Highpoint Pipeline Condition Assessment *Vallecitos Water District*
FINAL DRAFT
TECHNICAL MEMORANDUM

Date:	May 4, 2020 May 21, 2020 (Rev 1.0) June 8, 2020 (Rev 2.0) June 23, 2020 (Rev 2.1)
Subject:	**Summary of Condition Assessment Results and Recommendations**
Prepared By:	Robert S. Weber, PE
Reviewed By:	Amy Czajkowski, PE, CCM, QSP/D

PROJECT BACKGROUND

The Vallecitos Water District (District) provides water, wastewater, and recycled water service to the City of San Marcos; the community of Lake San Marcos; parts of Carlsbad, Escondido and Vista and other unincorporated areas in north San Diego County. The Highpoint site located north of the City of Escondido has been under development and had previously constructed 8-inch and 12-inch diameter ductile iron waterlines that were never put in service and have remained non-operational for a period of 13 years. It should be noted that the report (Attachments A, A1) submitted by PICA incorrectly states that the pipelines are owned and operated by the Vallecitos Water District. As part of potential future development plans the District initiated a condition assessment of subject pipelines at the Highpoint site to review their current condition and suitability for acceptance into the District's potable system.

PURPOSE

The purpose of this Technical Memorandum is to summarize work performed and the associated findings and recommendations for the inspected pipelines.

INVESTIGATORY APPROACH

The subject pipelines were inspected by Pipeline Inspection & Condition Analysis Corporation (PICA). PICA is a North American leader in pipeline condition assessment and focuses exclusively on the municipal water and wastewater market. The inspection process uses Remote Field Testing (RFT) technology to inspect the pipelines from the inside to get a true representation of the remaining thickness of the pipe wall, or remaining wall (RW). Ductile Iron Pipe (DIP) has historically been used for water and wastewater service, however it has been known to experience soil side corrosion from corrosive soils or internal corrosion due to failed linings and in the case of wastewater service, exposure to hydrogen sulfide gas where pipes are not flowing full. DIP for municipal applications is customarily cement lined (interior lining) and externally wrapped with polyethylene sheeting. The measurement of remaining wall is intended to provide quantitative assessment of the condition of the pipe and in this case its suitability for potential future use in the District's system.

In the case of the Highpoint project, we understand the subject pipelines were constructed in approximately 2007 and pressure tested, however were not connected to the District's system. The pipes were reportedly constructed with an exterior protective wrap of polyethylene which is common when DIP is installed in corrosive soils. The concern with the subject pipelines was twofold: first the potential for exterior soil side corrosion due to failed exterior protective polyethylene wrap and internal corrosion where linings may have failed and the line was subsequently exposed to air. DIP in the size range installed at the Highpoint project is manufactured pursuant to AWWA C150/151 and has historically only been available in pressure class 350 (350 pound per square inch working pressure).

The scope of the investigatory program was developed by the IEC and PICA with input from District staff and the Developer. The intent of the investigation was twofold: to investigate the external condition of the pipeline at select locations to visually assess the integrity of the polyethylene wrap and internally inspect the pipeline along representative lengths to internally assess the pipe wall thickness. The external locations were selected based on areas that met criteria in IEC's experience have historically been prone to damage to the polyethylene wrap. These occur most often at locations where other utilities cross the waterline, in particular dry utility "packages" that are housed in a concrete encasement. These dry utility packages customarily cross on top of the waterline and at times it has been observed that the concrete encasement installation can result in nicks or tears in the polyethylene sheeting which allows moisture to come in contact with the exterior of the DIP and potentially cause corrosion. The internal pipe reaches were selected based on accessibility and the desire to assess high points in the line where air could collect and potentially cause corrosion if the lining were damaged. The internal pipe inspection was performed by excavating and exposing then removing a section of pipe then inserting the PICA inspection tool and winching it through to the other end. This method has the added benefit of allowing the inspection team to also observe the condition of the polyethylene wrap and exterior of the pipe. Following the inspection, the sections of removed pipe were repaired with PVC pipe and repair couplings.

The existing 12-inch DIP line in Woodland Heights Glen (WHG) was potholed in two locations where dry utilities cross to assess the potential for damage to the polyethylene encasement. Internal inspection was performed by PICA at the following locations:

1. The 8-inch diameter line in Kensington Glen (KG) was inspected from the Kensington Glen/Hampton Glen intersection to the southeast end of Kensington Glen – approximately 706 linear feet.

2. The 12-inch diameter line in Woodland Heights Glen was inspected from the Woodland Heights Glen/Hampton Intersection to the Palos Vista Reservoir – approximately 2,059 linear feet.

INVESTIGATION RESULTS

Potholing of the existing 12-inch DIP line in Woodland Heights Glen and the associated visual observations by District staff and the consultant team did not reveal damage to the polyethylene wrap surrounding the pipeline at these two locations.

Analysis of the remote field technology data obtained from the two segments of pipe inspected by PICA indicate the following:

1. The 8-inch diameter line in Kensington Glen was found to have three (3) pitting indications.

2. The 12-inch diameter line in Woodland Heights Glen was found to have thirty-four (34) pitting indications.

A summary table is provided herein as Table 1 and the results graphically depicted on Figures 1 and 2. A full description of the internal inspection is provided in the PICA report provided as Attachment A and Technology Addendum provided as Attachment A1.

Table 1 - Summary of Remote Field Technology findings

	8"Kensington Glen	12" Woodland Heights Glen
Inspected length:	**706.46ft**	**2058.98ft**
Total number of pipe sections (including features):	**56**	**129**
Total number of analyzed pipe sections:	**52**	**123**
Total number of pipes without localized wall loss indications:	**50**	**89**
Total number of pipes with localized wall loss indications:	**2**	**34**
Total number of wall loss indications reported:	**3**	**49**
Number of defects measuring >60% RW:	**3**	**18**
• Number of defects measuring 41 - 60% RW:	0	12
• Number of defects measuring 21 - 40% RW:	0	14
• Number of defects measuring ≤20% RW:	0	5
Total number of possible through-holes (≤5% RW):	**0**	**2**
Total number of construction features:	6	25
• Number of hydrant tees:	2	5 *includes 4 hot-tapped tees.
• Number of service connections:	4	10
• Number of 2" air release valves:	0	3
• Number of in-line valves:	0	1
• Number of 2" blow-offs:	0	3
• Number of unknown features:	0	3 *includes 2 suspected hydrant tees and 1 service connection.

Notes:
1. RW – remaining wall thickness
2. RFT – remote field technology

ANALYSIS

The investigatory program's primary findings are the remaining wall thickness of the pipe. Assessment of the acceptable remaining wall for the subject pipelines should consider industry standards as well as District standards. Industry standards are relevant in assessment of the pipe's functionality under conditions such as internal pressure and trench and live loading. District standards are relevant in consideration of the minimum requirements for acceptance into the District's water system if this were a new project. We have assessed the findings against both standards.

Industry Standards

IEC calculated required wall thickness for the DIP based on AWWA Standard C150-14 Thickness Design of Ductile Iron Pipe. We performed these calculations for working pressures of 150, 175, 200, and 225 psi internal pressure. This pressure range was selected for comparison with a range of pressures that a new system constructed pursuant to District standards would be designed under. Subsequent trench load and deflection checks were also made.

		Internal Pressure Check	Trench Load Check	Deflection Check
Working Pressure (psi)	Min Allowable Wall, %	Min Allowable Wall, %	Min Allowable Wall, %	Min Allowable Wall, %
150	**60**	56.6	54.5	52.1
175	**60**	59.4	54.5	52.1
200	**70**	62.2	54.5	52.1
225	**70**	65.1	54.5	52.1

Calculations are provided as Attachment B.

District Standards

District Water System Standard Specification Section 500 sets forth design criteria for water facilities. Type of water main pipe mandated for distribution pipe in the 4 through 12-inch diameter size is AWWA C900 polyvinyl chloride (PVC), DR 14 pipe. Standard Specification Section 15064 provides further details on the allowable pipe materials and performance requirements. AWWA C900 DR 14 pipe has a stated pressure class of 305 psi which has a published long-term capacity safety factor of 2.

Working Pressure Determination

For the purposes of this analysis we selected 200 psi as the benchmark for evaluation of the existing pipe condition with respect to how much remaining wall in the existing DIP should be considered as acceptable. This is based on engineering judgement on a reasonable maximum pressure service that an equivalent new PVC water distribution pipe system mandated by current District design criteria and standard specifications should be expected to provide.

Using a 200 psi working pressure, the minimum allowable remaining wall in the existing DIP would be 70%. Of the 34 pitting locations identified in the 12-inch diameter Woodland Heights Glen pipe, 30 were found to have less than 70% remaining wall. The three pitting locations found in the 8-inch diameter Kensington Glen pipe; one was found to be at 70% of remaining wall; the others greater than 70% remaining wall.

These findings are based on inspection of a portion of pipe at the project site. It is reasonable to expect to see a similar pattern of degraded wall thickness across the remaining uninspected pipe (approximately 9,100 linear feet of pipe). A linear extrapolation suggests there could be 100 to 150 additional pitting indications of similar magnitude across the remaining uninspected pipe.

DISCUSSION OF REMAINING AND CONDITION BASED USEFUL LIFE

Table 2 provides an assessment of remaining and condition based useful life for the existing 12-inch diameter Woodland Heights Glen pipe, where most of the defects were found. An assessment was made for each inspected pipe length. An initial useful life for DIP of 75 years was selected for the evaluation. The pipe was then derated by 13 years for the time it has already spent in the ground to arrive at a remaining useful life. Then a condition based useful life was determined by applying a linear degradation pattern for pipe without pitting indications, pipe with pitting indications of 70% or less remaining wall assigned a zero useful life , and pipe with pitting indications slightly over 70% remaining wall assigned at 10-12% remaining useful life and converted to years. Using this approach an additional 8 sections of pipe would need approach zero useful life within approximately the next 8 years.

Table 2 – Remaining Useful Life
12" Woodland Heights Glen
Ductile Iron Watermain

Pipe Number	Length [ft]	Avg Remaining Wall Thickness	Total Expected Useful Life (years)	Remaining Expected Useful Life (years)	Defect Identification with % Remaining Wall Thickness	Condition-based Remaining Useful Life
0010*	9.29*	95%	75	62		59
0020*	9.29*	98%	75	62	49	0
0030*	9.29*	101%	75	62		63
0040*	9.29*	99%	75	62		61
0050*	9.29*	88%	75	62	58	0
0060*	9.29*	96%	75	62		60
0070*	9.29*	90%	75	62		56
0080*	9.29*	96%	75	62	68	0
0090*	9.29*	98%	75	62	59	0
0100*	9.29*	94%	75	62		58
0110*	9.29*	99%	75	62	79	6

Table 2 – Remaining Useful Life 12" Woodland Heights Glen Ductile Iron Watermain						
Pipe Number	Length [ft]	Avg Remaining Wall Thickness	Total Expected Useful Life (years)	Remaining Expected Useful Life (years)	Defect Identification with % Remaining Wall Thickness	Condition-based Remaining Useful Life
0120	18.75	97%	75	62		60
0130*	18.80*	98%	75	62		61
0140*	18.80*	101%	75	62	59	0
	18.80*	101%	75	62	63	0
	18.80*	101%	75	62	79	6
	18.80*	101%	75	62	80	8
0150*	18.80*	98%	75	62		61
0160*	18.80*	98%	75	62	66	0
0170*	18.80*	95%	75	62		59
0180	18.89	96%	75	62		60
0190	18.58	97%	75	62		60
0200	18.46	99%	75	62		61
0210	18.50	97%	75	62		60
0220	18.45	94%	75	62		58
0230*	18.53*	95%	75	62		59
0240*	18.53*	100%	75	62		62
0250*	18.53*	95%	75	62		59
0260	18.65	95%	75	62		59
0270	18.80	98%	75	62		61
0280	18.36	98%	75	62		61
0290	18.52	102%	75	62		63
0300	18.79	97%	75	62		60
0310	18.21	93%	75	62		58
0320	18.54	106%	75	62		66
0330	18.65	106%	75	62		66
0340	14.47	95%	75	62		59
0350	18.51	97%	75	62		60
0360	17.80	102%	75	62	57	0
	17.80	102%	75	62	80	8
0370	18.59	102%	75	62	80	8
0380	18.39	104%	75	62		64
0390	18.53	104%	75	62		64
0400	18.11	105%	75	62		65
0410	16.92	109%	75	62		68
0420	18.23	111%	75	62		69

Table 2 – Remaining Useful Life 12" Woodland Heights Glen Ductile Iron Watermain						
Pipe Number	Length [ft]	Avg Remaining Wall Thickness	Total Expected Useful Life (years)	Remaining Expected Useful Life (years)	Defect Identification with % Remaining Wall Thickness	Condition-based Remaining Useful Life
0430	18.52	107%	75	62		66
0440	18.64	106%	75	62		66
0450	18.30	109%	75	62	80	8
	18.30	109%	75	62	80	8
	18.30	109%	75	62	80	8
0460	18.09	109%	75	62		68
0470	18.55	107%	75	62	29	0
0480	18.14	99%	75	62		61
0490	17.58	100%	75	62		62
0500	18.04	101%	75	62		63
0510	18.49	102%	75	62		63
0520	18.47	96%	75	62		60
0530	18.66	98%	75	62		61
0540	18.63	97%	75	62		60
0550	18.78	96%	75	62		60
0560	16.55	91%	75	62		56
0570	17.97	95%	75	62		59
0580	17.07	93%	75	62		58
0590	18.62	100%	75	62	27	0
0600	18.05	93%	75	62		58
0610	18.10	105%	75	62		65
0620	18.32	105%	75	62	24	0
	18.32	105%	75	62	45	0
0630	8.01	107%	75	62	66	0
	8.01	107%	75	62	80	8
0640	9.79	95%	75	62	1	0
	9.79	95%	75	62	63	0
0650	17.38	92%	75	62	32	0
0660	18.31	95%	75	62	21	0
	18.31	95%	75	62	25	0
0670	18.57	88%	75	62		55
0680	18.64	85%	75	62	67	0
0690	18.30	105%	75	62	26	0
	18.30	105%	75	62	56	0
0700	18.38	107%	75	62		66

Table 2 – Remaining Useful Life 12” Woodland Heights Glen Ductile Iron Watermain						
Pipe Number	Length [ft]	Avg Remaining Wall Thickness	Total Expected Useful Life (years)	Remaining Expected Useful Life (years)	Defect Identification with % Remaining Wall Thickness	Condition-based Remaining Useful Life
0710	18.41	92%	75	62		57
0720	18.58	93%	75	62		58
0730	18.52	97%	75	62		60
0740	18.62	97%	75	62		60
0750	18.42	92%	75	62	12	0
0760	9.42	90%	75	62		56
0770	9.19	91%	75	62		56
0780	9.28	92%	75	62		57
0790	18.20	103%	75	62		64
0800	18.28	103%	75	62	70	0
0810	18.26	98%	75	62	52	0
	18.26	98%	75	62	59	0
0820	18.54	107%	75	62		66
0830	17.20	102%	75	62		63
0840	18.53	103%	75	62		64
0850	9.25	91%	75	62		56
0860	18.44	107%	75	62		66
0870	18.53	94%	75	62		58
0880	18.15	85%	75	62	28	0
	18.15	85%	75	62	40	0
0890	18.36	85%	75	62	41	0
0900	9.36	88%	75	62		55
0910	18.30	90%	75	62		56
0920	18.72	88%	75	62		55
0930	18.55	85%	75	62		53
0940	18.62	85%	75	62	19	0
0950	18.54	87%	75	62	47	0
0960	18.26	87%	75	62		54
0970	18.56	95%	75	62	32	0
0980	5.08	100%	75	62		62
0990	13.41	100%	75	62		62
1000	18.63	110%	75	62		68
1010	18.14	84%	75	62		52
1020	18.66	83%	75	62	0	0
	18.66	83%	75	62	24	0

Table 2 – Remaining Useful Life 12" Woodland Heights Glen Ductile Iron Watermain						
Pipe Number	Length [ft]	Avg Remaining Wall Thickness	Total Expected Useful Life (years)	Remaining Expected Useful Life (years)	Defect Identification with % Remaining Wall Thickness	Condition-based Remaining Useful Life
1030	18.44	90%	75	62	23	0
1040	18.19	98%	75	62	14	0
1050	18.52	86%	75	62	37	0
	18.52	86%	75	62	59	0
1060	18.74	85%	75	62	44	0
1070	18.69	88%	75	62		55
1080	18.14	87%	75	62		54
1090	18.59	92%	75	62		57
1100	18.69	85%	75	62		53
1110	18.48	106%	75	62		66
1120	18.46	109%	75	62		68
1130	18.46	94%	75	62		58
1140	18.63	96%	75	62		60
1150	18.65	86%	75	62	65	0
1170	18.57	90%	75	62		56
1180	18.09	101%	75	62		63
1190	9.18	94%	75	62		58
1200	18.50	87%	75	62		54
1210	9.23	89%	75	62		55
1220	9.11	90%	75	62		56
1230	18.11	97%	75	62	65	0
1240	1.18	N/A	N/A	N/A	N/A	N/A

CONCLUSIONS AND RECOMMENDATIONS

12-inch Pipe

Based on the inspection findings and subsequent calculations and analysis, there is a substantial pattern of premature failure in the 12-inch Woodland Heights Glen pipe and additional pitting locations can be expected in the uninspected portions of pipe. With an approximate projected total of 200 pitting locations in the 12-inch Woodland Heights Glen pipe spot repairs or surgical replacement of pipe sticks may not be practical in that unintended damage to adjacent pipe may be unavoidable and additional leaks encountered as an unintentional consequence and the entire piping system may be compromised. A more efficient and better long term solution would be to simply remove the entire linear footage of 12-inch ductile iron pipe and replace it in the same alignment with new 12-inch diameter AWWA C-900 PVC pipe and fittings that is procured and installed in accordance with District standards and subject to a rigorous construction inspection process by District staff. Existing services and appurtenances can likely be re-connected to the new pipeline.

