Courtenay Pump Station 750/820-Millimetre Force Main

Condition Assessment Report

DRAFT

Report Prepared for:

Comox Valley Regional District

By:

Pure Technologies Ltd.
September 2017

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Quality Assurance and Quality Control Statement

By my signature, I attest that this report has been prepared and reviewed in accordance with the Pure Technologies Ltd. Quality Assurance and Quality Control procedures:

September 8*, 2017*

Vasilis Sagiannos, Project Manager — Date

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1. Executive Summary

The Comox Valley Regional District (CVRD) retained the services of Pure Technologies to perform a condition assessment inspection consisting of a SmartBall™ leak detection survey, a PipeDiver™ electromagnetic inspection, and transient pressure monitoring on the Courtenay Pump Station 750/820-millimetre Force Main (CPS Force Main). The force main was installed in the early 1980's and spans a distance of 8.80 kilometers, servicing the communities of Courtenay and Comox, BC. The inspected portion of the CPS Force Main is composed of 750-millimetre lined cylinder pipe (LCP) and 820-millimetre bar wrapped pipe (BWP).

Acoustic data was collected on May 2, and May 4, 2017 for the CPS Force Main. The inspection was completed in two (2) runs, as the SmartBall tool was launched from the CPS and Jane Place Pump Station (JPPS) and extracted at the CVWPCC on both occasions. The inspected section spanned a total distance of 8.80 kilometres. Analysis of the acoustic data collected during the inspections identified zero (0) acoustic events characteristic of leaks, one (1) acoustic anomaly characteristic of pockets of trapped transient gas, five (5) acoustic anomalies characteristic of transient gas and two (2) acoustic anomalies characteristic of entrained air, all within the 750-mm LCP section. No acoustic anomalies were identified within the 820-mm BWP section.

Electromagnetic data was collected on May 3, 2017 for the CPS Force Main. The inspected section spanned an overall distance of 8.80 kilometres. Of the 1,258 pipes inspected in the CPS Force Main, no pipes had electromagnetic anomalies consistent with broken prestressing wire wraps or broken bar wraps. However, eight (8) pipes were identified with anomalous signals. The signal shift identified in the anomalous pipes is different from both a standard non-distressed pipe and a pipe with broken wire wraps. The signal shift could be caused by a change in pipe property. Anomalous Pipe 1099 corresponds to a spot repair, implemented in 2003, due to a small breach that occurred while the exterior of the pipe was being chipped away for inspection associated with cathodic protection work. In regards to the rest anomalous pipes, Pure Technologies requires more information to provide a conclusive evaluation of the electromagnetic signal.

The inspection results are summarized in *Table ES.1*.

Table ES.1: Inspection Results Summary

Date	Pipeline	Pipe Material	Distance	Results
May 2 to May 4, 2017	CPS Force Main	LCP	4.83 kilometers	No leaks; 1 acoustic anomaly characteristic gas pocket; 5 acoustic anomalies characteristic of slugs; No pipes with broken wire wraps; 3 pipes with anomalous signal not characteristic of broken wire wraps;
		BWP	3.97 kilometers	No leaks or gas pockets; No pipes with broken bars[1]
	Jane Place PS Tie-in	BWP	0.1 kilometers	No leaks or gas pockets[2]

[1]EM inspection for broken bars conducted for 1.48 kiometers, up to Beech Str. as per project scope

[2] Jane Place PS Tie was not electromagnetically inspected for broken bars as per project scope

Pump Station. Pressure data was recorded between May 24, 2017 and June 29, 2017, in order to identify the hydraulic stresses acting on the pipeline. The monitor recorded minimum, average, and maximum pressure readings every 2 minutes, and increased the sampling rate to 20 samples per second when transient events occurred. During the monitoring period, the sensor recorded an average pressure of 31.8 psi, with a maximum pressure of 68.2 psi. Transient pressure events were detected during the monitoring period which coincide with pump operation on and off. This is consistent with the normal diurnal operation of a typical wastewater force main.

The data collected from both the inspections and monitoring was used to complete a structural evaluation of the force main, to provide CVRD with actionable information regarding any necessary repairs or rehabilitation. The assessment of the structural condition of the distressed pipes involved a three-dimensional, nonlinear finite element analysis (FEA). A performance curve was developed for each distressed pipe class to evaluate the pipe's ability to perform under the design pressures of the pipeline, given the estimated number of broken wire wraps. No pipes were identified to exceed the FEA Limits in the inspected portion of CPS Force Main.

The CPS Force Main has no electromagnetic distress, while the industry average that Pure Technologies has observed in other PCCP lines is four percent (4%). This distress rate is in regards to the quantity of pipes showing evidence of prestressing wire wrap damage and does not directly portray the extent of the damage within individual PCCPs. Furthermore, AWWA failure statistics [15] for PCCP from the same era (1979-1991) as the CPS Force Main, indicate that approximately 0.55 percent of pipe sticks are anticipated to display significant deterioration or structural weakness.

In summary, for the 2017 condition assessment evaluation of the CPS Force Main, Pure Technologies concludes that:

- One (1) acoustic anomaly characteristic of pockets of trapped transient gas, five (5) acoustic anomalies characteristic of transient gas and two (2) acoustic anomalies characteristic of entrained air were identified within the 750-mm LCP section.
- No acoustic anomalies were identified within the 450-mm and the 820-mm sections of the force main during the SmartBall inspection.
- Of the 1,258 pipes inspected in the CPS Force Main, no pipes had electromagnetic anomalies consistent with broken prestressing wire wraps or broken bar wraps.
- The electromagnetic analysis of the 750-mm LCP identified eight (8) pipes with anomalous signals. The signal shift identified in the anomalous pipes is different from both a standard non-distressed pipe and a pipe with broken wire wraps. The signal shift could be caused by a change in pipe property. Anomalous Pipe 1099 corresponds to a spot repair, implemented in 2003. In regards to the rest anomalous pipes, Pure Technologies requires more information to provide a conclusive evaluation of the electromagnetic signal.

- A transient pressure monitor was installed on the header of the force main at the Courtenay Pump Station. Pressure data was recorded between May 24, 2017 and June 29, 2017, in order to identify the hydraulic stresses acting on the pipeline. During the monitoring period, the sensor recorded an average pressure of 31.8 psi, with a maximum pressure of 68.2 psi.

- Based on the results of the AWWA C301 analysis, the pipe design for 750-mm LCP satisfied the criteria for the current design pressure and earth cover. However, the pipe design at 2- and 4-feet of earth cover and a design working pressure of 108 psi did not satisfy the AWWA C304 design criteria. Two (2) Serviceability Limiting Criteria were not satisfied (i.e., the calculated value exceeded the limiting value). The pipes created using this design are not expected to fail; rather, the pipes should be considered under-designed by the current standard, based on the earth cover and pressure (68 psi) used in the analysis. Although the 750-mm LCP design does not meet the design standard, the values are within 5 percent of passing.

- Based on the results of the AWWA C303 analysis, the pipe design for the 820-mm BWP, Class 100 satisfied the criteria for the current design pressure and earth cover.

- No pipes on the CPS Force Main were identified to exceed any of the Micro Cracking, Visible Cracking, Yield, or Strength Limits based on the finite element analysis.

Recommendations

Based on the results of the internal inspection and subsequent condition assessment of the CPS Force Main Pure Technologies' recommends the following:

- In order to address acoustic anomalies characteristic of static air pockets and transient gas, verify operation of all the air valves on the pipeline.

- In order to detect any new distress on the CPS Force Main, Pure Technologies recommends reinspecting the pipeline in seven (7) years.

- The CPS Force Main has no damaged pipes at this time as detected by the electromagnetic assessment. However, the rate of wire break activity can vary significantly depending on a number of variables. As a result, and since the CPS Force Main is a critical asset with a high consequence of failure, it is recommended that CVRD implement procedures to proactively manage the transmission main system via acoustic monitoring. An acoustic monitoring system will detect and report wire breaks as they occur in near real time. This information is combined with the electromagnetic inspection data to allow CVRD to analyze the condition of the CPS Force Main (i.e., the number of broken wire wraps on each pipe section). This is the best available and most economical option to minimize the risk of future pipeline failure when combined with proactive rehabilitations.

2. Project Background

The Comox Valley Regional District (CVRD) owns and operates a major raw wastewater pump station and 8.80-km of force main that service the communities of Courtenay and Comox, BC.

CVRD retained the services of Pure Technologies to perform a condition assessment inspection, consisting of a SmartBall™ leak detection survey, a PipeDiver™ electromagnetic inspection, and transient pressure monitoring on the Courtenay Pump Station 750/820-millimetre Force Main.

2.1 Description of Pipeline

The inspected portion of the Courtenay Pump Station Force Main is composed of 750-millimetre lined cylinder pipe (LCP) and 820-millimetre bar wrapped pipe (BWP). The pipes were manufactured by Canron Inc. Pipe Division in 1982 and the 750/820-Millimetre Courtenay Pump Station Force Main is owned and operated by the CVRD.

The CPS Force Main consists of two sections:

- The CPS to Goose Spit section, and
- The Goose Spit to CVWPCC section (also known as the Willemar Bluffs section).

The CPS to Goose Spit section consists of an "on-land" buried section along the Comox Road alignment from CPS to the foreshore adjacent to Bayside Road, and an "intertidal" foreshore section from Bayside Road to Goose Spit. The force main pipeline exiting the CPS is 750-mm and consists of prestressed concrete cylinder pipe (PCCP), LCP type. At location 4+808 the Jane Place Pump Station discharges into the force main at location via a 450-mm pipeline, consisting of BWP, the 450-mm force main is not included in the scope of this project. Downstream of the JPPS connection, the pipeline is 820-mm and also consists of BWP. The Willemar Bluffs "intertidal" section consists of a 2.1-km foreshore section from Goose Spit to Curtis Road, followed by a short "on-land' section from the foreshore at Curtis Road to the CVWPCC.

No failures have been reported on the force main. However, on September 5, 2003 a leak occurred while Uplands Excavating were exposing a pipe joint, in order to provide a bonded connection between the pipe joints for electrical continuity for an impressed current cathodic protection system. The leak was chainage station 0+066 (cumulative station numbers from Goose Spit Valve Chamber is 1+210). The hole was approximately 25-mm in diameter, at the crown of the pipe and was repaired with a patch consisting of geotextile cloth and a wooden stake plug.

A map of the inspected section of the CPS Force Main is shown below *(Figure 2.1)*. This map shows the approximate geographical location of the pipeline.

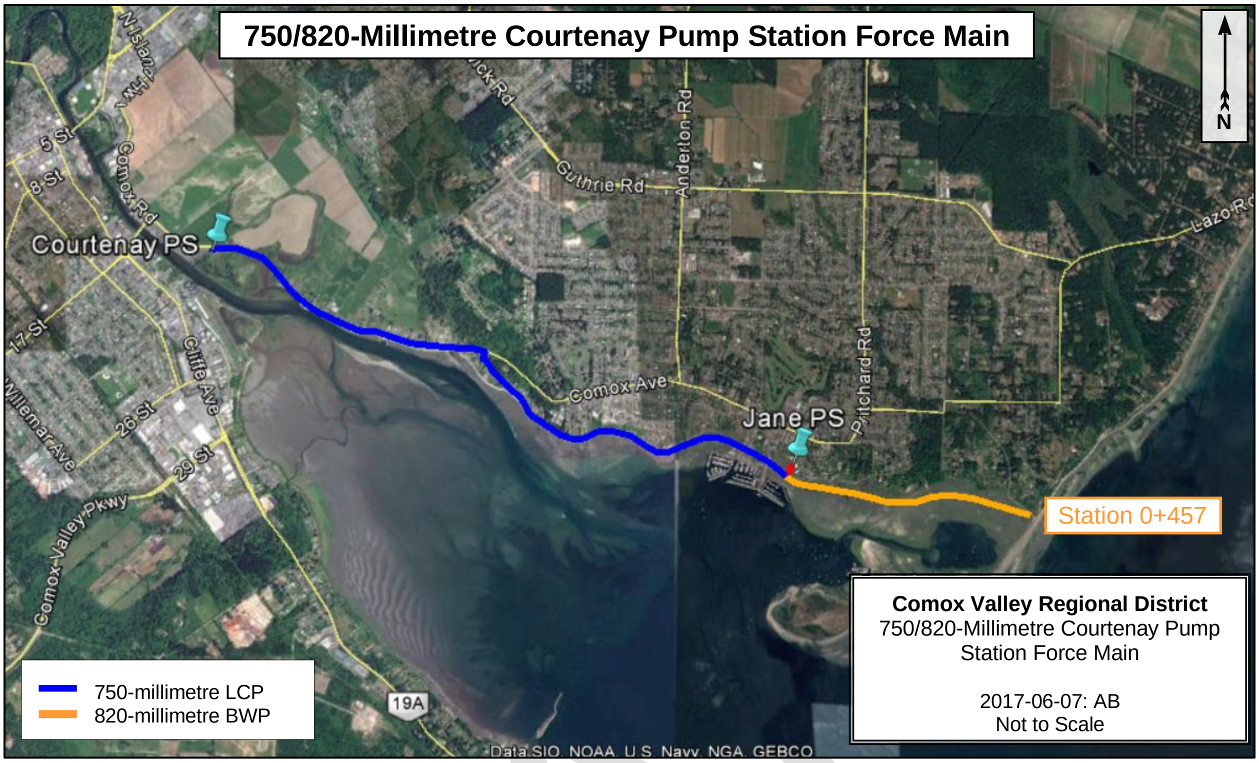


Figure 2.1: Inspection Limits

2.2 Project Scope

The scope of this report includes an assessment of the Courtenay Pump Station 750/820-Millimeter Force Main in order to provide an effective pipeline management strategy for Comox Valley Regional District. The assessment utilized the following investigative techniques:

- SmartBall leak and gas pocket detection survey
- PipeDiver electromagnetic inspection
- Transient pressure monitoring
- American Water Works Association (AWWA) C301/C304 risk of failure evaluation
- AWWA C303 risk of failure evaluation
- Finite element analysis of LCP and BWP

This report details the results of the condition assessment of the CPS Force Main and provides recommendations for the management of the pipelines.

2.3 Overview of PCCP

The subject force main comprises a type of PCCP known as lined cylinder pipe, or LCP. LCP is a complex, composite structure consisting of a concrete core, a steel cylinder, high-strength steel prestressing wire, and a mortar coating. The concrete core and prestressing wire are the main structural components, while the steel cylinder acts primarily as a water barrier. The prestressing wire produces a uniform compressive force on the core that holds the concrete in compression when the pipe is subjected to internal water pressure and external loading. A mortar coating surrounds the prestressing wire, embedding the wraps in an alkaline environment to protect them from external corrosive influences and physical damage. *Figure 2.2* shows a typical LCP cross section.

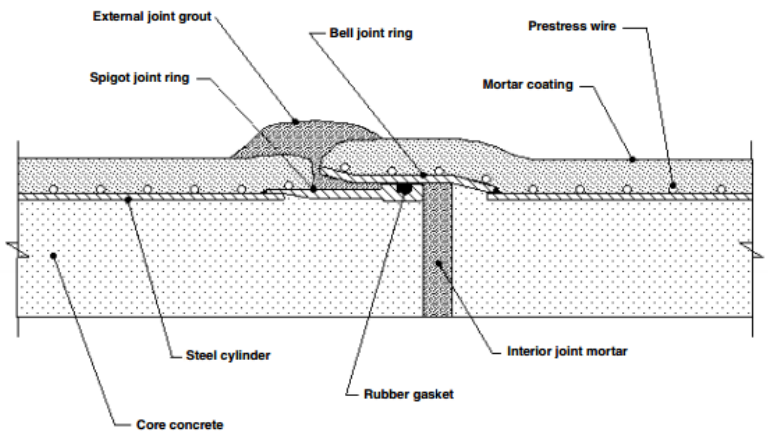


Figure 2.2: Typical LCP Cross Section [2]

PCCP design and manufacturing standards were gradually developed beginning in 1943 and the first tentative consensus standard for PCCP was approved by the AWWA in 1949. The AWWA C301 *Standard Specifications for Reinforced Concrete Water Pipe - Steel Cylinder Type, Prestressed* (AWWA C301-52) was revised multiple times, with the latest revision being released in 2007. The pipes in the subject force main were manufactured in 1982, in accordance with AWWA C301-79 and designed in accordance with AWWA C304-79.

The early structural design requirements for the manufacturing of PCCP tended to be conservative [1, 5, 6], with high factors of safety. As experience with using this composite pipe grew, understanding of the behavior of PCCP increased, and advances in material sciences were achieved, the structural design and manufacturing processes for PCCP were changed to facilitate what appeared to be a more efficient design and cost-effective manufacturing process. Due to the competitive cost of PCCP in comparison to other pipe materials, its popularity grew significantly with water and wastewater utilities in the United States for their large diameter pressure pipelines in the 1960s and 1970s.

As the standards changed and the prestressing wire strength increased, classifications of prestressing wire were developed based on their tensile strength (Class I, Class II, and Class III).

These practices culminated in the 1970s, when pipes using much more liberal manufacturing standards were introduced.

Beginning in the mid-1980s, PCCP design and manufacturing standards began to improve in response to the large number of failures that occurred in the late 1970s and early 1980s. The major revisions in the standards, design, and manufacturing of the PCCP consisted of changes in the maximum diameter of the PCCP, the quality (strength) of the concrete, the thickness of the steel cylinder, the prestressing wire specifications (e.g., wire diameter, wrapping stress, spacing), and the thickness of the mortar coating [1].

A more detailed overview of PCCP is included in *Appendix A* of this report.

2.4 Overview of BWP

BWP is a semi-rigid pipe that has a composite structure consisting of an inner lining, a steel cylinder, steel reinforcing bar wraps, and an outer coating. The internal pressure in the pipe is resisted by the steel components (steel cylinder and reinforcing bars) while the external loads are resisted by a combination of the stiffness of the composite pipe structure and the force applied by the bedding and backfill. The inner concrete lining and outer mortar coating protect the underlying steel from corrosion. *Figure 2.3* shows the construction and joint of a typical AWWA C303 pipe.

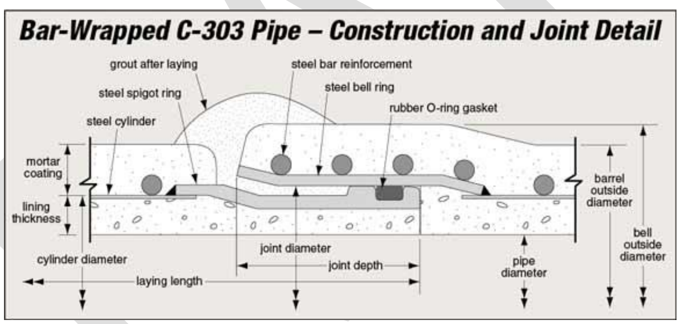


Figure 2.3: AWWA C303 BWP Construction Details

AWWA C303, Concrete Pressure Pipe, Bar-Wrapped, Steel-Cylinder Type, published in 2008, is the current standard that governs the design of BWP. The first edition of AWWA C303 was issued in 1970 and the pipes in the subject force main (manufactured in 1982) were designed in accordance with the 1978 standard.

An AWWA C303 analysis evaluates two (2) criteria to determine if a design is adequate for the analyzed loading conditions:

- Circumferential Stress in the Steel: Internal pressure causes circumferential stress (also known as hoop stress) to be developed in the pipe wall. In BWP, these loads are carried by the steel components of the pipe and the level of stress is limited to a percentage of the yield strength of the steel.

- Deflection: Because BWP is semi-rigid, it does deflect under external loading. The horizontal deflection of the pipe is limited to prevent cracking of the inner lining and outer coating.

A more detailed overview of BWP is included in *Appendix A* of this report.

3. Inspection Methodology and Results

3.1 SmartBall Acoustic Inspection Results

3.1.1 Introduction

Acoustic data was collected on May 2, and May 4, 2017 for the CPS Force Main. The inspection was completed in two (2) runs, as the SmartBall tool was launched from the CPS and Jane Place Pump Station (JPPS) and extracted at the CVWPCC on both occasions. The inspected section spanned a total distance of 8.80 kilometres. The SmartBall tool ran out of battery shortly after passing the JPPS connection, therefore the remaining distance was inspected during the second run, with the launch taking place from the JPPS. Below are Pure Technologies' resources used to perform the inspection, as well as the inspection schedule (*Table 3.1.1*).

Table 3.1.1: Inspection Summary					
On-Site Staff	A. Bernal, A. Yapp, J. Buntag, S. CAstro, V. Sagiannos				
Analysts	Andrew Mok, O. Ojala				
Project Manager	V. Sagiannos				
Tool	SmartBall™				
Date	**Pipeline**	**Diameter (millimeters)**	**Start Station**	**End Station**	**Distance**
May 2 & May 4, 2017	CPS Force Main	750 & 820	NA	0+735	4.83 kilometres
		450 & 820	0+735	0+295	3.97 kilometres
Total Distance					**8.80 kilometres**

Analysis of the acoustic data collected during the inspections identified zero (0) acoustic events characteristic of leaks, one (1) acoustic anomaly characteristic of pockets of trapped transient gas, five (5) acoustic anomalies characteristic of transient gas and two (2) acoustic anomalies characteristic of entrained air within the 750-mm PCCP section. Transient gas consists of entrained air or gas slugs moving through the pipeline, while gas pockets are classified as trapped gas. The results of the CPS Force Main 750-mm pipeline section inspection are summarized in *Table 3.1.2.*

Table 3.1.2: CPS Force Main SmartBall Inspection Results – Run 1	
Acoustic Anomalies Characteristic of Leaks:	0
Acoustic Anomalies Characteristic of Static Air/Trapped Gas Events:	1
Acoustic Anomalies Characteristic of Pockets of Transient Gas:	5
Acoustic Anomalies Characteristic of Static Air/Trapped Gas Events:	2
Duration of the Inspection:	9 hours, 10 minutes
Average SmartBall Tool Velocity:	0.2 m/s

No acoustic anomalies were identified within the 450-mm and 820-mm force main during the inspection. The inspection summary for this section is presented in *Table 3.1.3*.

Table 3.3: CPS Force Main SmartBall Inspection Results – Run 2	
Acoustic Anomalies Characteristic of Leaks:	0
Acoustic Anomalies Characteristic of Static Air/Trapped Gas Events:	0
Acoustic Anomalies Characteristic of Pockets of Transient Gas:	0
Acoustic Anomalies Characteristic of Static Air/Trapped Gas Events:	0
Duration of the Inspection:	5 hours, 56 minutes
Average SmartBall Tool Velocity:	0.2 m/s

The inspection route for the CPS Force Main is displayed on the aerial photograph in *Figure 3.1.1*. The geographical locations of the acoustic anomaly characteristic of trapped and the acoustic anomalies characteristic of transient gas on the 750-mm pipeline are also displayed on the map.

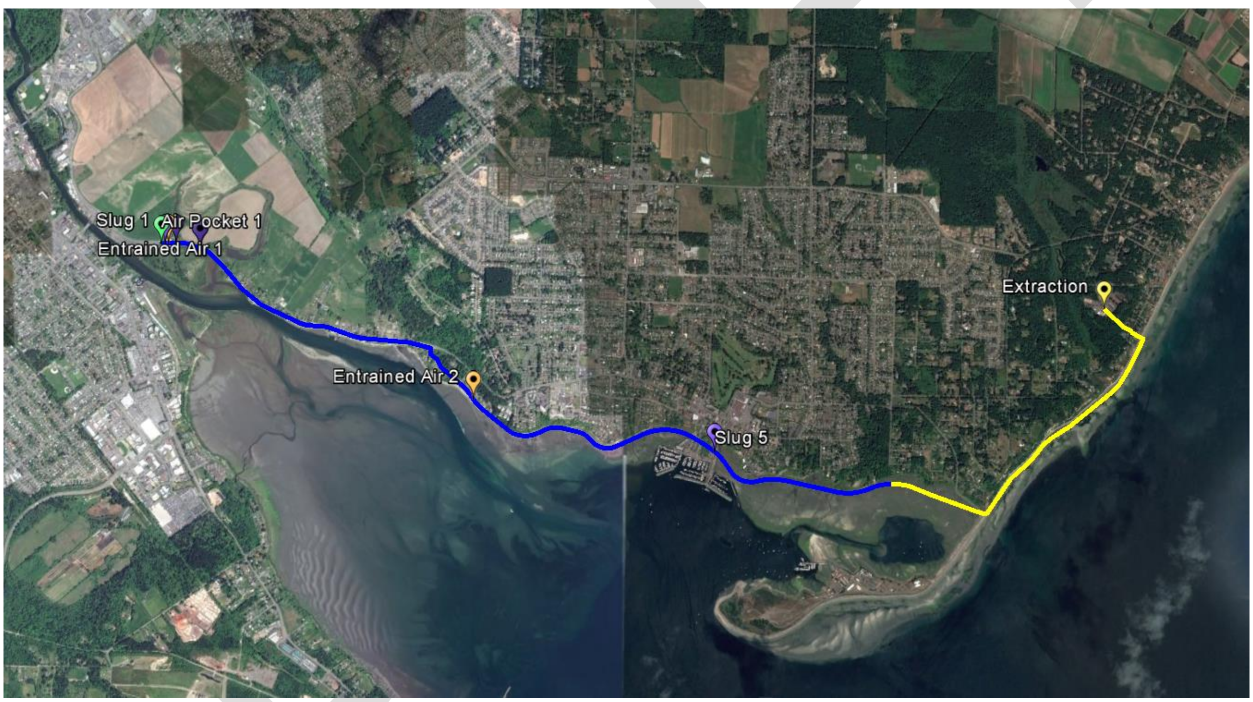


Figure 3.1.1: Layout of the Courtenay Pump Station Force Main

3.1.2 *Acoustic Inspection Results*

Analysis of the acoustic data collected during the inspection identified zero (0) acoustic events characteristic of leaks, one (1) acoustic anomaly characteristic of pockets of trapped transient gas, five (5) acoustic anomalies characteristic of transient gas and two (2) acoustic anomalies characteristic of entrained air within the 750-mm PCCP section. The acoustic data recorded by the SmartBall tool during the inspection was analyzed and cross-referenced with the position data from each SBR to determine a location for the acoustic anomaly. No acoustic anomalies were identified within the 450- and 820-mm sections of the pipeline during the inspection.

A summary of the findings identified during the SmartBall inspection of the 750-mm section is provided in *Table 3.1.4.*

Table 3.1.4: Summary of Air Events

Description	Distance from Insertion (Start of Pocket)	Distance from Insertion (End of Pocket)	Comments
Air Pocket (~5m long)	3m	7m	Air events located in proximity of Insertion point – likely related to tool insertion procedures.
Slug (~7m long)	31m	38m	
Entrained Air (~38m long)	39m	77m	
Slug (~2m long)	112m	114m	
Slug (~2m long)	289m	291m	
Slug (~1m long)	294m	295m	
Entrained Air (~2m long)	2,661m	2,663m	Small entrained air event before brief tool stoppage.
Slug (~1m long)	4,607m	4,608m	Slug overlaps SBR 7 location

Figure 3.1.2 shows the acoustic profile of the CPS Force Main inspection with respect to the position of the tool within pipeline, as detected by the SmartBall leak detection technology on the 750-mm section of the pipeline (Run 1). The magnitude of the transient gas pocket is estimated by correlating the value of the acoustic signal with historical calibration data.

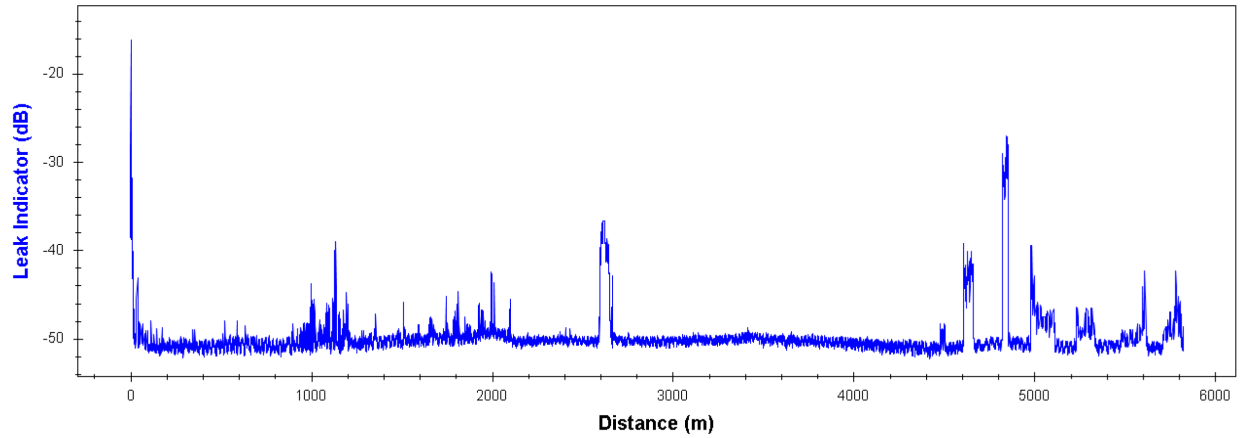


Figure 3.1.2: Acoustic Summary of the SmartBall inspection versus Distance Traveled for the 750-mm Section of the Pipeline – Run1

Figure 3.1.3 shows the acoustic profile of the 450- and 820-mm section of the pipeline (Run 2) inspection with respect to the position of the tool within pipeline, as detected by the SmartBall leak detection technology. No leaks or air events were found on this portion of the CPS Force Main.

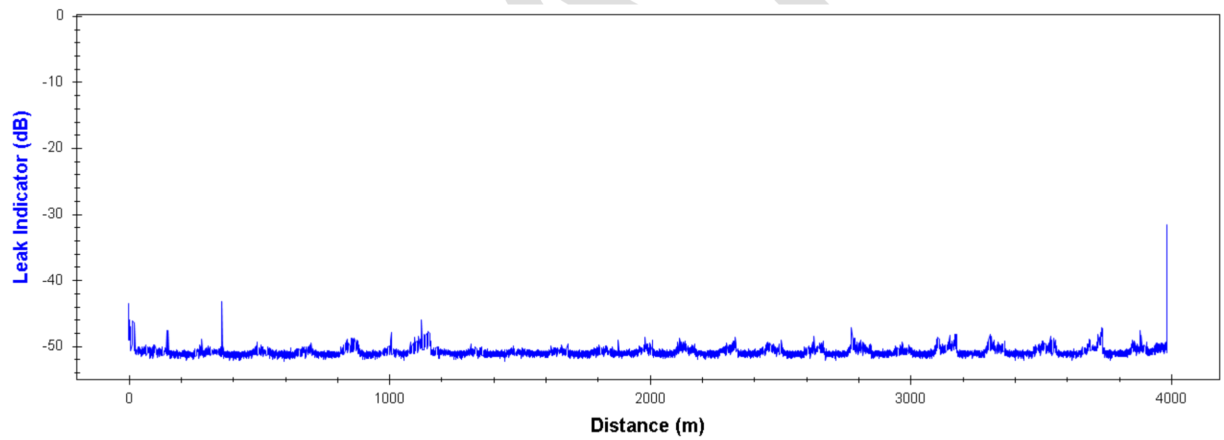


Figure 3.1.2: Acoustic Summary of the SmartBall Inspection versus Distance Traveled for the 450- and 820-mm Sections of the Pipeline – Run 2

It is important to note that these overviews may contain anomalous spikes in the data. These spikes may have been caused by ambient noise around the pipeline from external sources such as pumps or nearby traffic. These sources of ambient noise are easily distinguishable from leaks or other points of interest upon further analysis by trained personnel. Ambient noise generally occurs at a much lower frequency than the frequencies generated by a leak or pockets of trapped gas.

3.2 Electromagnetic Inspection Results

3.2.1 Introduction

Electromagnetic data was collected on May 3, 2017 for the 750/820-Millimetre Courtenay Pump Station Force Main. The inspected section spanned an overall distance of 8.80 kilometres.[1] Below are Pure Technologies' resources used to perform the inspection, as well as the inspection schedule *(Table 3.2.1)*.

Table 3.2.1: Inspection Summary						
On-Site Staff	A. Bernal, J. Buntag, S. Castro, J. Hebner, V. Sagiannos, A. Yap					
Analysts	J. Suryadi, N. Bose, L.Vu					
Project Manager	V. Sagiannos					
Tool	PipeDiver™					
Date	**Diameter (millimetres)**	**Pipe Type**	**Contract**	**Start Station**	**End Station**	**Distance**
May 3, 2017	750	LCP	S5	N/A*	0+735	4.83 kilometres
	820	BWP	S5	0+735	0+457	1.90 kilometres
			S7	0+457	0+295	2.02 kilometres
		Unknown	S6	0+295	N/A*	0.05 kilometres
Total Distance						**8.80 kilometres**

** Station number is not provided due to unavailability of pipeline drawings.*

A summary of the total number of pipes that had electromagnetic signatures consistent with broken prestressing wire wraps or broken bar wraps is shown below *(Table 3.2.2)*.

Table 3.2.2: Summary of Inspected Pipes						
Pipeline	**Contract**	**Diameter (millimetres)**	**Length (metres)**	**Number of Inspected Pipes**	**Pipes with Broken Wire or Bar Wraps**	**Anomalous Pipes**
Courtenay Pump Station Force Main	S5	750	4,830	690	0	3
	S5	820	1,900	262	0	0
	S7		2,021	298	0	5
	S6		53	8	0	0
Total			**8,803**	**1,258**	**0**	**8**

Anomalous Pipes are pipes identified with electromagnetic signals that are different from a typical distress signal.

[1] All reported distance is based on pipe laying lengths, and accounts for station equations, correlation differences and unavailability of pipe laying schedules and plan and profile drawings.

3.2.2 Comparison and Correlation to the Pipe Laying Schedule

The Comox Valley Regional District provided Pure Technologies with the pipe laying schedules and plan and profile drawings for most of the inspected portions of the CPS Force Main. The stationing used in this report was obtained from the pipe laying schedules, where available. Where pipe laying schedules were not available, the pipe lengths and stationing were not reported.

A few differences were noted in the provided pipe laying schedules and the collected data for the CPS Force Main. These differences included either a pipe observed in the data that was not listed in the pipe laying schedules or vice versa, or variations in the pipe length or layout from what is stated in the pipe laying schedules. Due to these differences and for clarity in reporting, Pure Technologies created a Pipe List. The Pipe List is attached to this report as a spreadsheet and includes information that can be used to locate specific pipes.

3.2.3 Electromagnetic Inspection Results

Of the 895 pipes inspected in the subject force main, no pipes had electromagnetic anomalies consistent with broken prestressing wire wraps or broken bar wraps.

3.2.3.1 Anomalous Pipes

The electromagnetic analysis of the 750-mm LCP identified eight (8) pipes with anomalous signals *(Table 3.2.3 and Table 3.2.4)*. The signal shift identified in the anomalous pipes is different from both a standard non-distressed pipe and a pipe with broken wire wraps. The signal shift could be caused by a change in pipe property. Anomalous Pipe 1099 aligns with a spot repair, implemented in 2003, due to a small breach that occurred while the exterior of the pipe was being chipped away for inspection associated with cathodic protection work. In regards to the rest anomalous pipes, Pure Technologies requires more information to provide a conclusive evaluation of the electromagnetic signal.

