ASSESSMENT OF CRITICAL RISING MAINS FOR RISK BASED ASSET MANAGEMENT

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ABSTRACT

A critical component of Queensland Urban Utilities’ waste water system is the conveyance of raw sewerage from the Eagle Farm Sewerage Pump Station to the Luggage Point Sewerage Treatment Plant via three large-diameter sewerage rising mains. The total flow through these mains accounts for 50% of Brisbane’s raw sewerage. A failure on these mains would result in a high-impact from a customer and environmental perspective. This paper outlines Queensland Urban Utilities’ proactive approach in undertaking an Australian first-of-its-kind comprehensive condition assessment, utilising innovative inspection technologies and risk assessment techniques, to conduct selective rehabilitation and extend asset life.

INTRODUCTION

Queensland Urban Utilities own and operate a critical network of large-diameter sewerage pressure mains – also known as force mains – which are responsible for transporting 50 percent of raw sewerage in the Brisbane area. The rising mains run from the Eagle Farm Sewerage Pump Station (SPS) to the Luggage Point Sewerage Treatment Plant (STP). With such a large volume of flow (up to 6000 L/s), the reliability of these rising mains is important from both a customer and environmental perspective.

The rising main network is comprised of the following:

- 1370 mm diameter Mild Steel Cement Lined (MSCL) rising main, also known as Line 54, from the Eagle Farm SPS to the Luggage Point STP (9,530 m in length). Typically, this is used to convey dry weather flows.
- 1840 mm diameter MSCL rising main from the Eagle Farm SPS to the Serpentine Road SPS (3,360 m in length). Typically this is used to convey additional flows during wet weather.
- At the Serpentine Road SPS, the 1840 mm diameter main connects to twin 1295 mm prestressed concrete pipe (PCP) mains, also known as Line 51 and Line 36, which continue to the vent stacks at Bancroft Road (5,720 m in length).
- The twin mains then connect to two 1370 mm diameter MSCL rising mains from the vent stacks to the Luggage Point STP (500 m in length).

An exposed section of the twin mains is shown in Figure 1.

The focus of this paper is the twin MSCL and PCP mains. The twin 1370 mm MSCL mains, constructed in 1974, will need to last until 2035 in accordance with the Capital Investment Plan and Asset Management’s requirement of a 60-year asset life. The twin 1295 mm PCP mains were constructed in 1952 and need to last until 2025 when the mains are scheduled to be replaced.

Purpose of Condition Assessment

Queensland Urban Utilities understands that there is a strong relationship between asset life and criticality (likelihood of failure and consequence of

Figure 1: Sewerage Rising Mains from Eagle Farm SPS to Luggage Point STP
failure) – ultimately leading to performance risk and service standards. Asset condition and how it changes over time is an important element in enhancing this understanding and in supporting decision making activities including maintenance planning, network operation and renewal planning.

Queensland Urban Utilities engaged Pure Technologies as Prime Consultant to conduct a detailed condition assessment and confirm:

- The current condition of these sewerage rising mains;
- Their estimated remaining operable asset life; and
- The work required to confirm the rising mains reach their design life in accordance with the Capital Investment Plan.

CONDITION ASSESSMENT PHASES

Building upon previous assessments conducted by Pure Technologies’ Engineering Services, Queensland Urban Utilities sought to identify industry best practices for assessing these critical large-diameter rising mains. Given that no single technique or technology can be used to assess all mains, a customised approach is required based on asset criticality, budget, pipe material, failure mechanisms, accessibility and operation. Queensland Urban Utilities worked with Pure Technologies to develop a comprehensive assessment plan tailored to the specific assets and stakeholder needs.

Separate condition assessment techniques were chosen for the MSCL pipes and PCP, but both techniques focused on identifying individual pipes with structural deterioration and quantifying the deterioration to determine the pipe’s integrity.

MSCL pipes are comprised of a steel cylinder, cement lining and various coatings for protection against corrosive elements. The primary structural component of MSCL pipe is the steel cylinder itself, so identifying any steel wall deterioration (e.g. wall thickness loss) is of primary concern. PCP is a composite pipe with a concrete core, high-tensile steel prestressing wire coiled around the core, and gunite coating to protect the prestressing steel wire. The primary structural component of PCP is the prestressing wire, so when the wire deteriorates or breaks there is a loss of core compression.