8-inch Pipe

The 8-inch ductile iron pipe on Kensington Glen is in considerably better condition and did not exhibit pipe sections with less than 70% remaining wall. Consideration should be given to inspecting the remaining portions of 8-inch pipe at the site to determine its condition.

These solutions would provide the District with a robust and more reliable water system that is able to be properly pressure tested and placed into service to serve the needs of the community well into the future.

ATTACHMENTS:

Figure 1 – 12-inch Woodland Heights Glen Pipeline
Figure 2 – 8-inch Kensington Glen Pipeline
A – PICA Report
A1 – PICA Report Addendum – Technology & Analysis
B – Allowable RW Calculations

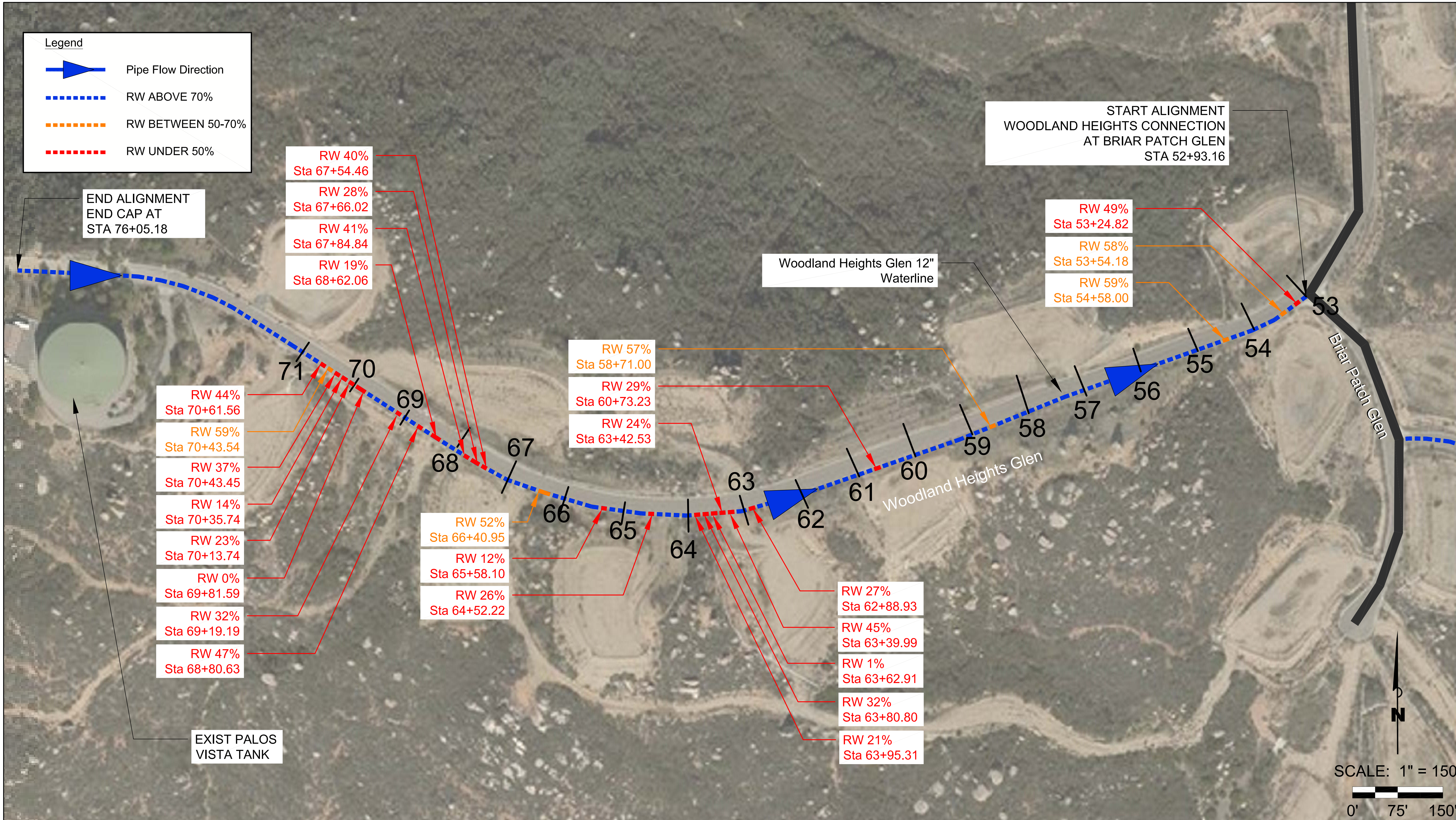

FIGURE 1: WOODLAND HEIGHTS GLEN DEFECT LOCATIONS

VALLECITOS WATER DISTRICT
HIGH POINT WATERLINE CONDITION ASSESSMENT

Infrastructure
ENGINEERING CORPORATION
14271 Danielson Street
Poway, California 92064
T 858.413.2400 F 858.413.2440
www.iecorporation.com

FIGURE 2: KENSINGTON GLEN DEFECT LOCATIONS

VALLECITOS WATER DISTRICT
HIGH POINT WATERLINE CONDITION ASSESSMENT

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IEC – Vallecitos Water District

Condition Assessment Report

PICA – Pipeline Inspection & Condition Analysis Corporation
(A Subsidiary of Russell NDT Holdings Ltd.)

RFT ILI Tool

8" Kensington Glen Ductile Iron Watermain

12" Woodland Heights Glen Ductile Iron Watermain

Mesa Rock, CA

PICA Project: 7095

Inspection Date:	December 4-5, 2019
Report Submission:	February 28, 2020
Operators:	P. Ryhanen, A. Shatat, K. Embry, K. Lingnau, A. Bonenfant
Analyst:	A. Liwoch
Reviewer:	J. Regala, A. Shatat
Report Revision:	1.0

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Table of Contents

Infrastructure Engineering Corporation
Vallecitos Water District
8" Kensington Glen, 12" Woodland Heights Glen Ductile Iron Watermains
Condition Assessment Report

Executive Summary

Between December 4th and 5th, 2019, PICA, under contract with Infrastructure Engineering Corporation, inspected two ductile watermain sections using Remote Field Testing (RFT) technology. The inspected watermains, which are located in Mesa Rock, California, are owned and operated by the Vallecitos Water District (VWD). More specifically, the inspected sections are:

- ***The 8" Kensington Glen (KG) DI Watermain:*** From the Kensington Glen/ Hampton Glen intersection to the southeast end of Kensington Glen.
- ***The 12" Woodland Heights (WHG) DI Watermain:*** From the Woodland Heights Glen/ Hampton intersection to the Palos Vista Reservoir tank.

Access to the watermains was gained through excavated access pits at the above-noted locations. In both lines, the SeeSnake tool successfully inspected the entire distance between access points. A total distance of 706ft was logged along the 8" KG watermain, while 2,059ft was logged along the 12" WHG watermain.

Analysis of the RFT data from both sections identified the following pitting indications:

- ***8" Kensington Glen (KG) DI Watermain:*** A total of three (3) pitting indications were identified in two (2) pipe segments, all measuring 70% remaining wall (RW) or more. The two shallowest indications, both measuring 80% RW and found in Pipe 0410, are reported with lower confidence due to being small volume defects.
- ***12" Woodland Heights (WHG) DI Watermain:*** A total of 49 pitting indications were identified among 34 pipe segments. More specifically, five (5) indications measured less than 21% remaining wall (RW), 14 indications measured between 21% and 40% RW, 12 indications measured between 41% and 60% RW and 18 indications measured 60% RW or shallower. The two deepest defect indications measured as a through-hole (0% RW) and a likely through-hole (1% RW). These defects are found in the following segments:
  - Pipe 0640: 1% RW, 7:00 at 1060.32ft;
  - Pipe 1020: 0% RW, 10:00 at 1695.22ft.

Immediately following the RFT inspection of the 12" Woodland Heights Glen watermain, detailed preliminary analysis results were provided for two areas of interest (AOI):

- AOI #1: 70% deep defect at 1665.6ft at 10:00 – "Large indication – other nearby wall loss"
- AOI #2: 60% deep defect at 1120.0ft at 10:30 – "Wall loss close to a feature, possible collar"

On December 24 and 30, 2019, Cass Arrieta crews potholed and excavated the above locations in order to verify the accuracy of the RFT results. Both AOI's were located precisely where the RFT data identified them axially and circumferentially. The feedback received from both verifications was used to re-calibrate the results during the comprehensive analysis of the RFT data. As a result, the values contained within this report supersede those submitted following the preliminary analysis. In general, the refined defect sizing was found to be 20% to 30% deeper than the preliminary results.

Table 1 provides an overview of the RFT findings for both sections.

Table 1: Feature Indication Summary		
	8" KG	12" WHG
Inspected length:	706.46ft	2058.98ft
Total number of pipe sections (including features):	56	129
Total number of analyzed pipe sections:	52	123
Total number of pipes without localized wall loss indications:	50	89
Total number of pipes with localized wall loss indications:	2	34
Total number of wall loss indications reported:	3	49
• ***Number of defects measuring >60% RW:***	*3*	*18*
• ***Number of defects measuring 41 - 60% RW:***	*0*	*12*
• ***Number of defects measuring 21 - 40% RW:***	*0*	*14*
• ***Number of defects measuring ≤20% RW:***	*0*	*5*
Total number of possible through-holes (≤5% RW):	0	2
Total number of construction features:	6	25
• ***Number of hydrant tees:***	*2*	*5* **Includes 4 hot-tapped tees.*
• ***Number of service connections:***	*4*	*10*
• ***Number of 2" air release valves:***	*0*	*3*
• ***Number of in-line valves:***	*0*	*1*
• ***Number of 2" blow-offs:***	*0*	*3*
• ***Number of unknown features:***	*0*	*3* **Includes 2 suspected hydrant tees and 1 service connection.*

Figures 1a and 1b illustrate the distribution of localized wall loss with respect to remaining wall and circumferential location along the inspected section of the 8” Kensington Glen DI Watermain. Note that there may be some (partially) overlapping data points due to defect proximity.

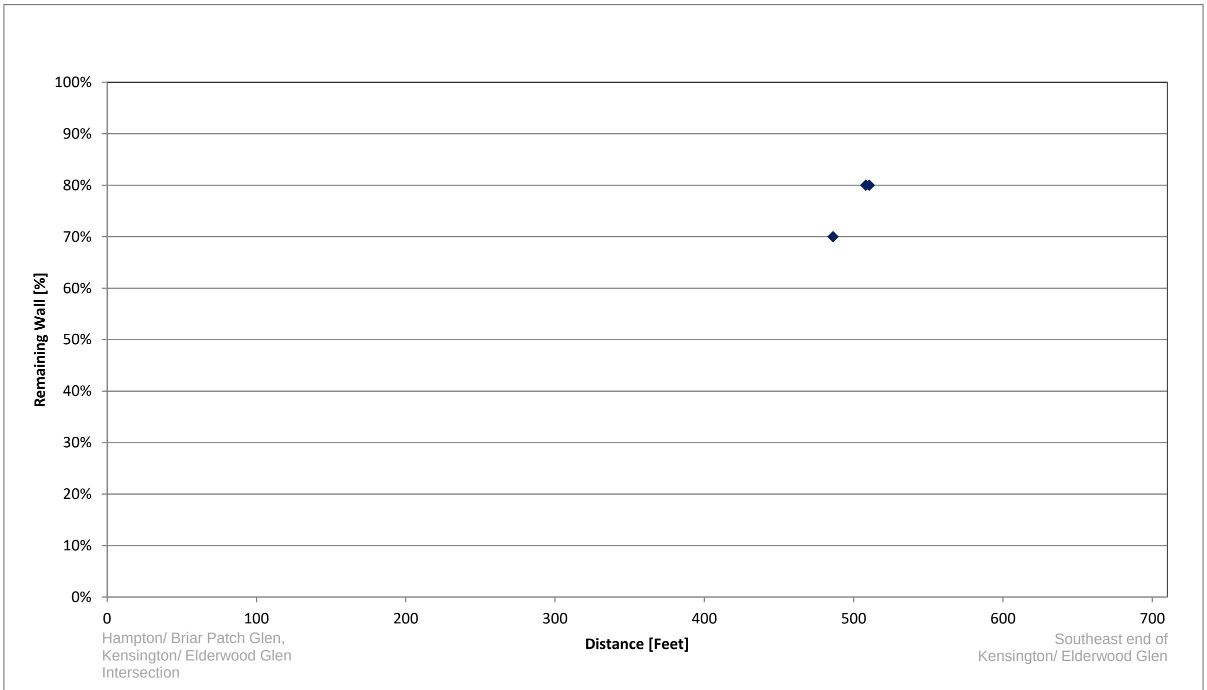


Figure 1a: Distribution of wall loss with respect to remaining wall (%NWT) in pitting regions along the inspected section of the 8” Kensington Glen DI Watermain.

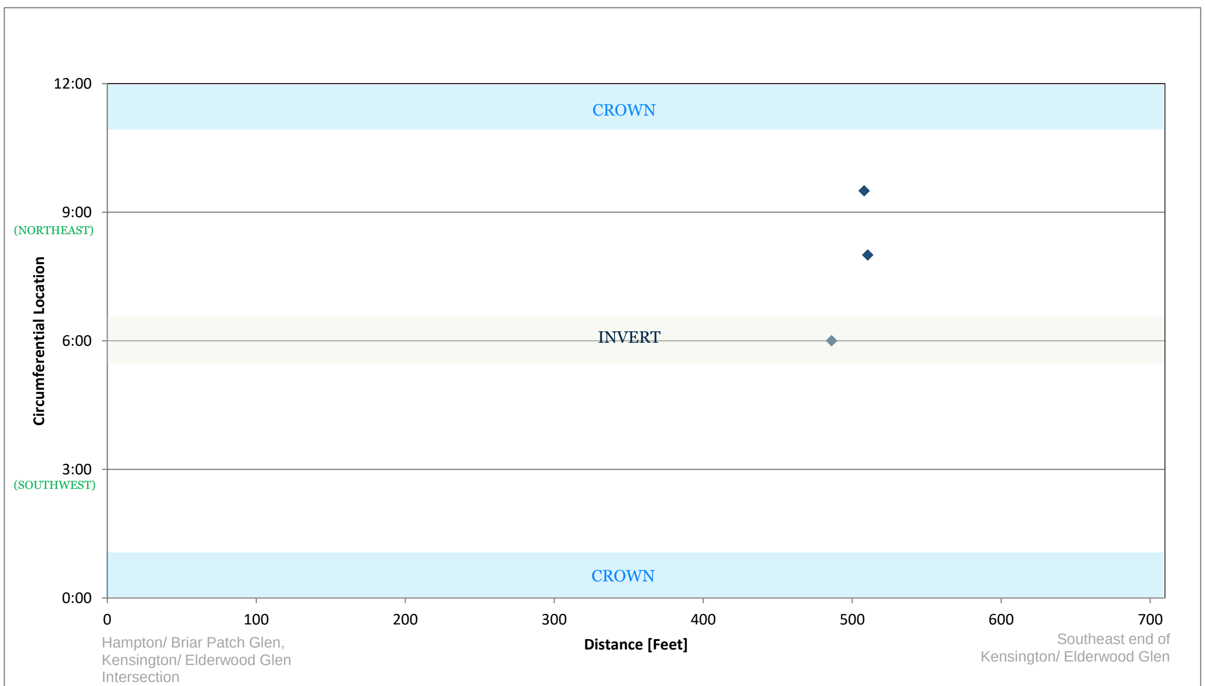


Figure 1b: Circumferential distribution of pitting regions along the inspected section of the 8” Kensington Glen DI Watermain.

