WEST ORANGE COUNTY WATER BOARD

CONDITION ASSESSMENT REPORT FOR OC-9 & OC-35 PIPELINES

CONDITION ASSESSMENT REPORT | DECEMBER, 2025

Prepared by:

ARDURRA

Ardurra Group, Inc.
3737 Birch St, Suite 250
Newport Beach, CA 92660
TBPE Firm No. F-10053

REGISTERED PROFESSIONAL ENGINEER
JAMIE L. FAGNANT
No. C78967
CIVIL
STATE OF CALIFORNIA

Dated: 12/29/2025

TABLE OF CONTENTS

SECTION 1 LIST OF TERMS.. 1-1

SECTION 2 PROJECT BACKGROUND.. 2-1

2.1 Introduction 2-1

SECTION 3 CONDITION INSPECTION METHODOLOGY 3-1

3.1 p-CAT™ Overview 3-1
3.2 Implementation 3-1
3.3 Results... 3-1

SECTION 4 RECOMMENDATIONS 4-1

4.1 Recommendation Introduction 4-1
4.2 Recommendations for Repair and Destructive Testing 4-2
4.3 Recommendations for Additional Monitoring 4-8
4.4 Potential Implementation of Cathodic Protection 4-8
4.5 Recommendations for Future Testing, Lifecycle Analysis 4-9

FIGURES

Figure 1 Site Overview 2-2
Figure 2 OC-9 Dale St. 4-3
Figure 3 OC-9 Newland St. 4-4
Figure 4 OC-35 Katella Ave Section 1 4-5
Figure 5 OC-35 Katella Ave Section 2 4-6
Figure 6 OC-35 Knott St 4-7

TABLES

Table 4-1 Lifecycle Analysis.. Error! Bookmark not defined.

APPENDIX A: HYDROMAX P-CAT™ INSPECTION WORKPLAN
APPENDIX B: HYDROMAX PIPELINE CONDITION ASSESSMENT REPORT
APPENDIX C: ENGINEER’S OPINION OF PROBABLE CONSTRUCTION COST – DESTRUCTIVE TESTING
APPENDIX D: ENGINEER’S OPINION OF PROBABLE CONSTRUCTION COST – FULL REPLACEMENT

SECTION 1 LIST OF TERMS

Term	Definition
p-CAT™	Pipeline Condition Assessment Technology
AWWA	American Water Works Association
BWP	Bar Wrapped Pipe
CML&C WSP	Cement Mortar Lined & Coated Welded Steel Pipe
Anomaly	Signal in the pipeline identified in the collected transient traces that does not correspond to a known feature on the pipeline
OC-9	West Orange County Water Board Pipeline from Katella Ave to Edinger Ave along Dale St and Newland St.
OC-35	West Orange County Water Board pipeline from Katella Ave to Hazard Ave along Knott Ave, Edwards St, Springdale St, and misc.
WOCWB	West Orange County Water Board
Hydromax USA (HUSA)	Subconsultant that completed the p-CAT™ Assessment

SECTION 2 PROJECT BACKGROUND

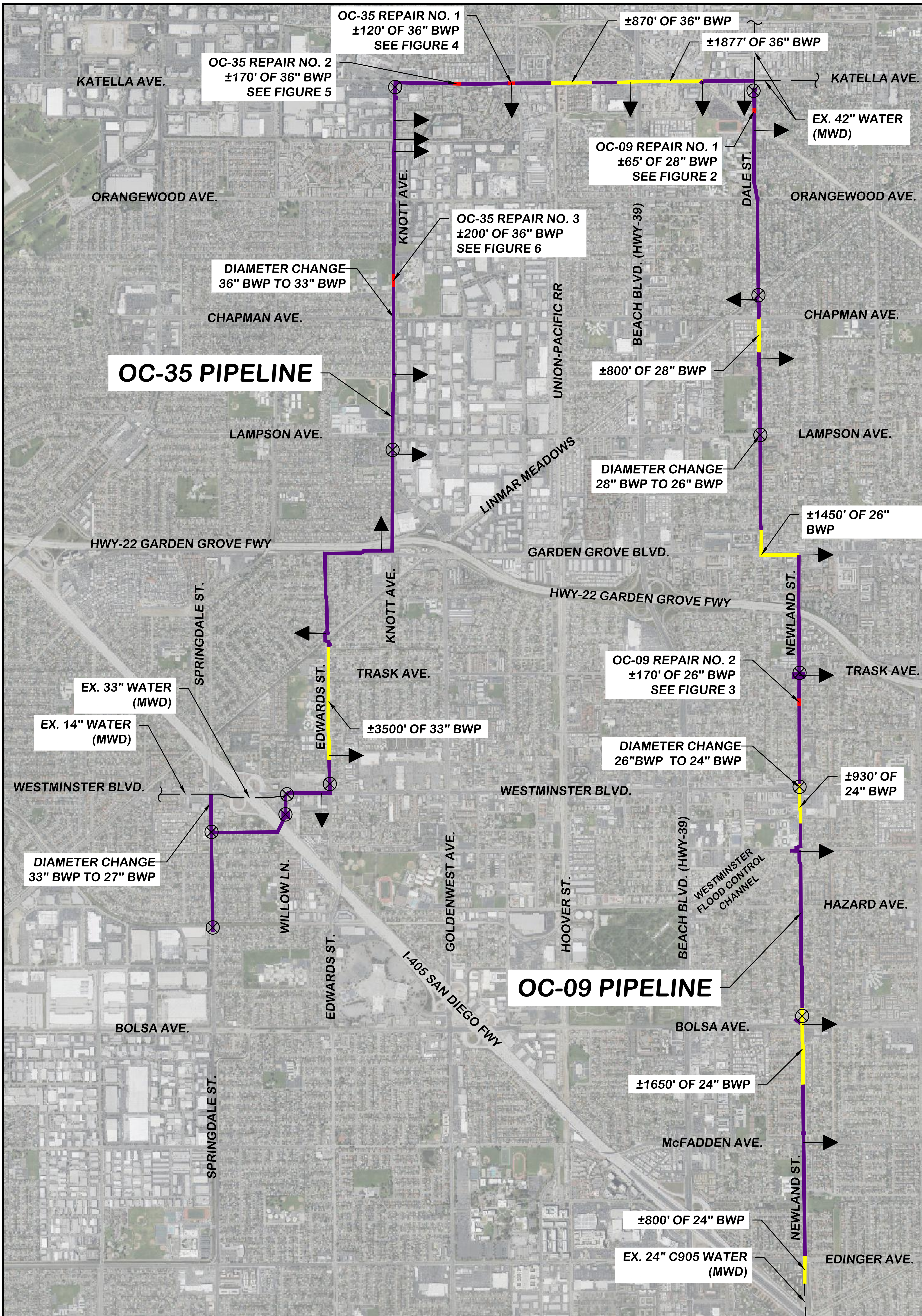
2.1 Introduction

The City of Huntington Beach (City) is the lead agency in the West Orange County Water Board (WOCWB) and manages operations and capital improvement projects necessary to maintain the WOCWB's pipelines. This report details the results of a screening level condition assessment and subsequent recommendations for further inspection and repair. Two pipelines were assessed during this process. An overview of these two pipelines are shown in **Figure 1**.

The existing OC-9 pipeline was constructed between 1955 and 1958 and consists of 5.2 miles of 16", 24", 26", and 28" cement mortar lined and coated steel pipe with electrically discontinuous rubber gasketed joints. This pipeline was scheduled to be retrofitted with cathodic protection in 2024 and 2025 but due to identification of smaller diameter portions of the pipeline during the initial data collection period an alternate approach of condition assessment screening was identified as preferable. The selected condition assessment screening technology was inspection by the p-CAT^{TM} inspection method as employed by Hydromax USA (HUSA) with data assessed by Pipeline Inspection & Assessment (PIA) and Detection Services Party Limited (DS). To take advantage of an economy of scale, the WOCWB elected to also assess the OC-35 pipeline constructed around 1963 consisting of 5.5 miles of 27", 33", and 36" cement mortar lined and coated steel pipe, with a portion of this line under I-405 replaced with 30" cement mortar lined and coated steel pipe in 2017.

During development of the condition assessment work plan it was noted that the record drawings indicated two potential materials for the pipeline construction, AWWA C200 Steel Water Pipe, or AWWA C303 Bar Wrapped Steel Cylinder Pipe. Both very similar in construction, a steel cylinder, concrete mortar lined and coated, with reinforcement embedded in the layer of cement coating outside of the steel cylinder. Ardurra reached out to Northwest Pipe who confirmed that the joint details included in the OC-9 and OC-35 record drawings are indicative of these pipe types. Additionally, based on the depth of bury, joint details, and year of construction, Northwest Pipe indicated that the pipeline material is NOT expected to be AWWA C301, Prestressed Concrete Pressure Pipe.

The p-CAT^{TM} assessment models the data collected against a theoretical model of the pipe based on available record data. Theoretical models of the pipelines were identified based on record drawing information and AWWA standards to include steel cylinder thickness and weight and quantity of reinforcement (both provided in the record drawings), and thicknesses of cement mortar lining and coating (derived from AWWA standards). These values were developed for each size of pipeline evaluated. Because the p-CAT^{TM} assessment compares the data collected against this theoretical model, a deviation in the theoretical model from actual field conditions can yield reported results that are consistently thicker or thinner than actual field conditions.



November 21, 2025 Y:\POW\Projects\ARDU (0258)\0059 City of HB OC-9\Docs\Condition Assessment Report\Condition Assessment Exhibit.dwg

CONDITION ASSESSMENT REPORT FOR OC-09 & OC-35 PIPELINES

FIGURE 1

0 2000 4000
SCALE: FEET

ARDURRA
COLLABORATE. INNOVATE. CREATE.

LEGEND

- OC-9, OC-35 PIPE ALIGNMENTS
- REPLACEMENT RECOMMENDED
- RECOMMEND FURTHER INVESTIGATION
- AIR VALVE
- GATE VALVES

SECTION 3 CONDITION INSPECTION METHODOLOGY

3.1 p-CAT™ Overview

p-CAT™ is a fluid transient based pipeline condition assessment technology. It is efficient because transient data collected in a few seconds can analyze pipe integrity across thousands of feet of pipeline down to a granular level of about thirty feet. A controlled transient pressure wave (approx. 5-9 psi) is introduced into the pipe system by artificially accelerating or decelerating fluid in the water column. The transient is generated by rapid closure of a spring-loaded check valve temporarily installed at an air valve connection. The transient pressure waves can travel at high speed inside a fluid-filled pipe and reflections occur when the wave encounters any physical anomalies along the pipe. Anomalies in the pressure wave can be the result of air pockets, sedimentation, an unknown structural feature such as an unrecorded repair, or most importantly, pipeline deterioration. Reflections are measured by pressure transducers installed at both ends of the pipe segment, the data is stored manually into Excel spreadsheets and eventually interpreted by HUSA signal analysts to assess the condition of the pipe.

3.2 Implementation

Ardurra coordinated with the City's Engineering and Operations divisions and HUSA to identify proposed access points to the pipeline, introduce pressure transients and monitoring devices into the pipeline water columns, and identify the traffic control needs. This process entailed an initial coordination meeting, a preassessment field visit to verify proposed access locations, and submission of a Condition Assessment Work Plan by HUSA to Ardurra and the City (included as **Appendix A)**.

Inspection proceeds along each pipeline with the pressure transient introduced three times at each injection location, each spaced approximately 1,500 feet apart and located at existing air valve locations. At each pressure transient injection location, the pressure transient was introduced three times and monitored at the upstream and downstream access points. City Operations staff removed and replaced the air valves head and established traffic control at each inspection location. The inspections were completed over the span of three days, May 6th through May 8th, 2025.

3.3 Results

The p-CAT™ assessment models the data collected against a theoretical model of the pipe based on available record data. Because the OC-9 and OC-35 pipelines have not experienced failures and are expected to be in reasonably good condition, when the results consistently show a thicker or thinner wall thickness than expected that is indicative that the pipe installed was different than available record information. When one segment of pipe shows significantly less thickness than the surrounding areas, that is an area where there could be potential concrete/steel deterioration, or it could be an air pocket or sedimentation. Portions of the pipeline having a marked decrease in reported thickness from adjacent sections of the pipeline are shown in red on **Figure 1**. Additional longer portions of the pipelines showing a sustained lower reported thickness are shown in yellow on **Figure 1**. The complete condition assessment raw results can be found in **Appendix B** – Hydromax p-CAT^{TM} Pipeline Condition Assessment.

SECTION 4 RECOMMENDATIONS

4.1 Recommendation Introduction:

A p-CAT^{TM} assessment is a condition assessment screening tool. The results of the assessment can assist the WOCWB in optimizing Capital Improvement Planning (CIP) by identifying potential areas of degradation, sedimentation or air pockets. While a screening level assessment cannot confirm a pipeline is in good condition (i.e. localized defects may still occur), it is a useful tool in allocating CIP money to the areas of the pipeline(s) most likely to be experiencing degradation.

As mentioned in the introduction, the p-CAT^{TM} assessment models the data collected against a theoretical model of the pipe based on available record data. The model developed for the OC-9 and OC-35 inspections was based on steel cylinder thickness (and bar thickness as applicable) as noted on the record drawings, and applicable current AWWA standards for the cement mortar lining and coating. The HUSA inspection returned results of a thinner wall thickness than expected along the majority of the pipeline. It is considered likely that the pipeline installed had a thinner concrete mortar lining and coating than current AWWA standards for the following two main reasons: the OC-9 and OC-35 pipelines have not experienced main line failures and are expected to be in reasonably good condition, and secondly, the reported thickness of the pipeline is consistent. This consistency of results along with the absence of failures indicates that the results likely reflect the as-built condition of the pipelines.

However, when one segment of pipe shows significantly less thickness than the surrounding areas, that is an area where there could be potential concrete/steel deterioration, or it could be an air pocket or sedimentation. Destructive testing of those sections would allow the WOCWB to mitigate potential deterioration and provide physical data on the remaining pipeline that could help inform further investigations.

4.2 Recommendations For Repair and Destructive Testing

Five sections of pipeline, approximately 120 feet to 200 feet in length were identified as significantly thinner than adjacent pipe and are recommended for destructive testing. Destructive testing entails full replacement of these pipeline sections with new AWWA C200 Steel Cylinder Pipe. It is recommended to reserve at least one stick of pipe from each of these locations for testing. The testing will consist of the following items: confirm the pipeline condition, cement mortar lining and coating thicknesses, the steel can thickness, bar diameter if applicable, and to determine if the pipe is AWWA C200 Steel Cylinder Pipe or AWWA C303 Bar Wrapped Steel Pipe. The information gathered from this destructive testing can be utilized to inform a refinement of the pipeline inspection and increase accuracy of future inspections. These locations are shown in red on **Figure 1** and in more detail in **Figures 2 through 6**.

The following pipe sections are recommended to be replaced with at least one pipe stick to be retained for analysis:

Sections recommended for repair/testing on OC-9:

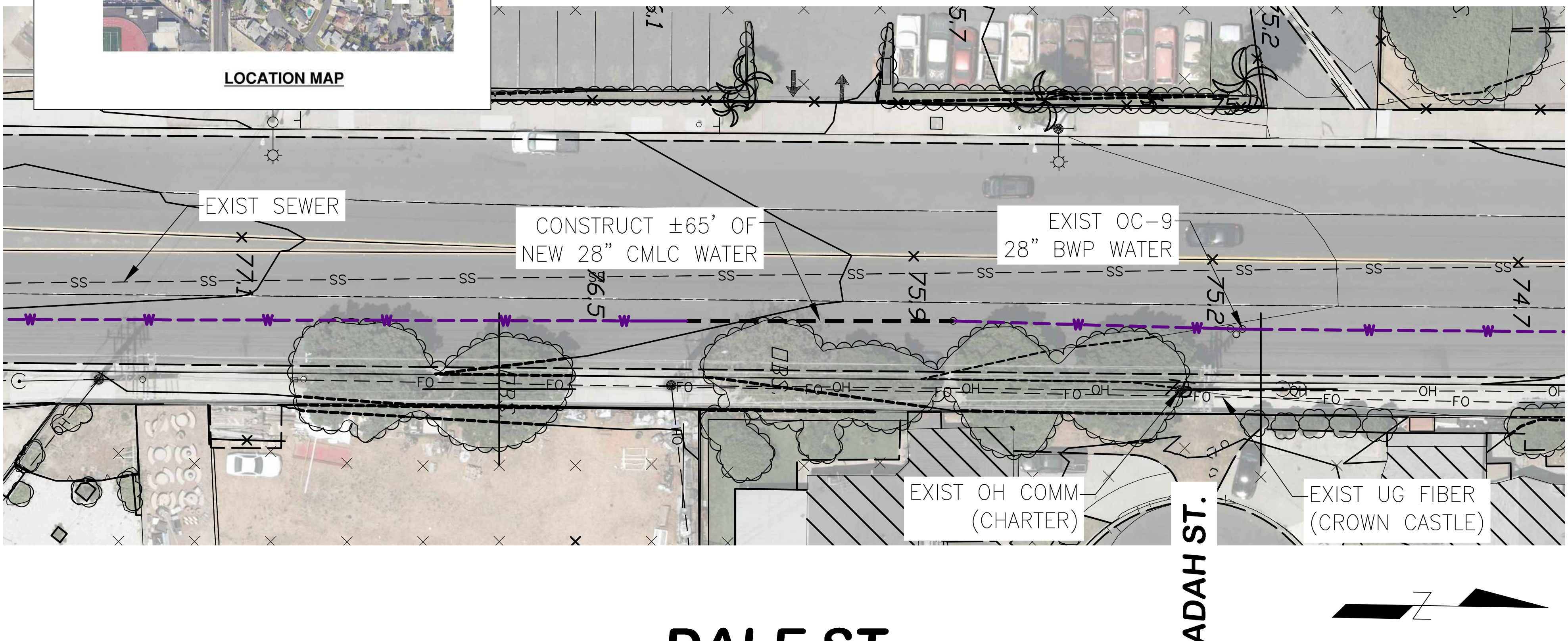
- **Figure 2** – Approximately 65 LF of 28" Dia steel pipe Along Dale Street
- **Figure 3** – Approximately 170 LF of 26" Dia steel pipe Along Newland Street

Sections recommended for repair/testing on OC-35:

- **Figure 4** – Approximately 120 LF of 36" steel pipe Along Katella Avenue
- **Figure 5** – Approximately 170 LF of 36" steel pipe Along Katella Avenue
- **Figure 6** – Approximately 200 LF of 36" steel pipe Along Knott Avenue

An engineer's opinion of probable construction cost to perform these repairs is $634,000 and is detailed in Appendix C.

LOCATION MAP



DALE ST.

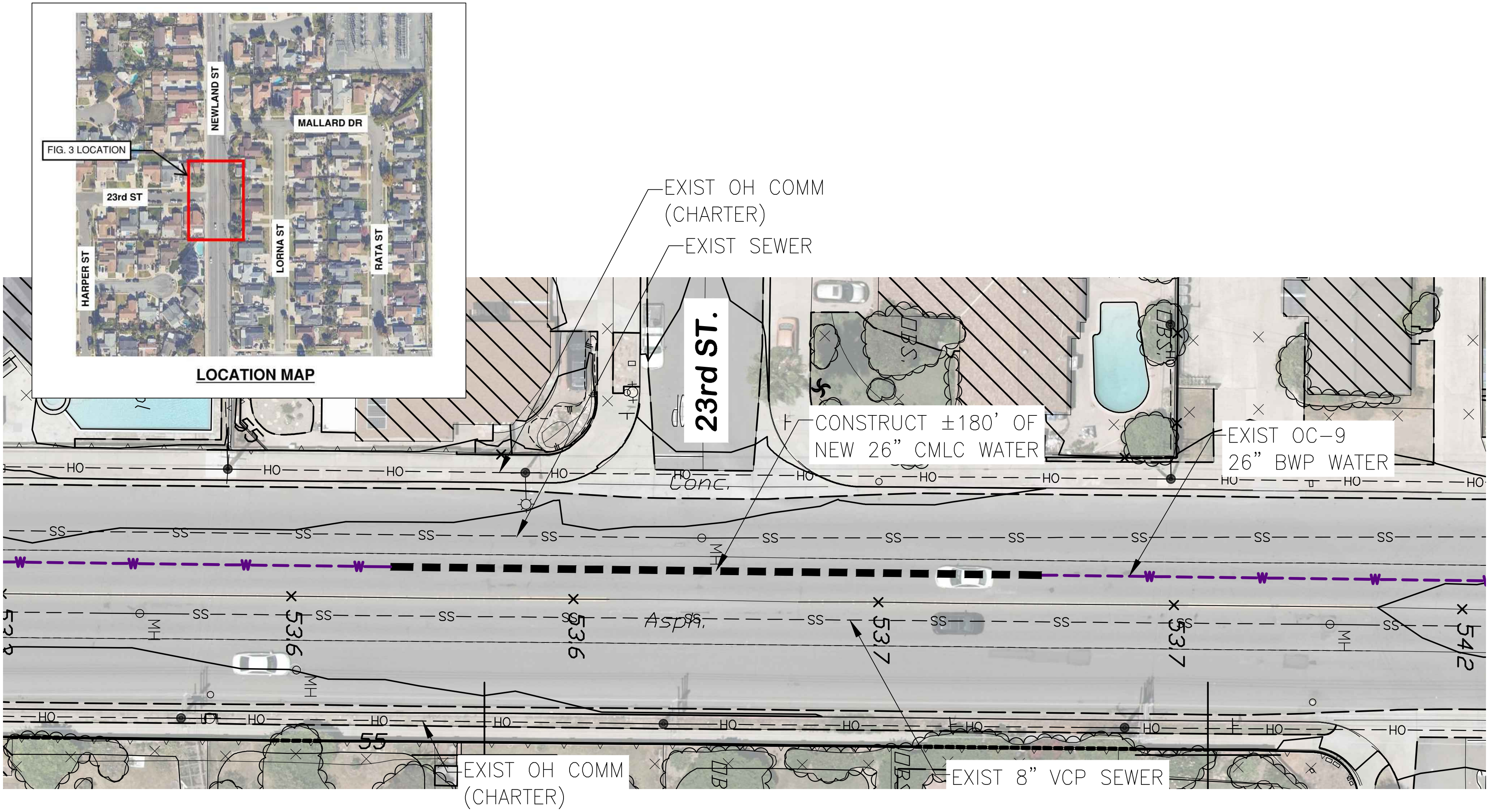
0 40 80
SCALE: FEET

ARDURRA
COLLABORATE. INNOVATE. CREATE.
14271 Danielson Street
Poway, California 92064
(858) 413-2400
www.Ardurra.com

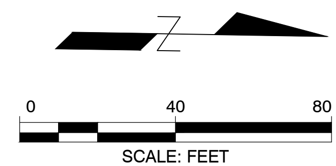
CITY OF HUNTINGTON BEACH - CONDITION ASSESSMENT OF OC-09 & OC-35

OC-09 REPAIR NO. 1

FIGURE
2



NEWLAND ST.



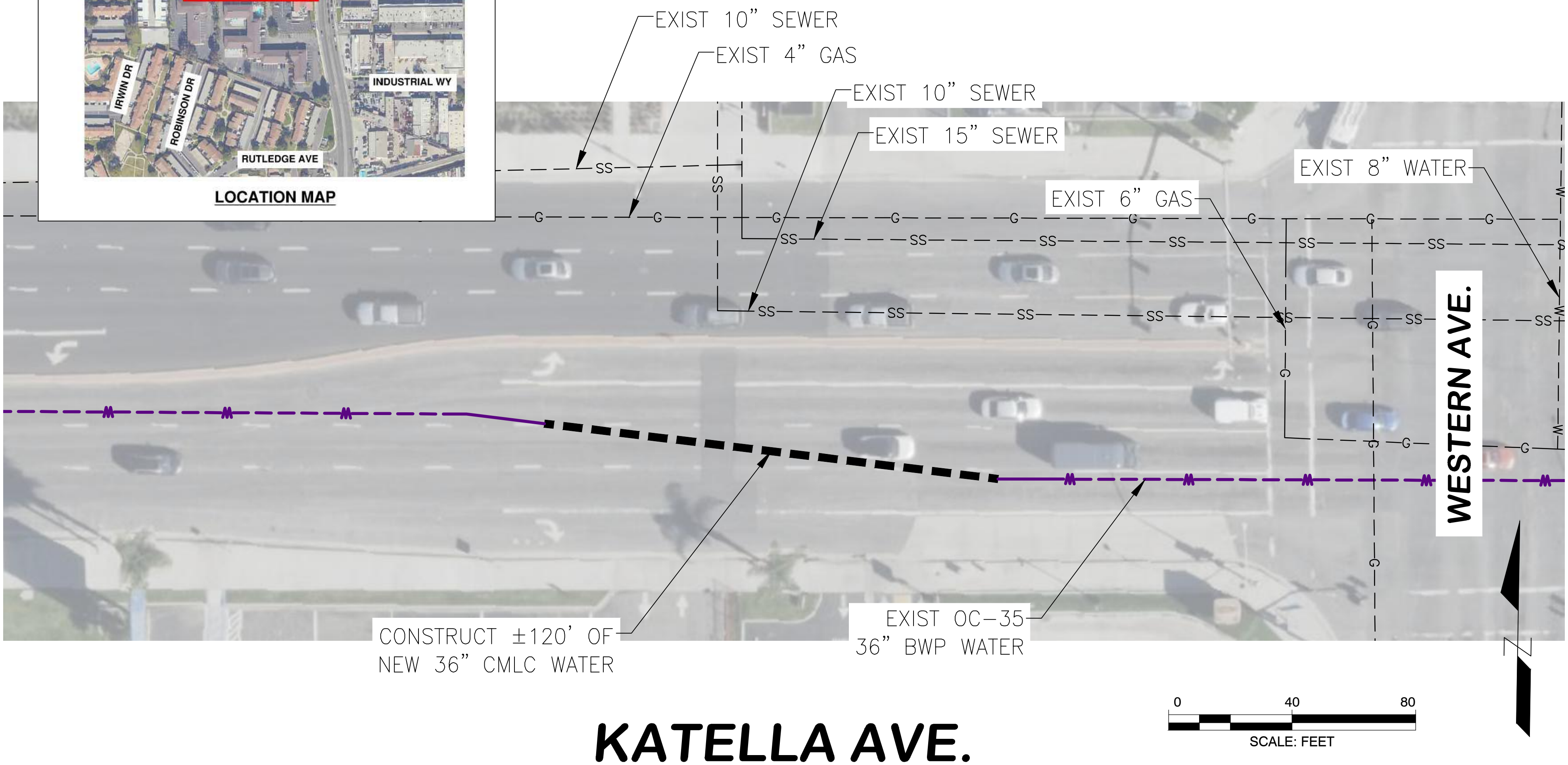
ARDURRA
COLLABORATE. INNOVATE. CREATE.
14271 Danielson Street
Poway, California 92064
(858) 413-2400
www.Ardurra.com

CITY OF HUNTINGTON BEACH - CONDITION ASSESSMENT OF OC-09 & OC-35

OC-09 REPAIR NO. 2

FIGURE
3

LOCATION MAP



ARDURRA
COLLABORATE. INNOVATE. CREATE.
14271 Danielson Street
Poway, California 92064
(858) 413-2400
www.Ardurra.com

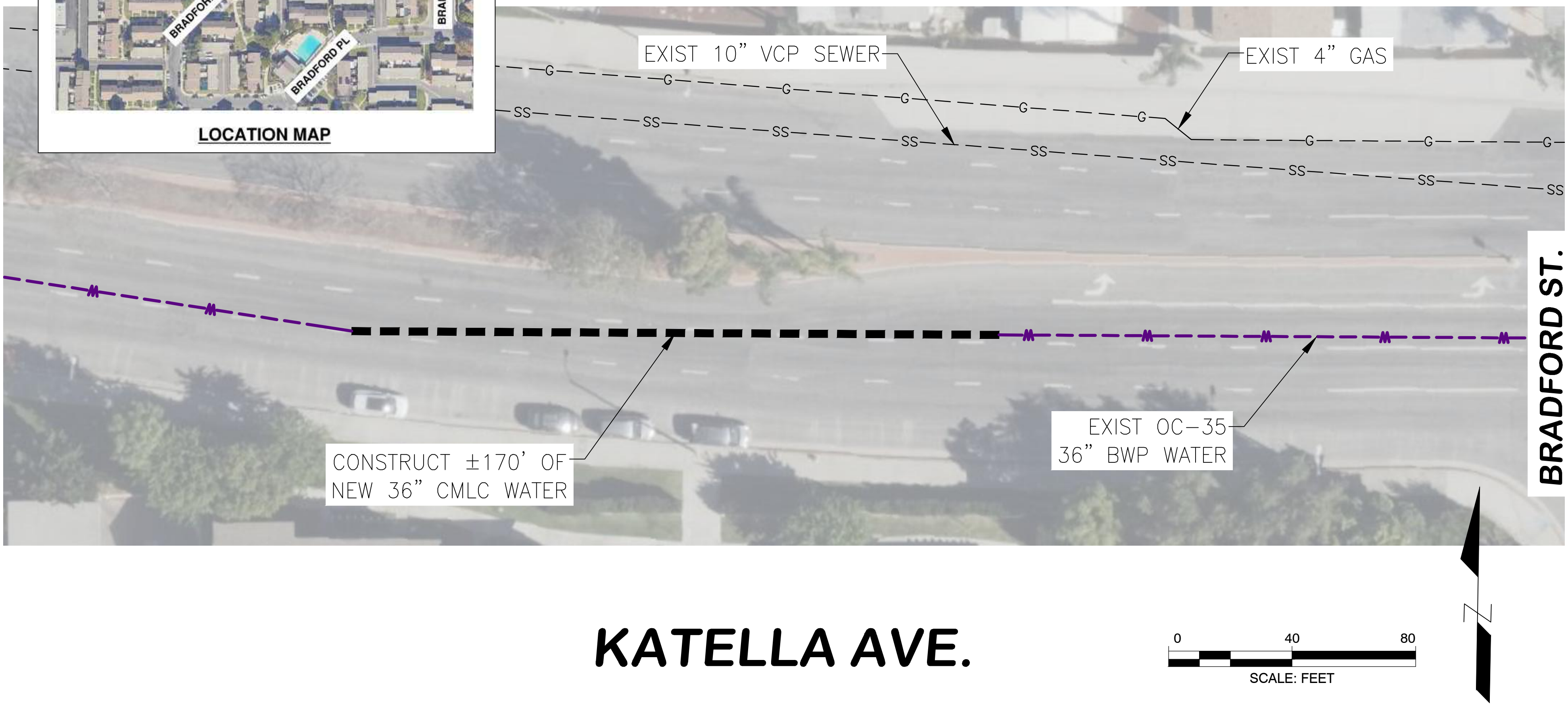
CITY OF HUNTINGTON BEACH - CONDITION ASSESSMENT OF OC-09 & OC-35

OC-09 REPAIR NO. 3

FIGURE

4

LOCATION MAP



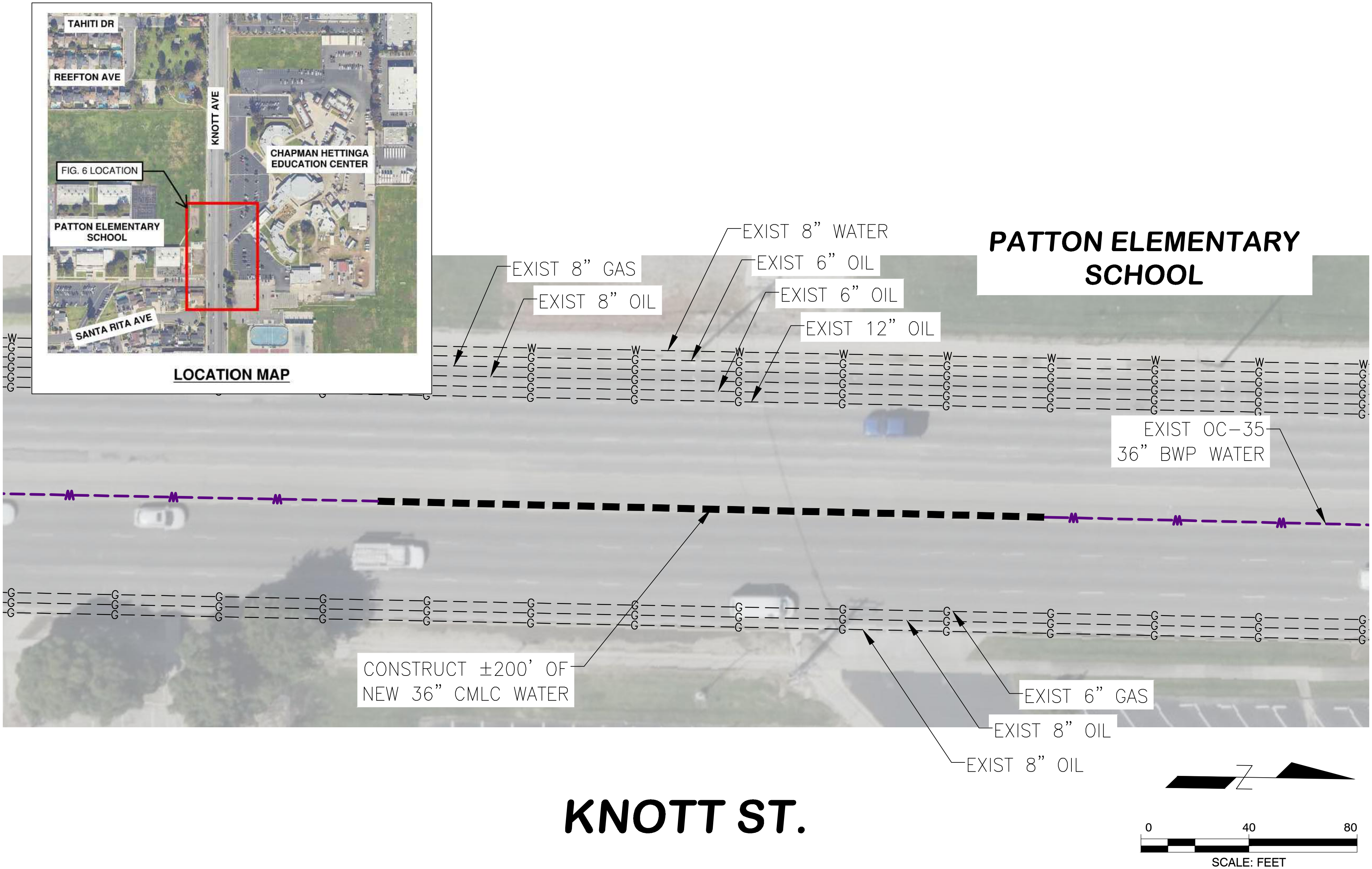
ARDURRA
COLLABORATE. INNOVATE. CREATE.
14271 Danielson Street
Poway, California 92064
(858) 413-2400
www.Ardurra.com

CITY OF HUNTINGTON BEACH - CONDITION ASSESSMENT OF OC-09 & OC-35

OC-09 REPAIR NO. 4

FIGURE

5



ARDURRA
COLLABORATE. INNOVATE. CREATE.

14271 Danielson Street
Poway, California 92064
(858) 413-2400
www.Ardurra.com

CITY OF HUNTINGTON BEACH - CONDITION ASSESSMENT OF OC-09 & OC-35

OC-09 REPAIR NO. 5

FIGURE

6

4.3 Recommendations for Additional Monitoring

Upon detailed inspection of the portions of pipeline selected for repair/destructive testing, updated theoretical pipe models (actual metal and cement mortar thicknesses from the destructive testing) can be provided to HUSA for reanalysis by PIA/DS. HUSA indicated that they would perform one reanalysis at no cost.