Table 3.3: Anomalous Pipes in the 750-Millimetre Courtenay Pump Station Force Main

Pure Reference Number	Pipe Type	Piece Number	Low Station	Pipe Length (metres)	Pipe Class	Signal Positional Range (metres)
21	LCP	STD	0+089	7.3	10	3.3-7.3
26	LCP	STD	0+126	7.3	10	4.6-7.3
178	LCP	STD	0+531	7.3	10	0.0-2.5

Signal Positional Range - represents the portion of the pipe affected by the anomalous signal. Signal position is measured from low station (metres).

Table 3.2.4: Anomalous Pipes in the 820-Millimetre CPS Force Main						
Pure Reference Number	**Pipe Type**	**Piece Number**	**Low Station**	**Pipe Length (metres)**	**Pipe Class**	**Signal Positional Range (metres)**
1081	BWP	STD	0+587	7.3	100	4.0-7.3
1099[1]	BWP	STD	0+066	7.3	100	3.9-7.3
1126	BWP	STD	0+264	7.3	100	4.8-7.3
1160	BWP	STD	0+506	7.3	100	0.0-2.8
1164	BWP	STD	0+532	7.3	100	4.2-7.3

Signal Positional Range - represents the portion of the pipe affected by the anomalous signal. Signal position is measured from low station (metres).

[1]Anomalous signal corresponds to 2003 spot repair

3.3 Pressure Monitoring and Hydraulic Analysis

3.3.1 Methodology

A Hydraulic Evaluation is conducted in order to understand the operational and surge pressures within a pipeline. When pipe wall degradation is combined with surge pressures, the likelihood of pipe failure can be significantly increased. Evaluation of the pump station operation, such as pump startup mode, typical and peak flows, operating and surge pressures, and surge protection, can provide important information on the stresses imparted on the pipeline.

Hydraulic pressure transients occur in pipelines when the steady-state conditions of the system change due to pressure and/or flow disturbances (e.g., the rapid closure of a valve, pump start-up/shutdown, gas pockets). The magnitude of a transient is related to several factors including the flow rate within the pipeline, the time (how fast) in which the change in steady-state condition occurs, and pipe hoop rigidity. During a transient event, the kinetic energy of the flow momentum is converted into potential energy, a rise in pressure, and strain energy in the pipe walls with the propagation of pressure waves. The resultant pressure transient is superimposed on the existing, steady-state pressure within the pipeline. Gas pockets combined with pressure transients can also have a significant impact on the structural integrity of the pipeline as vacuum conditions may be created. The rapid collapse of these gas pocket vacuum regions may cause cavitation as the transient passes, resulting in mechanical wear on the pipe wall and thereby increasing the risk of failure if the structural capacity has been compromised.

Conventional pressure monitors collect data in intervals of seconds or minutes while transients may occur in fractions of seconds and may be missed by traditional equipment. The LPR-31i pressure monitor, utilized on this project, continuously samples pressure at a high rate and records data every few minutes under normal operating conditions; however, when a transient pressure event is detected in the pipeline, the device records at the high sample rate 20 Hz to provide an accurate recording of the pressure transient event.

3.3.2 Results

A hydraulic evaluation of the subject pipeline was conducted to understand the operational and surge pressures. Pressure data was collected for a total of 36 days, from May 24, 2017 to June 29, 2017, in order to identify the hydraulic stresses acting on the pipeline.

As part of the hydraulic analysis, a LPR-31i was installed on the header that feeds the force main of the Courtenay Pump Station as shown in *Figure 3.3.1*.

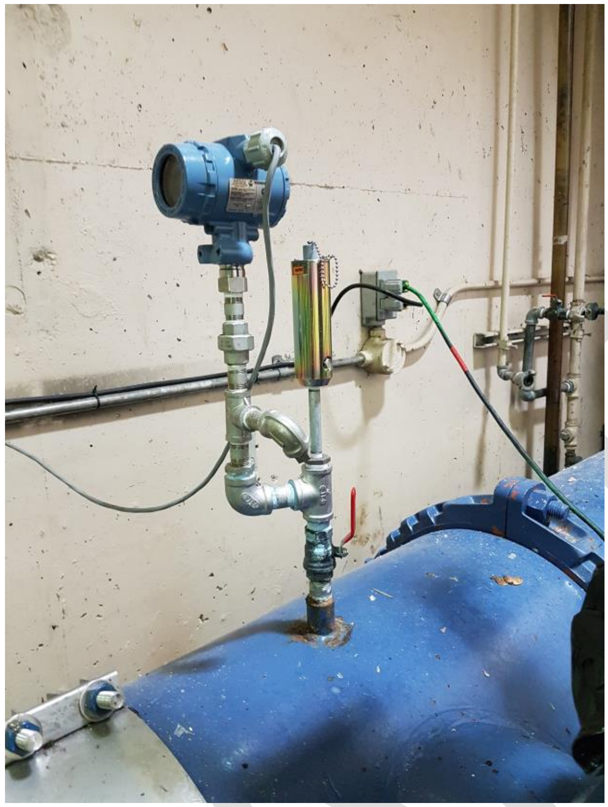


Figure 3.3.1 LPR-31i Monitoring Location

Maximum, minimum, and average pressures were recorded by the pressure logger at 2-minute intervals. The maximum pressure recorded during the monitoring period was 68.2 psi, and the minimum pressure recorded was -0.6 psi, with an average pressure of 31.8 psi. A chart of the pressures recorded over the full monitoring period is included in *Figure 3.3.2*. Maximum pressures in a given 2-minute recording interval are plotted along red lines, minimum pressures are plotted along blue lines, and average pressures are plotted along green lines.

The standard deviation of the recorded pressure data is 11.2 psi. Of all the pressure samples recorded, 68.2% are between 19.9 psi and 42.8 psi, and 95.4% are between 8.1 psi and 53.8 psi.

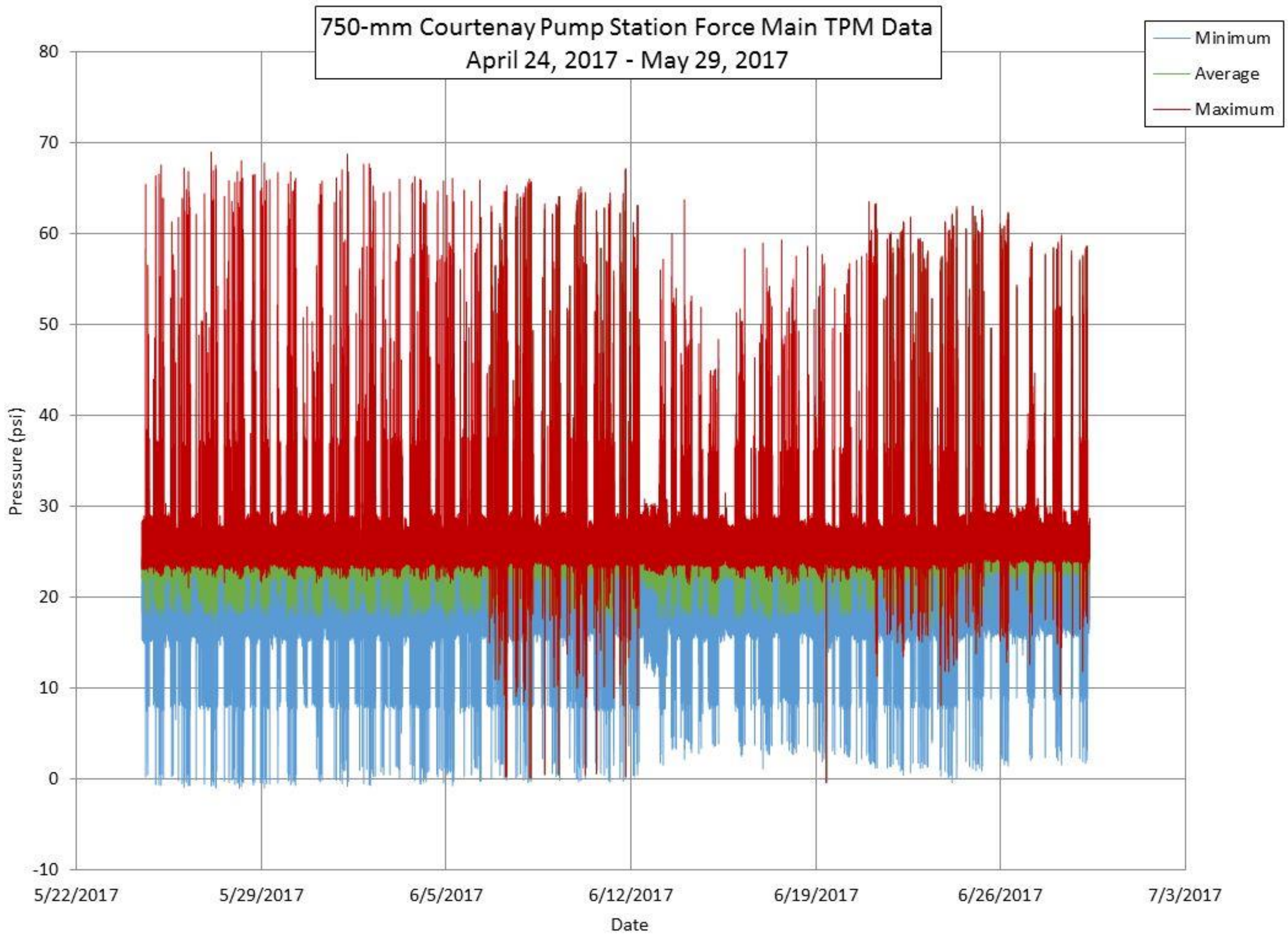


Figure 3.3.2: Pressure Recordings for 750/820-mm Courtenay Pump Station Force Main TPM Data

To translate the recorded pressures from the installation location along the downstream length of the transmission main, basic assumptions about the transmission of the transient pressures were made:

1. Observed transient pressures are superimposed on the steady-state pressure at each point along the pipeline.
2. The observed transient amplitude (above the background steady-state pressure) is consistent along the length of the pipeline.
3. Dynamic losses along the length of the pipeline are neglected; the static elevation pressure differences are assumed to govern and are used in the translation of the recorded pressures.

Hydraulic surge modeling may be performed to refine these assumptions, or additional transient pressure monitoring locations may be selected based on these initial findings if there are areas of particular concern.

The maximum recorded pressure of 68.2 psi occurred on May 27, 2017. Based on the observed system operating pattern, the maximum pressure correlates with a pump shutoff. The transient pressure logger was installed at the Courtenay Pump Station on the header that feeds the force main, where the crown elevation of the pipe is approximately 3 meters below MSL. The low point of the force main is approximately 2.9 meters below MSL. Based on these elevations and the maximum recorded pressure, the maximum pressure in the force main during the monitoring period with normal operations (non-inspection) at the low point would have been approximately 68.2 psi.

The minimum recorded pressure of -0.6 psi was recorded on May 27, 2017 and is associated with pump shutoff. The high point of the force main is 2.6 meters above MSL. Based on the elevations and assumptions stated above, the minimum pressure in the force main during the monitoring period was approximately -8.7 psi.

Significant transient pressure events were detected during the monitoring period which coincide with pump operation on and off. This is consistent with the normal diurnal operation of a typical wastewater force main. A sample week of transient pressure data is shown in *Figure 3.3.3* and a sample day is shown in *Figure 3.3.4*. *Figure 3.3.5* shows the day with both the maximum and minimum pressure event.

Cyclic loading in other pipe materials is well understood to be a mode of failure and is a primary design consideration. It is understood that a component subjected to fluctuating stresses, such as cyclic loading or regularly occurring transients, may fail at stress levels much lower than its fracture strength. Strength reduction due to fatigue is attributed to two primary factors: cycle frequency and amplitude. In the case of pipelines, the recurring amplitude is half the pressure differential and the frequency is the pressure cycle. The less than two pump cycles per hour observed at the Courtenay Pump Station is compliant with industry standards for pump operation.

These early morning cycles occur per low flow when the flow in is less than the minimum speed of the VFD. Going forward, SCADA should be used to determine the cause of the maximum and minimum pressure events, and additional monitoring at the high point of the line would confirm or deny the existence of damaging negative pressures.

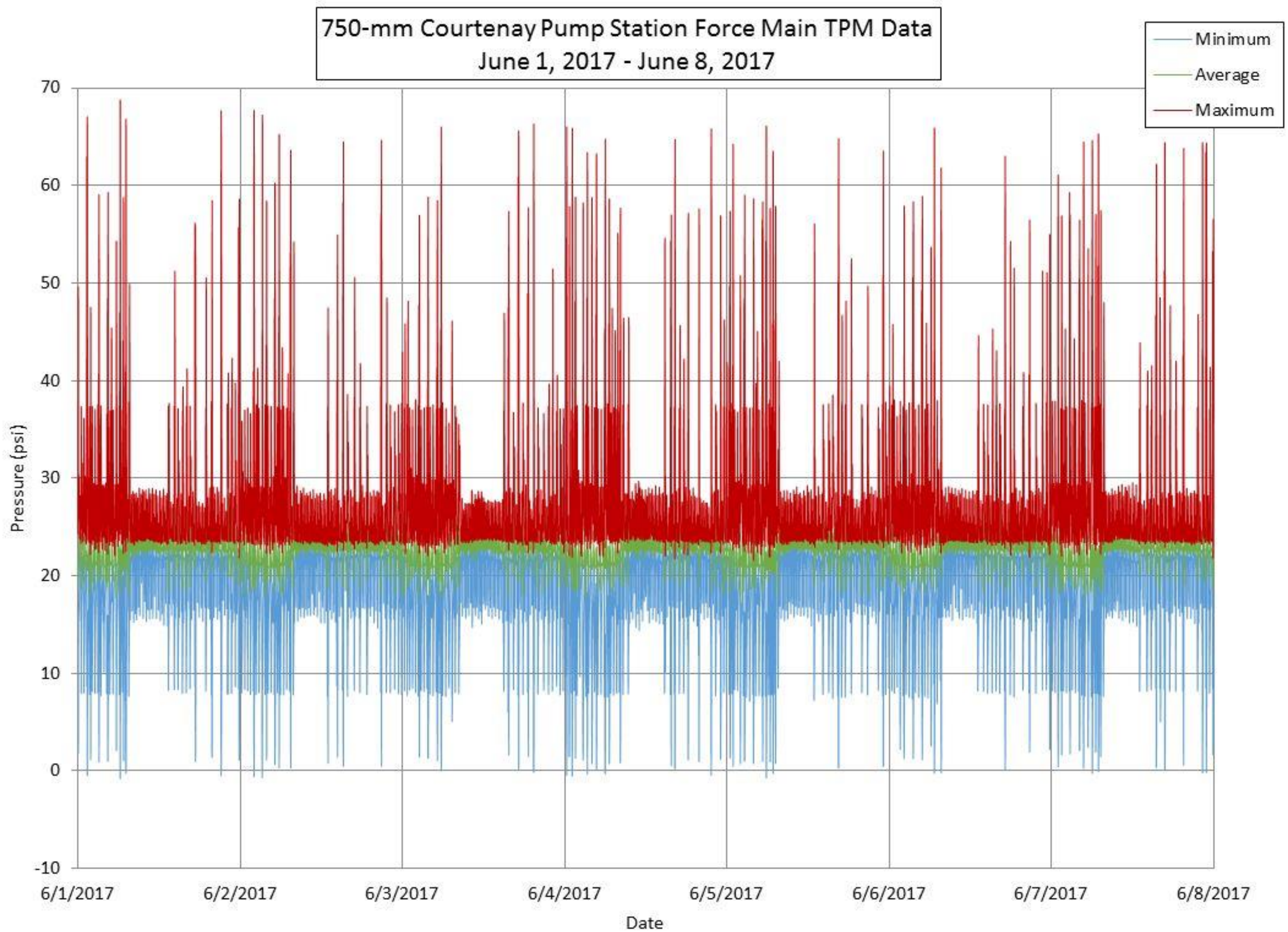


Figure 3.3.3: Pressure Recordings: June 1, 2017 to June 8, 2017

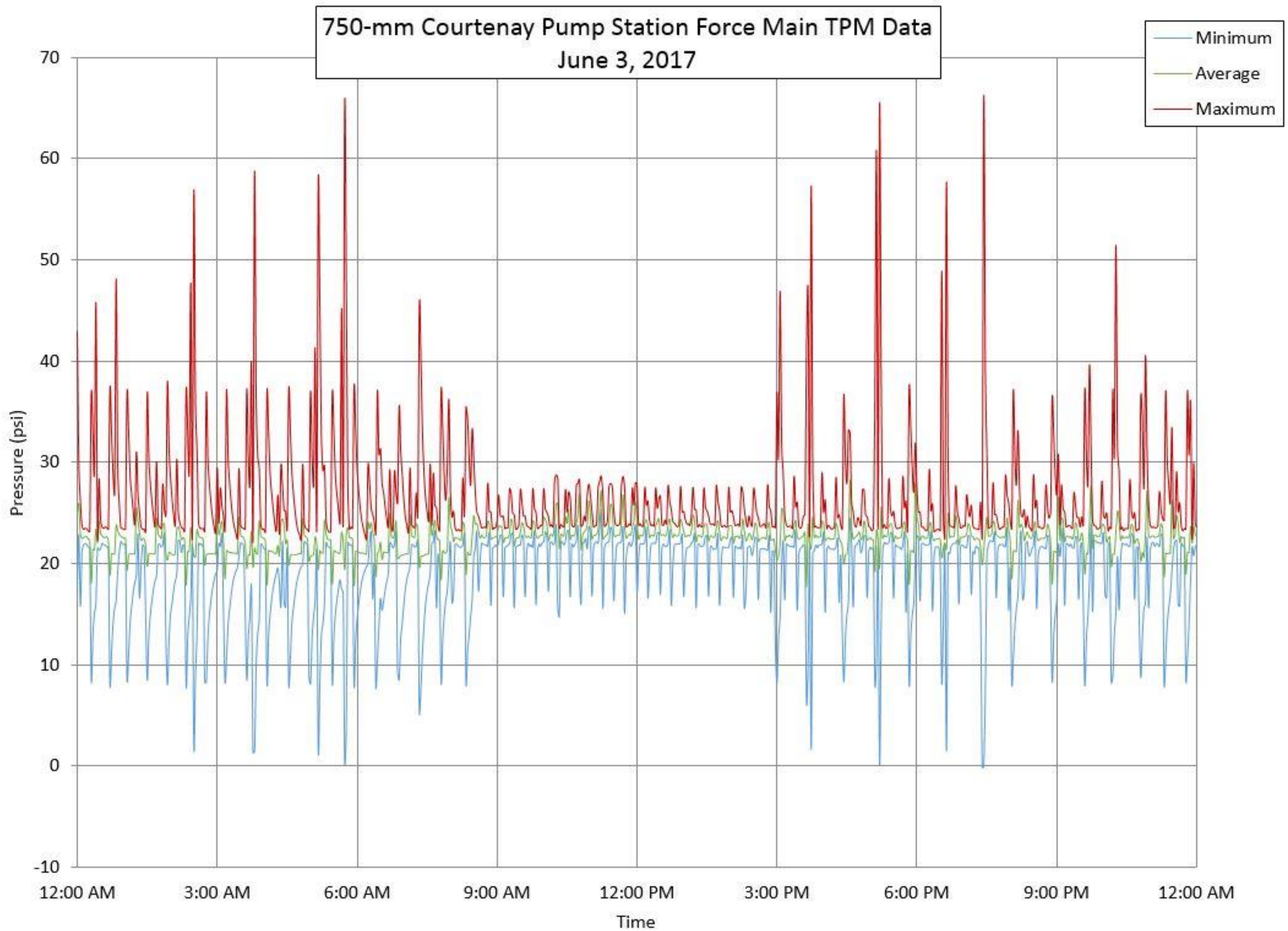


Figure 3.3.4: Pressure Recordings: June 3, 2017

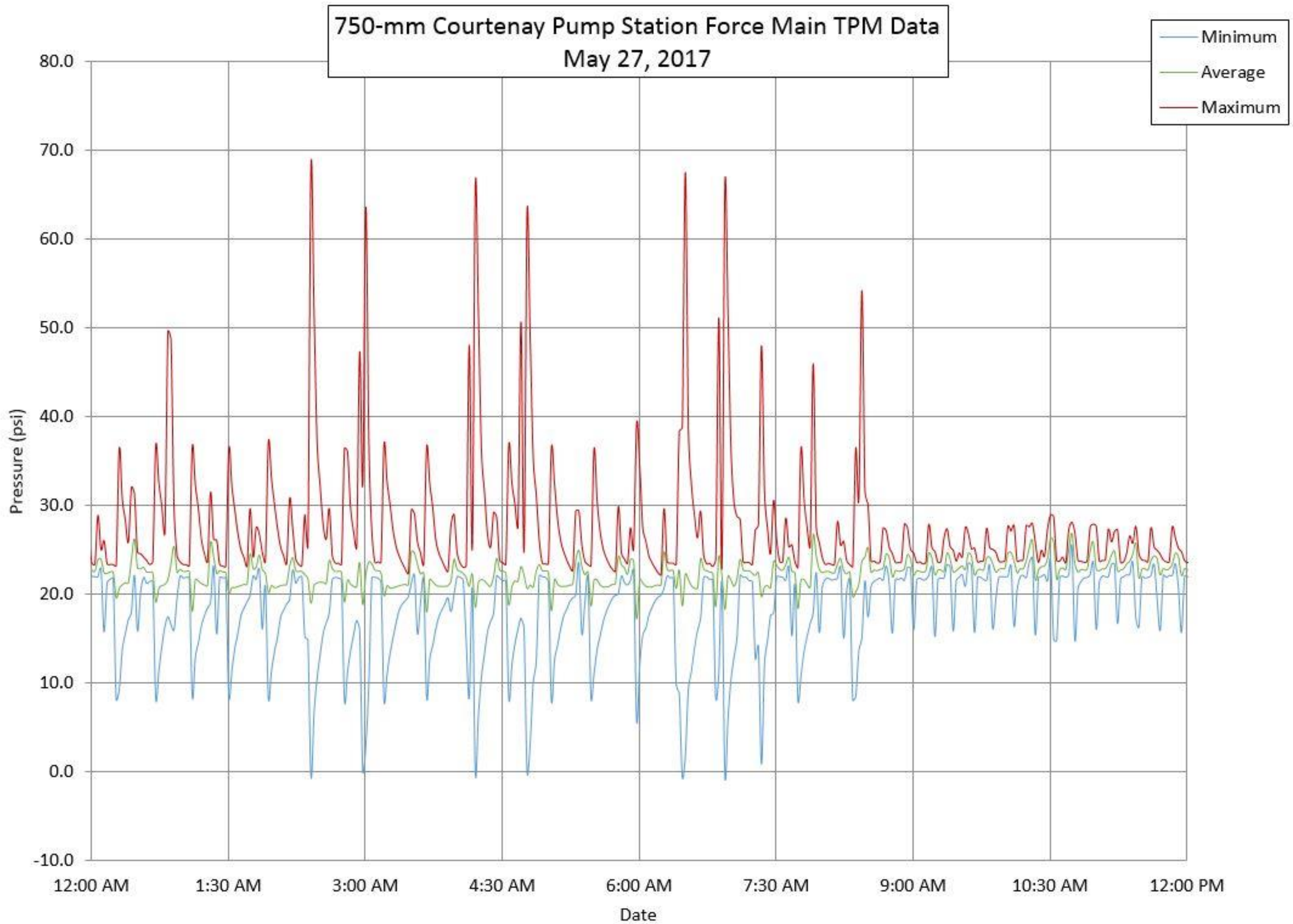


Figure 3.3.5: Pressure Recordings: May 27, 2017 12:00 AM – 12:00 PM

4. Structural Analysis

4.1 AWWA C301 Structural Analysis

Pure Technologies performed a structural analysis of the distressed pipes to determine if their PCCP design used in the Courtenay Pump Station 750-mm Force Main satisfies the contemporary and current PCCP design standards. These analyses are detailed in the following sections.

4.1.1 Design Specifications and Assumptions for Modeling

4.1.1.1 Pipe Properties

Table 4.1.1 lists the design specifications used by Pure Technologies for the structural analysis of the LCP design used in the CPS 750-mm LCP section of the force main. The pipe design was evaluated for two (2) separate cases: the on-land section and the intertidal section, as each section is subject to different loading conditions. All values were obtained from the design specification sheets provided by the Comox Valley Regional District and were assessed based on the C301-79 design standard.

Table 4.1.1: Design Specifications

Pipe Parameters	Units	750-mm On-land Section	750-mm Intertidal Section
Pipe Type		LCP	
Internal diameter of the pipe	inch	30	
Design Operating pressure	psi	100	
Earth cover	feet	2*	4*
Outside diameter of the cylinder	inches	35.6	
Thickness of the steel cylinder	inches	0.0598	
Steel cylinder gage		16**	
Thickness of the concrete core	inches	2.74	
Minimum mortar coating thickness	inches	1	
Prestressing wire diameter	inches	0.162	
Prestressing wire gage		8**	
Prestressing wire area	in^2/ft	0.176	
No. of wraps of wire	/ft	15	
Wire wrapping stress	ksi	195	
Wire ultimate strength	ksi	262	
Prestressing wire class		3	
Steel cylinder yield strength	ksi	27**	
Zero Compression Pressure	psi	127	
Burst Pressure	psi	367	

**Earth cover was verified with plan and profile drawings provided by CVRD and tide information*
***Values unavailable in specifications and obtained via respective AWWA standards*

4.1.1.2 External Loading

The external earth load is extremely influential in the AWWA C301 and C304 analysis. For the CPS 750-mm section of the force main, the earth cover depth was determined to be approximately 2 feet for the on-land section, and 1.5 feet of sand plus 2.5 feet of water for the intertidal section. The earth cover was verified from the pipe profile drawings and tide information.

The earth loading assumed a soil unit weight of 120 pounds per cubic foot (lb/ft^3) and a Kµ value of 0.165, which is representative of sand and gravel. Kµ is the ratio of the active lateral unit pressure to the vertical unit pressure times the coefficient of friction between the fill material and the sides of the trench. Additionally, an Olander bedding angle of 45 degrees was used for the analysis, indicating a typical installation in sand and gravel.

In order to determine the effect of traffic loading on the pipeline for the inland section, the AASHTO HS-20 truck wheel load was used as the live load condition. An associated live load impact factor was applied to take into account the dynamic nature of the traffic loading [4].

4.1.1.3 Internal Pressure

An important input for the structural evaluation is the actual operating pressure of the pipeline, including working pressure and transient pressures. The structural analysis was performed using the actual operating pressure of 68 psi for the 750-mm LCP. If the operating conditions differ from those used in the structural analyses, the analyses will also change.

To provide a level of conservatism for the analysis, a surge allowance was also considered during the AWWA C304 evaluation. As the actual operating pressures are below 100 psi (high value of 68 psi), a 40-psi surge pressure was considered as part of the structural evaluation. An assumed surge allowance of 40 percent of the operating pressure or 40 psi, whichever is greater, was specified in the AWWA C304 design standard.

Although it in no way reflects actual transients occurring in the pipeline, the addition of 40 psi to the pressure includes a level of conservatism in the analysis that is important because it provides allowances for variances in the operating conditions in the pipeline that cannot be predicted and may not be detected. Note that the actual maximum pressure may be different from those used in this analysis, depending on the system operation and maintenance of the valves.

4.1.2 AWWA C301 Analysis

Pure Technologies evaluated the pipe design utilizing *Appendix A*, *"Cubic Parabola Design Method"* of the 1955 and 1984 AWWA C301 *Standard for Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, For Water and Other Liquids* [3]. The AWWA C301 *Appendix A* design method used a semi-empirical approach for evaluating the strength of a PCCP based on the three-edge bearing test load that causes incipient cracking and the maximum internal design pressure that relieves the residual compression in the concrete core. Analyzing the pipe design using the AWWA C301-79 standard allowed Pure Technologies to evaluate the structural adequacy of the design based on the contemporary standard. The AWWA C301 curve for the

750-mm LCP design at a pressure of 108 psi (actual operating pressure of 68 psi, plus 40 psi surge pressure) and 2 feet of earth cover (on-land section) is shown in *Figure 4.1.1*.

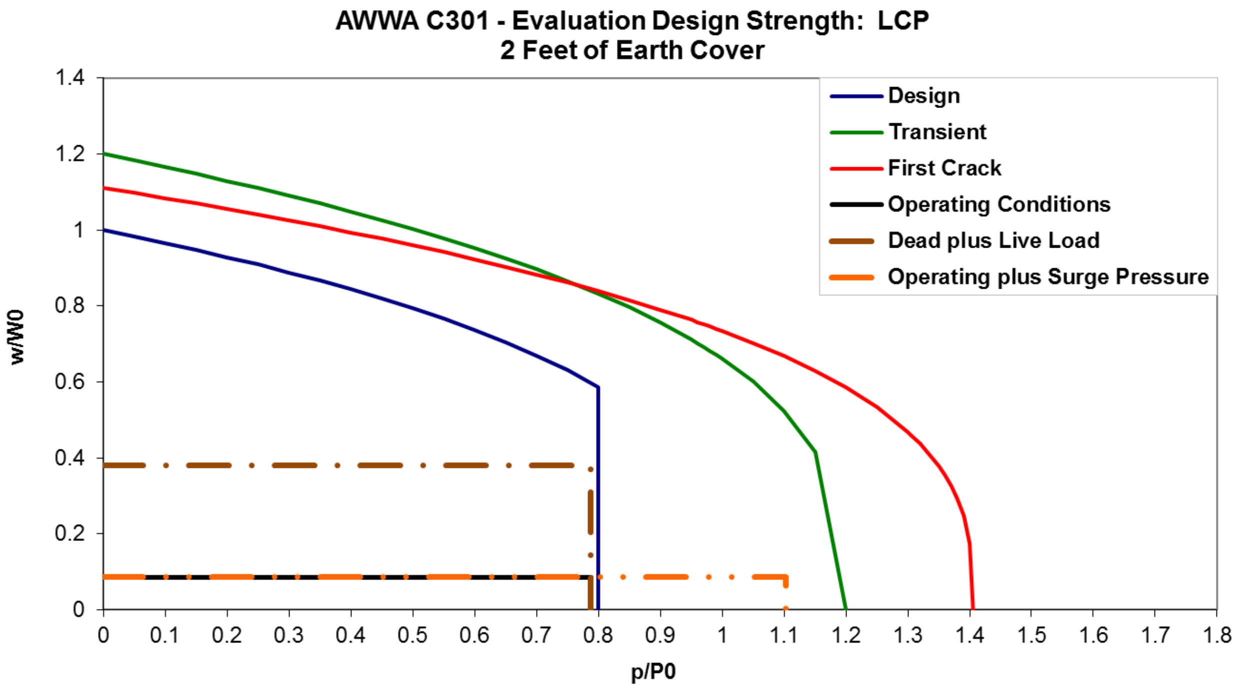


Figure 4.1.2: AWWA C301 Curve for the 750-mm, LCP Design at Design, 2 Feet of Earth Cover, Operating Pressure (100 psi)

The AWWA C301 curve for the 750-mm LCP design at a pressure of 108 psi (actual operating pressure of 68 psi, plus 40 psi surge pressure) and 1.5 feet of earth cover (intertidal section) is shown in *Figure 4.1.2*.

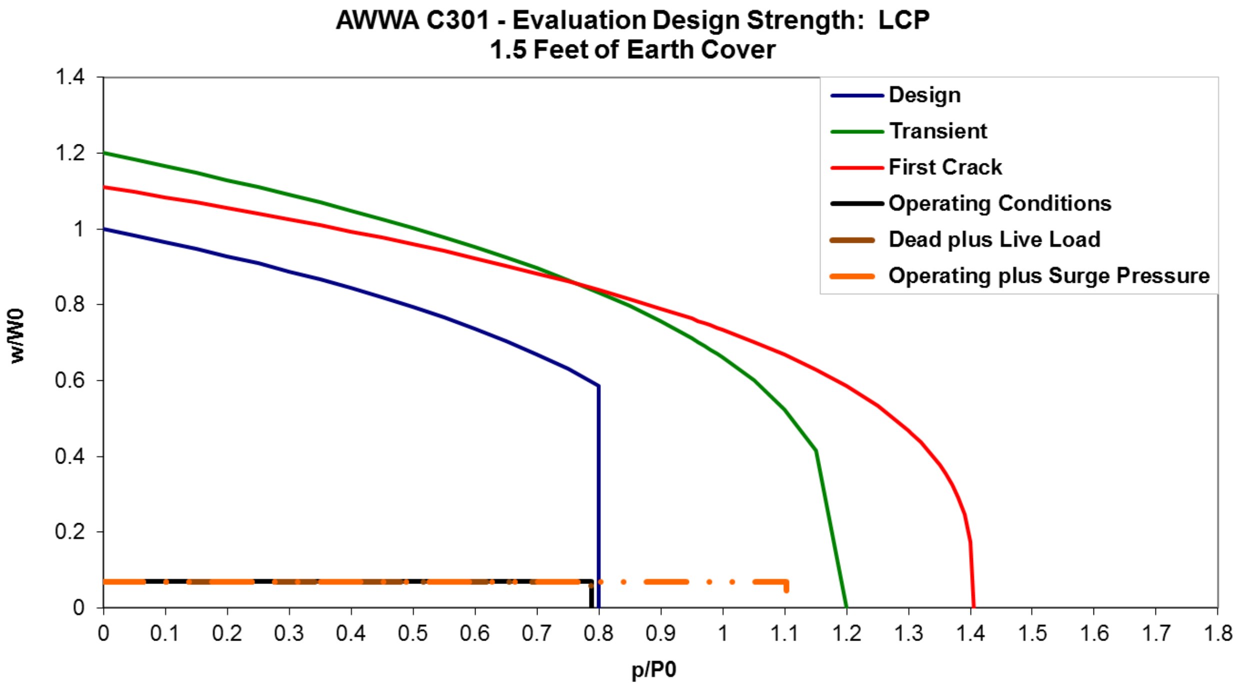


Figure 4.1.2: AWWA C301 Curve for the 750-mm, LCP Design at Design, 1.5 Feet of Earth Cover, Operating Pressure (100 psi)

The AWWA C301 *Appendix A* design method evaluates a particular pipe design using the actual internal pressure and external loading conditions for the pipeline and then compares the calculated values with the Design and Transient Limit curves (blue and green curves, respectively). The y-axis represents the external loading conditions on the pipe. W is the external load considered while W0 is equivalent to 90 percent of the three-edge-bearing load that produces incipient cracking in the concrete core when no internal pressure is applied [3]. The x-axis represents the internal pressure conditions in the pipeline. P is the internal pressure being considered while P0 is the zero compression pressure, which is the threshold between tension and compression in the concrete when the total stress is equal to 0 psi. P0 is independent of any external loading [3].

The black “Operating Conditions” curve is calculated using the dead load on the pipe as W and the internal operating pressure as P. This curve must remain inside of the blue “Design” curve to satisfy the AWWA C301-*Appendix A* Design Standard. The brown “Dead plus Live Load” curve considers the dead and live loads on the pipe as W, while P is taken as the internal operating pressure. The orange “Operating Pressure plus Surge Pressure” curve considers the operating plus a surge allowance as P and uses the dead load on the pipe as W. The AWWA C301-*Appendix A* Design Standard is satisfied when both the brown and orange curves remain inside of the green “Transient” curve.

