NON DESTRUCTIVE PIPELINE CONDITION ASSESSMENT – HUTT VALLEY MAIN OUTFALL PIPELINE

S.J. Hutchison
MWH NZ Ltd, Wellington, New Zealand
R.J. Mascarenhas
Pure Technologies Ltd, Sydney, Australia

ABSTRACT

A key feature of the Hutt Valley wastewater system is an 18.3 kilometre land based outfall pipeline. The condition of this pipeline, which was commissioned in 1962 is a major consideration in planning for renovation or replacement by Hutt City Council.

Investigations of pipe condition inspection options led MWH to a patented electromagnetic technology (PureEM™) developed by Pure Technologies. The Australasian branch of Pure Technologies was engaged to undertake a survey using their proprietary equipmentin May 2013.

Following the data analysis, physical validation testing was undertaken on selected pipes by excavating and confirming the amount of distress that was reported from the PureEM survey. The correlation was very high, confirming the accuracy of the use of this technology for this pipeline.

In order to detect leaks, Pure Technologies were also commissioned to undertake a survey using their patented SmartBall® inspection technology in November 2013. This in-line tool is "free floating" and locates leaks and gas pockets in pressurised pipes by measurement of acoustic activity.

This paper describes the investigations undertaken during these condition surveys, the challenges of planning and completing the inspections and the modern non destructive condition inspection plus assessment options which are now available.

KEYWORDS

Condition Assessment, Non-Destructive, Large Diameter Pipelines

1 INTRODUCTION

A key feature of the Hutt Valley wastewater system is an 18.3 kilometre land based outfall pipeline originally known as the Main Outfall Sewer. This prestressed concrete rising main was commissioned in 1962 and required a number of repairs since commissioning, including joint failures, soffit corrosion, pipe displacement and damage from tree roots.

The quality of the effluent has been progressively improved since the Main Outfall Sewer has been in operation. Initially preliminary grit removal and macerating screens treatment was provided. A milliscreening facility replacing these was commissioned in 1984. A full biological treatment plant with ultra-violet disinfection was commissioned in 2002 and the pipeline has since been referred to as the Main Outfall Pipeline to reflect the change from essentially raw sewage. Prior to the treatment plant commissioning the hydrogen sulphide gas released from the effluent was the primary cause of the soffit corrosion.

The pipeline was originally commissioned to operate at a maximum 35m pressure head, with vacuum assisted syphonic action during low flows. Following difficulties with air leaks that occurred during the first 10 years of operation, the vacuum pump was decommissioned and a weir installed at the outer end to keep the pipe full during operation.

The route of the pipeline is through the industrial area of Seaview for 2km, then under the narrow, winding road that serves the Eastern Bay communities of Eastbourne for 8km, then along a gravel track originally built for the pipeline construction that follows the eastern side of Wellington Harbour for 8km to a short outfall south of Pencarrow Head. Access and working conditions are often difficult, with a high groundwater table and challenging traffic management in the urban sections.

MWH New Zealand Ltd has been assisting in the management of the trunk wastewater activity under a Professional Services Contract with the Hutt City Council since 2003.

Figure 1:   Pipeline route

2 DESCRIPTION OF THE PIPELINE

2.1 ROCLA PIPE CONSTRUCTION

The pipeline consists of about 4,600 rubber ring jointed prestressed concrete pipes (PCP) including precast concrete mitre blocks and other specials used at manhole sections and around some of the curves. The 63mm thick concrete cores were formed by a process known as the "Rocla" roller suspension method and were longitudinally pretensioned using cold drawn steel wires. Circumferential prestressing was applied by wrapping the cured cores with a high tensile wire on a varying pitch, based on the pressure rating for that section of pipeline. The prestressing wires were protected with shotcrete that had a specified minimum thickness of 20mm. Details of the pipe section are shown below.