The repair/ destructive testing focused on sections with a localized reported thinner wall section that could be indicative of pipeline degradation. Replacement of these sections mitigates the areas of greatest concern. However, there are several more sustained lengths of pipeline that were reported by HUSA to have thinner wall sections. It is recommended that these sections be evaluated based on the updated data analysis obtained through reevaluation following update of the theoretical pipe models developed during the proposed destructive testing. These sections are shown in yellow on Figure 1 and summarized below.

- ± 3380 LF of 24" BWP Along Newland St.
- ± 1450 LF of 26" BWP Along Garden Grove Blvd.
- ± 800 LF of 28" BWP Along Dale St.
- ± 3500 LF of 33" BWP Along Edwards St.
- ± 1747 LF of 36" BWP Along Katella Ave.

While the longer sustained lengths of these results suggest that they were installed with pipe that was consistent (i.e., they might have been from a different run of pipe than surrounding pipeline), it is recommended that future testing and repair consider targeting these areas both to confirm condition and pipe cross sectional data in order to refine testing results, and because these if these areas have thinner cross sections they would have a lower factor of safety from corrosion and degradation.

4.4 Potential Implementation of Cathodic Protection

Installation of cathodic protection involves bonding electrically discontinuous pipeline segments via the installation of bonding wires "jumping" over joints in the pipeline. This can be accomplished via manned entry into the pipelines and the welding of bonding wires to either side of the joints. This approach is not recommended for the OC-9 pipeline in order to prioritize worker safety due to the smaller diameter of the pipeline (24" to 28" with sections at valves necked down to 16"). Manned entry to perform internal joint bonding could be considered for the larger OC-35 pipeline, however, it is recommended that the type of pipeline be determined through destructive testing prior to considering implementing cathodic protection.

As noted previously, the record drawings indicated two potential materials for the pipeline construction, AWWA C200 Steel Water Pipe, or AWWA C303 Bar Wrapped Steel Cylinder Pipe. Both are very similar in construction, a steel cylinder, concrete mortar lined and coated, with reinforcement embedded in the layer of cement coating outside of the steel cylinder. However, AWWA C303 Bar Wrapped Steel Cylinder Pipe relies both on the cross sectional area of a steel cylinder and on the cross-sectional area of steel of a bar spirally wound around the steel cylinder and a thin layer of concrete to provide tensile reinforcement for the pipeline. Since the bar wrapping is electrically insulated from the steel canister by a layer of concrete mortar, this portion of steel would not be rendered electrically continuous via internal joint bonding and therefore would not be protected from corrosion via cathodic protection. For this reason it is NOT recommended to install cathodic protection on OC-35 if it is found to consist of AWWA C303 Bar Wrapped Steel Cylinder pipe during destructive testing. It is only recommended to consider internal joint bonding and installation of cathodic protection if the pipeline is confirmed to consist of AWWA C200 Steel Water Pipe during destructive testing.

4.5 Recommendations for Future Testing, Lifecycle Analysis

It is recommended to retest both pipelines every five years. It is assumed that a similar level of repair to that outlined herein may be required every ten years. This expenditure is compared to an overall pipeline replacement cost in the below table extended to the year 2050. This table is presented in 2025 dollars. No escalation factor or allowance for inflation has been incorporated into these values.

Table 4-1 – Lifecycle Analysis

Comparison of Replacement vs Repair and Testing Costs for OC-9 and OC-35

Year	Replacement Description	Replacement Costs	Repair and Testing Description	Repair and Testing
2026	Design (15% of Construction)	$10,500,000	Destructive Testing	$620,000
2027	Construction	$23,400,000		
2028	Construction	$23,400,000		
2029	Construction	$23,400,000		
2030			Reinspection	$500,000
2035			Reinspection and Destructive Testing	$1,120,000
2040			Reinspection	$500,000
2045			Reinspection and Destructive Testing	$1,120,000
2050			Reinspection	$500,000
Total	Total Replacement	$80,700,000	Total Reinspection and Destructive Testing	$4,360,000

APPENDIX A: HYDROMAX P-CAT^{TM} PIPELINE CONDITION ASSESSMENT WORK PLAN

HYDROMAX USA
Advanced Water, Wastewater and Gas Data Collection

Huntington Beach Feeder Lines

Work Plan:

Condition Assessment of OC9 24-inch to 28-inch & OC35 27-inch to 36-inch BWP Water Pipelines using p-CAT™

February 14, 2025

Prepared For:
Ardurra

Prepared by:
Hydromax USA

OVERVIEW

p-CAT^TM testing will be performed on a total of 11.4 miles of Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) water mains in Garden Grove and Westminster, CA. Assessment of OC-9 will cover up to 5.2 miles of 24-inch to 28-inch BWP pipe from Dale Ave and Katella Ave south to Newland St and Edinger Ave (Fig. 1). The ability to collect usable data between McFadden Ave and the southern end of project scope (Fig. 1, outlined in black) may be compromised by a roughly 500' segment of assumed PVC in this segment. Assessment of OC-35 will cover 6.2 miles of 24-inch to 28-inch BWP pipe from Katella Ave and Dale Ave west and south to Springdale St and Glenwood Dr, including a branch of OC-35 north that extends north from Springdale St and Mahogany Ave (Fig. 1).

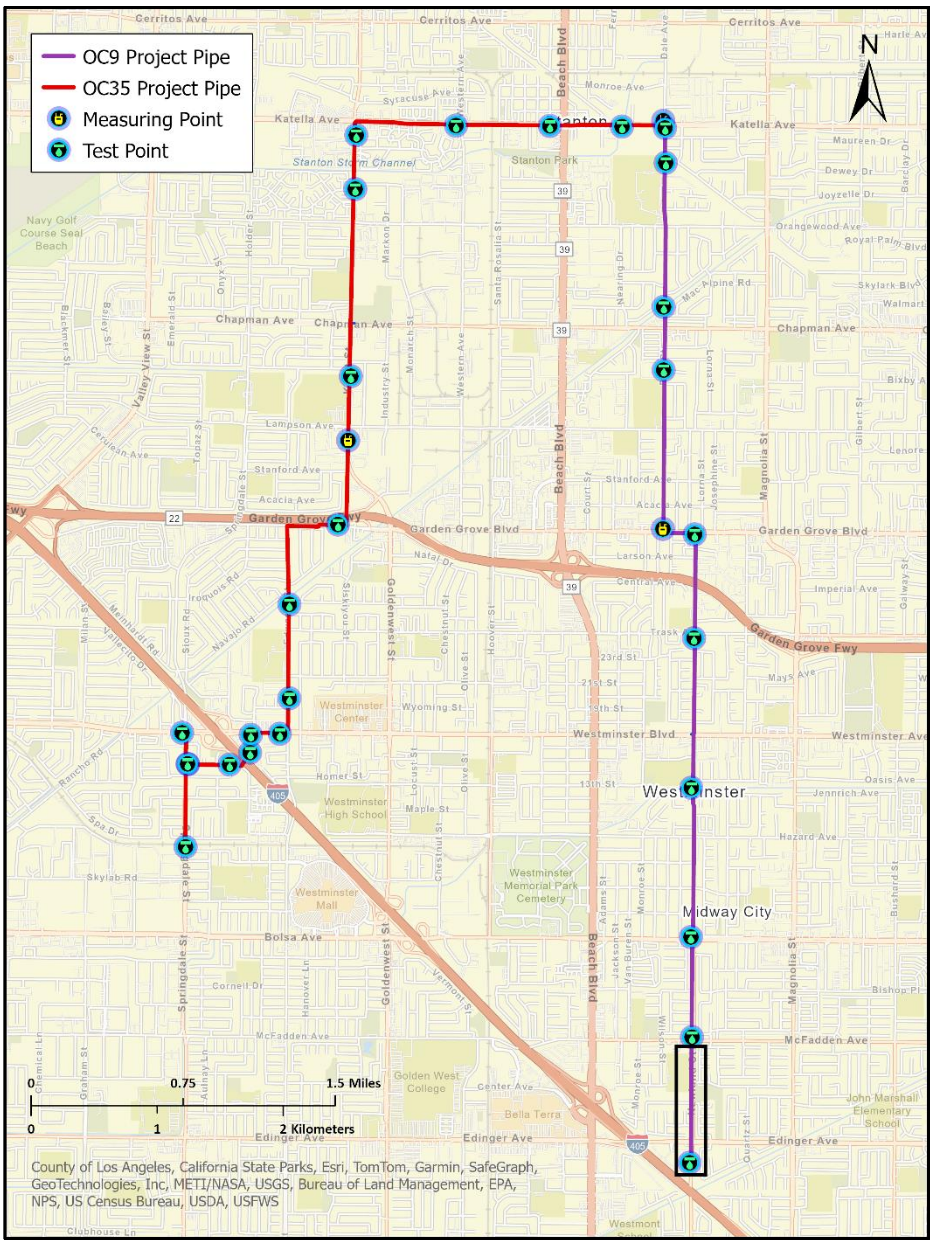


Figure 1: Overview of Project Scope for Inspection of Huntington Beach Feeder Lines

Hydromax USA has carefully inspected the available data and performed a site visit to better understand the available assets on the proposed pipeline. From these efforts it has been determined that testing may be completed using existing access points along the pipeline. This document will highlight each access point and identify any additional steps or tasks necessary for a successful p-CAT assessment.

OC-9 PLAN DETAILS

Testing will be performed typically by utilizing 2, sometimes 3, test points. A test consists of 1 generation point and at least 1 measuring point. A small amount of water will be released at the transient generation point and then the transient generator will be quickly closed to create hydraulic transient signals that are used for pipeline condition assessment by signal analysis. During a test multiple data sets will be recorded to ensure consistency and accuracy. Table 1 outlines assets along the project pipeline that will be used during testing, either for generating pressure transients or measuring the transients. It is the client's responsibility to ensure that all vaults are clear of dirt/debris and that all ARVs are disassembled prior to the inspection.

Table 1: Access Locations for Inspection of OC-9*

Work Plan ID	Asset	Client WTRINDEX	Distance from Start of Pipe (ft)	Distance from Previous Test Point (ft)	Client Task
WP 9-1	2-inch tap	2116TNO001	0	0	Provide vault access and traffic control
WP 9-2	2.5-inch ARV	2116AVK004	911	911	Remove ARV
WP 9-3	3-inch ARV	2216AVK001	4,693	3,782	Remove ARV
WP 9-4	2.5-inch ARV	2316AVK001	6,334	1,641	Remove ARV
WP 9-5	1-inch ARV	2416AVK001	10,462	4,128	Remove ARV
WP 9-6	2.5-inch ARV	2516AVK001	11,404	942	Remove ARV
WP 9-7	2.5-inch ARV	2616AVK001	14,138	2,734	Remove ARV
WP 9-8	2-inch ARV	2716AVK001	18,091	3,953	Remove ARV
WP 9-9	2-inch ARV	2816AVK001	21,989	3,898	Remove ARV
WP 9-10	2-inch ARV	NEWAVK001	24,557	2,568	Remove ARV and provide traffic control
WP 9-11	2-inch ARV	NEWAVK002	27,866	3,309	Remove ARV

*Contingent on availability

Table 2 below, outlines the current plan for generation and measurement points. Based on site conditions at the time of field testing this plan is subject to change. Note that a minimum overnight low of 45° F is required to conduct tests due to the sensitive nature of equipment involved.

Table 2: OC-9 Preliminary Test Plan

Test #	Generator Station	Measurement Point
1*	WP 9-11	WP 9-10
2*	WP 9-10	WP 9-11
3	WP 9-10	WP 9-9
4	WP 9-9	WP 9-8
5	WP 9-8	WP 9-7
6	WP 9-7	WP 9-6
7	WP 9-6	WP 9-5
8	WP 9-4	WP 9-5
9	WP 9-4	WP 9-3
10	WP 9-3	WP 9-2
11	WP 9-2	WP 9-1

*WP 9-11 may not be used during inspection if pipe segment from Edinger Ave South is confirmed to be PVC

Prior to testing, confirmation of operational status (including full closure and full open states) for all valves within the test boundaries must be completed. If necessary, HUSA can make crews available to perform valve operation testing in preparation for p-CAT testing, an additional fee may apply. During testing all inline valves to be in full open position unless otherwise noted (Table 3). All offtakes to be fully closed if operationally possible (Table 3). If the segment of pipe from Edinger Ave South is determined to be <u>a material other than PVC</u>, HUSA requests that the inline valve at the southern end of the project scope (Valve 253VLN040, Table 3) be fully closed until at least Test #4 (Table 2). If a full closure is not possible, a partial closure of 70% would still be effective. If the segment of pipe from Edinger Ave South is confirmed to be PVC, then the closure of valve 253VLN040 will not be needed.

City operations staff to relay timing of closures and openings to HUSA field staff during inspection.

Table 3: Valves Requiring Operational Status Confirmation for OC-9

WTRINDEX	Valve Type	Valve Size (in)	Position for Inspection	Notes
2116VLN002	Inline	16	Open	
2116VLN004	Offtake	8	Closed	
2216VLN001	Offtake	8	Closed	
2216VLN002	Offtake	8	Closed	
2216VLN003	Inline	16	Open	
2316VLN001	Offtake	8	Closed	
2316VLN002	Offtake	8	Closed	
2416VLN001	Inline	16	Open	
2416	Offtake	10	NA	Should be plug valve per GIS
2416VLN002	Inline	16	Open	
2416VLN003	Offtake	8	Closed	
2516VLN001	Offtake	8	Closed	
2516VLN002	Inline	16	Open	
2517TNO001	Offtake (Turnout)	10	Closed	Trask Ave Branch, no gate valve shown in GIS
2516VLN003	Inline	16	Open	
2616VLN001	Inline	16	Open	
2616TNO001	Offtake (Turnout)	14	Closed	Westminster Branch, abandoned?- no gate valve shown in GIS
2616VLN002	Inline	16	Open	
NA	Inline	14	Open	Near Bolsa Ave per as builts
2816VLN001	Offtake	10	Closed	Bolsa Ave Branch; as builts show an 8-inch offtake opposite
253VLN011	Offtake	8	Closed	(Normally closed per GIS)
253VLN012	Offtake	8	Closed	(Normally closed per GIS)
253VLN013	Inline	14	Open	
253VLN052	Inline	24	Open	
253VLN039	Inline	12	TBD	**Possible Boundary valve** (Full or partial closure for inspection as needed)
253VLN040	Inline	12	TBD	**Possible Boundary valve** (Full or partial closure for inspection as needed)

OC-35 PLAN DETAILS

Table 4 outlines assets along the project pipeline that will be used during testing, either for generating pressure transients or measuring the transients. It is the client's responsibility to ensure that all vaults are clear of dirt/debris and that all ARVs are disassembled prior to the inspection.

Table 4: Access Locations for Inspection of OC-35*

Work Plan ID	Asset	Client WTRINDEX	Distance from Start of Pipe (ft)	Distance from Previous Test Point (ft)	Client Tasks
WP 35-1	Tap	2016TNO001	0	0	Provide access to vault
WP 35-2	4-inch ARV	2116AVK001	1,206	1,206	Remove ARV
WP 35-3	2-inch ARV	2115AVK001	3,085	1,879	Remove ARV
WP 35-4	4-inch ARV	2114AVK001	5,535	2,450	Remove ARV
WP 35-5	2-inch ARV	2113AVK001	8,492	2,957	Remove ARV
WP 35-6	2-inch ARV	2113AVK003	9,893	1,401	Remove ARV
WP 35-7	2-inch ARV	2313AVK001	14,775	4,882	Remove ARV
WP 35-8	1-inch Tap	NEWTap001	16,443	1,668	Provide traffic control
WP 35-9	4-inch ARV	2413AVK002	18,897	2,454	Remove ARV
WP 35-10	2-inch ARV	2513AVK002	22,260	3,363	Remove ARV
WP 35-11	2-inch ARV	2613AVK001	24,753	2,493	Remove ARV and provide traffic control
WP 35-12	2-inch ARV	2712AVK003	25,881	1,128	Remove ARV
WP 35-13	4-inch ARV	2712AVK007	26,688	807	Remove ARV
WP 35-14	4-inch ARV	2712AVK006	27,164	476	Remove ARV
WP 35-15	4-inch ARV	2712AVK005	27,885	721	Remove ARV
WP 35-16	4-inch ARV	2712AVK008	28,965	1,080	Remove ARV
WP 35-17	2-inch Tap	128VLN007	31,158	2,193	Remove ARV and provide traffic control
WP 35-18	2-inch ARV	2712AVK004	8 (from Mahogany Ave)	2,147	Remove ARV
WP 35-19**	2.5-inch Fire Thread Tap	2711VLN001	919	903	Remove fire fighter fitting and connect new 2" ball valve. Flush prior to inspection. Provide traffic control

*Contingent on availability
**See Fig. 2 for details

Figure 2: Fire-threaded tap in vault at Westminster Blvd and Springdale St

Table 5 below, outlines the current plan for generation and measurement points. Based on site conditions at the time of field testing this plan is subject to change. Note that a minimum overnight low of 45° F is required to conduct tests due to the sensitive nature of equipment involved.

Table 5: OC-35 Preliminary Test Plan

Test #	Generator Station	Measurement Point	Measurement Point
1	WP 35-17	WP 35-18	WP 35-19
2	WP 35-18	WP 35-17	WP 35-19
3	WP 35-19	WP 35-18	WP 35-17
4	WP 35-16	WP 35-15	
5	WP 35-15	WP 35-16	
6	WP 35-15	WP 35-14	
7	WP 35-14	WP 35-13	
8	WP 35-13	WP 35-12	
9	WP 35-12	WP 35-11	
10	WP 35-11	WP 35-10	
11	WP 35-10	WP 35-9	
12	WP 35-9	WP 35-8	
13	WP 35-7	WP 35-8	
14	WP 35-7	WP 35-6	
15	WP 35-6	WP 35-5	
16	WP 35-5	WP 35-4	
17	WP 35-4	WP 35-3	
18	WP 35-3	WP 35-2	
19	WP 35-2	WP 35-1	

Prior to testing, confirmation of operational status (including full closure and full open states) for all valves within the test boundaries must be completed. If necessary, HUSA can make crews available to perform valve operation testing in preparation for p-CAT testing, an additional fee may apply. During testing all inline valves to be in full open position unless otherwise noted (Table 6). All offtakes to be fully closed if operationally possible (Table 6). HUSA requests that the inline valve at the southern and northern ends of the project scope on Springdale St (Valves 2711VLN001 and 128VLN007, Table 6) be fully closed until at least Test #5 (Table 5). If a full closure is not possible, a partial closure of 70% would still be effective.

City operations staff to relay timing of closures and openings to HUSA field staff during inspection.

Table 6: Valves Requiring Operational Status Confirmation for OC-35

WTRINDEX	Valve Type	Valve Size (in)	Position for Inspection	Notes
2113VLN001	Inline valve	24	Open	
2213VLN001	Offtake	12	Closed	Chapman Ave PRS
2413VLN001	Inline valve	24	Open	
2613VLN001	Offtake	12	Closed	Trask Ave PRS
2613VLN002	Inline valve	24	Open	
2613VLN003	Offtake	12	Closed	
2712VLN002	Offtake	12	Closed	PRS for 18" line
2712VLN007	Inline valve	30	Open	
2712VLN006	Inline valve	30	Open	
2712VLN003	Inline valve	30	Open	
2712VLN005	Inline valve	30	Open	
2712VLN004	Inline valve	30	Open	
128VLN007	Inline valve	27	Closed	**Boundary valve** (Full or partial closed requested)
2712VLN001	Offtake	12	Closed	
2711VLN001	Inline valve	14	Closed	**Boundary valve** (Full or partial closed requested)

TRAFFIC CONTROL

Maintenance of traffic (MOT) responsibilities for this project will be the responsibility of the client. From site visits Hydromax USA has identified several sites that will require traffic control to perform testing in a safe and effective manner. Below in Table 7 is a list of preliminary sites identified as traffic locations. Dependent on conditions at time of testing this is subject to be adjusted. Traffic control at each location listed below should accommodate several trucks and equipment while testing at each location, typically 4 hours for the first set up and 1 -2 hours at each subsequent location. During testing, at least two locations will be used simultaneously, therefore MOT resources should be sufficient to cover multiple locations.

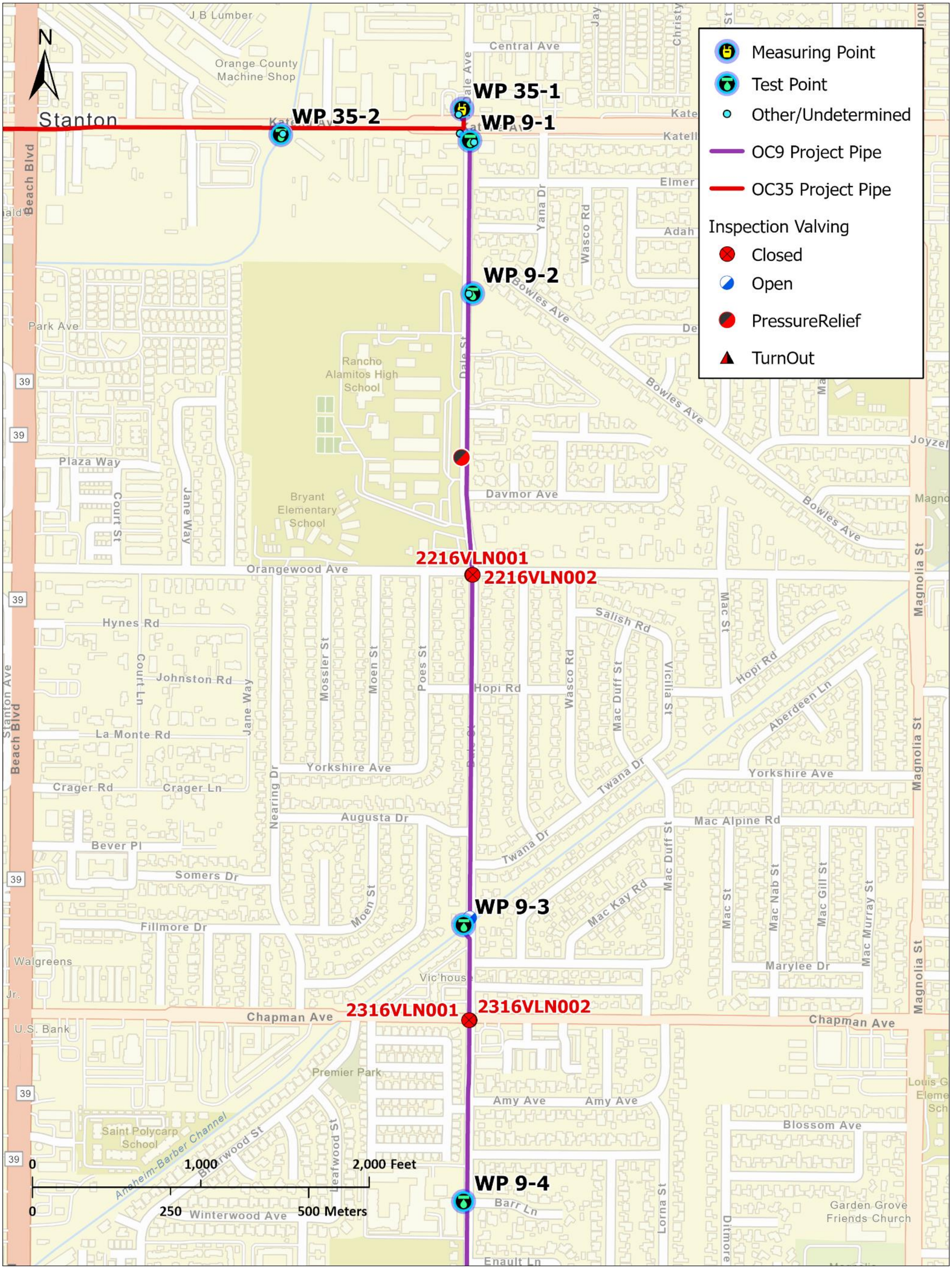
Table 7: Preliminary Sites Requiring Traffic Control

Site ID	Asset	Approximate Location	Flaggers/Semi-Mobile MOT	Street View
WP 9-1	Rectangular vault	Dale Ave, south side of Katella Ave intersection	Northbound Center Lane	
WP 9-10	ARV	Newland Ave, north side of McFadden Ave intersection	Southbound Left Lane	
WP 35-8	Manhole	Knott St, south of Lampson Ave	Northbound Left Lane	
WP 35-11	ARV	13836 Edwards St	Northbound Right Lane	
WP 35-17	Manhole	Springdale St and Glenwood Dr	Southbound Left Turn Lane	
WP 35-19	Manhole	Westminster Blvd, west side of Springdale St intersection	Eastbound Right Turn Lane	

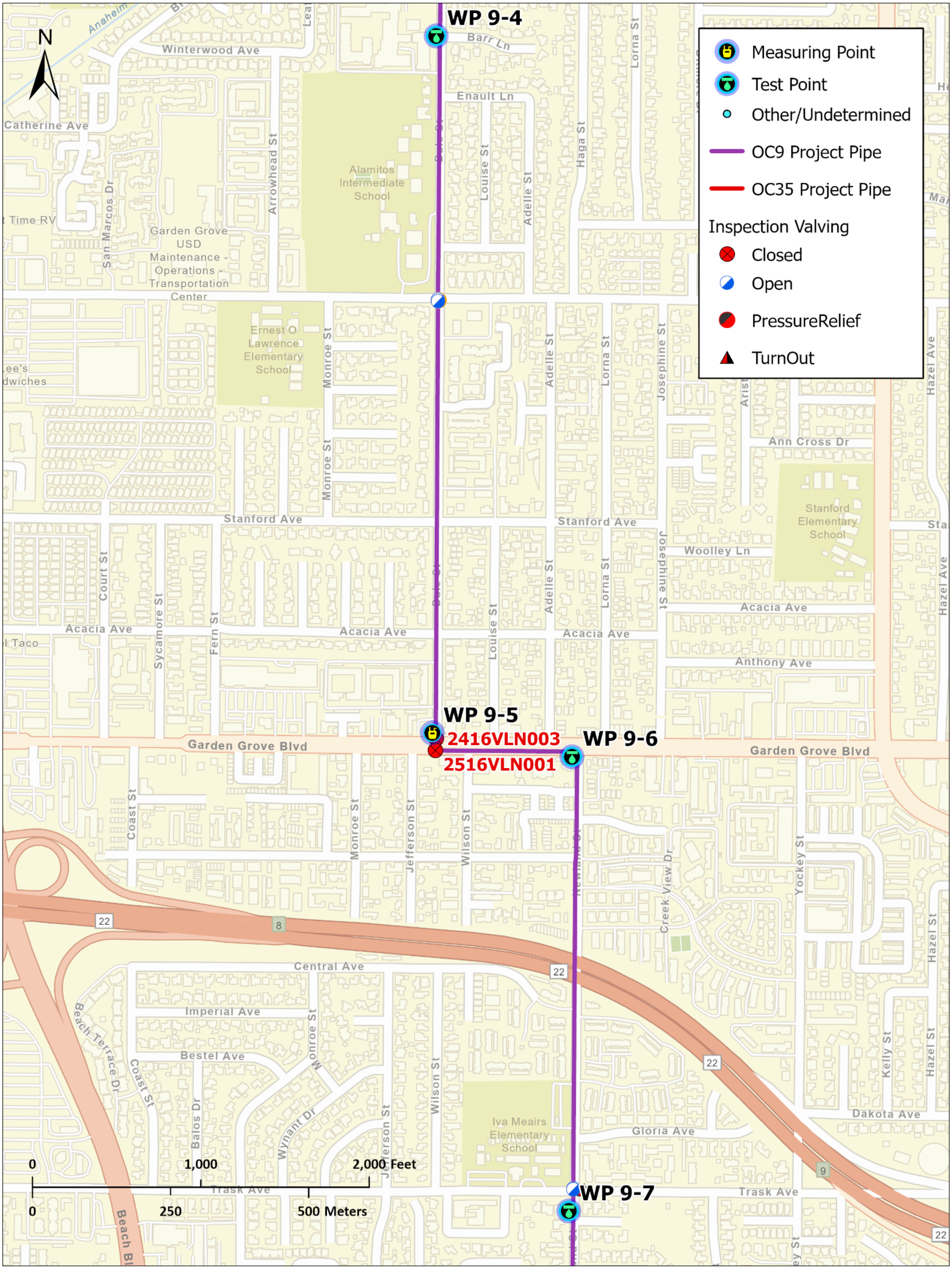
Detailed Plan Maps for p-CAT Testing

Detailed Map for p-CAT Test Locations

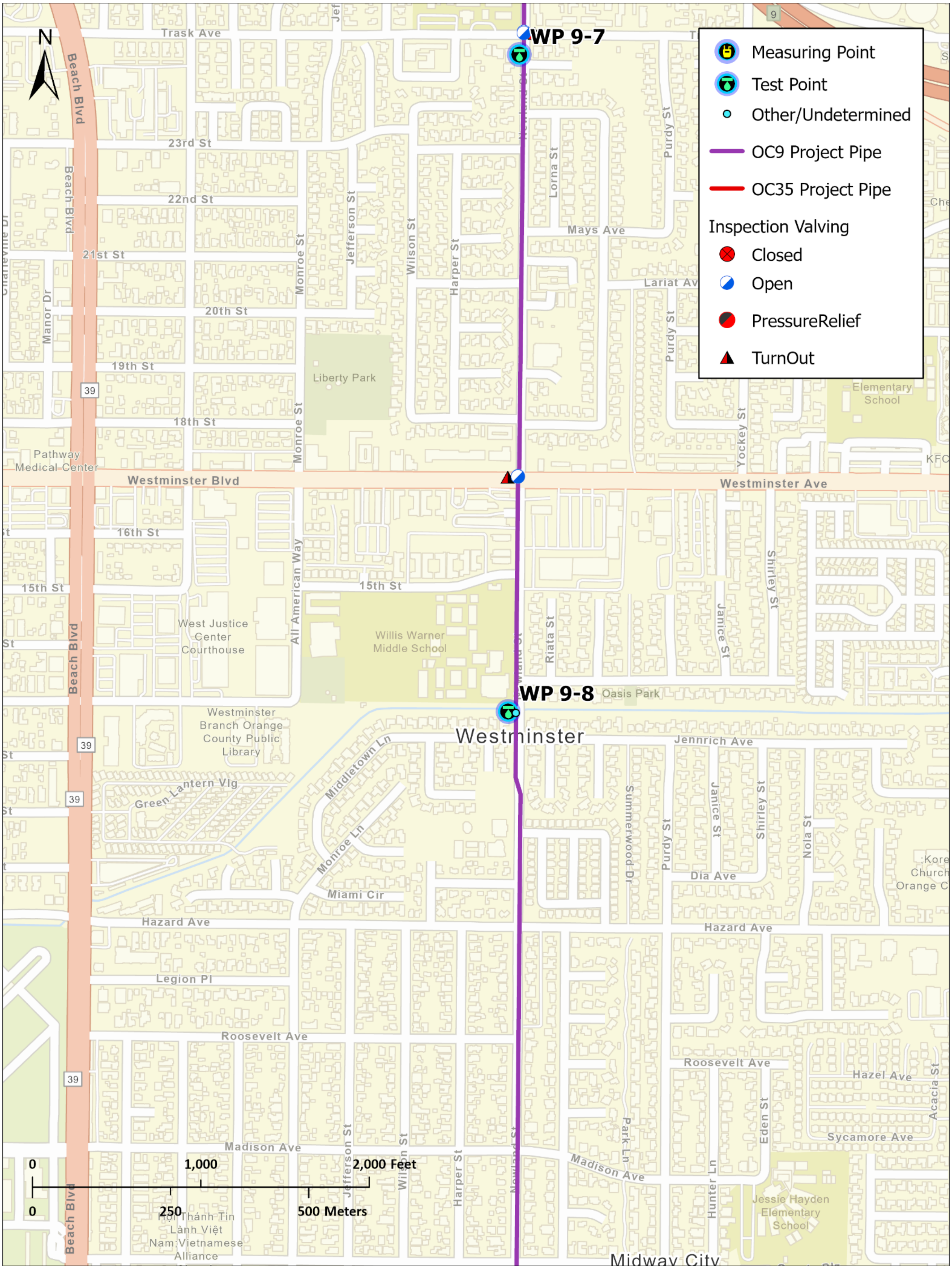
HYDROMAX USA
Advanced Water, Wastewater and Gas Data Collection