The red “First Crack” curve is an empirical equation that represents the point when cracking is first expected in a pipe. Based on laboratory testing, the first crack is considered to be 0.001

inches wide and 12 inches long. The pressure and external load associated with this limit are calculated assuming a conservative concrete tensile strength of 300 psi [14]. Because transient loads are not constant, these first cracks would be expected to close once the increased loading is removed. If the brown or orange curves exceed the red curve, cracking could occur in the concrete core; however, the AWWA C301 *Appendix A* Design Standard would still be satisfied as long as the curves remain below the green “Transient” curve.

Using the aforementioned design information, the AWWA C301 analysis for 36-inch SP-5 LCP design was satisfied using the design operating pressure. The AWWA C301 analysis sheets are included in *Appendix B*.

4.1.3 AWWA C304 Analysis

In 1992, the AWWA Committee created a new standard for the design of PCCP called AWWA C304 *Design of Prestressed Concrete Cylinder Pipe* [2]. AWWA C304 is a more rigorous design method than AWWA C301, which was the design standard used by the industry prior to 1992. This report uses the AWWA C304 3rd edition, which was approved in 2007, to evaluate the pipe design. The AWWA C304 Design Standard evaluates stress and strain in undamaged PCCP under several loading combinations and is especially sensitive to the effect of external loading. Pure Technologies analyzed the pipe design using AWWA C304-07 to evaluate its adequacy in relation to the current PCCP design standard.

The AWWA C304 adopted three (3) Limits with criteria that consider multiple load combinations of external loads, pipe and fluid weights, and internal pressures. The three (3) Limits are the Serviceability Limit, the Elastic Limit, and the Strength Limit. The Serviceability Limit is defined by stress and strain criteria that preclude the appearance of both micro cracks and visible cracks in the concrete core and the mortar coating under different loading conditions. This Limit is also controlled by criteria related to the radial tensile stress, the core compressive stress, and the pressure in the pipe. The Elastic Limit is determined by the elastic response of the pipe under operational and operational plus surge pressures. The Elastic Limit controls the amount of stress applied to the prestressing wire and the steel cylinder. The Strength Limit provides a factor of safety for operational and abnormal conditions to protect the pipe against yielding of the prestressing wire or crushing of the concrete core.

Based on the results of the AWWA C304 analysis, at 2- and 4-feet of earth cover and a design working pressure of 108 psi, two (2) Serviceability Limiting Criteria were not satisfied (i.e., the calculated value exceeded the limiting value). The pipes created using this design are not expected to fail; rather, the pipes should be considered under-designed by the current standard, based on the earth cover and pressure used in the analysis. Although the 750-mm LCP design does not meet the design standard, the values are within 5 percent of passing

4.1.4 Finite Element Analysis

Finite Element Analysis is an accurate method for modeling complex geometry under different loading conditions. Recent developments in finite element modeling and increased computational speed allow for the analysis of complex nonlinear problems, which is required to provide accurate models of PCCP with broken prestressing wire wraps.

The FEA model has been developed by Pure Technologies to determine the structural consequence of broken prestressing wire wraps by utilizing pipe design specifications, design parameters, and the current condition of the prestressing wire wraps, as determined during the electromagnetic inspection. During the analysis, the model of a pipe design is subjected to internal pressure, pipe and fluid weights, and external loads while varying the number of broken wire wraps. Commercial finite element analysis software (Abaqus) was used to investigate the response of a PCCP under these different loading conditions.

The FEA model predicts the performance of a PCCP utilizing the tensile strengths of the prestressing wire, the steel cylinder, and the concrete core, as well as a plasticity algorithm that simulates concrete crushing in compression regions. A performance curve, displaying the effects of broken wire wraps, is formulated and used to determine the number of broken wraps required for the design to exceed theoretical Limits. It should be noted that in performing the structural analysis, the pipe properties used in the models were assumed, based on the age and manufacturer of the pipes and standard values provided in the AWWA C301-72 Standard.

A typical LCP is modeled using a composite element with four (4) layers to represent the concrete core, the steel cylinder, the prestressing wire, and the mortar coating. Care was needed to be taken when modeling the prestressing wire wraps and the joint rings to ensure that a realistic behavior for PCCP was achieved. Once the pipe was modeled correctly, all other loads (pipe weight, fluid weight, earth load, live loads, and internal pressure) were applied. *Figure 4.1.3* shows the 3D mesh and composite model used in the analysis of an LCP.

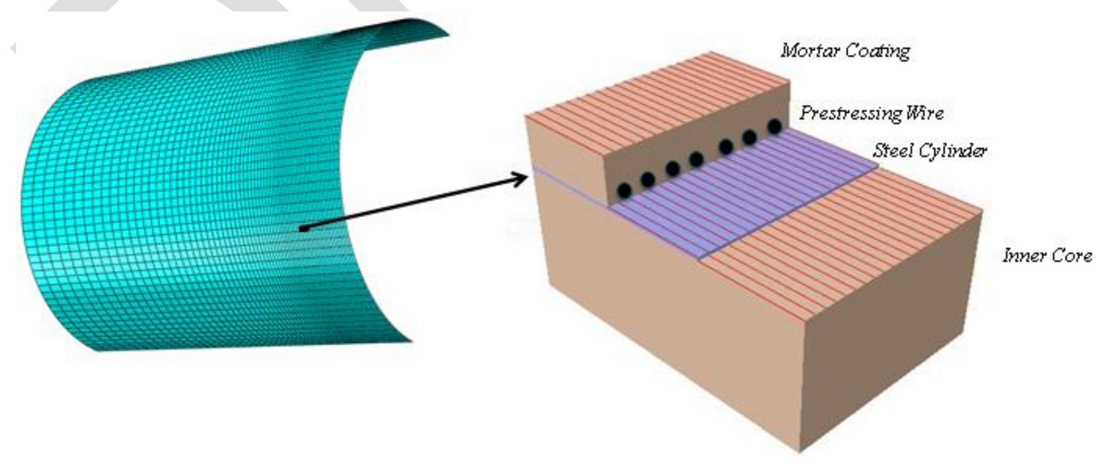


Figure 4.1.3: 3D FEA Representation of an LCP

The FEA was performed for the pipe design at the depth of cover of 5 feet. *Figure 4.1.3* shows the stresses developed in the concrete core, mortar coating, prestressing wire, and steel cylinder during the analysis of a pipe with 25 broken wire wraps. In the figures, the zone of broken wire wraps is located at the far right edge of each image. Stress is measured in the 1-1 direction of the local coordinate system (S_{11}), which is comparable to the hoop stress developed circumferentially around the pipe in the global coordinate system (σ_H). In the figures below, color gradients indicate the calculated range of stress for each element in the FEA model. Positive values for stress, shown as red and orange areas for the concrete core (*Figure 4.1.4* (a)), represent tension. Negative values, shown as yellow, green, and blue areas for the concrete core, indicate compression. In the models, stress is measured in pounds per square inch (psi).

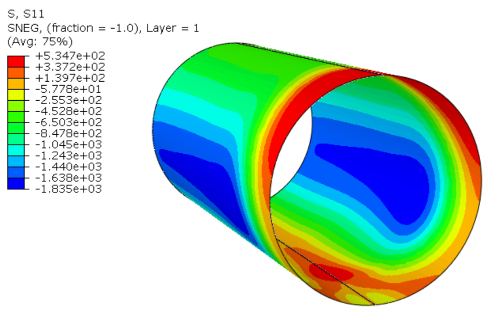


Figure 4.1.3 (a): Stresses in the Concrete Core

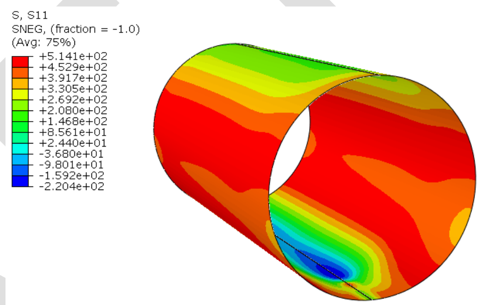


Figure 4.1.3 (b): Stresses in the Mortar Coating

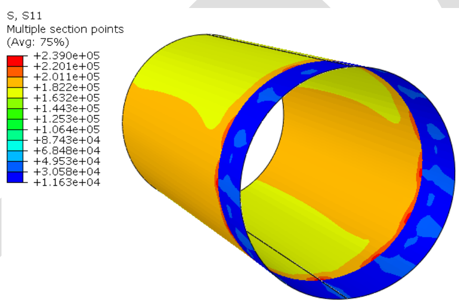


Figure 4.1.3 (c): Stresses in the Prestressing Wire

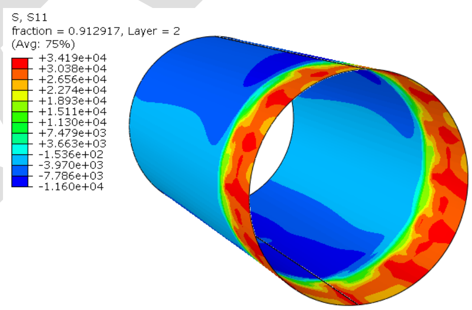


Figure 4.1.3 (d): Stresses in the Steel Cylinder

Cracking in PCCP is due to excessive tension in the concrete core and the mortar coating. *Figure 4.1.4* shows the damage due to tension in the concrete core and mortar coating of a pipe with 25 broken wire wraps. In this figure, the color gradients indicate the probability of visible cracking for each element in the FEA model. Dark blue areas indicate sections of the model where there is a very low probability of visible cracking. By contrast, bright red areas indicate sections of the model where there is over a 90 percent probability of visible cracking.

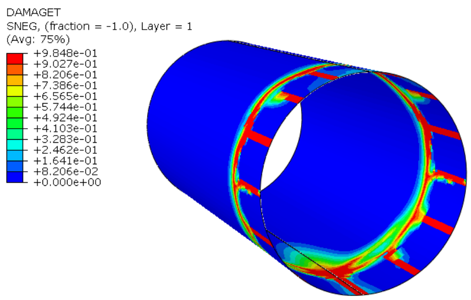


Figure 4.1.4 (a): Damage in the Concrete Core

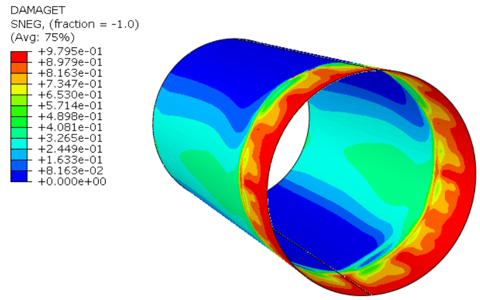


Figure 4.1.4 (b): Damage in Mortar Coating

2.1.4.1 Performance Curves

The number of broken prestressing wire wraps that a particular pipe design will tolerate under operational and surge conditions can be determined using an FEA performance curve. Pure Technologies uses four (4) Limits, Micro Cracking, Visible Cracking, Yield, and Strength, to classify the condition of a distressed PCCP. Note that although they have similar descriptions and values, these Limits are different than the Limits and Limiting Criteria described in the AWWA C304 analysis.

Table 4.1.2 defines the Limits used by Pure Technologies to describe the predicted condition of a PCCP with a known quantity of broken wire wraps. The actual number of broken wire wraps required to reach these Limits varies according to the pipe design and earth cover.

Table 4.1.2: Predicted Condition of a Pipe with Broken Wire Wraps

Limit	Description
Micro Cracking	Micro cracking of the mortar coating or concrete core (defined by the strain associated with a crack that is ≥ 0.001 inches wide)
Visible Cracking	Visible cracking of the mortar coating or concrete core (defined by the strain associated with a crack that is ≥ 0.002 inches wide)
Yield	Prestressing wire or steel cylinder reach their yield strength
Strength	Prestressing wire or steel cylinder reach their ultimate tensile strength

A pipe reaches the Micro Cracking Limit when strain in the mortar coating or concrete core exceeds the AWWA C304 tensile strain limit for micro cracking. Micro cracking in the mortar coating or concrete core is described as cracks greater than 0.001 inches wide and 12 inches in length and can be considered the preliminary level of damage in a PCCP. The Visible Cracking Limit is reached when the mortar coating or concrete core experience cracks greater than 0.002 inches wide and 12 inches in length.

The values used to represent the performance of the steel components in the field are based on the yield and ultimate strengths provided on the pipe design specifications sheet or the standard values in the relevant design standard, if the pipe is not available. The yield strength for the prestressing wire is typically 85 percent of its ultimate strength, while the yield strength of the steel cylinder is either denoted on the pipe design specification sheet or taken from the design standard in place at the time of production. The Yield Limit is reached when either the steel cylinder or the prestressing wire exceed its yield strength. The ultimate strength of the prestressing wire is dictated by the gage and class of the wire, while the ultimate strength of the steel cylinder is determined by the grade of the steel. The Strength Limit is exceeded when one of the PCCP components reaches its ultimate strength, which, theoretically, will cause the failure of the pipe.

By evaluating the predicted structural condition of a pipe using FEA and analyzing all critical variables, a risk assessment for all distressed pipes can be performed to determine if and when a particular pipe should be rehabilitated. An FEA performance curve evaluates the impact of a growing number of broken prestressing wire wraps on the performance of a pipe and the corresponding likelihood of failure as a result of this damage. Failure risk is expressed in terms of the Limits, given in *Table 4.1.2*, as it relates to the capacity of a pipe with broken prestressing wire wraps. FEA curves were created for the 750-mm pipe design at 2- and 1.5-feet of earth cover. Based on this analysis, a plot was generated that shows the Limits in terms of the number of broken wire wraps and the applied internal pressure. A more detailed description of the FEA methodology and limitations is provided in *Appendix C* while the FEA performance curves are provided in *Appendix D*.

Figure 4.1.5 shows the performance curve generated for the 750-mm pipe design at actual operating conditions, considering 2-feet of earth cover and live loads (on-land sections).

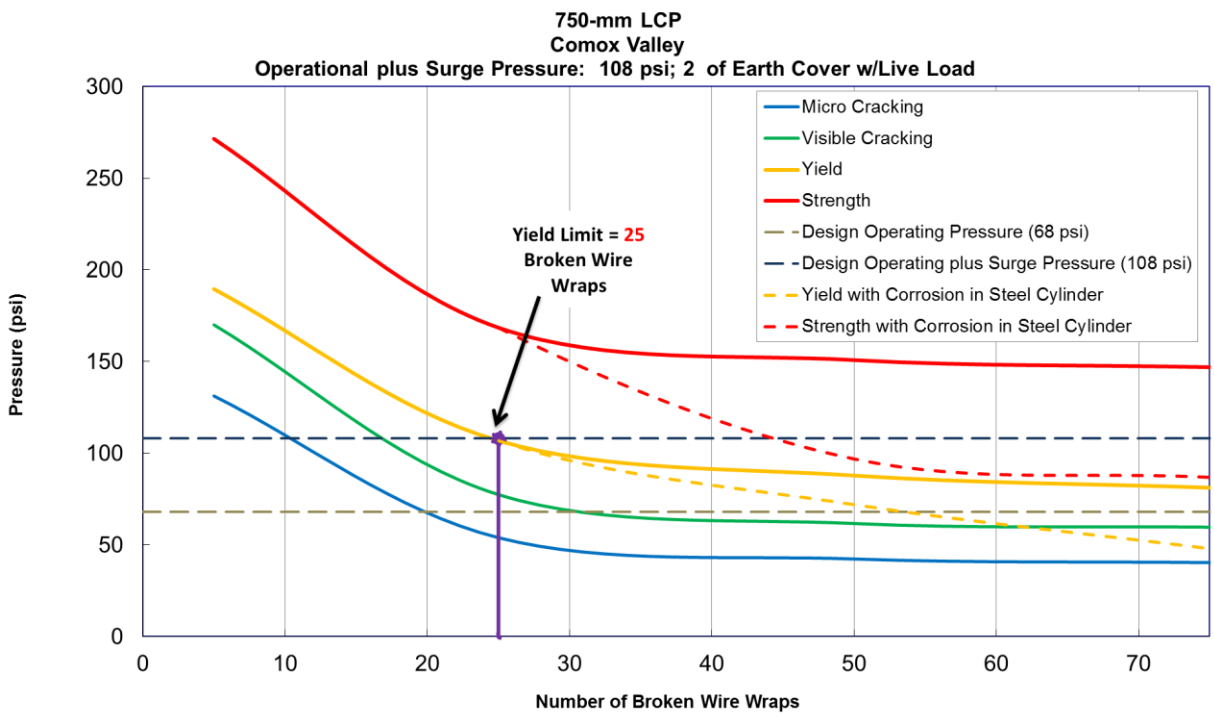


Figure 4.1.5: Performance Curve for the 750-mm LCP in the CPS Force Main, with 2-feet of earth cover and live load (On-land Section)

Figure 4.1.6 shows the performance curve generated for the 750-mm pipe design at actual operating conditions, considering 1.5-feet of earth cover and 2.5-feet of water above due to tide conditions (intertidal section).

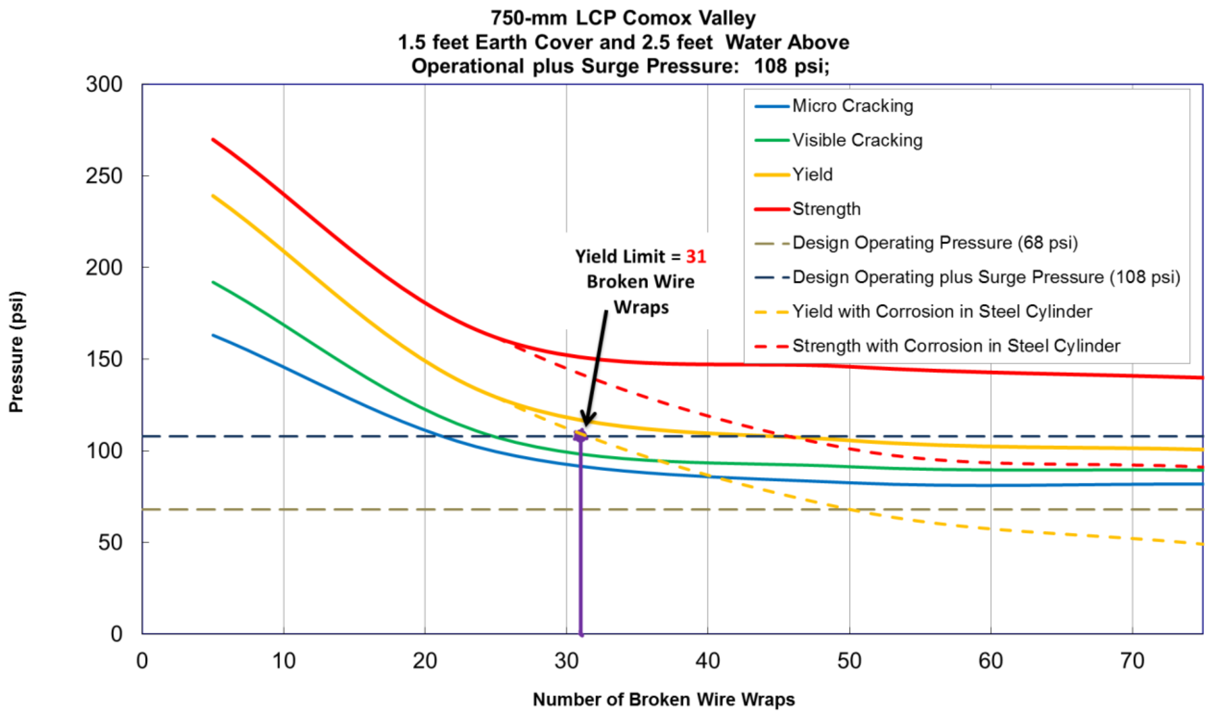


Figure 4.1.5: Performance Curve for the 750-mm LCP in the CPS Force Main, with 1.5-feet of earth cover and 2.5-feet of water above (Intertidal Section)

Table 4.1.3 gives the number of broken prestressing wire wraps required to exceed each Limit at the actual operating pressure plus transient pressure for the analyzed pipe design.

Table 4.1.3: Number of Broken Wire Wraps Required to Exceed Each Limit

Pipe Section	Analysis Pressure (psi)	Micro Cracking	Visible Cracking	Yield	Strength
750-mm On-land	108	10	17	25	44
750-mm Intertidal	108	21	25	31	45

Pure Technologies typically recommends mitigating the risk associated with operating a particular pipe when the model predicts that the pipe meets or exceeds the Yield Limit. In reality, the Limit that a pipe exceeds is only one factor to consider when deciding whether to rehabilitate a pipe. Other variables that are critical for the CVRD (e.g., redundancy, consequence of failure, and criticality) should be evaluated when determining the risk tolerance associated with a distressed pipe. Once the number of broken wire wraps on a pipe reaches the Yield Limit, a pipe may experience a higher rate of wire breaks until it reaches the Strength Limit. Due to the conservative nature of the FEA, reaching the Strength Limit does not necessarily indicate an immediate failure.

4.2 AWWA C303 Structural Analysis

Pure Technologies performed a structural analysis to determine if the BWP design used in the force main satisfied the requirements of the current American Water Works Association (AWWA) C303 Standard, *Concrete Pressure Pipe, Bar-Wrapped (ASTM) A570 Grade 33, Steel-Cylinder (ASTM) A615 Grade 40.* Pure Technologies also performed a three-dimensional finite element analysis (FEA) to evaluate the structural capacity of pipes with broken bar wraps. These analyses are detailed in the following sections.

4.2.1 Design Specifications and Assumptions for Modeling

4.2.1.1 Pipe Properties

Table 4.2.1 provides the values used to complete the structural analysis for CPS Force Main 820-mm BWP design per AWWA 1978 standards. All values used to model the design were obtained from the Ameron pipe design specifications sheet provided by the CVRD.

Table 4.2.1: Values used for FEA Modeling – Standard Pipe Designs

Pipe Parameters	Units	820-mm Class 100 BWP
Earth Cover (to top of pipe)	feet	4
Design Pressure	psi	86
Inside Diameter	inches	32.25
Outside Diameter of the Pipe	inches	35.23
Outside Diameter of the Cylinder	inches	33.80
Cylinder Thickness	inches	0.0747
Cylinder Gage	-	14
Inner Mortar Lining Thickness	inches	0.7
Outer Mortar Coating Thickness	inches	0.5
Bar Diameter	inches	0.21875
Center-to-Center Bar Spacing	inches	1.37
Ultimate Strength of the Bars	psi	72,500
Yield Strength of the Cylinder	psi	33,000

4.2.1.2 External Loading

The external earth load is extremely influential in the AWWA C303 analysis and the FEA. Based on the approximate bury depth for the most severely distressed pipe, the earth cover depth considered for the 820-mm BWP design was 1.5 feet of earth cover, plus 2.5 feet of water. The earth cover was verified from the pipe profile drawings and tide information.

The earth loading assumed a soil unit weight of 120 lb/ft^3 and a Kμ value of 0.165, which is representative of sand and gravel. Kμ is the ratio of the active lateral unit pressure to the vertical unit pressure times the coefficient of friction between the fill material and the sides of the trench. A bedding angle of 45 degrees was used for the analysis and Pure Technologies assumed that coarse-grained soil with some fines was the primary bedding material. To analyze the manhole pipe designs for the worst-case scenario, Pure Technologies also assumed a moderate level of compaction (90-95%) of the bedding material.

4.2.1.3 Internal Pressure

An important input for the structural evaluation is the actual operating pressure of the pipeline, including working pressure and transient pressures. Based on the denoted class of pipe, the actual operating pressure used in the analysis was 68 psi for the 820-mm BWP. If the operating conditions differ from those used in the structural analyses, the analyses will also change.

To provide a level of conservatism for the analysis, a surge allowance was also considered during the AWWA C303 evaluation. As the actual operating pressures are below 100 psi (high value of 68 psi), a 40-psi surge pressure was considered as part of the structural evaluation. An assumed surge allowance of 40 percent of the operating pressure or 40 psi, whichever is greater, was specified in the AWWA C303 design standard.

Although it in no way reflects actual transients occurring in the pipeline, the addition of 40 psi to the pressure includes a level of conservatism in the analysis that is important because it provides allowances for variances in the operating conditions in the pipeline that cannot be predicted and may not be detected. Note that the actual maximum pressure may be different from those used in this analysis, depending on the system operation and maintenance of the valves.

4.2.2 AWWA C303 Analysis

As part of the structural analysis, an AWWA C303 analysis was performed for the 820-mm, Class 100 BWP design that was used for the FEA. *Table 4.2.2* summarizes the results of the AWWA C303 analysis.

Table 4.2.2: Result of the AWWA C303 Analysis		
Specified Class (Design Pressure, psi)	150	
Working Pressure, psi[1]	10	
Earth Cover, feet	7	
Maximum Allowable Deflection, inches	0.324	
Horizontal Deflection: Un-cracked, inches	0.043	Satisfied
Horizontal Deflection: Cracked, inches	0.104	Satisfied
Circumferential Stress Limit: Steady State Conditions, psi	Lesser of 16,500 psi or 50% of Cylinder Yield Strength	
Circumferential Steel Stress: Working Pressure, psi	862	Satisfied
Circumferential Steel Stress: Design Pressure, psi	12,935	Satisfied
Circumferential Stress Limit: Transient Conditions, psi	Lesser of 24,500 psi or 75% of Cylinder Yield Strength	
Circumferential Steel Stress: Working plus Transient Pressure, psi	6,209	Satisfied
Circumferential Steel Stress: Design plus Transient Pressure, psi	18,282	Satisfied

The requirements of the AWWA C303 analysis were satisfied for the 820-mm, Class 100 pipe design at both the actual operating pressure (68 psi) and the design operating pressure (100 psi). The complete result sheet for the AWWA C303 analysis is found in *Appendix A*.

4.2.3 Finite Element Analysis (FEA)

FEA is an accurate method for modeling complex geometry under different loading conditions. Recent developments in finite element modeling and increased computational speed allow for the analysis of complex nonlinear problems, which is required to provide accurate models of BWP with broken bar wraps and corrosion.

The FEA model developed by Pure Technologies determines the structural consequence of broken bar wraps and corrosion by utilizing pipe design specifications, design parameters, and the current condition of the pipes, as determined during the enhanced electromagnetic inspection. In the analysis, the model of a pipe design is subjected to internal pressure, pipe and fluid weights, and external loads while varying the amount of steel available to carry the load. Commercial finite element software (ABAQUS) was used to investigate the response of a BWP under these different loading conditions.

The FEA model predicts the performance of a BWP, utilizing the strengths of the inner lining, the steel cylinder, the reinforcing bar, and the outer coating. A performance curve, displaying the effects of distress, is formulated and used to determine the number of broken bar wraps required for the design to exceed theoretical limits. It should be noted that in performing the structural analysis, the values used in the models were taken directly from the AWWA C303 Design Standard.

A typical BWP is modeled using a composite element with four (4) layers to represent the inner lining, the steel cylinder, the reinforcing bar, and the outer coating. Care was taken when modeling the broken bar wraps and corrosion to ensure that a realistic behavior for BWP was achieved. Once the pipe was modeled correctly, all other loads (pipe weight, fluid weight, earth load, live loads, and internal pressure) were applied. *Figure 4.2.1* shows the 3D mesh and composite model used in the analysis of a BWP (note that the reinforcing bar layer is not visible as it is embedded in the outer coating).

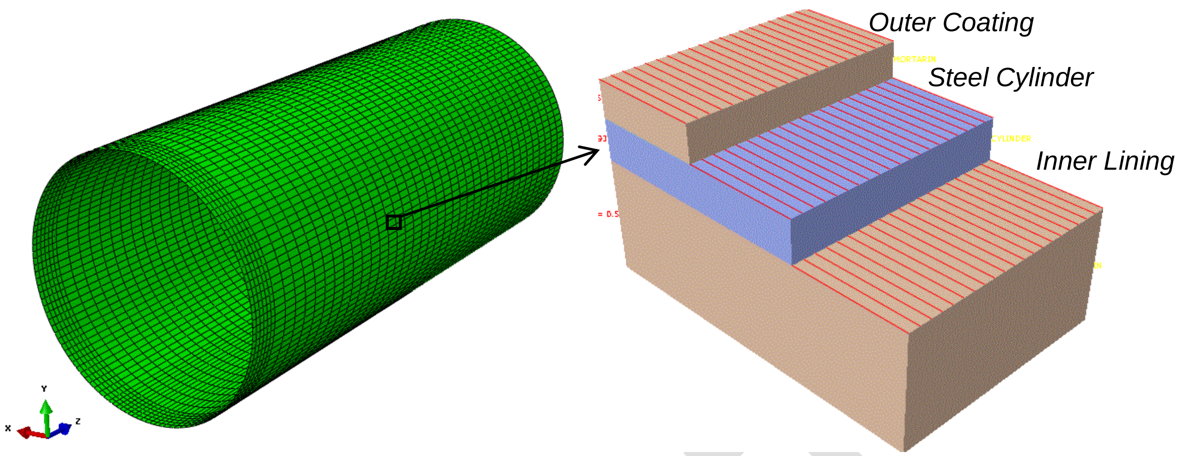


Figure 4.2.1: 3D FEA Representation of a BWP

The FEA was performed for the 820-mm, Class100 BWP design while varying the level of distress in the pipe wall. *Figure 4.2.2* shows the hoop stress developed in the inner lining, the outer coating, the reinforcing bar, and the steel cylinder during the analysis of an 820-mm BWP with 20 broken bar wraps and 70% corrosion. In the figures below, color gradients indicate the calculated range of stress for each element in the FEA model. Positive values, shown as red and orange areas for the inner lining (*Figure 4.2.2a*) represent tension, while negative values, shown as green and blue areas for inner lining, indicate compression. In *Figure 4.2.2*, stress is reported in pounds per square inch (psi).

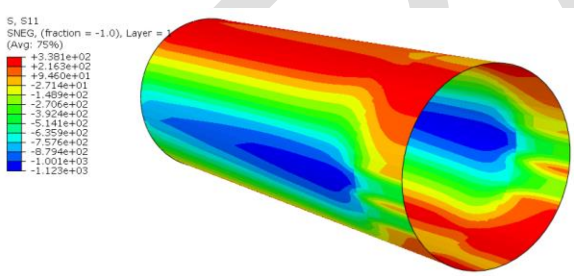


Figure 4.2.2 (a): Stress in the Inner Lining

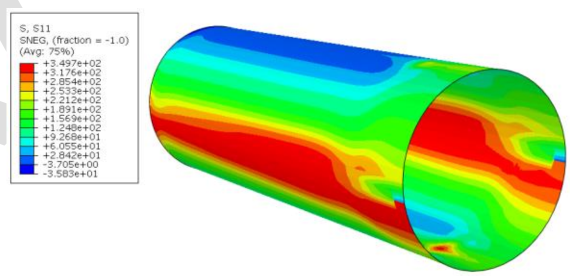


Figure 4.2.2 (b): Stress in the Outer Coating

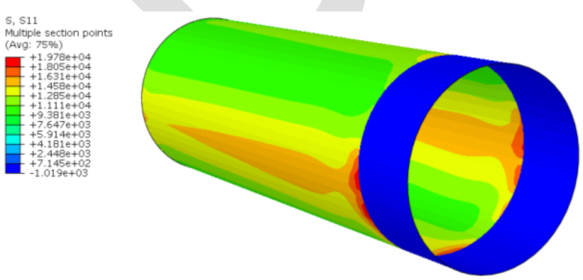


Figure 4.2.2 (c): Stress in the Reinforcing Bar

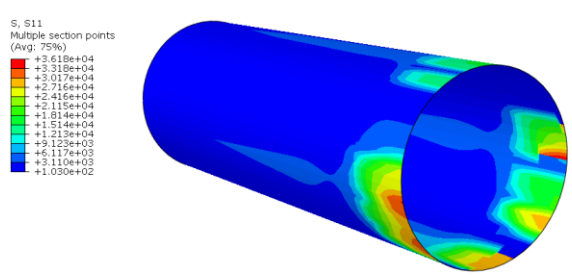


Figure 4.2.2 (d): Stress in the Steel Cylinder

4.2.3.1 Performance Curve

The level of distress that a particular pipe design will tolerate under operational and transient conditions can be determined using FEA performance curves. For BWP, Pure Technologies evaluates distress using both deflection performance curves and pressure performance curves.

A pressure performance curve displays the maximum pressure that a distressed pipe design can tolerate before the stress or strain reaches pre-determined limiting values. In this type of performance curve, three (3) Limits, Micro Cracking, Visible Cracking, and Yield, are used to classify the condition of a distressed BWP and determine whether a particular pipe should be rehabilitated. *Table 4.2.3* defines the Limits used to describe the predicted condition of a BWP with a known level of distress. The actual amount of distress required to reach these Limits varies according to the pipe design and earth cover.

Table 4.2.3: Predicted Condition of a Pipe with Broken Wire Wraps

Limit	Description
Micro Cracking	Micro cracking of the mortar coating or concrete core (defined by the strain associated with a crack that is ≥ 0.001 inches wide)
Visible Cracking	Visible cracking of the mortar coating or concrete core (defined by the strain associated with a crack that is ≥ 0.002 inches wide)
Yield	Prestressing wire or steel cylinder reach their yield strength

A pipe reaches the Micro Cracking Limit when strain in the outer coating or inner lining indicates cracking that is greater than 0.001 inches wide and 12 inches in length. This Limit is considered the preliminary level of damage in a BWP. The Visible Cracking Limit is reached when the outer coating or inner lining experience cracks greater than 0.002 inches wide and 12 inches in length.

The values used to represent the performance of the steel components in the field are based on the yield strengths provided on the pipe design specifications sheet. The yield strengths provided in the Ameron specifications are references to standard American Society for Testing and Material (ASTM) steel grades. All steel used for the cylinder is ASTM A570 Grade 33, and all steel used for the reinforcing bars is ASTM A615 Grade 40 Smooth. The Yield Limit is reached when either the steel cylinder or the reinforcing bar reaches the yield strength.

By evaluating the predicted structural condition of a pipe using FEA and analyzing all critical variables, a risk assessment for all distressed pipes can be performed to determine if and when a particular pipe should be rehabilitated. An FEA performance curve evaluates the impact of distress on the performance of a pipe and the corresponding likelihood of failure as a result of this damage. Failure risk is expressed in terms of the limits, given in *Table 4.2.3*, as it relates to the capacity of a pipe with broken bar wraps or corrosion.

FEA was performed for the 820-mm, Class 100 BWP design at five (5) varying levels of distress. Based on each analysis, deflection and pressure performance curves were generated to show the zones or Limits in terms of the number of broken reinforcing bars and the applied internal pressure. Each level of distress consisted of a specific number of broken bar wraps and a uniform amount of corrosion at the location of the broken wraps.

Figure 4.2.3 shows the performance curves generated for the 820-mm, Class 100 BWP design. Note that for the pressure performance curve, the Micro Cracking Limit is exceeded at 0 psi with no broken bar wraps; therefore, this curve is not visible in the figure. Full-page FEA performance curves are provided in *Appendix B*.