Figure 2: Pipe dimensions

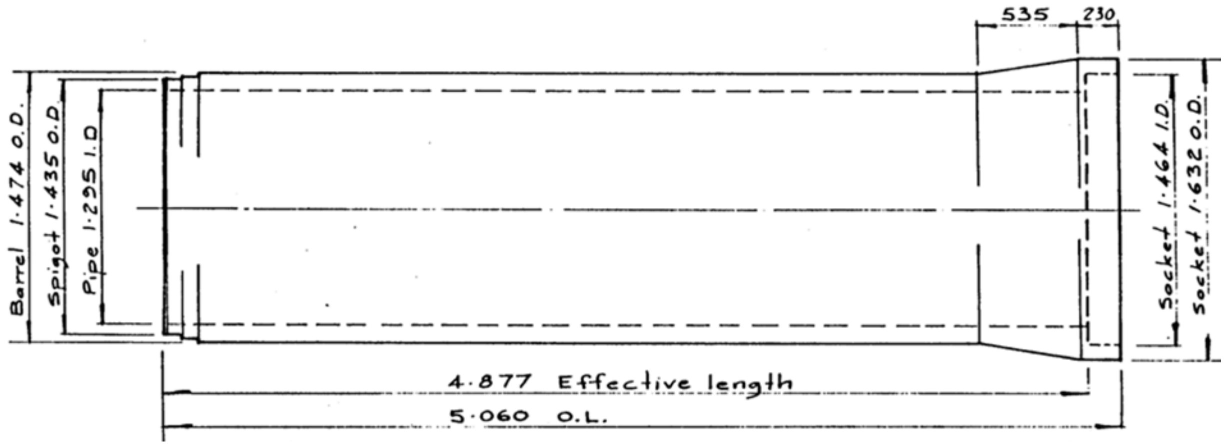
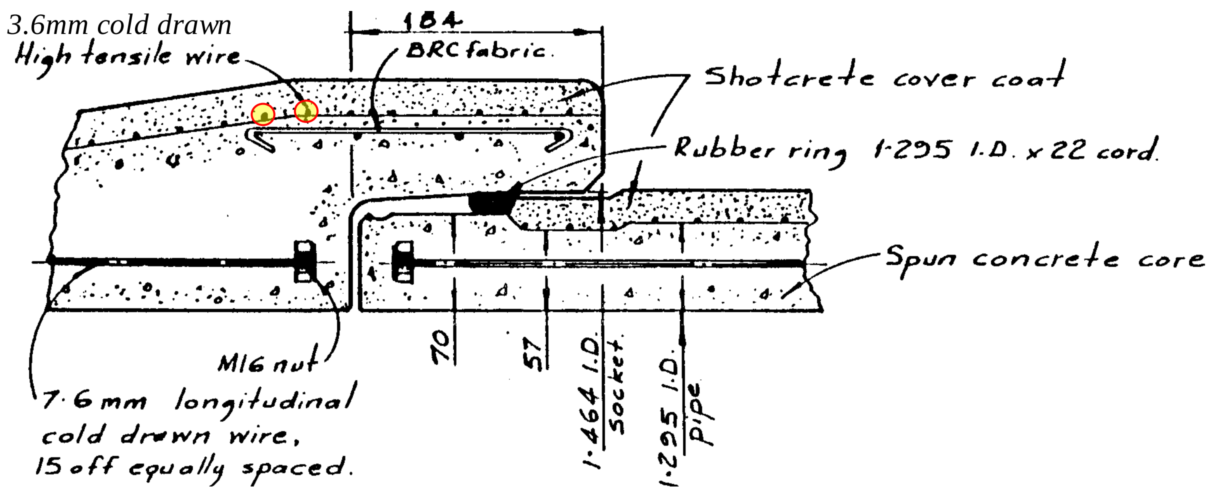


Figure 3: Pipe joint and reinforcing details



The pipeline was laid in a trench with two short tunnel sections at the southern end. Much of the pipeline route is below normal groundwater level.

2.2 HISTORIC PROBLEMS WITH THE PIPELINE

2.2.1 INTERNAL CORROSION

Concrete corrosion developed in the pipe soffit in the first 10 years of operation over a length of about 5km which operated in partly full condition. The corrosion was caused by release of hydrogen sulphide from the sewage, which then formed sulphuric acid on the surface of the concrete. To overcome this problem a flap-gate valve was installed to keep the line full under most conditions. This was then replaced in 1985 with a vortex chamber near the outfall which in effect provides a weir and energy dissipating structure and has proven successful at limiting further concrete corrosion.

A number of repairs were carried out on the worst parts of the soffit corrosion between 1971 and 1984.

