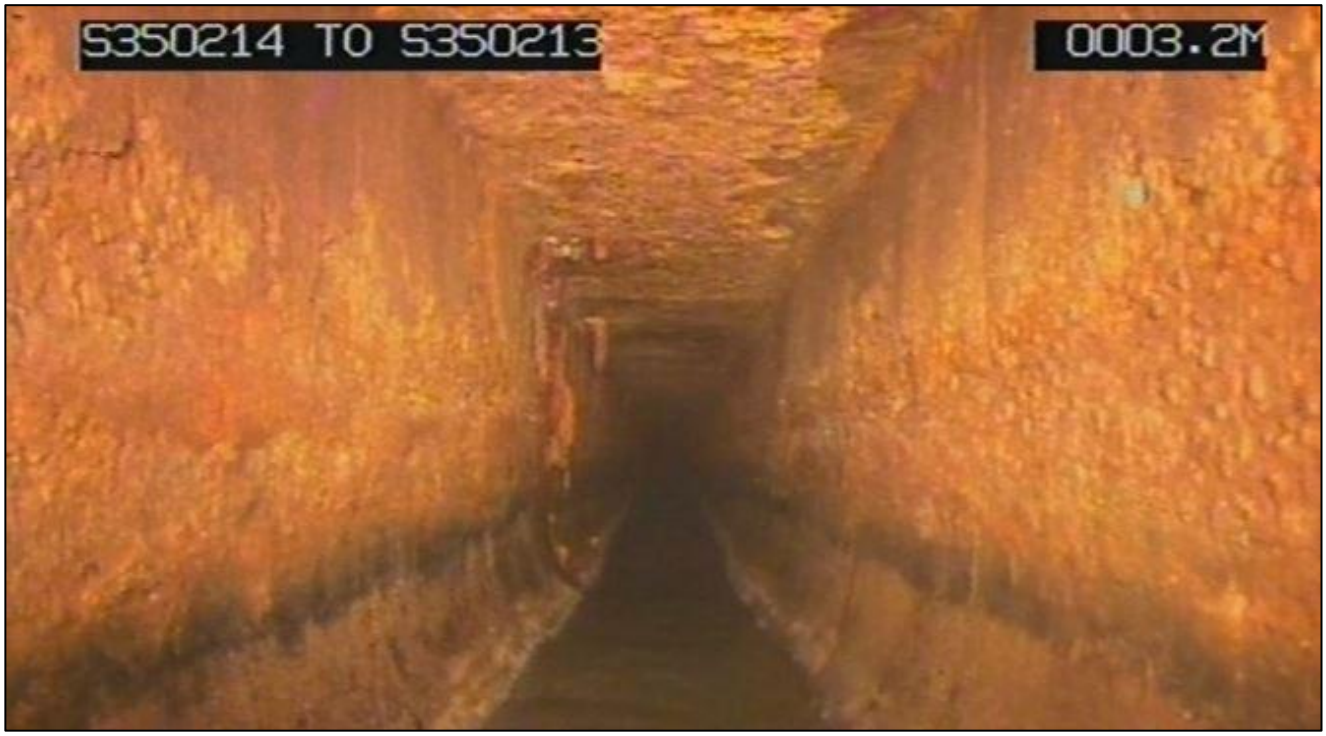
3 EXISTING SYSTEM DESCRIPTION

Inspection of the trunk main determined that the condition was in a poor state, confirming the need for renewal. Access to the main along the renewal length was limited with the existing manholes having narrow access (650mm square risers). A significant number of these manholes were located in private property or adjacent to structures, including the Titahi Bay World War II memorial and cenotaph.

All manholes along the alignment were non-compliant with the Wellington Water Regional Standard for Water Services (RSWS) 2012. The PCC operations team informed Stantec that entering the majority of the manholes on this alignment had a high risk status due to the narrow access, rusted step irons and depth of up to 4m to invert. CCTV was completed of the two pipe profiles as shown below in Figures 2 and 3. The condition of the U-shaped main was more deteriorated than the DN900 main.

Figure 2:DN900mm Circular Main

Figure 3:1000mm x 685mm U-Shaped Pipe



The U-shaped sewer had high levels of aggregate exposure with areas of reinforcing exposed. Encrustation was found to be present at most joint sections along the alignment with several areas showing significant material build-ups and deposits.