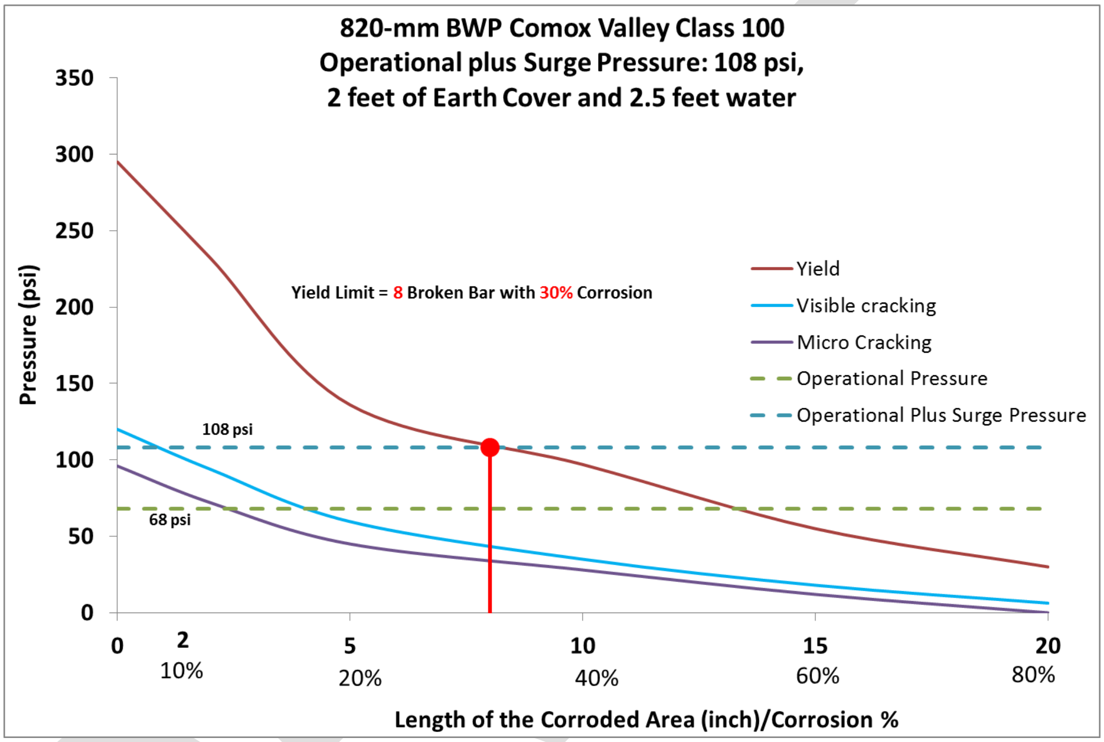


Figure 2.4: Pressure Performance Curve for an 820-mm Class 100 BWP

Pure Technologies typically recommends mitigating the risk associated with operating a particular pipe when the model predicts that the pipe meets or exceeds the Yield Limit. In reality, the Limit that a pipe exceeds is only one factor to consider when deciding whether to rehabilitate a pipe. Other variables that are critical for HDR (e.g., redundancy, consequence of failure, and criticality), should be evaluated when determining the risk tolerance associated with a distressed pipe.

5. Analysis and Discussion

Analysis of the data obtained during the inspection determined that no pipes in the CPS Force Main displayed electromagnetic anomalies consistent with prestressing wire damage. Additionally, no leaks were identified and the majority of air events were located in proximity of the insertion point, near Courtenay Pump Station and are likely related to tool insertion procedures.

FEA evaluates the impact of a growing number of broken prestressing wire wraps on the performance of a PCCP and the corresponding likelihood of failure associated with this damage. Failure risk is expressed in terms of Limits, given in *Table 4.1.2 and Table 4.2.3*. These Limits describe the ability of a pipe with broken prestressing wire wraps to resist deformation and further deterioration.

For the CPS Force Main, 750-mm LCP and 820-mm BWP were evaluated using FEA performance curves, the number of broken wire wraps required to exceed the Micro Cracking Limit, Visible Cracking Limit, Yield Limit, and Strength Limit were derived from the intersection of the associated Limit Curve and the design operating pressure plus surge pressure (detailed in *Table 4.1.2*).

No pipes on the CPS Force Main were identified to exceed any of the Micro Cracking, Visible Cracking, Yield, or Strength Limits.

6. Conclusions and Recommendations

6.1 Conclusions

In summary, for the 2017 condition assessment evaluation of the CPS Force Main, Pure Technologies concludes that:

- One (1) acoustic anomaly characteristic of pockets of trapped transient gas, five (5) acoustic anomalies characteristic of transient gas and two (2) acoustic anomalies characteristic of entrained air were identified within the 750-mm LCP section.

- No acoustic anomalies were identified within the 450-mm and the 820-mm sections of the force main during the SmartBall inspection.

- Of the 1,258 pipes inspected in the CPS Force Main, no pipes had electromagnetic anomalies consistent with broken prestressing wire wraps or broken bar wraps.

- The electromagnetic analysis of the 750-mm LCP identified eight (8) pipes with anomalous signals. The signal shift identified in the anomalous pipes is different from both a standard non-distressed pipe and a pipe with broken wire wraps. The signal shift could be caused by a change in pipe property. Anomalous Pipe 1099 corresponds to a spot repair, implemented in 2003. In regards to the rest anomalous pipes, Pure Technologies requires more information to provide a conclusive evaluation of the electromagnetic signal.

- A transient pressure monitor was installed on the header of the force main at the Courtenay Pump Station. Pressure data was recorded between May 24, 2017 and June 29, 2017, in order to identify the hydraulic stresses acting on the pipeline. During the monitoring period, the sensor recorded an average pressure of 31.8 psi, with a maximum pressure of 68.2 psi.

- Based on the results of the AWWA C301 analysis, the pipe design for 750-mm LCP satisfied the criteria for the current design pressure and earth cover. However, the pipe design at 2- and 4-feet of earth cover and a design working pressure of 108 psi did not satisfy the AWWA C304 design criteria. Two (2) Serviceability Limiting Criteria were not satisfied (i.e., the calculated value exceeded the limiting value). The pipes created using this design are not expected to fail; rather, the pipes should be considered under-designed by the current standard, based on the earth cover and pressure (68 psi) used in the analysis. Although the 750-mm LCP design does not meet the design standard, the values are within 5 percent of passing.

- Based on the results of the AWWA C303 analysis, the pipe design for the 820-mm BWP, Class 100 satisfied the criteria for the current design pressure and earth cover.

- No pipes on the CPS Force Main were identified to exceed any of the Micro Cracking, Visible Cracking, Yield, or Strength Limits based on the finite element analysis.

6.2 Recommendations

Based on the results of the internal inspection and subsequent condition assessment of the CPS Force Main Pure Technologies' recommends the following:

- In order to address acoustic anomalies characteristic of static air pockets and transient gas, verify operation of all the air valves on the pipeline.

- In order to detect any new distress on the CPS Force Main, Pure Technologies recommends reinspecting the pipeline in seven (7) years.

- The CPS Force Main has no damaged pipes at this time as detected by the electromagnetic assessment. However, the rate of wire break activity can vary significantly depending on a number of variables. As a result, and since the CPS Force Main is a critical asset with a high consequence of failure, it is recommended that CVRD implement procedures to proactively manage the transmission main system via acoustic monitoring. An acoustic monitoring system will detect and report wire breaks as they occur in near real time. This information is combined with the electromagnetic inspection data to allow CVRD to analyze the condition of the CPS Force Main (i.e., the number of broken wire wraps on each pipe section). This is the best available and most economical option to minimize the risk of future pipeline failure when combined with proactive rehabilitations.

References

1. American Water Works Association Research Foundation, Failure of Prestressed Concrete Cylinder Pipe, Denver, Colorado: AWWA; 2007.

2. American Water Works Association, AWWA C304 Standard for Design of Prestressed Concrete Cylinder Pipe, Denver, Colorado: AWWA; 2007.

3. American Water Works Association, AWWA C301 Standard for Prestressed Concrete Pressure Pipe, Steel-Cylinder Type, For Water and Other Liquids, Denver, Colorado: AWWA; 1992.

4. Interpace, Lock Joint Concrete Pressure Pipe, Engineering Manual. Cherry Hill: Interpace; 1973.

5. American Concrete Pipe Association, Concrete Pipe Design Manual, Vienna: ACPA; 2007.

6. Villalobos J. L., Effects of Prestressed Concrete Pipe in a High Chloride Environment after 19 Years of Service, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 575-583.

7. Price R. E., Lewis R. A., and Erlin B., Effects of Environment on the Durability of Prestressed Concrete Cylinder Pipe, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 584-593.

8. Walsh T. L., Hodge D.S., Overcoming the Challenges of Replacing 20 km of Defective 1524 mm Diameter PCCP, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 602-611.

9. Knowles W. L. C., Failure of Prestressed Concrete Embedded Cylinder Pipe, Design and Installation, Kenneth Kienow ed., ASCE, NY, 1990, pp. 434-441.

10. Galleher J. J., Stift M.T., Internal Inspection and Database Development of PCCP, Pipelines in the Constructed Environment, ASCE, Reston, VA, 1998, pp. 721-730.

11. Ojdrovic R. P., Zarghamee M. S., Hegar J.R., and Westman T., Condition Assessment of a PCCP Line Accessible from Outside Only, Pipelines 2001-Advances in Pipeline Engineering & Construction, Joseph Castronov ed., ASCE, Reston, VA (CD-ROM) ,2001.

12. Parks R. R., Drager J. K. and Ojdrovic R. P., Condition Assessment and Rehabilitation of the Windy Gap Pipeline – An Owner's Perspective, Pipelines 2001-Advances in Pipeline Engineering & Construction, Joseph Castronov ed., ASCE, Reston, VA (CD-ROM), 2001.

13. Price R. E., The Investigation Cause and Prevention of PCCP Failures, Proceeding AWWA Annual Conference, 1990, pp. 663-681.

14. Drimalas T., Clement J., Folliard K., Dhole R., Thomas M., Laboratory and Field Evaluations of External Sulfate Attack in Concrete, Center for Transportation Research at The University of Texas at Austin, 2010, pp. 1-13.

15. Romer E. A., Graham E., Bell C., Clark B., Failure of Prestressed Concrete Cylinder Pipe for AWWA Research Foundation

APPENDIX A

History of PCCP

A. Overview of PCCP

A.1 PCCP History and Manufacturing

PCCP has been used for large diameter water transmission and distribution mains since 1942. PCCP is a complex, composite structure consisting of a concrete core, a thin steel cylinder, high-strength steel prestressing wire, and a mortar coating. The concrete core and prestressing wire are the main structural components, while the steel cylinder acts primarily as a water barrier. The prestressing wire produces a uniform compressive force on the concrete core that holds the concrete in compression when the pipe is subjected to internal water pressure and external loading. A mortar coating surrounds the prestressing wire, embedding the wraps in an alkaline environment to protect them from external corrosive influences and physical damage.

Two types of PCCP are used in transmission mains: lined cylinder pipe (LCP) and embedded cylinder pipe (ECP). In LCP, the prestressing wire is wrapped directly against the steel cylinder, while in ECP the steel cylinder is embedded in the concrete core, meaning that the prestressing wire is wrapped against the outer concrete core rather than the steel cylinder. The diameter ranges for LCP and ECP are 16 to 60 inches and 30 to 256 inches, respectively. Cross-sectional views of LCP and ECP, as described in the current AWWA C304-07 Standard, *Design of Prestressed Concrete Cylinder Pipe*, are shown in Figure A.1.

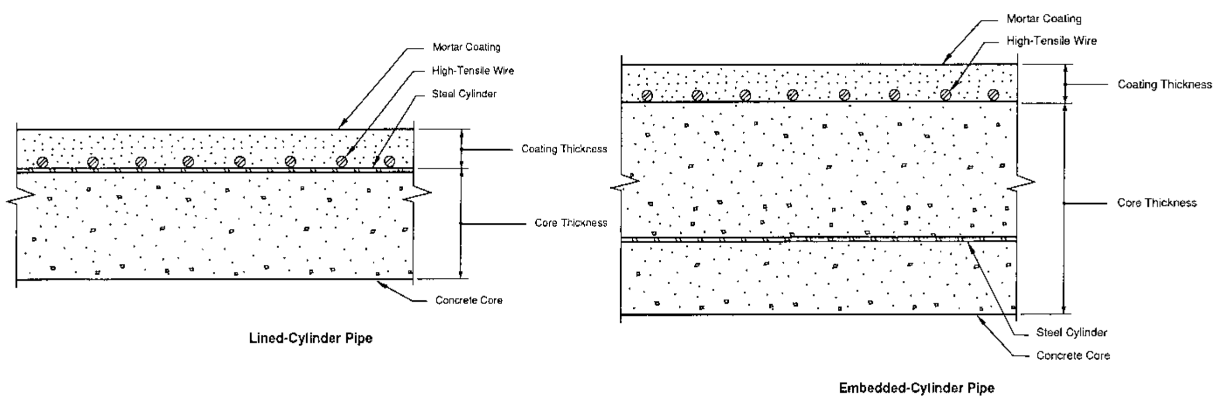


Figure A.1: Cross Sectional Views of PCCP [2].

PCCP design and manufacturing standards have gradually developed since 1943, with the first tentative consensus standard for PCCP being approved by the AWWA in 1949. The AWWA C301 *Standard Specifications for Reinforced Concrete Water Pipe - Steel Cylinder Type, Prestressed* (AWWA C301-52) was revised multiple times, with the latest revision being released in 2007. In 1992, the AWWA created a new standard for PCCP design and manufacturing called AWWA C304 *Design of Prestressed Concrete Cylinder Pipe* (AWWA C304).

The initial structural design requirements for the manufacturing of PCCP tended to be conservative [1, 5, 6], with high factors of safety. As experience with using this composite pipe grew, understanding of the behavior of PCCP increased, and advances in material sciences were achieved, the structural design of PCCP was changed to reduce the cost of manufacturing. Increases in the applied tensile strength of the wire that occurred during manufacturing in the late 1960s and early 1970s reduced the amount of prestressing steel wire required and allowed for the use of smaller diameter wire. This resulted in what appeared to be a more efficient design and cost-effective manufacturing process.

Changes in PCCP design with respect to the prestressing wire were primarily based on updates to the American Society for Testing and Materials (ASTM) A227, *Standard Specifications for Hard-Drawn Steel Spring Wire,* and ASTM A648, *Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Pipe*. The updated standards significantly changed the composition of the steel prestressing wire in order to increase its tensile strength. Tensile strength is defined as the amount of stress the wires are able to withstand before either permanent deformation or failure occurs. Increasing the material strength by modifying the composition of the steel and the manufacturing process allowed for a reduction in the overall amount of steel needed to achieve the minimum tensile strength required for the pipe design. This created a cost reduction for the pipe manufacturer and provided a cost advantage for the pipe owner. Due to the competitive cost of PCCP in comparison to other pipe materials, its popularity grew significantly with water and wastewater utilities in the United States for their large diameter pressure pipelines in the 1960s and 1970s.

Updates to the ASTM standards and the adoption of the AWWA C301-64 Standard in 1964 led to significant changes in the design and manufacture of PCCP that decreased the minimum prestressing wire diameter, increased the allowable concrete core stress when the wire was wrapped, reduced the amount of Portland cement in the core, and decreased the minimum coating thickness [1]. As the ASTM standards changed and wire strength increased, classifications of wire were developed based on their tensile strength (Class I, Class II, and Class III).

These practices culminated in the 1970s when pipes using an even stronger Class IV wire and other cost saving measures were manufactured. Class IV wire was produced by using a loophole in the ASTM and AWWA standards, which did not define a maximum tensile strength. Class IV prestressing wire was drawn at very high temperatures to increase the ultimate tensile strength and thereby reduce the amount of steel required. All classes of prestressing wire are susceptible to external corrosion, hydrogen embrittlement, and other failure modes; however, the high temperatures used to manufacture Class IV wire made it particularly sensitive to hydrogen embrittlement and dynamic strain aging effects. Pipe from this era using Class IV prestressing wire started experiencing a high rate of premature failures, primarily related to the new standards and manufacturing processes.

Updates to the AWWA C301 Standard beginning in the 1980s have significantly improved the design and manufacturing of PCCP, increasing the quality of pipe produced and installed. The major revisions in the standards, design, and manufacturing of the PCCP consisted of changes in the maximum diameter of the PCCP, the quality (strength) of the concrete, the thickness of the steel cylinder, the prestressing wire specifications (e.g., wire diameter, wrapping stress, spacing), and the thickness of the mortar coating [1].

Figures A.2 (a), A.2 (b), and A.2 (c) provide graphic representations of the minimum steel cylinder thickness, prestressing wire diameter, and mortar coating thickness required by the AWWA C301 and AWWA C304 Design Standards between 1949 and 2007 [1].

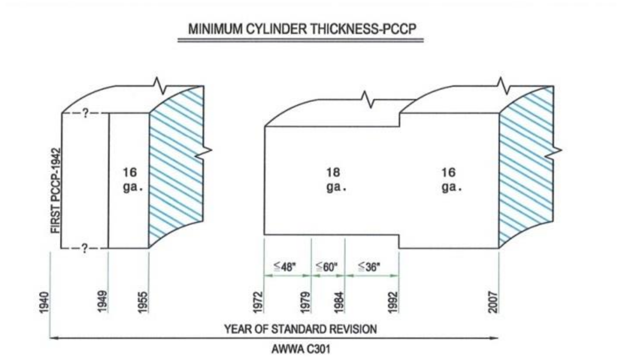
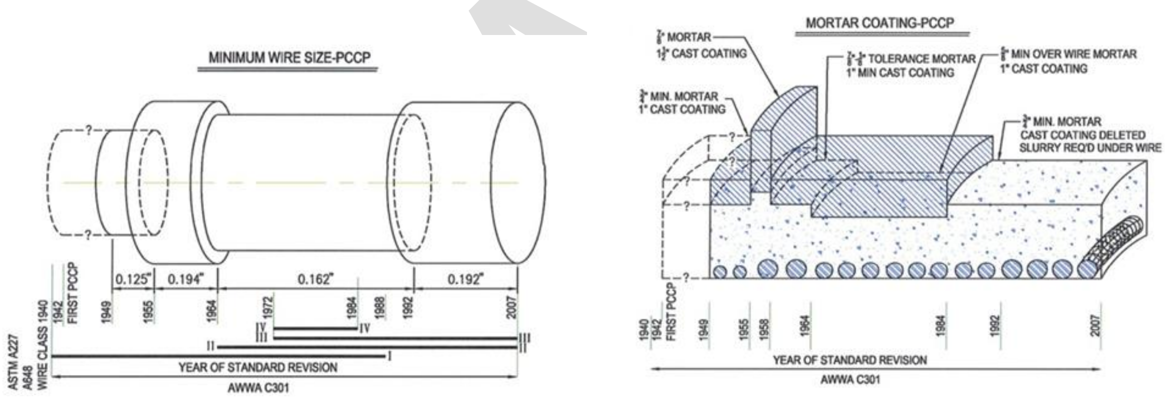


Figure A.2 (a): Minimum Required Steel Cylinder Thickness [1].



Figures A.2 (b) and A.2 (c): Minimum Required Prestressing Wire Diameter [1] and Minimum Required Mortar Coating Thickness [1].

A.2 PCCP Failure Modes

Several causes for PCCP failure have been reported: a high chloride environment [7], poor quality of mortar coating [8], poor quality of prestressing wire [9, 10], a corrosive environment [11], inadequate thrust resistance [12], construction damage, cracks in the cylinder welds, and delamination of the coating [13]. Most PCCP failures result from a breakdown of the mortar coating leading to corrosion or hydrogen embrittlement of the prestressing wire wraps. This causes incremental wire break damage that grows with time until the pipe eventually ruptures. As each wire wrap breaks, the individual pipe's strength is incrementally reduced. A summary of PCCP failures, as reported in the AWWA Research Foundation report [1], include:

- Ruptures or breaks in the prestressing wire wraps

- Leaking at the joints
- Cracks in the concrete core
- Low quality concrete core (poor concrete strength)
- Hydrogen sulfide (H_2S – wastewater applications)
- Cracking in the cylinder welds (poor fit up)
- Low quality prestressing wire
- Overloading due to excessive dead load and live load during service life
- Excessive surge pressures
- Inadequate total prestressing following a wire splice
- Low quality of mortar (low density, low thickness, low cement content)
- High chlorides in the soil (corrosive or aggressive soil)
- Poor bedding
- Dents in the PCCP due to fabrication and construction defects
- Overwrapping of the prestressing wire, resulting in the wire wraps being spaced too closely
- Inadequate total prestressing in the pipe
- Loss of prestress during production
- Missing joint coating
- Hydrogen embrittlement
- Construction damage (coating damaged and not repaired)
- Coating delamination
- Cracking in the joint welds
- Hydrotest pressure in excess of the design pressure
- Excessive external load (greater than the design load)
- Inadequate joint restraint (pipe moved, exposing the joint to the environment)

A.3 PCCP Failure Rate by Pipe Vintage

The American Water Works Association Research Foundation completed a study on the modes of failure experienced in nearly 36,000 sections of PCCP [1]. Category 1 failures were characterized as catastrophic ruptures and leaks of the main. Category 2 failures were defined as pipes with significant deterioration or structural weakness discerned by various inspection techniques including visual, sounding, and electromagnetics, while Category 3 failures resulted in a loss of service. In the figure, failure rates for each era were calculated as number of failures divided by the number of pipes produced. The Category 1 (Blue) failure rate for pipes manufactured after 1991 continued to decrease with the introduction of more stringent PCCP design requirements. Figure A.3 details the failure rates of PCCP based on the year of production.

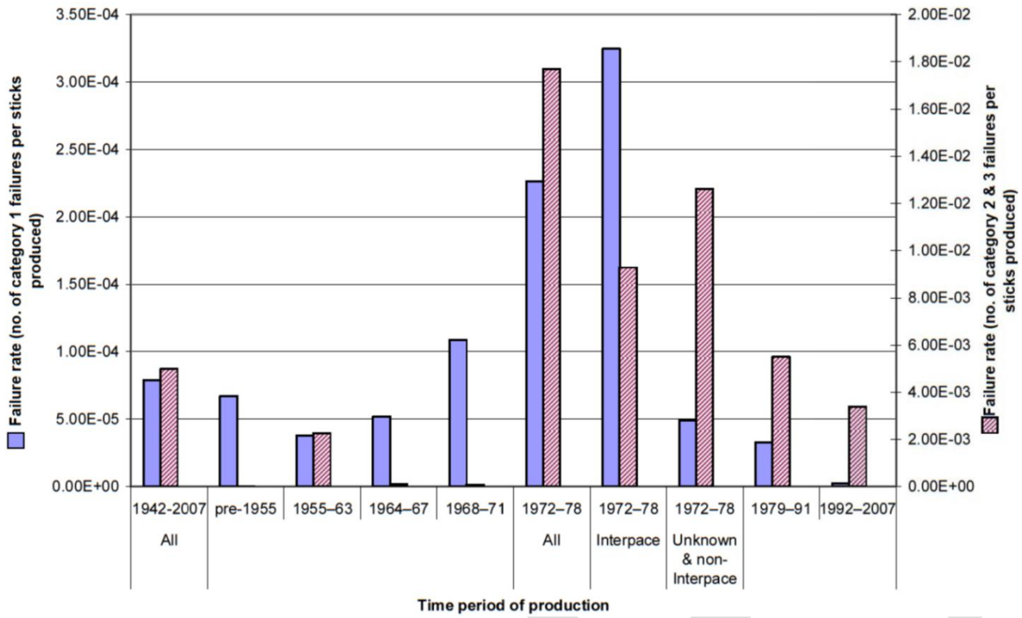


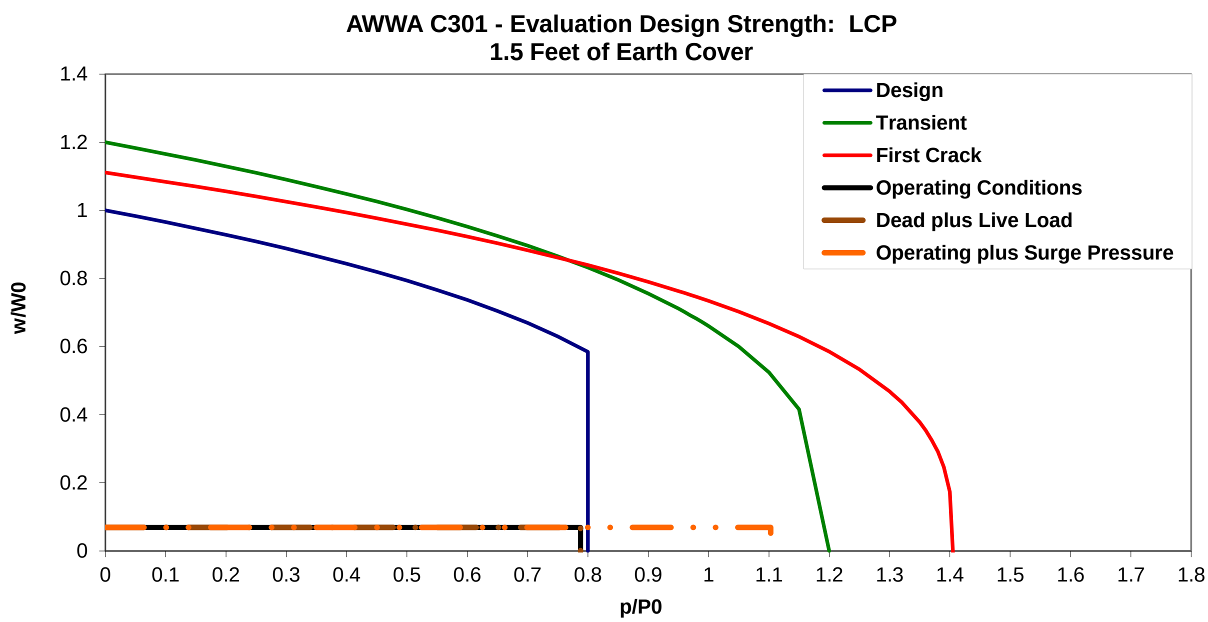
Figure A.3 Failure Rate of PCCP by Pipe Vintage [1]

APPENDIX B

AWWA C301/C304/C303 Results

AWWA C-301 PCCP Design Analysis - Lined Cylinder Pipe		Openaka Inc.
30-inch Diameter PCCP under 1.5 Feet of Earth Cover		Date
45 degree bedding angle	LCP	Project No.

Pipe Dimensions				**Design Conditions (AWWA C-301)**		
Diameter of Pipe	**D**	30 in		Working Pressure	**Pw**	100 psi
Core Thickness	**tc**	2.7402 in		Surge/Water Hammer Press.	**Psp/Pwh**	40 psi
Outside Diameter of Cylinder	**Dy**	35.6 in		Test Pressure	**Pt**	140 psi
Cylinder Thickness	**ty**	0.0598 in		Live Load H-20		
Diameter of Wire	**dw**	0.162 in		Live Load Impact Factor	**If**	27%
Specified Coating Thickness	**---**	1 in		**Calculation**		
Prestressed Wires Properties				Area of Concrete Core	**Ac**	32.16 sq in/LF
Area of Steel Wire	**As**	0.176 sq in/LF		Area of Steel Cylinder	**Ay**	0.7176 sq in/LF
Ultimate Strength of Wire	**fsu**	262,000 psi		Weight of the Pipe	**Wp**	417.2 lb/LF
Gross Wrapping Stress of Wire	**fsg**	196,500 psi		Weight of Water	**Ww**	306.3 lb/LF
Wire Relaxation Loss Factor	**R1**	0.05		W Dead (Earth Load)	**Wd**	493.5 lb/LF
Wire Embedment Loss Factor	**R2**	0		W live (H-20+Impact Factor)	**Wl**	0.0 lb/LF
Concrete Properties				**Initial Conditions (C-301)**		
Concrete Core	**f'c**	5500 psi		Initial Wire Stress	**fsi**	181,422 psi
Coating Mortar	**f'm**	6000 psi		Initial Cylinder Stress	**fyi**	5,253 psi
Soil & Bedding Properties				Initial Concrete Core Stress	**fci**	876 psi
Height of Earth Cover	**H**	1.5 ft		Concrete Strength at Wrap	**f'ci**	3,000 psi
Soil Density	**γs**	127 lb/cft		**Resultant Conditions (C-301)**		
Coeff. of Lateral Earth Pressure	**Kμ'**	0.165		Resultant Wire Stress	**fsr**	176,548 psi
Clearance(Pipe & Trench Wall)	**x**	1 ft*		Resultant Cylinder Stress	**fyr**	10,127 psi
Trench Width	**Bd**	4.12 ft		Resultant Concrete Core Stress	**fcr**	740 psi
Bedding Factor (Load Factor)	**Lf**	1.50		**Pressures (C-301)**		
Transition Width	**Tw**	12.30 ft		Zero Concrete Stress Press.	**P0**	127 psi
Other Constants				Elastic Limit Pressure	**Pl**	195 psi
C-301 constants				Bursting Pressure	**Pb**	367 psi
Initial Modular Ratio of Elasticity	**ni**	6 Es/Eci		**Pipe's Strength (C-301)**		
Resultant Modular Ratio	**nr**	5 Es/Ecr		Three Edge Bearing Strength	**W001**	7,926 lb/LF
Concrete Core Creep Factor	**Cr**	1.5		0.9*W001	**W0**	7,134 lb/LF



AWWA C-304 PCCP Design Analysis - Lined Cylinder Pipe		Openaka Inc.
30-inch Diameter PCCP under 1.5 Feet of Earth Cover		Date
45 degree bedding angle	LCP	Project No.

Severity Level: 1

Factors of Safety Calculations: 1.45

Load case	core compr.	cylinder yield	wire yield
WT1			1.45
WT2	7.36		1.46
WT3	7.36		
Pressure			3.67
Pressure+transient			2.62

Severity Level	
5	no issue as microcracking limits are not exceeded
4	microcracking limits exceeded, but visable cracking limits not e
3	visual cracking limits are exceeded, but not elastic limits
2	elastic limits are exceeded, but strength limits are not exceede
1	strength limits are exceeded

Caution	Strain or Stress/Limit > 80%
Extreme Caution	Strain of Stress/Limit > 90%
CRITICAL	Strain of Stress/Limit > 100%

- Microcracking
- Visable Cracking
- Elastic Limit
- Strength Limit

Serviceability

Limit State Criterion	Load Comb	N1	M1	Strain or Stress	Limit		Criterion Satisfied	
Full Pipe Circumference								
Produce Core Decompression	W1	21152.93	4392.324	100	90.1		Not Satisfied	CRITICAL
(P≤P0)								
Produce Coating Cracking	WT1	29696.93	4392.324	140	135.1		Not Satisfied	CRITICAL
P≤min(Pk',1.4P0)								
Invert & Crown								
Inside Core Tensile Strain	W1	21152.93	4392.324	-1.12E-05	2.03E-04		Yes	
εci ≤ 1.5*ε't								
Inside Core Tensile Strain	WT1	29696.93	4,392	3.86E-05	1.49E-03		Yes	
εci ≤ ε'k	WT2	21152.93	4392.324	-1.12E-05	1.49E-03		Yes	
	FT1	32666.62	4831.556	7.07E-05	1.49E-03		Yes	
Core to Cylinder Radial Tension	FW1	-273.43	4886.184	-88	12	Psi	Yes	
σr ≤ 12 psi	WT3	-207.072	4392.324	-88	12	Psi	Yes	
Springline								
Outer Core Tensile Strain	W1	20806.59	2280.227	-3.50E-08	2.03E-04		Yes	
εco ≤ 1.5*ε't								
Outer Coating Tensile Strain	W1	20806.59	2280.227	1.80E-04	9.28E-04		Yes	
εmo ≤ 0.8*ε'km								
Outer Core Tensile Strain	WT1	29350.59	2,280	5.84E-05	1.49E-03		Yes	
εco ≤ ε'k	WT2	20806.59	2280.227	-3.50E-08	1.49E-03		Yes	
	FT1	32285.65	2508.25	7.91E-05	1.49E-03		Yes	
Outer Coating Tensile Strain	WT1	29350.59	2,280	2.40E-04	1.16E-03		Yes	
εmo ≤ ε'km	WT2	20806.59	2280.227	1.80E-04	1.16E-03		Yes	
	FT1	32285.65	2508.25	2.61E-04	1.16E-03		Yes	
Inner Core Compression	W2	-553.407	2280.227	747.46	3025	Psi	Yes	
fci ≤ 0.55f'c, fci ≤ 0.65f'c	WT3	-553.407	2280.227	747.46	3575	Psi	Yes	

Elastic Limit

Limit State Criterion	Load Comb	N1	M1	Strain or Stress	Limit	Criterion Satisfied	
Invert & Crown							
Yielding of cylinder	WT1	29696.93	4392.324	-8,151.51	27,000	Yes	
.-fyr+n'*fcr+Δfy≤ fyy	WT2	21152.93	4392.324	-9,401.03	27,000	Yes	
	FT1	32666.62	4831.556	-7,898.33	27,000	Yes	
Onset of Tension in Cylinder	WT3	-207.072	4,392	-12,700.59	0	Yes	
.-fyr+n'*fcr+Δfy≤ 0							
Springline							
Wire Elastic Limit	FWT1	32,286	2,508	169,283	196,500	Yes	Caution
fs≤ fsg or .-fsr+nfcr+Δfs≤ fsg	FWT2	22,887	2,508	167,529	196,500	Yes	Caution
	FT2	35,514	2,759	169,958	196,500	Yes	Caution
Core Compression Limit	FWT1	32,286	2,508	-82	4,125	Yes	
fc ≤ 0.75f'c	FWT2	22,887	2,508	159	4,125	Yes	
	FT2	35,514	2,759	-151	4,125	Yes	

Strength Limit

Limit State Criterion	Load Comb	N2	M2	M2, Fs	Limit	Criterion Satisfied
Springline						
Wire-Yield Limit for	FWT3	38155.77	2964.295	2,964.30	154,219	Yes
$N_2 \geq N_k'$, $M_2 \leq M_{2sy}$	FWT4	27048.57	2964.295	2,964.30	23,666	Yes
fs≤ fsg or -fsr+nfcr+Δfs≤ fsy	FWT3	38155.77	2964.295	170,437.67	222,700	Yes
fs≤ fsg or -fsr+nfcr+Δfs≤ fsy	FWT4	27048.57	2964.295	168,364.29	222,700	Yes

Ultimate Moment

	Load Comb	N2	M2	Strain or Stress	Limit	Criterion Satisfied
Core Crashing						
$(M \leq M_{2ult})$	FWT5	-885	3,648	3,648	126,872	Yes