Figures 2a and 2b illustrate the distribution of localized wall loss with respect to remaining wall and circumferential location along the inspected section of the 12” Woodland Heights Glen DI Watermain. Note that there may be some (partially) overlapping data points due to defect proximity.

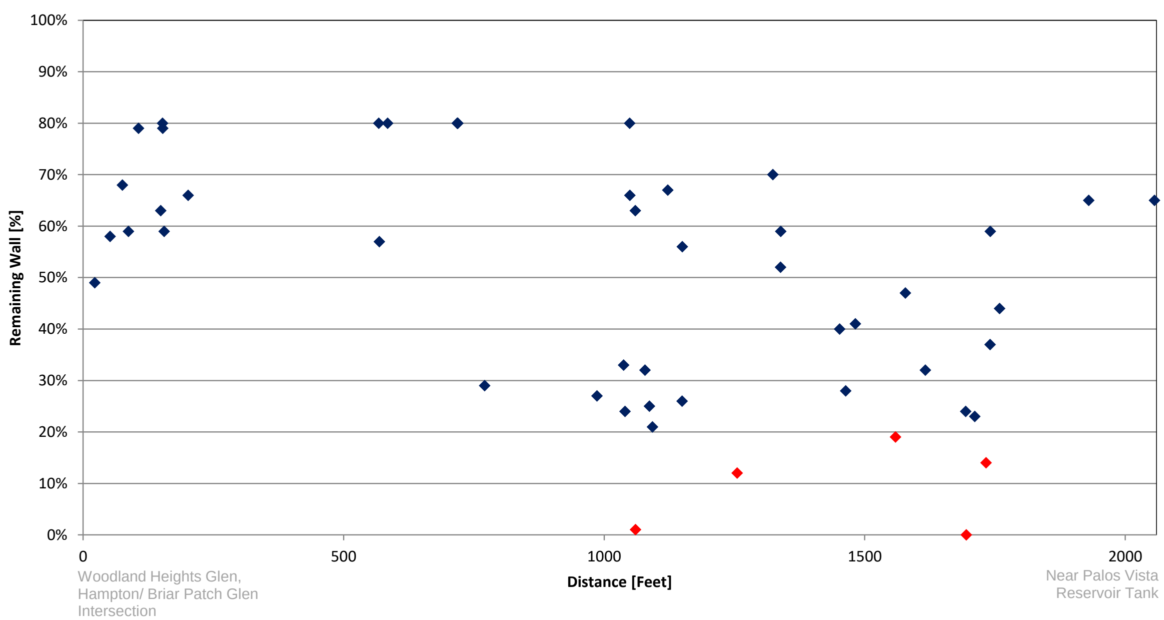


Figure 2a: Distribution of wall loss with respect to remaining wall (%NWT) in pitting regions along the inspected section of the 12” Woodland Heights Glen DI Watermain.

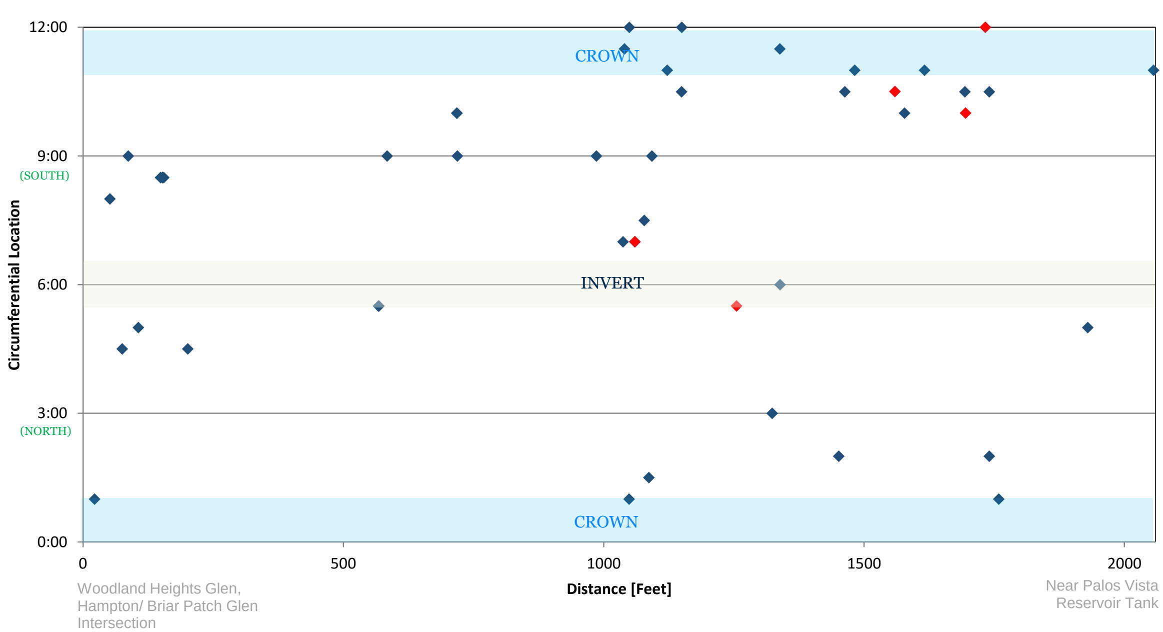


Figure 2b: Circumferential distribution of pitting regions along the inspected section of the 12” Woodland Heights Glen DI Watermain.

Inspection Overview

RFT Tool Information

PICA's SeeSnake RFT tool is an advanced condition assessment tool for the inspection of ferrous pipelines. The SeeSnake tool is designed to find localized areas of wall loss and provide the depth and length of individual wall loss defects. These parameters are critical in predicting the burst pressure of pipes, aiding in the prevention of leaks and catastrophic burst failures. Unlike screening technologies such as leak detection or average wall assessments that require follow-up inspection efforts, the SeeSnake inspection tool provides engineers with high resolution and actionable information that can be used to make rehabilitation and replacement decisions.

Two different sized SeeSnake RFT tools were used during the inspection of the 8" Kensington Glen and 12" Woodland Heights Glen DI watermains. Figure 3 shows both tools prior to the December 2019 inspections.

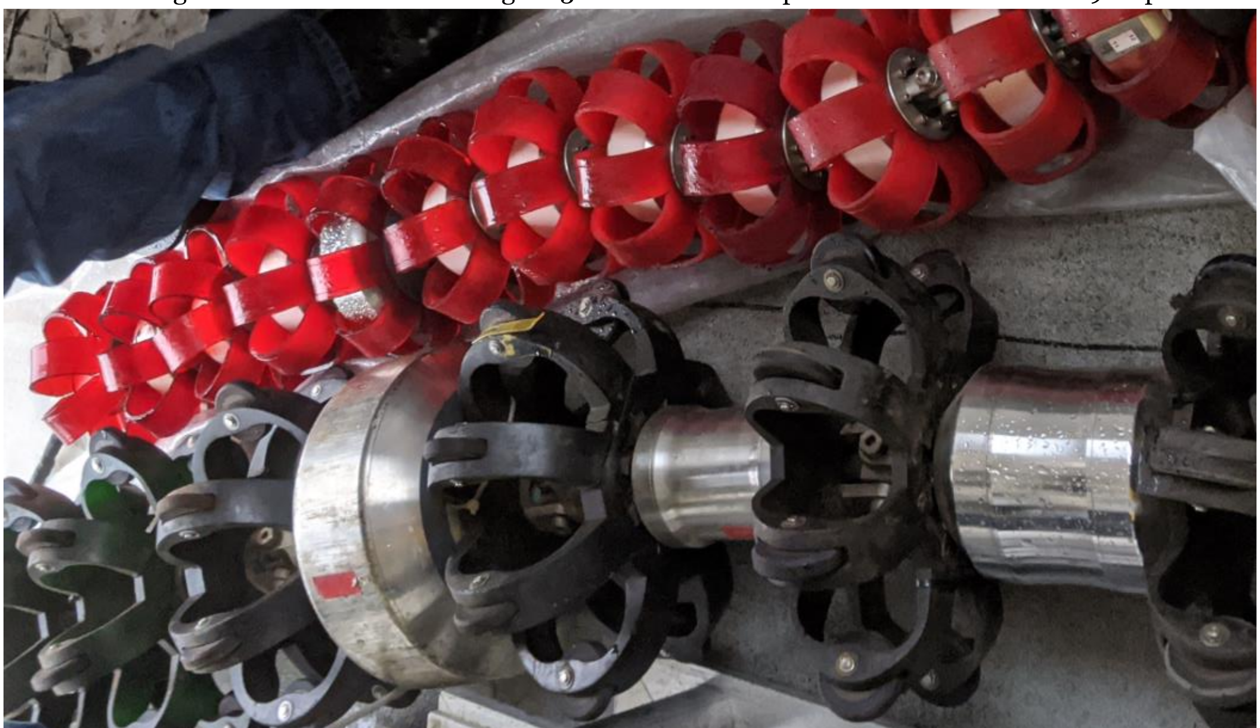


Figure 3: Both 8" SeeSnake (top, with red centralizers) and 12" SeeSnake (bottom, with black centralizers) RFT tools ready to be sanitized with a chlorine solution prior to the inspections.

Calibration

In order to determine the optimal RFT tool settings (for the highest possible defect sensitivity), a test run of the SeeSnake RFT tool is performed using a short section of pipe with the same nominal properties (wall thickness and grade) as the pipe being inspected. Short calibration test runs were performed prior to the RFT inspections of both the 8" Kensington Glen and 12" Woodland Heights Glen lines.

The calibration scans spanned the first 30ft from the respective launch pits of both lines. The results of these scans allowed for the selection of optimal inspection frequency settings, which were determined to be 77Hz for the 8" KG watermain and 42Hz for the 12" WHG watermain.

In addition to the 30ft test scans, verification information supplied shortly after the submission of preliminary results was used to further refine the 12” WHG results. The verification information provided physical pit-depth measurements for two areas of interest (AOIs), which had been identified in the RFT data as having localized wall loss during the preliminary analysis. The confirmed wall loss depths from the verifications were used as “ground truth” references and used to re-calibrate the analysis results of the 12” line contained within this report.

Inspection Details

8” Kensington Glen DI Watermain

On December 4th, PICA technicians arrived on site for inspection of the 8” Kensington Glen DI watermain. Winches were set up at two excavated access pits – the launch pit, located near the intersection of Kensington Glen and Hampton Glen, and the retrieve pit, located at the upper southeast end of Kensington Glen. Using compressed air, a foam pig with trailing winchline was blown from the retrieve pit (cul-de-sac end) to the launch pit (intersection end) thus stringing the watermain. At the launch pit, both winch lines were attached to the leading and trailing ends of the SeeSnake tool and the tool was inserted into the line. Two 30ft-long calibration scans were performed at different frequencies to determine the optimal tool settings for this inspection.

The SeeSnake tool was winched towards the retrieve pit at an average inspection velocity of 14ft/min. Upon arrival at the retrieve pit, the SeeSnake was removed from the line. The data was downloaded on site and confirmed to be of acceptable quality for analysis. Figure 4 shows the excavated access pits used during the inspection of the 8” KG watermain.

Figure 4: 8” KG access pits – Left: launch pit near the Hampton Glen intersection with the 8” SeeSnake visible just before commencing the 706ft run between both access pits; right: retrieve pit at the southeast end of Kensington Glen. as the 8” SeeSnake is being pulled through the line for the RFT inspection.

12" Woodland Heights Glen DI Watermain

On December 5th, PICA technicians arrived on site for inspection of the 12" KG DI watermain. Winches were set up at two excavated access pits: the "*launch pit*" located near the intersection of Woodland Heights Glen and Hampton Glen, and the "*retrieve pit*" located at the west end of Woodland Heights Glen, near the Palos Vista Reservoir tank. Using compressed air, a foam pig with trailing winchline was blown from the retrieve pit to the launch pit. A slight delay was encountered as one of the air release valves was found to be bleeding off air. In consultation with VWD personnel, it was decided that a gauge run was not required given the excellent condition of the tethering pig.

The winch line from the retrieve pit was then attached to the leading end of the SeeSnake tool, while a secondary winchline was attached to the trailing end. Using the two winchlines, a single 30ft-long test run was performed prior to the RFT inspection (the tool was pulled into the main using the leading winchline and pulled out again with the trailing tether).

Once the tool setting was confirmed, the SeeSnake tool was winched towards the retrieve pit at an average inspection velocity of 12ft/min. The tool surged and travelled at slightly higher velocities in the first 200ft of the line before eventually reaching and maintaining an optimal speed.

Upon arrival at the retrieve pit, the SeeSnake was removed from the line. The data was downloaded on site and confirmed to be of acceptable quality for analysis. Figure 5 shows the excavated access pits used during the inspection of 12" WHG watermain.

Figure 5: 12" WHG access pits – Left: *launch pit* near the Hampton Glen intersection with the 12" SeeSnake tool being lowered for insertion into the line; right: *retrieve pit* near the Palos Vista Reservoir tank prior to setting up the winch line.

Table 2: Inspection Overview			
Pipeline Owner:	Vallecitos Water District	**Location:**	Mesa Rock, CA
Line Identifier:	8” Kensington Glen watermain (KG) 12” Woodland Heights Glen watermain (WHG)		
Pipe Diameter and Material:	**8” KG -** Ductile Iron **12” WHG -** Ductile Iron	**Nominal Wall:**	0.250” (8” Class 350) 0.280” (12” Class 350)
Joint Type:	Bell and Spigot connections	**External Coating Type:**	Polyethylene Encasement/ Wrap
Year Installed:	2007	**Repair History:**	Unknown
Inspection Date(s):	**8” KG** - December 4, 2019 **12” WHG** - December 5, 2019	**Inspected Length:**	**8” KG** - 706.46ft **12” WHG** – 2058.98ft
Technicians:	P. Ryhanen, A. Shatat, K. Embry, K. Lingnau, A. Bonenfant		
Launch Access:	**8” KG** - Excavation near the intersection of Hampton Glen (aka Briar Patch Glen) and Kensington Glen (aka Elderwood Glen) **12” WHG** - Excavation near the intersection of Woodland Heights Glen and Hampton (Briar Patch) Glen		
Extraction Access:	**8” KG** - Excavation at the southeast end of Kensington (Elderwood) Glen **12” WHG** - Excavation near the Palos Vista Reservoir Tank (90° elbow removed)		

Operational Overview:

December 4, 2019 (8” Kensington Glen DI Watermain)

- 9:00AM: Ready to launch the tethering pig from the retrieve pit (cul-de-sac end) to the launch pit (intersection end).
- 9:19AM: The wireline tether is through the watermain.
- 10:00AM: Two 30ft-long calibration runs were performed to determine optimal inspection settings.
- 11:30AM: Calibration runs downloaded; optimal inspection frequency of 77Hz determined.
- 11:34AM: RFT tool launched from the launch pit (intersection of Hampton/Briar Patch Glen and Kensington/ Elderwood Glen).
- 12:25pM: RFT tool arrived at the retrieve pit (southeast end of Kensington/ Elderwood Glen).
- 12:36PM: RFT tool was extracted from the line. Data immediately downloaded and confirmed to be of good quality.
- 2:00PM: Site packed up. Crews demobilize.

December 5, 2019 (12” Woodland Heights Glen DI Watermain)

- 9:10AM: Ready to launch the tethering pig from the retrieve pit (Palos Vista reservoir end) to the launch pit (Hampton Glen intersection end).
- 9:45AM: The wireline tether is through the watermain (minor delay caused by one of the air release valves bleeding off air). The tethering foam pig was in great shape with not a single gouge visible on the exterior foam. In consultation with VWD personnel, it was decided that a gauge run was not required given the excellent condition of the tethering pig.
- 11:09AM: Single 30ft-long calibration run was performed, settling on an optimal inspection frequency of 42Hz.
- 12:18PM: RFT tool launched from the launch pit (Hampton Glen intersection).
- 3:18PM: RFT tool arrived at the retrieve pit (Palos Vista reservoir end).
- 3:33PM: RFT tool was extracted from the line. Data immediately downloaded and confirmed to be of good quality.
- 5:00PM: Reservoir site packed up.
- 5:45PM: Hampton Glen site packed up. Crews demobilize.