Due to several sections of the main being located beneath houses in private residential areas, a renewal method with minimal impact to residents and local business was preferred.

4 RENEWAL OPTIONS

As noted above, the pipeline was initially proposed to be renewed via slip lining however this method was not considered a viable option given Wellington Water's requirement to minimise loss of hydraulic capacity.

An options assessment was completed to determine a renewal method that would meet Wellington Water's design requirements: a structural pipeline with a 100 year design life in which any reduction in hydraulic capacity was minimised. Furthermore, it was to be constructed in a way that would minimise disruption to private property.

4.1 SECTION 1 RENEWAL (DN900)

Offline renewal was considered however due to the private properties over that in some cases had been built over the main, an offline renewal would need to be laid in the carriageway and would result in an increased length of up to 125m. Due to the already shallow grade, any increase in length would have a significant impact on the capacity of the main and it would need to be upsized. The additional length also had a significant impact on cost.

The DN900 main (Section 1) was designed to be replaced through lining. Either CIPP or spiral wound options were considered suitable. This was put to tender in December 2015 with the contract being awarded to PipeWorks in June 2016.

As part of the Section 1 renewal works, three manholes were identified as being suitable for replacement with the remaining three manholes selected to be rehabilitated.

4.2 SECTION 2 RENEWAL (U-SHAPED SEWER)

Options for renewing the U-Shaped sewer (Sections 02) were evaluated and included CIPP, spiral wound lining and open trenching.

Due to the profile of this main, spiral-wound lining was not considered suitable, as it would result in a circular profile and have too large a reduction in hydraulic capacity.

Open trenching options were considered and evaluated. These options were dismissed due to the significant level of disruption that it would cause and a reduced hydraulic performance from a significantly increased pipeline and high cost.

CIPP renewal was recommended for the completion of lining Section 2 as it was the only lining technique available to renew the U-shaped sewer without significant loss of hydraulic capacity whilst also providing a structural solution to the main. Wellington Water directly engaged PipeWorks as they were already establishing a work site for the Section 1 renewal and there were also (at the time of planning) no other contractors in NZ, of which Stantec was aware, who were capable of completing non-standard CIPP lining works at that diameter.

5 MANHOLE WORKS

PipeWorks started construction on Section 1 in early July 2016 with replacement of the manholes. Replacing these manholes ahead of the lining works had to be completed to allow safe and suitable access to the pipeline for lining and future maintenance. The existing manhole structures comprised of riser chambers positioned upon the existing main with a small window cut into the pipe. This was insufficient access to allow the liner entry to the existing main and was also below the current standard.

The Section 1 and 2 replacement works required the construction of four 1800mm diameter manholes, with excavation depths of up to 5.0m.

The remaining three manholes on the alignment were rehabilitated as they were in close proximity to existing properties. Excavating to replace them would have required significant underpinning of private dwellings and result in prolonged disruption to residents and their access. The rehabilitation of these manholes saw their step irons removed and their internal walls coated with a cement based sealer used for permanently waterproofing concrete structures. This product contains an additive that causes crystalline growth in the capillaries of the substrate as it reacts chemically with the free lime in the concrete. Additionally, these manholes had their lids and covers replaced.

During a high rainfall event it was found that the excavation protection in place during the construction of the most upstream manhole on the Section 1 alignment was insufficient to stabilise the face of the excavation. This resulted in a trench washout of the excavation sides. Debris were deposited into the sewer resulting in the contractor having to clean approximately 400m of the trunk main and remove significant amounts of gravel and debris.

The four manholes that were replaced required significant excavation to complete, in areas with restricted access. The construction of one manhole required access through several private properties with heavy plant and machinery. Photographs of the site during and after construction can be seen in Figures 4 and 5.

Figure 4: Manhole Replacement in private property

Figure 5: High quality reinstatement of manhole works area in private property

Minor infiltration occurred at two of the new manholes. The point of this infiltration was at the interface between the new concrete base and the existing pipeline which was used to form the invert of the manhole. It is likely that the depth of the manholes and shallow water table may have contributed to this issue as the civil contractor had difficulties creating a dry excavation to complete the work. This has since been remedied.