2.2.2 CORROSION OF PRESTRESSING STEEL

Catastrophic failures occurred in two pipes in one of two short tunnels in the southern end of the pipeline in 1978. These failures were mainly due to severe corrosion of the prestressing wire, although internal corrosion was also a factor and accidental over-pressurisation may have occurred. The corrosion of the prestressing wires was caused by contact of saline groundwater dripping onto the pipes in the tunnel. In 1995 the annular space of these tunnels was filled with concrete to remove the risk of further wall failure in the tunnels.

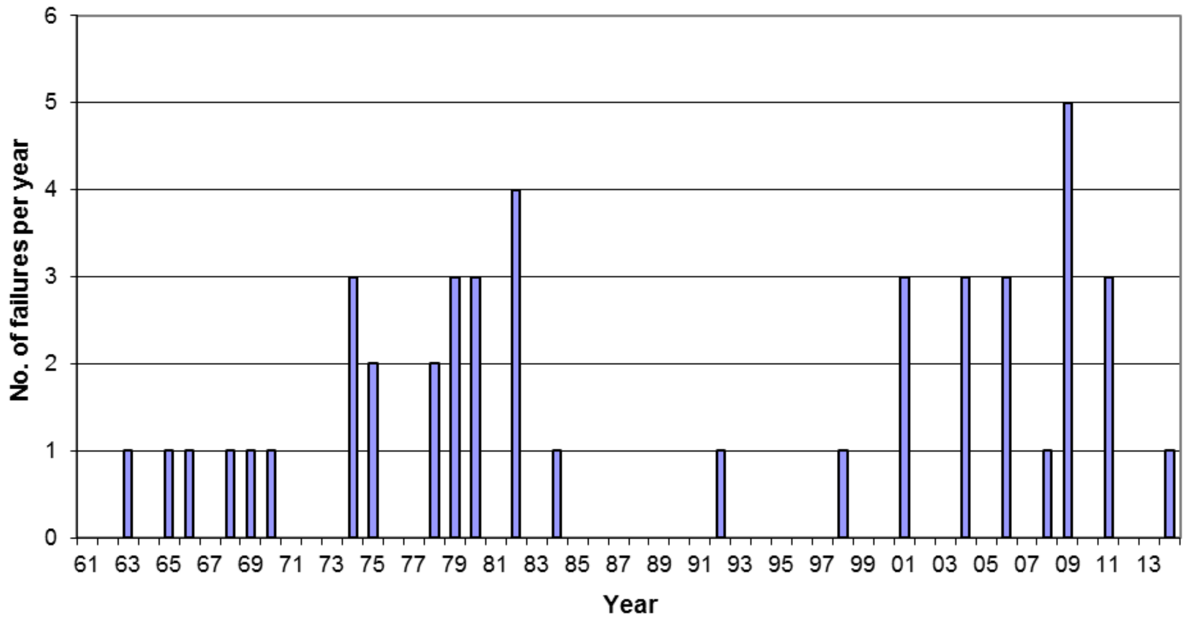
This failure raised the concern over possible, albeit slower, corrosion of the prestressing wire due to groundwater conditions. Condition survey work in 1989 and 2003 has found areas of prestressing wire corrosion in five of 44 inspected pipes, however only one of these was significant. One of the pipes inspected also had extensive delamination of the protective shotcrete that was a separate concern.

Photograph 1: View of exposed and corroded prestressing wire

2.2.3 PIPE JOINTS

Prior to 2009 there had been 36 joint failures in the 47 years of operation of the pipe. The frequency had varied, with an obvious reduction in failures from 1982 due to the installation of new pumps and variable speed drives controlled by new computer control system in 1981 which limited the rate of change of pressure in the pipeline. There are several contributing factors to these joint failures, including pipe settlement, unsatisfactory original installation tolerances, internal pressure fluctuations, ingress of tree roots and loss of integrity of the rubber ring due to loss of elasticity and general degradation with age.

Figure 4: Pipe joint failure histogram from 1962 commissioning to July 2014



3 CONDITION INSPECTIONS AND MANAGEMENT OF THE PIPELINE

3.1 2004 CONDITION INSPECTION

Condition inspection of rising mains is inherently difficult as there is seldom any redundancy to allow the pipelines to be taken off-line. In the case of the Main Outfall Pipeline treated effluent has to be diverted from the Seaview wastewater treatment plant into the lower reaches of the Waiwhetu Stream from where it flows into Wellington harbour. Resource consents were obtained for an internal condition inspection of the pipeline in 2004. The previous inspection had been in 1991 and the key finding in 2004, using methods of that time, was that most of the pipeline was in good condition and no further deterioration had occurred. The remaining life of the pipeline was assessed as being unlikely to be less than 15 years based on about two joint failures per year being reasonably acceptable to the community.