Table 2: Inspection Overview

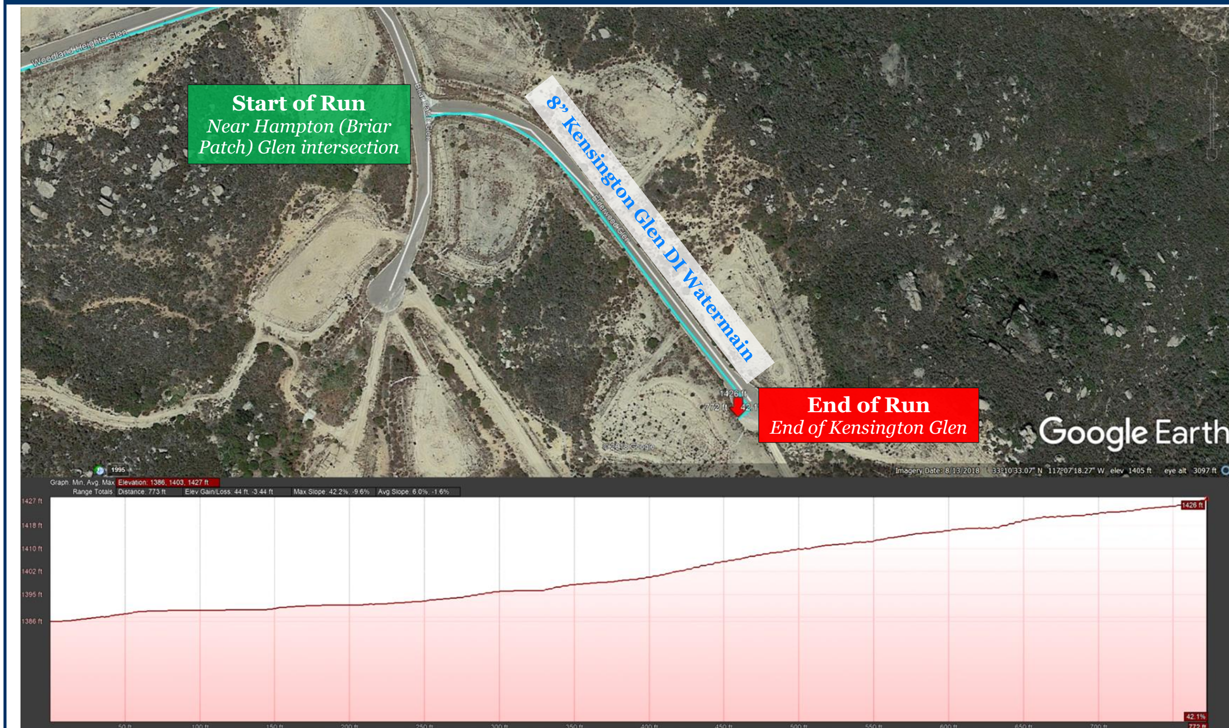


Figure 6a: Overview of the 8" Kensington Glen DI Watermain.

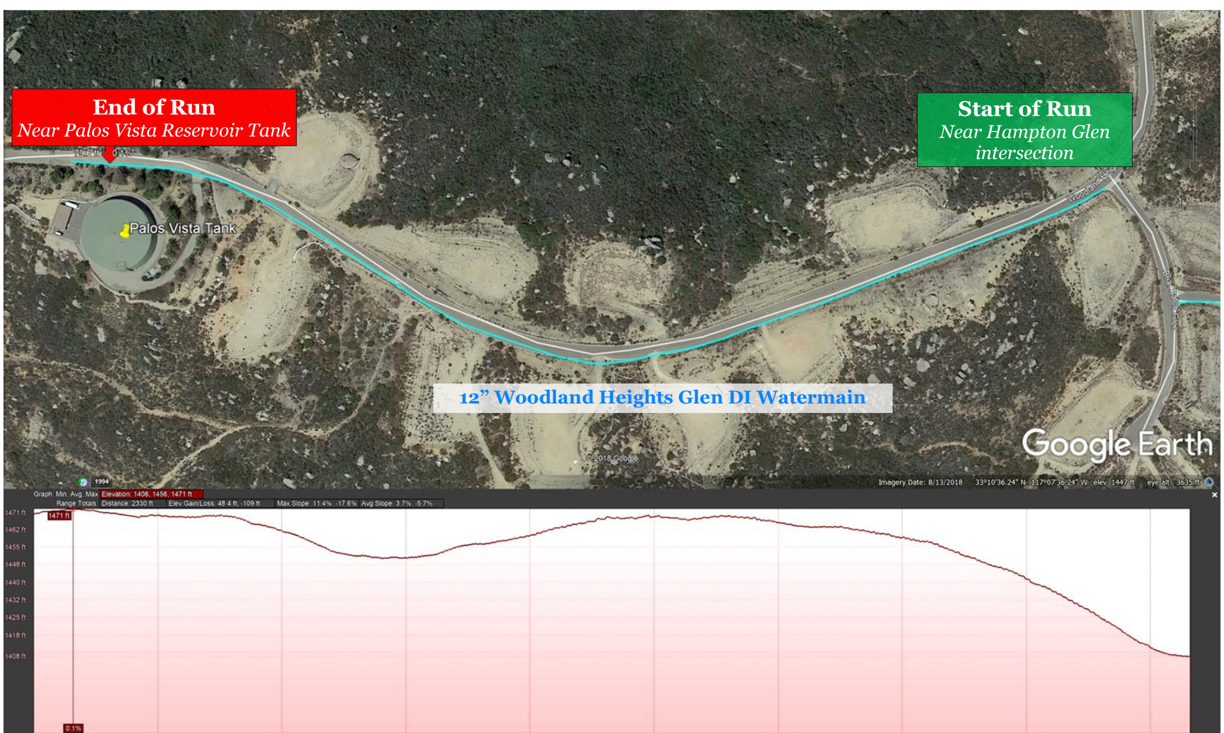


Figure 6b: Overview of the 12" Woodland Heights Glen DI Watermain.

**Note: The above maps provide a general overview of the inspected sections and do not represent exact pipeline locations, features or access points.*

Analysis Results – 8” Kensington (Elderwood) Glen DI Watermain

Location Reporting, Pipe Lengths & Features

The total distance logged during inspection of the 8” Kensington Glen DI Watermain was 706.46ft, with the zero-datum point set at the edge of the pipe cut-out in the excavation near the intersection of Hampton (Briar Patch) Glen and Kensington (Elderwood) Glen. A second excavation, located at the southeast end of Kensington Glen, served as the retrieve pit. The inspected distance represents the full span between both access pits. Note that the data for the first 3.10ft long pipe segment was not analyzed due to its short length and proximity to the open end of the watermain.

Two standard pipe lengths were observed within the inspected section. The first 25 standard pipe segments averaged 9ft in length, and the remaining 24 standard pipes averaged 18ft. A number of shorter pipe segments were identified adjacent to pipeline features and are documented in Table A1 in Appendix A. A total of six (6) pipeline features, listed in Table 3 below, were identified in this section.

Table 3: List of Pipeline Features *8” Kensington (Elderwood) Glen DI Watermain*

Pipe Number	Location (ft) **Measured from the launch pit near Hampton (Briar Patch) Glen*	Feature Type
0080	68.58	Service connection
F	234.22 – 235.46	Hydrant tee
0320	334.09	Service connection
0430	543.20	Service connection
0440	565.28	Service connection
F	644.65 – 645.95	Hydrant tee

General Wall Thickness

All pipe segments longer than 2.5ft were analyzed to obtain the average remaining wall thickness calculated over the length of the pipe. This average remaining wall thickness is referred to as the “PARW” value (Pipe Average Remaining Wall).

Due to manufacturing tolerances, fluctuations of ±15% in the individual PARW values are common. Variations outside the normal ±15% spread can be an indicator of a different nominal wall thickness or pipe type, or point towards a problem like aggregate pitting or general wall loss. The PARW values in this section were found to be within the expected tolerances.

Figure 7a on page 16 plots the measured PARW values in addition to the minimum circumferential ($T_{circmin}$) and maximum circumferential remaining wall ($T_{circmax}$) for each pipe in the inspected section. Note the wall thickness variations within each of the 18ft sticks; a number of those have portions considerably thicker than the 0.25-inch nominal. All values for this figure can be found in Table A1 in Appendix A.

Local Wall Thickness

A total of three (3) pitting indications were identified in two (2) pipe segments, all measuring 70% remaining wall (RW) or more. The two shallowest indications, both measuring 80% RW and found in Pipe 0410, are reported with lower confidence due to being small volume indications. Table A1 in the Appendix details the three worst pitting indications per pipe (Tmin1, Tmin2 and Tmin3) in this section. The same results are shown graphically in Figure 7a on page 16.

Analysis Results – 12" Woodland Heights Glen DI Watermain

Location Reporting, Pipe Lengths & Features

The total distance logged during inspection of the 12" Woodland Heights Glen DI Watermain was 2,059.0ft, with the zero datum point set at the edge of the pipe cut-out in the excavation near the intersection of Woodland Heights Glen and Hampton (Briar Patch) Glen. A second excavation, located at the west end near the Palos Vista Tank, served as the retrieve pit. The inspected distance represents the full span between both access pits. Note that the data for the first 7.70ft was not analyzed due to its short length and the tool's proximity to the pipe opening.

During the launch of the tool, odometer information for three short sections of the 12" watermain was slightly compromised by the tool surging and increased velocities over short distances. The overall impact of these surging events and higher velocities over the fully inspected distance of the line is believed to be minimal as wheeled ground measurements between pipeline features were used to correct for any discrepancies.

For sections where the tool surged, local length adjustments were made by averaging the observed odometer errors across all affected pipes. The affected sections are listed below:

- *Pipes 0030 to 0110*: Tool velocities ranged between 9ft/min and 16ft/min in this section, with localized surging occurring intermittently over a 70ft span. An averaging of the odometer errors was applied to a total of nine (9) pipes, resulting in a length of 9.29ft for all affected pipes.
- *Pipes 0130 to 0170*: Tool velocities ranged between 9ft/min and 14ft/min in this section, with localized surging occurring intermittently over a 58ft span. An averaging of the odometer errors was applied to a total of five (5) pipes, resulting in a length of 18.80ft for all affected pipes.
- *Pipes 0230 to 0250*: While no surging occurred in this section, tool velocity gradually increased up to 13ft/min over a 40ft span. An averaging of the odometer errors was applied to a total of three (3) pipes, resulting in a length of 18.53ft for each affected pipe.

Two standard pipe lengths were observed within the inspected section of the watermain - 9ft and 18ft. The majority of the section is comprised of 18ft segments while a small number of pipes, including the first 109ft from the launch pit near the Hampton (Briar Patch) Glen intersection, were found to consist of the shorter 9ft segments.

Table 4 below provides a complete list of all pipeline features identified in this section. Please note that the ARV in pipe 0640 is 12ft further east in the RFT data than Cas Arrieta's above ground measurements.

Table 4: List of Pipeline Features - *12" Woodland Heights Glen DI Watermain*

Pipe Number	Location (ft) **Measured from the launch pit near Hampton/Briar Patch Glen*	Feature Type
F	26.28 – 27.72	Hydrant tee
0090	87.54	Suspected service connection, 9:00
0280	413.23	Service connection
0330	515.58	Hydrant tee (hot tapped with PVC lateral), 9:00
0340	526.05	2" Air Release valve, 12:00
F	533.38 – 534.53	In-line valve
0350	536.89	2" Blow-off, 7:30
0480	776.66	Service connection
0600	990.84	Hydrant tee (hot tapped with PVC lateral), 3:00
0620	1034.92	2" Air Release valve, 12:00
0620	1036.91	Service connection
F*	1051.18 – 1052.31	Suspected hydrant tee*
0640	1058.53	2" Air Release valve, 12:00
0690	1150.51	Service connection
0750	1256.86	Service connection
0840	1397.75	Service connection
0920	1515.66	Service connection
0930	1541.98	Hydrant tee (hot tapped with PVC lateral), 9:00
0970	1618.80	2" Blow-off, 7:00
F*	1627.87 – 1628.83	Suspected hydrant tee*
0990	1635.76	2" Blow-off, 7:00
1050	1740.38	Service connection
1120	1870.13	Service connection
1160	1949.08	Hydrant tee (hot tapped with PVC lateral), 9:00
1170	1962.53	Service connection

** These tees are suspected to be the original laterals for the hydrants in this area. It is believed that the hydrants were later relocated following the construction of the watermain and that new tees were hot-tapped at different locations. If this assumption is correct, it is likely that these tees are capped/blinded.*

General Wall Thickness

All pipe segments longer than 4ft were analyzed to obtain the average remaining wall thickness calculated over the length of the pipe. This average remaining wall thickness is referred to as the "PARW" value (Pipe Average Remaining Wall).

Due to manufacturing tolerances, fluctuations of ±15% in the individual PARW values are common. Variations outside the normal ±15% spread can be an indicator of a different nominal wall thickness or pipe type, or point towards a problem like aggregate pitting or general wall loss. While PARW values in the inspected section of the watermain were largely within the expected tolerances, a general trend of decreasing PARW values was noted along the line from east to west. More specifically:

- The first 1000ft from the launch at Hampton (Briar Patch) Glen (Pipes 0010 to 0630) measured PARW values within a few percentage points of 100% nominal thickness.
- The following 395ft (Pipes 0640 to 0870) exhibited a slight decrease in PARW across a number of pipes suggesting that this area may be experiencing low-level general corrosion (~5% deep). It is worth noting that three segments within this span, Pipes 0640, 0690 and 0750, are reported to contain a significant localized wall loss indication (1% RW, 26% RW and 12% RW respectively).
- A noticeable PARW decrease of up to 15% was observed in the last 612ft of the line (Pipes 0880 to 01240). While the PARW values in this region remained within the noted manufacturing tolerances, the increased incidence of localized corrosion with a large number of defects measuring deeper than 30% RW indicates that it is probable that a fair number of pipes in this area are experiencing general corrosion.

Figure 7b on page 17 plots the measured PARW values in addition to the minimum circumferential ($T_{circmin}$) and maximum circumferential remaining wall ($T_{circmax}$) for each pipe in the inspected section. All values for this figure can be found in Table A2 in the Appendix section.

Local Wall Thickness

A total of 49 pitting indications were identified among 34 pipe segments. More specifically, five (5) indications measured less than 21% remaining wall (RW), 14 indications measured between 21% and 40% RW, 12 indications measured between 41% and 60% RW and 18 indications measured 60% RW or shallower. Additional details are provided below for all "deep" pitting indications that measured less than 21% RW.

- ***Pipe 0640:*** 1% RW, 7:00 at 1060.32ft – This defect may be a through-hole.
- ***Pipe 0750:*** 12% RW, 5:30 at 1255.51ft
- ***Pipe 0940:*** 19% RW, 10:30 at 1559.47ft
- ***Pipe 1020:*** 0% RW, 10:00 at 1695.22ft – This defect was reported as area of interest (AOI) #1 following the preliminary analysis. This defect was excavated and verified as a through-hole. Additional information regarding the verification is provided in the following section.
- ***Pipe 1040:*** 14% RW, 12:00 at 1733.15ft

Table A2 in the Appendix details the three worst pitting indications per pipe (Tmin1, Tmin2 and Tmin3) in 12" watermain. The same results are shown graphically in Figure 7b on page 17.

It is important to note that the results presented in this report supersede those provided following the preliminary analysis, wherein two AOIs were highlighted for immediate attention. Both reported AOIs were excavated and verified following the RFT inspection, with the results summarized in the following section.

Verification Results

Immediately following the RFT inspection of the 12" Woodland Heights Glen watermain, detailed preliminary analysis results were provided for two areas of interest (AOI):

- ***AOI #1:*** 70% deep defect at 1665.6ft at 10:00 – "Large indication – other nearby wall loss"
- ***AOI #2:*** 60% deep defect at 1120.0ft at 10:30 – "Wall loss close to a feature, possible collar"

On December 24, 2019, Cass Arrieta crews potholed and excavated the above locations in order to verify the accuracy of the RFT results. Both AOI's were located precisely where the RFT data identified them axially and circumferentially.

On December 30, 2019, the pipe sections containing the AOIs' were cut out and replaced, and detailed wall thickness measurements were performed. The reported sizing for the both defects was found to under call the actual depths by about 25%. Table 5 below summarizes the results of the verification work:

Table 5: Verification Results - *12" Woodland Heights Glen DI Watermain*

AOI No.	Pipe No.	Location (ft)	Remaining Wall* (%)	Clock Position	December 2019 Verification Findings
1	**1020**	1695.22	0%	10:00	This defect developed a leak when the line was filled and pressurized following the RFT inspection. The polyethylene wrap was found to be in good condition and no OD corrosion deposits were observed.
2	**0690**	1149.63	26%*	10:30	Considerable external corrosion was observed at this AOI. The corrosion is suspected to have been initiated by a nearby service connection, ~10" away. RFYeager Engineering measured the max pit depth to be 0.230" (82% wall loss) based on a 0.280" nominal thickness. Verification photos from this AOI are provided in Appendix B (courtesy of RFYeager Engineering).