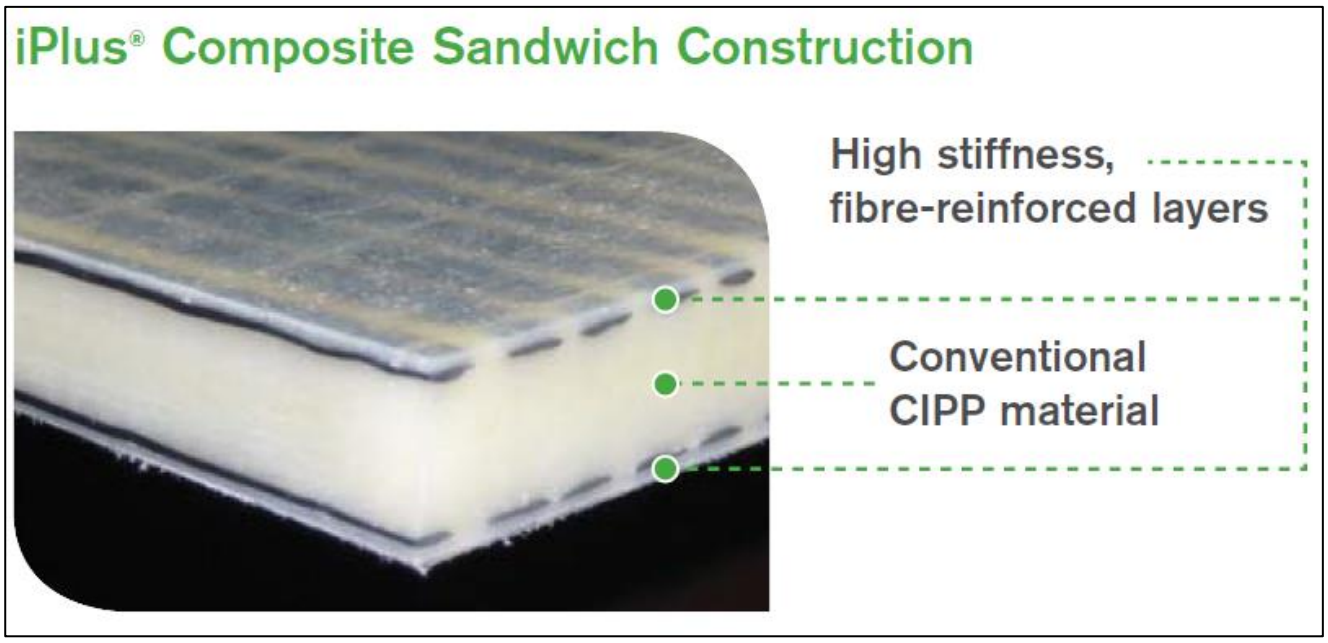
6 U-SHAPE CIPP LINER DESIGN

Due to the profile of the U-shaped pipe, a circular profile lining calculation was not suitable for determining the thickness of the liner required. To obtain full structural support across the top of the pipe, a 34mm thick liner was initially required.

PipeWorks proposed an alternative using their iPlus® liner, a fibre reinforced composite, allowing the thickness reduction of 23mm. This significantly decreased the volume of resin required whilst also maximising the cross sectional area of the lined main.

This proposed liner was accepted and used to line the Section 2 area of the trunk main.

Figure 6: iPlus® Composite Liner Cross Sectional Cut-Away



7 CIPP LINING PROCESS

The CIPP works involved the insertion of three separate circular felt liners. The Section 1 (DN900) and the Section 2 (U-shaped) mains were both lined from the same manhole. Lining these sections was completed sequentially with the lining insertion rig located in the carriageway of Whitehouse Road. The third section (Potts Lane DN150) was inserted from an upstream manhole in an alleyway.

The felt liners were impregnated with the resin mixture on site. This was then inserted to the liner under a vacuum head from suction cups applied at set intervals along the liner. The resin was evenly distributed to the felt by two large mechanical rolling pins positioned above and below the liner as it was inserted to the main, as can be seen in Figures 7 and 8.

Water was added to the inside of the liner at the rate of inversion required. The weight of the water above the invert caused the liner to invert itself and fold out into the existing pipeline. Starting ropes attached to the liner at predetermined measurements facilitated the liner turning at the base of the manhole so as to be directed inside the host pipe.

The pressure head to drive the liner into the existing main was controlled using water from the local network.