3.2 REQUEST FOR QUALIFICATION

During the 2004 condition inspection the Hutt City Council issued a Request for Proposal for Structural Rehabilitation of the Main Outfall Pipeline. This was undertaken as part of the management planning for the pipeline, in order to identify contractors and techniques which could be used to undertake the specialised works to renew or rehabilitate this large diameter pipeline when those works are required.

One of the proposers also noted the electromagnetic condition inspection technology available from Pure Technologies, a company based in Canada.

Photograph 2: Internal condition inspection 2004

4 ELECTROMAGNETIC INSPECTION

4.1 PREPARATORY WORKS – RESOURCE CONSENTS

As per the 2004 inspection, resource consents were required to allow the pipeline to be drained for this planned inspection. Following a major contamination remediation project on the Waiwhetu Stream there was more sensitivity to this application and the resource consent process took 15 months with the outcome being a suite of consents for a five year period.

The consent application was to undertake planned work in the May-June period as this time of year was assessed as being the least sensitive period for diversion of the treated effluent to the Waiwhetu Stream with regard to fish migration timing and lowest contact recreation. The Seaview treatment plant produces a high quality secondary treated and disinfected effluent and operational changes to maximise the ultraviolet disinfection treatment and to use storm storage capacity for tidal buffering of the effluent were agreed as part of the consent conditions.

4.2 TECHNOLOGY DESCRIPTION

Pure Technologies was contracted to inspect the Main Outfall Pipeline and utilise their patented PureEM™ technology to identify structural distress. In the case of metallic pipes, a PureEM survey detects areas of metallic wall thinning (e.g. corrosion). For PCP, PureEM detects and quantifies the number of breaks in the prestressing wire that strengthens the concrete. This type of inspection provides water and wastewater system operators with the information on the location, distribution and number of wire breaks along the length of the pipeline.

This technology can be utilised on a number of platforms including: manned carts; robotics; pigs; and external scanners. For the Main Outfall Pipeline, the technology was fitted onto manned tricycles (PipeRider), which can be broken down into small pieces to pass through standard manholes. The tricycles and electronics are then assembled inside the pipeline in less than an hour.

Photograph 3: PureEM Tricycle (PipeRider)

PureEM functions much in the same way as a radio transmitter and receiver. The "transmitter" produces an electromagnetic field. The prestressing wires in the pipe amplify the signal that is recorded by the "receiver". If there is distress (e.g. broken wires or metal wall thinning), the signal is distorted. A measurement of the distortion quantifies the number of broken wires.

4.3 CALIBRATION

In order to provide accurate results, calibration testing is recommended every time that a PureEM survey is conducted on an previously untested class of pipe. This was the first time testing Rocla's PCP, thus calibration tests were recommended and conducted on two spare pipes above ground. Calibration testing involves simulating distress on PCP by intentionally cutting a known amount of prestressing wire wraps and progressively increasing the number of cuts. Data is collected each time the wires are cut to examine the signal response with varying levels of distress.

The Main Outfall Pipeline is comprised of several classes of PCP and two slightly different designs: with and without a backwinding wire. Each variable change in the design of PCP requires calibration testing on that type of pipe, thus additional calibration testing was performed in-situ during the distress validation tests.

4.4 INSPECTION

In May 2014, Pure Technologies conducted a PureEM survey of the Main Outfall Pipeline using the PipeRider and inspected the 18km of pipeline from the Seaview Treatment Plant to the outfall. Existing features (i.e. manholes) were utilised for access to the pipe and for periodic check points as the inspection took place.

This type of inspection required that the pipeline be dewatered and made ready for manned entry. Close coordination between the network operator, the civil contractor, MWH and Pure Technologies was required to ensure that all safety precautions were put into place. The survey took three days to complete and covered 4,662 individual sections of pipe.