The condition assessment program included: management of the isolation, dewatering and cleaning of the mains; confined space and safety rescue plans; access and permit approvals; internal/external investigations; recharging of the mains; and analysis of all collected data for a risk assessment. Given the criticality of the twin mains, there was a short window of time to conduct the field work, which required strong planning and communication between Queensland Urban Utilities, Pure Technologies and its sub-contractors.

After the isolation, dewatering and cleaning of the mains, Pure Technologies were able to complete a comprehensive condition assessment of the mains utilising the following techniques:

- A SmartBall® inspection to detect leaks and gas pockets. This inspection helps to identify discrete locations along the mains with likely deterioration in the form of cracks, perforations, joint issues, and internal corrosion where H₂S gas is trapped. The SmartBall (shown in Figure 2) requires one access for insertion and one for retrieval utilising the most convenient method (e.g. existing features). It is tracked in real time above ground to determine the location of any anomalies detected during post-processing of collected data.

- A ground survey to determine the residual ground cover and identify external loading on the mains. A surveyor (shown in Figure 3) traversed the length of the mains taking high-accuracy GPS points at periodic intervals. The GPS data was compared with as-built drawings to determine the residual ground cover.
• CCTV and laser profiling to determine and record internal deterioration in the twin mains, specifically lining deterioration, and highlight locations for further visual inspection. As the mains were being dewatered and cleaned, a robotic unit (shown in Figure 4) followed closely behind to confirm completion of work, but also collect CCTV and laser profiling information. The robotic unit is tethered and would be inserted through an open manhole, but would be retracted through the same manhole after reaching its deployment limit. Additional manholes were utilised for the robotic unit to traverse the length of the mains.

Likewise, for the PCP section of the mains, an internal manned tool was utilised. In PCP, PureEM is utilised to detect and quantify the number of wire breaks in the prestressing wire. A different configuration of electronics is required to detect deterioration in PCP; thus, a custom made tricycle platform (shown in Figure 6) can be utilised for these inspections.

• Visual inspections of valves to examine their condition. The inspections identified several valves with excessive corrosion, which required replacement. This ensured that the critical assets were assessed as a whole.

• PureEM™ electromagnetic inspection to determine the structural condition of each pipe. For MSCL pipes, a 48-detector manned cart (shown in Figure 5) was developed to scan the pipes internally and identify large areas of deterioration (e.g. steel wall thinning). This technology was able to penetrate through the PVC and cement lining of the MSCL pipes. Given that the mains were dewatered and cleaned for the CCTV and laser profiling, it was advantageous to utilise a manned internal platform. However, other platforms exist for PureEM inspections including a flexible pig platform for use while a main remains in operation, and a robotics unit for smaller diameter pipes which are partially depressurised.

• Internal visual inspection to confirm and further document findings. Initially, visual spot checks were to be performed based on the SmartBall inspection, CCTV and laser profiling results; however, a more comprehensive visual was deemed necessary to pick up as much details as possible. The internal visual inspection coincided with the internal PureEM inspection.

• Transient pressure monitoring to identify and quantify internal loading conditions. A self contained unit (shown in Figure 7) was installed at an air release valve and left to monitor for roughly a month. This period ensured that the pressure was monitored through an activation and isolation period of the main.
An engineering assessment was conducted to analyse all of the condition data, conduct a risk assessment, and provide rehabilitation recommendations for the mains to reach their design life. For both MSCL pipes and PCP, structural evaluations were performed, and in the case of PCP, a finite element analysis (FEA) was performed (see Figure 8).

See Figure 8: Example FEA of PCP

This was a first-of-its-kind assessment in Australia applying new inspection technologies, including the customisation of a 48-detector PureEM tool, as well as a new risk assessment technique for analysing the remaining life of metallic pipes.

Detections from the PureEM inspection in the MSCL pipes (i.e. discrete areas of structural deterioration) were validated utilising alternate electromagnetic and ultrasonic techniques, which also provided supplemental condition information (i.e. wall thickness) for the engineering assessment.