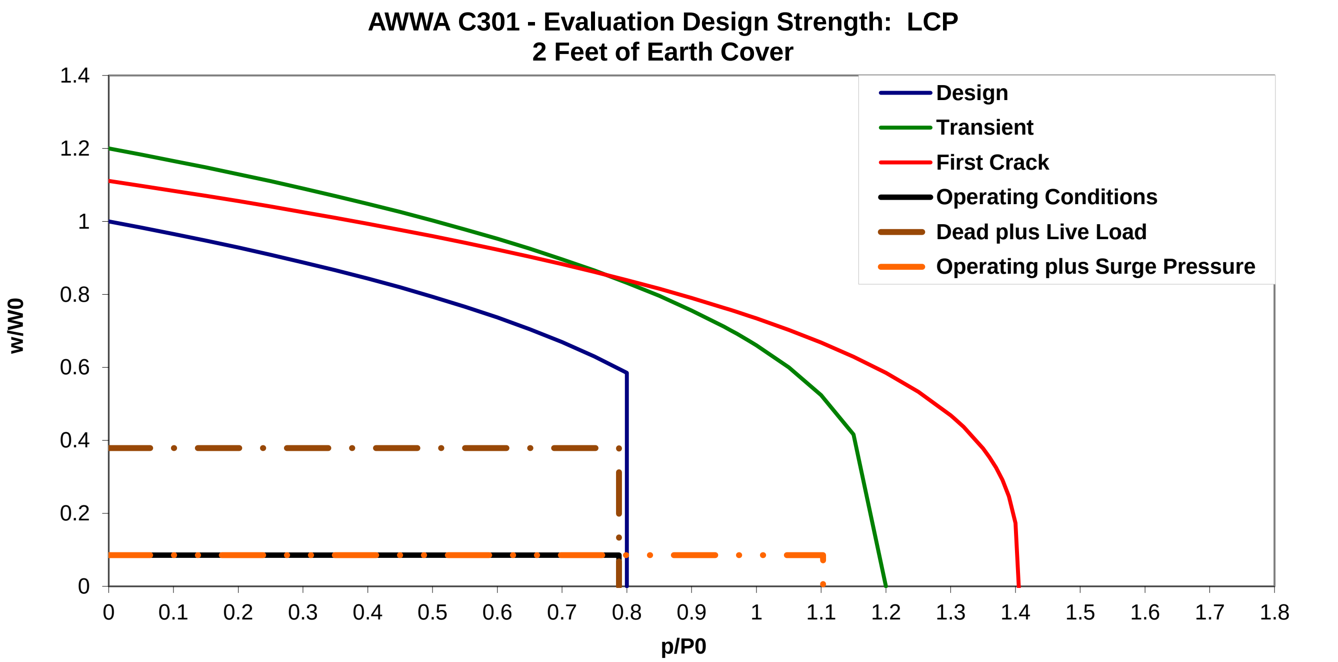
Burst Pressure

	Load Comb	N	M	Strain or Stress	Limit	Criterion Satisfied
Burst Failure	FWT6	0	0	240	367	Yes
(P≤Pb)						

AWWA C-301 PCCP Design Analysis - Lined Cylinder Pipe		**Openaka Inc.**
30-inch Diameter PCCP under 2 Feet of Earth Cover		**Date**
45 degree bedding angle	LCP	**Project No.**

Pipe Dimensions			
Diameter of Pipe	**D**	30	in
Core Thickness	**tc**	2.7402	in
Outside Diameter of Cylinder	**Dy**	35.6	in
Cylinder Thickness	**ty**	0.0598	in
Diameter of Wire	**dw**	0.162	in
Specified Coating Thickness	**---**	1	in
Prestressed Wires Properties			
Area of Steel Wire	**As**	0.176	sq in/LF
Ultimate Strength of Wire	**fsu**	262,000	psi
Gross Wrapping Stress of Wire	**fsg**	196,500	psi
Wire Relaxation Loss Factor	**R1**	0.05	
Wire Embedment Loss Factor	**R2**	0	
Concrete Properties			
Concrete Core	**f'c**	5500	psi
Coating Mortar	**f'm**	6000	psi
Soil & Bedding Properties			
Height of Earth Cover	**H**	2	ft
Soil Density	**γs**	120	lb/cft
Coeff. of Lateral Earth Pressure	**Kμ'**	0.165	
Clearance(Pipe & Trench Wall)	**x**	1	ft*
Trench Width	**Bd**	4.12	ft
Bedding Factor (Load Factor)	**Lf**	1.50	
Transition Width	**Tw**	12.30	ft
Other Constants			
C-301 constants			
Initial Modular Ratio of Elasticity	**ni**	6	Es/Eci
Resultant Modular Ratio	**nr**	5	Es/Ecr
Concrete Core Creep Factor	**Cr**	1.5	

Design Conditions (AWWA C-301)			
Working Pressure	**Pw**	100	psi
Surge/Water Hammer Press.	**Psp/Pwh**	40	psi
Test Pressure	**Pt**	140	psi
Live Load H-20			
Live Load Impact Factor	**If**	25%	
Calculation			
Area of Concrete Core	**Ac**	32.16	sq in/LF
Area of Steel Cylinder	**Ay**	0.7176	sq in/LF
Weight of the Pipe	**Wp**	417.2	lb/LF
Weight of Water	**Ww**	306.3	lb/LF
W Dead (Earth Load)	**Wd**	609.6	lb/LF
W live (H-20+Impact Factor)	**Wl**	2093.5	lb/LF
Initial Conditions (C-301)			
Initial Wire Stress	**fsi**	181,422	psi
Initial Cylinder Stress	**fyi**	5,253	psi
Initial Concrete Core Stress	**fci**	876	psi
Concrete Strength at Wrap	**f'ci**	3,000	psi
Resultant Conditions (C-301)			
Resultant Wire Stress	**fsr**	176,548	psi
Resultant Cylinder Stress	**fyr**	10,127	psi
Resultant Concrete Core Stress	**fcr**	740	psi
Pressures (C-301)			
Zero Concrete Stress Press.	**P0**	127	psi
Elastic Limit Pressure	**Pl**	195	psi
Bursting Pressure	**Pb**	367	psi
Pipe's Strength (C-301)			
Three Edge Bearing Strength	**W001**	7,926	lb/LF
0.9*W001	**W0**	7,134	lb/LF



AWWA C-304 PCCP Design Analysis - Lined Cylinder Pipe		Openaka Inc.
30-inch Diameter PCCP under 2 Feet of Earth Cover		Date
45 degree bedding angle	LCP	Project No.

Severity Level: 1

Factors of Safety Calculations: 1.45

Load case	core compr.	cylinder yield	wire yield
WT1			1.45
WT2	7.21		1.45
WT3	5.28		
Pressure			3.67
Pressure+transient			2.62

Severity Level	
5	no issue as microcracking limits are not exceeded
4	microcracking limits exceeded, but visable cracking limits not exceeded
3	visual cracking limits are exceeded, but not elastic limits
2	elastic limits are exceeded, but strength limits are not exceeded
1	strength limits are exceeded

Caution	Strain or Stress/Limit > 80%
Extreme Caution	Strain of Stress/Limit > 90%
CRITICAL	Strain of Stress/Limit > 100%

Microcracking
Visable Cracking
Elastic Limit
Strength Limit

Serviceability

Limit State Criterion	Load Comb	N1	M1	Strain or Stress	Limit		Criterion Satisfied	
Full Pipe Circumference								
Produce Core Decompression	W1	21090.43	4857.467	100	90.1		Not Satisfied	CRITICAL
(P≤P0)								
Produce Coating Cracking	WT1	29634.43	4857.467	140	135.1		Not Satisfied	CRITICAL
P≤min(Pk',1.4P0)								
Invert & Crown								
Inside Core Tensile Strain	W1	21090.43	4857.467	-7.27E-06	2.03E-04		Yes	
εci ≤ 1.5*ε't								
Inside Core Tensile Strain	WT1	29634.43	4,857	4.22E-05	1.49E-03		Yes	
εci ≤ ε'k	WT2	19964.36	13238.17	6.34E-05	1.49E-03		Yes	
	FT1	32597.87	5343.213	7.50E-05	1.49E-03		Yes	
Core to Cylinder Radial Tension	FW1	-351.553	5467.612	-87	12	Psi	Yes	
σr ≤ 12 psi	WT3	-1395.64	13238.17	-78	12	Psi	Yes	
Springline								
Outer Core Tensile Strain	W1	20701.76	2529.264	2.12E-06	2.03E-04		Yes	
εco ≤ 1.5*ε't								
Outer Coating Tensile Strain	W1	20701.76	2529.264	1.84E-04	9.28E-04		Yes	
εmo ≤ 0.8*ε'km								
Outer Core Tensile Strain	WT1	29245.76	2,529	5.92E-05	1.49E-03		Yes	
εco ≤ ε'k	WT2	18812.93	7016.277	3.29E-05	1.49E-03		Yes	
	FT1	32170.34	2782.19	8.10E-05	1.49E-03		Yes	
Outer Coating Tensile Strain	WT1	29245.76	2,529	2.42E-04	1.16E-03		Yes	
εmo ≤ ε'km	WT2	18812.93	7016.277	2.53E-04	1.16E-03		Yes	
	FT1	32170.34	2782.19	2.65E-04	1.16E-03		Yes	
Inner Core Compression	W2	-658.24	2529.264	762.98	3025	Psi	Yes	
fci ≤ 0.55f'c, fci ≤ 0.65f'c	WT3	-2547.07	7016.277	1042.54	3575	Psi	Yes	

Elastic Limit

Limit State Criterion	Load Comb	N1	M1	Strain or Stress	Limit	Criterion Satisfied	
Invert & Crown							
Yielding of cylinder	WT1	29634.43	4857.467	-8,209.78	27,000	Yes	
.-fyr+n'*fcr+Δfy≤ fyy	WT2	19964.36	13238.17	-10,569.67	27,000	Yes	
	FT1	32597.87	5343.213	-7,965.45	27,000	Yes	
Onset of Tension in Cylinder	WT3	-1395.64	13,238	-13,869.24	0	Yes	
.-fyr+n'*fcr+Δfy≤ 0							
Springline							
Wire Elastic Limit	FWT1	32,170	2,782	169,341	196,500	Yes	Caution
fs≤ fsg or .-fsr+nfcr+Δfs≤ fsg	FWT2	20,694	7,718	168,628	196,500	Yes	Caution
	FT2	35,387	3,060	170,022	196,500	Yes	Caution
Core Compression Limit	FWT1	32,170	2,782	-65	4,125	Yes	
fc ≤ 0.75f'c	FWT2	20,694	7,718	484	4,125	Yes	
	FT2	35,387	3,060	-133	4,125	Yes	

Strength Limit

Limit State Criterion	Load Comb	N2	M2	M2, Fs	Limit	Criterion Satisfied
Springline						
Wire-Yield Limit for	FWT3	38019.49	3288.043	3,288.04	155,249	Yes
$N_2 \geq N_k'$, $M_2 \leq M_{2sy}$	FWT4	24456.81	9121.16	9,121.16	33,007	Yes
fs≤ fsg or -fsr+nfcr+Δfs≤ fsy	FWT3	38019.49	3288.043	170,505.99	222,700	Yes
fs≤ fsg or -fsr+nfcr+Δfs≤ fsy	FWT4	24456.81	9121.16	169,663.59	222,700	Yes

Ultimate Moment

	Load Comb	N2	M2	Strain or Stress	Limit	Criterion Satisfied
Core Crashing						
($M \leq M_{2ult}$)	FWT5	-4,831	13,021	13,021	124,417	Yes

Burst Pressure

	Load Comb	N	M	Strain or Stress	Limit	Criterion Satisfied
Burst Failure	FWT6	0	0	240	367	Yes
(P≤Pb)						

AWWA C-303
Pipe Description: Parley's Canyon Pipeline - 24" BWP - Manhole 3

Openaka Inc.
28-Jun-17
Openaka Job 2013.48

Pipe Dimensions				
Inside Diameter of the Pipe	**D**	32.25	in	
Outside Diameter of the Pipe	**OD**	35.2369	in	
Outside Diameter of Cylinder	**Dy**	33.80	in	
Cylinder Thickness	**ty**	0.0747	in	0.875
Inner Mortar Thickness	**tm**	0.7	in	
Outer Coating Thickness	**hmo**	0.5	in	
Rebar Properties				
Diameter of Bars	**dw**	0.21875	in	
Bar Wrap Spacing	**C-C**	1.37	in	
Ultimate Strength of Rebars	**fsu**	72,500	psi	
Gross Wrapping Stress of Rebars	**fsg**	9,000	psi	
Area of Bars	**As**	0.329	sq in/LF	
Concrete Properties				
Concrete Core	**f'c**	4500	psi	
Coating Mortar	**f'm**	4500	psi	
Soil & Bedding Properties				
Height of Maximum Earth Cover	**H**	2	ft	
Soil Density	**γs**	120	lb/cft	
Coeff. of Lateral Earth Pressure	**Kμ'**	0.165		
Clearance(Pipe & Trench Wall)	**x**	1	ft*	
Bedding Factor (Load Factor)	**Lf**	1.00		
Bedding Angle	α	45		
Transition Width	**Tw**	4.8	ft	
Unified Classification Soil Type	**ST**	Coarse Grained with Fines (SM, SC)		
Relative Compaction	**Com**	Slight Density		
Trench Width	**Bd**	3.94	ft	
Constants				
Design E of Steel Cylinder	**Es**	30,000,000	psi	
Yield Strength of Cylinder	**fyy**	33,000	psi	
Ultimate Strength of Cylinder	**fyu**	52,000	psi	
Steel Density	**γst**	489	lb/cft	
Concrete Density	**γc**	145	lb/cft	
Water Density	**γw**	62.4	lb/cft	
Modulus of soil passive resistance	**E' (Esoil)**	400	psi	
Defelection lag factor	**Dl**	1		
E of Concrete	**Ec**	3.62E+06		
E of Mortar	**Em**	3.62E+06		
Bedding constant	**K**	0.105		
Pipe Mean Radius	**r_mean**	16.871725	in	
EI Uncracked	**EI**	941312.1716	lb.in^2	
	y'	0.718107643	in	
I of uncracked section	**I**	0.161965411	in^4	
Steel volume fraction	**Vf**	0.083208244		
	Eeq	5811809.855	psi	
I of cracked section	**I_crack**	0.040491353	in^4	

Design Conditions (AWWA C-303)				
Design Pressure	**Pd**	86	psi	
Operational Pressure	**Pw**	40	psi	
Test Pressure	**Pt**	126	psi	
Surge/Water Hammer Press.	**Psp/Pwh**	50	psi	
Live Load H-20				
Live Load Impact Factor	**If**	25%		
Calculation				
Area of Mortar	**Am**	14.40	sq in/LF	
Area of Steel Cylinder	**Ay**	0.8964	sq in/LF	
Weight of the Pipe	**Wp**	185.4	lb/LF	
Weight of Water	**Ww**	354.0	lb/LF	
W Dead (Earth Load) Marston Flexible Pipe	**Wd_m**	642.0	lb/LF	
W Dead (Earth Load) Prism Load	**Wd_p**	697.4	lb/LF	
W Dead (Earth Load)	**Wd**	58.1	lb/in	
W live (H-20+Impact Factor)	**Wl**	0.0	lb/in	
Vertical Load-Top	**Pa**	1.72	lb/in	
Vertical Load-Bottom	**Pb**	4.50	lb/in	
Max-Lateral Soil Pressure	**Ph**	0.3282	lb/in	
Maximum allowable deflection	**ΔX Max**	**0.260**	in	
Horizontal Deflection_uncracked	**Δx**	**0.028**	in	**Δx Satisfied**
Horizontal Deflection_cracked	**Δx_crack**	**0.083**	in	**Δx Satisfied**
Circumferential Steel stress (Pw)	**fs_pw**	**6,589**	psi	**fs_pw Satisfied**
Circumferential Steel stress (Pw+Ps)	**fs(Pw+Psg)**	**14,826**	psi	**fs(Pw+Psg) Satisfied**
Circumferential Steel stress (Pd)	**fs_pd**	**14,167**	psi	**fs_pd Satisfied**
Circumferential Steel stress (Pd+Ps)	**fs(Pd+Psg)**	**22,404**	psi	**fs(Pd+Psg) Satisfied**
Burst Pressure	**Pb**	**316**	psi	

Spangler-Watkins Deflection Formula (no internal pressure)			
Horizental deflection of the pipe	**Δx**	0.003	in

Spangler-Watkins Deflection Formula (with internal pressure)			
Horizental deflection of the pipe	**Δx**	0.0	in

Criteria			
Max Tensile Strength of Concrete	**f't**	470	0.104349839
Max Tensile Strength of Mortar	**f'tm**	470	
Max Tensile Strain of Mortar	**ε'tm**	1.30E-04	
Max Tensile Strain of Concrete	**εt'**	1.30E-04	
Concrete			
Microcracking	**1.5*εt'**	############	
Visible Cracking	**εk'**	############	
Mortar			
Microcracking	**6.4*ε'tm**	############	
Visible Cracking	**ε'km**	1.038742E-03	

SoilFluidWt	2.284405357
SoilPipeWt	1.196268231

Notes

Value from STD

** - ASTM A570 Grade 33 Steel (Ameron '88 & ASTM A570-79)
*** - ASTM A615 Grade 40 Steel (Ameron '88 & ASTM A615-07)
**** - From Masood--Values range from 8,000 to 10,000

6* - From Elevations and HGL from Adam

4.04E+06

10

	E'soil= 400		E'soil= 1000	
Cover (ft)	**Uncracked**	**Cracked**	**Uncracked**	**Cracked**
0.5	**0.007**	**0.021**		
1	**0.014**	**0.042**		
1.75	**0.024**	**0.073**		
2.75	**0.038**	**0.114**		
3.75	**0.052**	**0.156**		
4.75	**0.066**	**0.197**		
5.75	**0.080**	**0.239**		
6	**0.083**	**0.249**		
6.25	**0.087**	**0.260**		
6.5	**0.090**	**0.270**		
6.75	**0.093**	**0.281**		
7	**0.097**	**0.291**		
7.25	**0.100**	**0.301**		
7.5	**0.104**	**0.312**		
7.875	**0.109**	**0.327**		
8.25	**0.114**	**0.343**		
8.625	**0.119**	**0.359**		
9	**0.125**	**0.374**		
9.5625	**0.132**	**0.397**		
10	**0.138**	**0.416**		
10				

Appendix C
Detailed FEA Methodology

C. Detailed FEA Methodology

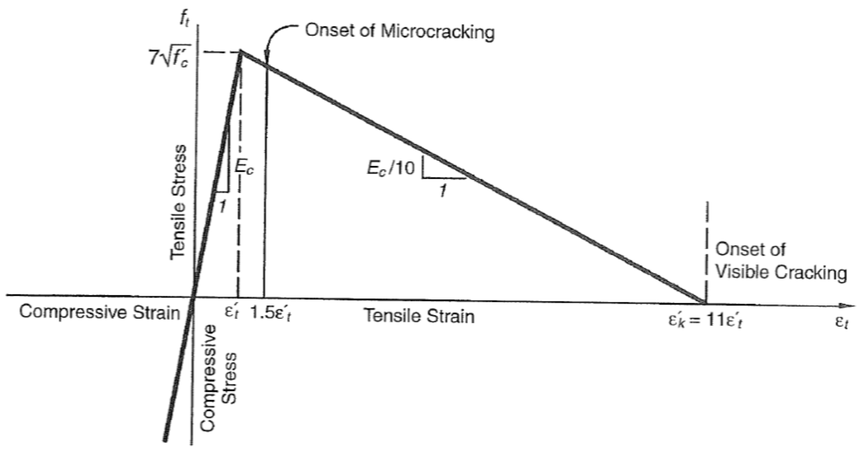
The AWWA C304 Design Standard is a comprehensive tool used for the design of PCCP; however, it is not directly applicable for the evaluation of PCCP with broken prestressing wire wraps. FEA is an accurate method for modeling complex geometry under different loading conditions. Recent developments in FEA and increased computational speed allow for the analysis of complex nonlinear problems, which is required to provide accurate models of PCCP with broken prestressing wire wraps.

The FEA model has been developed by Pure Technologies to determine the structural consequence of broken prestressing wire wraps, based on the AWWA C301 and AWWA C304 Design Standards, by utilizing pipe design specifications, design parameters, and the assumed current condition of the prestressing wire wraps. In the analysis, the model of a pipe is subjected to internal pressure, pipe and fluid weights, and external loads while varying the number of broken wire wraps. A performance curve, displaying the effects of broken wire wraps, is formulated and used to determine the number of broken wraps required for the pipe to exceed theoretical Limits. It should be noted that in performing the structural analysis, the values used in the models were taken directly from the provided specifications and the applicable AWWA C301 Design Standard.

Significant increases in internal pressure and external earth and live loads cause higher tensile and bending stresses in the pipe wall, which may lead to wire wrap breaks and increasing stress in the remaining, adjacent wire wraps. As the stress increases, more prestressing wire wraps break and the concrete core and steel cylinder are able to expand. This leads to load and stress redistribution in the pipe. To account for this change during the FEA, the prestressing wire, concrete core, and steel cylinder are modeled as a composite element to simulate the material interactions in an actual pipe. As the stress in the prestressing wire increases and the concrete core and steel cylinder are able to expand, the response of the composite element becomes increasingly nonlinear, adding further complexity to the model.

Commercial finite element software (ABAQUS) was used to investigate the response of a PCCP under different loading conditions. The FEA model predicts the performance limits of a PCCP utilizing the tensile strengths of the prestressing wire, the steel cylinder, and the concrete core, as well as a plasticity algorithm that simulates concrete crushing in compression regions. The behavior of the concrete is particularly complex to model as, in the field, either cracking or crushing may occur once the ultimate strength of the concrete is exceeded. Cracking and crushing are determined along a failure surface, with cracks appearing when the principle stresses at the surface are in tension and crushing occurring when the principle stresses are in compression. The concrete core of a PCCP is modeled as part of the three-dimensional composite element, with additional adjustments made to predict the failure of brittle materials.

Analyzing PCCP with broken prestressing wire wraps adds even more complexity to the model. Broken wire wraps change the load and stress distribution in the pipe. Once concrete in tension begins to crack, its load carrying ability begins to decrease with additional strain. If the strain is high enough, the load carrying ability goes to zero. This means that loads must be transferred through the other components of the pipe. Figure C.1 shows a schematic of the Stress-Strain behavior of concrete from the AWWA C304-07 Design Standard. ABAQUS modeling software, by using its sophisticated material models, can handle this complex condition.



A. Assumed for concrete core of the pipe

Figure C.1: Stress-Strain Relationship in the Concrete Core [2]

C.1 Performance Curve

The number of broken prestressing wire wraps that a particular pipe design will tolerate under operational and surge conditions can be determined using an FEA performance curve. An example of a performance curve for PCCP is shown in Figure C.2. Pure Technologies uses four (4) Limits, Micro Cracking (blue), Visible Cracking (green), Yield (yellow), and Strength (red), to classify the condition of a distressed PCCP. Note that although they have similar descriptions and values, these Limits are different from the Limits and Limiting Criteria used in the AWWA C304 analysis.

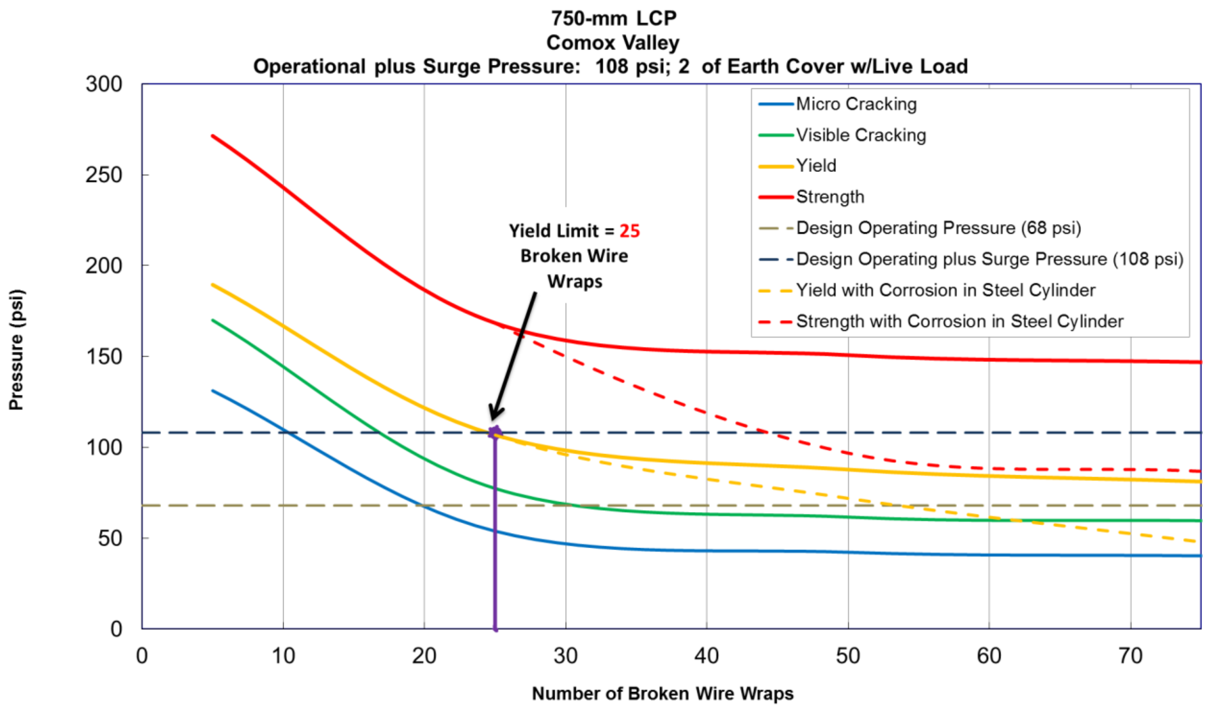


Figure C.2: Performance Curve for the 750-mm LCP in the CPS Force Main, with 2-feet of earth cover and live load (On-land Section)

Table C.1 defines the Limits used by Pure Technologies to describe the predicted condition of a PCCP with a known quantity of broken wire wraps. The actual number of broken wire wraps required to reach these conditions varies according to the pipe design and earth cover. These terms are referred to and used consistently throughout this report.

Table C.1: Predicted Condition of a Pipe with Broken Wire Wraps	
Limit	**Description**
Micro Cracking	Micro cracking of the mortar coating or concrete core (defined by the strain associated with a crack that is ≥ 0.001 inches wide)
Visible Cracking	Visible cracking of the mortar coating or concrete core (defined by the strain associated with a crack that is ≥ 0.002 inches wide)
Yield	Prestressing wire or steel cylinder reach their yield strength
Strength	Prestressing wire or steel cylinder reach their ultimate tensile strength

The Serviceability Limit described in AWWA C304 is represented in the performance curves by the Micro Cracking and Visible Cracking Limits. A pipe reaches the Micro Cracking Limit when strain in the mortar coating or concrete core exceeds the AWWA C304 tensile strain limit for micro cracking. Micro cracking in the mortar coating or concrete core is described as cracks greater than 0.0254 mm wide and 300 mm in length and can be considered the preliminary level of damage in a PCCP. The Visible Cracking Limit is reached when the mortar coating or concrete core reach the strain associated with cracks greater than 0.0508 mm wide and 300 mm in length.

When the mortar coating on the exterior of the pipe cracks, chloride ions present in the water may seep through the cracks, exposing the prestressing wire wraps to a corrosive environment. Corrosion can reduce the cross-sectional area of the prestressing wire, decreasing its load carrying ability and causing the wire wraps to break as the stress is increased. Individual wire wrap breaks also increase the amount of stress placed on the adjacent wire wraps. This increasing stress, as well as a persisting corrosive environment, will cause the adjacent wraps to break. While a long period may pass between initial and subsequent breaks, eventually the wire wraps will begin to fail at a faster rate as more stress is placed on the remaining wire wraps.

Prior to reaching the Yield Limit, the prestressing wire and steel cylinder are able to elongate and deform elastically, meaning that after the load is removed, they return to their original shape. Once the Yield Limit is reached in the steel cylinder, it undergoes plastic deformation, where it experiences large amounts of strain (elongation) in response to a relatively small increase in applied stress. The Strength Limit for the steel cylinder is the point at which the steel begins to elongate while experiencing lower stresses. This condition is also known as necking and it immediately precedes the failure of the steel cylinder. The elongation experienced by the prestressing wire wraps due to loading beyond the Yield Limit eventually causes an individual wrap to break. The prestressing wire has a relatively brittle behavior compared to the steel cylinder, meaning that the wire wraps undergo less plastic deformation before they break. This situation often occurs simultaneously in adjacent wire wraps, especially as more prestressing wire wraps break and the stress in the remaining wraps increases in response. Additionally, as more wire wrap breaks occur, the concrete core and steel cylinder are able to expand in response to the internal pressure. As the core expands, the concrete is placed in tension, which can cause structural cracking in the core if the stress becomes high enough.

The values used to represent the performance of the steel components in the field are based on the yield and ultimate strengths provided on the pipe design specifications sheet or the standard values in the relevant design standard, if the pipe design is not available. The yield strength for the prestressing wire is typically 85% of its ultimate strength, while the yield strength of the steel cylinder is either denoted on the pipe design specification sheet or taken from the Design Standard in place at the time of production. The Yield Limit will be reached when either the steel cylinder or the prestressing wire reach its yield strength. The ultimate strength of the prestressing wire is dictated by the gage and class of the wire, while the ultimate strength of the steel cylinder is determined by the grade of the steel. The Strength Limit is exceeded when one of the PCCP components reaches its ultimate strength, which, theoretically, will cause the failure of the pipe.

By evaluating the predicted structural condition of a pipe using FEA and analyzing all critical variables, a risk assessment of all distressed pipes can be performed to determine if and when a particular pipe should be rehabilitated.

C.2 Variables that Affect the FEA

Part of the structural analysis is to evaluate the risk of PCCP structural failure due to reduced structural capacity caused by broken prestressing wire wraps and concrete deterioration. The prestressing wire is a principal structural component of prestressed pipe and each class of pipe installed in a particular pipeline is designed specifically for the maximum hydraulic operating pressure and earth covers expected along the route. Thus, any amount of broken wire wraps poses some level of risk to the pipeline and should be carefully evaluated.

It is important to recognize that the structural analysis is subject to several complex variables that cannot be modeled with 100% certainty. In order to evaluate the modeling results and to make recommendations on how to manage the pipeline, it is important to understand the variables affecting the structural model and their associated risk. The primary variables affecting the FEA are detailed below.

C.2.1 Effects of Cover

Earth cover plays a significant role in the number of broken prestressing wire wraps that a pipe will tolerate. PCCP is designed based on a combined load design method where increasing the depth of earth cover over a pipe originally designed for a specific combination of pressure and earth cover has the effect of reducing the pipe's capacity for internal operating pressure. For instance, if a pipe were originally designed for a working pressure of 100 psi and an earth cover of 3 meters, the allowable internal pressure would be reduced if the earth cover over the pipe were increased over the design earth cover.

Earth loads tend to apply flexural stresses to the extreme fibers of the concrete core at the springline, invert, and crown. High earth loads due to deep earth covers will impose high flexural stresses on the pipe's concrete core. Under very high earth covers and relatively low internal pressures, prestressed pipe design is typically controlled by the external load. This situation often requires a thicker than standard concrete core to tolerate the high flexural stresses. The current AWWA C304 design method is especially sensitive to external loading and this directly affects the results of a finite element analysis.

C.2.2 Effects of Wire Bond

When a prestressing wire wrap breaks, its tension is completely released at the point of breakage. The ends of the wire retract and are subjected to the friction forces applied to the wire by the mortar coating and the concrete core. These friction forces enable the wire to redevelop its tension over a relatively short distance from the point of breakage. The redevelopment length can vary up to several feet depending on the prestressing wire's class and diameter as well as the condition and quality of the mortar coating. A sound mortar coating may not experience any delamination following a wire wrap break and if the prestressing wire breaks and quickly redevelops its tension, the structural consequence of the break is minimal. Conversely, a poor quality mortar coating may crack or deteriorate following a wire wrap break and, in this case, the redevelopment length would be significantly longer.

For a specific wire diameter and class, the primary variable affecting the redevelopment length is the wire's bond to the mortar coating. If the coating is hard and remains well attached to the concrete core, wire bond will remain high and full tension in the wire will redevelop in a short distance from the point of breakage. When the coating becomes soft, cracks, or is delaminated from the core, the wire bond is reduced and the redevelopment length is increased significantly. Also, if the mortar is under attack by aggressive soil and groundwater conditions surrounding the pipeline, wire bond is reduced.

In the field, a severely damaged pipe may not experience a catastrophic failure because wire bond is holding the pipe together. Since it is not practical to understand the actual wire bond for each wire wrap, a conservative assumption must be made for the FEA. The most conservative assumption for finite element analysis is to remove the broken wire wraps from the model all together; meaning that the Strength Limit on a performance curve will be reached at the ultimate strength limits of the PCCP components.

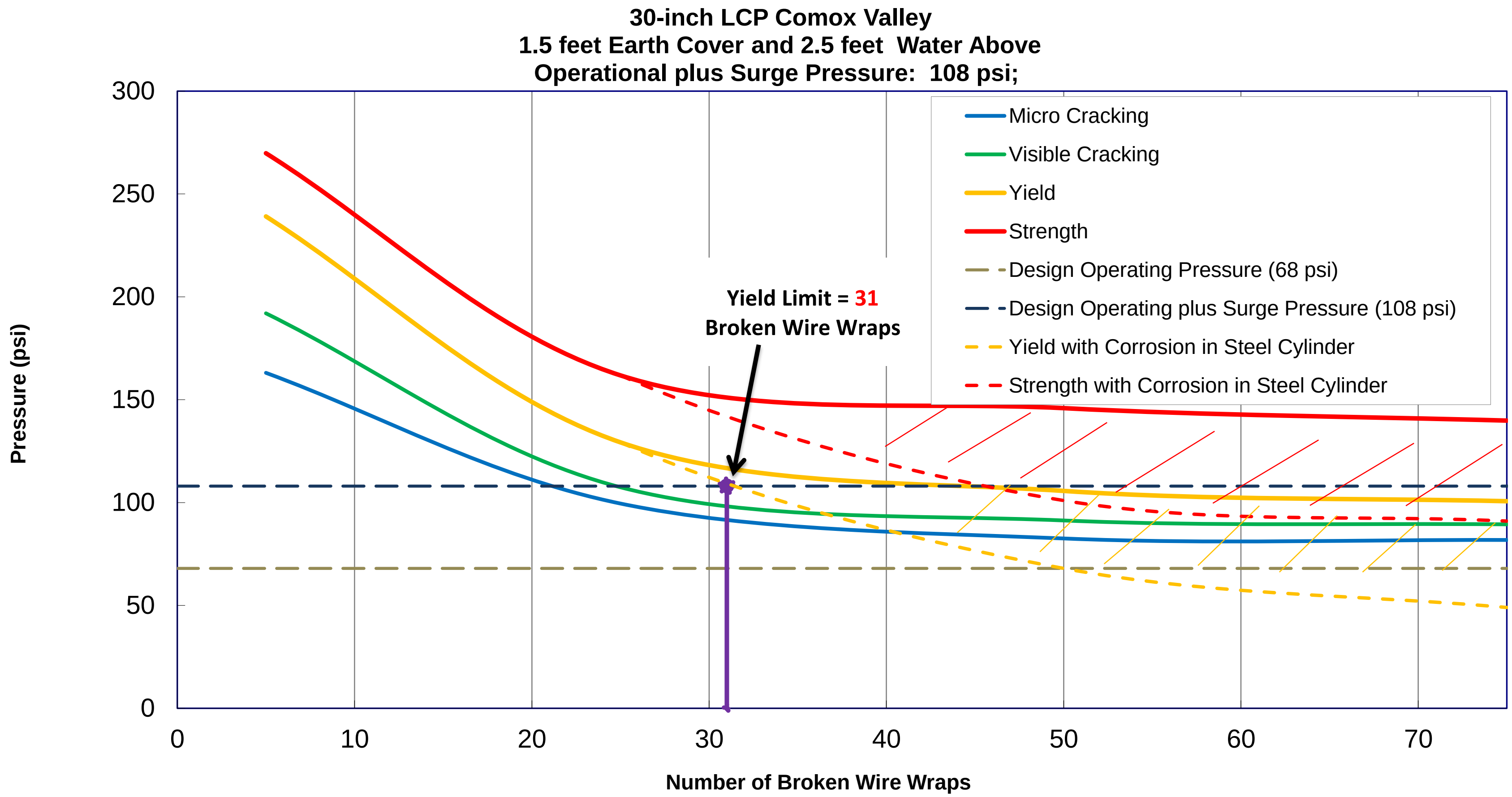
C.3 Field Observations vs. Predicted Results

It is Pure Technologies' recommendation that caution be used when viewing the performance curves produced by the FEA. These curves are useful for evaluating the structural capacity of a distressed PCCP, but modeling a complex condition like broken wire wraps is not an exact science. When opportunities arise to excavate and inspect pipes in the field, the actual condition should be compared to the estimated number of broken wire wraps, as well as the predicted results from the structural model, to determine if they are consistent with the observed conditions.