**PICA's remaining wall measurements after calibration finetuning. PICA's updated sizing of 26% RW for AOI2 is within the standard reporting error margin.*

The feedback received from the two verifications was subsequently used by PICA to finetune the calibration during the comprehensive analysis of the RFT data. As a result, the values contained within this report supersede those submitted following the preliminary analysis. In general, the refined defect sizing was found to be 20% to 30% deeper than the preliminary results.

Figure 7a shows an overview of the structural condition of the 8" Kensington Glen DI Watermain. This figure plots the minimum circumferential (Tcircmin), maximum (Tcircmax) and average (Tavg) remaining wall of each segment of pipe, as well as the three deepest defects within each pipe segment.

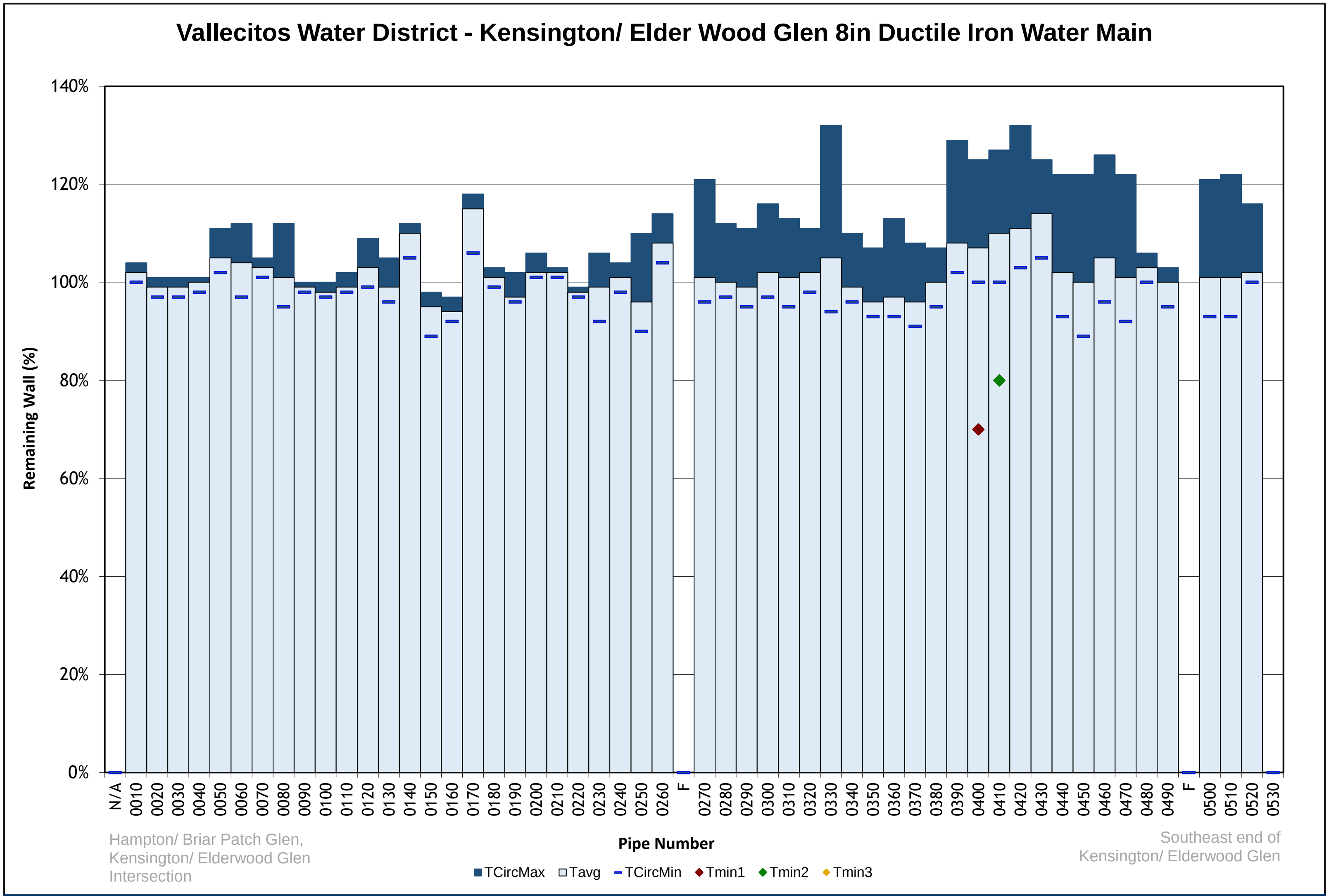


Figure 7a: Structural Condition Assessment Summary – 8" Kensington Glen Ductile Iron Watermain.

Figure 7b shows an overview of the structural condition of the 12" Woodland Heights Glen DI Watermain. This figure plots the minimum circumferential (Tcircmin), maximum (Tcircmax) and average (Tavg) remaining wall of each segment of pipe, as well as the three deepest defects within each pipe segment.

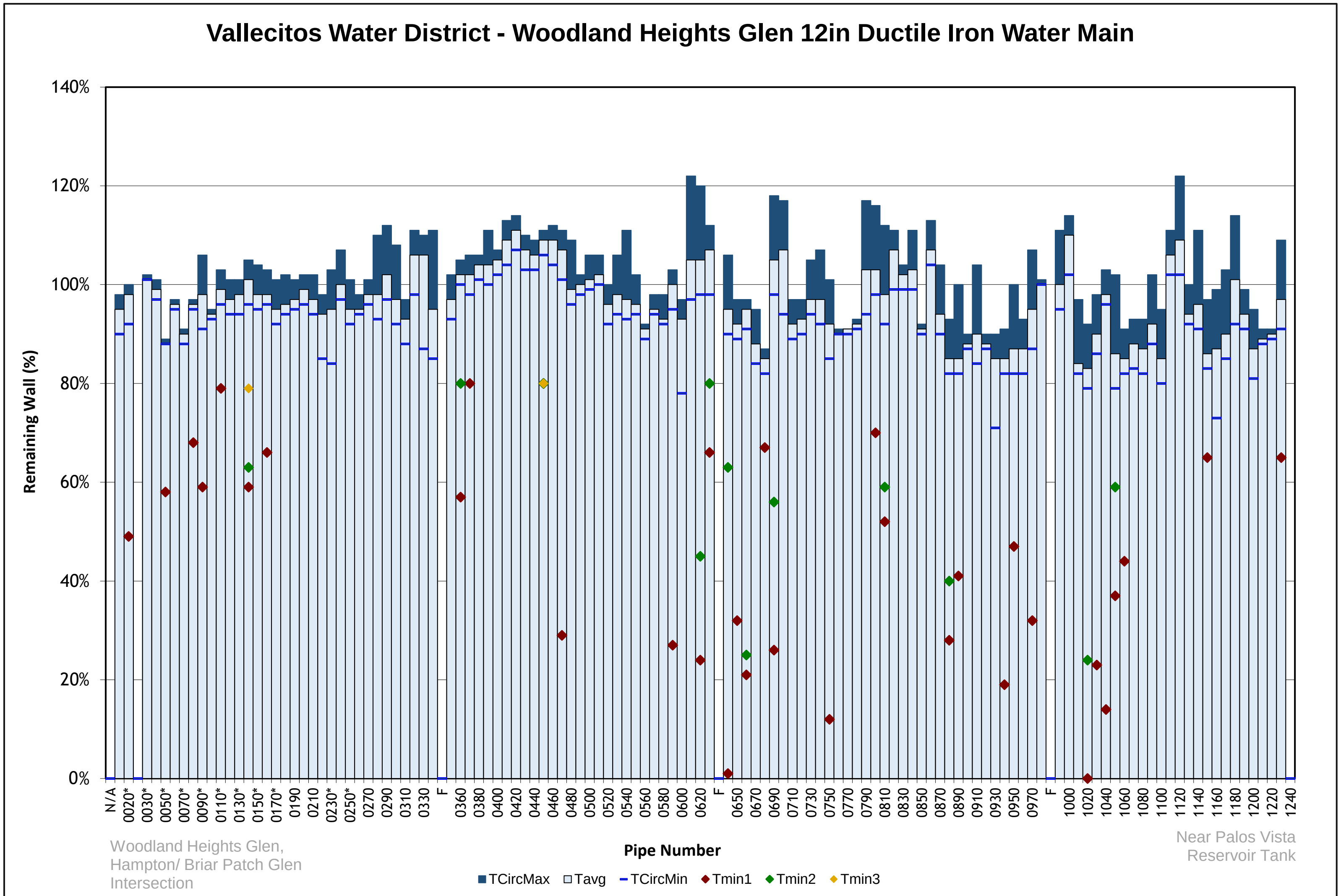


Figure 7b: Structural Condition Assessment Summary – 12" Woodland Heights Glen Ductile Iron Watermain.

Appendix A – Pipe List and Wall Thickness Readings

Table A1: Pipe List and Wall Thickness Readings – 8" Kensington Glen Ductile Iron Watermain																
Pipe No.	**Joint Location**			**Tavg RW (%)**	**Circumferential Wall Thickness**		**Local Wall Thickness** *Clock positions are with a Northwest to Southeast perspective (e.g. 3:00=SW, 9:00=NE).*									**Comments**
							Tmin1			**Tmin2**			**Tmin3**			
	Start (ft)	**End (ft)**	**Length (ft)**		**Min Circ RW (%)**	**Max Circ RW (%)**	**RW (%)**	**Location (ft)**	**Clock Position**	**RW (%)**	**Location (ft)**	**Clock Position**	**RW (%)**	**Location (ft)**	**Clock Position**	
N/A	0.00	3.10	3.10	N/A	N/A	N/A										The zero-datum point was set at the pipe's cut end within the excavation near the intersection of Hampton (Briar Patch) Glen and Kensington (Elderwood) Glen. This partial segment is where the RFT tool was loaded. Because of the segment's short length, the detectors on the tool had already moved into the next segment by the time the exciter entered through the pipe opening. As a result, data collected within this short pipe segment is not suitable for analysis.
0010	3.10	12.09	8.99	102%	100%	104%										
0020	12.09	21.07	8.98	99%	97%	101%										
0030	21.07	30.14	9.07	99%	97%	101%										
0040	30.14	39.10	8.96	100%	98%	101%										
0050	39.10	48.00	8.90	105%	102%	111%										
0060	48.00	56.99	8.99	104%	97%	112%										
0070	56.99	65.90	8.91	103%	101%	105%										
0080	65.90	74.91	9.01	101%	95%	112%										Service connection at 68.58ft.
0090	74.91	83.88	8.97	99%	98%	100%										
0100	83.88	92.86	8.98	98%	97%	100%										
0110	92.86	101.83	8.97	99%	98%	102%										
0120	101.83	110.85	9.02	103%	99%	109%										
0130	110.85	119.87	9.01	99%	96%	105%										
0140	119.87	128.84	8.97	110%	105%	112%										
0150	128.84	137.80	8.96	95%	89%	98%										
0160	137.80	146.80	9.00	94%	92%	97%										
0170	146.80	155.83	9.03	115%	106%	118%										
0180	155.83	164.78	8.95	101%	99%	103%										
0190	164.78	173.78	9.00	97%	96%	102%										
0200	173.78	182.74	8.97	102%	101%	106%										
0210	182.74	191.74	9.00	102%	101%	103%										
0220	191.74	200.77	9.03	98%	97%	99%										
0230	200.77	209.78	9.01	99%	92%	106%										
0240	209.78	218.83	9.06	101%	98%	104%										
0250	218.83	227.84	9.01	96%	90%	110%										
0260	227.84	234.22	6.38	108%	104%	114%										

Table A1: Pipe List and Wall Thickness Readings – 8” Kensington Glen Ductile Iron Watermain

Pipe No.	Joint Location			Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness *Clock positions are with a Northwest to Southeast perspective (e.g. 3:00=SW, 9:00=NE).*									Comments
	Start (ft)	End (ft)	Length (ft)		Min Circ RW (%)	Max Circ RW (%)	Tmin1			Tmin2			Tmin3			
							RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	
F	234.22	235.46	1.24	N/A	N/A	N/A										Hydrant tee
0270	235.46	253.69	18.23	101%	96%	121%										
0280	253.69	272.05	18.36	100%	97%	112%										
0290	272.05	290.02	17.98	99%	95%	111%										
0300	290.02	308.28	18.26	102%	97%	116%										
0310	308.28	326.63	18.35	101%	95%	113%										
0320	326.63	345.06	18.43	102%	98%	111%										Service connection at 334.09ft.
0330	345.06	363.63	18.57	105%	94%	132%										
0340	363.63	382.30	18.68	99%	96%	110%										
0350	382.30	401.03	18.73	96%	93%	107%										
0360	401.03	419.71	18.67	97%	93%	113%										
0370	419.71	438.34	18.63	96%	91%	108%										
0380	438.34	456.96	18.63	100%	95%	107%										
0390	456.96	475.53	18.57	108%	102%	129%										
0400	475.53	494.13	18.60	107%	100%	125%	70%	486.16	6:00							
0410	494.13	512.72	18.59	110%	100%	127%	80%	504.46	9:30	80%	506.80	8:00				Low volume/shallow indications. Reported with lower confidence.
0420	512.72	531.36	18.64	111%	103%	132%										
0430	531.36	549.96	18.60	114%	105%	125%										Service connection at 543.20ft.
0440	549.96	568.54	18.57	102%	93%	122%										Service connection at 565.28ft.
0450	568.54	587.17	18.64	100%	89%	122%										
0460	587.17	605.80	18.62	105%	96%	126%										
0470	605.80	624.48	18.68	101%	92%	122%										
0480	624.48	633.64	9.16	103%	100%	106%										
0490	633.64	644.65	11.01	100%	95%	103%										
F	644.65	645.95	1.29	N/A	N/A	N/A										Hydrant tee
0500	645.95	664.17	18.22	101%	93%	121%										
0510	664.17	682.81	18.65	101%	93%	122%										
0520	682.81	701.34	18.52	102%	100%	116%										
0530	701.34	706.46	5.12	N/A	N/A	N/A										Partially inspected pipe. The last datum is at the cut end within the excavation at the southeast end of Kensington (Elderwood) Glen.

Table A2: Pipe List and Wall Thickness Readings – 12" Woodland Heights Glen Ductile Iron Watermain

Pipe No.	Joint Location			Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness *Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South)* **Defects measuring ≤20% RW are highlighted in red.*									Comments
	Start (ft)	End (ft)	Length (ft)		Min Circ RW (%)	Max Circ RW (%)	Tmin1			Tmin2			Tmin3			
							RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	
**These pipes were affected by minor odometry errors as the tool did not travel steadily through this section. The length variations that resulted from these errors were averaged across all affected pipes.*																
N/A	0.00	7.70	7.70	N/A	N/A	N/A	The zero-datum point was set at the pipe's cut end within the excavation along Woodland Heights Glen near Hampton (Briar Patch) Glen. This partial segment is where the RFT tool was loaded. Because of the segment's short length, the detectors on the tool had already moved into the next segment by the time the exciter was far enough away from the pipe opening. As a result, data collected within this short pipe segment is unsuitable for analysis.									
0010*	7.70	16.99	9.29*	95%	90%	98%										
0020*	16.99	26.28	9.29*	98%	92%	100%	49%	22.23	1:00							
F	26.28	27.72	1.44	N/A	N/A	N/A										Hydrant tee
0030*	27.72	35.68	9.29*	101%	101%	102%										
0040*	35.68	44.47	9.29*	99%	97%	101%										
0050*	44.47	52.53	9.29*	88%	88%	89%	58%	51.59	8:00							
0060*	52.53	61.46	9.29*	96%	95%	97%										
0070*	61.46	71.95	9.29*	90%	88%	91%										
0080*	71.95	81.76	9.29*	96%	95%	97%	68%	75.33	4:30							
0090*	81.76	89.72	9.29*	98%	91%	106%	59%	87.07	9:00							Unknown feature at 87.54ft, 9:00; Suspected service connection.
0100*	89.72	99.30	9.29*	94%	93%	95%										
0110*	99.30	109.19	9.29*	99%	96%	103%	79%	106.39	5:00							
0120	109.19	127.93	18.75	97%	94%	101%										
0130*	127.93	146.73	18.80*	98%	94%	101%										
0140*	146.73	165.53	18.80*	101%	96%	105%	59%	155.41	8:30	63%	148.92	8:30	79%	152.84	8:30	This pipe contains one additional defect measuring 80% RW.
0150*	165.53	184.33	18.80*	98%	95%	104%										
0160*	184.33	203.13	18.80*	98%	96%	103%	66%	201.36	4:30							
0170*	203.13	221.93	18.80*	95%	92%	101%										
0180	221.93	240.82	18.89	96%	94%	102%										
0190	240.82	259.39	18.58	97%	95%	101%										
0200	259.39	277.85	18.46	99%	96%	102%										
0210	277.85	296.35	18.50	97%	94%	102%										
0220	296.35	314.80	18.45	94%	85%	98%										
0230*	314.80	333.33	18.53*	95%	84%	103%										
0240*	333.33	351.86	18.53*	100%	97%	107%										
0250*	351.86	370.39	18.53*	95%	92%	101%										