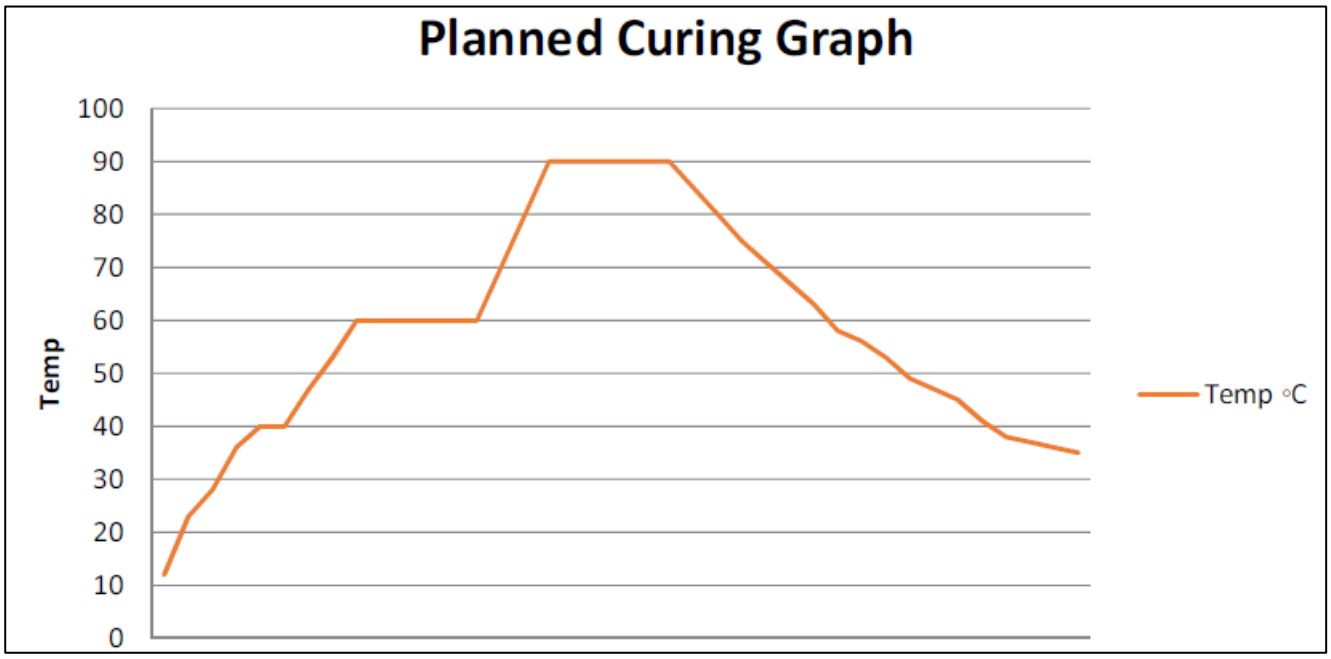
Figure 7: Liner being raised over the insertion manhole for inversion under head pressure

Feeding the liner into the main was an iterative process where a crane was brought in to guide and re-raise the liner as it was inserted, ensuring that there was a constant head pressure. Later discussions with PipeWorks identified this insertion method as not preferred as it was relatively stop-start and prevented there being a continuous insertion movement. This is identified as a lesson learnt.

Figure 8: Liner being raised over the insertion manhole for inversion under head pressure.

Once the liner was inserted, a boiling unit was connected to the hoses running along the liner which circulated hot water through the line to cure it. The curing process required the water to be heated to 60° Celsius, at which point the resin undergoes an exothermic reaction and heats itself to 90° Celsius. The curing graph can be seen below in Figure 9 showing the variation in temperature over time.

Figure 9: Liner Curing Graph Over Time



A sewer bypass system was implemented to over-pump flows. Flow monitoring of the main confirmed that dry weather diurnal peaks were 23 L/s which were manged by 6" pumps on site. Works undertaken to arrange the bypass system which included an alignment through private property as seen in Figure 10.