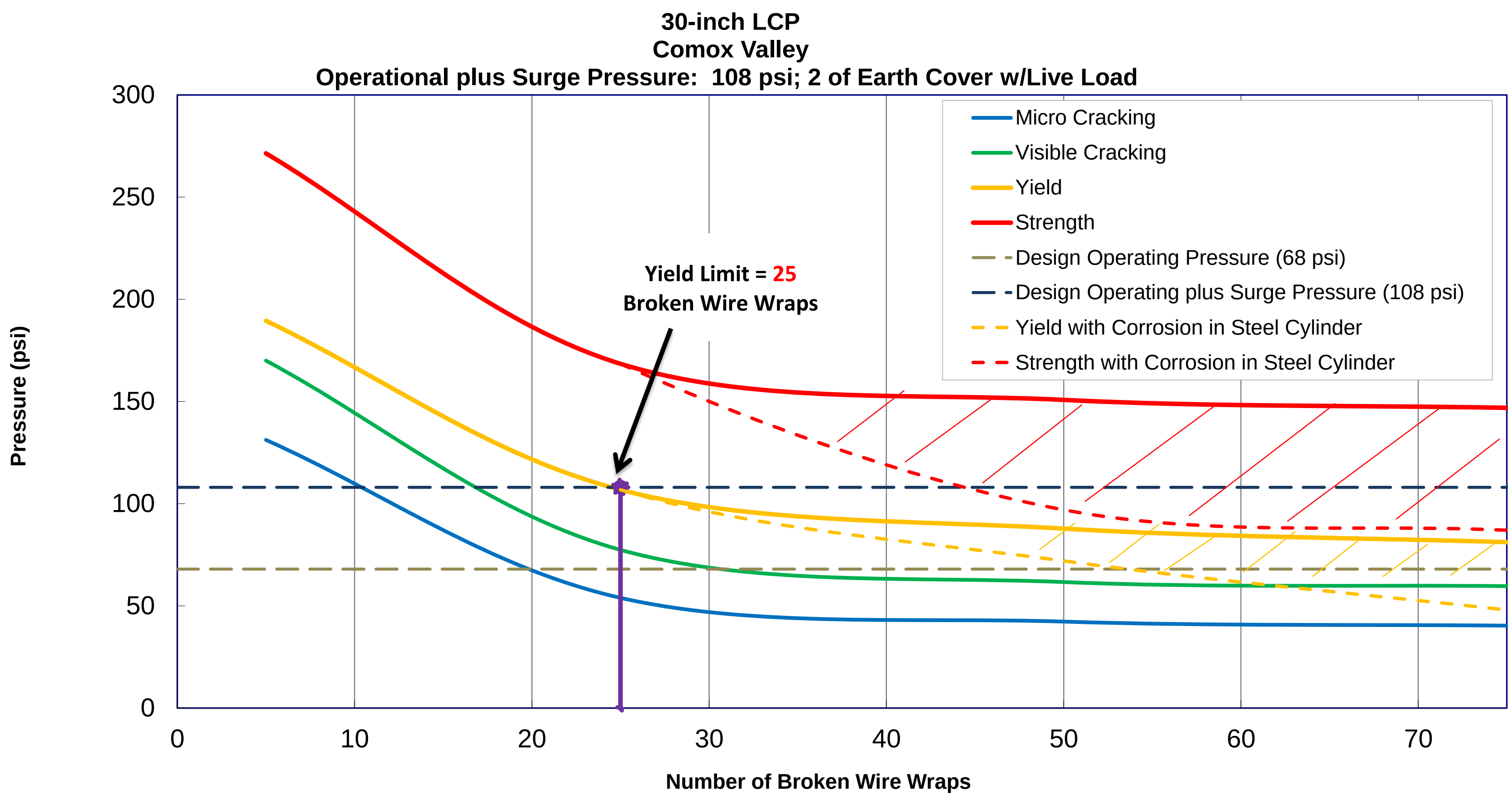
During previous excavations of prestressed concrete cylinder pipes, it has been observed that structural models generally produce results that are conservative. This level of conservatism is important because it provides allowances for extraordinary circumstances. Although a pipe can tolerate more broken prestressing wire wraps prior to reaching a particular Limit, the risk of failure can be alleviated by actively managing the pipeline.

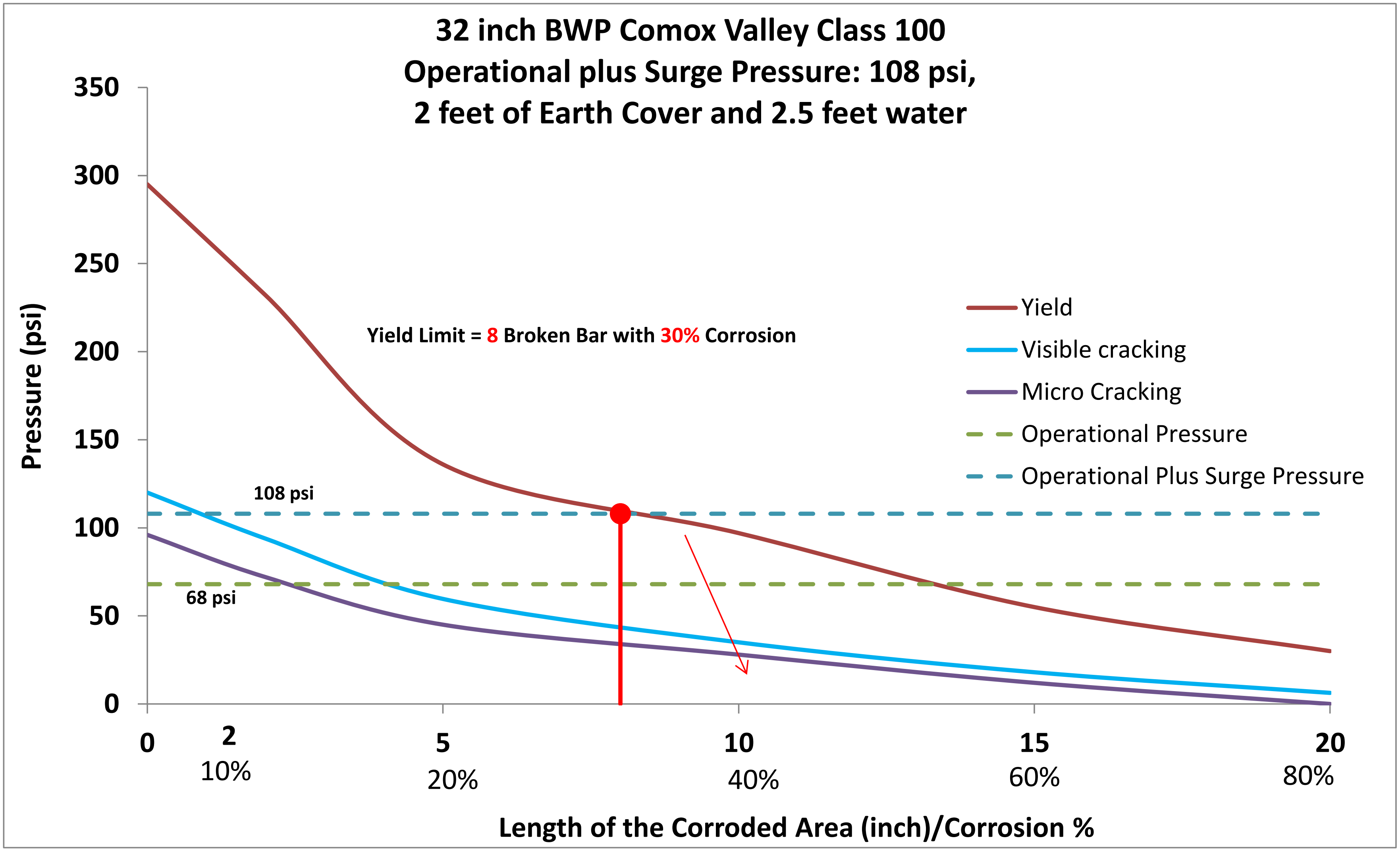
Appendix D

FEA Curves



30-inch LCP Comox Valley
1.5 feet Earth Cover and 2.5 feet Water Above
Operational plus Surge Pressure: 108 psi;
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
Pressure (psi)
Number of Broken Wire Wraps
Yield Limit = 31
Broken Wire Wraps
Micro Cracking
Visible Cracking
Yield
Strength
Design Operating Pressure (68 psi)
Design Operating plus Surge Pressure (108 psi)
Yield with Corrosion in Steel Cylinder
Strength with Corrosion in Steel Cylinder


30-inch LCP
Comox Valley
Operational plus Surge Pressure: 108 psi; 2 of Earth Cover w/Live Load
Pressure (psi)
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
Number of Broken Wire Wraps
Yield Limit = 25
Broken Wire Wraps
Micro Cracking
Visible Cracking
Yield
Strength
Design Operating Pressure (68 psi)
Design Operating plus Surge Pressure (108 psi)
Yield with Corrosion in Steel Cylinder
Strength with Corrosion in Steel Cylinder



32 inch BWP Comox Valley Class 100
Operational plus Surge Pressure: 108 psi,
2 feet of Earth Cover and 2.5 feet water
Pressure (psi)
350
300
250
200
150
100
50
0
Yield Limit = 8 Broken Bar with 30% Corrosion
108 psi
68 psi
Yield
Visible cracking
Micro Cracking
Operational Pressure
Operational Plus Surge Pressure
0
2
10%
5
20%
10
40%
15
60%
20
80%
Length of the Corroded Area (inch)/Corrosion %

Appendix E
Pipe List

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
Insertion: Towards 20-inch Access at Courtenay Pump Station													
1	S5	N/A	750	LCP	N/A	7.3	N/A	N/A					Drawings not available. Suspected steel pipe. Pipe reported with less certainty.
2	S5	N/A	750	LCP	N/A	7.3	N/A	N/A					Drawings not available. Suspected steel pipe. Pipe reported with less certainty.
3	S5	N/A	750	LCP	N/A	7.3	0+000	N/A					Drawings not available. Suspected steel pipe. Pipe reported with less certainty.
4	S5	72	750	LCP	0+000	1.0	0+001	B					
5	S5	45	750	LCP	0+001	7.3	0+008	10					
6	S5	45	750	LCP	0+008	7.3	0+016	10					
7	S5	45	750	LCP	0+016	7.3	0+023	10					
8	S5	71	750	LCP	0+023	1.8	0+025	B					
9	S5	70	750	LCP	0+025	2.9	0+028	B				WYE	750 x 750 x 750mm WYE @ Station 0+025.
10	S5	69	750	LCP	0+028	3.0	0+032	10					4m SP in pipe laying schedules. Data indicates 3m SP.
11	S5	N/A	750	LCP	N/A	1.0	N/A	10					Not listed in pipe laying schedules. Data indicates ~1m SP.
12	S5	N/A	750	LCP	N/A	2.5	N/A	10					Not listed in pipe laying schedules. Data indicates ~2.5m SP.
13	S5	45	750	LCP	0+032	4.0	0+039	10					7.3m STD in pipe laying schedules. Data indicates 4m SP.
14	S5	45	750	LCP	0+039	7.3	0+046	10					
15	S5	45	750	LCP	0+046	7.3	0+053	10					
16	S5	45	750	LCP	0+053	7.3	0+061	10					
17	S5	45	750	LCP	0+061	7.3	0+068	10					
18	S5	44	750	LCP	0+068	7.3	0+075	10					
19	S5	STD	750	LCP	0+075	7.3	0+082	10					
20	S5	STD	750	LCP	0+082	7.3	0+089	10					
21	S5	STD	750	LCP	0+089	7.3	0+097	10				A	Anomalous signal from 3.3-7.3m.
22	S5	STD	750	LCP	0+097	7.3	0+104	10					
23	S5	STD	750	LCP	0+104	7.3	0+111	10					
24	S5	STD	750	LCP	0+111	7.3	0+118	10					
25	S5	STD	750	LCP	0+118	7.3	0+126	10					
26	S5	STD	750	LCP	0+126	7.3	0+133	10				A	Anomalous signal from 4.6-7.3m.
27	S5	STD	750	LCP	0+133	7.3	0+140	10					
28	S5	STD	750	LCP	0+140	7.3	0+147	10					
29	S5	STD	750	LCP	0+147	7.3	0+154	10					
30	S5	68	750	LCP	0+154	2.6	0+157	10					
31	S5	40	750	LCP	0+157	7.4	0+164	10					
32	S5	40	750	LCP	0+164	7.4	0+172	10					
33	S5	40	750	LCP	0+172	7.4	0+179	10					
34	S5	40	750	LCP	0+179	7.4	0+187	10					
35	S5	40	750	LCP	0+187	7.4	0+194	10					
36	S5	40	750	LCP	0+194	7.4	0+201	10					
37	S5	40	750	LCP	0+201	7.4	0+209	10					
38	S5	67	750	LCP	0+209	7.4	0+216	10					
39	S5	STD	750	LCP	0+216	7.3	0+224	10					
40	S5	STD	750	LCP	0+224	7.3	0+231	10					
41	S5	STD	750	LCP	0+231	7.3	0+238	10					
42	S5	STD	750	LCP	0+238	7.3	0+246	10					
43	S5	STD	750	LCP	0+246	7.3	0+253	10					
44	S5	STD	750	LCP	0+253	7.3	0+260	10					
45	S5	STD	750	LCP	0+260	7.3	0+267	10					
46	S5	STD	750	LCP	0+267	7.3	0+275	10					
47	S5	STD	750	LCP	0+275	7.3	0+282	10					
48	S5	STD	750	LCP	0+282	7.3	0+289	10					
49	S5	STD	750	LCP	0+289	7.3	0+297	10					
50	S5	STD	750	LCP	0+297	7.3	0+304	10					
51	S5	STD	750	LCP	0+304	7.3	0+311	10					
52	S5	STD	750	LCP	0+311	7.3	0+319	10					
53	S5	STD	750	LCP	0+319	7.3	0+326	10					
54	S5	66A	750	LCP	0+326	7.0	0+333	10					
55	S5	STD	750	LCP	0+333	7.3	0+340	10					
56	S5	66	750	LCP	0+340	0.9	0+341	B					
57	S5	N/A	750	LCP	0+341	9.0	0+350	N/A					Steel.
58	S5	65	750	LCP	0+350	2.3	0+353	B				TEE	Access Hatch #1. 500mm TEE @ Station 0+352.
59	S5	64	750	LCP	0+353	4.0	0+357	10				AV	100mm AV @ Station 0+354.
60	S5	63	750	LCP	0+357	2.6	0+359	10					
61	S5	N/A	750	LCP	N/A	2.5	N/A	N/A					Not listed in pipe laying schedules. Data indicates ~2.5m SP.
62	S5	43	750	LCP	0+359	7.3	0+367	10					
63	S5	62	750	LCP	0+367	1.1	0+368	B					
64	S5	61	750	LCP	0+368	2.5	0+370	10					
65	S5	44	750	LCP	0+370	7.3	0+377	10					
66	S5	STD	750	LCP	0+377	7.3	0+385	10					
67	S5	STD	750	LCP	0+385	7.3	0+392	10					
68	S5	STD	750	LCP	0+392	7.3	0+399	10					
69	S5	STD	750	LCP	0+399	7.3	0+407	10					
70	S5	STD	750	LCP	0+407	7.3	0+414	10					
71	S5	STD	750	LCP	0+414	7.3	0+421	10					
72	S5	60	750	LCP	0+421	3.6	0+425	10					
73	S5	STD	750	LCP	0+425	7.3	0+432	10					
74	S5	STD	750	LCP	0+432	7.3	0+440	10					
75	S5	STD	750	LCP	0+440	7.3	0+447	10					
76	S5	STD	750	LCP	0+447	7.3	0+454	10					
77	S5	STD	750	LCP	0+454	7.3	0+462	10					
78	S5	STD	750	LCP	0+462	7.3	0+469	10					
79	S5	STD	750	LCP	0+469	7.3	0+476	10					

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
80	S5	STD	750	LCP	0+476	7.3	0+484	10					
81	S5	STD	750	LCP	0+484	7.3	0+491	10					
82	S5	STD	750	LCP	0+491	7.3	0+498	10					
83	S5	STD	750	LCP	0+498	7.3	0+506	10					
84	S5	STD	750	LCP	0+506	7.3	0+513	10					
85	S5	STD	750	LCP	0+513	7.3	0+520	10					
86	S5	STD	750	LCP	0+520	7.3	0+527	10					
87	S5	STD	750	LCP	0+527	7.3	0+535	10					
88	S5	STD	750	LCP	0+535	7.3	0+542	10					
89	S5	STD	750	LCP	0+542	7.3	0+549	10					
90	S5	STD	750	LCP	0+549	7.3	0+557	10					
91	S5	STD	750	LCP	0+557	7.3	0+564	10					
92	S5	STD	750	LCP	0+564	7.3	0+571	10					
93	S5	STD	750	LCP	0+571	7.3	0+579	10					
94	S5	STD	750	LCP	0+579	7.3	0+586	10					
95	S5	STD	750	LCP	0+586	7.3	0+593	10					
96	S5	STD	750	LCP	0+593	7.3	0+601	10					
97	S5	STD	750	LCP	0+601	7.3	0+608	10					
98	S5	STD	750	LCP	0+608	7.3	0+615	10					
99	S5	STD	750	LCP	0+615	7.3	0+623	10					
100	S5	STD	750	LCP	0+623	7.3	0+630	10					
101	S5	STD	750	LCP	0+630	7.3	0+637	10					
102	S5	STD	750	LCP	0+637	7.3	0+645	10					
103	S5	43	750	LCP	0+645	7.3	0+652	10					
104	S5	45	750	LCP	0+652	7.3	0+004	10					Equation: 0+654.772BK=0+000.000AH.
105	S5	45	750	LCP	0+004	7.3	0+012	10					
106	S5	45	750	LCP	0+012	7.3	0+019	10					
107	S5	45	750	LCP	0+019	7.3	0+026	10					
108	S5	45	750	LCP	0+026	7.3	0+034	10					
109	S5	45	750	LCP	0+034	7.3	0+041	10					
110	S5	45	750	LCP	0+041	7.3	0+048	10					
111	S5	45	750	LCP	0+048	7.3	0+056	10					
112	S5	45	750	LCP	0+056	7.3	0+063	10					
113	S5	45	750	LCP	0+063	7.3	0+070	10					
114	S5	45	750	LCP	0+070	7.3	0+078	10					
115	S5	45	750	LCP	0+078	7.3	0+085	10					
116	S5	45	750	LCP	0+085	7.3	0+092	10					
117	S5	45	750	LCP	0+092	7.3	0+100	10					
118	S5	45	750	LCP	0+100	7.3	0+107	10					
119	S5	45	750	LCP	0+107	7.3	0+114	10					
120	S5	44	750	LCP	0+114	7.3	0+122	10					
121	S5	STD	750	LCP	0+122	7.3	0+129	10					
122	S5	STD	750	LCP	0+129	7.3	0+136	10					
123	S5	STD	750	LCP	0+136	7.3	0+144	10					
124	S5	STD	750	LCP	0+144	7.3	0+151	10					
125	S5	STD	750	LCP	0+151	7.3	0+158	10					
126	S5	STD	750	LCP	0+158	7.3	0+166	10					
127	S5	STD	750	LCP	0+166	7.3	0+173	10					
128	S5	STD	750	LCP	0+173	7.3	0+180	10					
129	S5	STD	750	LCP	0+180	7.3	0+188	10					
130	S5	STD	750	LCP	0+188	7.3	0+195	10					
131	S5	STD	750	LCP	0+195	7.3	0+202	10					
132	S5	STD	750	LCP	0+202	7.3	0+209	10					
133	S5	STD	750	LCP	0+209	7.3	0+217	10					
134	S5	STD	750	LCP	0+217	7.3	0+224	10					
135	S5	33	750	LCP	0+224	7.4	0+232	10					
136	S5	59	750	LCP	0+232	2.0	0+234	B				TEE	Access Hatch #2. 500mm TEE and 200mm BO @ Station 0+233.
137	S5	58	750	LCP	0+234	4.3	0+238	10					
138	S5	40	750	LCP	0+238	7.4	0+245	10					
139	S5	40	750	LCP	0+245	7.4	0+253	10					
140	S5	40	750	LCP	0+253	7.4	0+260	10					
141	S5	40	750	LCP	0+260	7.4	0+267	10					
142	S5	33	750	LCP	0+267	7.4	0+275	10					
143	S5	STD	750	LCP	0+275	7.3	0+282	10					
144	S5	STD	750	LCP	0+282	7.3	0+290	10					
145	S5	STD	750	LCP	0+290	7.3	0+297	10					
146	S5	STD	750	LCP	0+297	7.3	0+304	10					
147	S5	STD	750	LCP	0+304	7.3	0+311	10					
148	S5	STD	750	LCP	0+311	7.3	0+319	10					
149	S5	STD	750	LCP	0+319	7.3	0+326	10					
150	S5	STD	750	LCP	0+326	7.3	0+333	10					
151	S5	STD	750	LCP	0+333	7.3	0+341	10					
152	S5	STD	750	LCP	0+341	7.3	0+348	10					
153	S5	STD	750	LCP	0+348	7.3	0+355	10					
154	S5	STD	750	LCP	0+355	7.3	0+363	10					
155	S5	STD	750	LCP	0+363	7.3	0+370	10					
156	S5	STD	750	LCP	0+370	7.3	0+377	10					
157	S5	STD	750	LCP	0+377	7.3	0+385	10					
158	S5	STD	750	LCP	0+385	7.3	0+392	10					
159	S5	STD	750	LCP	0+392	7.3	0+399	10					
160	S5	STD	750	LCP	0+399	7.3	0+407	10					
161	S5	STD	750	LCP	0+407	7.3	0+414	10					
162	S5	STD	750	LCP	0+414	7.3	0+421	10					
163	S5	STD	750	LCP	0+421	7.3	0+429	10					
164	S5	STD	750	LCP	0+429	7.3	0+436	10					
165	S5	STD	750	LCP	0+436	7.3	0+443	10					
166	S5	STD	750	LCP	0+443	7.3	0+451	10					

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
167	S5	STD	750	LCP	0+451	7.3	0+458	10					
168	S5	STD	750	LCP	0+458	7.3	0+465	10					
169	S5	STD	750	LCP	0+465	7.3	0+473	10					
170	S5	STD	750	LCP	0+473	7.3	0+480	10					
171	S5	STD	750	LCP	0+480	7.3	0+487	10					
172	S5	STD	750	LCP	0+487	7.3	0+494	10					
173	S5	STD	750	LCP	0+494	7.3	0+502	10					
174	S5	STD	750	LCP	0+502	7.3	0+509	10					
175	S5	STD	750	LCP	0+509	7.3	0+516	10					
176	S5	STD	750	LCP	0+516	7.3	0+524	10					
177	S5	STD	750	LCP	0+524	7.3	0+531	10					
178	S5	STD	750	LCP	0+531	7.3	0+538	10				A	Anomalous signal from 0.0-2.5m.
179	S5	STD	750	LCP	0+538	7.3	0+546	10					
180	S5	STD	750	LCP	0+546	7.3	0+553	10					
181	S5	33	750	LCP	0+553	7.4	0+560	10					
182	S5	31	750	LCP	0+560	7.4	0+568	10					
183	S5	31	750	LCP	0+568	7.4	0+575	10					
184	S5	31	750	LCP	0+575	7.4	0+583	10					
185	S5	31	750	LCP	0+583	7.4	0+590	10					
186	S5	31	750	LCP	0+590	7.4	0+598	10					
187	S5	31	750	LCP	0+598	7.4	0+605	10					
188	S5	31	750	LCP	0+605	7.4	0+612	10					
189	S5	31	750	LCP	0+612	7.4	0+620	10					
190	S5	31	750	LCP	0+620	7.4	0+627	10					
191	S5	31	750	LCP	0+627	7.4	0+635	10					
192	S5	57	750	LCP	0+635	1.3	0+636	10					
193	S5	STD	750	LCP	0+636	7.3	0+643	10					
194	S5	STD	750	LCP	0+643	7.3	0+651	10					
195	S5	STD	750	LCP	0+651	7.3	0+658	10					
196	S5	STD	750	LCP	0+658	7.3	0+665	10					
197	S5	STD	750	LCP	0+665	7.3	0+672	10					
198	S5	43	750	LCP	0+672	7.3	0+680	10					
199	S5	56	750	LCP	0+680	1.1	0+001	B					Equation: 0+680.386BK=0+000.000AH.
200	S5	55	750	LCP	0+001	4.2	0+005	10					
201	S5	STD	750	LCP	0+005	7.3	0+012	10					
202	S5	STD	750	LCP	0+012	7.3	0+019	10					
203	S5	STD	750	LCP	0+019	7.3	0+027	10					
204	S5	STD	750	LCP	0+027	7.3	0+034	10					
205	S5	STD	750	LCP	0+034	7.3	0+041	10					
206	S5	STD	750	LCP	0+041	7.3	0+049	10					
207	S5	STD	750	LCP	0+049	7.3	0+056	10					
208	S5	STD	750	LCP	0+056	7.3	0+063	10					
209	S5	STD	750	LCP	0+063	7.3	0+071	10					
210	S5	43	750	LCP	0+071	7.3	0+078	10					
211	S5	54	750	LCP	0+078	1.1	0+079	B					
212	S5	53	750	LCP	0+079	2.1	0+081	10					
213	S5	STD	750	LCP	0+081	2.0	0+089	10				TEE	7.3m STD in pipe laying schedules. Data indicates 2.0m-500m TEE (Access Hatch #3).
214	S5	STD	750	LCP	0+089	7.3	0+096	10					
215	S5	STD	750	LCP	0+096	7.3	0+103	10					
216	S5	STD	750	LCP	0+103	7.3	0+111	10					
217	S5	STD	750	LCP	0+111	7.3	0+118	10					
218	S5	STD	750	LCP	0+118	7.3	0+125	10					
219	S5	STD	750	LCP	0+125	7.3	0+133	10					
220	S5	STD	750	LCP	0+133	7.3	0+140	10					
221	S5	STD	750	LCP	0+140	7.3	0+147	10					
222	S5	STD	750	LCP	0+147	7.3	0+155	10					
223	S5	26	750	LCP	0+155	7.3	0+156	B					2.0m-500mm TEE in pipe laying schedules. Data indicates 7.3m STD.
224	S5	STD	750	LCP	0+156	7.3	0+164	10					
225	S5	STD	750	LCP	0+164	7.3	0+171	10					
226	S5	STD	750	LCP	0+171	7.3	0+178	10					
227	S5	STD	750	LCP	0+178	7.3	0+186	10					
228	S5	STD	750	LCP	0+186	7.3	0+193	10					
229	S5	STD	750	LCP	0+193	7.3	0+200	10					
230	S5	STD	750	LCP	0+200	7.3	0+208	10					
231	S5	STD	750	LCP	0+208	7.3	0+215	10					
232	S5	STD	750	LCP	0+215	7.3	0+222	10					
233	S5	STD	750	LCP	0+222	7.3	0+230	10					
234	S5	STD	750	LCP	0+230	7.3	0+237	10					
235	S5	STD	750	LCP	0+237	7.3	0+244	10					
236	S5	STD	750	LCP	0+244	7.3	0+252	10					
237	S5	STD	750	LCP	0+252	7.3	0+259	10					
238	S5	STD	750	LCP	0+259	7.3	0+266	10					
239	S5	STD	750	LCP	0+266	7.3	0+274	10					
240	S5	STD	750	LCP	0+274	7.3	0+281	10					
241	S5	STD	750	LCP	0+281	7.3	0+288	10					
242	S5	STD	750	LCP	0+288	7.3	0+296	10					
243	S5	STD	750	LCP	0+296	7.3	0+303	10					
244	S5	STD	750	LCP	0+303	7.3	0+310	10					
245	S5	STD	750	LCP	0+310	7.3	0+318	10					
246	S5	STD	750	LCP	0+318	7.3	0+325	10					
247	S5	STD	750	LCP	0+325	7.3	0+332	10					
248	S5	STD	750	LCP	0+332	7.3	0+340	10					
249	S5	STD	750	LCP	0+340	7.3	0+347	10					
250	S5	STD	750	LCP	0+347	7.3	0+354	10					
251	S5	STD	750	LCP	0+354	7.3	0+361	10					
252	S5	STD	750	LCP	0+361	7.3	0+369	10					

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
253	S5	STD	750	LCP	0+369	7.3	0+376	10					
254	S5	STD	750	LCP	0+376	7.3	0+383	10					
255	S5	STD	750	LCP	0+383	7.3	0+391	10					
256	S5	STD	750	LCP	0+391	7.3	0+398	10					
257	S5	STD	750	LCP	0+398	7.3	0+405	10					
258	S5	STD	750	LCP	0+405	7.3	0+413	10					
259	S5	STD	750	LCP	0+413	7.3	0+420	10					
260	S5	STD	750	LCP	0+420	7.3	0+427	10					
261	S5	STD	750	LCP	0+427	7.3	0+435	10					
262	S5	STD	750	LCP	0+435	7.3	0+442	10					
263	S5	STD	750	LCP	0+442	7.3	0+449	10					
264	S5	STD	750	LCP	0+449	7.3	0+457	10					
265	S5	STD	750	LCP	0+457	7.3	0+464	10					
266	S5	STD	750	LCP	0+464	7.3	0+471	10					
267	S5	STD	750	LCP	0+471	7.3	0+479	10					
268	S5	STD	750	LCP	0+479	7.3	0+486	10					
269	S5	STD	750	LCP	0+486	7.3	0+493	10					
270	S5	STD	750	LCP	0+493	7.3	0+501	10					
271	S5	STD	750	LCP	0+501	7.3	0+508	10					
272	S5	STD	750	LCP	0+508	7.3	0+515	10					
273	S5	STD	750	LCP	0+515	7.3	0+523	10					
274	S5	STD	750	LCP	0+523	7.3	0+530	10					
275	S5	STD	750	LCP	0+530	7.3	0+537	10					
276	S5	STD	750	LCP	0+537	7.3	0+545	10					
277	S5	STD	750	LCP	0+545	7.3	0+552	10					
278	S5	STD	750	LCP	0+552	7.3	0+559	10					
279	S5	STD	750	LCP	0+559	7.3	0+566	10					
280	S5	STD	750	LCP	0+566	7.3	0+574	10					
281	S5	STD	750	LCP	0+574	7.3	0+581	10					
282	S5	52	750	LCP	0+581	7.3	0+588	10				OL	200mm OL @ Station 0+584.
283	S5	STD	750	LCP	0+588	7.3	0+596	10					
284	S5	STD	750	LCP	0+596	7.3	0+603	10					
285	S5	STD	750	LCP	0+603	7.3	0+610	10					
286	S5	STD	750	LCP	0+610	7.3	0+618	10					
287	S5	STD	750	LCP	0+618	7.3	0+625	10					
288	S5	STD	750	LCP	0+625	7.3	0+632	10					
289	S5	STD	750	LCP	0+632	7.3	0+640	10					
290	S5	STD	750	LCP	0+640	7.3	0+647	10					
291	S5	STD	750	LCP	0+647	7.3	0+654	10					
292	S5	STD	750	LCP	0+654	7.3	0+662	10					
293	S5	51	750	LCP	0+662	7.4	0+669	10					Pipe length reported with less certainty due to change in pipeline flow.
294	S5	40	750	LCP	0+669	7.4	0+677	10					Pipe length reported with less certainty due to change in pipeline flow.
295	S5	40	750	LCP	0+677	4.4	0+684	10					Pipe length reported with less certainty due to change in pipeline flow.
296	S5	40	750	LCP	0+684	7.4	0+691	10					
297	S5	40	750	LCP	0+691	7.4	0+699	10					
298	S5	50	750	LCP	0+000	4.0	0+004	10					Equation: 0+695.753BK=0+000.000AH.
299	S5	N/A	750	LCP	0+004	10.7	0+015	10				VAL	Valve Chamber VC #1 and Air Release Valve (at Comox Road).
300	S5	49	750	LCP	0+015	4.2	0+019	10					
301	S5	STD	750	LCP	0+019	7.3	0+026	10					
302	S5	STD	750	LCP	0+026	7.3	0+034	10					
303	S5	STD	750	LCP	0+034	7.3	0+041	10					
304	S5	STD	750	LCP	0+041	7.3	0+048	10					
305	S5	43	750	LCP	0+048	7.3	0+056	10					
306	S5	45	750	LCP	0+056	7.3	0+063	10					
307	S5	45	750	LCP	0+063	7.3	0+070	10					
308	S5	45	750	LCP	0+070	7.3	0+078	10					
309	S5	45	750	LCP	0+078	7.3	0+085	10					
310	S5	45	750	LCP	0+085	7.3	0+092	10					
311	S5	45	750	LCP	0+092	7.3	0+099	10					
312	S5	45	750	LCP	0+099	7.3	0+107	10					
313	S5	45	750	LCP	0+107	7.3	0+114	10					
314	S5	45	750	LCP	0+114	7.3	0+121	10					
315	S5	45	750	LCP	0+121	7.3	0+129	10					
316	S5	45	750	LCP	0+129	7.3	0+136	10					
317	S5	45	750	LCP	0+136	7.3	0+143	10					
318	S5	45	750	LCP	0+143	7.3	0+151	10					
319	S5	48	750	LCP	0+151	3.8	0+154	B					
320	S5	45	750	LCP	0+154	7.3	0+162	10					
321	S5	45	750	LCP	0+162	7.3	0+169	10					
322	S5	45	750	LCP	0+169	7.3	0+176	10					
323	S5	45	750	LCP	0+176	7.3	0+184	10					
324	S5	45	750	LCP	0+184	7.3	0+191	10					
325	S5	47	750	LCP	0+191	2.5	0+194	B					
326	S5	46	750	LCP	0+194	2.5	0+196	10					
327	S5	45	750	LCP	0+196	7.3	0+203	10					
328	S5	45	750	LCP	0+203	7.3	0+211	10					
329	S5	44	750	LCP	0+211	7.3	0+218	10					
330	S5	STD	750	LCP	0+218	7.3	0+225	10					
331	S5	STD	750	LCP	0+225	7.3	0+233	10					
332	S5	STD	750	LCP	0+233	7.3	0+240	10					
333	S5	43	750	LCP	0+240	7.3	0+247	10					
334	S5	N/A	750	LCP	N/A	7.3	N/A	N/A					Not listed in pipe laying schedules. Data indicates 7.3m STD.
335	S5	42	750	LCP	0+247	1.8	0+249	B					