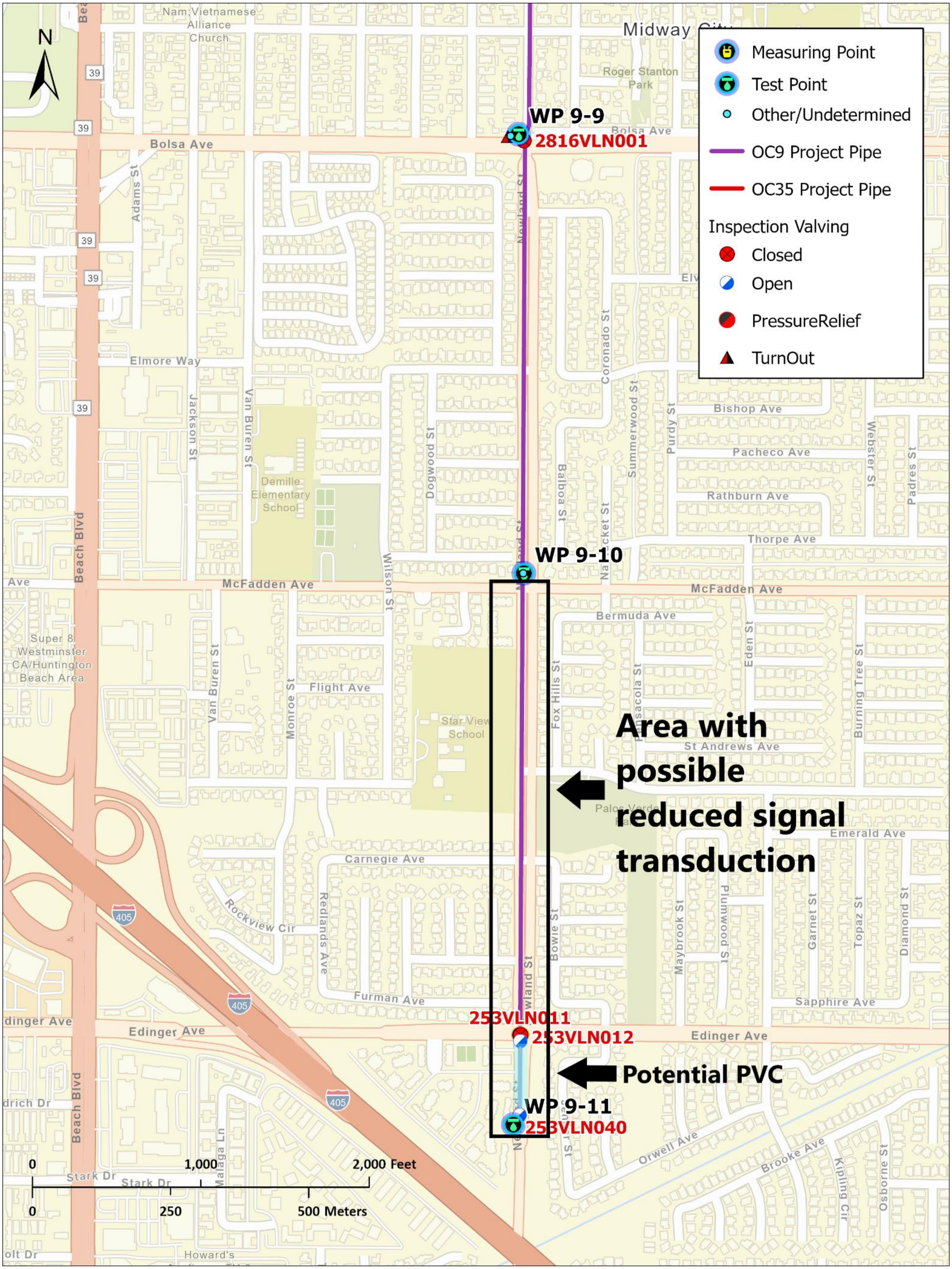
Detailed Map for p-CAT Test Locations



Detailed Map for p-CAT Test Locations



Detailed Map for p-CAT Test Locations



Detailed Map for p-CAT Test Locations

HYDROMAX USA
Advanced Water, Wastewater and Gas Data Collection

HYDROMAX USA
Advanced Water, Wastewater and Gas Data Collection

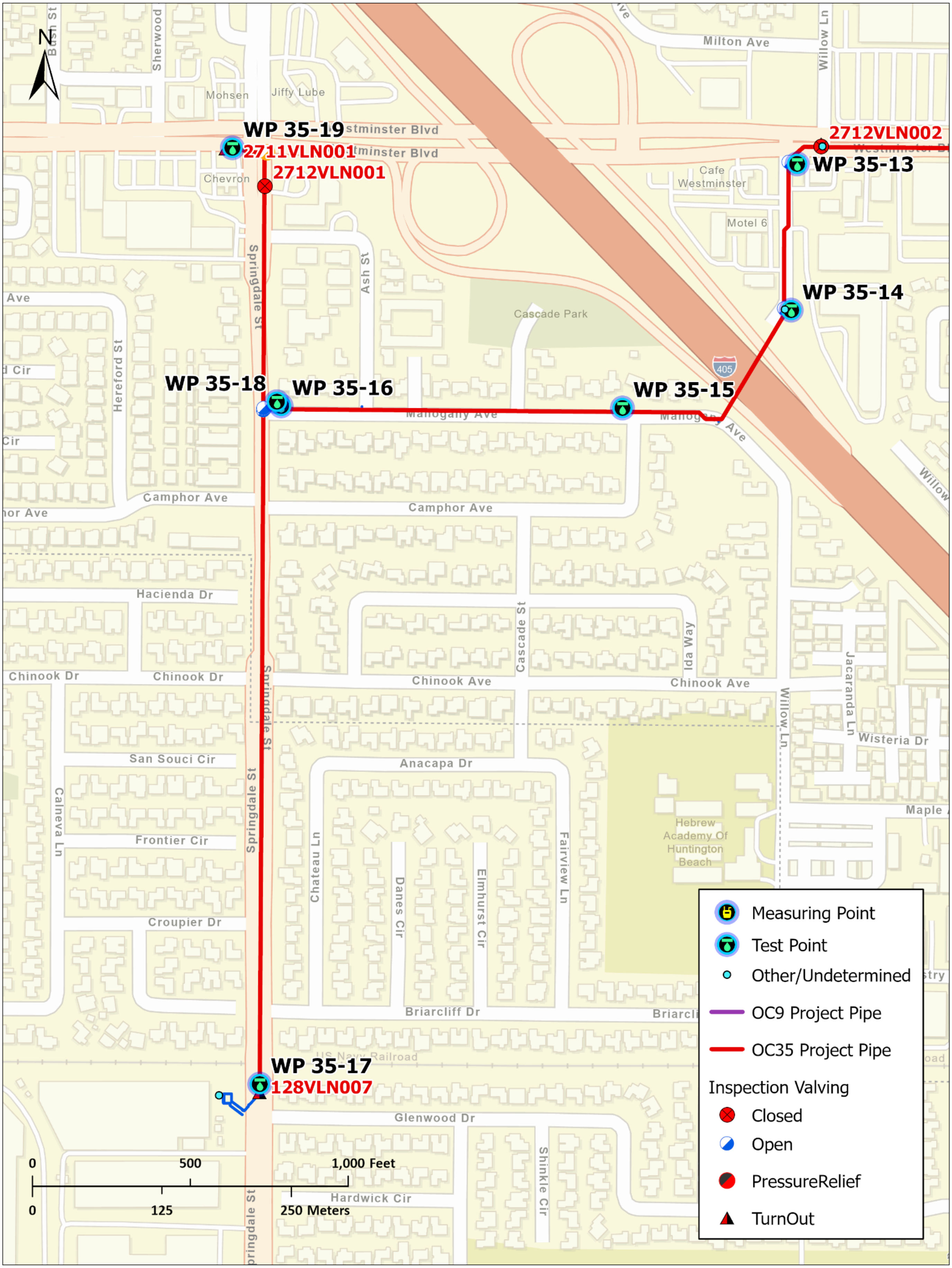
Detailed Map for p-CAT Test Locations

Detailed Map for p-CAT Test Locations

Detailed Map for p-CAT Test Locations

Detailed Map for p-CAT Test Locations

HYDROMAX USA
Advanced Water, Wastewater and Gas Data Collection



APPENDIX B: HYDROMAX P-CAT^{TM} PIPELINE CONDITION ASSESSMENT RESULTS

p-CAT™

pipeline condition assessment

OC9 and OC35 Water Pipelines

Section OC9: 5.2 miles of 16-inch to 28-inch BWP

Section OC35: 6.1 miles of 27-inch to 36-inch BWP

NOT FOR DISTRIBUTION – COMMERCIAL IN CONFIDENCE

Contractor	Pipeline Inspection & Assessment (PIA), Detection Services Pty Ltd (DS) and Hydromax USA
Circulation list	Pipeline Inspection & Assessment (PIA), Detection Services Pty Ltd (DS), Hydromax USA, Ardurra and the City of Huntington Beach
Client	the City of Huntington Beach
Date	December 19, 2025
Version	Report v3

HYDROMAX USA
Advanced Water, Wastewater and Gas Data Collection

PIA
PIPELINE INSPECTION AND ASSESSMENT

&

DETECTION SERVICES
PIPELINE INSPECTION AND ANALYSIS

December 19, 2025

Jamie Fagnant, PE
Ardurra
301 Mission Avenue
Ste 202
Oceanside CA 92054

RE: p-CAT - Report for Condition Assessment of Huntington Beach OC9 and OC35 Water Pipelines

Dear Jamie and Team,

Hydromax USA (HUSA) is pleased to deliver the report for Pipeline Condition Assessment Technology based on transient signal analysis on the 16-inch to 28-inch OC9 and 27-inch to 36-inch OC35 Water Pipelines owned and operated by the City of Huntington Beach (Client). The p-CAT™ technology delivers non-invasive, mid to high resolution, cost-effective diagnosis of pipeline condition over long distances with minimal disruption of current service.

The accompanying documents include a detailed report that identifies pipeline properties used for the analysis, along with testing results. P-CAT results are twofold and include pipeline condition assessment as well as anomaly detection. Typically, anomalies are identified at specific locations along the assessed pipeline or are identified as a specific length of pipe. This is separate from the pipe wall condition assessment analysis. Additional supporting documents include the Visual Summary Overview document and GIS that illustrate pipe conditions overlayed along the pipe segments.

Please contact me should you have questions, comments, or feedback regarding the reported p-CAT™ results.

Sincerely,

Alex Sutton
Operations Manager
812.746.5840
Alex.Sutton@hydromaxusa.com

Executive Summary

The following report details the p-CAT™ testing and findings of the OC9 and OC35 Water Pipelines, conducted by Pipeline Inspection & Assessment (PIA), Detection Services (DS) and Hydromax USA (HUSA). The condition assessment of the pipeline of interest was completed for Ardurra and the City of Huntington Beach.

The tests were conducted on the 6th, 7th and 8th of May 2025 by HUSA. The field tests were conducted on the pipelines with the purpose of assessing the pipeline condition and identifying known and unknown features and anomalies such as blockages, air pockets and wall thickness deterioration. The following table describes the sections of interest:

Huntington Beach Pipelines	
Location	Huntington Beach, California USA
Section OC9 (S9)	
Approx. Length	5.2 miles
Section of Interest	The pipeline begins approximately at Newland St and Edinger Ave and extends north along Newland St, Garden Grove Blvd, and Dale St, ending near Katella Avenue.
Primary Materials	16, 24, 26 and 28-inch BWP (1956)
Section OC35 (S35)	
Approx. Length	5.5 miles
Section of Interest	The pipeline begins near the intersection of Dale St and Katella Ave, then runs west and south along Katella Ave, Knott Ave, Garden Grove Blvd, Edwards St, Westminster Blvd, and Willow Ln ending at the intersection of Mahogany Ave and Springdale St.
Primary Materials	27, 33 and 36-inch BWP (1963) and 30-inch BWP (2017)
Section OC35A (S35A)	
Approx. Length	0.6 miles
Section of Interest	The pipeline begins at the intersection of Mailbu St and Springdale St, then continues north along Springdale St until it reaches Westminster Blvd.
Primary Materials	27 and 33-inch BWP (1963)

The OC35 pipeline is analyzed in two parts to simplify the analysis and results. The first section is named section OC35 (S35) which covers 5.5 miles. The second section is named OC35A (S35A) and covers 0.6 miles.

The analysis undertaken to determine the pipeline wall condition was based on the following assumption as per the typical ANSI/AWWA C303 for Bar Wrapped Steel Cylinder Type Concrete Pressure Pipe, GIS Shapefiles, as-constructed drawings and the information supplied by the City of Huntington Beach:

Assumed physical properties			BWP							
Standard used			ANSI/AWWA C303							
Year of installation			1956	1956	1956	1963	1956	2017	1963	1963
Nominal Diameter			16	24	26	27	28	30	33	36
Outside diameter	(OD)	in	19.28	27.91	29.91	30.94	31.91	33.97	37.00	40.04
Wall thickness	(e_W)[1]	in	0.14	0.20	0.20	0.22	0.20	0.23	0.25	0.27
Equivalent thickness	(e_{eq})[2]	in	1.64	1.95	1.95	1.97	1.95	1.98	2.00	2.02

The following table summarizes the pipeline wall conditions identified during the p-CAT™ analysis:

Section	Wall Remaining (%)					
	100 – 90%	90 – 80%	80 – 70%	70 – 60%	60 - 50%	Not applicable
OC9	-	3.9%	84.7%	9.4%	-	2.0%
OC35	8.0%	3.7%	10.7%	65.3%	12.3%	-
OC35A	-	-	59.2%	40.0%	-	0.8%

It should be noted that these remaining wall thickness results are determined using assumed initial wall thicknesses and outer diameters as provided by the City of Huntington Beach based on the City's best available data. Should the City of Huntington Beach obtain further information regarding the initial wall thickness of the pipelines PIA and DS will be able to recalculate the percentage remaining wall thickness.

The following table summarizes the anomalies identified in each section during the signal analysis:

Number of Anomalies						
Section	**Total**	**Very Good (5)**	**Good (4)**	**Fair (3)**	**Poor (2)**	**Very Poor (1)**
OC9	43	7	8	25	3	-
OC35	58	8	16	32	2	-
OC35A	8	1	3	4	-	-

[1]Description of anomaly categories

Very Good: The detected feature corresponds to known system components based on the collected system information.

Good: Known anomaly requiring some maintenance or Unknown anomaly not corresponding to any known system components.

Fair: The detected anomaly does not correspond to any known system components and/or requires corrective maintenance

Poor: The detected anomaly indicates a location of possible future failure; It is potentially interrupting the system serviceability and may be vulnerable to bursts and leaks.

Very Poor: The detected anomaly indicates a location of probable failure; It is most likely interrupting the system serviceability and is vulnerable to bursts and leaks.

The percentage of remaining wall thickness is determined by comparing the theoretical pipeline specifications with the signal analysis, which ultimately defines the remaining structural strength based on the current conditions of the pipeline.

It is recommended that the City of Huntington Beach assess the remaining strength of the pipeline using the percentage of remaining wall strength, rather than based only on the wall thickness values provided. This approach is recommended because the strength of the pipeline is more significantly impacted by factors such as the debonding of the metal wires from the concrete and wire breakage, rather than a reduction in wall thickness due to leaching. The City of Huntington Beach should also investigate the current pipeline properties and configuration, and the presence of possible entrained or entrapped gas before coming to the conclusion that sections are deteriorated. These faults can also affect the accuracy of the p-CAT™ results for both the condition assessment and the anomaly identification. By considering all these factors, the City of Huntington Beach can gain a more accurate understanding of the pipeline's condition.

Due to the large amount of information provided, including various shapefiles, GPS points, as-constructed drawings, and other data, the information was cleaned and merged. GPS points were snapped and merged with the GIS pipeline shapefiles to ensure they could be included in the analysis. During the analysis, GIS data was primarily used, with confirmation from GPS points and as-constructed drawings. Distances were estimated accordingly. Should the City of Huntington Beach obtain additional information regarding the original pipe specifications, the results can be updated by PIA, DS and HUSA.

As requested by HUSA and the City of Huntington Beach, an additional scenario is presented in Appendix F, illustrating results under the assumption that the pipe material is a steel water pipe in accordance with ANSI/AWWA C200. Other documents in the report packages such as the Visual Summary (VS), Overview Visual Summary (OVS), GIS, and HTML, will not be updated to reflect this scenario. This decision is based not only on time considerations but also on preserving the integrity and consistency of the standardized report package, avoiding duplication or potential misalignment across outputs.

It is important to note that this additional scenario does not affect the identification of anomalies, subsection identifiers, or segmentation, as these remain consistent between both analyses. The primary difference lies in the percentage of potential deterioration associated with the material specification. Therefore, users can easily compare results by referencing the subsection identifiers, chainage, and lengths provided, ensuring a straightforward interpretation of differences between the BWP and steel pipe scenarios.

Section 5 includes a summary and recommendations from the p-CAT™ analysis results. An in-depth visual summary of the obtained results is also provided in a separate document and in an active GIS package accompanying this report.

Contents

Executive Summary i

List of Figures v

List of Tables vi

1 Introduction 1

1.1 Non-invasive Pipe Conditional Assessment (p-CAT™) 2

1.2 Pipeline Configuration 2

2 Tests Conducted 7

3 Pipeline Properties and Theoretical Wave Speeds 8

3.1 Intact Theoretical Pipeline Properties 8

3.2 Theoretical Deterioration from Intact Pipeline 9

4 Results 11

4.1 Signal Analysis for the Identification of Known Features and Anomalies 11

4.2 Pipeline Wall Deterioration (Sub-sectional Condition) 20

5 Summary and Recommendations 33

Appendix A: Glossary of Terms 37

Appendix B: Pipeline Feature Chainages 38

Appendix C: Example of Pressure Traces 43

Appendix D. Test Methodology and Equipment 44

D1. Non-invasive Pipe Condition Assessment (p-CAT™) 44

D2. Sub-Section Partitioned Wave Speed Analysis™ 45

D3. Signal Analysis 45

D4. Test Procedure 45

D5. Test Equipment 46

Appendix E: Theory 47

E1. Theory and Equations 47

E2. Interpretation of Variations in Wave Speed in a Pipe Section between Two Points 48

E3. Example of Sub-Section Partitioned Wave Speed Analysis™ 48

Appendix F: Additional scenario (ANSI/AWWA C200 standard) 49

List of Figures

Figure 1.1: OC9 Water Pipeline, southern portion 3
Figure 1.2: OC9 Water Pipelines, northern portion 4
Figure 1.3: OC35 Water Pipeline, northeastern portion 5
Figure 1.4: OC35 and OC35A Water Pipelines, southern portion 6
Figure 3.1: Modes of bar wrapped pipeline deterioration 10
Figure 3.2: Modes of steel cylinder pipeline deterioration 10
Figure 4.1: Pipeline wall deterioration for OC9 30
Figure 4.2: Pipeline wall deterioration for OC35 31
Figure 4.3: Pipeline wall deterioration for the OC35A 32
Figure C.1: Anomaly identification for transient generated at WP9-10 43
Figure C.2: Anomaly identification for transient generated at WP35-17 43
Figure D.1: Field testing equipment 46
Figure E.1: Segment for estimation of wave speed variation between measurement stations 48

List of Tables

Table 1-1: Project background for the OC9 and OC35 Water Pipelines 1
Table 1-2: OC9 material/size sections (as per provided information) 2
Table 1-3: OC35 material/size sections (as per provided information) 2
Table 1-4: OC35A material/size sections (as per provided information) 2
Table 2-1: Field test set up 7
Table 3-1: Physical properties of the potential pipeline classes and diameters 8
Table 3-2: Material properties of the pipeline 9
Table 4-1: Known features and anomaly priority terminology 12
Table 4-2: Summary of anomalies detected in the Huntington Beach Pipelines 12
Table 4-3: Summary of the features and anomalies detected in the HB pipelines, section OC9 15
Table 4-4: Summary of features and anomalies detected in the HB pipelines, section OC35 17
Table 4-5: Summary of the features and anomalies detected in the HB pipelines, section OC35A . 19
Table 4-6: Sub-sectional terminology 20
Table 4-7: Pipeline wall condition summary 21
Table 4-8: BWP pipe wall deterioration results for OC9 22
Table 4-9: BWP pipe wall deterioration results for OC35 25
Table 4-10: BWP pipe wall deterioration results for OC35A 29
Table 5-1: Pipeline wall condition summary 33
Table 5-2: Summary of anomalies detected in the Huntington Beach Pipelines 34
Table B.1: Surveyed pipeline chainages for OC9 and OC35 Water Pipelines, section OC9 38
Table B.2: Surveyed pipeline chainages for OC9 and OC35 Water Pipelines, section OC35 40
Table B.3: Surveyed pipeline chainages for OC9 and OC35 Water Pipelines, section OC35A 42
Table F.1: SCP pipe wall deterioration results for OC9 and OC35 Water Pipelines, section OC9 49
Table F.2: SCP pipe wall deterioration results for OC9 and OC35 Water Pipelines, section OC35 ... 52
Table F.3: SCP pipe wall deterioration results for OC9 and OC35 Water Pipelines, section OC35A . 56

1 Introduction

This report gives details and findings from the non-invasive pipe condition assessment (p-CAT™) testing of the OC9 and OC35 Water Pipelines, as shown in Table 1-1. The field tests were conducted by Hydromax USA (HUSA) for the City of Huntington Beach for the purpose of assessing the pipeline condition and identifying known and unknown features and anomalies such as blockages, air pockets, and wall thickness deterioration.

For the following information regarding this project please refer to the Appendix:

- Appendix A: Glossary of Terms
- Appendix B: Pipeline Feature Chainage
- Appendix C: Examples of Pressure Traces
- Appendix D: Test Methodology and Equipment
- Appendix E: Theory
- Appendix F: Additional scenario (Based on ANSI/AWWA C200 standard)

Table 1-1: Project background for the OC9 and OC35 Water Pipelines

Project Name	**Huntington Beach Pipelines**
Location	Huntington Beach, California USA
Client	City of Huntington Beach
Test Date	6th, 7th and 8th of May, 2025
Report Date	19th of December, 2025
Information Provided to PIA and DS	GIS maps, GPS points, as-constructed drawings, site visits and general information.
Section OC9 (S9)	
Approx. Length	5.2 miles
Section of Interest	The pipeline begins approximately at Newland St and Edinger Ave and extends north along Newland St, Garden Grove Blvd, and Dale St, ending near Katella Avenue.
Primary Materials	16, 24, 26 and 28-inch BWP (1956)
Section OC35 (S35)	
Approx. Length	5.5 miles
Section of Interest	The pipeline begins near the intersection of Dale St and Katella Ave, then runs west and south along Katella Ave, Knott Ave, Garden Grove Blvd, Edwards St, Westminster Blvd, and Willow Ln ending at the intersection of Mahogany Ave and Springdale St.
Primary Materials	27, 33 and 36-inch BWP (1963) and 30-inch BWP (2017)
Section OC35A (S35A)	
Approx. Length	0.6 miles
Section of Interest	The pipeline begins at the intersection of Mailbu St and Springdale St, then continues north along Springdale St until it reaches Westminster Blvd.
Primary Materials	27 and 33-inch BWP (1963)

1.1 Non-invasive Pipe Conditional Assessment (p-CAT™)

p-CAT™ uses two main techniques for interpreting the transient pressure wave tests results:

- Sub-Section Partitioned Wave Speed Analysis™ for assessment of the level of deterioration of the pipe wall in a sub-section, and
- Signal Analysis for detection of known features and significant anomalies such as air pockets and blockages.

1.2 Pipeline Configuration

The pipe materials, lengths and features of the OC9 and OC35 Water Pipelines and their locations are listed in Table 1-2, Table 1-3, Table 1-4, and shown in Figure 1.1, Figure 1.2, Figure 1.3 and Figure 1.4.

Table 1-2: OC9 material/size sections (as per provided information)

Location	Approx. Length (ft)	Size (in)	Material	Year
Ch. 0 ft to Ch. 566 ft	566	24	Unknown	2005
Ch. 566 ft to Ch. 11256 ft	10689	24	BWP	1956
Ch. 11256 ft to Ch. 11259 ft	3	16	BWP	1956
Ch. 11259 ft to Ch. 13891 ft	2632	26	BWP	1956
Ch. 13891 ft to Ch. 13894 ft	3	16	BWP	1956
Ch. 13894 ft to Ch. 19998 ft	6105	26	BWP	1956
Ch. 19998 ft to Ch. 20007 ft	9	16	BWP	1956
Ch. 20007 ft to Ch. 27897 ft	7890	28	BWP	1956
Ch. 27897 ft to Ch. 27905 ft	7	16	BWP	1956

Table 1-3: OC35 material/size sections (as per provided information)

Location	Approx. Length (ft)	Size (in)	Material	Year
Ch. 0 ft to Ch. 13397 ft	13397	36	BWP	1963
Ch. 13397 ft to Ch. 25485 ft	12087	33	BWP	1963
Ch. 25485 ft to Ch. 26679 ft	1195	27	BWP	1963
Ch. 26679 ft to Ch. 29020 ft	2341	30	BWP	2017

Table 1-4: OC35A material/size sections (as per provided information)

Location	Approx. Length (ft)	Size (in)	Material	Year
Ch. 0 ft to Ch. 2865 ft	2865	27	BWP	1963
Ch. 2865 ft to Ch. 3082 ft	217	33	BWP	1963
Ch. 3082 ft to Ch. 3102 ft	20	27	BWP	1963

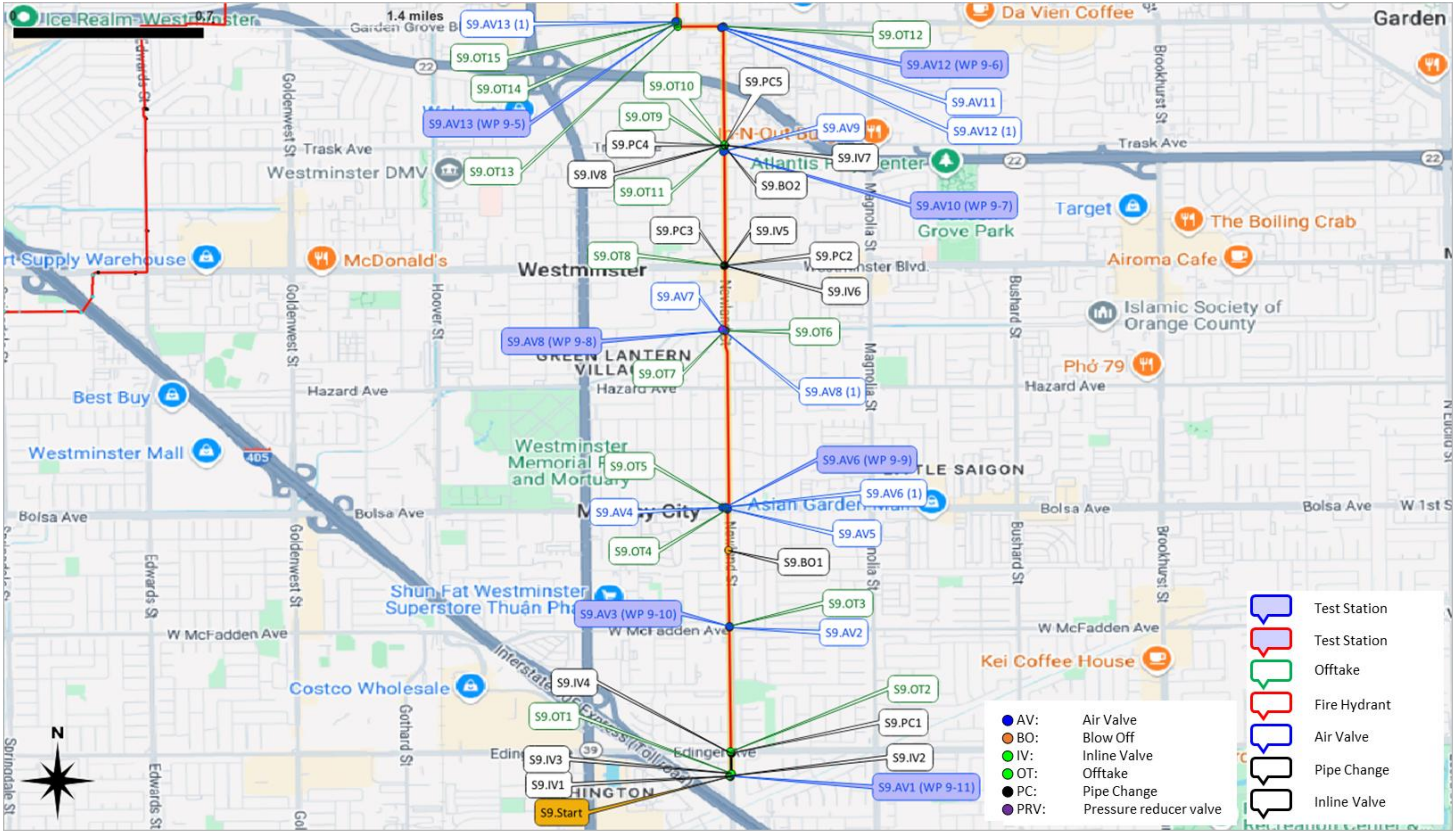


Figure 1.1: OC9 Water Pipeline, southern portion

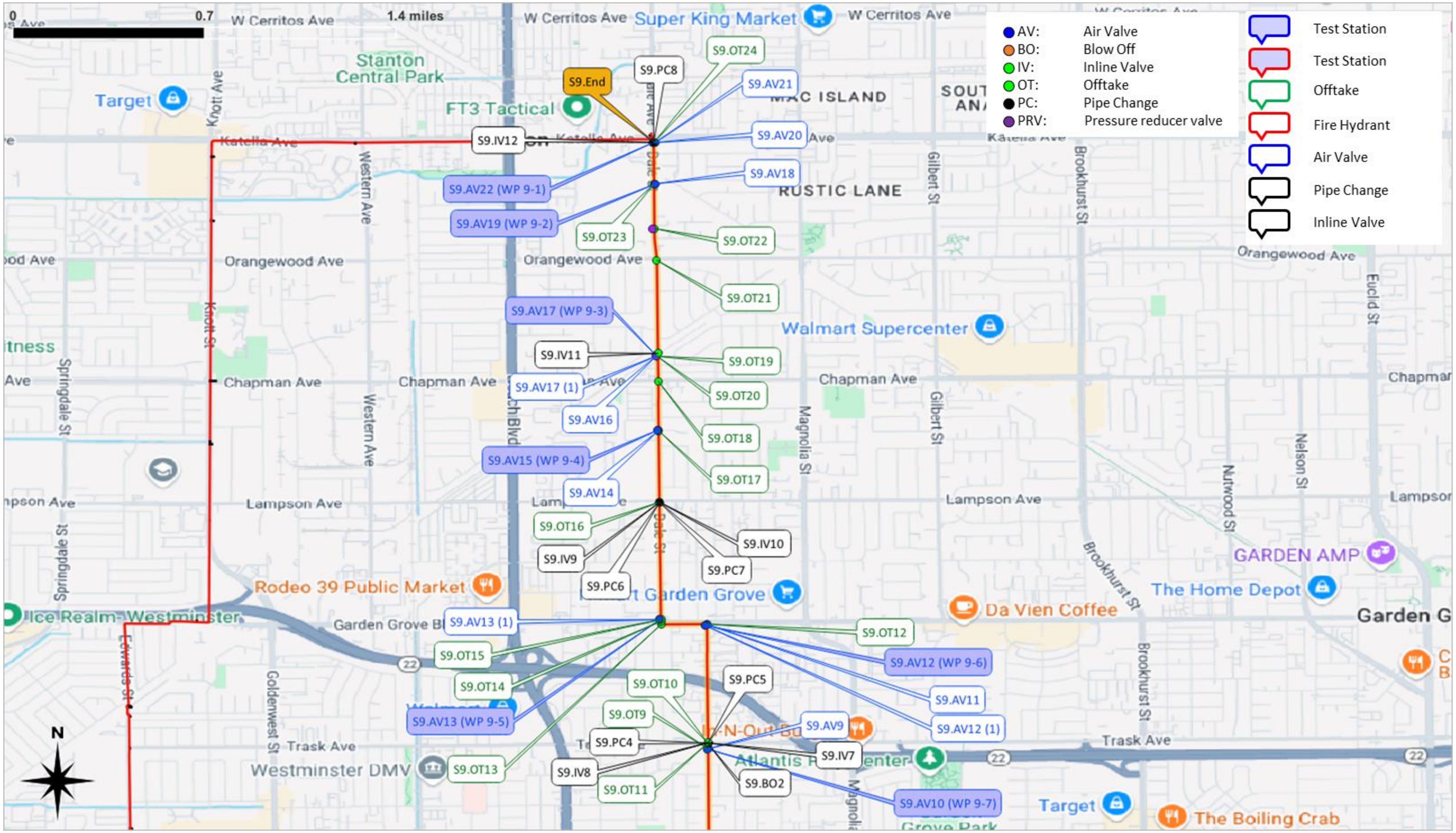


Figure 1.2: OC9 Water Pipelines, northern portion

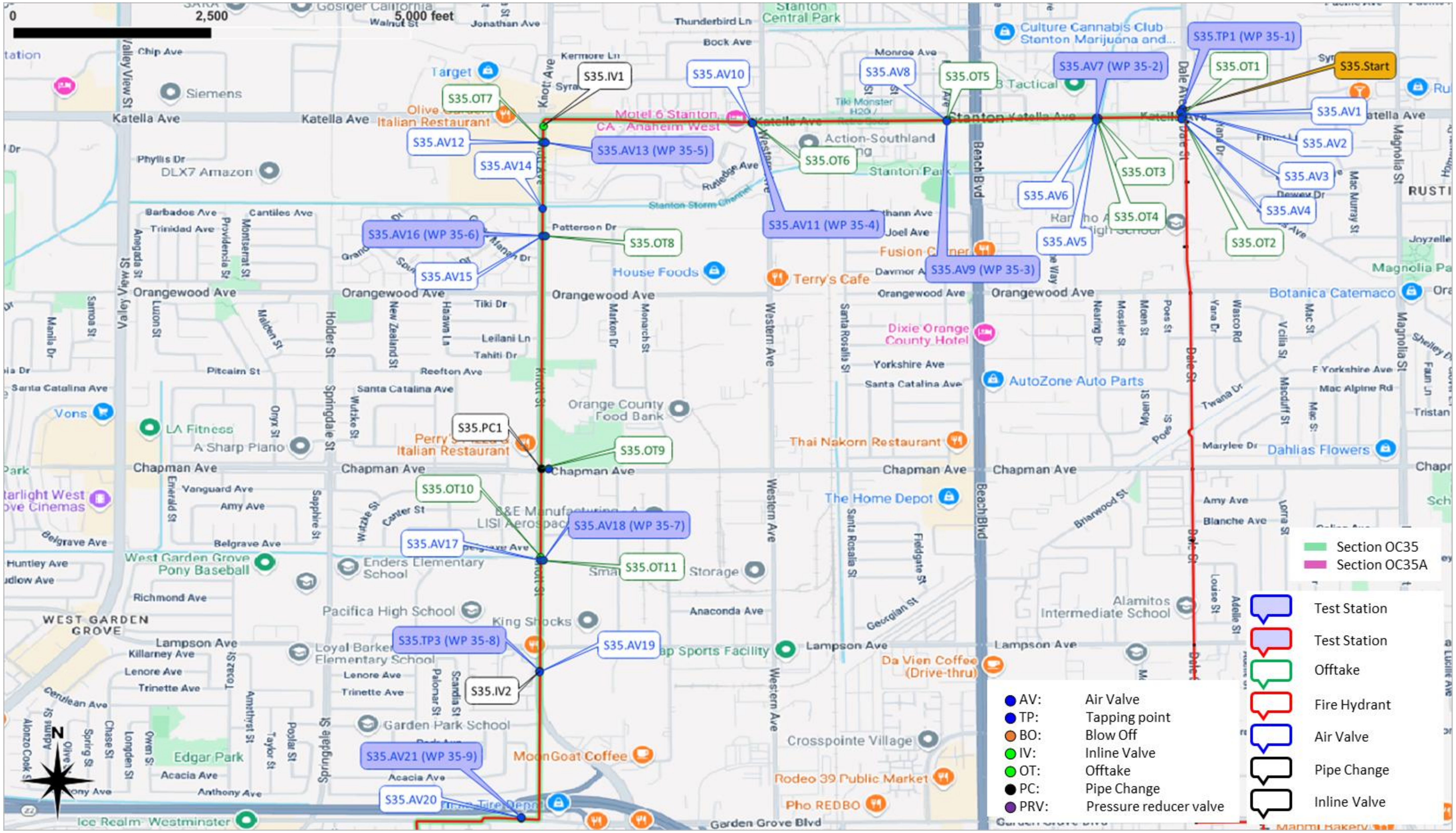


Figure 1.3: OC35 Water Pipeline, northeastern portion

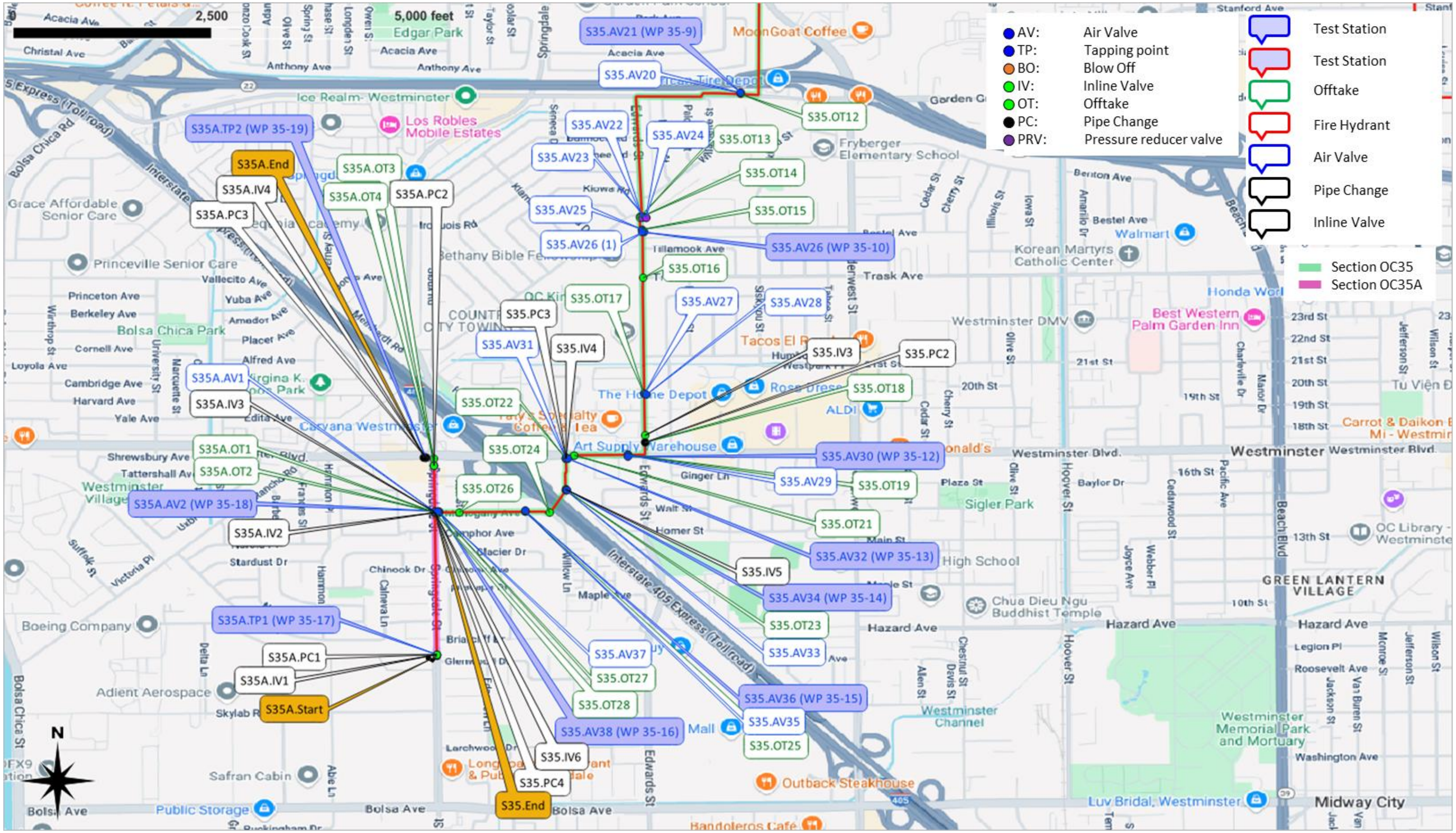


Figure 1.4: OC35 and OC35A Water Pipelines, southern portion

2 Tests Conducted

The tests conducted, and the test set up used for each test are listed in Table 2-1. The locations of the generation points, measurement points and valves are shown in schematic form in Figure 1.1**,** Figure 1.2**,** Figure 1.3 and Figure 1.4.