Table A2: Pipe List and Wall Thickness Readings – 12” Woodland Heights Glen Ductile Iron Watermain																
Pipe No.	**Joint Location**			**Tavg RW (%)**	**Circumferential Wall Thickness**		**Local Wall Thickness** *Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South)* **Defects measuring ≤20% RW are highlighted in red.*									**Comments**
	Start (ft)	**End (ft)**	**Length (ft)**		**Min Circ RW (%)**	**Max Circ RW (%)**	**Tmin1**			**Tmin2**			**Tmin3**			
							RW (%)	**Location (ft)**	**Clock Position**	**RW (%)**	**Location (ft)**	**Clock Position**	**RW (%)**	**Location (ft)**	**Clock Position**	
0260	370.39	389.04	18.65	95%	94%	98%										
0270	389.04	407.84	18.80	98%	96%	101%										
0280	407.84	426.20	18.36	98%	93%	110%										Service connection at 413.23ft.
0290	426.20	444.72	18.52	102%	97%	112%										
0300	444.72	463.51	18.79	97%	92%	108%										
0310	463.51	481.72	18.21	93%	88%	97%										
0320	481.72	500.26	18.54	106%	98%	111%										
0330	500.26	518.91	18.65	106%	87%	110%										Hydrant tee (hot tap) at 515.58ft, 9:00.
0340	518.91	533.38	14.47	95%	85%	111%										2" Air Release Valve at 526.05ft, 12:00.
F	533.38	534.53	1.15	N/A	N/A	N/A										In-line valve
0350	534.53	553.04	18.51	97%	93%	102%										2" Blow Off at 536.89ft, 7:30.
0360	553.04	570.83	17.80	102%	100%	105%	57%	568.41	5:30	80%	567.42	5:30				
0370	570.83	589.43	18.59	102%	98%	106%	80%	584.39	9:00							
0380	589.43	607.82	18.39	104%	101%	106%										
0390	607.82	626.34	18.53	104%	100%	111%										
0400	626.34	644.46	18.11	105%	102%	107%										
0410	644.46	661.38	16.92	109%	104%	113%										
0420	661.38	679.61	18.23	111%	107%	114%										
0430	679.61	698.13	18.52	107%	103%	110%										
0440	698.13	716.77	18.64	106%	103%	109%										
0450	716.77	735.07	18.30	109%	106%	111%	80%	718.54	10:00	80%	718.99	9:00	80%	717.81	10:00	
0460	735.07	753.17	18.09	109%	104%	112%										
0470	753.17	771.72	18.55	107%	101%	111%	29%	770.64	12:30							
0480	771.72	789.86	18.14	99%	96%	109%										Service connection at 776.66ft.
0490	789.86	807.44	17.58	100%	98%	102%										
0500	807.44	825.48	18.04	101%	99%	106%										
0510	825.48	843.96	18.49	102%	100%	106%										
0520	843.96	862.43	18.47	96%	92%	100%										
0530	862.43	881.09	18.66	98%	94%	106%										
0540	881.09	899.72	18.63	97%	93%	111%										

Table A2: Pipe List and Wall Thickness Readings – 12" Woodland Heights Glen Ductile Iron Watermain																
Pipe No.	Joint Location			Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness *Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South)* **Defects measuring ≤20% RW are highlighted in red.*									Comments
							Tmin1			Tmin2			Tmin3			
	Start (ft)	End (ft)	Length (ft)		Min Circ RW (%)	Max Circ RW (%)	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	
0550	899.72	918.50	18.78	96%	94%	102%										
0560	918.50	935.05	16.55	91%	89%	92%										
0570	935.05	953.02	17.97	95%	94%	98%										
0580	953.02	970.09	17.07	93%	92%	98%										
0590	970.09	988.70	18.62	100%	95%	103%	27%	986.34	9:00							
0600	988.70	1006.76	18.05	93%	78%	97%										Hydrant tee (hot tap) at 990.84ft, 3:00.
0610	1006.76	1024.85	18.10	105%	97%	122%										
0620	1024.85	1043.17	18.32	105%	98%	120%	24%	1039.94	11:30	45%	1037.40	7:00				2" Air Release Valve at 1034.92ft, 12:00; Service connection at 1036.91ft.
0630	1043.17	1051.18	8.01	107%	98%	112%	66%	1049.48	12:00	80%	1048.87	1:00				
F	1051.18	1052.31	1.13	N/A	N/A	N/A										Suspected tee
0640	1052.31	1062.10	9.79	95%	90%	106%	1%	1060.32	7:00	63%	1059.89	7:00				2" Air Release Valve at 1058.53ft, 12:00. Please note that this ARV is 12ft further east in the RFT data than Cas Arrieta's above ground measurements. A possible through-hole (1% RW, 7:00) was identified at 1060.32ft.
0650	1062.10	1079.48	17.38	92%	89%	97%	32%	1078.21	7:30							
0660	1079.48	1097.79	18.31	95%	91%	97%	21%	1092.72	9:00	25%	1086.89	1:30				
0670	1097.79	1116.36	18.57	88%	84%	95%										
0680	1116.36	1135.00	18.64	85%	82%	87%	67%	1122.10	11:00							
0690	1135.00	1153.30	18.30	105%	98%	118%	26%	1149.63	10:30	56%	1150.05	12:00				Service connection at 1150.51ft. The 26% RW defect was reported as AOI#2 in the preliminary report. This location was excavated and cut out. Considerable external corrosion was observed, possibly due to the nearby water service connection (10" away). RFYeager Engineering measured the max pit depth 0.230" (82% wall loss based on a 0.280" nominal thickness). PICA's reported sizing of 26% RW is

Table A2: Pipe List and Wall Thickness Readings – 12” Woodland Heights Glen Ductile Iron Watermain																
Pipe No.	Joint Location			Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness *Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South)* **Defects measuring ≤20% RW are highlighted in red.*									Comments
	Start (ft)	End (ft)	Length (ft)		Min Circ RW (%)	Max Circ RW (%)	Tmin1			Tmin2			Tmin3			
							RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	
																within the standard reporting error margin. The 56% RW defect is reported with lower confidence due to the overlapping wall gain signal effect of the service connection collar.
0700	1153.30	1171.68	18.38	107%	94%	117%										
0710	1171.68	1190.09	18.41	92%	89%	97%										
0720	1190.09	1208.66	18.58	93%	90%	97%										
0730	1208.66	1227.19	18.52	97%	94%	105%										
0740	1227.19	1245.81	18.62	97%	92%	107%										
0750	1245.81	1264.23	18.42	92%	85%	101%	12%	1255.51	5:30							Service connection at 1256.86ft.
0760	1264.23	1273.65	9.42	90%	90%	91%										
0770	1273.65	1282.85	9.19	91%	90%	91%										
0780	1282.85	1292.13	9.28	92%	91%	93%										
0790	1292.13	1310.33	18.20	103%	94%	117%										
0800	1310.33	1328.61	18.28	103%	98%	116%	70%	1323.63	3:00							
0810	1328.61	1346.87	18.26	98%	92%	112%	52%	1338.36	11:30	59%	1338.98	6:00				
0820	1346.87	1365.41	18.54	107%	99%	111%										
0830	1365.41	1382.61	17.20	102%	99%	104%										
0840	1382.61	1401.15	18.53	103%	99%	111%										Service connection at 1397.75ft.
0850	1401.15	1410.40	9.25	91%	90%	92%										
0860	1410.40	1428.84	18.44	107%	104%	113%										
0870	1428.84	1447.37	18.53	94%	90%	104%										
0880	1447.37	1465.52	18.15	85%	82%	93%	28%	1463.43	10:30	40%	1451.87	2:00				
0890	1465.52	1483.88	18.36	85%	82%	100%	41%	1482.25	11:00							
0900	1483.88	1493.24	9.36	88%	87%	90%										
0910	1493.24	1511.54	18.30	90%	84%	104%										
0920	1511.54	1530.26	18.72	88%	87%	90%										Service connection at 1515.66ft.
0930	1530.26	1548.81	18.55	85%	71%	90%										Hydrant tee (hot tap) at 1541.98ft, 9:00.
0940	1548.81	1567.42	18.62	85%	82%	91%	19%	1559.47	10:30							

Table A2: Pipe List and Wall Thickness Readings – 12" Woodland Heights Glen Ductile Iron Watermain

Pipe No.	Joint Location			Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness *Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South)* **Defects measuring ≤20% RW are highlighted in red.*									Comments
	Start (ft)	End (ft)	Length (ft)		Min Circ RW (%)	Max Circ RW (%)	Tmin1			Tmin2			Tmin3			
							RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	
0950	1567.42	1585.97	18.54	87%	82%	100%	47%	1578.04	10:00							
0960	1585.97	1604.23	18.26	87%	82%	93%										
0970	1604.23	1622.79	18.56	95%	87%	107%	32%	1616.60	11:00							2" Blow Off at 1618.80ft, 7:00.
0980	1622.79	1627.87	5.08	100%	100%	101%										
F	1627.87	1628.83	0.95	N/A	N/A	N/A										Suspected tee
0990	1628.83	1642.24	13.41	100%	95%	111%										2" Blow Off at 1635.76ft, 7:00.
1000	1642.24	1660.86	18.63	110%	102%	114%										
1010	1660.86	1679.00	18.14	84%	82%	97%										
1020	1679.00	1697.66	18.66	83%	79%	92%	0%	1695.22	10:00	24%	1693.76	10:30				The through-hole (0% RW) defect was reported as AOI #1 in the preliminary report. This defect developed a leak when the line was filled and pressurized after the RFT inspection. The polyethylene wrap was found to be in good condition and no OD corrosion deposits were observed. This segment was cut out and replaced since the inspection.
1030	1697.66	1716.10	18.44	90%	86%	98%	23%	1711.15	12:30							
1040	1716.10	1734.29	18.19	98%	96%	103%	14%	1733.15	12:00							
1050	1734.29	1752.81	18.52	86%	79%	102%	37%	1740.86	2:00	59%	1740.95	10:30				Service connection at 1740.38ft.
1060	1752.81	1771.55	18.74	85%	82%	91%	44%	1758.97	1:00							
1070	1771.55	1790.25	18.69	88%	83%	93%										
1080	1790.25	1808.39	18.14	87%	82%	93%										
1090	1808.39	1826.98	18.59	92%	88%	102%										
1100	1826.98	1845.67	18.69	85%	80%	95%										
1110	1845.67	1864.15	18.48	106%	102%	111%										
1120	1864.15	1882.60	18.46	109%	102%	122%										Service connection at 1870.13ft.
1130	1882.60	1901.07	18.46	94%	92%	100%										
1140	1901.07	1919.70	18.63	96%	91%	111%										
1150	1919.70	1938.36	18.65	86%	83%	97%	65%	1929.87	5:00							
1160	1938.36	1957.00	18.64	87%	73%	99%										Hydrant tee (hot tap) at 1949.08ft, 9:00
1170	1957.00	1975.57	18.57	90%	85%	103%										Service connection at 1962.53ft.

Table A2: Pipe List and Wall Thickness Readings – 12" Woodland Heights Glen Ductile Iron Watermain

Pipe No.	Joint Location			Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness *Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South)* **Defects measuring ≤20% RW are highlighted in red.*									Comments
	Start (ft)	End (ft)	Length (ft)		Min Circ RW (%)	Max Circ RW (%)	Tmin1			Tmin2			Tmin3			
							RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	RW (%)	Location (ft)	Clock Position	
1180	1975.57	1993.66	18.09	101%	92%	114%										
1190	1993.66	2002.84	9.18	94%	91%	99%										
1200	2002.84	2021.35	18.50	87%	81%	95%										
1210	2021.35	2030.58	9.23	89%	88%	91%										
1220	2030.58	2039.69	9.11	90%	89%	91%										
1230	2039.69	2057.80	18.11	97%	91%	109%	65%	2056.34	11:00							
1240	2057.80	2058.98	1.18	N/A	N/A	N/A										Partially inspected pipe. The last datum is at the cut end within the excavation near the Palos Vista Reservoir tank.

Appendix B – Verification Photos of AOI #2 (Pipe 0690) - 12” Woodland Heights Glen DI Watermain

Figure B1: Verification photos of AOI #2 - Pipe 0690, 26% remaining wall (10:30) at 1149.63ft. To the right of the corrosion patch is a collar for a service connection. *All photos are courtesy of RFYeager Engineering*.

Disclaimer – PICA Corporation

Scope of Services

The agreement of PICA Corp to perform services extends only to those services provided for in writing. Under no circumstances shall such services extend beyond the performance of the requested services. It is expressly understood that all descriptions, comments and expressions of opinion reflect the opinions or observations of PICA Corp based on information and assumptions supplied by the owner/operator and are not intended nor can they be construed as representations or warranties. PICA Corp is not assuming any responsibilities of the owner/operator and the owner/operator retains complete responsibility for the engineering, manufacture, repair and use decisions as a result of the data or other information provided by PICA Corp. Nothing contained in this Agreement shall create a contractual relationship with or cause of action in favor of a third party against either the Line Owner or PICA Corp. In no event shall PICA Corp's liability in respect of the services referred to herein exceed the amount paid for such services.

Standard of Care

In performing the services provided, PICA Corp uses the degree, care, and skill ordinarily exercised under similar circumstances by others performing such services in the same or similar locality. No other warranty, expressed or implied, is made or intended by PICA Corp.

Addendum to RFT Condition Assessment Reports
Technology & Analysis Background

PICA – Pipeline Inspection & Condition Analysis Corporation
(A Subsidiary of Russell NDT Holdings Ltd.)

Supplementary Information for RFT Reports:

Revision: 1.0

Abbreviations & Terminology

Abbreviations

AGM	Above-Ground Monitor
B&S:	Bell and Spigot connection
CC	Coupled or Clamped connection
CI	Cast Iron
DI	Ductile Iron
DS	Downstream
F	Feature
FM	Force Main
ILI	In-Line Inspection
NWT	Nominal Wall Thickness
P&P	Plan & Profile drawings
PARW	Pipe Average Remaining Wall (also Tavg)
PRC	Probable Repair Coupling
RFT	Remote Field Testing
RW	Remaining Wall
STL	Steel
Tavg	Average Wall Thickness (also PARW)
Tcircmin	Minimum Circumferential Wall Thickness
Tcircmax	Maximum Circumferential Wall Thickness
Tmin	Minimum Wall Thickness
TH	Through Hole (ie: 0% Remaining Wall)
UF	Unknown or Unidentifiable Feature
US	Upstream
WL	Wall Loss

Glossary

Average Wall Thickness (Tavg, PARW): The wall thickness that would occur by recasting the existing metal on the pipe barrel so that it is uniform across the axial length. The average pipe wall can vary up to ±15% due to manufacturing. Variations outside the normal 15% spread can be an indicator of a different nominal wall thickness or pipe type, or a point towards a problem like aggregate pitting or general wall loss.

Circumferential Wall Thickness: Metal loss that is uniform in depth around the pipe's circumference at a given axial location. The "maximum" circumferential wall thickness (Tcircmax) indicates the thickest circumferential wall thickness for a single pipe while the "minimum" circumferential wall thickness (Tcircmin) indicates the thinnest. Figure 1 illustrates all wall thickness terms.

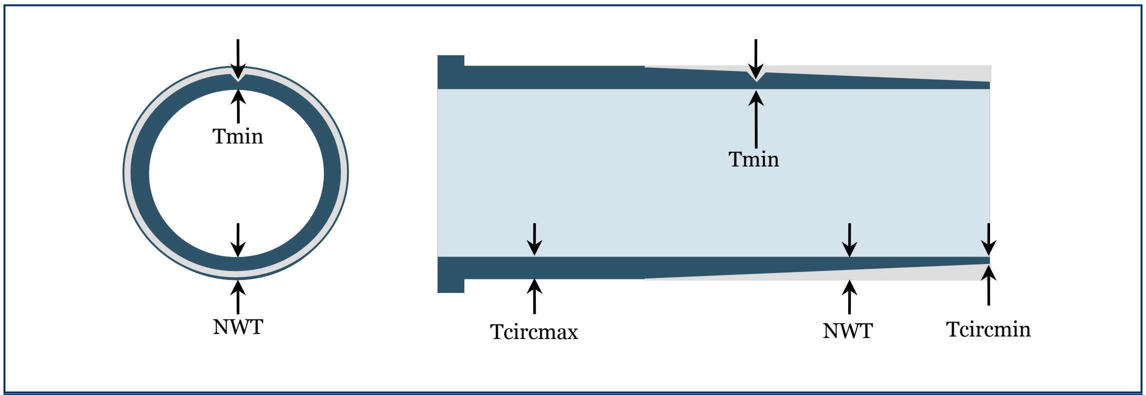


Figure 1. Wall loss terminology

Nominal Wall Thickness (NWT): The thickness of the pipe wall where there is assumed to be no corrosion or circumferential wall loss (ie: 100% RW). Normally, a manufacturer will designate a NWT or NWT range (in mm or inches) for a specific pipe material, diameter and class.