RESULTS AND ANALYSIS

MSCL Results

The primary inspection results of the MSCL pipes show that:

- The PureEM inspection was able to identify discrete locations along the main with suspected steel wall thinning.
- The subsequent validation tests utilising electromagnetic and ultrasonic methods were able to quantify the remaining wall thickness at the locations suspected with wall thinning; also, additional “random” tests showed that the remaining pipes along the mains have an average wall thickness greater than the areas with suspected wall thinning.
- The internal visual inspections uncovered additional areas along the mains where the liners had deteriorated and subsequently identified joints where flexible internal seals were required to be installed.
- The transient monitoring showed that no substantial transients occur during normal operation of the mains.

The Engineering Analysis utilised all of the condition sets to:

1. Identify the remaining wall thickness at deteriorated sections of the mains;
2. Determine a rate of deterioration;
3. Structurally model the MSCL pipes and identify a failure limit; and
4. Predict the remaining life until the pipes reach the failure limit.

Upon analysing the results, and predicting the amount of failures through the years, results show that the MSCL pipes are expected to last much beyond the required asset life expectancy. Figure 9 shows an example of a failure simulation, which was conducted for each section of pipe highlighted from the PureEM inspection.

See Figure 9: Example Failure Simulation
PCP Results
The primary inspection results of the PCP show that:

- The PureEM inspection was able to identify over 30% of pipes exhibiting signs of distress (i.e. wire breaks) - the inspection was able to quantify the number of wire breaks in each pipe and results show that the majority of pipes have a low amount of distress (see Figure 10).

The laser profiling was able to identify and quantify the internal diameter of each PCP, which identified areas of lining deterioration and loss of concrete core thickness.

The Engineering Analysis utilised all of the condition sets to:

1. Create structural models (i.e. performance curves) of different cases of the PCP; and
2. Compare the current condition of each pipe against the performance curves.

The performance curves identify the different limit states of PCP under varying internal loading conditions (i.e. pressure) and varying deterioration (i.e. wire breaks). The curves are able to identify the maximum operating pressures for the pipes given current deterioration levels; alternatively, the curves can identify the maximum deterioration permissible given desired operating conditions. Figure 11 shows an example performance curve.

Comparing the varying levels of distress across the mains shows that less than 1% of pipes are at a higher risk of failure and require repair or replacement. The vast majority of pipes in the mains are currently at deterioration levels below the failure limits. This means that with selective rehabilitation of a small percentage of pipes the service life can be extended. However, PCP deterioration is complex to model and at times can be a random variable; thus, condition monitoring through repeated inspections over time or continuous monitoring through specialised acoustic based monitoring systems is required.

CONCLUSIONS AND RECOMMENDATIONS
Given the criticality of the twin rising mains, a custom assessment plan was developed to enable risk based asset management. Not one, but a combination of techniques was required to assess the condition of these critical assets.

For the MSCL pipes:
- The inspection data identified discrete locations with large areas of wall thinning;
- Results were verified and quantified through the use of subsequent inspection techniques; and
- Through the use of structural modelling and failure forecasting, the MSCL pipes were deemed to have a low risk of failure through the desired life span.

For the PCP sections of the mains:
- The inspection data located and quantified specific pipes with varying levels of distress;
- Through the use of structural modelling and a risk assessment, individual pipes (less than 1%) with a higher risk of failure were identified for selective repair or replacement;
- Through short term remedial efforts and continued condition monitoring, the risk of failure can be managed.
The collection of direct condition data coupled with the engineering assessment has provided Queensland Urban Utilities the information required to make informed decisions regarding: selective repair or replacement, operational changes, and condition monitoring – all for a fraction of the cost of capital replacement. This will ensure the mains can meet the requirements of the Capital Investment Plan.

Application of such an approach is the first-of-its-kind in Australia utilising new inspection technologies and assessment techniques for renewal planning and general decision making. The same scope of work would not be prescribed for all sewer rising mains; rather, a customised approach is needed based on asset criticality, pipe material, and accessibility.