The relevant chainages are provided in Appendix B and are used for all the conducted analysis.

Table 2-1: Field test set up

Day	Test	Station position		
		Generation	Measurement	
1	1	**WP 9-10 (S9.AV3-NEWAVK001)**	WP 9-11 (S9.AV1-NEWAVK002)	WP 9-9 (S9.AV6-2816AVK001)
	2	**WP 9-9 (S9.AV6-2816AVK001)**	WP 9-10 (S9.AV3-NEWAVK001)	WP 9-8 (S9.AV8-2716AVK001)
	3	**WP 9-8 (S9.AV8-2716AVK001)**	WP 9-7 (S9.AV10-2616AVK001)	-
	4	**WP 9-7 (S9.AV10-2616AVK001)**	WP 9-6 (S9.AV12-2516AVK001)	-
	5	**WP 9-6 (S9.AV12-2516AVK001)**	WP 9-5 (S9.AV13-2416AVK001)	-
	6	**WP 9-4 (S9.AV15-2316AVK001)**	WP 9-5 (S9.AV13-2416AVK001)	WP 9-3 (S9.AV17-2216AVK001)
	7	**WP 9-3 (S9.AV17-2216AVK001)**	WP 9-4 (S9.AV15-2316AVK001)	WP 9-2 (S9.AV19-2116AVK004)
	8	**WP 9-2 (S9.AV19-2116AVK004)**	WP 9-1 (S9.AV22-2116TNO001)	-
2	1	**WP 35-17 (S35A.TP1-128VLN007 (1))**	WP 35-18 (S35A.AV2-2712AVK004)	WP 35-19 (S35A.TP2-2711VLN001 (1))
	2	**WP 35-18 (S35A.AV2-2712AVK004)**	WP 35-17 (S35A.TP1-128VLN007 (1))	WP 35-19 (S35A.TP2-2711VLN001 (1))
	3	**WP 35-16 (S35.AV38-2712AVK008)**	WP 35-15 (S35.AV36-2712AVK005)	-
	4	**WP 35-15 (S35.AV36-2712AVK005)**	WP 35-16 (S35.AV38-2712AVK008)	-
	5	**WP 35-15 (S35.AV36-2712AVK005)**	WP 35-14 (S35.AV34-2712AVK006)	-
	6	**WP 35-14 (S35.AV34-2712AVK006)**	WP 35-13 (S35.AV32-2712AVK007)	-
	7	**WP 35-13 (S35.AV32-2712AVK007)**	WP 35-12 (S35.AV30-2712AVK003)	-
	8	**WP 35-12 (S35.AV30-2712AVK003)**	WP 35-10 (S35.AV26-2513AVK002)	-
3	1	**WP 35-10 (S35.AV26-2513AVK002)**	WP 35-9 (S35.AV21-2413AVK002)	WP 35-12 (S35.AV30-2712AVK003)
	2	**WP 35-9 (S35.AV21-2413AVK002)**	WP 35-7 (S35.AV18-2313AVK001)	WP 35-8 (S35.TP3-NEWTap001)
	3	**WP 35-7 (S35.AV18-2313AVK001)**	WP 35-6 (S35.AV16-2113AVK003)	WP 35-8 (S35.TP3-NEWTap001)
	4	**WP 35-6 (S35.AV16-2113AVK003)**	WP 35-5 (S35.AV13-2113AVK001)	WP 35-7 (S35.AV18-2313AVK001)
	5	**WP 35-5 (S35.AV13-2113AVK001)**	WP 35-4 (S35.AV11-2114AVK001)	-
	6	**WP 35-4 (S35.AV11-2114AVK001)**	WP 35-3 (S35.AV9-2115AVK001)	-
	7	**WP 35-3 (S35.AV9-2115AVK001)**	WP 35-2 (S35.AV7-2116AVK001)	-
	8	**WP 35-2 (S35.AV7-2116AVK001)**	WP 35-1 (S35.TP1-2016TNO001)	-
		Maximum Transient Size		7 psi
		Maximum Discharge		5 gal

Further details on the test equipment and process can be found in Appendix D.

3 Pipeline Properties and Theoretical Wave Speeds

The original pipeline dimensions are required for the p-CAT™ analysis in order to provide an accurate estimate of the current pipe wall condition. This is carried out by comparing the theoretical intact wave speed against the wave speeds measured during testing.

3.1 Intact Theoretical Pipeline Properties

Assumed pipeline properties are taken from the standard ANSI/AWWA C303, GIS Shapefiles, as-constructed drawings and the information supplied by the City of Huntington Beach to determine theoretical wave speeds and pipeline conditions for deterioration calculations. These initial properties are evaluated to create a model of the pipelines in a theoretical intact condition and are summarized below in Table 3-1 and Table 3-2.

The method of determining this intact pipeline state is explored in Appendices D and E.

Table 3-1: Physical properties of the potential pipeline classes and diameters

Assumed physical properties			**BWP**							
Standard used			ANSI/AWWA C303							
Year of installation			1956	1956	1956	1963	1956	2017	1963	1963
Nominal Diameter			16	24	26	27	28	30	33	36
Outside diameter	(OD)	in	19.28	27.91	29.91	30.94	31.91	33.97	37.00	40.04
Wall thickness	(e_W)[1]	in	0.14	0.20	0.20	0.22	0.20	0.23	0.25	0.27
Equivalent thickness	(e_{eq})[2]	in	1.64	1.95	1.95	1.97	1.95	1.98	2.00	2.02

[1] The subscript W indicates that the property is that of the metallic wall.

[2] The subscript eq indicates that the property is that of the equivalent wall.

Refer to Appendix E1 for the adopted method of calculating total equivalent wall thickness.

Table 3-2: Material properties of the pipeline

Material properties			Lining	Coating	Wires	Steel Cylinder
Young's modulus of elasticity	(E_M)	GPa	27	27	193	207
Poisson's ratio	(μ_M)		0.2	0.2	0.3	0.3

The Young's modulus used in this analysis has been taken from the typical elastic moduli and was chosen as a general approximation of the various Young's Modulus that are found in pipes with a large range in age and method of production.

3.2 Theoretical Deterioration from Intact Pipeline

Using the above-mentioned intact pipeline properties, the theoretical wave speeds can be determined for various equivalent wall thicknesses in the pipe. The total equivalent wall thickness is the combined thickness of various materials in terms of metallic wall. For instance, 0.5 in of cement mortar lining is equivalent to 0.06 in of mild steel wall.

The total equivalent wall thicknesses are determined by p-CAT™ using the sub-sectional wave speeds obtained from the test data. The wall thickness is determined by assuming that the following mode of pipeline deterioration for unlined metal pipes has occurred:

- For bar wrapped pipeline and steel cylinder pipeline, the loss of structural integrity can result from calcium leaching, breakage of helically wrapped steel wire, debonding of concrete from the steel cylinder, corrosion of the steel cylinder and bars, and weakening of the concrete matrix due to cracking from relaxation of the prestressed steel wire. Considering these various deterioration mechanisms, the wall thickness of bar wrapped pipeline and steel cylinder pipeline are determined by assuming one mode of deterioration with no physical wall loss.

p-CAT™ is able to determine the effective wall thicknesses along the length of the analyzed pipeline, which is a representation of the pipe wall strength. A visual depiction of bar wrapped pipeline and steel cylinder pipeline deterioration is presented in Figure 3.1 and Figure 3.2.

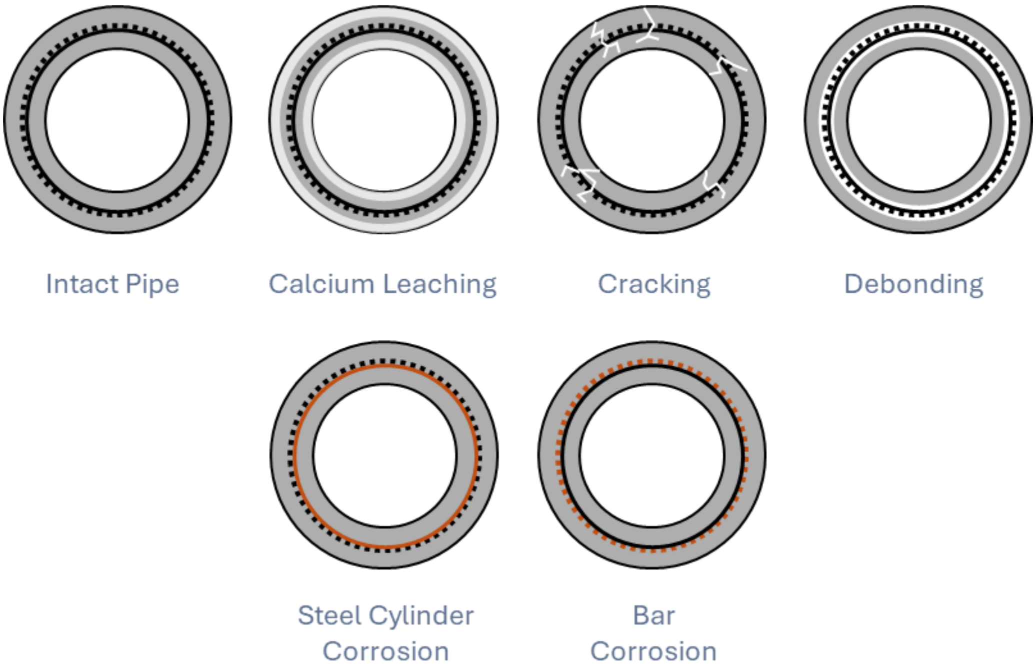


Figure 3.1: Modes of bar wrapped pipeline deterioration
Intact reinforced concrete pipeline, pipeline subjected to calcium leaching, cracking, de-bonding of concrete from steel cylinder and wire, and steel bar corrosion

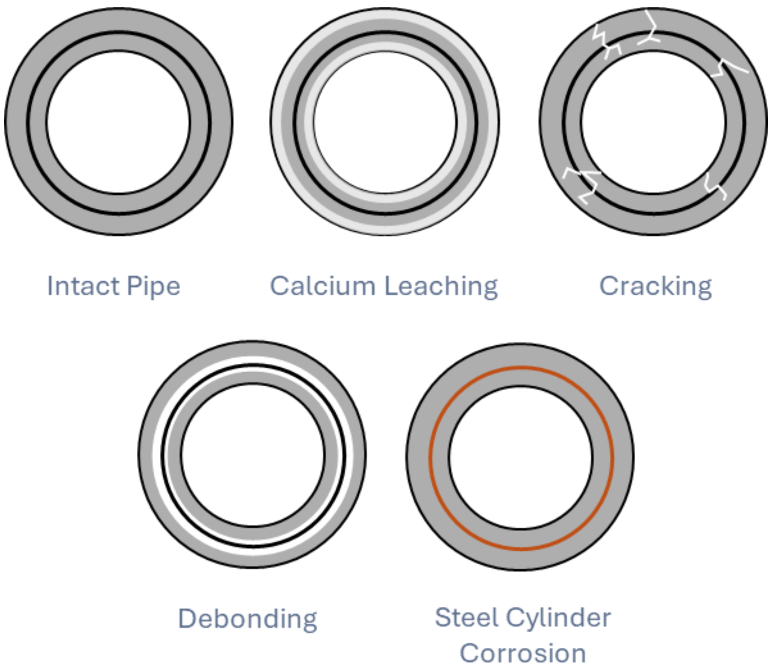


Figure 3.2: Modes of steel cylinder pipeline deterioration
Intact steel cylinder pipeline, pipeline subjected to calcium leaching, cracking, de-bonding of concrete from steel cylinder and wire, and steel corrosion

4 Results

All the information that was provided to PIA, DS and HUSA by Ardurra and the City of Huntington Beach, and has been obtained through site visits and meetings, has been collated. This information was used in the following analysis to determine the known pipeline features (e.g. isolation valves and offtakes) as well as their condition and locations, and the sections of pipeline deterioration.

4.1 Signal Analysis for the Identification of Known Features and Anomalies

For each of the test sites, signal analysis for known features and anomaly identification has been undertaken. The priority terminology used when referring to the anomalies identified in the signal analysis is shown in Table 4-1.

Examples of pressure traces, at which known features are identified by p-CAT™ signal analysis are provided in Appendix C.

Table 4-1: Known features and anomaly priority terminology

Condition Score	Description	Recommended action required
1 Very Poor	The detected anomaly indicates a location of probable failure; It is most likely interrupting the system serviceability and is vulnerable to bursts and leaks.	It is suggested that action/renewal is required to be taken immediately.
2 Poor	The detected anomaly indicates a location of possible future failure; It is potentially interrupting the system serviceability and may be vulnerable to bursts and leaks.	It is suggested that action/renewal is required.
3 Fair	The detected anomaly does not correspond to any known system components and/or requires corrective maintenance	It is suggested that the client to conduct further investigation via records or site visit. A lack of known components (such as a pipe replacement section) in this location may indicate a deteriorated section or a fault.
4 Good	Known anomaly requiring some maintenance or Unknown anomaly not corresponding to any known system components.	No action (minor defects) or minor corrective maintenance.
5 Very Good	The detected feature corresponds to known system components based on the collected system information.	No action is required.

The following known features and anomalies, and their resulting recommended actions were also identified during the signal analysis:

Table 4-2: Summary of anomalies detected in the Huntington Beach Pipelines

Number of Anomalies						
Section	**Total**	**Very Good (5)**	**Good (4)**	**Fair (3)**	**Poor (2)**	**Very Poor (1)**
OC9	43	7	8	25	3	-
OC35	58	8	16	32	2	-
OC35A	8	1	3	4	-	-

Section OC9

- 3 Poor priority anomalies representing:
  - 1 Potential unrecorded pipe change, sedimentation, deterioration, or air pocket.
  - 1 Potential unrecorded pipe change, air pocket, deterioration, or sedimentation.
  - 1 Potential deterioration, air pocket, or unknown offtake at a pipe change (S9.PC8).
- 25 Fair priority anomalies representing:
  - 4 Potential sedimentations, blockages, pipe changes, or concrete encasements.
  - 2 Minor potential air pockets, deteriorations, pipe changes, or offtakes.
  - 8 Potential air pockets, deteriorations, pipe changes, or offtakes.
  - 2 Potential sedimentations, blockages, pipe changes, or concrete encasement sections.
  - 1 Potential closed or partially closed inline valve, sedimentation, pipe change, or concrete encasement (S9.IV6).
  - 3 Minor potential sedimentation, blockage, pipe change, or concrete encasement.
  - 1 Potential open or partially open offtake valve, air pocket, or pipe change (S9.OT13).
  - 2 Potential deteriorations, air pockets, or offtakes at pipe changes (S9.PC6 and S9.PC7).
  - 1 Very minor potential air pocket, deterioration, pipe change, or offtake.
  - 1 Potential deterioration, sedimentation, air pocket or pipe change section (S9.CE3.1 to S9.CE3.2).
- 8 Good priority anomalies representing known features including:
  - 1 Presence of a known pipe change (S9.PC1), open inline valve (S9.IV4) or minor sedimentation.
  - 1 Presence of a known blow off (S9.BO1) or minor sedimentation.
  - 4 Presences of known closed offtake valves (S9.OT2, S9.OT21, S9.OT22 and S9.OT4) or minor issues.
  - 2 Presences of known open offtake valves (S9.OT20, S9.OT6) or minor airs.
- 7 Very Good priority anomalies representing known features including:
  - 1 Presence of a known air valve (S9.AV3).
  - 2 Presences of known closed offtakes (S9.OT11 and S9.OT18).
  - 1 Presence of a known open inline valve (S9.IV4.1).
  - 2 Presences of known open offtakes (S9.OT12 and S9.OT15).
  - 1 Presence of a known open offtake (S9.OT9).

Section OC35

- 2 Poor priority anomalies representing:
  - 2 Potential deteriorations, air pockets, or unknown offtakes at pipe changes (S35.PC1 and S35.PC2).

- 32 Fair priority anomalies representing:
  - 9 Minor potential air pockets, deteriorations, pipe changes, or offtakes.
  - 9 Minor potential sedimentations, blockages, pipe changes, or concrete encasements.
  - 1 Potential air pocket or deterioration at a feature (S35.AV14).
  - 2 Potential air pockets, deteriorations, pipe changes, or offtakes.
  - 1 Potential deterioration, air pocket or pipe change section (S35.CE5.1 to S35.CE5.2).
  - 1 Potential deterioration, air pocket, pipe change, or concrete encasement.

    - 2 Potential open or partially open offtake valves, air pockets, or pipe changes (S35.OT10 and S35.OT14).
    - 1 Potential sedimentation, blockage, pipe change, or concrete encasement section.
    - 6 Potential sedimentations, blockages, pipe changes, or concrete encasements.
- 16 Good priority anomalies representing known features including:
    - 1 Presence of a known pressure reduction valve (S35.PRV1) or minor sedimentation.
    - 3 Presences of concrete encasements sections (S35.CE3.1 to S35.CE3.2, S35.CE4.1 to S35.CE4.2 and S35.CE6.1 to S35.CE6.2) or minor sedimentations.
    - 1 Presence of a known closed offtake valve (S35.OT21) or minor issue.
    - 1 Presence of a known open inline valve (S35.IV5), or minor issue.
    - 9 Presences of known open offtake valves (S35.OT8, S35.OT11, S35.OT12, S35.OT17, S35.OT19, S35.OT22, S35.OT25, S35.OT27 and S35.OT28) or minor airs.
    - 1 Presence of a known pipe change (S35.PC3) or minor sedimentation.
- 8 Very Good priority anomalies representing known features including:
    - 1 Presence of a known air valve (S35.AV5).
    - 1 Presence of a known closed offtake (S35.OT16).
    - 1 Presence of a known concrete encasement section (S35.CE9.1 to S35.CE9.2).
    - 2 Presences of known open inline valves (S35.IV1 and S35.IV2).
    - 2 Presences of known open offtakes (S35.OT5 and S35.OT6).
    - 1 Presence of a known taping point (S35.TP3).

Section OC35A

- 4 Fair priority anomalies representing:
    - 1 Potential sedimentation, blockage, pipe change, or concrete encasement section.
    - 1 Minor potential air pocket, deterioration, pipe change, or offtake.
    - 2 Potential deteriorations, air pockets, or offtakes at pipe changes (S35A.PC2 and S35A.PC3).
- 3 Good priority anomalies representing known features including:
    - 1 Presence of a known closed inline valve (S35A.IV1) or minor issue.
    - 2 Presences of known open offtake valves (S35A.OT1 and S35A.OT4) or minor airs.
- 1 Very Good priority anomalies representing known features including:
    - 1 Presence of a known open inline valve (S35A.IV2).

Table 4-3: Summary of the features and anomalies detected in the HB pipelines, section OC9

Identifier	Approximate location	Interpretation	Condition Score	Recommended action
S9.A	At S9.PC1	Presence of a known pipe change (S9.PC1), open inline valve (S9.IV4) or minor sedimentation.	**4**	None, known system feature or minor issue.
S9.B	At S9.OT2	Presence of a known closed offtake valve (S9.OT2) or minor issue.	**4**	None, known system feature or minor issue.
S9.C	Approx. Ch. 974 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.D	Approx. Ch. 1054 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.E	Approx. Ch. 1909 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.F	Approx. Ch. 2802 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.G	At S9.AV3	Presence of a known air valve (S9.AV3).	**5**	None, known system features.
S9.H	Approx. Ch. 4562 ft	Potential unrecorded pipe change, sedimentation, deterioration, or air pocket.	**2**	Check records for pipe change or replacement. Investigate pipeline condition. Remove sedimentation or air pocket as it may affect system performance. There is an increased likelihood of localised internal deterioration at this point.
S9.I	At S9.BO1	Presence of a known blow off (S9.BO1) or minor sedimentation.	**4**	None, known system feature or minor issue.
S9.J	At S9.OT4	Presence of a known closed offtake valve (S9.OT4) or minor issue.	**4**	None, known system feature or minor issue.
S9.K	At S9.IV4.1	Presence of a known open inline valve (S9.IV4.1).	**5**	None, known system features.
S9.L	Approx. Ch. 6516 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.M	Approx. Ch. 6726 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.N	Approx. Ch. 6852 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.O	From Ch. 8407 to Ch. 8505 ft	Potential sedimentation, blockage, pipe change, or concrete encasement section.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.P	Approx. Ch. 9045 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.Q	At S9.OT6	Presence of a known open offtake valve (S9.OT6) or minor air.	**4**	None, known system feature or minor issue.
S9.R	Approx. Ch. 10190 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.S	At S9.IV6	Potential closed or partially closed inline valve, sedimentation, pipe change, or concrete encasement (S9.IV6).	**3**	Exercise the valve to determine valve status, check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.T	Approx. Ch. 12533 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.U	At S9.OT9	Presence of a known open offtake (S9.OT9).	**5**	None, known system features.
S9.V	At S9.OT11	Presence of a known closed offtake (S9.OT11).	**5**	None, known system features.
S9.W	Approx. Ch. 14534 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.X	Approx. Ch. 14711 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.Y	From Ch. 14779 to Ch. 14920 ft	Potential sedimentation, blockage, pipe change, or concrete encasement section.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.Z	Approx. Ch. 16442 ft	Potential unrecorded pipe change, air pocket, deterioration, or sedimentation.	**2**	Check records for pipe change or replacement. Investigate pipeline condition. Remove air pocket or sedimentation as it may affect system performance. There is an increased likelihood of localised internal deterioration at this point.

Table 4-3 Continued

Identifier	Approximate location	Interpretation	Condition Score	Recommended action
S9.AA	At S9.OT12	Presence of a known open offtake (S9.OT12).	**5**	None, known system features.
S9.AB	At S9.OT13	Potential open or partially open offtake valve, air pocket, or pipe change (S9.OT13).	**3**	Exercise the valve to determine valve status, check records for pipe change, replacement, concrete encasement. If no change, remove air. Investigate pipeline condition.
S9.AC	At S9.OT15	Presence of a known open offtake (S9.OT15).	**5**	None, known system features.
S9.AD	Approx. Ch. 18175 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.AE	Approx. Ch. 18997 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.AF	At S9.PC6	Potential deterioration, air pocket, or offtake at a pipe change (S9.PC6).	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.AG	At S9.PC7	Potential deterioration, air pocket, or offtake at a pipe change (S9.PC7).	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.AH	Approx. Ch. 21005 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.AI	Approx. Ch. 21452 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.AJ	At S9.OT18	Presence of a known closed offtake (S9.OT18).	**5**	None, known system features.
S9.AK	At S9.OT20	Presence of a known open offtake valve (S9.OT20) or minor air.	**4**	None, known system feature or minor issue.
S9.AL	Approx. Ch. 24042 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S9.AM	Approx. Ch. 24411 ft	Very minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S9.AN	At S9.OT21	Presence of a known closed offtake valve (S9.OT21) or minor issue.	**4**	None, known system feature or minor issue.
S9.AO	At S9.OT22	Presence of a known closed offtake valve (S9.OT22) or minor issue.	**4**	None, known system feature or minor issue.
S9.AP	From S9.CE3.1 to S9.CE3.2	Potential deterioration, sedimentation, air pocket or pipe change section (S9.CE3.1 to S9.CE3.2).	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation or air pocket. Investigate pipeline condition.
S9.AQ	At S9.PC8	Potential deterioration, air pocket, or unknown offtake at a pipe change (S9.PC8).	**2**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition. There is an increased likelihood of localised internal deterioration at this point.

Table 4-4: Summary of features and anomalies detected in the HB pipelines, section OC35

Identifier	Approximate location	Interpretation	Condition Score	Recommended action
S35.A	At S35.PRV1	Presence of a known pressure reduction valve (S35.PRV1) or minor sedimentation.	**4**	None, known system feature or minor issue.
S35.B	Approx. Ch. 246 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.C	Approx. Ch. 1093 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.D	At S35.AV5	Presence of a known air valve (S35.AV5).	**5**	None, known system features.
S35.E	From S35.CE3.1 to S35.CE3.2	Presence of a concrete encasement section (S35.CE3.1 to S35.CE3.2) or minor sedimentation.	**4**	None, known system feature or minor issue.
S35.F	At S35.OT5	Presence of a known open offtake (S35.OT5).	**5**	None, known system features.
S35.G	Approx. Ch. 3676 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.H	From S35.CE4.1 to S35.CE4.2	Presence of a concrete encasement section (S35.CE4.1 to S35.CE4.2) or minor sedimentation.	**4**	None, known system feature or minor issue.
S35.I	From S35.CE5.1 to S35.CE5.2	Potential deterioration, air pocket or pipe change section (S35.CE5.1 to S35.CE5.2).	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove air pocket. Investigate pipeline condition.
S35.J	At S35.OT6	Presence of a known open offtake (S35.OT6).	**5**	None, known system features.
S35.K	Approx. Ch. 5971 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.L	Approx. Ch. 6420 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.M	Approx. Ch. 6592 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.N	Approx. Ch. 6760 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.O	Approx. Ch. 7743 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.P	At S35.IV1	Presence of a known open inline valve (S35.IV1).	**5**	None, known system features.
S35.Q	At S35.AV14	Potential air pocket or deterioration at a feature (S35.AV14).	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.R	At S35.OT8	Presence of a known open offtake valve (S35.OT8) or minor air.	**4**	None, known system feature or minor issue.
S35.S	Approx. Ch. 9939 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.T	Approx. Ch. 10499 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.U	Approx. Ch. 10729 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.V	Approx. Ch. 10997 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.W	Approx. Ch. 11517 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.X	Approx. Ch. 12169 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.Y	Approx. Ch. 12632 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.Z	Approx. Ch. 13019 ft	Potential deterioration, air pocket, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove air pocket. Investigate pipeline condition.

Table 4-4 Continued

Identifier	Approximate location	Interpretation	Condition Score	Recommended action
S35.AA	At S35.PC1	Potential deterioration, air pocket, or unknown offtake at a pipe change (S35.PC1).	**2**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition. There is an increased likelihood of localised internal deterioration at this point.
S35.AB	Approx. Ch. 13618 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.AC	At S35.OT10	Potential open or partially open offtake valve, air pocket, or pipe change (S35.OT10).	**3**	Exercise the valve to determine valve status, check records for pipe change, replacement, concrete encasement. If no change, remove air. Investigate pipeline condition.
S35.AD	At S35.OT11	Presence of a known open offtake valve (S35.OT11) or minor air.	**4**	None, known system feature or minor issue.
S35.AE	Approx. Ch. 15909 ft	Potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.AF	At S35.IV2	Presence of a known open inline valve (S35.IV2).	**5**	None, known system features.
S35.AG	At S35.TP3	Presence of a known taping point (S35.TP3).	**5**	None, known system features.
S35.AH	Approx. Ch. 17103 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.AI	Approx. Ch. 17224 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AJ	From S35.CE6.1 to S35.CE6.2	Presence of a concrete encasement section (S35.CE6.1 to S35.CE6.2) or minor sedimentation.	**4**	None, known system feature or minor issue.
S35.AK	At S35.OT12	Presence of a known open offtake valve (S35.OT12) or minor air.	**4**	None, known system feature or minor issue.
S35.AL	Approx. Ch. 19225 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.AM	Approx. Ch. 19491 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35.AN	Approx. Ch. 19810 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AO	Approx. Ch. 20209 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AP	Approx. Ch. 20899 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AQ	Approx. Ch. 21171 ft	Potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AR	From Ch. 21381 to Ch. 21419 ft	Potential sedimentation, blockage, pipe change, or concrete encasement section.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AS	At S35.OT14	Potential open or partially open offtake valve, air pocket, or pipe change (S35.OT14).	**3**	Exercise the valve to determine valve status, check records for pipe change, replacement, concrete encasement. If no change, remove air. Investigate pipeline condition.
S35.AT	At S35.OT16	Presence of a known closed offtake (S35.OT16).	**5**	None, known system features.
S35.AU	Approx. Ch. 24109 ft	Minor potential sedimentation, blockage, pipe change, or concrete encasement.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35.AV	At S35.OT17	Presence of a known open offtake valve (S35.OT17) or minor air.	**4**	None, known system feature or minor issue.
S35.AW	At S35.PC2	Potential deterioration, air pocket, or unknown offtake at a pipe change (S35.PC2).	**2**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition. There is an increased likelihood of localised internal deterioration at this point.
S35.AX	At S35.OT19	Presence of a known open offtake valve (S35.OT19) or minor air.	**4**	None, known system feature or minor issue.
S35.AY	At S35.OT21	Presence of a known closed offtake valve (S35.OT21) or minor issue.	**4**	None, known system feature or minor issue.
S35.AZ	At S35.PC3	Presence of a known pipe change (S35.PC3) or minor sedimentation.	**4**	None, known system feature or minor issue.
S35.BA	At S35.OT22	Presence of a known open offtake valve (S35.OT22) or minor air.	**4**	None, known system feature or minor issue.
S35.BB	At S35.IV5	Presence of a known open inline valve (S35.IV5), or minor issue.	**4**	None, known system feature or minor issue.

Table 4-4 Continued

Identifier	Approximate location	Interpretation	Condition Score	Recommended action
S35.BC	From S35.CE9.1 to S35.CE9.2	Presence of a known concrete encasement section (S35.CE9.1 to S35.CE9.2).	**5**	None, known system features.
S35.BD	At S35.OT25	Presence of a known open offtake valve (S35.OT25) or minor air.	**4**	None, known system feature or minor issue.
S35.BE	At S35.OT27	Presence of a known open offtake valve (S35.OT27) or minor air.	**4**	None, known system feature or minor issue.
S35.BF	At S35.OT28	Presence of a known open offtake valve (S35.OT28) or minor air.	**4**	None, known system feature or minor issue.

Table 4-5: Summary of the features and anomalies detected in the HB pipelines, section OC35A

Identifier	Approximate location	Interpretation	Condition Score	Recommended action
S35A.A	At S35A.IV1	Presence of a known closed inline valve (S35A.IV1) or minor issue.	**4**	None, known system feature or minor issue.
S35A.B	From Ch. 817 to Ch. 869 ft	Potential sedimentation, blockage, pipe change, or concrete encasement section.	**3**	Check records for pipe change, replacement, concrete encasement. If no change, remove sedimentation, or blockage. Investigate pipeline condition.
S35A.C	Approx. Ch. 1470 ft	Minor potential air pocket, deterioration, pipe change, or offtake.	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35A.D	At S35A.IV2	Presence of a known open inline valve (S35A.IV2).	**5**	None, known system features.
S35A.E	At S35A.OT1	Presence of a known open offtake valve (S35A.OT1) or minor air.	**4**	None, known system feature or minor issue.
S35A.F	At S35A.PC2	Potential deterioration, air pocket, or offtake at a pipe change (S35A.PC2).	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.
S35A.G	At S35A.OT4	Presence of a known open offtake valve (S35A.OT4) or minor air.	**4**	None, known system feature or minor issue.
S35A.H	At S35A.PC3	Potential deterioration, air pocket, or offtake at a pipe change (S35A.PC3).	**3**	Remove air pocket as it may affect system performance, check records for pipe change, offtake, or replacement. Investigate pipeline condition.

4.2 Pipeline Wall Deterioration (Sub-sectional Condition)

The average deterioration of the pipe wall over determined sub-sections are determined using Sub-Section Partitioned Wave Speed Analysis™ and are presented in Table 4-8, Table 4-9 and Table 4-10. The varying levels of deterioration of the pipeline subjected to external and internal corrosion are shown in Figure 4.1, Figure 4.2 and Figure 4.3 respectively.

Note that p-CAT™ is able to provide the total equivalent wall thickness along the length of the pipeline. Table 4-8, Table 4-9 and Table 4-10 present varying levels of deterioration of the pipeline. In BWP and SCP pipelines, structural integrity is compromised by several deterioration mechanisms, including the rupture of helically wrapped steel wires and the weakening of the concrete matrix due to cracking from steel wire relaxation. Considering these modes of deterioration, the remaining wall thickness is analysed regardless of either external or internal corrosion. The percentage of remaining wall thicknesses reflect remaining wall strength rather than the actual physical wall thickness loss, and it is recommended that the City of Huntington Beach assess the remaining strength of the pipeline using the percentage of remaining wall strength, rather than based only on the wall thickness values provided.

An in-depth summary that visually presents the results of the remaining wall thicknesses is provided to the City of Huntington Beach in a separate document accompanying this report.

The method used to determine the deterioration is further explained in Appendix E. The priority terminology used when referring to the anomalies identified in the signal analysis is shown in Table 4-6 below.

Table 4-6: Sub-sectional terminology

Score	Condition	Remaining Wall
1	Very Poor	< 60 %
2	Poor	60 - 70 %
3	Fair	70 - 80 %
4	Good	80 - 90 %
5	Very Good	90 - 100 %
NA	N/A	Unable to be analysed

The following pipeline wall condition was identified during the p-CAT™ analysis:

Table 4-7: Pipeline wall condition summary

Section	Wall Remaining (%)					
	100 – 90%	90 – 80%	80 – 70%	70 – 60%	60 - 50%	Not applicable
OC9	-	3.9%	84.7%	9.4%	-	2.0%
OC35	8.0%	3.7%	10.7%	65.3%	12.3%	-
OC35A	-	-	59.2%	40.0%	-	0.8%

Section OC9 (S9)

- 9.4% of the total pipeline length has a remaining wall thickness of between 60% and 70%.
- 84.7% of the total pipeline length has a remaining wall thickness of between 70% and 80%.
- 3.9% of the total pipeline length has a remaining wall thickness of between 80% and 90%.
- 2.0% of the total pipeline length has an unknown material.