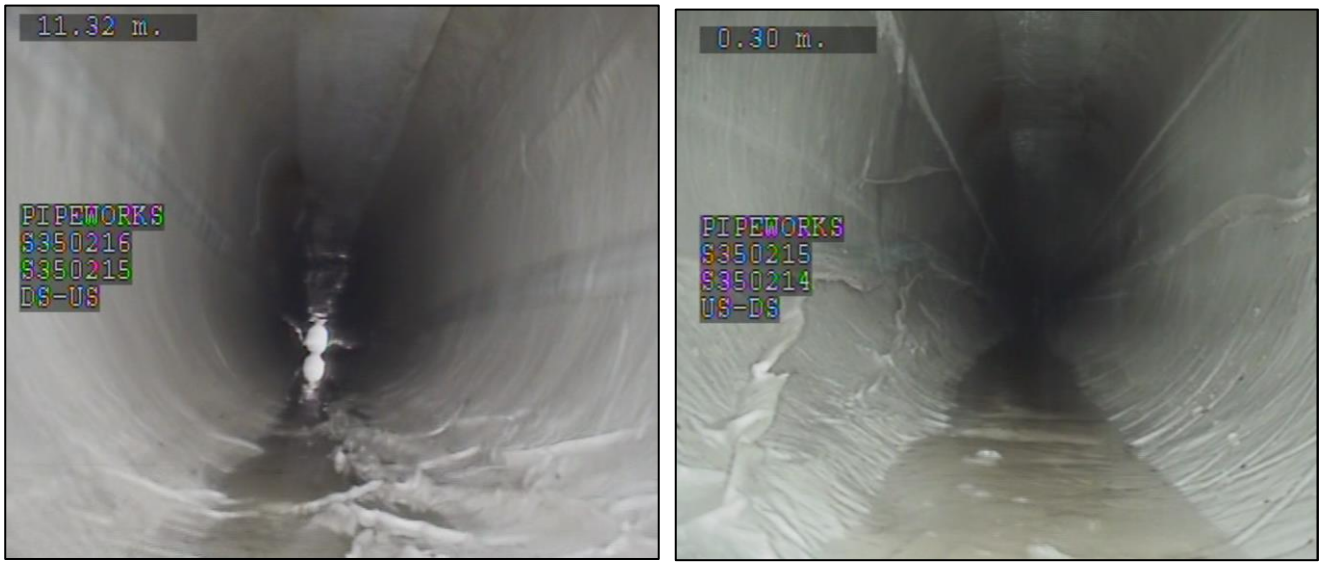
Figure 10: Bridged walkway constructed to manage over pumping alignment.

No landowner or public complaints were received despite the distinct chemical smell emitted during the CIPP curing process and requirement to work through the night once inversion commenced. This demonstrates that an effective communication process was used with all parties and stakeholders.

8 LONGITUDINAL FINS AND INVERT WRINKLES

Whilst the liner was successfully inverted in the U-Shaped host pipe, a number of longitudinal fins were found to be present. In addition, bunching of the liner had occurred at the invert of the pipeline at some locations.

Figures 11 and 12: Photos of lined pipe showing longitudinal fins and invert wrinkling



The fins and invert wrinkling occurred to an extent that was non-compliant with the contract specification requirements. This states that wrinkling could not occur in an excess of 2.5% of nominal pipe diameter and that a hydraulically smooth finish was compulsory.

Once the remaining lining works and reinstatement phase of the project had been completed, a meeting was held with PipeWorks, Stantec and Wellington Water to discuss the impact of these defects on the liner. It was suggested by PipeWorks that the longitudinal fins along the U-Shaped main could be removed by a worker entering the pipeline to cut them off whilst at the same time remedying a number of the invert wrinkles. The liner supplier was consulted and confirmed that cutting the fins off would not have any negative impact on the structural performance of the liner.

9 DEFECT REMEDY

Entering the pipeline to remove the fins was a significant health and safety issue in itself. Wellington Water aims to avoid people entering confined spaces where it is not essential. It is for this reason that the safety plan required attentive planning, including the implementation of an emergency rescue plan. PipeWorks prepared this and rehearsed a mock medical emergency event.

PipeWorks commenced remedial entry works. This was completed in relatively short span of time. PipeWorks manually removed majority of the fins, with specific focus on ones located in the lower half of the pipeline. A measure of the remaining fins were completed which showed that they were within the specification tolerances of 2.5% of the nominal pipe diameter.

Although the fins have been removed some invert wrinkling remained. This is to be monitored by ongoing inspection for the duration of the Defects Notification Period.

Figure 13: Cut liners removed from the U-Shaped Pipeline.