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
336	S5	41	750	LCP	0+249	6.0	0+255	10					
337	S5	40	750	LCP	0+255	7.4	0+263	10					
338	S5	40	750	LCP	0+263	7.4	0+270	10					
339	S5	40	750	LCP	0+270	7.4	0+277	10					
340	S5	40	750	LCP	0+277	7.4	0+285	10					
341	S5	40	750	LCP	0+285	7.4	0+292	10					
342	S5	40	750	LCP	0+292	7.4	0+300	10					
343	S5	40	750	LCP	0+300	7.4	0+307	10					
344	S5	40	750	LCP	0+307	7.4	0+314	10					
345	S5	40	750	LCP	0+314	7.4	0+322	10					
346	S5	40	750	LCP	0+322	7.4	0+329	10					
347	S5	40	750	LCP	0+329	7.4	0+337	10					
348	S5	40	750	LCP	0+337	7.4	0+344	10					
349	S5	39	750	LCP	0+344	3.0	0+347	10					
350	S5	STD	750	LCP	0+347	7.3	0+354	10					
351	S5	STD	750	LCP	0+354	7.3	0+362	10					
352	S5	STD	750	LCP	0+362	7.3	0+369	10					
353	S5	STD	750	LCP	0+369	7.3	0+376	10					
354	S5	STD	750	LCP	0+376	7.3	0+384	10					
355	S5	STD	750	LCP	0+384	7.3	0+391	10					
356	S5	STD	750	LCP	0+391	7.3	0+398	10					
357	S5	STD	750	LCP	0+398	7.3	0+406	10					
358	S5	STD	750	LCP	0+406	7.3	0+413	10					
359	S5	STD	750	LCP	0+413	7.3	0+420	10					
360	S5	STD	750	LCP	0+420	7.3	0+428	10					
361	S5	STD	750	LCP	0+428	7.3	0+435	10					
362	S5	STD	750	LCP	0+435	7.3	0+442	10					
363	S5	STD	750	LCP	0+442	7.3	0+450	10					
364	S5	STD	750	LCP	0+450	7.3	0+457	10					
365	S5	STD	750	LCP	0+457	7.3	0+464	10					
366	S5	STD	750	LCP	0+464	7.3	0+472	10					
367	S5	STD	750	LCP	0+472	7.3	0+479	10					
368	S5	STD	750	LCP	0+479	7.3	0+486	10					
369	S5	STD	750	LCP	0+486	7.3	0+494	10					
370	S5	STD	750	LCP	0+494	7.3	0+501	10					
371	S5	STD	750	LCP	0+501	7.3	0+508	10					
372	S5	STD	750	LCP	0+508	7.3	0+515	10					
373	S5	STD	750	LCP	0+515	7.3	0+523	10					
374	S5	STD	750	LCP	0+523	7.3	0+530	10					
375	S5	STD	750	LCP	0+530	7.3	0+537	10					
376	S5	STD	750	LCP	0+537	7.3	0+545	10					
377	S5	STD	750	LCP	0+545	7.3	0+552	10					
378	S5	STD	750	LCP	0+552	2.1	0+559	10					7.3m STD in pipe laying schedules. Data indicates 2.1m SP.
379	S5	STD	750	LCP	0+559	7.3	0+567	10					
380	S5	STD	750	LCP	0+567	7.3	0+574	10					
381	S5	STD	750	LCP	0+574	7.3	0+581	10					
382	S5	STD	750	LCP	0+581	7.3	0+589	10					
383	S5	STD	750	LCP	0+589	7.3	0+596	10					
384	S5	STD	750	LCP	0+596	7.3	0+603	10					
385	S5	STD	750	LCP	0+603	7.3	0+611	10					
386	S5	38	750	LCP	0+611	7.3	0+614	10					3.6m SP in pipe laying schedules. Data indicates 7.3m STD.
N/A	S5	STD	750	LCP	0+614	7.3	0+622	10					7.3m STD in pipe laying schedules. Pipe does not exist in data.
387	S5	37	750	LCP	0+622	3.6	0+624	10					2.1m SP in pipe laying schedules. Data indicates 3.6m SP.
388	S5	STD	750	LCP	0+624	7.3	0+631	10					
389	S5	STD	750	LCP	0+631	7.3	0+638	10					
390	S5	STD	750	LCP	0+638	7.3	0+646	10					
391	S5	STD	750	LCP	0+646	7.3	0+653	10					
392	S5	STD	750	LCP	0+653	7.3	0+660	10					
393	S5	STD	750	LCP	0+660	7.3	0+668	10					
394	S5	STD	750	LCP	0+668	7.3	0+675	10					
395	S5	STD	750	LCP	0+675	7.3	0+682	10					
396	S5	STD	750	LCP	0+682	7.3	0+690	10					
397	S5	STD	750	LCP	0+690	7.3	0+697	10					
398	S5	STD	750	LCP	0+697	7.3	0+704	10					
399	S5	STD	750	LCP	0+704	7.3	0+712	10					
400	S5	STD	750	LCP	0+712	7.3	0+719	10					
401	S5	STD	750	LCP	0+719	7.3	0+726	10					
402	S5	STD	750	LCP	0+726	7.3	0+734	10					
403	S5	STD	750	LCP	0+734	7.3	0+741	10					
404	S5	STD	750	LCP	0+741	7.3	0+748	10					
405	S5	STD	750	LCP	0+748	7.3	0+755	10					
406	S5	STD	750	LCP	0+755	7.3	0+002	10					Equation: 0+761.057BK=0+000.000AH.
407	S5	STD	750	LCP	0+002	7.3	0+009	10					
408	S5	STD	750	LCP	0+009	7.3	0+016	10					
409	S5	STD	750	LCP	0+016	7.3	0+024	10					
410	S5	STD	750	LCP	0+024	7.3	0+031	10					
411	S5	STD	750	LCP	0+031	7.3	0+038	10					
412	S5	STD	750	LCP	0+038	7.3	0+046	10					
413	S5	STD	750	LCP	0+046	7.3	0+053	10					
414	S5	STD	750	LCP	0+053	7.3	0+060	10					
415	S5	STD	750	LCP	0+060	7.3	0+068	10					
416	S5	STD	750	LCP	0+068	7.3	0+075	10					
417	S5	STD	750	LCP	0+075	7.3	0+082	10					
418	S5	STD	750	LCP	0+082	7.3	0+090	10					

Comox Valley Regional District

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Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
419	S5	STD	750	LCP	0+090	7.3	0+097	10					
420	S5	STD	750	LCP	0+097	7.3	0+104	10					
421	S5	STD	750	LCP	0+104	7.3	0+112	10					
422	S5	STD	750	LCP	0+112	7.3	0+119	10					
423	S5	STD	750	LCP	0+119	7.3	0+126	10					
424	S5	STD	750	LCP	0+126	7.3	0+134	10					
425	S5	STD	750	LCP	0+134	7.3	0+141	10					
426	S5	STD	750	LCP	0+141	7.3	0+148	10					
427	S5	STD	750	LCP	0+148	7.3	0+155	10					
428	S5	STD	750	LCP	0+155	7.3	0+163	10					
429	S5	STD	750	LCP	0+163	7.3	0+170	10					
430	S5	STD	750	LCP	0+170	7.3	0+177	10					
431	S5	STD	750	LCP	0+177	7.3	0+185	10					
432	S5	STD	750	LCP	0+185	7.3	0+192	10					
433	S5	STD	750	LCP	0+192	7.3	0+199	10					
434	S5	33	750	LCP	0+199	7.4	0+207	10					
435	S5	31	750	LCP	0+207	7.4	0+214	10					
436	S5	31	750	LCP	0+214	7.4	0+222	10					
437	S5	31	750	LCP	0+222	7.4	0+229	10					
438	S5	31	750	LCP	0+229	7.4	0+236	10					
439	S5	31	750	LCP	0+236	7.4	0+244	10					
440	S5	31	750	LCP	0+244	7.4	0+251	10					
441	S5	31	750	LCP	0+251	7.4	0+259	10					
442	S5	31	750	LCP	0+259	7.4	0+266	10					
443	S5	31	750	LCP	0+266	7.4	0+274	10					
444	S5	31	750	LCP	0+274	7.4	0+281	10					
445	S5	31	750	LCP	0+281	7.4	0+288	10					
446	S5	31	750	LCP	0+288	7.4	0+296	10					
447	S5	31	750	LCP	0+296	7.4	0+303	10					
448	S5	31	750	LCP	0+303	7.4	0+311	10					
449	S5	31	750	LCP	0+311	7.4	0+318	10					
450	S5	26	750	LCP	0+318	2.0	0+320	10				TEE	Access Hatch #4. 500mm TEE @ Station 0+319.
451	S5	31	750	LCP	0+320	7.4	0+327	10					
452	S5	31	750	LCP	0+327	7.4	0+335	10					
453	S5	31	750	LCP	0+335	7.4	0+342	10					
454	S5	31	750	LCP	0+342	7.4	0+350	10					
455	S5	31	750	LCP	0+350	7.4	0+357	10					
456	S5	31	750	LCP	0+357	7.4	0+364	10					
457	S5	31	750	LCP	0+364	7.4	0+372	10					
458	S5	31	750	LCP	0+372	7.4	0+379	10					
459	S5	31	750	LCP	0+379	7.4	0+387	10					
460	S5	31	750	LCP	0+387	7.4	0+394	10					
461	S5	31	750	LCP	0+394	7.4	0+401	10					
462	S5	31	750	LCP	0+401	7.4	0+409	10					
463	S5	36	750	LCP	0+409	4.8	0+414	10					
464	S5	STD	750	LCP	0+414	7.3	0+421	10					
465	S5	STD	750	LCP	0+421	7.3	0+428	10					
466	S5	STD	750	LCP	0+428	7.3	0+436	10					
467	S5	STD	750	LCP	0+436	7.3	0+443	10					
468	S5	STD	750	LCP	0+443	7.3	0+450	10					
469	S5	STD	750	LCP	0+450	7.3	0+458	10					
470	S5	STD	750	LCP	0+458	7.3	0+465	10					
471	S5	STD	750	LCP	0+465	7.3	0+472	10					
472	S5	STD	750	LCP	0+472	7.3	0+480	10					
473	S5	STD	750	LCP	0+480	7.3	0+487	10					
474	S5	STD	750	LCP	0+487	7.3	0+494	10					
475	S5	STD	750	LCP	0+494	7.3	0+502	10					
476	S5	35	750	LCP	0+502	4.7	0+506	10					
477	S5	31	750	LCP	0+506	7.4	0+514	10					
478	S5	31	750	LCP	0+514	7.4	0+521	10					
479	S5	31	750	LCP	0+521	7.4	0+528	10					
480	S5	31	750	LCP	0+528	7.4	0+536	10					
481	S5	31	750	LCP	0+536	7.4	0+543	10					
482	S5	31	750	LCP	0+543	7.4	0+551	10					
483	S5	31	750	LCP	0+551	7.4	0+558	10					
484	S5	31	750	LCP	0+558	7.4	0+565	10					
485	S5	31	750	LCP	0+565	7.4	0+573	10					
486	S5	31	750	LCP	0+573	7.4	0+580	10					
487	S5	31	750	LCP	0+580	7.4	0+588	10					
488	S5	31	750	LCP	0+588	7.4	0+595	10					
489	S5	31	750	LCP	0+595	7.4	0+603	10					
490	S5	31	750	LCP	0+603	7.4	0+610	10					
491	S5	31	750	LCP	0+610	7.4	0+617	10					
492	S5	31	750	LCP	0+617	7.4	0+625	10					
493	S5	31	750	LCP	0+625	7.4	0+632	10					
494	S5	34	750	LCP	0+000	4.1	0+004	10					Equation: 0+632.185BK=0+000.000AH.
495	S5	STD	750	LCP	0+004	7.3	0+011	10					
496	S5	STD	750	LCP	0+011	7.3	0+019	10					
497	S5	STD	750	LCP	0+019	7.3	0+026	10					
498	S5	STD	750	LCP	0+026	7.3	0+033	10					
499	S5	STD	750	LCP	0+033	7.3	0+041	10					
500	S5	STD	750	LCP	0+041	7.3	0+048	10					
501	S5	STD	750	LCP	0+048	7.3	0+055	10					
502	S5	STD	750	LCP	0+055	7.3	0+063	10					
503	S5	STD	750	LCP	0+063	7.3	0+070	10					
504	S5	STD	750	LCP	0+070	7.3	0+077	10					
505	S5	STD	750	LCP	0+077	7.3	0+085	10					
506	S5	STD	750	LCP	0+085	7.3	0+092	10					

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
507	S5	33	750	LCP	0+092	7.4	0+099	10					
508	S5	31	750	LCP	0+099	7.4	0+107	10					
509	S5	31	750	LCP	0+107	7.4	0+114	10					
510	S5	31	750	LCP	0+114	7.4	0+122	10					
511	S5	31	750	LCP	0+122	7.4	0+129	10					
512	S5	31	750	LCP	0+129	7.4	0+136	10					
513	S5	31	750	LCP	0+136	7.4	0+144	10					
514	S5	31	750	LCP	0+144	7.4	0+151	10					
515	S5	31	750	LCP	0+151	7.4	0+159	10					
516	S5	31	750	LCP	0+159	7.4	0+166	10					
517	S5	31	750	LCP	0+166	7.4	0+173	10					
518	S5	32	750	LCP	0+173	2.0	0+175	B				TEE	Access Hatch #5. 500mm TEE and 200mm BO @ Station 0+174.
519	S5	31	750	LCP	0+175	7.4	0+183	10					
520	S5	31	750	LCP	0+183	7.4	0+190	10					
521	S5	31	750	LCP	0+190	7.4	0+198	10					
522	S5	31	750	LCP	0+198	7.4	0+205	10					
523	S5	31	750	LCP	0+205	7.4	0+213	10					
524	S5	30	750	LCP	0+213	4.6	0+217	10					
525	S5	STD	750	LCP	0+217	7.3	0+224	10					
526	S5	29	750	LCP	0+224	3.0	0+227	10					
527	S5	28	750	LCP	0+227	7.4	0+235	10					
528	S5	28	750	LCP	0+235	7.4	0+242	10					
529	S5	28	750	LCP	0+242	7.4	0+250	10					
530	S5	28	750	LCP	0+250	7.4	0+257	10					
531	S5	28	750	LCP	0+257	7.4	0+264	10					
532	S5	28	750	LCP	0+264	7.4	0+272	10					
533	S5	28	750	LCP	0+272	7.4	0+279	10					
534	S5	28	750	LCP	0+279	7.4	0+287	10					
535	S5	28	750	LCP	0+287	7.4	0+294	10					
536	S5	28	750	LCP	0+294	7.4	0+302	10					
537	S5	28	750	LCP	0+302	7.4	0+309	10					
538	S5	28	750	LCP	0+309	7.4	0+316	10					
539	S5	28	750	LCP	0+316	7.4	0+324	10					
540	S5	28	750	LCP	0+324	7.4	0+331	10					
541	S5	28	750	LCP	0+331	7.4	0+339	10					
542	S5	28	750	LCP	0+339	7.4	0+346	10					
543	S5	28	750	LCP	0+346	7.4	0+353	10					
544	S5	28	750	LCP	0+353	7.4	0+361	10					
545	S5	28	750	LCP	0+361	7.4	0+368	10					
546	S5	28	750	LCP	0+368	7.4	0+376	10					
547	S5	28	750	LCP	0+376	7.4	0+383	10					
548	S5	28	750	LCP	0+383	7.4	0+390	10					
549	S5	28	750	LCP	0+390	7.4	0+398	10					
550	S5	28	750	LCP	0+398	7.4	0+405	10					
551	S5	28	750	LCP	0+405	7.4	0+413	10					
552	S5	27	750	LCP	0+413	6.7	0+419	10					
553	S5	STD	750	LCP	0+419	7.3	0+427	10					
554	S5	STD	750	LCP	0+427	7.3	0+434	10					
555	S5	STD	750	LCP	0+434	7.3	0+441	10					
556	S5	STD	750	LCP	0+441	7.3	0+449	10					
557	S5	STD	750	LCP	0+449	3.1	0+456	10					7.3m STD in pipe laying schedules. Data indicates 3.1m SP.
558	S5	STD	750	LCP	0+456	7.3	0+463	10					
559	S5	STD	750	LCP	0+463	7.3	0+471	10					
560	S5	STD	750	LCP	0+471	7.3	0+478	10					
561	S5	STD	750	LCP	0+478	7.3	0+485	10					
562	S5	STD	750	LCP	0+485	7.3	0+493	10					
563	S5	STD	750	LCP	0+493	7.3	0+500	10					
564	S5	STD	750	LCP	0+500	7.3	0+507	10					
565	S5	STD	750	LCP	0+507	7.3	0+515	10					
566	S5	STD	750	LCP	0+515	7.3	0+522	10					
567	S5	STD	750	LCP	0+522	7.3	0+529	10					
568	S5	STD	750	LCP	0+529	7.3	0+537	10					
569	S5	STD	750	LCP	0+537	7.3	0+544	10					
570	S5	STD	750	LCP	0+544	7.3	0+551	10					
571	S5	STD	750	LCP	0+551	7.3	0+558	10					
572	S5	STD	750	LCP	0+558	7.3	0+566	10					
573	S5	STD	750	LCP	0+566	7.3	0+573	10					
574	S5	STD	750	LCP	0+573	7.3	0+580	10					
575	S5	STD	750	LCP	0+580	7.3	0+588	10					
576	S5	STD	750	LCP	0+588	7.3	0+595	10					
577	S5	STD	750	LCP	0+595	7.3	0+602	10					
578	S5	STD	750	LCP	0+602	7.3	0+610	10					
579	S5	STD	750	LCP	0+610	7.3	0+617	10					
580	S5	STD	750	LCP	0+617	7.3	0+624	10					
581	S5	STD	750	LCP	0+624	7.3	0+632	10					
582	S5	STD	750	LCP	0+632	7.3	0+639	10					
583	S5	STD	750	LCP	0+639	7.3	0+005	10					Equation: 0+641.273BK=0+000.000AH.
584	S5	STD	750	LCP	0+005	7.3	0+012	10					
585	S5	STD	750	LCP	0+012	7.3	0+020	10					
586	S5	STD	750	LCP	0+020	7.3	0+027	10					
587	S5	STD	750	LCP	0+027	7.3	0+034	10					
588	S5	STD	750	LCP	0+034	7.3	0+042	10					
589	S5	STD	750	LCP	0+042	7.3	0+049	10					
590	S5	26	750	LCP	0+049	7.3	0+051	B					2.0m-500mm TEE in pipe laying schedules. Data indicates 7.3m STD.

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
591	S5	25	750	LCP	0+051	2.0	0+054	10				TEE	3.1m SP in pipe laying schedules. Data indicates 2.0m-500mm TEE.
592	S5	STD	750	LCP	0+054	7.3	0+061	10					
593	S5	STD	750	LCP	0+061	7.3	0+069	10					
594	S5	STD	750	LCP	0+069	7.3	0+076	10					
595	S5	STD	750	LCP	0+076	7.3	0+083	10					
596	S5	STD	750	LCP	0+083	7.3	0+091	10					
597	S5	STD	750	LCP	0+091	7.3	0+098	10					
598	S5	STD	750	LCP	0+098	7.3	0+105	10					
599	S5	STD	750	LCP	0+105	7.3	0+113	10					
600	S5	STD	750	LCP	0+113	7.3	0+120	10					
601	S5	STD	750	LCP	0+120	7.3	0+127	10					
602	S5	STD	750	LCP	0+127	7.3	0+135	10					
603	S5	STD	750	LCP	0+135	7.3	0+142	10					
604	S5	STD	750	LCP	0+142	7.3	0+149	10					
605	S5	STD	750	LCP	0+149	7.3	0+157	10					
606	S5	STD	750	LCP	0+157	7.3	0+164	10					
607	S5	STD	750	LCP	0+164	7.3	0+171	10					
608	S5	STD	750	LCP	0+171	7.3	0+179	10					
609	S5	STD	750	LCP	0+179	7.3	0+186	10					
610	S5	STD	750	LCP	0+186	7.3	0+193	10					
611	S5	STD	750	LCP	0+193	7.3	0+200	10					
612	S5	STD	750	LCP	0+200	7.3	0+208	10					
613	S5	STD	750	LCP	0+208	7.3	0+215	10					
614	S5	STD	750	LCP	0+215	7.3	0+222	10					
615	S5	STD	750	LCP	0+222	7.3	0+230	10					
616	S5	STD	750	LCP	0+230	7.3	0+237	10					
617	S5	STD	750	LCP	0+237	7.3	0+244	10					
618	S5	STD	750	LCP	0+244	7.3	0+252	10					
619	S5	STD	750	LCP	0+252	7.3	0+259	10					
620	S5	STD	750	LCP	0+259	7.3	0+266	10					
621	S5	STD	750	LCP	0+266	7.3	0+274	10					
622	S5	STD	750	LCP	0+274	7.3	0+281	10					
623	S5	STD	750	LCP	0+281	7.3	0+288	10					
624	S5	STD	750	LCP	0+288	7.3	0+296	10					
625	S5	STD	750	LCP	0+296	7.3	0+303	10					
626	S5	STD	750	LCP	0+303	7.3	0+310	10					
627	S5	STD	750	LCP	0+310	7.3	0+318	10					
628	S5	STD	750	LCP	0+318	7.3	0+325	10					
629	S5	23	750	LCP	0+325	1.1	0+326	B					
630	S5	24	750	LCP	0+326	5.5	0+332	10					
631	S5	23	750	LCP	0+332	1.1	0+333	B					
632	S5	22	750	LCP	0+333	7.3	0+336	10					3.7m SP in pipe laying schedules. Data indicates 7.3m STD.
633	S5	STD	750	LCP	0+336	7.3	0+344	10					
634	S5	STD	750	LCP	0+344	3.7	0+351	10					7.3m STD in pipe laying schedules. Data indicates 3.7m SP.
635	S5	STD	750	LCP	0+351	7.3	0+358	10					
636	S5	STD	750	LCP	0+358	7.3	0+366	10					
637	S5	STD	750	LCP	0+366	7.3	0+373	10					
638	S5	STD	750	LCP	0+373	7.3	0+380	10					
639	S5	STD	750	LCP	0+380	7.3	0+388	10					
640	S5	STD	750	LCP	0+388	7.3	0+395	10					
641	S5	STD	750	LCP	0+395	7.3	0+402	10					
642	S5	STD	750	LCP	0+402	7.3	0+410	10					
643	S5	STD	750	LCP	0+410	7.3	0+417	10					
644	S5	STD	750	LCP	0+417	7.3	0+424	10					
645	S5	STD	750	LCP	0+424	7.3	0+432	10					
646	S5	STD	750	LCP	0+432	7.3	0+439	10					
647	S5	STD	750	LCP	0+439	7.3	0+446	10					
648	S5	STD	750	LCP	0+446	7.3	0+453	10					
649	S5	STD	750	LCP	0+453	7.3	0+461	10					
650	S5	STD	750	LCP	0+461	7.3	0+468	10					
651	S5	STD	750	LCP	0+468	7.3	0+475	10					
652	S5	STD	750	LCP	0+475	7.3	0+483	10					
N/A	S5	74	750	LCP	0+483	3.7	0+486	10					3.6m SP in pipe laying schedules. Pipe does not exist in data.
N/A	S5	73	750	LCP	0+486	4.2	0+490	10					4.1m SP in pipe laying schedules. Pipe does not exist in data.
653	S5	N/A	750	LCP	N/A	7.3	N/A	N/A					Not listed in pipe laying schedules. Data indicates 7.3m STD.
654	S5	STD	750	LCP	0+490	7.3	0+497	10					
655	S5	STD	750	LCP	0+497	7.3	0+505	10					
656	S5	STD	750	LCP	0+505	7.3	0+512	10					
657	S5	STD	750	LCP	0+512	7.3	0+519	10					
658	S5	STD	750	LCP	0+519	7.3	0+527	10					
659	S5	STD	750	LCP	0+527	7.3	0+534	10					
660	S5	21	750	LCP	0+534	7.3	0+541	10					
661	S5	N/A	750	LCP	0+541	10.7	0+552	N/A				VAL	Valve Chamber.
662	S5	17	750	LCP	0+552	2.4	0+554	10					
663	S5	STD	750	LCP	0+554	7.3	0+562	10					
664	S5	STD	750	LCP	0+562	7.3	0+569	10					
665	S5	15	750	LCP	0+569	2.1	0+571	B					
666	S5	16	750	LCP	0+571	4.0	0+575	10					
667	S5	15	750	LCP	0+575	2.1	0+577	B					
668	S5	N/A	750	LCP	N/A	3.0	N/A	N/A					Not listed in pipe laying schedules. Data indicates ~3m SP.
669	S5	STD	750	LCP	0+577	7.3	0+584	10					

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
670	S5	STD	750	LCP	0+584	7.3	0+591	10					
671	S5	STD	750	LCP	0+591	7.3	0+599	10					
672	S5	STD	750	LCP	0+599	7.3	0+606	10					
673	S5	STD	750	LCP	0+606	7.3	0+613	10					
674	S5	STD	750	LCP	0+613	7.3	0+620	10					
675	S5	STD	750	LCP	0+620	7.3	0+628	10					
676	S5	STD	750	LCP	0+628	7.3	0+635	10					
677	S5	STD	750	LCP	0+635	7.3	0+642	10					
678	S5	STD	750	LCP	0+642	7.3	0+650	10					
679	S5	STD	750	LCP	0+650	7.3	0+657	10					
680	S5	STD	750	LCP	0+657	7.3	0+664	10					
681	S5	STD	750	LCP	0+664	7.3	0+672	10					
682	S5	STD	750	LCP	0+672	7.3	0+679	10					
683	S5	STD	750	LCP	0+679	7.3	0+686	10					
684	S5	STD	750	LCP	0+686	7.3	0+694	10					
685	S5	STD	750	LCP	0+694	7.3	0+701	10					
686	S5	STD	750	LCP	0+701	7.3	0+708	10					
687	S5	STD	750	LCP	0+708	7.3	0+716	10					
688	S5	STD	750	LCP	0+716	7.3	0+723	10					
689	S5	STD	750	LCP	0+723	7.3	0+730	10					
690	S5	13	750	LCP	0+730	4.9	0+735	B				WYE	Access Hatch #7. 750 x 820 x 450mm WYE and 500mm OL @ Station 0+733.
691	S5	STD	820	BWP	0+735	7.3	0+743	100					
692	S5	12	820	BWP	0+743	7.4	0+007	100					Equation: 0+742.794BK=0+000.000AH.
693	S5	11	820	BWP	0+007	7.4	0+015	100					
694	S5	11	820	BWP	0+015	7.4	0+022	100					
695	S5	11	820	BWP	0+022	7.4	0+029	100					
696	S5	11	820	BWP	0+029	7.4	0+037	100					
697	S5	11	820	BWP	0+037	7.4	0+044	100					
698	S5	11	820	BWP	0+044	7.4	0+052	100					
699	S5	11	820	BWP	0+052	7.4	0+059	100					
700	S5	11	820	BWP	0+059	7.4	0+066	100					
701	S5	11	820	BWP	0+066	7.4	0+074	100					
702	S5	11	820	BWP	0+074	7.4	0+081	100					
703	S5	11	820	BWP	0+081	7.4	0+089	100					
704	S5	11	820	BWP	0+089	7.4	0+096	100					
705	S5	11	820	BWP	0+096	7.4	0+103	100					
706	S5	11	820	BWP	0+103	7.4	0+111	100					
707	S5	11	820	BWP	0+111	7.4	0+118	100					
708	S5	11	820	BWP	0+118	7.4	0+126	100					
709	S5	11	820	BWP	0+126	7.4	0+133	100					
710	S5	11	820	BWP	0+133	7.4	0+141	100					
711	S5	11	820	BWP	0+141	7.4	0+148	100					
712	S5	11	820	BWP	0+148	7.4	0+155	100					
713	S5	11	820	BWP	0+155	7.4	0+163	100					
714	S5	11	820	BWP	0+163	7.4	0+170	100					
715	S5	11	820	BWP	0+170	7.4	0+178	100					
716	S5	11	820	BWP	0+178	7.4	0+185	100					
717	S5	11	820	BWP	0+185	7.4	0+192	100					
718	S5	11	820	BWP	0+192	7.4	0+200	100					
719	S5	11	820	BWP	0+200	7.4	0+207	100					
720	S5	10	820	BWP	0+207	1.4	0+209	100					
721	S5	STD	820	BWP	0+209	7.3	0+216	100					
722	S5	STD	820	BWP	0+216	7.3	0+223	100					
723	S5	STD	820	BWP	0+223	7.3	0+231	100					
724	S5	STD	820	BWP	0+231	7.3	0+238	100					
725	S5	STD	820	BWP	0+238	7.3	0+245	100					
726	S5	STD	820	BWP	0+245	7.3	0+253	100					
727	S5	STD	820	BWP	0+253	7.3	0+260	100					
728	S5	STD	820	BWP	0+260	7.3	0+267	100					
729	S5	STD	820	BWP	0+267	7.3	0+274	100					
730	S5	STD	820	BWP	0+274	7.3	0+282	100					
731	S5	STD	820	BWP	0+282	7.3	0+289	100					
732	S5	STD	820	BWP	0+289	7.3	0+296	100					
733	S5	STD	820	BWP	0+296	7.3	0+304	100					
734	S5	STD	820	BWP	0+304	7.3	0+311	100					
735	S5	STD	820	BWP	0+311	7.3	0+318	100					
736	S5	STD	820	BWP	0+318	7.3	0+326	100					
737	S5	STD	820	BWP	0+326	7.3	0+333	100					
738	S5	STD	820	BWP	0+333	7.3	0+340	100					
739	S5	STD	820	BWP	0+340	7.3	0+348	100					
740	S5	STD	820	BWP	0+348	7.3	0+355	100					
741	S5	STD	820	BWP	0+355	7.3	0+362	100					
742	S5	STD	820	BWP	0+362	7.3	0+370	100					
743	S5	STD	820	BWP	0+370	7.3	0+377	100					
744	S5	STD	820	BWP	0+377	7.3	0+384	100					
745	S5	STD	820	BWP	0+384	7.3	0+392	100					
746	S5	STD	820	BWP	0+392	7.3	0+399	100					
747	S5	STD	820	BWP	0+399	7.3	0+406	100					
748	S5	STD	820	BWP	0+406	7.3	0+414	100					
749	S5	STD	820	BWP	0+414	7.3	0+421	100					
750	S5	STD	820	BWP	0+421	7.3	0+428	100					
751	S5	STD	820	BWP	0+428	7.3	0+436	100					
752	S5	STD	820	BWP	0+436	7.3	0+443	100					
753	S5	STD	820	BWP	0+443	7.3	0+450	100					
754	S5	STD	820	BWP	0+450	7.3	0+457	100					
755	S5	STD	820	BWP	0+457	7.3	0+465	100					
756	S5	STD	820	BWP	0+465	7.3	0+472	100					

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
757	S5	STD	820	BWP	0+472	7.3	0+479	100					
758	S5	STD	820	BWP	0+479	7.3	0+487	100					
759	S5	STD	820	BWP	0+487	7.3	0+494	100					
760	S5	STD	820	BWP	0+494	7.3	0+501	100					
761	S5	STD	820	BWP	0+501	7.3	0+509	100					
762	S5	STD	820	BWP	0+509	7.3	0+516	100					
763	S5	STD	820	BWP	0+516	7.3	0+523	100					
764	S5	STD	820	BWP	0+523	7.3	0+531	100					
765	S5	STD	820	BWP	0+531	7.3	0+538	100					
766	S5	STD	820	BWP	0+538	7.3	0+545	100					
767	S5	STD	820	BWP	0+545	7.3	0+553	100					
768	S5	STD	820	BWP	0+553	7.3	0+560	100					
769	S5	STD	820	BWP	0+560	7.3	0+567	100					
770	S5	STD	820	BWP	0+567	7.3	0+575	100					
771	S5	STD	820	BWP	0+575	7.3	0+582	100					
772	S5	STD	820	BWP	0+582	7.3	0+589	100					
773	S5	9	820	BWP	0+589	2.0	0+591	B				OL	Access Hatch #8. 500mm OL and 200mm Blowdown @ Station 0+590.
774	S5	STD	820	BWP	0+591	7.3	0+599	100					
775	S5	STD	820	BWP	0+599	7.3	0+606	100					
776	S5	STD	820	BWP	0+606	7.3	0+613	100					
777	S5	STD	820	BWP	0+613	7.3	0+621	100					
778	S5	STD	820	BWP	0+621	7.3	0+628	100					
779	S5	STD	820	BWP	0+628	7.3	0+635	100					
780	S5	STD	820	BWP	0+635	7.3	0+643	100					
781	S5	STD	820	BWP	0+643	7.3	0+650	100					
782	S5	STD	820	BWP	0+650	7.3	0+657	100					
783	S5	STD	820	BWP	0+657	7.3	0+664	100					
784	S5	STD	820	BWP	0+664	7.3	0+672	100					
785	S5	STD	820	BWP	0+672	7.3	0+679	100					
786	S5	STD	820	BWP	0+679	7.3	0+686	100					
787	S5	STD	820	BWP	0+686	7.3	0+694	100					
788	S5	STD	820	BWP	0+694	7.3	0+701	100					
789	S5	STD	820	BWP	0+701	7.3	0+708	100					
790	S5	STD	820	BWP	0+708	7.3	0+716	100					
791	S5	STD	820	BWP	0+716	7.3	0+723	100					
792	S5	STD	820	BWP	0+723	7.3	0+730	100					
793	S5	STD	820	BWP	0+730	7.3	0+003	100					Equation: 0+735.047BK=0+000.000AH.
794	S5	STD	820	BWP	0+003	7.3	0+010	100					
795	S5	STD	820	BWP	0+010	7.3	0+017	100					
796	S5	STD	820	BWP	0+017	7.3	0+025	100					
797	S5	STD	820	BWP	0+025	7.3	0+032	100					
798	S5	STD	820	BWP	0+032	7.3	0+039	100					
799	S5	STD	820	BWP	0+039	7.3	0+047	100					
800	S5	STD	820	BWP	0+047	7.3	0+054	100					
801	S5	STD	820	BWP	0+054	7.3	0+061	100					
802	S5	STD	820	BWP	0+061	7.3	0+069	100					
803	S5	STD	820	BWP	0+069	7.3	0+076	100					
804	S5	STD	820	BWP	0+076	7.3	0+083	100					
805	S5	STD	820	BWP	0+083	7.3	0+090	100					
806	S5	STD	820	BWP	0+090	7.3	0+098	100					
807	S5	STD	820	BWP	0+098	7.3	0+105	100					
808	S5	STD	820	BWP	0+105	7.3	0+112	100					
809	S5	STD	820	BWP	0+112	7.3	0+120	100					
810	S5	STD	820	BWP	0+120	7.3	0+127	100					
811	S5	STD	820	BWP	0+127	7.3	0+134	100					
812	S5	STD	820	BWP	0+134	7.3	0+142	100					
813	S5	STD	820	BWP	0+142	7.3	0+149	100					
814	S5	STD	820	BWP	0+149	7.3	0+156	100					
815	S5	STD	820	BWP	0+156	7.3	0+164	100					
816	S5	STD	820	BWP	0+164	7.3	0+171	100					
817	S5	STD	820	BWP	0+171	7.3	0+178	100					
818	S5	STD	820	BWP	0+178	7.3	0+186	100					
819	S5	STD	820	BWP	0+186	7.3	0+193	100					
820	S5	STD	820	BWP	0+193	7.3	0+200	100					
821	S5	STD	820	BWP	0+200	7.3	0+208	100					
822	S5	STD	820	BWP	0+208	7.3	0+215	100					
823	S5	STD	820	BWP	0+215	7.3	0+222	100					
824	S5	STD	820	BWP	0+222	7.3	0+230	100					
825	S5	STD	820	BWP	0+230	7.3	0+237	100					
826	S5	STD	820	BWP	0+237	7.3	0+244	100					
827	S5	STD	820	BWP	0+244	7.3	0+252	100					
828	S5	STD	820	BWP	0+252	7.3	0+259	100					
829	S5	STD	820	BWP	0+259	7.3	0+266	100					
830	S5	STD	820	BWP	0+266	7.3	0+274	100					
831	S5	STD	820	BWP	0+274	7.3	0+281	100					
832	S5	STD	820	BWP	0+281	7.3	0+288	100					
833	S5	8	820	BWP	0+288	1.7	0+290	100					
834	S5	STD	820	BWP	0+290	7.3	0+297	100					
835	S5	STD	820	BWP	0+297	7.3	0+304	100					
836	S5	STD	820	BWP	0+304	7.3	0+312	100					
837	S5	STD	820	BWP	0+312	7.3	0+319	100					
838	S5	STD	820	BWP	0+319	7.3	0+326	100					
839	S5	STD	820	BWP	0+326	7.3	0+334	100					
840	S5	STD	820	BWP	0+334	7.3	0+341	100					
841	S5	STD	820	BWP	0+341	7.3	0+348	100					
842	S5	STD	820	BWP	0+348	7.3	0+356	100					
843	S5	STD	820	BWP	0+356	7.3	0+363	100					