Section OC35 (S35)

- 12.3% of the total pipeline length has a remaining wall thickness of between 50% and 60%.
- 65.3% of the total pipeline length has a remaining wall thickness of between 60% and 70%.
- 10.7% of the total pipeline length has a remaining wall thickness of between 70% and 80%.
- 3.7% of the total pipeline length has a remaining wall thickness of between 80% and 90%.
- 8.0% of the total pipeline length has a remaining wall thickness of between 90% and 100%.

Section OC35A (S35A)

- 40.0% of the total pipeline length has a remaining wall thickness of between 60% and 70%.
- 59.2% of the total pipeline length has a remaining wall thickness of between 70% and 80%.
- 0.8% of the total pipeline length was before a closed inline valve (S35A.IV1).

The percentage of remaining wall thickness is determined by comparing the theoretical pipeline specifications with the signal analysis, which ultimately defines the remaining structural strength based on the current conditions of the pipeline.

It is recommended that the City of Huntington Beach assess the remaining strength of the pipeline using the percentage of remaining wall strength, rather than based only on the wall thickness values provided. This approach is recommended because the strength of the pipeline is more significantly impacted by factors such as the debonding of the metal wires from the concrete and wire breakage, rather than a reduction in wall thickness due to leaching. The City of Huntington Beach should also investigate the current pipeline properties and configuration, and the presence of possible entrained or entrapped gas before coming to the conclusion that sections are deteriorated. These faults can also affect the accuracy of the p-CAT™ results for both the condition assessment and the anomaly identification. By considering all these factors, the City of Huntington Beach can gain a more accurate understanding of the pipeline's condition.

Table 4-8: BWP pipe wall deterioration results for OC9
Assuming nominal theoretical values as original wall thickness (specified in the ANSI/AWWA C303)

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.1	0	566	S9.Start to S9.PC1 **(Anomaly S9.A)**	566	Unknown	NA	Unknown material		
S9.2	566	603	S9.PC1 to S9.OT2 **(Anomaly S9.B)**	36	DN24 BWP	1.95	1.36 (-0.59)	69.6%	2
S9.3	603	842	As per chainage	239	DN24 BWP	1.95	1.49 (-0.46)	76.4%	3
S9.4	842	974	Previous point to **Anomaly S9.C**	132	DN24 BWP	1.95	1.51 (-0.45)	77.1%	3
S9.5	974	1054	Previous point to **Anomaly S9.D**	81	DN24 BWP	1.95	1.48 (-0.47)	76.0%	3
S9.6	1054	1271	As per chainage	216	DN24 BWP	1.95	1.47 (-0.48)	75.4%	3
S9.7	1271	1395	As per chainage	124	DN24 BWP	1.95	1.45 (-0.50)	74.1%	3
S9.8	1395	1487	As per chainage	92	DN24 BWP	1.95	1.46 (-0.49)	74.7%	3
S9.9	1487	1726	As per chainage	239	DN24 BWP	1.95	1.47 (-0.49)	75.1%	3
S9.10	1726	1909	Previous point to **Anomaly S9.E**	184	DN24 BWP	1.95	1.48 (-0.47)	75.8%	3
S9.11	1909	2152	As per chainage	243	DN24 BWP	1.95	1.53 (-0.42)	78.4%	3
S9.12	2152	2362	As per chainage	210	DN24 BWP	1.95	1.52 (-0.44)	77.6%	3
S9.13	2362	2617	As per chainage	256	DN24 BWP	1.95	1.53 (-0.42)	78.4%	3
S9.14	2617	2802	Previous point to **Anomaly S9.F**	184	DN24 BWP	1.95	1.52 (-0.43)	78.0%	3
S9.15	2802	3344	Previous point to S9.AV3 **(Anomaly S9.G)**	542	DN24 BWP	1.95	1.44 (-0.51)	73.9%	3
S9.16	3344	3623	As per chainage	279	DN24 BWP	1.95	1.44 (-0.51)	73.9%	3
S9.17	3623	3987	As per chainage	364	DN24 BWP	1.95	1.46 (-0.49)	75.0%	3
S9.18	3987	4111	As per chainage	125	DN24 BWP	1.95	1.43 (-0.53)	73.1%	3
S9.19	4111	4331	As per chainage	219	DN24 BWP	1.95	1.48 (-0.47)	75.7%	3
S9.20	4331	4472	As per chainage	141	DN24 BWP	1.95	1.45 (-0.50)	74.2%	3
S9.21	4472	4562	Previous point to **Anomaly S9.H**	90	DN24 BWP	1.95	1.44 (-0.51)	73.9%	3
S9.22	4562	4839	As per chainage	277	DN24 BWP	1.95	1.64 (-0.32)	83.9%	4
S9.23	4839	5000	Previous point to S9.BO1 **(Anomaly S9.I)**	161	DN24 BWP	1.95	1.64 (-0.31)	83.9%	4
S9.24	5000	5110	As per chainage	110	DN24 BWP	1.95	1.38 (-0.57)	70.7%	3
S9.25	5110	5307	As per chainage	197	DN24 BWP	1.95	1.35 (-0.60)	69.3%	2
S9.26	5307	5465	As per chainage	159	DN24 BWP	1.95	1.37 (-0.58)	70.1%	3
S9.27	5465	5712	As per chainage	246	DN24 BWP	1.95	1.37 (-0.58)	70.0%	3
S9.28	5712	5906	Previous point to S9.OT4 **(Anomaly S9.J)**	194	DN24 BWP	1.95	1.36 (-0.59)	69.6%	2
S9.29	5906	5912	S9.OT4 to S9.OT5	6	DN24 BWP	1.95	1.48 (-0.47)	76.0%	3
S9.30	5912	5985	S9.OT5 to S9.IV4.1 **(Anomaly S9.K)**	73	DN24 BWP	1.95	1.56 (-0.40)	79.7%	3
S9.31	5985	6290	As per chainage	305	DN24 BWP	1.95	1.45 (-0.51)	74.1%	3
S9.32	6290	6516	Previous point to **Anomaly S9.L**	225	DN24 BWP	1.95	1.43 (-0.52)	73.1%	3
S9.33	6516	6726	Previous point to **Anomaly S9.M**	210	DN24 BWP	1.95	1.48 (-0.47)	76.0%	3
S9.34	6726	6852	Previous point to **Anomaly S9.N**	126	DN24 BWP	1.95	1.53 (-0.42)	78.6%	3
S9.35	6852	7095	As per chainage	243	DN24 BWP	1.95	1.47 (-0.48)	75.5%	3
S9.36	7095	7233	As per chainage	138	DN24 BWP	1.95	1.49 (-0.47)	76.0%	3
S9.37	7233	7492	As per chainage	259	DN24 BWP	1.95	1.49 (-0.46)	76.3%	3
S9.38	7492	7757	As per chainage	265	DN24 BWP	1.95	1.48 (-0.47)	75.7%	3
S9.39	7757	7925	As per chainage	168	DN24 BWP	1.95	1.47 (-0.48)	75.3%	3
S9.40	7925	8207	As per chainage	282	DN24 BWP	1.95	1.48 (-0.47)	75.9%	3
S9.41	8207	8407	Previous point to **Anomaly S9.O (Start)**	200	DN24 BWP	1.95	1.49 (-0.46)	76.2%	3
S9.42	8407	8505	**Anomaly S9.O**	97	DN24 BWP	1.95	1.58 (-0.37)	81.1%	4

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-8 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.43	8505	8659	As per chainage	154	DN24 BWP	1.95	1.59 (-0.37)	81.2%	4
S9.44	8659	8957	As per chainage	298	DN24 BWP	1.95	1.57 (-0.39)	80.3%	4
S9.45	8957	9045	Previous point to **Anomaly S9.P**	88	DN24 BWP	1.95	1.58 (-0.37)	81.0%	4
S9.46	9045	9223	As per chainage	178	DN24 BWP	1.95	1.48 (-0.47)	75.9%	3
S9.47	9223	9433	As per chainage	210	DN24 BWP	1.95	1.48 (-0.47)	75.9%	3
S9.48	9433	9673	As per chainage	240	DN24 BWP	1.95	1.50 (-0.46)	76.6%	3
S9.49	9673	9810	Previous point to S9.OT6 **(Anomaly S9.Q)**	137	DN24 BWP	1.95	1.48 (-0.48)	75.6%	3
S9.50	9810	10082	As per chainage	273	DN24 BWP	1.95	1.40 (-0.55)	71.7%	3
S9.51	10082	10190	Previous point to **Anomaly S9.R**	108	DN24 BWP	1.95	1.42 (-0.54)	72.5%	3
S9.52	10190	10479	As per chainage	289	DN24 BWP	1.95	1.42 (-0.54)	72.5%	3
S9.53	10479	10620	As per chainage	141	DN24 BWP	1.95	1.41 (-0.54)	72.4%	3
S9.54	10620	10745	As per chainage	124	DN24 BWP	1.95	1.38 (-0.57)	70.9%	3
S9.55	10745	10984	As per chainage	240	DN24 BWP	1.95	1.43 (-0.52)	73.2%	3
S9.56	10984	11256	Previous point to S36 (PC2)	271	DN24 BWP	1.95	1.41 (-0.54)	72.4%	3
S9.57	11256	11259	S36 (PC2) to S9.IV6 **(Anomaly S9.S)**	3	DN16 BWP	1.64	1.05 (-0.59)	64.2%	2
S9.58	11259	11622	As per chainage	364	DN26 BWP	1.95	1.52 (-0.43)	77.8%	3
S9.59	11622	11897	As per chainage	275	DN26 BWP	1.95	1.52 (-0.43)	77.9%	3
S9.60	11897	12003	As per chainage	105	DN26 BWP	1.95	1.52 (-0.44)	77.7%	3
S9.61	12003	12202	As per chainage	200	DN26 BWP	1.95	1.51 (-0.44)	77.3%	3
S9.62	12202	12383	As per chainage	181	DN26 BWP	1.95	1.51 (-0.44)	77.5%	3
S9.63	12383	12533	Previous point to **Anomaly S9.T**	150	DN26 BWP	1.95	1.54 (-0.42)	78.6%	3
S9.64	12533	12664	As per chainage	131	DN26 BWP	1.95	1.47 (-0.48)	75.2%	3
S9.65	12664	12873	As per chainage	210	DN26 BWP	1.95	1.47 (-0.48)	75.2%	3
S9.66	12873	13109	As per chainage	236	DN26 BWP	1.95	1.46 (-0.49)	74.9%	3
S9.67	13109	13254	As per chainage	144	DN26 BWP	1.95	1.47 (-0.48)	75.5%	3
S9.68	13254	13496	As per chainage	243	DN26 BWP	1.95	1.46 (-0.49)	74.8%	3
S9.69	13496	13763	Previous point to S9.OT9 **(Anomaly S9.U)**	267	DN26 BWP	1.95	1.47 (-0.49)	75.1%	3
S9.70	13763	13891	S9.OT9 to S46.1 (PC4)	127	DN26 BWP	1.95	1.45 (-0.51)	74.1%	3
S9.71	13891	13894	S46.1 (PC4) to S9.OT11 **(Anomaly S9.V)**	3	DN16 BWP	1.64	1.04 (-0.60)	63.2%	2
S9.72	13894	14169	As per chainage	275	DN26 BWP	1.95	1.37 (-0.58)	70.3%	3
S9.73	14169	14261	As per chainage	92	DN26 BWP	1.95	1.41 (-0.55)	72.1%	3
S9.74	14261	14534	Previous point to **Anomaly S9.W**	274	DN26 BWP	1.95	1.38 (-0.58)	70.4%	3
S9.75	14534	14711	Previous point to **Anomaly S9.X**	177	DN26 BWP	1.95	1.32 (-0.64)	67.5%	2
S9.76	14711	14779	Previous point to **Anomaly S9.Y (Start)**	67	DN26 BWP	1.95	1.39 (-0.57)	70.9%	3
S9.77	14779	14920	**Anomaly S9.Y**	142	DN26 BWP	1.95	1.56 (-0.39)	79.8%	3
S9.78	14920	15143	As per chainage	223	DN26 BWP	1.95	1.38 (-0.57)	70.8%	3
S9.79	15143	15481	As per chainage	338	DN26 BWP	1.95	1.39 (-0.57)	70.9%	3
S9.80	15481	15658	As per chainage	177	DN26 BWP	1.95	1.38 (-0.57)	70.9%	3
S9.81	15658	15772	As per chainage	114	DN26 BWP	1.95	1.38 (-0.58)	70.5%	3
S9.82	15772	16018	As per chainage	246	DN26 BWP	1.95	1.39 (-0.56)	71.4%	3
S9.83	16018	16162	As per chainage	144	DN26 BWP	1.95	1.37 (-0.58)	70.1%	3
S9.84	16162	16442	Previous point to **Anomaly S9.Z**	280	DN26 BWP	1.95	1.39 (-0.56)	71.1%	3

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-8 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.85	16442	16498	Previous point to S9.OT12 **(Anomaly S9.AA)**	56	DN26 BWP	1.95	1.48 (-0.47)	75.9%	3
S9.86	16498	16625	As per chainage	128	DN26 BWP	1.95	1.29 (-0.67)	65.9%	2
S9.87	16625	16868	As per chainage	243	DN26 BWP	1.95	1.31 (-0.65)	66.8%	2
S9.88	16868	16979	As per chainage	111	DN26 BWP	1.95	1.25 (-0.70)	64.1%	2
S9.89	16979	17163	As per chainage	183	DN26 BWP	1.95	1.29 (-0.66)	66.0%	2
S9.90	17163	17331	Previous point to S9.OT13 **(Anomaly S9.AB)**	169	DN26 BWP	1.95	1.30 (-0.65)	66.8%	2
S9.91	17331	17439	S9.OT13 to S9.OT15 **(Anomaly S9.AC)**	108	DN26 BWP	1.95	1.33 (-0.62)	68.1%	2
S9.92	17439	17639	As per chainage	200	DN26 BWP	1.95	1.45 (-0.51)	74.1%	3
S9.93	17639	17882	As per chainage	243	DN26 BWP	1.95	1.41 (-0.54)	72.2%	3
S9.94	17882	18032	As per chainage	151	DN26 BWP	1.95	1.46 (-0.49)	74.8%	3
S9.95	18032	18175	Previous point to **Anomaly S9.AD**	143	DN26 BWP	1.95	1.46 (-0.50)	74.7%	3
S9.96	18175	18509	As per chainage	334	DN26 BWP	1.95	1.39 (-0.56)	71.3%	3
S9.97	18509	18670	As per chainage	160	DN26 BWP	1.95	1.39 (-0.57)	71.0%	3
S9.98	18670	18810	As per chainage	141	DN26 BWP	1.95	1.38 (-0.57)	70.8%	3
S9.99	18810	18997	Previous point to **Anomaly S9.AE**	186	DN26 BWP	1.95	1.38 (-0.57)	70.6%	3
S9.100	18997	19223	As per chainage	226	DN26 BWP	1.95	1.44 (-0.51)	73.7%	3
S9.101	19223	19364	As per chainage	141	DN26 BWP	1.95	1.41 (-0.54)	72.4%	3
S9.102	19364	19492	As per chainage	128	DN26 BWP	1.95	1.46 (-0.49)	74.9%	3
S9.103	19492	19754	As per chainage	262	DN26 BWP	1.95	1.46 (-0.50)	74.6%	3
S9.104	19754	19998	Previous point to S9.PC6 **(Anomaly S9.AF)**	244	DN26 BWP	1.95	1.43 (-0.53)	73.0%	3
S9.105	19998	20007	S9.PC6 to S9.PC7 **(Anomaly S9.AG)**	9	DN16 BWP	1.64	1.22 (-0.43)	74.1%	3
S9.106	20007	20309	As per chainage	302	DN28 BWP	1.95	1.46 (-0.49)	74.9%	3
S9.107	20309	20470	As per chainage	161	DN28 BWP	1.95	1.46 (-0.49)	74.9%	3
S9.108	20470	20679	As per chainage	210	DN28 BWP	1.95	1.47 (-0.48)	75.3%	3
S9.109	20679	20781	As per chainage	101	DN28 BWP	1.95	1.52 (-0.43)	77.8%	3
S9.110	20781	21005	Previous point to **Anomaly S9.AH**	225	DN28 BWP	1.95	1.45 (-0.50)	74.3%	3
S9.111	21005	21268	As per chainage	262	DN28 BWP	1.95	1.48 (-0.48)	75.6%	3
S9.112	21268	21452	Previous point to **Anomaly S9.AI**	184	DN28 BWP	1.95	1.46 (-0.49)	75.0%	3
S9.113	21452	21566	Previous point to S9.OT17	115	DN28 BWP	1.95	1.53 (-0.42)	78.4%	3
S9.114	21566	21825	As per chainage	259	DN28 BWP	1.95	1.39 (-0.56)	71.2%	3
S9.115	21825	22206	As per chainage	380	DN28 BWP	1.95	1.39 (-0.56)	71.2%	3
S9.116	22206	22415	As per chainage	210	DN28 BWP	1.95	1.41 (-0.54)	72.4%	3
S9.117	22415	22649	Previous point to S9.OT18 **(Anomaly S9.AJ)**	234	DN28 BWP	1.95	1.38 (-0.57)	70.6%	3
S9.118	22649	22973	As per chainage	324	DN28 BWP	1.95	1.37 (-0.58)	70.3%	3
S9.119	22973	23226	Previous point to S9.OT20 **(Anomaly S9.AK)**	253	DN28 BWP	1.95	1.36 (-0.59)	69.7%	2
S9.120	23226	23444	As per chainage	218	DN28 BWP	1.95	1.51 (-0.45)	77.2%	3
S9.121	23444	23733	As per chainage	289	DN28 BWP	1.95	1.52 (-0.44)	77.6%	3
S9.122	23733	24042	Previous point to **Anomaly S9.AL**	309	DN28 BWP	1.95	1.50 (-0.45)	77.0%	3
S9.123	24042	24411	Previous point to **Anomaly S9.AM**	369	DN28 BWP	1.95	1.48 (-0.48)	75.6%	3
S9.124	24411	24647	As per chainage	236	DN28 BWP	1.95	1.47 (-0.48)	75.3%	3
S9.125	24647	24913	As per chainage	266	DN28 BWP	1.95	1.45 (-0.50)	74.4%	3
S9.126	24913	25067	As per chainage	154	DN28 BWP	1.95	1.51 (-0.44)	77.3%	3

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-8 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.127	25067	25323	Previous point to S9.OT21 **(Anomaly S9.AN)**	257	DN28 BWP	1.95	1.44 (-0.51)	73.8%	3
S9.128	25323	25448	As per chainage	125	DN28 BWP	1.95	1.51 (-0.44)	77.3%	3
S9.129	25448	25723	As per chainage	276	DN28 BWP	1.95	1.48 (-0.48)	75.6%	3
S9.130	25723	26018	Previous point to S9.OT22 **(Anomaly S9.AO)**	295	DN28 BWP	1.95	1.51 (-0.44)	77.3%	3
S9.131	26018	26365	As per chainage	347	DN28 BWP	1.95	1.47 (-0.48)	75.4%	3
S9.132	26365	26552	As per chainage	187	DN28 BWP	1.95	1.48 (-0.47)	75.8%	3
S9.133	26552	26785	As per chainage	233	DN28 BWP	1.95	1.46 (-0.49)	74.9%	3
S9.134	26785	26990	Previous point to S9.OT23	206	DN28 BWP	1.95	1.48 (-0.47)	76.0%	3
S9.135	26990	27014	S9.OT23 to S9.CE3.1 **(Anomaly S9.AP (Start))**	24	DN28 BWP	1.95	1.35 (-0.61)	68.9%	2
S9.136	27014	27094	**Anomaly S9.AP**	80	DN28 BWP	1.95	1.44 (-0.51)	74.0%	3
S9.137	27094	27398	As per chainage	305	DN28 BWP	1.95	1.32 (-0.63)	67.6%	2
S9.138	27398	27645	As per chainage	246	DN28 BWP	1.95	1.31 (-0.65)	66.9%	2
S9.139	27645	27897	Previous point to S9.PC8 **(Anomaly S9.AQ)**	253	DN28 BWP	1.95	1.33 (-0.62)	68.2%	2
S9.140	27897	27900	S9.PC8 to S9.AV22	2	DN16 BWP	1.64	0.95 (-0.69)	58.1%	1
S9.141	27900	27905	S9.AV22 to S9.End	5	DN16 BWP	1.64	0.92 (-0.72)	56.0%	1

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-9: BWP pipe wall deterioration results for OC35
Assuming nominal theoretical values as original wall thickness (specified in the ANSI/AWWA C303)

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.1	0	2	S35.Start to S35.PRV1 **(Anomaly S35.A)**	2	DN36 BWP	2.02	1.27 (-0.75)	63.0%	2
S35.2	2	246	S35.PRV1 to **Anomaly S35.B**	244	DN36 BWP	2.02	1.26 (-0.76)	62.2%	2
S35.3	246	594	As per chainage	348	DN36 BWP	2.02	1.27 (-0.75)	62.8%	2
S35.4	594	846	As per chainage	252	DN36 BWP	2.02	1.27 (-0.75)	62.9%	2
S35.5	846	1093	Previous point to **Anomaly S35.C**	246	DN36 BWP	2.02	1.27 (-0.75)	63.0%	2
S35.6	1093	1184	Previous point to S35.AV5 **(Anomaly S35.D)**	92	DN36 BWP	2.02	1.32 (-0.70)	65.1%	2
S35.7	1184	1206	S35.AV5 to S35.OT4	22	DN36 BWP	2.02	1.35 (-0.67)	66.9%	2
S35.8	1206	1498	As per chainage	292	DN36 BWP	2.02	1.17 (-0.85)	57.8%	1
S35.9	1498	1740	As per chainage	243	DN36 BWP	2.02	1.18 (-0.84)	58.2%	1
S35.10	1740	2013	As per chainage	272	DN36 BWP	2.02	1.17 (-0.85)	57.8%	1
S35.11	2013	2206	As per chainage	193	DN36 BWP	2.02	1.17 (-0.85)	57.9%	1
S35.12	2206	2406	As per chainage	200	DN36 BWP	2.02	1.18 (-0.84)	58.3%	1
S35.13	2406	2656	Previous point to S35.CE3.1 **(Anomaly S35.E (Start))**	251	DN36 BWP	2.02	1.17 (-0.85)	57.9%	1
S35.14	2656	2788	**Anomaly S35.E**	132	DN36 BWP	2.02	1.39 (-0.63)	68.8%	2
S35.15	2788	3085	S35.CE3.2 to S35.OT5 **(Anomaly S35.F)**	297	DN36 BWP	2.02	1.18 (-0.84)	58.3%	1
S35.16	3085	3357	As per chainage	272	DN36 BWP	2.02	1.24 (-0.78)	61.4%	2
S35.17	3357	3676	Previous point to **Anomaly S35.G**	319	DN36 BWP	2.02	1.24 (-0.78)	61.5%	2
S35.18	3676	3860	As per chainage	184	DN36 BWP	2.02	1.19 (-0.83)	58.8%	1
S35.19	3860	4021	As per chainage	161	DN36 BWP	2.02	1.20 (-0.82)	59.4%	1
S35.20	4021	4165	As per chainage	144	DN36 BWP	2.02	1.17 (-0.85)	58.0%	1
S35.21	4165	4401	As per chainage	236	DN36 BWP	2.02	1.19 (-0.83)	59.0%	1
S35.22	4401	4571	Previous point to S35.CE4.1 **(Anomaly S35.H (Start))**	170	DN36 BWP	2.02	1.19 (-0.83)	59.0%	1
S35.23	4571	4613	**Anomaly S35.H**	42	DN36 BWP	2.02	1.71 (-0.31)	84.8%	4

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-9 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.24	4613	4846	As per chainage	233	DN36 BWP	2.02	1.28 (-0.74)	63.2%	2
S35.25	4846	4986	As per chainage	141	DN36 BWP	2.02	1.29 (-0.73)	63.8%	2
S35.26	4986	5153	As per chainage	167	DN36 BWP	2.02	1.28 (-0.74)	63.6%	2
S35.27	5153	5370	Previous point to S35.CE5.1 **(Anomaly S35.I (Start))**	217	DN36 BWP	2.02	1.29 (-0.73)	63.7%	2
S35.28	5370	5410	**Anomaly S35.I**	40	DN36 BWP	2.02	1.61 (-0.41)	79.6%	3
S35.29	5410	5536	S35.CE5.2 to S35.OT6 **(Anomaly S35.J)**	125	DN36 BWP	2.02	1.19 (-0.83)	59.0%	1
S35.30	5536	5682	As per chainage	146	DN36 BWP	2.02	1.24 (-0.78)	61.2%	2
S35.31	5682	5971	Previous point to **Anomaly S35.K**	290	DN36 BWP	2.02	1.24 (-0.78)	61.2%	2
S35.32	5971	6204	As per chainage	233	DN36 BWP	2.02	1.30 (-0.72)	64.2%	2
S35.33	6204	6420	Previous point to **Anomaly S35.L**	216	DN36 BWP	2.02	1.29 (-0.73)	64.0%	2
S35.34	6420	6592	Previous point to **Anomaly S35.M**	172	DN36 BWP	2.02	1.23 (-0.79)	60.7%	2
S35.35	6592	6760	Previous point to **Anomaly S35.N**	168	DN36 BWP	2.02	1.15 (-0.87)	57.2%	1
S35.36	6760	7051	As per chainage	292	DN36 BWP	2.02	1.24 (-0.78)	61.3%	2
S35.37	7051	7157	As per chainage	105	DN36 BWP	2.02	1.24 (-0.78)	61.6%	2
S35.38	7157	7367	As per chainage	210	DN36 BWP	2.02	1.24 (-0.78)	61.2%	2
S35.39	7367	7511	As per chainage	144	DN36 BWP	2.02	1.22 (-0.80)	60.5%	2
S35.40	7511	7743	Previous point to **Anomaly S35.O**	232	DN36 BWP	2.02	1.25 (-0.77)	61.7%	2
S35.41	7743	8018	As per chainage	275	DN36 BWP	2.02	1.28 (-0.74)	63.4%	2
S35.42	8018	8242	Previous point to S35.IV1 **(Anomaly S35.P)**	223	DN36 BWP	2.02	1.26 (-0.76)	62.4%	2
S35.43	8242	8492	S35.IV1 to S35.OT7	251	DN36 BWP	2.02	1.24 (-0.78)	61.5%	2
S35.44	8492	8699	As per chainage	206	DN36 BWP	2.02	1.32 (-0.70)	65.4%	2
S35.45	8699	8931	As per chainage	233	DN36 BWP	2.02	1.30 (-0.72)	64.2%	2
S35.46	8931	9093	As per chainage	161	DN36 BWP	2.02	1.31 (-0.71)	64.8%	2
S35.47	9093	9356	As per chainage	263	DN36 BWP	2.02	1.31 (-0.71)	64.8%	2
S35.48	9356	9487	Previous point to S35.AV14 **(Anomaly S35.Q)**	132	DN36 BWP	2.02	1.32 (-0.70)	65.3%	2
S35.49	9487	9727	As per chainage	240	DN36 BWP	2.02	1.37 (-0.65)	67.9%	2
S35.50	9727	9893	Previous point to S35.OT8 **(Anomaly S35.R)**	166	DN36 BWP	2.02	1.38 (-0.64)	68.1%	2
S35.51	9893	9939	S35.OT8 to **Anomaly S35.S**	46	DN36 BWP	2.02	1.34 (-0.68)	66.2%	2
S35.52	9939	10252	As per chainage	312	DN36 BWP	2.02	1.30 (-0.72)	64.1%	2
S35.53	10252	10499	Previous point to **Anomaly S35.T**	247	DN36 BWP	2.02	1.28 (-0.74)	63.5%	2
S35.54	10499	10729	Previous point to **Anomaly S35.U**	230	DN36 BWP	2.02	1.30 (-0.72)	64.3%	2
S35.55	10729	10997	Previous point to **Anomaly S35.V**	268	DN36 BWP	2.02	1.34 (-0.68)	66.2%	2
S35.56	10997	11240	As per chainage	243	DN36 BWP	2.02	1.29 (-0.73)	63.9%	2
S35.57	11240	11517	Previous point to **Anomaly S35.W**	276	DN36 BWP	2.02	1.28 (-0.74)	63.1%	2
S35.58	11517	11853	As per chainage	337	DN36 BWP	2.02	1.34 (-0.68)	66.2%	2
S35.59	11853	12169	Previous point to **Anomaly S35.X**	315	DN36 BWP	2.02	1.33 (-0.69)	65.8%	2
S35.60	12169	12421	As per chainage	252	DN36 BWP	2.02	1.25 (-0.77)	62.0%	2
S35.61	12421	12632	Previous point to **Anomaly S35.Y**	211	DN36 BWP	2.02	1.23 (-0.79)	60.7%	2
S35.62	12632	12898	As per chainage	266	DN36 BWP	2.02	1.30 (-0.72)	64.5%	2
S35.63	12898	13019	Previous point to **Anomaly S35.Z**	122	DN36 BWP	2.02	1.30 (-0.72)	64.2%	2
S35.64	13019	13397	Previous point to S35.PC1 **(Anomaly S35.AA)**	378	DN36 BWP	2.02	1.28 (-0.74)	63.2%	2
S35.65	13397	13618	S35.PC1 to **Anomaly S35.AB**	221	DN33 BWP	2.00	1.24 (-0.76)	62.0%	2

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-9 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.66	13618	13851	As per chainage	233	DN33 BWP	2.00	1.25 (-0.75)	62.5%	2
S35.67	13851	14146	As per chainage	295	DN33 BWP	2.00	1.25 (-0.75)	62.3%	2
S35.68	14146	14415	As per chainage	269	DN33 BWP	2.00	1.25 (-0.75)	62.4%	2
S35.69	14415	14722	Previous point to S35.OT10 **(Anomaly S35.AC)**	307	DN33 BWP	2.00	1.24 (-0.76)	62.1%	2
S35.70	14722	14776	S35.OT10 to S35.OT11 **(Anomaly S35.AD)**	54	DN33 BWP	2.00	1.30 (-0.70)	65.1%	2
S35.71	14776	15064	As per chainage	289	DN33 BWP	2.00	1.32 (-0.68)	66.1%	2
S35.72	15064	15301	As per chainage	236	DN33 BWP	2.00	1.33 (-0.67)	66.4%	2
S35.73	15301	15501	As per chainage	200	DN33 BWP	2.00	1.32 (-0.68)	65.9%	2
S35.74	15501	15738	As per chainage	237	DN33 BWP	2.00	1.32 (-0.68)	66.1%	2
S35.75	15738	15909	Previous point to **Anomaly S35.AE**	171	DN33 BWP	2.00	1.33 (-0.67)	66.6%	2
S35.76	15909	16191	As per chainage	282	DN33 BWP	2.00	1.30 (-0.70)	64.9%	2
S35.77	16191	16441	Previous point to S35.IV2 **(Anomaly S35.AF)**	249	DN33 BWP	2.00	1.29 (-0.71)	64.7%	2
S35.78	16441	16443	S35.IV2 to S35.TP3 **(Anomaly S35.AG)**	3	DN33 BWP	2.00	1.37 (-0.63)	68.7%	2
S35.79	16443	16647	As per chainage	203	DN33 BWP	2.00	1.37 (-0.63)	68.4%	2
S35.80	16647	16916	As per chainage	269	DN33 BWP	2.00	1.37 (-0.63)	68.4%	2
S35.81	16916	17103	Previous point to **Anomaly S35.AH**	188	DN33 BWP	2.00	1.37 (-0.63)	68.7%	2
S35.82	17103	17224	Previous point to **Anomaly S35.AI**	121	DN33 BWP	2.00	1.36 (-0.64)	68.1%	2
S35.83	17224	17532	As per chainage	308	DN33 BWP	2.00	1.31 (-0.69)	65.7%	2
S35.84	17532	17804	As per chainage	272	DN33 BWP	2.00	1.32 (-0.68)	65.9%	2
S35.85	17804	17981	As per chainage	177	DN33 BWP	2.00	1.31 (-0.69)	65.3%	2
S35.86	17981	18145	As per chainage	164	DN33 BWP	2.00	1.31 (-0.69)	65.3%	2
S35.87	18145	18350	Previous point to S35.CE6.1 **(Anomaly S35.AJ (Start))**	205	DN33 BWP	2.00	1.32 (-0.68)	65.8%	2
S35.88	18350	18598	**Anomaly S35.AJ**	248	DN33 BWP	2.00	1.73 (-0.27)	86.4%	4
S35.89	18598	18896	S35.CE6.2 to S35.OT12 **(Anomaly S35.AK)**	298	DN33 BWP	2.00	1.37 (-0.63)	68.5%	2
S35.90	18896	19225	S35.OT12 to **Anomaly S35.AL**	329	DN33 BWP	2.00	1.51 (-0.49)	75.4%	3
S35.91	19225	19491	Previous point to **Anomaly S35.AM**	266	DN33 BWP	2.00	1.57 (-0.43)	78.3%	3
S35.92	19491	19810	Previous point to **Anomaly S35.AN**	318	DN33 BWP	2.00	1.60 (-0.40)	80.1%	4
S35.93	19810	20049	As per chainage	240	DN33 BWP	2.00	1.45 (-0.55)	72.5%	3
S35.94	20049	20209	Previous point to **Anomaly S35.AO**	160	DN33 BWP	2.00	1.44 (-0.56)	72.2%	3
S35.95	20209	20508	As per chainage	298	DN33 BWP	2.00	1.53 (-0.47)	76.6%	3
S35.96	20508	20760	As per chainage	253	DN33 BWP	2.00	1.51 (-0.49)	75.7%	3
S35.97	20760	20899	Previous point to **Anomaly S35.AP**	139	DN33 BWP	2.00	1.53 (-0.47)	76.5%	3
S35.98	20899	21171	Previous point to **Anomaly S35.AQ**	272	DN33 BWP	2.00	1.47 (-0.53)	73.5%	3
S35.99	21171	21381	Previous point to **Anomaly S35.AR (Start)**	209	DN33 BWP	2.00	1.61 (-0.39)	80.5%	4
S35.100	21381	21419	**Anomaly S35.AR**	39	DN33 BWP	2.00	1.39 (-0.61)	69.5%	2
S35.101	21419	21577	As per chainage	157	DN33 BWP	2.00	1.49 (-0.51)	74.5%	3
S35.102	21577	21776	As per chainage	200	DN33 BWP	2.00	1.50 (-0.50)	74.9%	3
S35.103	21776	22085	Previous point to S35.OT14 **(Anomaly S35.AS)**	308	DN33 BWP	2.00	1.49 (-0.51)	74.7%	3
S35.104	22085	22321	S35.OT14 to S35.AV26	236	DN33 BWP	2.00	1.60 (-0.40)	80.1%	4
S35.105	22321	22691	As per chainage	370	DN33 BWP	2.00	1.20 (-0.80)	60.1%	2
S35.106	22691	23009	Previous point to S35.OT16 **(Anomaly S35.AT)**	318	DN33 BWP	2.00	1.21 (-0.79)	60.7%	2
S35.107	23009	23301	As per chainage	292	DN33 BWP	2.00	1.23 (-0.77)	61.4%	2