One-Sided Wall Loss: Metal loss that occurs predominantly on one side of the pipe – also referred to as "pitting" or "eccentric wall loss".

Pipe Average Wall Thickness (Tavg, PARW): The wall thickness that would occur by recasting the existing metal on the pipe barrel so that it is uniform across the axial length. The average pipe wall can vary up to ±15% due to manufacturing. Variations outside the normal 15% spread can be an indicator of a different nominal wall thickness or pipe type, or a point towards a problem like aggregate pitting or general wall loss.

Pitting: Localized corrosion of a metal surface that is confined to a point or small area. Up to three deepest pitting regions in each pipe are provided in this report as Tmin1, Tmin2 and Tmin3.

Remote Field Testing (RFT): A non-destructive examination method that induces an electromagnetic field that is then detected outside the direct coupling zone (ie: in the "remote" zone) after it has passed completely through the object being examined. RFT is also called "remote field eddy current" (RFEC).

Condition Categories

In some reports, pitting is expressed as Shallow, Medium, Deep or Advanced. For example, if a pitting region has 35% remaining wall, the pitting would be classified as "Deep" pitting.

Shallow	Wall thickness at thinnest point ≥ 65% of NWT
Medium	Wall thickness at thinnest point 40%-64% of NWT
Deep	Wall thickness at thinnest point 20%-39% of NWT
Advanced	Wall thickness at thinnest point < 20% of NWT

The condition of the thinnest point on each pipe (as defined above) in conjunction with the number of corrosion indications is used to determine the overall condition of the pipeline into poor, fair or good. Loosely defined:

Poor	The majority of inspected pipes have corrosion deeper than 50% of NWT
Fair	The majority of inspected pipes have corrosion between 25% - 50% of NWT
Good	The majority of inspected pipes have corrosion less than 25% of NWT

If you would prefer to use a different condition coding system for this report, please inform your PICA representative.

Remote Field Operation

SeeSnake Tool Description

PICA Corp's SeeSnake line of tools employs Remote Field Technology (RFT) for measuring pipe wall thickness. RFT technology works by detecting changes in an AC electromagnetic field generated by the tool by interacting with the metal in the pipe, becoming stronger in areas of metal loss. These electromagnetic field interactions are measured by on board detectors. All data is processed using A/D converters and digital processors and then stored on the tool itself. This data is then downloaded to PICA offices and analysed using dedicated in house software to calculate wall thickness of the line.

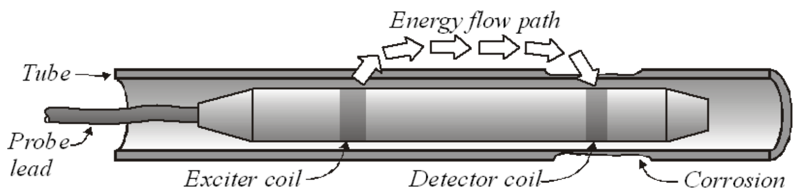
The SeeSnake tools' articulated mechanical design gives it flexibility to negotiate 90-degree short radius elbows. The hard diameter of the tool is significantly smaller than the inner diameter (ID) of the pipe to allow for protrusions, lining and scale. Centralizers maintain a uniform annulus between the tool and the pipe. The connection with the street-level operator is made through a wireline, which runs over an odometer sheave to provide an accurate distance reading of the tool's progress through the pipeline. The tool detects wall thinning caused by corrosion or erosion, as well as line features such as joint couplings, branches and elbows. The maximum range is defined by the length of the wireline for tethered runs.

Figure 2a: PICA's SeeSnake tool used for smaller diameter inspections.

Figure 2b: PICA's Chimera tool used for larger diameter inspections.

Background Information

In the basic RFT probe shown below, there is one exciter coil and one detector coil. Both coils are wound co-axially with respect to the examined pipe and are separated by a distance greater than two times the pipe diameter. The actual separation depends on the application, but will always be a minimum of two pipe diameters. It is this separation that gives RFT its name: the detector measures the electromagnetic field remote from the exciter. Although the fields have become very small at this distance from the exciter, they contain information on the full thickness of the pipe wall.



The detector electronics include high-gain instrumentation amplifiers and steep noise filters. These are necessary in order to retrieve the remote field signals. The detector electronics output the remote field signal to an on-board storage device. The data is recalled for display, analysis and reporting purposes after the examination process is completed.

Remote Field Technology (RFT)

RFT Tools work by measuring the "time of flight" (phase shift) and the signal strength (amplitude) of a signal emitted by an exciter coil and detected by an array of receivers. The receivers are positioned circumferentially so that they essentially are sensitive to the many clock locations of the pipe circumference.

For each cycle of the exciter frequency, a clock is started and the arrival time of the signal at the detector is used to re-set the clock. The time interval is a measurement of the time of flight, and indirectly, the wall thickness of the pipe.

There are many important considerations affecting in-line RFT inspection results. These can be subdivided into four categories:

- The physical quantities measured by the ILI tool. Most ILI tools indirectly measure the wall thickness and infer the wall thickness though a calibration. Ultrasonic (UT) tools measure the "time-of-flight" of sound, while Magnetic Flux Leakage (MFL) tools measure the magnetic field. RFT tools measure both the time-of-flight and the signal strength of a varying electromagnetic field.
- The design of the tool. Pipe inspection tool design is a compromise between countless design criteria. Lift-off and resolution are important considerations, but so are bend negotiation ability, battery life, pipe size range, centralization, wall thickness range, suspension, etc.
- The delivery procedure. Most tools have an optimal inspection speed and provide the best results when the speed is consistent. Going faster or slower means less than optimal results. This is an especially important consideration when tools are run in gaseous media.
- Noise and other interference sources. These can be caused by both internal sources and external sources. A major problem for many tools is the cleanliness of the pipe. A dirty pipe can cause artifacts in the data that may mask flaws.

Physical Parameters Measured by RFT Tools

RFT technology measures three quantities:

- Wall thickness of ferromagnetic pipes
- Magnetic permeability
- Electrical conductivity

These three factors are measured simultaneously and convey different, important information. For steel pipes, the electrical conductivity remains fairly constant over the length of a pipe segment, meaning that any RFT signal changes along the length of a pipe are mainly due to wall thickness and permeability changes.

Magnetic permeability is not usually a factor of interest. However, in lines that are subjected to soil load stresses, the permeability variations can be significant. For lines known to be under external stresses (for example due to geological ground movement) the permeability variations measured by an RFT tool can be very valuable. Permeability variations produce signals that generally lie just outside the RFT wall loss reference curve that analysts use to differentiate between wall loss and permeability; while wall loss signals lie inside the reference curve.

In the data from cast and ductile iron water lines, we generally notice significant changes in wall thickness along the length of a pipe segment. This appears to be fairly typical, even for brand new pipes that come straight from the foundry. The variation is believed to be the result of the manufacturing process. To capture the spread in wall thickness, we generally report both the minimum and maximum wall thickness per pipe (measured circumferentially without local defects).

Besides wall thickness variations, we occasionally note magnetic permeability variations in the data. These are generally from two sources:

- Roller marks. These present themselves as a band of noise across all channels on the tool. The marks can be sizeable and can mask small volume wall loss defects.
- Permeability changes caused by stresses induced during installation of the line. These typically are localized indications within a couple of feet of a bell and spigot joint. They are believed to mark the points where the pipes were held when the joints were assembled.

Tool Propulsion and Delivery

A common problem encountered during tethered runs in air-filled pipe is tool surging. The surges consist of the tool being stationary one moment and surging forward the next. Speed surges are most severe when the length of the tether on the pulling winch is at its maximum, or the tether is wrapping around multiple bends. The surges are often completely missed by the field operator as the winch reels in at a constant velocity and no surging is visible from above ground. Contributors to surging are tool friction, wireline friction and wireline stretch and weight.

Interference and Noise Sources

There are three different sources of interference on the RFT data:

1. Interference from electrical sources on board the tool

There are two types of interferences caused by the tool itself: electrical noise and the exciter response to defect signals.

Electrical noise from onboard the tool will be consistently present in the data and will therefore result in a constant noise amplitude. This type of noise can be filtered out easily during the post processing stage.

When the exciter coil on an RFT tool passes an area with significant wall thickness change, the "exciter response" to this wall thickness change (like a Bell and Spigot joint, an Elbow, or Valve) will be visible in the data. If the exciter response is large, it can mask the tool response to smaller defects.

2. Noise from electrical sources outside the tool

The noise from these types of sources will increase with proximity. The closer the tool to the source, the higher the noise level will become. The noise will fade out as the tool moves away from the noise source. This type of noise can be hard to remove during post-processing and may mask flaws in the pipe. Cathodic Protection systems can induce electrical noise on the data from the pipeline and electrical cables that run parallel to the line or cross it can induce noise as well.

3. Vibration induced noise

Mechanical vibration can create false indications or cause the tool to miss flaws. This is called "travel noise". For example when the tool moves through a larger cross, the tool is subjected to a significant diameter change that causes the tool modules to tilt and temporarily lose concentricity with the pipe. This tilting action will create signal artifacts on the data.

Presenting RFT Data: Stripchart Display & Phase-Amplitude Diagrams

A stripchart displays the detector data as a function of time or the axial distance along the length of the pipeline. Phase and log-amplitude are the preferred quantities for the stripchart display because they are both linear indicators of overall wall thickness. The general convention for stripcharts is that deflections to the left represent metal loss and deflections to the right wall thickening (Figure 3).

A phase-amplitude diagram (Figure B2) is a two-dimensional representation of the detector output voltage with the angle representing phase with respect to a reference signal and the radius representing amplitude (ASNT E 2096). Axial distance information is not available on phase-amplitude diagrams yet they are used for sizing flaws. By combining phase-amplitude diagrams with stripcharts, the distance information can be included.

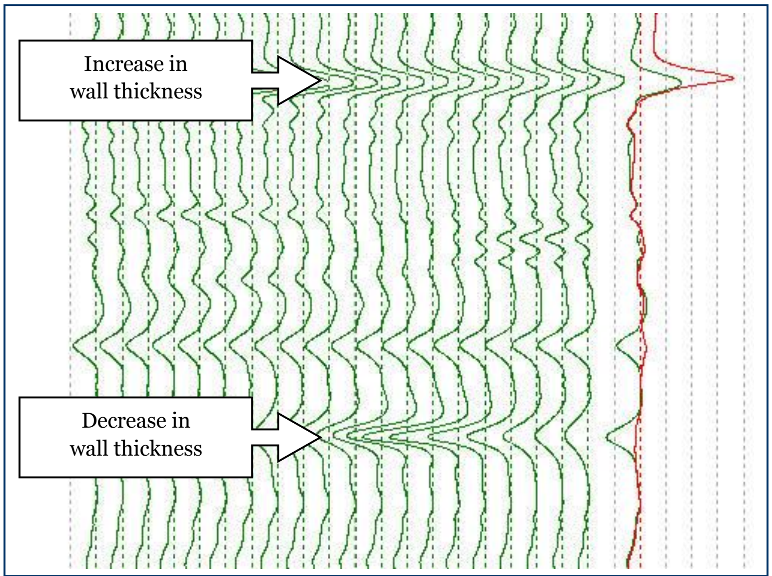


Figure 3: RFT stripchart display.

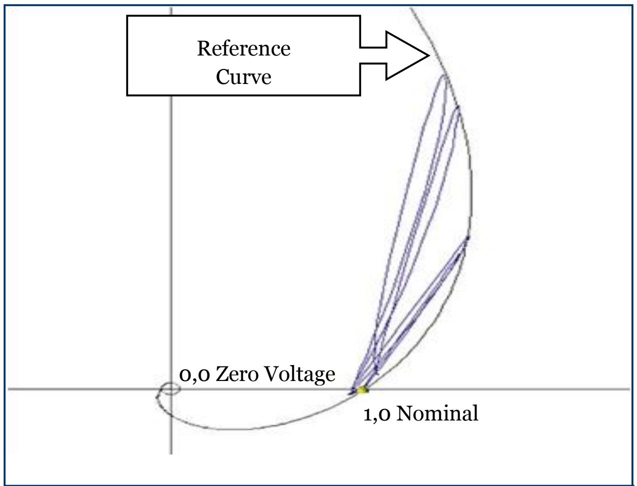


Figure 4: RFT phase-amplitude diagram.

Phase-amplitude diagrams are also known as "voltage plane displays". On the voltage plane display, the nominal signal is placed at (1,0). Besides the detector information, the voltage plane has a number of static components: the origin, the x- and y-axes and the exponential skin depth reference curve. The curve starts at (0,0) (ie: zero voltage at origin) and follows a spiral that traces the path (locus) of the phasors as the overall wall thickness decreases. Full circumferential flaws fall directly on this curve. The figure on the right illustrates examples of fully circumferential defect indications.

Calibration

For the best possible RFT accuracy, a calibration is performed using a short section of pipe with the same nominal pipe properties (wall thickness and grade) as the pipe being inspected. Under ideal conditions, a full pipe section with a half pipe on each end (to create two full connections and eliminate any "end effect") in good condition are provided by the Client. PICA will create artificial defects of varying depth and diameter in this pipe and run the RFT tool through it several times at various frequencies. The signal produced during this process is then compared to the signal produced during the field surveys to better quantify remaining wall calculations.

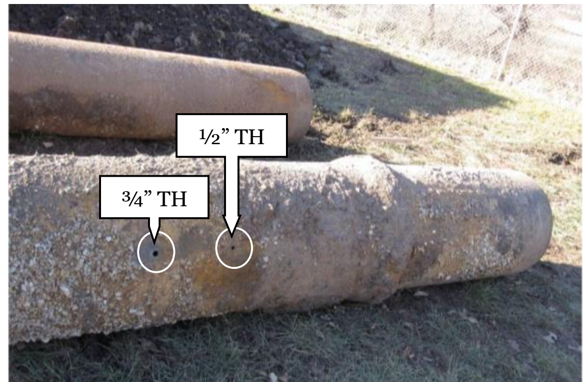


Figure 5: Typical calibration pipe.

In the absence of such a calibration pipe or to confirm the accuracy of the calibration (especially in the case where the test sample is not representative of the majority of the pipes in the inspected line), calibration test results are supplemented by mathematical calibrations. Simply, the analyst will build a histogram of the thickest RFT phase reading per inspected pipe section and create a calibration from this histogram. This assumes that the thickest phase readings are unaffected by possible corrosion. Using this method, defect sizing accuracy is expected to be ±20% for short (local) wall loss and ±10% for long (general) wall loss for pitting above the limit of detection and sufficiently removed from major features (such as Girth Weld connections).