10 POTTS LANE SEWER

Installation of the CIPP liner for the DN150 Potts Lane main (a reinforced concrete host pipe) reduced the internal diameter to a point where during opening of laterals, PipeWork's "cutter" machine was unable to pass and became stuck. Excavations were required to remove the cutter and repair sections of liner that had been damaged in the attempts to remove it.

11 ONGOING INSPECTION

Although most of the longitudinal fins were cut back to a capacity within the specification requirements, a number of invert wrinkles remain which the PipeWorks report states that it cannot be removed without a high risk of damaging the structural integrity and hydraulic seal of the liner. Minor concerns were still had regarding the invert wrinkles and the likelihood that they would allow sediment or other debris to accumulate resulting in odour issues. Due to the minimal grade that the pipeline has been constructed on, there is very minor air flow and this may result in debris building up and impacting on residents and/or corrosion of the manholes. There is less concern that the wrinkles will allow the main to block as the size of the main is much greater than the wrinkles and build-up of flow in the main should push any obstructions through.

CCTV inspections completed 6 and 12 months after the works have encountered no issues with debris accumulation in the pipe invert. At the time of this paper, two planned inspections remain within the defects period.

12 LESSONS LEARNT

Overall the project thoroughly planned and executed. Discussions with PipeWorks, Stantec and Wellington Water were had well in advance of works commencing on site to identify and pro-actively manage site issues and contingencies. Reinstatement of works in private property were completed to a high standard and were praised by the land owners.

Difficulty on site during the construction of some of the manholes due to a high water table. This could have been more effectively managed if site specific ground investigation was completed and the dewatering methodology was better implemented allowing for a high quality standard of work.

Discussions with PipeWorks with regards to the reason that the fins and wrinkles occurred determined the following thoughts and potential areas for improvement:

- A thicker, non-composite liner would have been able to stretch more. This holds the potential of less bunching of the inner liner.
- Installing the liner with a higher pressure head to stretch the liner further.
- Using a different hydraulic roller to insert the liner in a smoother more continuous motion would have been more beneficial, as opposed to the start/stop process that the crane method was undertaking.
- The liner would have been installed from the downstream manhole to have a 90° insertion angle which would provide a more controlled insertion.
- PipeWorks would have aligned the liner so that the flame bonded seam between layers was positioned at the soffit of the pipe to allow it to form evenly.
- PipeWorks would consider having the liner manufactured so as to have smaller, more frequent flame bonded seals.
- Stantec queried if the diameter of the liner was too large for the host pipe but PipeWorks confirmed it was the correct size and also noted that using a smaller liner would not have prevented bunching of the layers given no change to the other installation conditions.

Future lining works for non-circular pipes should consider the Lessons Learnt section of this report for improvement. Future lining works in non-circular pipe should also be laser scanned ahead of lining works to confirm internal dimensions and assess whether there is any longitudinal variation in dimensions.

Clients should develop an understanding with lining contractors about the risk of wrinkles occurring, the extent to which they will occur and the impact (if any) that may impose on the finished product of the liner and sewer system.

Expert advice should be sought for preparation of a specification targeted at non-circular pipes and for construction monitoring assistance at the time of installation.

For DN150 RC pipes sending a test barrel through first to identify any pinch points would be recommended to avoid getting the pipe cutter stuck and prevent the associated liner damage.

Manhole excavations in areas impacted by high groundwater tables should be sheet piled and sufficiently dewatered prior to excavations occurring.

13 CONCLUSION

The installation of the liner resulted in a number of defects being recorded including longitudinal fins and invert wrinkles along the trunk main. Pipeworks sought approval, planned and undertook a person entry to the pipe to remedy the defects in the pipeline which were completed so as to bring them in line with the Contract Specification.

Lessons have been learnt and processes refined for how to undertake works such as this in future lining of similar non-standard profiles.

The drivers for renewing the main in this manner have been met; the renewal has maximised the cross sectional area of the host pipe whilst also increasing the longevity of the main with a structural liner. The works were completed with minimal disturbance to the community and were completed in the required timeframe and within budget.

Downstream sections of the trunk main are planned for renewal. Since they have the same profile as the Section 2 U-shaped main, the foundations of this project and lessons learnt will be applied if they are to be lined.

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REFERENCES

Insituform Pacific – iPlus® Composite Catalogue for the image supplied in Figure 6.