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-9 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.108	23301	23574	As per chainage	273	DN33 BWP	2.00	1.22 (-0.78)	61.1%	2
S35.109	23574	23823	As per chainage	249	DN33 BWP	2.00	1.22 (-0.78)	61.1%	2
S35.110	23823	24109	Previous point to **Anomaly S35.AU**	286	DN33 BWP	2.00	1.22 (-0.78)	61.1%	2
S35.111	24109	24433	As per chainage	324	DN33 BWP	2.00	1.20 (-0.80)	59.9%	1
S35.112	24433	24753	Previous point to S35.OT17 **(Anomaly S35.AV)**	320	DN33 BWP	2.00	1.19 (-0.81)	59.5%	1
S35.113	24753	25038	As per chainage	285	DN33 BWP	2.00	1.20 (-0.80)	60.1%	2
S35.114	25038	25346	As per chainage	308	DN33 BWP	2.00	1.22 (-0.78)	60.8%	2
S35.115	25346	25485	Previous point to S35.PC2 **(Anomaly S35.AW)**	138	DN33 BWP	2.00	1.21 (-0.79)	60.6%	2
S35.116	25485	25750	As per chainage	265	DN27 BWP	1.97	1.25 (-0.72)	63.4%	2
S35.117	25750	25881	Previous point to S35.OT19 **(Anomaly S35.AX)**	131	DN27 BWP	1.97	1.24 (-0.73)	63.1%	2
S35.118	25881	26238	As per chainage	357	DN27 BWP	1.97	1.37 (-0.60)	69.6%	2
S35.119	26238	26561	Previous point to S35.OT21 **(Anomaly S35.AY)**	322	DN27 BWP	1.97	1.38 (-0.58)	70.3%	3
S35.120	26561	26679	S35.OT21 to S35.PC3 **(Anomaly S35.AZ)**	119	DN27 BWP	1.97	1.43 (-0.54)	72.8%	3
S35.121	26679	26689	S35.PC3 to S35.OT22 **(Anomaly S35.BA)**	10	DN30 BWP	1.98	1.81 (-0.18)	91.1%	5
S35.122	26689	26964	As per chainage	275	DN30 BWP	1.98	1.91 (-0.08)	96.0%	5
S35.123	26964	27154	Previous point to S35.IV5 **(Anomaly S35.BB)**	190	DN30 BWP	1.98	1.89 (-0.09)	95.3%	5
S35.124	27154	27164	S35.IV5 to S35.OT23	10	DN30 BWP	1.98	1.78 (-0.21)	89.6%	4
S35.125	27164	27208	S35.OT23 to S35.CE9.1 **(Anomaly S35.BC (Start))**	44	DN30 BWP	1.98	1.86 (-0.13)	93.6%	5
S35.126	27208	27553	**Anomaly S35.BC**	345	DN30 BWP	1.98	1.90 (-0.09)	95.5%	5
S35.127	27553	27885	S35.CE9.2 to S35.OT25 **(Anomaly S35.BD)**	332	DN30 BWP	1.98	1.83 (-0.15)	92.2%	5
S35.128	27885	28138	As per chainage	253	DN30 BWP	1.98	1.87 (-0.11)	94.4%	5
S35.129	28138	28377	As per chainage	239	DN30 BWP	1.98	1.86 (-0.12)	93.9%	5
S35.130	28377	28603	As per chainage	226	DN30 BWP	1.98	1.88 (-0.10)	94.9%	5
S35.131	28603	28748	As per chainage	145	DN30 BWP	1.98	1.87 (-0.11)	94.3%	5
S35.132	28748	28965	Previous point to S35.OT27 **(Anomaly S35.BE)**	217	DN30 BWP	1.98	1.87 (-0.11)	94.3%	5
S35.133	28965	29020	S35.OT27 to S35.OT28 **(Anomaly S35.BF)**	55	DN30 BWP	1.98	1.84 (-0.14)	92.7%	5

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

Table 4-10: BWP pipe wall deterioration results for OC35A
Assuming nominal theoretical values as original wall thickness (specified in the ANSI/AWWA C303)

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35A.1	0	25	S35A.Start to S35A.IV1 **(Anomaly S35A.A)**	25	DN27 BWP	1.97	Closed inline valve (S35A.IV1)		
S35A.2	25	247	As per chainage	223	DN27 BWP	1.97	1.35 (-0.62)	68.6%	2
S35A.3	247	539	As per chainage	292	DN27 BWP	1.97	1.35 (-0.61)	68.8%	2
S35A.4	539	817	Previous point to **Anomaly S35A.B (Start)**	278	DN27 BWP	1.97	1.36 (-0.61)	69.0%	2
S35A.5	817	869	**Anomaly S35A.C**	52	DN27 BWP	1.97	1.48 (-0.49)	75.2%	3
S35A.6	869	1187	As per chainage	318	DN27 BWP	1.97	1.40 (-0.57)	71.1%	3
S35A.7	1187	1470	Previous point to **Anomaly S35A.C**	283	DN27 BWP	1.97	1.41 (-0.56)	71.6%	3
S35A.8	1470	1713	As per chainage	243	DN27 BWP	1.97	1.39 (-0.58)	70.4%	3
S35A.9	1713	1935	As per chainage	223	DN27 BWP	1.97	1.38 (-0.59)	69.8%	2
S35A.10	1935	2160	Previous point to S35A.IV2 **(Anomaly S35A.D)**	224	DN27 BWP	1.97	1.38 (-0.59)	70.1%	3
S35A.11	2160	2163	S35A.IV2 to S35A.OT1 **(Anomaly S35A.E)**	4	DN27 BWP	1.97	1.47 (-0.50)	74.4%	3
S35A.12	2163	2171	S35A.OT1 to S35A.OT2	8	DN27 BWP	1.97	1.37 (-0.60)	69.3%	2
S35A.13	2171	2539	As per chainage	367	DN27 BWP	1.97	1.42 (-0.55)	72.2%	3
S35A.14	2539	2865	Previous point to S35A.PC2 **(Anomaly S35A.F)**	326	DN27 BWP	1.97	1.44 (-0.53)	73.3%	3
S35A.15	2865	2977	S35A.PC2 to S35A.OT4 **(Anomaly S35A.G)**	112	DN33 BWP	2.00	1.38 (-0.62)	69.2%	2
S35A.16	2977	3082	S35A.OT4 to S35A.PC3 **(Anomaly S35A.H)**	105	DN33 BWP	2.00	1.34 (-0.66)	67.2%	2
S35A.17	3082	3102	S35A.PC3 to S35A.End	20	DN27 BWP	1.97	1.42 (-0.55)	72.3%	3

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For BWP pipelines the two conditions are equivalent.

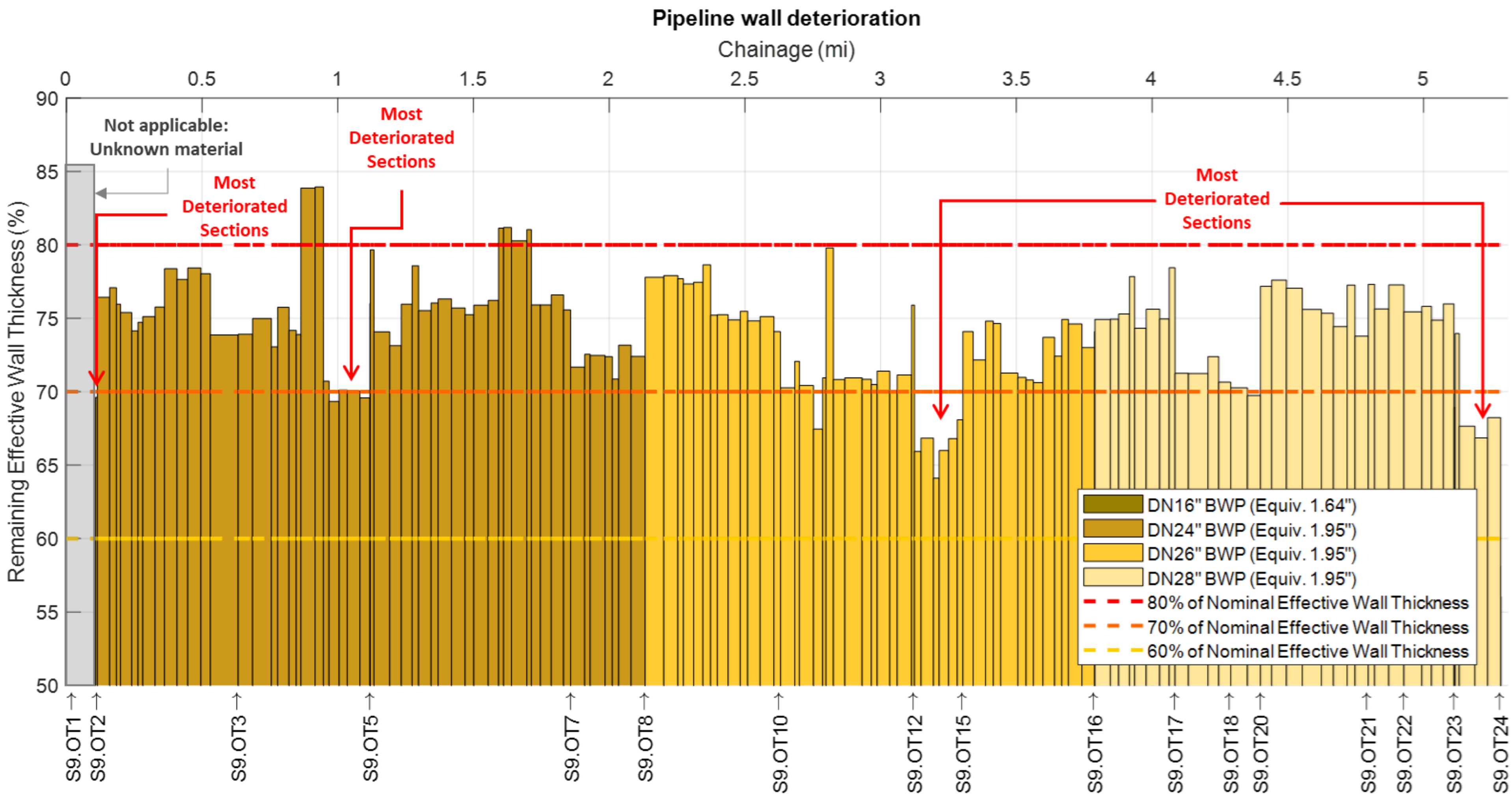


Figure 4.1: Pipeline wall deterioration for OC9

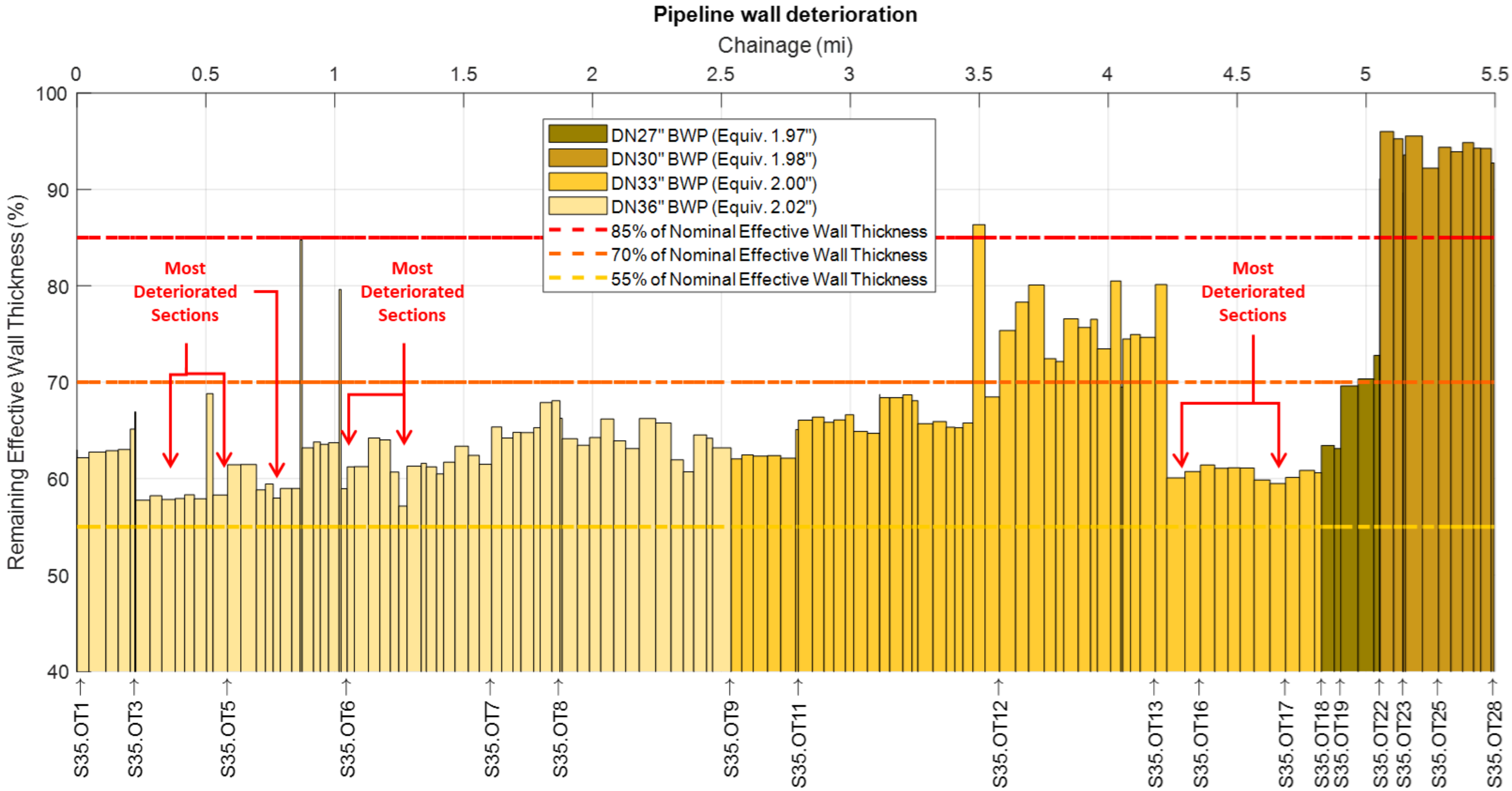


Figure 4.2: Pipeline wall deterioration for OC35

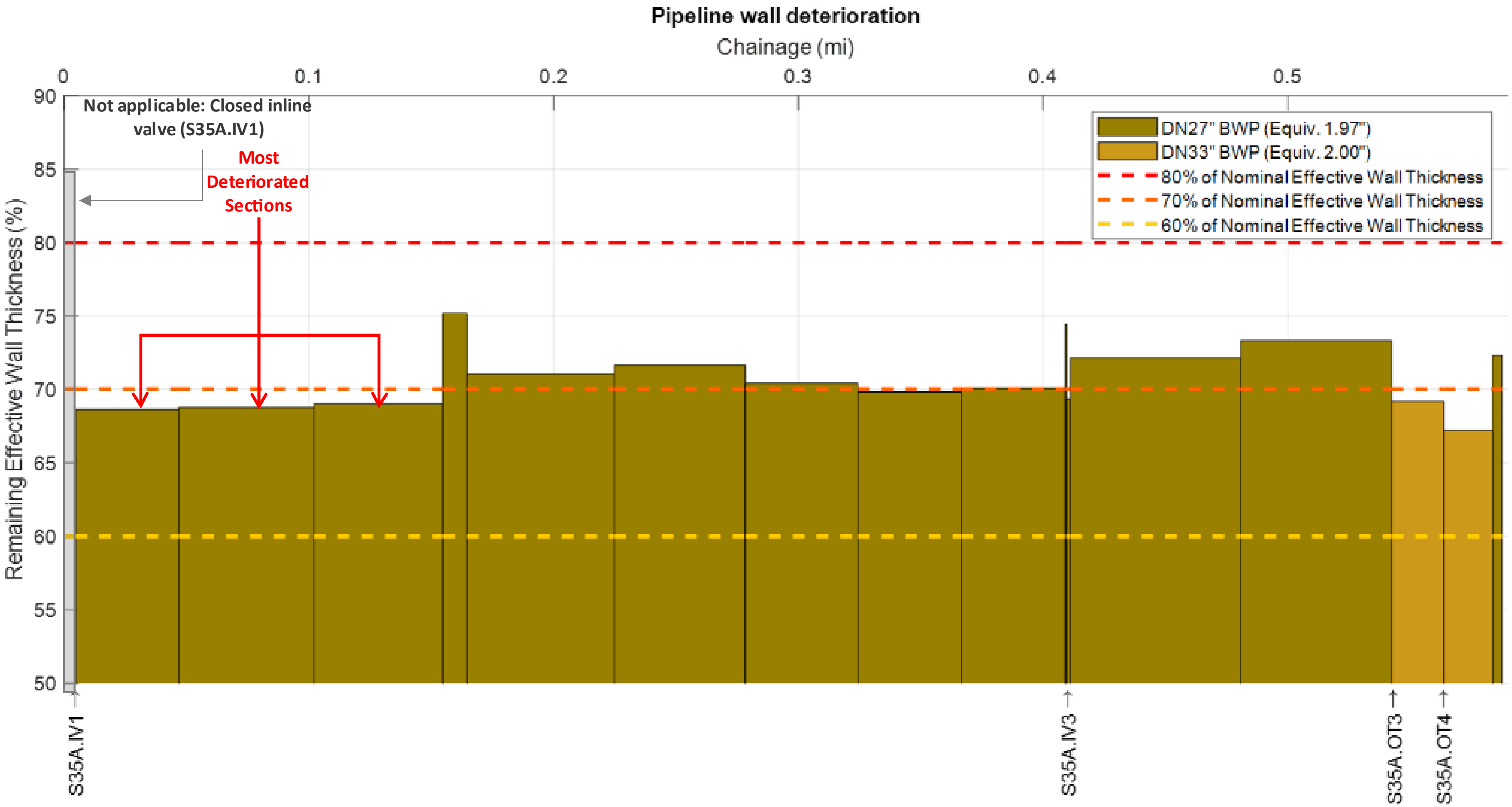


Figure 4.3: Pipeline wall deterioration for the OC35A

5 Summary and Recommendations

The sections of pipelines analyzed in this report are referred to as the OC9 and OC35 Water Pipelines and are approximately 11.3 miles.

The results provided in this report will assist in the assessment of the current condition of the OC9 and OC35 Water Pipelines. p-CAT™ has provided the theoretical remaining wall thicknesses for 291 sub-sections of different deterioration conditions over 11.3 miles of pipeline. A total of 5 poor, 61 fair, 27 good and 16 very good anomalies were also identified. This information can assist the City of Huntington Beach to make more informed decisions in planning and budgeting for future maintenance programs.

The following pipeline wall condition was identified during the p-CAT™ analysis:

Table 5-1: Pipeline wall condition summary

Section	Wall Remaining (%)					
	100 – 90%	90 – 80%	80 – 70%	70 – 60%	60 - 50%	Not applicable
OC9	-	3.9%	84.7%	9.4%	-	2.0%
OC35	8.0%	3.7%	10.7%	65.3%	12.3%	-
OC35A	-	-	59.2%	40.0%	-	0.8%

Section OC9 (S9)

- 9.4% of the total pipeline length has a remaining wall thickness of between 60% and 70%.
- 84.7% of the total pipeline length has a remaining wall thickness of between 70% and 80%.
- 3.9% of the total pipeline length has a remaining wall thickness of between 80% and 90%.
- 2.0% of the total pipeline length has an unknown material.

Section OC35 (S35)

- 12.3% of the total pipeline length has a remaining wall thickness of between 50% and 60%.
- 65.3% of the total pipeline length has a remaining wall thickness of between 60% and 70%.
- 10.7% of the total pipeline length has a remaining wall thickness of between 70% and 80%.
- 3.7% of the total pipeline length has a remaining wall thickness of between 80% and 90%.
- 8.0% of the total pipeline length has a remaining wall thickness of between 90% and 100%.

Section OC35A (S35A)

- 40.0% of the total pipeline length has a remaining wall thickness of between 60% and 70%.
- 59.2% of the total pipeline length has a remaining wall thickness of between 70% and 80%.
- 0.8% of the total pipeline length was before a closed inline valve (S35A.IV1).

It should be noted that these remaining wall thickness results are determined using assumed initial wall thicknesses and outer diameters as provided by the City of Huntington Beach. Should the City of Huntington Beach obtain further information regarding the initial wall thickness of the pipelines PIA and DS will be able to recalculate the percentage remaining wall thickness.

The following known features and anomalies, and their resulting recommended actions were also identified during the signal analysis:

Table 5-2: Summary of anomalies detected in the Huntington Beach Pipelines

Number of Anomalies						
Section	**Total**	**Very Good (5)**	**Good (4)**	**Fair (3)**	**Poor (2)**	**Very Poor (1)**
OC9	43	7	8	25	3	-
OC35	58	8	16	32	2	-
OC35A	8	1	3	4	-	-

Section OC9

- 3 Poor priority anomalies representing:
  - 1 Potential unrecorded pipe change, sedimentation, deterioration, or air pocket.
  - 1 Potential unrecorded pipe change, air pocket, deterioration, or sedimentation.
  - 1 Potential deterioration, air pocket, or unknown offtake at a pipe change (S9.PC8).
- 25 Fair priority anomalies representing:
  - 4 Potential sedimentations, blockages, pipe changes, or concrete encasements.
  - 2 Minor potential air pockets, deteriorations, pipe changes, or offtakes.
  - 8 Potential air pockets, deteriorations, pipe changes, or offtakes.
  - 2 Potential sedimentations, blockages, pipe changes, or concrete encasement sections.
  - 1 Potential closed or partially closed inline valve, sedimentation, pipe change, or concrete encasement (S9.IV6).
  - 3 Minor potential sedimentation, blockage, pipe change, or concrete encasement.
  - 1 Potential open or partially open offtake valve, air pocket, or pipe change (S9.OT13).
  - 2 Potential deteriorations, air pockets, or offtakes at pipe changes (S9.PC6 and S9.PC7).
  - 1 Very minor potential air pocket, deterioration, pipe change, or offtake.
  - 1 Potential deterioration, sedimentation, air pocket or pipe change section (S9.CE3.1 to S9.CE3.2).
- 8 Good priority anomalies representing known features including:
  - 1 Presence of a known pipe change (S9.PC1), open inline valve (S9.IV4) or minor sedimentation.
  - 1 Presence of a known blow off (S9.BO1) or minor sedimentation.
  - 4 Presences of known closed offtake valves (S9.OT2, S9.OT21, S9.OT22 and S9.OT4) or minor issues.
  - 2 Presences of known open offtake valves (S9.OT20, S9.OT6) or minor airs.
- 7 Very Good priority anomalies representing known features including:
  - 1 Presence of a known air valve (S9.AV3).
  - 2 Presences of known closed offtakes (S9.OT11 and S9.OT18).
  - 1 Presence of a known open inline valve (S9.IV4.1).
  - 2 Presences of known open offtakes (S9.OT12 and S9.OT15).
  - 1 Presence of a known open offtake (S9.OT9).

Section OC35

- 2 Poor priority anomalies representing:
    - 2 Potential deteriorations, air pockets, or unknown offtakes at pipe changes (S35.PC1 and S35.PC2).

- 32 Fair priority anomalies representing:
    - 9 Minor potential air pockets, deteriorations, pipe changes, or offtakes.
    - 9 Minor potential sedimentations, blockages, pipe changes, or concrete encasements.
    - 1 Potential air pocket or deterioration at a feature (S35.AV14).
    - 2 Potential air pockets, deteriorations, pipe changes, or offtakes.
    - 1 Potential deterioration, air pocket or pipe change section (S35.CE5.1 to S35.CE5.2).
    - 1 Potential deterioration, air pocket, pipe change, or concrete encasement.
    - 2 Potential open or partially open offtake valves, air pockets, or pipe changes (S35.OT10 and S35.OT14).
    - 1 Potential sedimentation, blockage, pipe change, or concrete encasement section.
    - 6 Potential sedimentations, blockages, pipe changes, or concrete encasements.
- 16 Good priority anomalies representing known features including:
    - 1 Presence of a known pressure reduction valve (S35.PRV1) or minor sedimentation.
    - 3 Presences of concrete encasements sections (S35.CE3.1 to S35.CE3.2, S35.CE4.1 to S35.CE4.2 and S35.CE6.1 to S35.CE6.2) or minor sedimentations.
    - 1 Presence of a known closed offtake valve (S35.OT21) or minor issue.
    - 1 Presence of a known open inline valve (S35.IV5), or minor issue.
    - 9 Presences of known open offtake valves (S35.OT8, S35.OT11, S35.OT12, S35.OT17, S35.OT19, S35.OT22, S35.OT25, S35.OT27 and S35.OT28) or minor airs.
    - 1 Presence of a known pipe change (S35.PC3) or minor sedimentation.
- 8 Very Good priority anomalies representing known features including:
    - 1 Presence of a known air valve (S35.AV5).
    - 1 Presence of a known closed offtake (S35.OT16).
    - 1 Presence of a known concrete encasement section (S35.CE9.1 to S35.CE9.2).
    - 2 Presences of known open inline valves (S35.IV1 and S35.IV2).
    - 2 Presences of known open offtakes (S35.OT5 and S35.OT6).
    - 1 Presence of a known taping point (S35.TP3).

Section OC35A

- 4 Fair priority anomalies representing:
    - 1 Potential sedimentation, blockage, pipe change, or concrete encasement section.
    - 1 Minor potential air pocket, deterioration, pipe change, or offtake.
    - 2 Potential deteriorations, air pockets, or offtakes at pipe changes (S35A.PC2 and S35A.PC3).
- 3 Good priority anomalies representing known features including:
    - 1 Presence of a known closed inline valve (S35A.IV1) or minor issue.
    - 2 Presences of known open offtake valves (S35A.OT1 and S35A.OT4) or minor airs.
- 1 Very Good priority anomalies representing known features including:
    - 1 Presence of a known open inline valve (S35A.IV2).

The percentage of remaining wall thickness is determined by comparing the theoretical pipeline specifications with the signal analysis, which ultimately defines the remaining structural strength based on the current conditions of the pipeline.

It is recommended that The City of Huntington Beach assess the remaining strength of the pipeline using the percentage of remaining wall strength, rather than based only on the wall thickness values provided. This approach is recommended because the strength of the pipeline is more significantly impacted by factors such as the debonding of the metal wires from the concrete and wire breakage, rather than a reduction in wall thickness due to leaching. The City of Huntington Beach should also investigate the current pipeline properties and configuration, and the presence of possible entrained or entrapped gas before coming to the conclusion that sections are deteriorated. These faults can also affect the accuracy of the p-CAT™ results for both the condition assessment and the anomaly identification. By considering all these factors, The City of Huntington Beach can gain a more accurate understanding of the pipeline's condition.

Due to the large amount of information provided, including various shapefiles, GPS points, as-constructed drawings, and other data, the information was cleaned and merged. GPS points were snapped and merged with the GIS pipeline shapefiles to ensure they could be included in the analysis. During the analysis, GIS data was primarily used, with confirmation from GPS points and as-constructed drawings. Distances were estimated accordingly. Should the City of Huntington Beach obtain additional information regarding the original pipe specifications, the results can be updated by PIA, DS and HUSA.

As requested by HUSA and the City of Huntington Beach, an additional scenario is presented in Appendix F, illustrating results under the assumption that the pipe material is a steel water pipe in accordance with ANSI/AWWA C200. Other documents in the report packages such as the Visual Summary (VS), Overview Visual Summary (OVS), GIS, and HTML, will not be updated to reflect this scenario. This decision is based not only on time considerations but also on preserving the integrity and consistency of the standardized report package, avoiding duplication or potential misalignment across outputs.

It is important to note that this additional scenario does not affect the identification of anomalies, subsection identifiers, or segmentation, as these remain consistent between both analyses. The primary difference lies in the percentage of corrosion associated with the material specification. Therefore, users can easily compare results by referencing the subsection identifiers, chainage, and lengths provided, ensuring a straightforward interpretation of differences between the BWP and steel pipe scenarios.

An in-depth visual summary of the obtained results is also provided in separate documents and in an active GIS package accompanying this report.

Appendix A: Glossary of Terms

Anomaly	-	Signal in the pipeline identified in the collected transient traces that does not correspond to a known feature on the pipeline. For example; entrapped or entrained air, blockage, pipe change.
Cement lining loss	-	Loss of lining refers to the loss of bond or structural integrity of the cement mortar lining. Cement mortar lining may still be present, however it does not contribute to the transient response of the pipeline.
Chainage	-	Accumulated distance as measured along a path/pipe with a combination of curves and straight lines from a datum point. It is used to identify where one section ends and another section starts.
DN	-	Nominal Diameter, Diameter, Size, etc
Effective wall thickness	-	Average wall thickness across the cross-section of the pipeline. The effective wall thickness refers to the wall contributing to the transient response and hence structural integrity. For example a portion of the AC wall that has experienced calcium leaching is not included in the effective wall thickness.
Equivalent wall thickness	-	The equivalent thickness is the wall thickness including the cement mortar lining in terms of the metallic wall material.
Point	-	Identified potential connection point for use as a station (measurement or generation).
Section	-	Pipeline between two stations (measurement or generation).
• **Sub-section**	-	Pipeline with similar wall condition as identified during analysis.
Station	-	Connection point used during transient testing
• **Generation**	-	Location at which the controlled transient was initiated and variation of the transient pressure was measured.
• **Measurement**	-	Location at which the variation of pressure during the transient pressure wave event was measured.
Transient	-	A transient event is a pressure wave that occurs in a pipeline whenever the flow is changed rapidly (e.g. by a rapid valve opening or closure). In this report it refers to a controlled small magnitude transient event.
Wave speed	-	The speed with which a wave front from a hydraulic transient pressure wave propagates along the pipeline.

Appendix B: Pipeline Feature Chainages

The pipeline was surveyed during testing to locate known features, and these chainages are shown in Table B.1 and Table B.2 and used for all analysis.

Table B.1: Surveyed pipeline chainages for OC9 and OC35 Water Pipelines, section OC9

Feature	Chainage (ft)		Feature	Chainage (ft)	
	GIS	ASCONS		GIS	ASCONS
S9.Start	0	-	S9.AV7 (2716VAV001)	9813	-
S9.IV1 (253VLN040)	28	-	S9.ST2 (2716SMP001)	9828	-
S9.TO1 (253TNO001)	32	-	S9.AV8 (2716AVK001)	9828	9895
S9.AV1 (NEWAVK002)	36	-	S9.OT7	9827	-
S9.IV2 (253VLN039)	36	-	S9.PRV1 (2716VLN001)	9829	9917
S9.IV3 (253VLN052)	127	-	S9.AV8 (1) (2716AVK001)	9889	9895
S9.OT1	129	-	S9.PRV2 (2716VPR001)	9892	-
S9.OV1 (253VPO001)	130	-	S9.CP1 (2716CPS001)	9847	-
S9.POR1 (253POR001)	149	-	S9.MH2	-	10095
S9.IV4 (253VLN013)	566	-	S9.IV5 (2616VLN002)	11256	-
S9.PC1	566	-	S9.PC2	11256	-
S9.OT2	603	-	S9.OT8 (2616TNO001)	11257	11295
S9.OV2 (253VLN011)	605	674	S9.TO3 (2616TNO001)	11318	11295
S9.PLG1 (253PLG001)	608	-	S9.IV6 (2616VLN001)	11259	11298
S9.OV2.1 (253VLN012)	605	674	S9.PC3	11259	-
S9.PLG2 (253PLG002)	608	-	S9.RED3	-	11288
S9.Cross1	3253	-	S9.RED4	-	11298
S9.AV2	3316	-	S9.OT9	13763	-
S9.OT3 (NEWVAV001)	3343	-	S9.AV9 (2616VAV001)	13764	-
S9.AV3 (NEWAVK001)	3344	3405	S9.ST3 (2616SMP001)	13789	-
S9.MH1	-	4938	S9.AV10 (2616AVK001)	13790	13805
S9.BO1 (2916BOR001)	5000	4955	S9.OT10	13878	-
S9.OT4	5906	-	S9.OV10 (2616VBO001)	13880	-
S9.OV4 (2816VLN001)	5915	5981	S9.BO2 (2616BOR001)	13881	13918
S9.AV4 (2816TNO001)	6018	-	S9.IV7 (2516VLN003)	13891	13931
S9.TO2 (2816TNO001)	6030	-	S9.PC4	13891	-
S9.OT5	5912	-	S9.OT11 (2517TNO001)	13894	13933
S9.AV5 (2816VAV001)	5913	-	S9.PC5	13894	-
S9.AV6 (2816AVK001)	5966	5973	S9.TO4 (2517TNO001)	13957	13933
S9.ST1 (2816SMP001)	5968	-	S9.IV8 (2516VLN002)	13897	13935
S9.AV6 (1) (2816AVK001)	5970	5973	S9.RED5	-	13918
S9.RED1	-	5973	S9.RED6	-	13938
S9.IV4.1	-	5985	S9.OT12	16498	-
S9.RED2	-	5985	S9.AV11 (2516VAV001)	16503	-
S9.OT6	9810	-	S9.AV12 (2516AVK001)	16538	16560

Table B.1 Continued

Feature	Chainage (ft)	
	GIS	ASCONS
S9.ST4 (2516SMP001)	16539	-
S9.AV12(1) (2516AVK001)	16540	16560
S9.OT13	17331	-
S9.OV13 (2516VLN001)	17333	17412
S9.CE1.1	-	17400
S9.OT14	17401	-
S9.OV14 (2416VLN003)	17404	17430
S9.CE1.2	-	17432
S9.OT15	17439	-
S9.AV13 (2416AVK001)	17459	-
S9.AV13 (1) (2416AVK001)	17464	-
S9.IV9 (2416VLN002)	19998	20031
S9.PC6	19998	-
S9.OT16	20003	-
S9.PLG3 (2416)	20006	20037
S9.IV10 (2416VLN001)	20007	20048
S9.PC7	20007	-
S9.RED7	-	20025
S9.RED8	-	20058
S9.OT17	21566	-
S9.AV14 (2316VAV001)	21568	-
S9.AV15 (2316AVK001)	21588	21605
S9.ST5 (2316SMP001)	21588	-
S9.OT18	22649	-
S9.OV18 (2316VLN001)	22651	22688
S9.OV18.1 (2316VLN002)	22651	22688
S9.OT19	23208	-
S9.AV16 (2216VAV001)	23212	-
S9.AV17 (1) (2216AVK001)	23213	23255
S9.OT20	23226	-

Feature	Chainage (ft)	
	GIS	ASCONS
S9.AV17 (2216AVK001)	23228	23255
S9.PRV3 (2216VLN004)	23229	23255
S9.PRV4 (2216VPR001)	23231	-
S9.IV11 (2216VLN003)	23284	23294
S9.CE2.1	-	23302
S9.CE2.2	-	23338
S9.OT21	25320	-
S9.OV21 (2216VLN001)	25322	25333
S9.OV21.1 (2216VLN002)	25322	25333
S9.OT22	26018	-
S9.OV22 (2116VLN004)	26020	26033
S9.PRV5 (2116VPR002)	26051	-
S9.MH3	-	26367
S9.OT23	26990	-
S9.AV18 (2116VAV004)	26992	-
S9.AV19 (2116AVK004)	27015	27005
S9.ST6 (2116SMP004)	27015	-
S9.CE3.1	-	27014
S9.CE3.2	-	27094
S9.OT24	27891	-
S9.AV20 (2116VAV003)	27893	-
S9.AV21 (2116AVK003)	27917	-
S9.ST7 (2116SMP003)	27918	-
S9.IV12 (2116VLN002)	27897	-
S9.PC8	27897	-
S9.PRV6 (2116TNO001)	27900	27901
S9.AV22 (2116TNO001)	27900	27901
S9.TO5 (2116TNO001)	27901	27901
S9.PRV7 (2116VLN001)	27905	-
S9.End	27905	-

Table B.2: Surveyed pipeline chainages for OC9 and OC35 Water Pipelines, section OC35