4.5 RESULTS

Out of the 4,662 pipes tested, approximately 7.6% of pipes showed signs of pretressing wire distress; however, only two pipes showed a level of distress much higher than the rest. This is consistent with what is seen in most prestressed concrete pipelines where less than 10% of pipes show distress and less than 1% of pipes have a high level of distress. This baseline condition information provides a snapshot of the structural condition of the pipeline at a moment in time and allows pipeline owners to make informed decisions on the long-term management strategy.

4.5.1 PERFORMANCE CURVES

In order to better understand the operational risk of the Main Outfall Pipeline given the known levels of distress, Pure Technologies created performance curves using finite element analysis (FEA). This structural modelling creates a relationship between internal loads (operational plus surge pressure) and distress (wire breaks), and takes into account external loading conditions as well as pipeline design. Different limit states are identified as curves on a graphical chart to help identify at what point is a particular pipe at high risk of failure.

5 VALIDATION SAMPLING

Subsequent tests were performed on the Main Outfall Pipeline in November 2013 to help calibrate and validate the PureEM results. For these tests, 11 pipes were selected of varying levels of distress and pipe class. Once each pipe was excavated, an external PureEM tool (PipeScanner) was used to scan the pipes once more as a method to verify that the right pipes were excavated.

Photograph 4: External PureEM (PipeScanner)

A strip of external shotcrete coating was removed from the top of each pipe to expose the prestressing wire, then resistivity tests were performed on each pair of wire wraps to determine the actual amount of distress. In all cases, the validation tests correlated very well with the PureEM results in estimating the quantity and location of distressed wire wraps.

6 LEAK DETECTION SURVEY

6.1 TECHNOLOGY DESCRIPTION

Given the history of leaks on the Main Outfall Pipeline and previous hydrogen sulphide related corrosion, it was decided to conduct an in-line leak and gas pocket detection survey across the whole pipeline. Pure Technologies was contracted to utilise their patented SmartBall® leak and gas pocket detection technology.

Figure 5: SmartBall core

The SmartBall is a free-swimming technology designed to operate in live large diameter water and wastewater mains. It need a single point of access for entry and another for retrieval but can traverse tens of kilometers in a single run. External tracking sensors are temporarily affixed to the pipe wall at pre-selected locations to track the ball's movement in real-time. As the Ball rolls through the pipeline, it records an acoustic profile and the data is then analysed for signatures representative of leaks or gas pockets.

6.2 INSPECTION AND RESULTS

The SmartBall survey was conducted in November 2013. The first run had the ball inserted at a valve at the Seaview Wastewater treatment, but due to operational issues a second run was required. The second run had the ball inserted at a valve at the Point Arthur Pumping Station in Eastbourne and retrieved out of the vortex structure towards the outfall. Upon analysing the data, one gas pocket was detected and no leaks.

7 ONGOING PIPELINE MANAGEMENT

The information obtained during this and previous condition assessments provides HCC and their advisers with a considerably improved level of understanding and confidence of the pipeline condition. This will enable future various repair, maintenance and replacement decisions to be made with a much higher level of information.

Following the PureEM survey it was decided to replace the two pipes identified as being most affected by corrosion of the prestressing wires. This work has now been done and the two pipes removed will be subject to further detailed analysis to gain a better appreciation of the condition of the various pipe elements which will be of benefit in refining pipeline remaining life forecasts.

8 CONCLUSIONS

Non-destructive pipeline condition assessment is a developing field. There is relatively limited experience in New Zealand of the more advanced technologies and the cost of the technologies is substantial compared to previous investigation methods; however, the investment in advanced condition survey technology can be justified for large assets with a high consequence of failure versus the likelihood of failure, and high capital replacement cost. In this case, the PureEM survey has provided a detailed understanding of the reinforcing steel condition, the primary structural component of the pipe for the entire pipeline route, which has given detailed information to identify and replace pipes that are in poor condition.

Although condition survey costs were significant they are only a small fraction of the very high capital replacement cost for this asset. Any worthwhile extension of the life of the pipeline through the use of these techniques to assist the development of repair, maintenance and replacement programmes and decisions is good value for money. More importantly, it has provided confidence to continue with the operation of the existing pipeline in the medium term.

ACKNOWLEDGEMENTS

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- E Carson & Sons, the civil and specialist pipe repair contractor
- John Wood, independent consulting engineer who provided technical advice and support
- Hutt Valley Water Services, the network operators
- MWH colleagues.

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