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
844	S5	STD	820	BWP	0+363	7.3	0+370	100					
845	S5	STD	820	BWP	0+370	7.3	0+378	100					
846	S5	STD	820	BWP	0+378	7.3	0+385	100					
847	S5	STD	820	BWP	0+385	7.3	0+392	100					
848	S5	STD	820	BWP	0+392	7.3	0+400	100					
849	S5	STD	820	BWP	0+400	7.3	0+407	100					
850	S5	STD	820	BWP	0+407	7.3	0+414	100					
851	S5	STD	820	BWP	0+414	7.3	0+422	100					
852	S5	STD	820	BWP	0+422	7.3	0+429	100					
853	S5	STD	820	BWP	0+429	7.3	0+436	100					
854	S5	STD	820	BWP	0+436	7.3	0+444	100					
855	S5	5	820	BWP	0+444	2.0	0+446	B				OL	Access Hatch #9. 500mm OL @ Station 0+446.
856	S5	STD	820	BWP	0+446	7.3	0+453	100					
857	S5	STD	820	BWP	0+453	7.3	0+460	100					
858	S5	STD	820	BWP	0+460	7.3	0+468	100					
859	S5	STD	820	BWP	0+468	7.3	0+475	100					
860	S5	STD	820	BWP	0+475	7.3	0+482	100					
861	S5	STD	820	BWP	0+482	7.3	0+490	100					
862	S5	STD	820	BWP	0+490	7.3	0+497	100					
863	S5	STD	820	BWP	0+497	7.3	0+504	100					
864	S5	STD	820	BWP	0+504	7.3	0+511	100					
865	S5	STD	820	BWP	0+511	7.3	0+519	100					
866	S5	STD	820	BWP	0+519	7.3	0+526	100					
867	S5	STD	820	BWP	0+526	7.3	0+533	100					
868	S5	STD	820	BWP	0+533	7.3	0+541	100					
869	S5	STD	820	BWP	0+541	7.3	0+548	100					
870	S5	STD	820	BWP	0+548	7.3	0+555	100					
871	S5	STD	820	BWP	0+555	7.3	0+563	100					
872	S5	STD	820	BWP	0+563	7.3	0+570	100					
873	S5	STD	820	BWP	0+570	7.3	0+577	100					
874	S5	STD	820	BWP	0+577	7.3	0+585	100					
875	S5	STD	820	BWP	0+585	7.3	0+592	100					
876	S5	STD	820	BWP	0+592	7.3	0+599	100					
877	S5	STD	820	BWP	0+599	7.3	0+607	100					
878	S5	STD	820	BWP	0+607	7.3	0+614	100					
879	S5	STD	820	BWP	0+614	7.3	0+621	100					
880	S5	STD	820	BWP	0+621	7.3	0+629	100					
881	S5	STD	820	BWP	0+629	7.3	0+636	100					
882	S5	STD	820	BWP	0+636	7.3	0+643	100					
883	S5	STD	820	BWP	0+643	7.3	0+651	100					
884	S5	STD	820	BWP	0+651	7.3	0+658	100					
885	S5	STD	820	BWP	0+658	7.3	0+665	100					
886	S5	STD	820	BWP	0+665	7.3	0+673	100					
887	S5	STD	820	BWP	0+673	7.3	0+680	100					
888	S5	STD	820	BWP	0+680	7.3	0+687	100					
889	S5	STD	820	BWP	0+687	7.3	0+694	100					
890	S5	STD	820	BWP	0+694	7.3	0+002	100					Equation: 0+700.000BK+O971=0+000.000AH
891	S5	STD	820	BWP	0+002	7.3	0+009	100					
892	S5	STD	820	BWP	0+009	7.3	0+016	100					
893	S5	STD	820	BWP	0+016	7.3	0+024	100					
894	S5	STD	820	BWP	0+024	7.3	0+031	100					
895	S5	STD	820	BWP	0+031	7.3	0+038	100					
896	S5	STD	820	BWP	0+038	7.3	0+046	100					
897	S5	STD	820	BWP	0+046	7.3	0+053	100					
898	S5	STD	820	BWP	0+053	7.3	0+060	100					
899	S5	STD	820	BWP	0+060	7.3	0+068	100					
900	S5	STD	820	BWP	0+068	7.3	0+075	100					
901	S5	STD	820	BWP	0+075	7.3	0+082	100					
902	S5	STD	820	BWP	0+082	7.3	0+090	100					
903	S5	STD	820	BWP	0+090	7.3	0+097	100					
904	S5	STD	820	BWP	0+097	7.3	0+104	100					
905	S5	STD	820	BWP	0+104	7.3	0+112	100					
906	S5	STD	820	BWP	0+112	7.3	0+119	100					
907	S5	STD	820	BWP	0+119	7.3	0+126	100					
908	S5	STD	820	BWP	0+126	7.3	0+134	100					
909	S5	STD	820	BWP	0+134	7.3	0+141	100					
910	S5	STD	820	BWP	0+141	7.3	0+148	100					
911	S5	STD	820	BWP	0+148	7.3	0+156	100					
912	S5	STD	820	BWP	0+156	7.3	0+163	100					
913	S5	STD	820	BWP	0+163	7.3	0+170	100					
914	S5	STD	820	BWP	0+170	7.3	0+178	100					
915	S5	STD	820	BWP	0+178	7.3	0+185	100					
916	S5	STD	820	BWP	0+185	7.3	0+192	100					
917	S5	STD	820	BWP	0+192	7.3	0+199	100					
918	S5	STD	820	BWP	0+199	7.3	0+207	100					
919	S5	STD	820	BWP	0+207	7.3	0+214	100					
920	S5	STD	820	BWP	0+214	7.3	0+221	100					
921	S5	STD	820	BWP	0+221	7.3	0+229	100					
922	S5	STD	820	BWP	0+229	7.3	0+236	100					
923	S5	STD	820	BWP	0+236	7.3	0+243	100					
924	S5	STD	820	BWP	0+243	7.3	0+251	100					
925	S5	STD	820	BWP	0+251	7.3	0+258	100					
926	S5	STD	820	BWP	0+258	7.3	0+265	100					
927	S5	STD	820	BWP	0+265	7.3	0+273	100					
928	S5	STD	820	BWP	0+273	7.3	0+280	100					
929	S5	STD	820	BWP	0+280	7.3	0+287	100					
930	S5	STD	820	BWP	0+287	7.3	0+295	100					
931	S5	STD	820	BWP	0+295	7.3	0+302	100					

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
932	S5	STD	820	BWP	0+302	7.3	0+309	100					
933	S5	STD	820	BWP	0+309	7.3	0+317	100					
934	S5	STD	820	BWP	0+317	7.3	0+324	100					
935	S5	STD	820	BWP	0+324	7.3	0+331	100					
936	S5	STD	820	BWP	0+331	7.3	0+339	100					
937	S5	STD	820	BWP	0+339	7.3	0+346	100					
938	S5	STD	820	BWP	0+346	7.3	0+353	100					
939	S5	STD	820	BWP	0+353	7.3	0+361	100					
940	S5	STD	820	BWP	0+361	7.3	0+368	100					
941	S5	STD	820	BWP	0+368	7.3	0+375	100					
942	S5	STD	820	BWP	0+375	7.3	0+383	100					
943	S5	STD	820	BWP	0+383	7.3	0+390	100					
944	S5	STD	820	BWP	0+390	7.3	0+397	100					
945	S5	STD	820	BWP	0+397	7.3	0+404	100					
946	S5	STD	820	BWP	0+404	7.3	0+412	100					
947	S5	STD	820	BWP	0+412	7.3	0+419	100					
948	S5	STD	820	BWP	0+419	7.3	0+426	100					
949	S5	STD	820	BWP	0+426	7.3	0+434	100					
950	S5	STD	820	BWP	0+434	7.3	0+441	100					
951	S5	4	820	BWP	0+441	7.1	0+448	100					
952	S5	N/A	820	BWP	0+448	8.8	0+457	100				VAL	Valve Chamber #3.
953	S7	39	820	BWP	0+000	2.3	0+002	100					Equation: 0+457.000BK (Contract S5) = 0+000.000AH (Contract S7).
954	S7	40	820	BWP	0+002	2.3	0+005	B				WYE	45˚ WYE.
955	S7	41	820	BWP	0+005	7.3	0+012	100					
956	S7	42	820	BWP	0+012	6.6	0+019	100					
957	S7	43	820	BWP	0+019	2.0	0+021	B					
958	S7	44	820	BWP	0+021	7.3	0+028	100					
959	S7	STD	820	BWP	0+028	7.3	0+035	100					
960	S7	STD	820	BWP	0+035	7.3	0+043	100					
961	S7	STD	820	BWP	0+043	7.3	0+050	100					
962	S7	STD	820	BWP	0+050	7.3	0+057	100					
963	S7	STD	820	BWP	0+057	7.3	0+065	100					
964	S7	STD	820	BWP	0+065	7.3	0+072	100					
965	S7	STD	820	BWP	0+072	7.3	0+079	100					
966	S7	STD	820	BWP	0+079	7.3	0+087	100					
967	S7	STD	820	BWP	0+087	7.3	0+094	100					
968	S7	STD	820	BWP	0+094	7.3	0+101	100					
969	S7	STD	820	BWP	0+101	7.3	0+108	100					
970	S7	STD	820	BWP	0+108	7.3	0+116	100					
971	S7	STD	820	BWP	0+116	7.3	0+123	100					
972	S7	STD	820	BWP	0+123	7.3	0+130	100					
973	S7	STD	820	BWP	0+130	7.3	0+138	100					
974	S7	STD	820	BWP	0+138	7.3	0+145	100					
975	S7	STD	820	BWP	0+145	7.3	0+152	100					
976	S7	STD	820	BWP	0+152	7.3	0+160	100					
977	S7	STD	820	BWP	0+160	7.3	0+167	100					
978	S7	STD	820	BWP	0+167	7.3	0+174	100					
979	S7	STD	820	BWP	0+174	7.3	0+182	100					
980	S7	STD	820	BWP	0+182	7.3	0+189	100					
981	S7	STD	820	BWP	0+189	7.3	0+196	100					
982	S7	STD	820	BWP	0+196	7.3	0+204	100					
983	S7	STD	820	BWP	0+204	7.3	0+211	100					
984	S7	STD	820	BWP	0+211	7.3	0+218	100					
985	S7	STD	820	BWP	0+218	7.3	0+226	100					
986	S7	STD	820	BWP	0+226	7.3	0+233	100					
987	S7	STD	820	BWP	0+233	7.3	0+240	100					
988	S7	STD	820	BWP	0+240	7.3	0+248	100					
989	S7	STD	820	BWP	0+248	7.3	0+255	100					
990	S7	STD	820	BWP	0+255	7.3	0+262	100					
991	S7	STD	820	BWP	0+262	7.3	0+270	100					
992	S7	STD	820	BWP	0+270	7.3	0+277	100					
993	S7	STD	820	BWP	0+277	7.3	0+284	100					
994	S7	STD	820	BWP	0+284	7.3	0+292	100					
995	S7	45	820	BWP	0+292	4.4	0+296	100					
996	S7	STD	820	BWP	0+000	7.3	0+007	100					Equation: 0+295.933AH=0+000.000BK.
997	S7	STD	820	BWP	0+007	7.3	0+015	100					
998	S7	STD	820	BWP	0+015	7.3	0+022	100					
999	S7	STD	820	BWP	0+022	7.3	0+029	100					
1000	S7	STD	820	BWP	0+029	7.3	0+037	100					
1001	S7	STD	820	BWP	0+037	7.3	0+044	100					
1002	S7	STD	820	BWP	0+044	7.3	0+051	100					
1003	S7	STD	820	BWP	0+051	7.3	0+059	100					
1004	S7	STD	820	BWP	0+059	7.3	0+066	100					
1005	S7	STD	820	BWP	0+066	7.3	0+073	100					
1006	S7	STD	820	BWP	0+073	7.3	0+081	100					
1007	S7	STD	820	BWP	0+081	7.3	0+088	100					
1008	S7	STD	820	BWP	0+088	7.3	0+095	100					
1009	S7	STD	820	BWP	0+095	7.3	0+102	100					
1010	S7	46	820	BWP	0+102	7.2	0+110	100					
1011	S7	STD	820	BWP	0+110	7.3	0+117	100					
1012	S7	STD	820	BWP	0+117	7.3	0+124	100					
1013	S7	47	820	BWP	0+124	7.3	0+129	100					4.4m SP in pipe laying schedules. Data indicates 7.3m STD.
1014	S7	48	820	BWP	0+129	7.3	0+131	B					2.0m-500mm OL in pipe laying schedules. Data indicates 7.3m STD.
1015	S7	STD	820	BWP	0+131	7.3	0+138	100					
1016	S7	STD	820	BWP	0+138	7.3	0+145	100					

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
1017	S7	STD	820	BWP	0+145	7.3	0+153	100					
1018	S7	STD	820	BWP	0+153	7.3	0+160	100					
1019	S7	STD	820	BWP	0+160	7.3	0+167	100					
1020	S7	STD	820	BWP	0+167	7.3	0+175	100					
1021	S7	STD	820	BWP	0+175	7.3	0+182	100					
1022	S7	STD	820	BWP	0+182	7.3	0+189	100					
1023	S7	STD	820	BWP	0+189	4.4	0+197	100					7.3m STD in pipe laying schedules. Data indicates 4.4m SP.
1024	S7	STD	820	BWP	0+197	2.0	0+204	100				OL	7.3m STD in pipe laying schedules. Data indicates 2.0m-500mm OL.
1025	S7	STD	820	BWP	0+204	7.3	0+211	100					
1026	S7	STD	820	BWP	0+211	7.3	0+219	100					
1027	S7	49	820	BWP	0+219	5.5	0+224	100					
1028	S7	STD	820	BWP	0+224	7.3	0+231	100					
1029	S7	STD	820	BWP	0+231	7.3	0+239	100					
1030	S7	STD	820	BWP	0+239	7.3	0+246	100					
1031	S7	STD	820	BWP	0+246	7.3	0+253	100					
1032	S7	STD	820	BWP	0+253	7.3	0+261	100					
1033	S7	STD	820	BWP	0+261	7.3	0+268	100					
1034	S7	STD	820	BWP	0+268	7.3	0+275	100					
1035	S7	STD	820	BWP	0+275	7.3	0+283	100					
1036	S7	STD	820	BWP	0+283	7.3	0+290	100					
1037	S7	STD	820	BWP	0+290	7.3	0+297	100					
1038	S7	STD	820	BWP	0+297	7.3	0+305	100					
1039	S7	STD	820	BWP	0+305	7.3	0+312	100					
1040	S7	STD	820	BWP	0+312	7.3	0+319	100					
1041	S7	STD	820	BWP	0+319	7.3	0+327	100					
1042	S7	50	820	BWP	0+327	0.7	0+327	100					
1043	S7	51	820	BWP	0+327	5.2	0+332	100					
1044	S7	STD	820	BWP	0+332	7.3	0+340	100					
1045	S7	STD	820	BWP	0+340	7.3	0+347	100					
1046	S7	STD	820	BWP	0+347	7.3	0+354	100					
1047	S7	STD	820	BWP	0+354	7.3	0+362	100					
1048	S7	STD	820	BWP	0+362	7.3	0+369	100					
1049	S7	STD	820	BWP	0+369	7.3	0+376	100					
1050	S7	STD	820	BWP	0+376	7.3	0+384	100					
1051	S7	STD	820	BWP	0+384	7.3	0+391	100					
1052	S7	STD	820	BWP	0+391	7.3	0+398	100					
1053	S7	STD	820	BWP	0+398	7.3	0+406	100					
1054	S7	STD	820	BWP	0+406	7.3	0+413	100					
1055	S7	STD	820	BWP	0+413	7.3	0+420	100					
1056	S7	STD	820	BWP	0+420	7.3	0+428	100					
1057	S7	STD	820	BWP	0+428	7.3	0+435	100					
1058	S7	STD	820	BWP	0+435	7.3	0+442	100					
1059	S7	STD	820	BWP	0+442	7.3	0+450	100					
1060	S7	STD	820	BWP	0+450	7.3	0+457	100					
1061	S7	STD	820	BWP	0+457	7.3	0+464	100					
1062	S7	STD	820	BWP	0+464	7.3	0+472	100					
1063	S7	STD	820	BWP	0+472	7.3	0+479	100					
1064	S7	STD	820	BWP	0+479	7.3	0+486	100					
1065	S7	STD	820	BWP	0+486	7.3	0+493	100					
1066	S7	STD	820	BWP	0+493	7.3	0+501	100					
1067	S7	STD	820	BWP	0+501	7.3	0+508	100					
1068	S7	STD	820	BWP	0+508	7.3	0+515	100					
1069	S7	STD	820	BWP	0+515	7.3	0+523	100					
1070	S7	STD	820	BWP	0+523	7.3	0+530	100					
1071	S7	STD	820	BWP	0+530	7.3	0+537	100					
1072	S7	52	820	BWP	0+537	5.2	0+543	100					
1073	S7	53	820	BWP	0+543	0.9	0+544	100					
1074	S7	STD	820	BWP	0+544	7.3	0+551	100					
1075	S7	STD	820	BWP	0+551	7.3	0+558	100					
1076	S7	STD	820	BWP	0+558	7.3	0+565	100					
1077	S7	54	820	BWP	0+565	7.3	0+570	100					4.5m SP in pipe laying schedules. Data indicates 7.3m STD.
1078	S7	55	820	BWP	0+570	2.0	0+572	B				OL	500mm OL @ Station 0+571.
1079	S7	STD	820	BWP	0+572	7.3	0+579	100					
1080	S7	STD	820	BWP	0+579	7.3	0+587	100					
1081	S7	STD	820	BWP	0+587	7.3	0+594	100				A	Anomalous signal from 4.0-7.3m.
1082	S7	STD	820	BWP	0+594	7.3	0+601	100					
1083	S7	STD	820	BWP	0+601	7.3	0+609	100					
1084	S7	STD	820	BWP	0+609	7.3	0+616	100					
1085	S7	STD	820	BWP	0+616	5.7	0+623	100					7.3m STD in pipe laying schedules. Data indicates 5.7m SP.
1086	S7	STD	820	BWP	0+623	7.3	0+631	100					
1087	S7	STD	820	BWP	0+631	7.3	0+638	100					
1088	S7	STD	820	BWP	0+638	7.3	0+645	100					
1089	S7	56	820	BWP	0+645	7.3	0+651	100					5.7m SP in pipe laying schedules. Data indicates 7.3m STD.
1090	S7	STD	820	BWP	0+000	7.3	0+007	100					Equation: 0+650.870AH=0+000.000BK.
1091	S7	STD	820	BWP	0+007	7.3	0+015	100					
1092	S7	STD	820	BWP	0+015	7.3	0+022	100					
1093	S7	STD	820	BWP	0+022	7.3	0+029	100					
1094	S7	STD	820	BWP	0+029	7.3	0+037	100					
1095	S7	STD	820	BWP	0+037	7.3	0+044	100					
1096	S7	STD	820	BWP	0+044	7.3	0+051	100					
1097	S7	STD	820	BWP	0+051	7.3	0+059	100					
1098	S7	STD	820	BWP	0+059	7.3	0+066	100					
1099	S7	STD	820	BWP	0+066	7.3	0+073	100				A	Anomalous signal from 3.9-7.3m.

Comox Valley Regional District
750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results
Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
1100	S7	STD	820	BWP	0+073	7.3	0+081	100					
1101	S7	STD	820	BWP	0+081	7.3	0+088	100					
1102	S7	STD	820	BWP	0+088	7.3	0+095	100					
1103	S7	STD	820	BWP	0+095	7.3	0+102	100					
1104	S7	STD	820	BWP	0+102	7.3	0+110	100					
1105	S7	STD	820	BWP	0+110	7.3	0+117	100					
1106	S7	STD	820	BWP	0+117	7.3	0+124	100					
1107	S7	STD	820	BWP	0+124	7.3	0+132	100					
1108	S7	STD	820	BWP	0+132	7.3	0+139	100					
1109	S7	STD	820	BWP	0+139	7.3	0+146	100					
1110	S7	STD	820	BWP	0+146	7.3	0+154	100					
1111	S7	STD	820	BWP	0+154	7.3	0+161	100					
1112	S7	STD	820	BWP	0+161	7.3	0+168	100					
1113	S7	STD	820	BWP	0+168	7.3	0+176	100					
1114	S7	STD	820	BWP	0+176	7.3	0+183	100					
1115	S7	STD	820	BWP	0+183	7.3	0+190	100					
1116	S7	STD	820	BWP	0+190	7.3	0+198	100					
1117	S7	STD	820	BWP	0+198	7.3	0+205	100					
1118	S7	STD	820	BWP	0+205	7.3	0+212	100					
1119	S7	STD	820	BWP	0+212	7.3	0+220	100					
1120	S7	STD	820	BWP	0+220	7.3	0+227	100					
1121	S7	STD	820	BWP	0+227	7.3	0+234	100					
1122	S7	STD	820	BWP	0+234	7.3	0+242	100					
1123	S7	STD	820	BWP	0+242	7.3	0+249	100					
1124	S7	STD	820	BWP	0+249	7.3	0+256	100					
1125	S7	STD	820	BWP	0+256	7.3	0+264	100					
1126	S7	STD	820	BWP	0+264	7.3	0+271	100				A	Anomalous signal from 4.8-7.3m.
1127	S7	STD	820	BWP	0+271	7.3	0+278	100					
1128	S7	STD	820	BWP	0+278	7.3	0+286	100					
1129	S7	STD	820	BWP	0+286	7.3	0+293	100					
1130	S7	STD	820	BWP	0+293	7.3	0+300	100					
1131	S7	STD	820	BWP	0+300	7.3	0+307	100					
1132	S7	STD	820	BWP	0+307	7.3	0+315	100					
1133	S7	STD	820	BWP	0+315	7.3	0+322	100					
1134	S7	STD	820	BWP	0+322	2.0	0+329	100					7.3m STD in pipe laying schedules. Data indicates 2.0m SP.
1135	S7	STD	820	BWP	0+329	7.3	0+337	100					
1136	S7	55	820	BWP	0+337	7.3	0+339	100					2.0m-500mm OL in pipe laying schedules. Data indicates 7.3m STD.
1137	S7	57	820	BWP	0+339	6.6	0+345	100					
1138	S7	STD	820	BWP	0+345	7.3	0+353	100					
1139	S7	STD	820	BWP	0+353	7.3	0+360	100					
1140	S7	STD	820	BWP	0+360	7.3	0+367	100					
1141	S7	STD	820	BWP	0+367	7.3	0+375	100					
1142	S7	STD	820	BWP	0+375	7.3	0+382	100					
1143	S7	STD	820	BWP	0+382	7.3	0+389	100					
1144	S7	STD	820	BWP	0+389	7.3	0+397	100					
1145	S7	STD	820	BWP	0+397	7.3	0+404	100					
1146	S7	STD	820	BWP	0+404	7.3	0+411	100					
1147	S7	STD	820	BWP	0+411	2.0	0+419	100				OL	7.3m STD in pipe laying schedules. Data indicates 2.0m-500mm OL.
1148	S7	STD	820	BWP	0+419	7.3	0+426	100					
1149	S7	STD	820	BWP	0+426	7.3	0+433	100					
1150	S7	STD	820	BWP	0+433	7.3	0+440	100					
1151	S7	STD	820	BWP	0+440	7.3	0+448	100					
1152	S7	STD	820	BWP	0+448	7.3	0+455	100					
1153	S7	STD	820	BWP	0+455	7.3	0+462	100					
1154	S7	STD	820	BWP	0+462	7.3	0+470	100					
1155	S7	STD	820	BWP	0+470	7.3	0+477	100					
1156	S7	STD	820	BWP	0+477	7.3	0+484	100					
1157	S7	STD	820	BWP	0+484	7.3	0+492	100					
1158	S7	STD	820	BWP	0+492	7.3	0+499	100					
1159	S7	STD	820	BWP	0+499	7.3	0+506	100					
1160	S7	STD	820	BWP	0+506	7.3	0+514	100				A	Anomalous signal from 0.0-2.8m.
1161	S7	58	820	BWP	0+514	3.3	0+517	100					
1162	S7	STD	820	BWP	0+517	7.3	0+524	100					
1163	S7	STD	820	BWP	0+524	7.3	0+532	100					
1164	S7	STD	820	BWP	0+532	7.3	0+539	100				A	Anomalous signal from 4.2-7.3m.
1165	S7	STD	820	BWP	0+539	7.3	0+546	100					
1166	S7	STD	820	BWP	0+546	7.3	0+554	100					
1167	S7	STD	820	BWP	0+554	7.3	0+561	100					
1168	S7	STD	820	BWP	0+561	7.3	0+568	100					
1169	S7	STD	820	BWP	0+568	7.3	0+576	100					
1170	S7	STD	820	BWP	0+576	7.3	0+583	100					
1171	S7	STD	820	BWP	0+583	7.3	0+590	100					
1172	S7	STD	820	BWP	0+590	7.3	0+598	100					
1173	S7	STD	820	BWP	0+598	7.3	0+605	100					
1174	S7	STD	820	BWP	0+605	7.3	0+612	100					
1175	S7	STD	820	BWP	0+612	7.3	0+620	100					
1176	S7	STD	820	BWP	0+620	7.3	0+627	100					
1177	S7	STD	820	BWP	0+627	7.3	0+634	100					
1178	S7	STD	820	BWP	0+634	7.3	0+641	100					
1179	S7	STD	820	BWP	0+641	7.3	0+649	100					
1180	S7	STD	820	BWP	0+649	7.3	0+656	100					
1181	S7	STD	820	BWP	0+656	7.3	0+663	100					
1182	S7	STD	820	BWP	0+663	7.3	0+671	100					
1183	S7	STD	820	BWP	0+671	7.3	0+678	100					
1184	S7	STD	820	BWP	0+678	7.3	0+685	100					

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
1185	S7	STD	820	BWP	0+685	7.3	0+693	100					
1186	S7	59	820	BWP	0+693	7.3	0+700	100					
1187	S7	41	820	BWP	0+700	7.3	0+707	100					
1188	S7	41	820	BWP	0+707	7.3	0+715	100					
1189	S7	41	820	BWP	0+715	7.3	0+722	100					
1190	S7	41	820	BWP	0+722	7.3	0+729	100					
1191	S7	41	820	BWP	0+729	7.3	0+737	100					
1192	S7	41	820	BWP	0+737	7.3	0+744	100					
1193	S7	41	820	BWP	0+744	7.3	0+751	100					
1194	S7	41	820	BWP	0+751	7.3	0+759	100					
1195	S7	N/A	820	BWP	N/A	4.0	N/A	N/A					Not listed in pipe laying schedules. Data indicates 4.0m SP.
1196	S7	60	820	BWP	0+759	5.0	0+765	100					6.4m SP in pipe laying schedules. Data indicates 5.0m SP.
1197	S7	61	820	BWP	0+765	2.5	0+768	100					
1198	S7	62	820	BWP	0+768	7.5	0+775	100					
1199	S7	63	820	BWP	0+775	4.0	0+002	B					Equation: 0+776.776AH=0+000.000BK.
1200	S7	41	820	BWP	0+002	4.0	0+009	100					7.3m STD in pipe laying schedules. Data indicates 4.0m SP.
1201	S7	41	820	BWP	0+009	7.3	0+017	100					
1202	S7	41	820	BWP	0+017	3.1	0+024	100					7.3m STD in pipe laying schedules. Data indicates 3.1m SP.
1203	S7	64	820	BWP	0+024	1.2	0+027	100					3.1m SP in pipe laying schedules. Data indicates 1.2m SP.
1204	S7	65	820	BWP	0+027	7.3	0+028	100					1.2m SP in pipe laying schedules. Data indicates 7.3m STD.
1205	S7	66	820	BWP	0+028	7.3	0+032	100					3.8m SP in pipe laying schedules. Data indicates 7.3m STD.
1206	S7	41	820	BWP	0+032	7.3	0+039	100					Casing begins @ Station 0+032.
1207	S7	41	820	BWP	0+039	7.3	0+047	100					Cased pipe.
1208	S7	41	820	BWP	0+047	7.3	0+054	100					Cased pipe.
1209	S7	41	820	BWP	0+054	7.3	0+061	100					Cased pipe.
1210	S7	41	820	BWP	0+061	7.3	0+068	100					Cased pipe.
1211	S7	41	820	BWP	0+068	7.3	0+076	100					Cased pipe.
1212	S7	41	820	BWP	0+076	7.3	0+083	100					Casing ends @ Station 0+082.
1213	S7	67	820	BWP	0+083	7.3	0+087	100					3.8m SP in pipe laying schedules. Data indicates 7.3m cased STD.
1214	S7	68	820	BWP	0+087	1.2	0+088	B					EL in data.
1215	S7	41	820	BWP	0+088	3.8	0+095	100					7.3m STD in pipe laying schedules. Data indicates 3.8m SP.
1216	S7	41	820	BWP	0+095	7.3	0+103	100					
1217	S7	69	820	BWP	0+103	2.2	0+105	100					
1218	S7	70	820	BWP	0+105	2.0	0+107	B				OL	500mm OL @ Station 0+106.
1219	S7	71	820	BWP	0+107	1.0	0+108	100					
1220	S7	68	820	BWP	0+108	1.2	0+109	B					
1221	S7	44	820	BWP	0+109	7.3	0+117	100					
1222	S7	STD	820	BWP	0+117	7.3	0+123	100					
1223	S7	72	820	BWP	0+123	6.7	0+131	100					
1224	S7	STD	820	BWP	0+131	7.3	0+138	100					
1225	S7	STD	820	BWP	0+138	7.3	0+145	100					
1226	S7	STD	820	BWP	0+145	7.3	0+153	100					
1227	S7	STD	820	BWP	0+153	7.3	0+160	100					
1228	S7	STD	820	BWP	0+160	7.3	0+167	100					
1229	S7	73	820	BWP	0+167	1.8	0+169	100					
1230	S7	74	820	BWP	0+169	1.2	0+170	B					
1231	S7	STD	820	BWP	0+170	7.3	0+178	100					
1232	S7	STD	820	BWP	0+178	7.3	0+185	100					
1233	S7	STD	820	BWP	0+185	7.3	0+192	100					
1234	S7	STD	820	BWP	0+192	7.3	0+199	100					
1235	S7	STD	820	BWP	0+199	7.3	0+207	100					
1236	S7	STD	820	BWP	0+207	7.3	0+214	100					
1237	S7	STD	820	BWP	0+214	7.3	0+221	100					
1238	S7	STD	820	BWP	0+221	7.3	0+229	100					
1239	S7	STD	820	BWP	0+229	7.3	0+236	100					
1240	S7	STD	820	BWP	0+236	7.3	0+243	100					
1241	S7	STD	820	BWP	0+243	7.3	0+251	100					
1242	S7	STD	820	BWP	0+251	1.2	0+258	100					7.3m STD in pipe laying schedules. Data indicates 1.2m SP.
1243	S7	75	820	BWP	0+258	7.3	0+264	100					5.9m SP in pipe laying schedules. Data indicates 7.3m STD.
1244	S7	76	820	BWP	0+264	7.3	0+265	B					1.2m SP in pipe laying schedules. Data indicates 7.3m STD.
1245	S7	STD	820	BWP	0+265	7.3	0+272	100					
1246	S7	STD	820	BWP	0+272	7.3	0+280	100					
1247	S7	STD	820	BWP	0+280	7.3	0+287	100					
1248	S7	77A	820	BWP	0+287	6.1	0+293	100					
1249	S7	77	820	BWP	0+293	0.6	0+294	B					
1250	S7	78	820	BWP	0+294	0.9	0+295	B					
1251	S6	N/A	820	N/A	0+295	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
1252	S6	N/A	820	N/A	N/A	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.

Comox Valley Regional District

750/820-Millimetre Courtenay Pump Station Force Main

Electromagnetic Inspection Results

Pipe Sections that Exhibit Electromagnetic Anomalies Consistent with Broken Wire Wraps

Pure Reference Number	Contract Number	Piece Number	Diameter (millimetres)	Pipe Type	Low Station	Pipe Length (metres)	High Station	Reported Class	Break Region Location (metres from Low Station)	Number of Broken Wire or Bar Wraps by Region	Total Number of Broken Wire or Bar Wraps	Layout	Comments
1253	S6	N/A	820	N/A	N/A	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
1254	S6	N/A	820	N/A	N/A	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
1255	S6	N/A	820	N/A	N/A	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
1256	S6	N/A	820	N/A	N/A	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
1257	S6	N/A	820	N/A	N/A	2.0	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
1258	S6	N/A	820	N/A	N/A	7.3	N/A	N/A					Pipe length reported with less certainty due to change in pipeline flow. Drawings and Pipe Manufacturing Details were not available for Contract S6.
Extraction: Towards the Comox Valley Water Pollution Control Centre													