Feature	Chainage (ft)		Feature	Chainage (ft)	
	GIS	ASCONS		GIS	ASCONS
S35.Start	0	-	S35.ST6 (2114SMP001)	5561	-
S35.ST1 (2016SMP002)	0	-	S35.IV1 (2113VLN001)	8242	8271
S35.TO1 (2016TNO001)	0	2	S35.OT7	8492	-
S35.PRV1 (2016TNO001)	2	2	S35.AV12 (2113VAV001)	8497	-
S35.TP1 (2016TNO001)	2	2	S35.AV13 (2113AVK001)	8531	8521
S35.CE1.1	-	50	S35.ST7 (2113SMP001)	8531	-
S35.OT1	80	-	S35.POR1 (2113POR001)	9462	9473
S35.AV1 (2016VAV001)	82	-	S35.AV14	9487	-
S35.AV2 (2016AVK001)	133	-	S35.AV14.1	-	9499
S35.ST2 (2016SMP001)	133	-	S35.OT8	9893	-
S35.CE1.2	-	116	S35.AV15 (2113VAV003)	9895	-
S35.OT2	124	-	S35.AV16 (2113AVK003)	9936	9921
S35.AV3 (2116VAV002)	125	-	S35.ST8 (2113SMP002)	9937	-
S35.AV4 (2116AVK002)	158	123	S35.OT9 (2213TNO001)	13394	13425
S35.ST3 (2116SMP001)	159	-	S35.OV9 (2213VLN001)	13397	-
S35.OT3	1184	-	S35.PRV4 (2213TNO001)	13495	13425
S35.PRV2 (2116VLN003)	1188	1180	S35.TP2 (2213TNO001)	13495	13425
S35.AV5 (2116VPR001)	1217	-	S35.ST9 (2213SMP001)	13495	-
S35.PRV3 (2116VPR001)	1217	-	S35.TO2 (2213TNO001)	13495	13425
S35.OT4	1206	-	S35.RED1 (2213RED001)	13397	-
S35.AV6 (2116VAV001)	1208	-	S35.PC1	13397	-
S35.ST4 (2116SMP002)	1242	-	S35.RED1.1	-	13428
S35.AV7 (2116AVK001)	1242	1199	S35.OT10	14722	-
S35.CE2.1	-	1288	S35.OV10 (2313VPO001)	14724	-
S35.CE2.2	-	1341	S35.POR2 (2313POR001)	14725	14752
S35.CE3.1	-	2656	S35.OT11	14776	-
S35.CE3.2	-	2788	S35.AV17 (2313VAV001)	14777	-
S35.OT5	3085	-	S35.AV18 (2313AVK001)	14807	14805
S35.AV8 (2115VAV001)	3088	-	S35.ST10 (2313SMP001)	14812	-
S35.AV9 (2115AVK001)	3097	3111	S35.IV2 (2413VLN001)	16441	16471
S35.ST5 (2115SMP001)	3097	-	S35.TP3 (NEWTap001)	16443	16484
S35.CE4.1	-	4571	S35.AV19	16454	-
S35.CE4.2	-	4613	S35.CE6.1	-	18350
S35.CE5.1	-	5370	S35.CE6.2	-	18592
S35.CE5.2	-	5410	S35.OT12	18896	-
S35.OT6	5536	-	S35.AV20 (2413VAV002)	18915	-
S35.AV10 (2114VAV001)	5554	-	S35.AV21 (2413AVK002)	18917	18896
S35.AV11 (2114AVK001)	5559	5536	S35.ST11 (2413SMP001)	18917	-

Table B.2 Continued

Feature	Chainage (ft)	
	GIS	ASCONS
S35.CE7.1	-	19403
S35.CE7.2	-	19451
S35.OT13	22079	-
S35.AV22 (2513VAV001)	22109	-
S35.ST12 (2513SMP001)	22138	-
S35.AV23 (2513AVK001)	22139	22163
S35.OT14	22085	-
S35.PRV5 (2513VLN001)	22115	22183
S35.AV24 (2513VPR001)	22160	-
S35.PRV6 (2513VPR001)	22161	-
S35.CE8.1	-	22153
S35.CE8.2	-	22227
S35.OT15	22282	-
S35.AV25 (2513VAV002)	22284	-
S35.ST13 (2513SMP002)	22317	-
S35.AV26(1)(2513AVK002)	22321	-
S35.AV26 (2513AVK002)	22321	-
S35.OT16	23009	-
S35.OV16 (2613VLN001)	23012	22999
S35.POR3 (2613POR001)	24328	24315
S35.OT17	24753	-
S35.AV27 (2613VAV001)	24755	-
S35.AV28 (2613AVK001)	24784	24740
S35.ST14 (2613SMP001)	24784	-
S35.IV3 (2613VLN002)	25379	25364
S35.OT18	25485	-
S35.PC2	25485	-
S35.OV18 (2613VLN003)	25487	25472
S35.OT19	25881	-
S35.AV29 (2712VAV003)	25882	-
S35.AV30 (2712AVK003)	25907	25869
S35.ST15 (2712SMP001)	25911	-
S35.TP5 (2712VLN002 (1))	26556	-
S35.OT21	26561	-
S35.OV21 (2712VLN002)	26562	26531
S35.ST16 (2712SMP001)	26573	-
S35.TO3 (2712TNO001)	26573	-

Feature	Chainage (ft)	
	GIS	ASCONS
S35.RED2	-	26602
S35.MH0.1	-	26723
S35.PC3	26679	-
S35.IV4 (2712VLN007)	26684	26617
S35.OT22	26689	-
S35.AV31 (2712VAV007)	26690	-
S35.CP1 (2712CPS007)	26706	-
S35.CP2 (2712CPS008)	26706	-
S35.AV32 (2712AVK007)	26713	26633
S35.MH1 (2712MAN002)	26725	-
S35.IV5 (2712VLN006)	27154	27153
S35.CP3 (2712CPS003)	27160	-
S35.OT23	27164	-
S35.AV33 (2712VAV006)	27166	-
S35.CP4 (2712CPS004)	27186	-
S35.AV34 (2712AVK006)	27186	27163
S35.ST17 (2712SMP002)	27186	-
S35.CE9.1	-	27208
S35.CP5 (2712CPS005)	27224	-
S35.CP6 (2712CPS006)	27542	-
S35.CE9.2	-	27553
S35.OT24	27570	-
S35.OV24 (2712VPO002)	27571	-
S35.POR4 (2712POR002)	27578	27573
S35.OT25	27885	-
S35.AV35 (2712VAV005)	27886	-
S35.AV36 (2712AVK005)	27898	27888
S35.CP7 (2712CPS002)	28226	-
S35.OT26	28708	-
S35.OV26 (2712VPO003)	28709	-
S35.POR5 (2712POR003)	28718	28208
S35.MH2	28920	-
S35.MH2.1	-	28923
S35.OT27	28965	-
S35.AV37 (2712VAV008)	28967	-
S35.ST18 (2712SMP003)	28973	-
S35.CP8 (2712CPS001)	28974	-

Table B.2 Continued

Feature	Chainage (ft)	
	GIS	ASCONS
S35.AV38 (2712AVK008)	28974	28968
S35.IV6 (2712VLN003)	29017	29018
S35.PC4	29020	-
S35.OT28 (2712VLN005)	29020	-
S35.End	29020	-

Table B.3: Surveyed pipeline chainages for OC9 and OC35 Water Pipelines, section OC35A

Feature	Chainage (ft)	
	GIS	ASCONS
S35A.TO1 (128TNO001)	0	0
S35A.TP1(128VLN007 (1))	25	-
S35A.PC1	25	-
S35A.IV1 (128VLN007)	25	18
S35A.CE1.1	-	60
S35A.CE1.2	-	102
S35A.IV2 (2712VLN004)	2160	-
S35A.OT1	2163	-
S35A.IV3(2712VLN005(1))	2167	2095
S35A.OT2	2171	-
S35A.AV1 (2712VAV004)	2173	-
S35A.AV2 (2712AVK004)	2214	-
S35A.RED1 (2712RED001)	2865	-

Feature	Chainage (ft)	
	GIS	ASCONS
S35A.PC2	2865	-
S35A.RED1.1	-	2866
S35A.OT3	2870	-
S35A.OV3 (2712VLN001)	2871	2871
S35A.OT4	2977	-
S35A.PLG1 (2711PLG001)	2985	2981
S35A.TP2(2711VLN001(1))	3081	-
S35A.IV4 (2711VLN001)	3082	-
S35A.PC3	3082	-
S35A.ST1 (2711SMP001)	3100	-
S35A.TO2 (2711TNO001)	3102	-
S35A.End	3102	-

Appendix C: Example of Pressure Traces

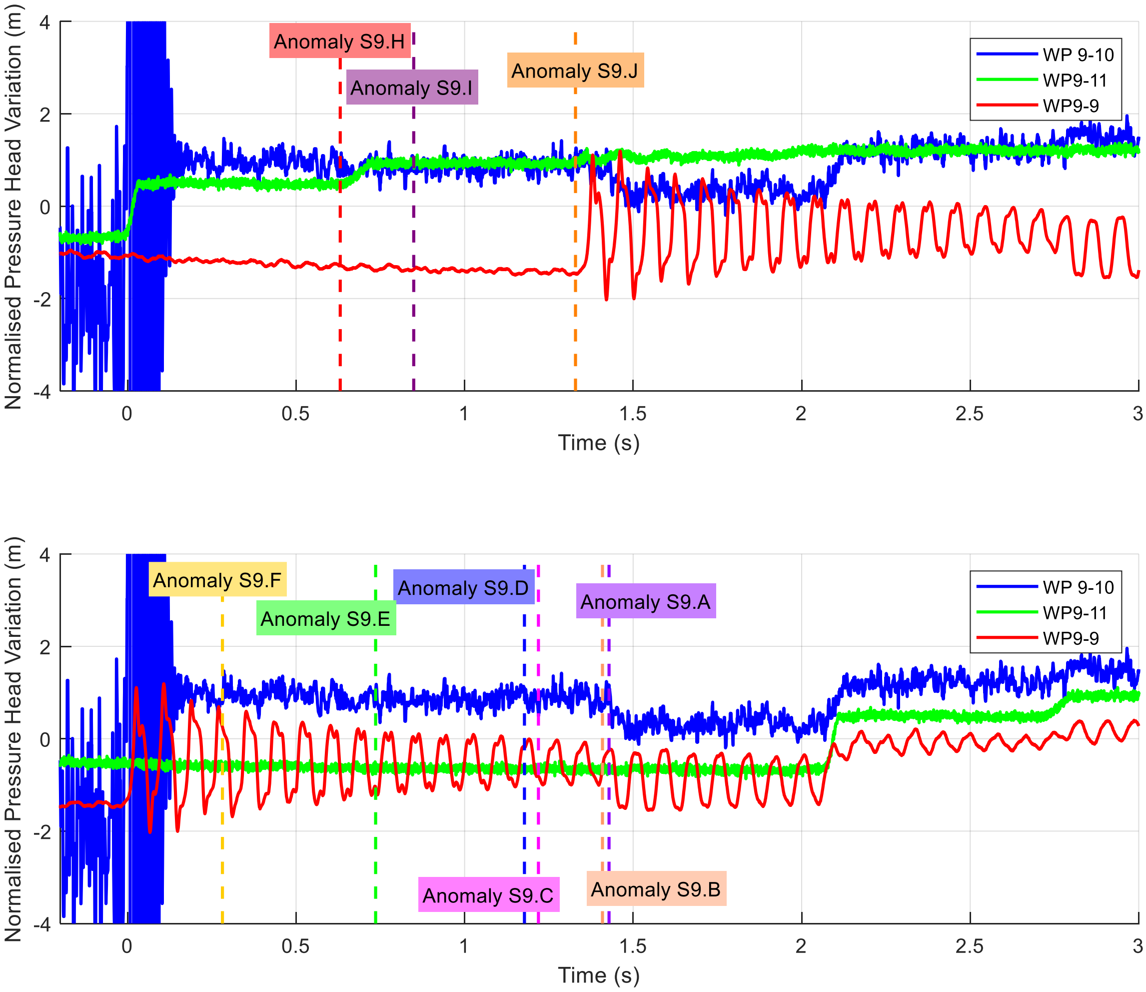


Figure C.1: Anomaly identification for transient generated at WP9-10

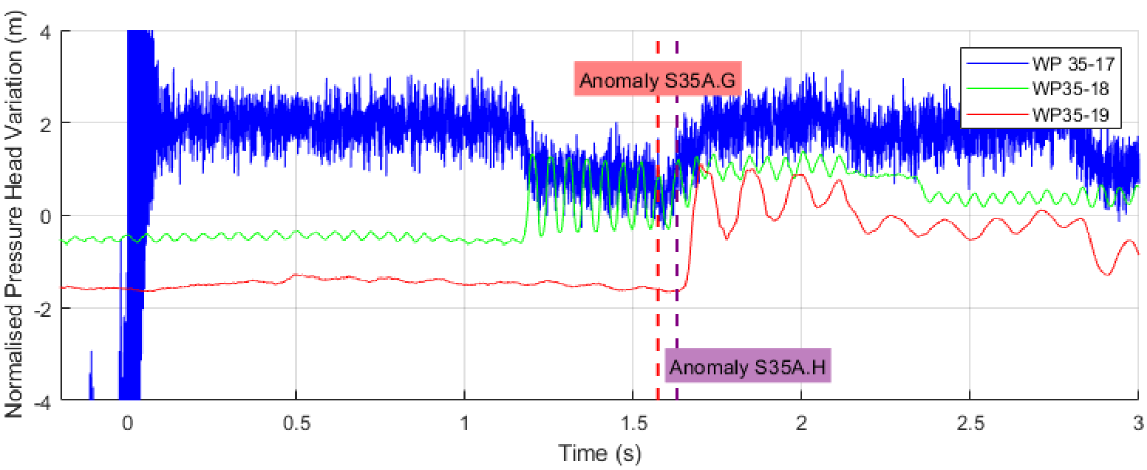


Figure C.2: Anomaly identification for transient generated at WP35-17

Appendix D. Test Methodology and Equipment

D1. Non-invasive Pipe Condition Assessment (p-CAT™)

The University of Adelaide (UoA) has developed a technology that enables the simultaneous non-invasive diagnosis of pipeline condition over long distances along pipelines with minimal disruption of current services, thereby allowing decisions to be made regarding pipes which require rehabilitation. Pipeline Inspection & Assessment (PIA) and Detection Services (DS) are putting the technology to practical use.

A controlled transient event (or small magnitude controlled water hammer event) is a pressure wave that occurs in a pipeline whenever the flow is changed rapidly (e.g. by a rapid valve opening or closure or sudden pump start or stop). The rapid change in flow is accompanied by a sharp change in pressure. The variation of pressure during the transient pressure wave event can be measured at locations along the pipes with pressure transducers. The presence of pipe wall damage due to metallic corrosion and/or cement mortar lining loss has a visible impact on the resultant transient pressure wave trace. This observation is the basis of advanced mathematical techniques that use fluid transient pressure waves for detecting the size and location of these defects.

For cement mortar lined metallic pipes, there is a relationship between changes in the thickness of metal and cement mortar lining forming a pipeline wall and the speed (or wave speed) with which a wavefront from a hydraulic transient pressure wave propagates along the pipeline. Changes in the thickness of metal and cement mortar lining give rise to reflections which can be theoretically interpreted to obtain a distribution of damage along the pipeline.

In Asbestos Cement (AC) pipelines there is a relationship between changes in the effective thickness of the cement forming a pipeline wall and the speed (or wave speed) with which a wave front from a hydraulic transient pressure wave propagates along the pipeline. Changes in the effective thickness of the cement (e.g. due to leaching of calcium) give rise to reflections which can be theoretically interpreted to obtain a distribution of damage along the pipeline. Softening of the AC pipe material would also be evident.

In CI pipelines tuberculation and graphitization may occur whereby the Iron is leached from the pipe wall by bacteria. This results in graphitized sections of the pipe wall and tubercules of iron composites connected to the pipe wall restricting the internal diameter. The graphitized sections and tubercules do not contribute to the structural integrity and are hence not included in the effective wall thickness.

Validation of the techniques on field pipelines by PIA, DS and UoA has shown that measured transient pressure wave traces can provide significant amounts of information about a pipe system. This is due to small reflections of propagating transient pressure waves resulting from variations in the pipeline surface. The reflections are used to predict both the location and extent of damage along the tested length of pipe and confirmed using point sampling methods.

p-CAT™ analysis uses two main techniques for interpreting the results from the transient pressure wave tests:

- Sub-Section Partitioned Wave Speed Analysis™ for assessment of the level of deterioration of the pipe wall in a sub-section, and
- Signal Analysis for detection of significant anomalies such as air pockets and blockages.

D2. Sub-Section Partitioned Wave Speed Analysis™

Changes in wall thickness are related directly to the speed of propagation of a transient pressure wave (wave speed) and these changes give rise to the observed reflections. If the wall of a pipeline has a reduction in thickness, then a transient pressure wave will propagate at a slower speed than the theoretical maximum. This wave speed variation results in a small reflection of the incident controlled transient event wave. Alternatively, if a change in pipe wall thickness occurs along the pipeline as a result of a connection between two different pipes that are similar in diameter but with different wall thicknesses, the wave speed will be different in the two sections. The p-CAT™ technique analyses the transient pressure wave traces and wave reflections to identify sub-sections of pipe between two measurement stations that have variations in wave speed. This variation could be the result of known changes in the pipe material or pipe material properties or appurtenances or changes in pipe wall condition. Details of the background theory on the Sub-Section Partitioned Wave Speed Analysis™ are provided in Appendix E.

D3. Signal Analysis

Signal analysis is a higher resolution analysis based on the same principles as the Sub-Section Partitioned Wave Speed Analysis™. It is used to identify known features in the pipeline system and significant anomalies within the system such as air pockets and blockages. It can also identify the locations of changes in pipeline material, inline valves and offtakes. A time shift is conducted of the measured responses on either side of the location at which the transient pressure wave is generated, such that the origin of each reflection can be uniquely determined by signal analysis. The known feature or anomaly is then categorized based on its characteristics.

The resolution of transient pressure wave signal analysis depends on the accuracy and sharpness of the measured and provided data, the extent of complexity of pipeline system configuration and the accuracy in the estimation of the distance between measurement stations. In the tests, the client provided pipe information was used to determine the locations of the measuring points and to approximate the pipe lengths. The average precision of the anomaly location is ±33 ft for tests due to the precision of the pipe lengths.

D4. Test Procedure

Each test was generally composed of one transient generation point (a water discharge point) and two or more pressure measurement points. The following is the procedure for equipment installation and collection of the pressure signal:

a) Installation of a hydraulic transient signal generator with a signal acquisition system on a fire hydrant and fire plug.
b) Installation of a signal acquisition system at the measurement points on fire hydrants, and fire plugs.
c) Carrying out tests for collecting pressure signals: water is released at the transient generation point, time is allowed for the resulting transients to settle, and then the transient generator is quickly closed to create a hydraulic transient signal. The size of outlet on the transient generator is selected to create a transient pulse of no more than 33 ft of head pressure. Transient input signals are repeated at each location 3 to 5 times.
d) Test equipment is then packed up and moved to another test location.
e) At the end of the day, the data is packaged and transferred for analysis.

One test set with one generation point and two measurement points can take one to two hours including moving, installing equipment and testing.

D5. Test Equipment

The hydraulic transient pressure wave generator and the signal acquisition system for the measurement points used in the testing is shown in Figure D.1. Pressure measurement recordings are transferred via amplifiers and 24-bit A/D converter to a personal laptop computer with a data acquisition interface based on LabVIEW software. The minimum sampling frequency for measuring pressure data was 2 kHz (2,000 samples per second).

(a)
Non-return valve type transient pressure wave generator (2 inch fitting) attached to an air valve

(b)
Pressure measurement equipment attached to an air valve

(c)
Data acquisition (DAQ) system

Figure D.1: Field testing equipment

Appendix E: Theory

E1. Theory and Equations

This Appendix describes the background information about the Sub-Section Partitioned Wave Speed Analysis™. The physical observation that there are reflections following the initiation of a hydraulic transient pressure wave event in a pipeline is the basis for the technique. The fundamental physical mechanism giving rise to the observed reflections is recognized as changes in the thickness of pipe wall and/or cement mortar lining, which in turn alters the speed of propagation of hydraulic transient pressure waves. The relationship between the changes in the equivalent pipe wall thickness and the variation in the wave speed can be used to classify the condition of the pipeline. This relationship can be theoretically described by the following equation:

$$a = \sqrt{\frac{K/\rho}{1 + (K/E)\cdot\left(D/e_{eq}\right)\cdot\psi}} \qquad \text{(E 1)}$$

where a = speed of propagation of hydraulic transient pressure wave (wave speed), K = bulk modulus of water, ρ = density of water, E = Young's modulus of elasticity of the pipeline wall material, D = internal diameter of the pipeline, e_{eq} = wall thickness of a single material pipe or the total equivalent wall thickness of composite material pipe, and ψ = the pipeline restraint factor.

The contribution of the cement mortar lining can be included as an equivalent thickness of steel using

$$e_{eq\_C} = e_C \times \frac{E_C}{E_M} \qquad \text{(E 2)}$$

where e_{eq_C} is the equivalent steel thickness given by the cement mortar lining, e_c = the original thickness of the cement mortar lining, E_C and E_M = the Young's moduli of elasticity of cement mortar lining and metal respectively.

When the cement mortar lining spalls off the inside of a section of pipeline, changes occur in the total equivalent pipe wall thickness. The loss of cement mortar lining reduces the stiffness of the pipeline wall by an amount proportional to the thickness and modulus of elasticity of the cement. Once exposed, the pipe wall begins to corrode, leading to a reduction in the thickness of the metal wall. External pipe wall corrosion can also cause a thinning of the pipe wall.

The impedance and wave speed of a pipe section are extremely sensitive to the combined effect of the loss of cement mortar lining and corrosion of the metal wall. As a consequence, the magnitude and frequency of reflections from the transient pressure wave will increase as the wavefront moves along a section of pipeline that is deteriorated. It is important to recognize that wave speed is also sensitive to the reduction of wall thickness caused by external corrosion (i.e., pipe wall thinning should give a slower wave speed and a micro-reflection regardless of it is due to external or internal corrosion).

E2. Interpretation of Variations in Wave Speed in a Pipe Section between Two Points

Determination of the average wave speed using the time for a transient pressure wave traveling between two measurement points is a quantitative low-resolution technique, whereby the average thickness of the remaining pipe wall can be estimated for the section bounded by the two measurement points. The Sub-Section Partitioned Wave Speed Analysis™ increases the resolution by incorporating the variations in wave speed in a pipe section bounded by two measurement points. When a transient pressure wave meets a segment of pipe with a change in material, pipe wall deterioration, or a concrete encasement (all result in a change in wave speed), it causes wave reflections which are shown as variations in pressure in the traces measured by transducers. In the Sub-Section Partitioned Wave Speed Analysis™, by analyzing the size and timing of these pressure variations, the wave speeds for two or more sub-sections between a pair of measurement points can be determined. Variations in pressure are translated to variations in wave speed from the average, which are then used to determine the condition of each sub-section.

E3. Example of Sub-Section Partitioned Wave Speed Analysis™

An example of the Sub-Section Partitioned Wave Speed Analysis™ is presented below in Figure E.1. This was selected as a good example of data and was taken from a test on a mining trunk main pipeline.

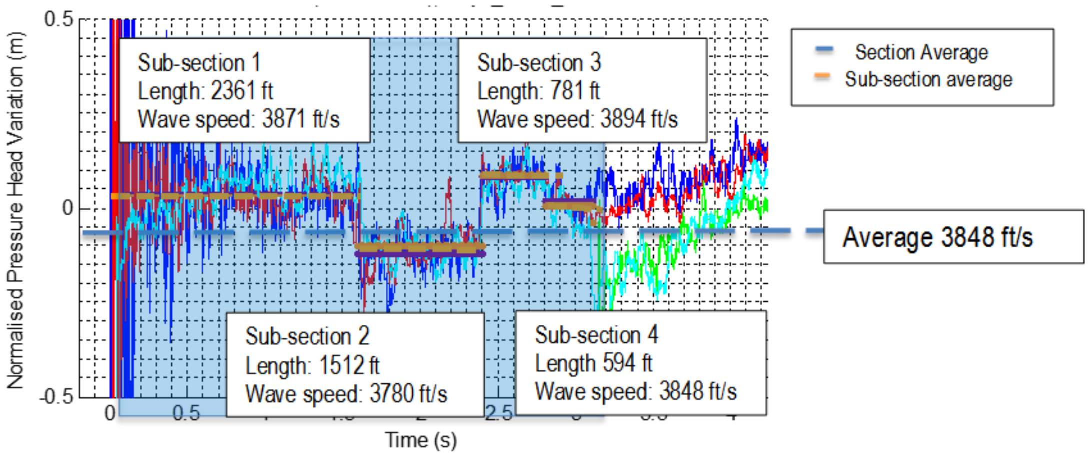


Figure E.1: Segment for estimation of wave speed variation between measurement stations

In Figure E.1, the dashed blue line depicts the inferred wave speed (3848 ft/s) for the entire example section (shaded blue box), which was estimated by the transient pressure wave arrival time. Within this section there are sub-sections of relatively stable pressure head. These sections represent sections with distinct wave speeds and Sub-Section Partitioned Wave Speed Analysis™ was used to determine the representative wave speeds in each sub-section. Note in this example sub-section 2 represents a section where a known MSCL replacement is located. The theoretical wave speed for 6mm OD MSCL is 3717 ft/s.

Appendix F: Additional scenario (ANSI/AWWA C200 standard)

Table F.1: SCP pipe wall deterioration results for OC9 and OC35 Water Pipelines, section OC9
Assuming nominal theoretical values as original wall thickness (specified in the ANSI/AWWA C200)

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.1	0	566	S9.Start to S9.PC1 **(Anomaly S9.A)**	566	Unknown	NA	Unknown material		
S9.2	566	603	S9.PC1 to S9.OT2 **(Anomaly S9.B)**	36	DN24 SCP	1.33	0.97 (-0.36)	72.7%	3
S9.3	603	842	As per chainage	239	DN24 SCP	1.33	1.06 (-0.26)	80.1%	4
S9.4	842	974	Previous point to **Anomaly S9.C**	132	DN24 SCP	1.33	1.07 (-0.25)	80.8%	4
S9.5	974	1054	Previous point to **Anomaly S9.D**	81	DN24 SCP	1.33	1.06 (-0.27)	79.6%	3
S9.6	1054	1271	As per chainage	216	DN24 SCP	1.33	1.05 (-0.28)	79.0%	3
S9.7	1271	1395	As per chainage	124	DN24 SCP	1.33	1.03 (-0.30)	77.6%	3
S9.8	1395	1487	As per chainage	92	DN24 SCP	1.33	1.04 (-0.29)	78.3%	3
S9.9	1487	1726	As per chainage	239	DN24 SCP	1.33	1.04 (-0.28)	78.7%	3
S9.10	1726	1909	Previous point to **Anomaly S9.E**	184	DN24 SCP	1.33	1.05 (-0.27)	79.4%	3
S9.11	1909	2152	As per chainage	243	DN24 SCP	1.33	1.09 (-0.24)	82.2%	4
S9.12	2152	2362	As per chainage	210	DN24 SCP	1.33	1.08 (-0.25)	81.4%	4
S9.13	2362	2617	As per chainage	256	DN24 SCP	1.33	1.09 (-0.24)	82.2%	4
S9.14	2617	2802	Previous point to **Anomaly S9.F**	184	DN24 SCP	1.33	1.09 (-0.24)	81.8%	4
S9.15	2802	3344	Previous point to S9.AV3 **(Anomaly S9.G)**	542	DN24 SCP	1.33	1.03 (-0.30)	77.3%	3
S9.16	3344	3623	As per chainage	279	DN24 SCP	1.33	1.03 (-0.30)	77.4%	3
S9.17	3623	3987	As per chainage	364	DN24 SCP	1.33	1.04 (-0.29)	78.5%	3
S9.18	3987	4111	As per chainage	125	DN24 SCP	1.33	1.02 (-0.31)	76.5%	3
S9.19	4111	4331	As per chainage	219	DN24 SCP	1.33	1.05 (-0.27)	79.4%	3
S9.20	4331	4472	As per chainage	141	DN24 SCP	1.33	1.03 (-0.30)	77.7%	3
S9.21	4472	4562	Previous point to **Anomaly S9.H**	90	DN24 SCP	1.33	1.03 (-0.30)	77.4%	3
S9.22	4562	4839	As per chainage	277	DN24 SCP	1.33	1.17 (-0.16)	88.1%	4
S9.23	4839	5000	Previous point to S9.BO1 **(Anomaly S9.I)**	161	DN24 SCP	1.33	1.17 (-0.16)	88.2%	4
S9.24	5000	5110	As per chainage	110	DN24 SCP	1.33	0.98 (-0.35)	73.9%	3
S9.25	5110	5307	As per chainage	197	DN24 SCP	1.33	0.96 (-0.37)	72.4%	3
S9.26	5307	5465	As per chainage	159	DN24 SCP	1.33	0.97 (-0.35)	73.3%	3
S9.27	5465	5712	As per chainage	246	DN24 SCP	1.33	0.97 (-0.36)	73.2%	3
S9.28	5712	5906	Previous point to S9.OT4 **(Anomaly S9.J)**	194	DN24 SCP	1.33	0.97 (-0.36)	72.7%	3
S9.29	5906	5912	S9.OT4 to S9.OT5	6	DN24 SCP	1.33	1.06 (-0.27)	79.6%	3
S9.30	5912	5985	S9.OT5 to S9.IV4.1 **(Anomaly S9.K)**	73	DN24 SCP	1.33	1.11 (-0.22)	83.6%	4
S9.31	5985	6290	As per chainage	305	DN24 SCP	1.33	1.03 (-0.30)	77.6%	3
S9.32	6290	6516	Previous point to **Anomaly S9.L**	225	DN24 SCP	1.33	1.02 (-0.31)	76.5%	3
S9.33	6516	6726	Previous point to **Anomaly S9.M**	210	DN24 SCP	1.33	1.06 (-0.27)	79.6%	3
S9.34	6726	6852	Previous point to **Anomaly S9.N**	126	DN24 SCP	1.33	1.09 (-0.23)	82.4%	4
S9.35	6852	7095	As per chainage	243	DN24 SCP	1.33	1.05 (-0.28)	79.1%	3
S9.36	7095	7233	As per chainage	138	DN24 SCP	1.33	1.06 (-0.27)	79.7%	3
S9.37	7233	7492	As per chainage	259	DN24 SCP	1.33	1.06 (-0.27)	80.0%	3
S9.38	7492	7757	As per chainage	265	DN24 SCP	1.33	1.05 (-0.27)	79.3%	3
S9.39	7757	7925	As per chainage	168	DN24 SCP	1.33	1.05 (-0.28)	78.8%	3
S9.40	7925	8207	As per chainage	282	DN24 SCP	1.33	1.06 (-0.27)	79.5%	3
S9.41	8207	8407	Previous point to **Anomaly S9.O (Start)**	200	DN24 SCP	1.33	1.06 (-0.27)	79.9%	3
S9.42	8407	8505	**Anomaly S9.O**	97	DN24 SCP	1.33	1.13 (-0.20)	85.2%	4

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.1 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.43	8505	8659	As per chainage	154	DN24 SCP	1.33	1.13 (-0.20)	85.2%	4
S9.44	8659	8957	As per chainage	298	DN24 SCP	1.33	1.12 (-0.21)	84.2%	4
S9.45	8957	9045	Previous point to **Anomaly S9.P**	88	DN24 SCP	1.33	1.13 (-0.20)	85.1%	4
S9.46	9045	9223	As per chainage	178	DN24 SCP	1.33	1.06 (-0.27)	79.5%	3
S9.47	9223	9433	As per chainage	210	DN24 SCP	1.33	1.06 (-0.27)	79.5%	3
S9.48	9433	9673	As per chainage	240	DN24 SCP	1.33	1.07 (-0.26)	80.3%	4
S9.49	9673	9810	Previous point to S9.OT6 **(Anomaly S9.Q)**	137	DN24 SCP	1.33	1.05 (-0.28)	79.2%	3
S9.50	9810	10082	As per chainage	273	DN24 SCP	1.33	1.00 (-0.33)	75.0%	3
S9.51	10082	10190	Previous point to **Anomaly S9.R**	108	DN24 SCP	1.33	1.01 (-0.32)	75.9%	3
S9.52	10190	10479	As per chainage	289	DN24 SCP	1.33	1.01 (-0.32)	75.8%	3
S9.53	10479	10620	As per chainage	141	DN24 SCP	1.33	1.01 (-0.32)	75.7%	3
S9.54	10620	10745	As per chainage	124	DN24 SCP	1.33	0.98 (-0.34)	74.1%	3
S9.55	10745	10984	As per chainage	240	DN24 SCP	1.33	1.02 (-0.31)	76.6%	3
S9.56	10984	11256	Previous point to S36 (PC2)	271	DN24 SCP	1.33	1.01 (-0.32)	75.7%	3
S9.57	11256	11259	S36 (PC2) to S9.IV6 **(Anomaly S9.S)**	3	DN16 SCP	1.20	0.81 (-0.40)	67.1%	2
S9.58	11259	11622	As per chainage	364	DN26 SCP	1.33	1.08 (-0.25)	81.5%	4
S9.59	11622	11897	As per chainage	275	DN26 SCP	1.33	1.08 (-0.24)	81.6%	4
S9.60	11897	12003	As per chainage	105	DN26 SCP	1.33	1.08 (-0.25)	81.4%	4
S9.61	12003	12202	As per chainage	200	DN26 SCP	1.33	1.08 (-0.25)	81.0%	4
S9.62	12202	12383	As per chainage	181	DN26 SCP	1.33	1.08 (-0.25)	81.1%	4
S9.63	12383	12533	Previous point to **Anomaly S9.T**	150	DN26 SCP	1.33	1.09 (-0.23)	82.4%	4
S9.64	12533	12664	As per chainage	131	DN26 SCP	1.33	1.05 (-0.28)	78.7%	3
S9.65	12664	12873	As per chainage	210	DN26 SCP	1.33	1.05 (-0.28)	78.8%	3
S9.66	12873	13109	As per chainage	236	DN26 SCP	1.33	1.04 (-0.29)	78.4%	3
S9.67	13109	13254	As per chainage	144	DN26 SCP	1.33	1.05 (-0.28)	79.0%	3
S9.68	13254	13496	As per chainage	243	DN26 SCP	1.33	1.04 (-0.29)	78.3%	3
S9.69	13496	13763	Previous point to S9.OT9 **(Anomaly S9.U)**	267	DN26 SCP	1.33	1.04 (-0.28)	78.6%	3
S9.70	13763	13891	S9.OT9 to S46.1 (PC4)	127	DN26 SCP	1.33	1.03 (-0.30)	77.6%	3
S9.71	13891	13894	S46.1 (PC4) to S9.OT11 **(Anomaly S9.V)**	3	DN16 SCP	1.20	0.79 (-0.41)	66.1%	2
S9.72	13894	14169	As per chainage	275	DN26 SCP	1.33	0.98 (-0.35)	73.5%	3
S9.73	14169	14261	As per chainage	92	DN26 SCP	1.33	1.00 (-0.33)	75.4%	3
S9.74	14261	14534	Previous point to **Anomaly S9.W**	274	DN26 SCP	1.33	0.98 (-0.35)	73.7%	3
S9.75	14534	14711	Previous point to **Anomaly S9.X**	177	DN26 SCP	1.33	0.94 (-0.39)	70.5%	3
S9.76	14711	14779	Previous point to **Anomaly S9.Y (Start)**	67	DN26 SCP	1.33	0.99 (-0.34)	74.2%	3
S9.77	14779	14920	**Anomaly S9.Y**	142	DN26 SCP	1.33	1.11 (-0.22)	83.6%	4
S9.78	14920	15143	As per chainage	223	DN26 SCP	1.33	0.98 (-0.34)	74.1%	3
S9.79	15143	15481	As per chainage	338	DN26 SCP	1.33	0.99 (-0.34)	74.2%	3
S9.80	15481	15658	As per chainage	177	DN26 SCP	1.33	0.98 (-0.34)	74.1%	3
S9.81	15658	15772	As per chainage	114	DN26 SCP	1.33	0.98 (-0.35)	73.8%	3
S9.82	15772	16018	As per chainage	246	DN26 SCP	1.33	0.99 (-0.34)	74.7%	3
S9.83	16018	16162	As per chainage	144	DN26 SCP	1.33	0.97 (-0.35)	73.3%	3
S9.84	16162	16442	Previous point to **Anomaly S9.Z**	280	DN26 SCP	1.33	0.99 (-0.34)	74.4%	3

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.1 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length (ft)	Assumed Pipe Material	Theoretical Wall Thickness (in)	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End					Wall	%Remain	
S9.85	16442	16498	Previous point to S9.OT12 **(Anomaly S9.AA)**	56	DN26 SCP	1.33	1.06 (-0.27)	79.5%	3
S9.86	16498	16625	As per chainage	128	DN26 SCP	1.33	0.92 (-0.41)	68.9%	2
S9.87	16625	16868	As per chainage	243	DN26 SCP	1.33	0.93 (-0.40)	69.9%	2
S9.88	16868	16979	As per chainage	111	DN26 SCP	1.33	0.89 (-0.44)	67.0%	2
S9.89	16979	17163	As per chainage	183	DN26 SCP	1.33	0.92 (-0.41)	69.0%	2
S9.90	17163	17331	Previous point to S9.OT13 **(Anomaly S9.AB)**	169	DN26 SCP	1.33	0.93 (-0.40)	69.8%	2
S9.91	17331	17439	S9.OT13 to S9.OT15 **(Anomaly S9.AC)**	108	DN26 SCP	1.33	0.95 (-0.38)	71.2%	3
S9.92	17439	17639	As per chainage	200	DN26 SCP	1.33	1.03 (-0.30)	77.6%	3
S9.93	17639	17882	As per chainage	243	DN26 SCP	1.33	1.00 (-0.33)	75.5%	3
S9.94	17882	18032	As per chainage	151	DN26 SCP	1.33	1.04 (-0.29)	78.3%	3
S9.95	18032	18175	Previous point to **Anomaly S9.AD**	143	DN26 SCP	1.33	1.04 (-0.29)	78.2%	3
S9.96	18175	18509	As per chainage	334	DN26 SCP	1.33	0.99 (-0.34)	74.6%	3
S9.97	18509	18670	As per chainage	160	DN26 SCP	1.33	0.99 (-0.34)	74.3%	3
S9.98	18670	18810	As per chainage	141	DN26 SCP	1.33	0.98 (-0.34)	74.1%	3
S9.99	18810	18997	Previous point to **Anomaly S9.AE**	186	DN26 SCP	1.33	0.98 (-0.35)	73.9%	3
S9.100	18997	19223	As per chainage	226	DN26 SCP	1.33	1.02 (-0.30)	77.2%	3
S9.101	19223	19364	As per chainage	141	DN26 SCP	1.33	1.01 (-0.32)	75.8%	3
S9.102	19364	19492	As per chainage	128	DN26 SCP	1.33	1.04 (-0.29)	78.4%	3
S9.103	19492	19754	As per chainage	262	DN26 SCP	1.33	1.04 (-0.29)	78.1%	3
S9.104	19754	19998	Previous point to S9.PC6 **(Anomaly S9.AF)**	244	DN26 SCP	1.33	1.01 (-0.31)	76.4%	3
S9.105	19998	20007	S9.PC6 to S9.PC7 **(Anomaly S9.AG)**	9	DN16 SCP	1.20	0.94 (-0.27)	77.8%	3
S9.106	20007	20309	As per chainage	302	DN28 SCP	1.33	1.04 (-0.29)	78.5%	3
S9.107	20309	20470	As per chainage	161	DN28 SCP	1.33	1.04 (-0.29)	78.5%	3
S9.108	20470	20679	As per chainage	210	DN28 SCP	1.33	1.05 (-0.28)	78.9%	3
S9.109	20679	20781	As per chainage	101	DN28 SCP	1.33	1.08 (-0.24)	81.6%	4
S9.110	20781	21005	Previous point to **Anomaly S9.AH**	225	DN28 SCP	1.33	1.03 (-0.29)	77.9%	3
S9.111	21005	21268	As per chainage	262	DN28 SCP	1.33	1.05 (-0.28)	79.2%	3
S9.112	21268	21452	Previous point to **Anomaly S9.AI**	184	DN28 SCP	1.33	1.04 (-0.29)	78.5%	3
S9.113	21452	21566	Previous point to S9.OT17	115	DN28 SCP	1.33	1.09 (-0.24)	82.2%	4
S9.114	21566	21825	As per chainage	259	DN28 SCP	1.33	0.99 (-0.34)	74.6%	3
S9.115	21825	22206	As per chainage	380	DN28 SCP	1.33	0.99 (-0.34)	74.5%	3
S9.116	22206	22415	As per chainage	210	DN28 SCP	1.33	1.01 (-0.32)	75.8%	3
S9.117	22415	22649	Previous point to S9.OT18 **(Anomaly S9.AJ)**	234	DN28 SCP	1.33	0.98 (-0.35)	73.9%	3
S9.118	22649	22973	As per chainage	324	DN28 SCP	1.33	0.98 (-0.35)	73.5%	3
S9.119	22973	23226	Previous point to S9.OT20 **(Anomaly S9.AK)**	253	DN28 SCP	1.33	0.97 (-0.36)	73.0%	3
S9.120	23226	23444	As per chainage	218	DN28 SCP	1.33	1.07 (-0.25)	80.9%	4
S9.121	23444	23733	As per chainage	289	DN28 SCP	1.33	1.08 (-0.25)	81.3%	4
S9.122	23733	24042	Previous point to **Anomaly S9.AL**	309	DN28 SCP	1.33	1.07 (-0.26)	80.8%	4
S9.123	24042	24411	Previous point to **Anomaly S9.AM**	369	DN28 SCP	1.33	1.05 (-0.28)	79.2%	3
S9.124	24411	24647	As per chainage	236	DN28 SCP	1.33	1.05 (-0.28)	78.9%	3
S9.125	24647	24913	As per chainage	266	DN28 SCP	1.33	1.04 (-0.29)	78.0%	3
S9.126	24913	25067	As per chainage	154	DN28 SCP	1.33	1.08 (-0.25)	81.0%	4

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.1 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S9.127	25067	25323	Previous point to S9.OT21 **(Anomaly S9.AN)**	257	DN28 SCP	1.33	1.03 (-0.30)	77.3%	3
S9.128	25323	25448	As per chainage	125	DN28 SCP	1.33	1.08 (-0.25)	81.0%	4
S9.129	25448	25723	As per chainage	276	DN28 SCP	1.33	1.05 (-0.28)	79.2%	3
S9.130	25723	26018	Previous point to S9.OT22 **(Anomaly S9.AO)**	295	DN28 SCP	1.33	1.08 (-0.25)	81.0%	4
S9.131	26018	26365	As per chainage	347	DN28 SCP	1.33	1.05 (-0.28)	79.0%	3
S9.132	26365	26552	As per chainage	187	DN28 SCP	1.33	1.06 (-0.27)	79.4%	3
S9.133	26552	26785	As per chainage	233	DN28 SCP	1.33	1.04 (-0.29)	78.4%	3
S9.134	26785	26990	Previous point to S9.OT23	206	DN28 SCP	1.33	1.06 (-0.27)	79.6%	3
S9.135	26990	27014	S9.OT23 to S9.CE3.1 **(Anomaly S9.AP (Start))**	24	DN28 SCP	1.33	0.96 (-0.37)	72.1%	3
S9.136	27014	27094	Anomaly S9.AP	80	DN28 SCP	1.33	1.03 (-0.30)	77.5%	3
S9.137	27094	27398	As per chainage	305	DN28 SCP	1.33	0.94 (-0.39)	70.7%	3
S9.138	27398	27645	As per chainage	246	DN28 SCP	1.33	0.93 (-0.40)	69.9%	2
S9.139	27645	27897	Previous point to S9.PC8 **(Anomaly S9.AQ)**	253	DN28 SCP	1.33	0.95 (-0.38)	71.3%	3
S9.140	27897	27900	S9.PC8 to S9.AV22	2	DN16 SCP	1.20	0.73 (-0.47)	60.5%	2
S9.141	27900	27905	S9.AV22 to S9.End	5	DN16 SCP	1.20	0.70 (-0.50)	58.3%	1

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.2: SCP pipe wall deterioration results for OC9 and OC35 Water Pipelines, section OC35
Assuming nominal theoretical values as original wall thickness (specified in the ANSI/AWWA C200)

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.1	0	2	S35.Start to S35.PRV1 **(Anomaly S35.A)**	2	DN36 SCP	1.40	0.92 (-0.48)	65.6%	2
S35.2	2	246	S35.PRV1 to **Anomaly S35.B**	244	DN36 SCP	1.40	0.90 (-0.49)	64.7%	2
S35.3	246	594	As per chainage	348	DN36 SCP	1.40	0.91 (-0.48)	65.4%	2
S35.4	594	846	As per chainage	252	DN36 SCP	1.40	0.91 (-0.48)	65.5%	2
S35.5	846	1093	Previous point to **Anomaly S35.C**	246	DN36 SCP	1.40	0.92 (-0.48)	65.7%	2
S35.6	1093	1184	Previous point to S35.AV5 **(Anomaly S35.D)**	92	DN36 SCP	1.40	0.95 (-0.45)	68.0%	2
S35.7	1184	1206	S35.AV5 to S35.OT4	22	DN36 SCP	1.40	0.97 (-0.42)	69.9%	2
S35.8	1206	1498	As per chainage	292	DN36 SCP	1.40	0.84 (-0.56)	60.0%	1
S35.9	1498	1740	As per chainage	243	DN36 SCP	1.40	0.84 (-0.55)	60.5%	2
S35.10	1740	2013	As per chainage	272	DN36 SCP	1.40	0.84 (-0.56)	60.1%	2
S35.11	2013	2206	As per chainage	193	DN36 SCP	1.40	0.84 (-0.56)	60.2%	2
S35.12	2206	2406	As per chainage	200	DN36 SCP	1.40	0.85 (-0.55)	60.6%	2
S35.13	2406	2656	Previous point to S35.CE3.1 **(Anomaly S35.E (Start))**	251	DN36 SCP	1.40	0.84 (-0.56)	60.1%	2
S35.14	2656	2788	**Anomaly S35.E**	132	DN36 SCP	1.40	1.00 (-0.39)	71.9%	3
S35.15	2788	3085	S35.CE3.2 to S35.OT5 **(Anomaly S35.F)**	297	DN36 SCP	1.40	0.84 (-0.55)	60.5%	2
S35.16	3085	3357	As per chainage	272	DN36 SCP	1.40	0.89 (-0.50)	64.0%	2
S35.17	3357	3676	Previous point to **Anomaly S35.G**	319	DN36 SCP	1.40	0.89 (-0.50)	64.0%	2
S35.18	3676	3860	As per chainage	184	DN36 SCP	1.40	0.85 (-0.54)	61.1%	2
S35.19	3860	4021	As per chainage	161	DN36 SCP	1.40	0.86 (-0.53)	61.8%	2
S35.20	4021	4165	As per chainage	144	DN36 SCP	1.40	0.84 (-0.56)	60.2%	2
S35.21	4165	4401	As per chainage	236	DN36 SCP	1.40	0.85 (-0.54)	61.3%	2
S35.22	4401	4571	Previous point to S35.CE4.1 **(Anomaly S35.H (Start))**	170	DN36 SCP	1.40	0.86 (-0.54)	61.3%	2
S35.23	4571	4613	**Anomaly S35.H**	42	DN36 SCP	1.40	1.24 (-0.15)	89.1%	4

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.2 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.24	4613	4846	As per chainage	233	DN36 SCP	1.40	0.92 (-0.48)	65.9%	2
S35.25	4846	4986	As per chainage	141	DN36 SCP	1.40	0.93 (-0.47)	66.5%	2
S35.26	4986	5153	As per chainage	167	DN36 SCP	1.40	0.92 (-0.47)	66.3%	2
S35.27	5153	5370	Previous point to S35.CE5.1 **(Anomaly S35.I (Start))**	217	DN36 SCP	1.40	0.93 (-0.47)	66.4%	2
S35.28	5370	5410	**Anomaly S35.I**	40	DN36 SCP	1.40	1.17 (-0.23)	83.6%	4
S35.29	5410	5536	S35.CE5.2 to S35.OT6 **(Anomaly S35.J)**	125	DN36 SCP	1.40	0.85 (-0.54)	61.3%	2
S35.30	5536	5682	As per chainage	146	DN36 SCP	1.40	0.89 (-0.51)	63.7%	2
S35.31	5682	5971	Previous point to **Anomaly S35.K**	290	DN36 SCP	1.40	0.89 (-0.51)	63.7%	2
S35.32	5971	6204	As per chainage	233	DN36 SCP	1.40	0.93 (-0.46)	67.0%	2
S35.33	6204	6420	Previous point to **Anomaly S35.L**	216	DN36 SCP	1.40	0.93 (-0.46)	66.8%	2
S35.34	6420	6592	Previous point to **Anomaly S35.M**	172	DN36 SCP	1.40	0.88 (-0.51)	63.2%	2
S35.35	6592	6760	Previous point to **Anomaly S35.N**	168	DN36 SCP	1.40	0.83 (-0.57)	59.3%	1
S35.36	6760	7051	As per chainage	292	DN36 SCP	1.40	0.89 (-0.50)	63.8%	2
S35.37	7051	7157	As per chainage	105	DN36 SCP	1.40	0.89 (-0.50)	64.1%	2
S35.38	7157	7367	As per chainage	210	DN36 SCP	1.40	0.89 (-0.51)	63.7%	2
S35.39	7367	7511	As per chainage	144	DN36 SCP	1.40	0.88 (-0.52)	62.9%	2
S35.40	7511	7743	Previous point to **Anomaly S35.O**	232	DN36 SCP	1.40	0.90 (-0.50)	64.2%	2
S35.41	7743	8018	As per chainage	275	DN36 SCP	1.40	0.92 (-0.47)	66.0%	2
S35.42	8018	8242	Previous point to S35.IV1 **(Anomaly S35.P)**	223	DN36 SCP	1.40	0.91 (-0.49)	65.0%	2
S35.43	8242	8492	S35.IV1 to S35.OT7	251	DN36 SCP	1.40	0.89 (-0.50)	64.0%	2
S35.44	8492	8699	As per chainage	206	DN36 SCP	1.40	0.95 (-0.44)	68.2%	2
S35.45	8699	8931	As per chainage	233	DN36 SCP	1.40	0.93 (-0.46)	67.0%	2
S35.46	8931	9093	As per chainage	161	DN36 SCP	1.40	0.94 (-0.45)	67.6%	2
S35.47	9093	9356	As per chainage	263	DN36 SCP	1.40	0.94 (-0.45)	67.6%	2
S35.48	9356	9487	Previous point to S35.AV14 **(Anomaly S35.Q)**	132	DN36 SCP	1.40	0.95 (-0.44)	68.1%	2
S35.49	9487	9727	As per chainage	240	DN36 SCP	1.40	0.99 (-0.41)	70.9%	3
S35.50	9727	9893	Previous point to S35.OT8 **(Anomaly S35.R)**	166	DN36 SCP	1.40	0.99 (-0.40)	71.1%	3
S35.51	9893	9939	S35.OT8 to **Anomaly S35.S**	46	DN36 SCP	1.40	0.96 (-0.43)	69.2%	2
S35.52	9939	10252	As per chainage	312	DN36 SCP	1.40	0.93 (-0.46)	66.9%	2
S35.53	10252	10499	Previous point to **Anomaly S35.T**	247	DN36 SCP	1.40	0.92 (-0.47)	66.2%	2
S35.54	10499	10729	Previous point to **Anomaly S35.U**	230	DN36 SCP	1.40	0.93 (-0.46)	67.0%	2
S35.55	10729	10997	Previous point to **Anomaly S35.V**	268	DN36 SCP	1.40	0.96 (-0.43)	69.1%	2
S35.56	10997	11240	As per chainage	243	DN36 SCP	1.40	0.93 (-0.47)	66.6%	2
S35.57	11240	11517	Previous point to **Anomaly S35.W**	276	DN36 SCP	1.40	0.92 (-0.48)	65.8%	2
S35.58	11517	11853	As per chainage	337	DN36 SCP	1.40	0.96 (-0.43)	69.1%	2
S35.59	11853	12169	Previous point to **Anomaly S35.X**	315	DN36 SCP	1.40	0.96 (-0.44)	68.6%	2
S35.60	12169	12421	As per chainage	252	DN36 SCP	1.40	0.90 (-0.50)	64.5%	2
S35.61	12421	12632	Previous point to **Anomaly S35.Y**	211	DN36 SCP	1.40	0.88 (-0.51)	63.2%	2
S35.62	12632	12898	As per chainage	266	DN36 SCP	1.40	0.94 (-0.46)	67.3%	2
S35.63	12898	13019	Previous point to **Anomaly S35.Z**	122	DN36 SCP	1.40	0.93 (-0.46)	66.9%	2
S35.64	13019	13397	Previous point to S35.PC1 **(Anomaly S35.AA)**	378	DN36 SCP	1.40	0.92 (-0.48)	65.9%	2
S35.65	13397	13618	S35.PC1 to **Anomaly S35.AB**	221	DN33 SCP	1.38	0.89 (-0.48)	64.7%	2

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.2 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.66	13618	13851	As per chainage	233	DN33 SCP	1.38	0.90 (-0.48)	65.2%	2
S35.67	13851	14146	As per chainage	295	DN33 SCP	1.38	0.89 (-0.48)	65.1%	2
S35.68	14146	14415	As per chainage	269	DN33 SCP	1.38	0.90 (-0.48)	65.1%	2
S35.69	14415	14722	Previous point to S35.OT10 **(Anomaly S35.AC)**	307	DN33 SCP	1.38	0.89 (-0.48)	64.8%	2
S35.70	14722	14776	S35.OT10 to S35.OT11 **(Anomaly S35.AD)**	54	DN33 SCP	1.38	0.94 (-0.44)	68.1%	2
S35.71	14776	15064	As per chainage	289	DN33 SCP	1.38	0.95 (-0.42)	69.2%	2
S35.72	15064	15301	As per chainage	236	DN33 SCP	1.38	0.96 (-0.42)	69.6%	2
S35.73	15301	15501	As per chainage	200	DN33 SCP	1.38	0.95 (-0.43)	69.0%	2
S35.74	15501	15738	As per chainage	237	DN33 SCP	1.38	0.95 (-0.42)	69.2%	2
S35.75	15738	15909	Previous point to **Anomaly S35.AE**	171	DN33 SCP	1.38	0.96 (-0.41)	69.8%	2
S35.76	15909	16191	As per chainage	282	DN33 SCP	1.38	0.93 (-0.44)	67.9%	2
S35.77	16191	16441	Previous point to S35.IV2 **(Anomaly S35.AF)**	249	DN33 SCP	1.38	0.93 (-0.44)	67.7%	2
S35.78	16441	16443	S35.IV2 to S35.TP3 **(Anomaly S35.AG)**	3	DN33 SCP	1.38	0.99 (-0.38)	72.2%	3
S35.79	16443	16647	As per chainage	203	DN33 SCP	1.38	0.99 (-0.39)	71.8%	3
S35.80	16647	16916	As per chainage	269	DN33 SCP	1.38	0.99 (-0.39)	71.8%	3
S35.81	16916	17103	Previous point to **Anomaly S35.AH**	188	DN33 SCP	1.38	0.99 (-0.38)	72.1%	3
S35.82	17103	17224	Previous point to **Anomaly S35.AI**	121	DN33 SCP	1.38	0.98 (-0.39)	71.5%	3
S35.83	17224	17532	As per chainage	308	DN33 SCP	1.38	0.95 (-0.43)	68.8%	2
S35.84	17532	17804	As per chainage	272	DN33 SCP	1.38	0.95 (-0.43)	69.1%	2
S35.85	17804	17981	As per chainage	177	DN33 SCP	1.38	0.94 (-0.43)	68.4%	2
S35.86	17981	18145	As per chainage	164	DN33 SCP	1.38	0.94 (-0.44)	68.3%	2
S35.87	18145	18350	Previous point to S35.CE6.1 **(Anomaly S35.AJ (Start))**	205	DN33 SCP	1.38	0.95 (-0.43)	68.9%	2
S35.88	18350	18598	**Anomaly S35.AJ**	248	DN33 SCP	1.38	1.26 (-0.11)	91.8%	5
S35.89	18598	18896	S35.CE6.2 to S35.OT12 **(Anomaly S35.AK)**	298	DN33 SCP	1.38	0.99 (-0.39)	71.9%	3
S35.90	18896	19225	S35.OT12 to **Anomaly S35.AL**	329	DN33 SCP	1.38	1.09 (-0.28)	79.6%	3
S35.91	19225	19491	Previous point to **Anomaly S35.AM**	266	DN33 SCP	1.38	1.14 (-0.24)	82.8%	4
S35.92	19491	19810	Previous point to **Anomaly S35.AN**	318	DN33 SCP	1.38	1.17 (-0.21)	84.8%	4
S35.93	19810	20049	As per chainage	240	DN33 SCP	1.38	1.05 (-0.33)	76.3%	3
S35.94	20049	20209	Previous point to **Anomaly S35.AO**	160	DN33 SCP	1.38	1.04 (-0.33)	76.0%	3
S35.95	20209	20508	As per chainage	298	DN33 SCP	1.38	1.11 (-0.26)	80.9%	4
S35.96	20508	20760	As per chainage	253	DN33 SCP	1.38	1.10 (-0.28)	79.9%	3
S35.97	20760	20899	Previous point to **Anomaly S35.AP**	139	DN33 SCP	1.38	1.11 (-0.26)	80.8%	4
S35.98	20899	21171	Previous point to **Anomaly S35.AQ**	272	DN33 SCP	1.38	1.06 (-0.31)	77.4%	3
S35.99	21171	21381	Previous point to **Anomaly S35.AR (Start)**	209	DN33 SCP	1.38	1.17 (-0.20)	85.3%	4
S35.100	21381	21419	**Anomaly S35.AR**	39	DN33 SCP	1.38	1.00 (-0.37)	73.0%	3
S35.101	21419	21577	As per chainage	157	DN33 SCP	1.38	1.08 (-0.29)	78.6%	3
S35.102	21577	21776	As per chainage	200	DN33 SCP	1.38	1.09 (-0.29)	79.1%	3
S35.103	21776	22085	Previous point to S35.OT14 **(Anomaly S35.AS)**	308	DN33 SCP	1.38	1.08 (-0.29)	78.8%	3
S35.104	22085	22321	S35.OT14 to S35.AV26	236	DN33 SCP	1.38	1.17 (-0.21)	84.8%	4
S35.105	22321	22691	As per chainage	370	DN33 SCP	1.38	0.86 (-0.51)	62.6%	2
S35.106	22691	23009	Previous point to S35.OT16 **(Anomaly S35.AT)**	318	DN33 SCP	1.38	0.87 (-0.50)	63.3%	2
S35.107	23009	23301	As per chainage	292	DN33 SCP	1.38	0.88 (-0.49)	64.0%	2

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.2 Continued

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35.108	23301	23574	As per chainage	273	DN33 SCP	1.38	0.88 (-0.50)	63.7%	2
S35.109	23574	23823	As per chainage	249	DN33 SCP	1.38	0.88 (-0.50)	63.7%	2
S35.110	23823	24109	Previous point to **Anomaly S35.AU**	286	DN33 SCP	1.38	0.88 (-0.50)	63.7%	2
S35.111	24109	24433	As per chainage	324	DN33 SCP	1.38	0.86 (-0.52)	62.3%	2
S35.112	24433	24753	Previous point to S35.OT17 **(Anomaly S35.AV)**	320	DN33 SCP	1.38	0.85 (-0.52)	61.9%	2
S35.113	24753	25038	As per chainage	285	DN33 SCP	1.38	0.86 (-0.51)	62.6%	2
S35.114	25038	25346	As per chainage	308	DN33 SCP	1.38	0.87 (-0.50)	63.4%	2
S35.115	25346	25485	Previous point to S35.PC2 **(Anomaly S35.AW)**	138	DN33 SCP	1.38	0.87 (-0.51)	63.2%	2
S35.116	25485	25750	As per chainage	265	DN27 SCP	1.34	0.89 (-0.46)	66.1%	2
S35.117	25750	25881	Previous point to S35.OT19 **(Anomaly S35.AX)**	131	DN27 SCP	1.34	0.88 (-0.46)	65.8%	2
S35.118	25881	26238	As per chainage	357	DN27 SCP	1.34	0.98 (-0.37)	72.7%	3
S35.119	26238	26561	Previous point to S35.OT21 **(Anomaly S35.AY)**	322	DN27 SCP	1.34	0.99 (-0.36)	73.5%	3
S35.120	26561	26679	S35.OT21 to S35.PC3 **(Anomaly S35.AZ)**	119	DN27 SCP	1.34	1.02 (-0.32)	76.1%	3
S35.121	26679	26689	S35.PC3 to S35.OT22 **(Anomaly S35.BA)**	10	DN30 SCP	1.36	1.29 (-0.07)	94.6%	5
S35.122	26689	26964	As per chainage	275	DN30 SCP	1.36	1.34 (-0.02)	98.8%	5
S35.123	26964	27154	Previous point to S35.IV5 **(Anomaly S35.BB)**	190	DN30 SCP	1.36	1.33 (-0.03)	98.1%	5
S35.124	27154	27164	S35.IV5 to S35.OT23	10	DN30 SCP	1.36	1.27 (-0.09)	93.3%	5
S35.125	27164	27208	S35.OT23 to S35.CE9.1 **(Anomaly S35.BC (Start))**	44	DN30 SCP	1.36	1.31 (-0.04)	96.7%	5
S35.126	27208	27553	**Anomaly S35.BC**	345	DN30 SCP	1.36	1.34 (-0.02)	98.4%	5
S35.127	27553	27885	S35.CE9.2 to S35.OT25 **(Anomaly S35.BD)**	332	DN30 SCP	1.36	1.30 (-0.06)	95.5%	5
S35.128	27885	28138	As per chainage	253	DN30 SCP	1.36	1.32 (-0.04)	97.4%	5
S35.129	28138	28377	As per chainage	239	DN30 SCP	1.36	1.32 (-0.04)	97.0%	5
S35.130	28377	28603	As per chainage	226	DN30 SCP	1.36	1.33 (-0.03)	97.8%	5
S35.131	28603	28748	As per chainage	145	DN30 SCP	1.36	1.32 (-0.04)	97.3%	5
S35.132	28748	28965	Previous point to S35.OT27 **(Anomaly S35.BE)**	217	DN30 SCP	1.36	1.32 (-0.04)	97.3%	5
S35.133	28965	29020	S35.OT27 to S35.OT28 **(Anomaly S35.BF)**	55	DN30 SCP	1.36	1.30 (-0.05)	96.0%	5

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

Table F.3: SCP pipe wall deterioration results for OC9 and OC35 Water Pipelines, section OC35A
Assuming nominal theoretical values as original wall thickness (specified in the ANSI/AWWA C200)

Section Identifier	Approx. Chainage (ft)		Sub-section Location on Pipeline	Approx. Length	Assumed Pipe Material	Theoretical Wall Thickness	Remaining Effective Wall Thickness[1] (Difference between remaining wall from the nominal theoretical value) (in)		Condition Score
	Start	End		(ft)		(in)	Wall	%Remain	
S35A.1	0	25	S35A.Start to S35A.IV1 **(Anomaly S35A.A)**	25	DN27 SCP	1.34	Closed inline valve		
S35A.2	25	247	As per chainage	223	DN27 SCP	1.34	0.96 (-0.38)	71.7%	3
S35A.3	247	539	As per chainage	292	DN27 SCP	1.34	0.97 (-0.38)	71.8%	3
S35A.4	539	817	Previous point to **Anomaly S35A.B (Start)**	278	DN27 SCP	1.34	0.97 (-0.37)	72.1%	3
S35A.5	817	869	**Anomaly S35b.C**	52	DN27 SCP	1.34	1.06 (-0.29)	78.7%	3
S35A.6	869	1187	As per chainage	318	DN27 SCP	1.34	1.00 (-0.35)	74.3%	3
S35A.7	1187	1470	Previous point to **Anomaly S35A.C**	283	DN27 SCP	1.34	1.01 (-0.34)	74.9%	3
S35A.8	1470	1713	As per chainage	243	DN27 SCP	1.34	0.99 (-0.35)	73.6%	3
S35A.9	1713	1935	As per chainage	223	DN27 SCP	1.34	0.98 (-0.36)	73.0%	3
S35A.10	1935	2160	Previous point to S35A.IV2 **(Anomaly S35A.D)**	224	DN27 SCP	1.34	0.98 (-0.36)	73.2%	3
S35A.11	2160	2163	S35A.IV2 to S35A.OT1 **(Anomaly S35A.E)**	4	DN27 SCP	1.34	1.05 (-0.30)	77.9%	3
S35A.12	2163	2171	S35A.OT1 to S35A.OT2	8	DN27 SCP	1.34	0.97 (-0.37)	72.4%	3
S35A.13	2171	2539	As per chainage	367	DN27 SCP	1.34	1.01 (-0.33)	75.4%	3
S35A.14	2539	2865	Previous point to S35A.PC2 **(Anomaly S35A.F)**	326	DN27 SCP	1.34	1.03 (-0.31)	76.7%	3
S35A.15	2865	2977	S35A.PC2 to S35A.OT4 **(Anomaly S35A.G)**	112	DN33 SCP	1.38	1.00 (-0.38)	72.7%	3
S35A.16	2977	3082	S35A.OT4 to S35A.PC3 **(Anomaly S35A.H)**	105	DN33 SCP	1.38	0.97 (-0.41)	70.5%	3
S35A.17	3082	3102	S35A.PC3 to S35A.End	20	DN27 SCP	1.34	1.02 (-0.33)	75.6%	3

[1] The values given are usually represent pipe conditions with either only external corrosion or only internal corrosion. For SCP pipelines the two conditions are equivalent.

APPENDIX C: ENGINEER’S OPINION OF PROBABLE CONSTRUCTION COST FOR DESTRUCTIVE TESTING

City Of Huntington Beach OC-9 & OC-35 Pipeline Replacement Engineer's Opinion of Probable Construction Cost For Destructive Testing December 2025					
Item	**Description**	**Qty.**	**Unit**	**Unit Price $**	**Total Price**
1	Mobilization, Permits, Bonds, Cleanup, & Demobilization	1	LS	-	$25,400
2	Prepare and Implement SWPPP and BMPs	1	LS	-	$2,000
3	Implement Traffic Control and Safety Measures	1	LS	-	$10,000
4	Provide Preconstruction Audio and Video	1	LS	-	$5,000
5	Potholing and Utility Verification	1	LS	-	$10,000
6	Perform Asphalt Concrete Trench Repair	11	CY	$1,500	$16,500
7	Replace In Place 26" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 30" Dia CML&C WSP	170	LF	$575	$97,800
8	Replace In Place 28" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 30" Dia CML&C WSP	65	LF	$580	$37,700
9	Replace In Place 36" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 36" Dia CML&C WSP	490	LF	$625	$306,300
10	Perform Destructive Testing of Pipeline Sections in red per Fig 4-1 on Condition Assessment Report	725	LF	$10	$7,300
11	Replace In Place 2" Air-Vac	1	EA	$2,000	$2,000
12	Unanticipated obstructions	5	EA	500	$2,500
13	Permit Allowance	1	LS	-	$10,000
				Subtotal	$507,100
				Contingency (10%):	$50,710
				Overhead (15%)	$76,065
				TOTAL[1]:	**$ 634,000**

[1] Total is rounded to the nearest thousand.
[2] This opinion of construction cost represents Ardurra's judgment as a design-professional and is supplied for the general guidance of District. Since Ardurra has no control over the cost of labor and material, or over competitive bidding or market conditions, Ardurra does not guarantee the accuracy of such opinions as compared to contractor bids or actual cost to District. This estimate is a planning level estimate and does not include items designated such as construction management, inspection, soft costs, or unforeseen contingencies.

APPENDIX D: ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST – FULL REPLACEMENT

City Of Huntington Beach
OC-9 & OC-35 Pipeline Replacement
Engineer's Opinion of Probable Construction Cost [2]
December 2025

Item	Description	Qty.	Unit	Unit Price $	Total Price
1	Mobilization, Permits, Bonds, Cleanup, & Demobilization	1	LS	-	$ 135,720
2	Prepare and Implement SWPPP and BMPs	1	LS	-	$200,000
3	Implement Traffic Control and Safety Measures	1	LS	-	$500,000
4	Provide Preconstruction Audio and Video	1	LS	-	$40,000
5	Potholing and Utility Verification	1	LS	-	$120,000
6	Perform Asphalt Concrete Trench Repair	2,489	CY	$1,500	$3,733,577
7	Replace In Place 24" PVC CL200 (SDR21)	947	LF	$550	$677,105
8	Replace In Place 24" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 24" Dia CML&C STL Pipe	10,218	LF	$560	$7,438,704
9	Replace In Place 26" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 30" Dia CML&C WSP	8,804	LF	$575	$6,580,990
10	Replace In Place 28" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 30" Dia CML&C WSP	7,897	LF	$580	$5,954,338
11	Replace In Place 27" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 30" Dia CML&C WSP	3,903	LF	$580	$2,942,862
12	Replace In Place 30" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 30" Dia CML&C WSP	2,277	LF	$600	$1,776,060
13	Replace In Place 33" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 36" Dia CML&C WSP	12,524	LF	$610	$9,931,532
14	Replace In Place 36" Dia Bar-Wrapped Steel Cylinder Concrete Pressure Pipe (BWP) W/ 36" Dia CML&C WSP	13,357	LF	$625	$10,852,563
15	Replace In Place 1" Air-Vac	1	EA	$4,000	$5,200
16	Replace In Place 2" Air-Vac	14	EA	$5,000	$91,000
17	Replace In Place 2.5" Air-Vac	4	EA	$5,500	$22,000
18	Replace In Place 3" Air-Vac	1	EA	$6,000	$6,000
19	Replace In Place 4" Air-Vac	9	EA	$7,000	$63,000
20	Replace In Place 24" Gate Valve	16	EA	45,000	$720,000
21	Install In Place 30" Gate Valve	35	EA	60,000	$2,100,000
22	Install In Place 36" Gate Valve	23	EA	70,000	$1,610,000
23	Replace In Place Blow Off Riser	1	EA	1,500	$1,500
24	Replace In Place Pump Out Riser	7	EA	1,500	$10,500
25	Replace In Place Sample Station	22	EA	1,500	$33,000
26	Replace In place Pressure Relief Valve	4	EA	25,000	$100,000
27	Replace In Place Cathodic Protection	8	EA	2,500	$20,000
28	Replace In Place Turn Out	9	EA	50,000	$450,000
29	Replace In Place Manhole Access	1	EA	20,000	$20,000
32	Unanticipated obstructions	50	EA	-	$25,000
33	Permit Allowance	1	LS	-	$10,000
				Subtotal	$ 56,170,651
				Contingency (10%):	$5,617,065
				Overhead (15%)	$8,425,598
				TOTAL[1]:	**$ 70,213,000**

[1] Total is rounded to the nearest thousand.
[2] This opinion of construction cost represents Ardurra's judgment as a design-professional and is supplied for the general guidance of District. Since Ardurra has no control over the cost of labor and material, or over competitive bidding or market conditions, Ardurra does not guarantee the accuracy of such opinions as compared to contractor bids or actual cost to District. This estimate is based on the 60% Design and does not include items designated such as construction management, inspection, soft costs, or unforeseen contingencies.