VALLECITOS WATER DISTRICT

A PUBLIC AGENCY

VALLECITOS WATER DISTRICT
HIGH POINT WATERLINE CONDITION ASSESSMENT
PROJECT NO #2019100544

CALCULATIONS FOR

CONDITION ASSESSMENT

MARCH 2020

Infrastructure ENGINEERING CORPORATION

HIGH POINT WATERLINE CONDITION ASSESSMENT
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CALCULATIONS CONDITION ASSESSMENT

Vallecitos Water District
High Point Waterline Condition Assessment
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Item	Pipe #	Pipe Joint Start	Pipe Joint End	Station	Remaining Wall	Position on Pipe	Comments
1	20	16.99	26.28	53+24.82	49%	1:00	
REF	FH	26.28	27.72	53+29.59	n/a	n/a	Reference Hydrant
2	50	44.47	52.53	53+54.18	58%	8:00	
3	140	146.73	165.53	54+58.00	59%	8:30	
				54+51.51	63%	8:30	
				54+55.43	79%	8:30	
4	360	553.04	570.83	58+71.00	57%	5:30	
5	470	753.17	771.72	60+73.23	29%	12:30	
6	590	970.09	988.7	62+88.93	27%	9:00	
7	620	1024.85	1043.17	63+42.53	24%	11:30	
				63+39.99	45%	7:00	
8	640	1052.31	1062.1	63+62.91	1%	7:00	ARV @ 1058.53
				63+62.48	63%	7:00	
9	650	1062.1	1079.48	63+80.80	32%	7:30	
10	660	1079.48	1097.79	63+95.31	21%	9:00	
11	690	1135	1153.3	64+52.22	26%	10:30	
12	750	1248.81	1264.23	65+58.10	12%	5:30	Service @ 1256.86
13	810	1328.61	1346.87	66+40.95	52%	11:30	
14	880	1447.37	1465.52	67+66.02	28%	10:30	
				67+54.46	40%	2:00	
15	890	1465.52	1483.88	67+84.84	41%	11:00	
16	940	1548.81	1567.42	68+62.06	19%	10:30	
17	950	1567.42	1585.97	68+80.63	47%	10:00	
18	970	1604.23	1622.79	69+19.19	32%	11:00	B/O @ 1618.80
19	1030	1697.66	1716.1	70+13.74	23%	12:30	
20	1040	1716.1	1734.29	70+35.74	14%	12:00	
21	1050	1734.29	1752.81	70+43.45	37%	2:00	
				70+43.54	59%	10:30	
22	1060	1752.81	1771.55	70+61.56	44%	1:00	

Table A2: Pipe List and Wall Thickness Readings – 12” Woodland Heights Glen Ductile Iron Watermain*

Pipe Number	Joint Location			Pipe NWT [in]	Tavg RW (%)	Circumferential Wall Thickness		Local Wall Thickness Information Clock positions are with an East to West perspective (e.g. 3:00=North, 9:00=South) *Defects measuring <20% RW are highlighted in red. Tmin1			Tmin2			Tmin3			Comment
	Start [ft]	End [ft]	Length [ft]			TCirc Min [%]	TCirc Max [%]	RW (%)	Location [ft]	Clock Position	RW (%)	Location [ft]	Clock Position	RW (%)	Location [ft]	Clock Position	
These pipes were affected by minor odometry errors as the tool did not travel steadily through this section. The length variations that resulted from these errors were averaged across all affected pipes.																	
N/A	0.00	7.70	7.70	0.28	N/A	N/A	N/A										The zero-datum point was set at the pipe's cut end within the excavation along Woodland Heights Glen near Hampton (Briar Patch) Glen. This partial segment is where the RFT tool was loaded. Because of the segment’s short length, the detectors on the tool had already moved into the next segment by the time the exciter was far enough away from the pipe opening. As a result, data collected within this short pipe segment is unsuitable for analysis
0010*	7.70	16.99	9.29*	0.28	95%	90%	98%										
0020*	16.99	26.28	9.29*	0.28	98%	92%	100%	49%	22.23	1:00							
CF	26.28	27.72	1.44	N/A	N/A	N/A	N/A										Hydrant tee
0030*	27.72	35.68	9.29*	0.28	101%	101%	102%										
0040*	35.68	44.47	9.29*	0.28	99%	97%	101%										
0050*	44.47	52.53	9.29*	0.28	88%	88%	89%	58%	51.59	8:00							
0060*	52.53	61.46	9.29*	0.28	96%	95%	97%										
0070*	61.46	71.95	9.29*	0.28	90%	88%	91%										
0080*	71.95	81.76	9.29*	0.28	96%	95%	97%	68%	75.33	4:30							
0090*	81.76	89.72	9.29*	0.28	98%	91%	106%	59%	87.07	9:00							Unknown feature at 87.54ft, 9:00; Suspected service connection.
0100*	89.72	99.30	9.29*	0.28	94%	93%	95%										
0110*	99.30	109.19	9.29*	0.28	99%	96%	103%	79%	106.39	5:00							
0120	109.19	127.93	18.75	0.28	97%	94%	101%										
0130*	127.93	146.73	18.80*	0.28	98%	94%	101%										
0140*	146.73	165.53	18.80*	0.28	101%	96%	105%	59%	155.41	8:30	63%	148.92	8:30	79%	152.84	8:30	This pipe contains one additional defect measuring 80% RW.
0150*	165.53	184.33	18.80*	0.28	98%	95%	104%										
0160*	184.33	203.13	18.80*	0.28	98%	96%	103%	66%	201.36	4:30							
0170*	203.13	221.93	18.80*	0.28	95%	92%	101%										
0180	221.93	240.82	18.89	0.28	96%	94%	102%										
0190	240.82	259.39	18.58	0.28	97%	95%	101%										
0200	259.39	277.85	18.46	0.28	99%	96%	102%										
0210	277.85	296.35	18.50	0.28	97%	94%	102%										
0220	296.35	314.80	18.45	0.28	94%	85%	98%										
0230*	314.80	333.33	18.53*	0.28	95%	84%	103%										
0240*	333.33	351.86	18.53*	0.28	100%	97%	107%										
0250*	351.86	370.39	18.53*	0.28	95%	92%	101%										
0260	370.39	389.04	18.65	0.28	95%	94%	98%										
0270	389.04	407.84	18.80	0.28	98%	96%	101%										
0280	407.84	426.20	18.36	0.28	98%	93%	110%										Service connection at 413.23ft.
0290	426.20	444.72	18.52	0.28	102%	97%	112%										
0300	444.72	463.51	18.79	0.28	97%	92%	108%										
0310	463.51	481.72	18.21	0.28	93%	88%	97%										

*Pipes with 60% or less wall thickness remaining highlighted in orange.

0320	481.72	500.26	18.54	0.28	106%	98%	111%										
0330	500.26	518.91	18.65	0.28	106%	87%	110%										Hydrant tee (hot tap) at 515.58ft, 9:00.
0340	518.91	533.38	14.47	0.28	95%	85%	111%										2" Air Release Valve at 526.05ft, 12:00.
CF	533.38	534.53	1.15	N/A	N/A	N/A	N/A										In-line valve
0350	534.53	553.04	18.51	0.28	97%	93%	102%										2" Blow Off at 536.89ft, 7:30.
0360	553.04	570.83	17.80	0.28	102%	100%	105%	57%	568.41	5:30	80%	567.42	5:30				
0370	570.83	589.43	18.59	0.28	102%	98%	106%	80%	584.39	9:00							
0380	589.43	607.82	18.39	0.28	104%	101%	106%										
0390	607.82	626.34	18.53	0.28	104%	100%	111%										
0400	626.34	644.46	18.11	0.28	105%	102%	107%										
0410	644.46	661.38	16.92	0.28	109%	104%	113%										
0420	661.38	679.61	18.23	0.28	111%	107%	114%										
0430	679.61	698.13	18.52	0.28	107%	103%	110%										
0440	698.13	716.77	18.64	0.28	106%	103%	109%										
0450	716.77	735.07	18.30	0.28	109%	106%	111%	80%	718.54	10:00	80%	718.99	9:00	80%	717.81	10:00	
0460	735.07	753.17	18.09	0.28	109%	104%	112%										
0470	753.17	771.72	18.55	0.28	107%	101%	111%	29%	770.64	12:30							
0480	771.72	789.86	18.14	0.28	99%	96%	109%										Service connection at 776.66ft.
0490	789.86	807.44	17.58	0.28	100%	98%	102%										
0500	807.44	825.48	18.04	0.28	101%	99%	106%										
0510	825.48	843.96	18.49	0.28	102%	100%	106%										
0520	843.96	862.43	18.47	0.28	96%	92%	100%										
0530	862.43	881.09	18.66	0.28	98%	94%	106%										
0540	881.09	899.72	18.63	0.28	97%	93%	111%										
0550	899.72	918.50	18.78	0.28	96%	94%	102%										
0560	918.50	935.05	16.55	0.28	91%	89%	92%										
0570	935.05	953.02	17.97	0.28	95%	94%	98%										
0580	953.02	970.09	17.07	0.28	93%	92%	98%										
0590	970.09	988.70	18.62	0.28	100%	95%	103%	27%	986.34	9:00							
0600	988.70	1006.76	18.05	0.28	93%	78%	97%										Hydrant tee (hot tap) at 990.84ft, 3:00.
0610	1006.76	1024.85	18.10	0.28	105%	97%	122%										
0620	1024.85	1043.17	18.32	0.28	105%	98%	120%	24%	1039.94	11:30	45%	1037.40	7:00				2" Air Release Valve at 1034.92ft, 12:00; Service connection at 1036.91ft.
0630	1043.17	1051.18	8.01	0.28	107%	98%	112%	66%	1049.48	12:00	80%	1048.87	1:00				
CF	1051.18	1052.31	1.13	N/A	N/A	N/A	N/A										Suspected tee.
0640	1052.31	1062.10	9.79	0.28	95%	90%	106%	1%	1060.32	7:00	63%	1059.89	7:00				2" Air Release Valve at 1058.53ft, 12:00. Please note that this ARV is 12ft further east in the RFT data than Cas Arrieta's above ground measurements. A possible through-hole (1% RW, 7:00) was identified at 1060.32ft.
0650	1062.10	1079.48	17.38	0.28	92%	89%	97%	32%	1078.21	7:30							
0660	1079.48	1097.79	18.31	0.28	95%	91%	97%	21%	1092.72	9:00	25%	1086.89	1:30				
0670	1097.79	1116.36	18.57	0.28	88%	84%	95%										
0680	1116.36	1135.00	18.64	0.28	85%	82%	87%	67%	1122.10	11:00							

*Pipes with 60% or less wall thickness remaining highlighted in orange.

0690	1135.00	1153.30	18.30	0.28	105%	98%	118%	26%	1149.63	10:30	56%	1150.05	12:00	Service connection at 1150.51ft. The 26% RW defect was reported as AOI#2 in the preliminary report. This location was excavated and cut out. Considerable external corrosion was observed, possibly due to the nearby water service connection (10" away). RFYeager Engineering measured the max pit depth 0.230" (82% wall loss based on a 0.280" nominal thickness). PICA's reported sizing of 26% RW is within the standard reporting error margin. The 56% RW defect is reported with lower confidence due to the overlapping wall gain signal effect of the service connection collar.
0700	1153.30	1171.68	18.38	0.28	107%	94%	117%							
0710	1171.68	1190.09	18.41	0.28	92%	89%	97%							
0720	1190.09	1208.66	18.58	0.28	93%	90%	97%							
0730	1208.66	1227.19	18.52	0.28	97%	94%	105%							
0740	1227.19	1245.81	18.62	0.28	97%	92%	107%							
0750	1245.81	1264.23	18.42	0.28	92%	85%	101%	12%	1255.51	5:30				Service connection at 1256.86ft.
0760	1264.23	1273.65	9.42	0.28	90%	90%	91%							
0770	1273.65	1282.85	9.19	0.28	91%	90%	91%							
0780	1282.85	1292.13	9.28	0.28	92%	91%	93%							
0790	1292.13	1310.33	18.20	0.28	103%	94%	117%							
0800	1310.33	1328.61	18.28	0.28	103%	98%	116%	70%	1323.63	3:00				
0810	1328.61	1346.87	18.26	0.28	98%	92%	112%	52%	1338.36	11:30	59%	1338.98	6:00	
0820	1346.87	1365.41	18.54	0.28	107%	99%	111%							
0830	1365.41	1382.61	17.20	0.28	102%	99%	104%							
0840	1382.61	1401.15	18.53	0.28	103%	99%	111%							Service connection at 1397.75ft.
0850	1401.15	1410.40	9.25	0.28	91%	90%	92%							
0860	1410.40	1428.84	18.44	0.28	107%	104%	113%							
0870	1428.84	1447.37	18.53	0.28	94%	90%	104%							
0880	1447.37	1465.52	18.15	0.28	85%	82%	93%	28%	1463.43	10:30	40%	1451.87	2:00	
0890	1465.52	1483.88	18.36	0.28	85%	82%	100%	41%	1482.25	11:00				
0900	1483.88	1493.24	9.36	0.28	88%	87%	90%							
0910	1493.24	1511.54	18.30	0.28	90%	84%	104%							
0920	1511.54	1530.26	18.72	0.28	88%	87%	90%							Service connection at 1515.66ft.
0930	1530.26	1548.81	18.55	0.28	85%	71%	90%							Hydrant tee (hot tap) at 1541.98ft, 9:00.
0940	1548.81	1567.42	18.62	0.28	85%	82%	91%	19%	1559.47	10:30				
0950	1567.42	1585.97	18.54	0.28	87%	82%	100%	47%	1578.04	10:00				
0960	1585.97	1604.23	18.26	0.28	87%	82%	93%							
0970	1604.23	1622.79	18.56	0.28	95%	87%	107%	32%	1616.60	11:00				2" Blow Off at 1618.80ft, 7:00.
0980	1622.79	1627.87	5.08	0.28	100%	100%	101%							
CF	1627.87	1628.83	0.95	N/A	N/A	N/A	N/A							Suspected tee.
0990	1628.83	1642.24	13.41	0.28	100%	95%	111%							2" Blow Off at 1635.76ft, 7:00.
1000	1642.24	1660.86	18.63	0.28	110%	102%	114%							
1010	1660.86	1679.00	18.14	0.28	84%	82%	97%							
1020	1679.00	1697.66	18.66	0.28	83%	79%	92%	0%	1695.22	10:00	24%	1693.76	10:30	The through-hole (0% RW) defect was reported as AOI #1 in the preliminary report. This defect developed a leak when the line was filled and pressurized after the RFT inspection. The polyethylene wrap was found to be in good condition and no OD corrosion deposits were observed. This segment was cut out and replaced since the inspection.
1030	1697.66	1716.10	18.44	0.28	90%	86%	98%	23%	1711.15	12:30				

*Pipes with 60% or less wall thickness remaining highlighted in orange.

1040	1716.10	1734.29	18.19	0.28	98%	96%	103%	14%	1733.15	12:00				
1050	1734.29	1752.81	18.52	0.28	86%	79%	102%	37%	1740.86	2:00	59%	1740.95	10:30	Service connection at 1740.38ft.
1060	1752.81	1771.55	18.74	0.28	85%	82%	91%	44%	1758.97	1:00				
1070	1771.55	1790.25	18.69	0.28	88%	83%	93%							
1080	1790.25	1808.39	18.14	0.28	87%	82%	93%							
1090	1808.39	1826.98	18.59	0.28	92%	88%	102%							
1100	1826.98	1845.67	18.69	0.28	85%	80%	95%							
1110	1845.67	1864.15	18.48	0.28	106%	102%	111%							
1120	1864.15	1882.60	18.46	0.28	109%	102%	122%							Service connection at 1870.13ft.
1130	1882.60	1901.07	18.46	0.28	94%	92%	100%							
1140	1901.07	1919.70	18.63	0.28	96%	91%	111%							
1150	1919.70	1938.36	18.65	0.28	86%	83%	97%	65%	1929.87	5:00				
1160	1938.36	1957.00	18.64	0.28	87%	73%	99%							Hydrant tee (hot tap) at 1949.08ft, 9:00
1170	1957.00	1975.57	18.57	0.28	90%	85%	103%							Service connection at 1962.53ft.
1180	1975.57	1993.66	18.09	0.28	101%	92%	114%							
1190	1993.66	2002.84	9.18	0.28	94%	91%	99%							
1200	2002.84	2021.35	18.50	0.28	87%	81%	95%							
1210	2021.35	2030.58	9.23	0.28	89%	88%	91%							
1220	2030.58	2039.69	9.11	0.28	90%	89%	91%							
1230	2039.69	2057.80	18.11	0.28	97%	91%	109%	65%	2056.34	11:00				
1240	2057.80	2058.98	1.18	0.28	N/A	N/A	N/A							Partially inspected pipe. The last datum is at the cut end within the excavation near the reservoir.

*Pipes with 60% or less wall thickness remaining highlighted in orange.

Infrastructure
ENGINEERING CORPORATION

SHEET NO. 01 OF 3

PROJECT High Point Waterline CLIENT VWD

ENGINEER Viet Vo DATE 3/11/2020 JOB NO.

SUBJECT Ductile Iron Pipe Thickness Design (Pressure)

$$t = \frac{P_i D}{2S}$$ (AWWA C150-14, Eq 1)

where

t = net thickness, in

P_i = design internal pressure, psi = $2(P_w + P_s)$

P_w = working pressure, psi

P_s = surge allowance, psi. typ 100 psi

D = outside diameter, in. (13.20 in for 12 in pipe)

S = min yield strength, psi. (42,000 psi)

For pipe on Woodland Heights Glen:

- 12" CL 350 DIP, Nominal thickness t_n = 0.28 in

Check thickness t:

Assume working pressure P_w = 150 psi

$$t = \frac{2(150 + 100)\text{ psi} \times 13.20\text{ in}}{2(42000\text{ psi})}$$

$$t = 0.079\text{ in}$$

Add service allowance of 0.08 in (AWWA C150)

$$t_{min} = 0.08\text{ in} + 0.079\text{ in} = 0.159\text{ in}$$

$$\text{Min Remaining Wall \%} = \frac{t_{min}}{t_n} = \frac{0.159}{0.280} = 56.8\%$$

Infrastructure
ENGINEERING CORPORATION

SHEET NO. 2 OF 3

PROJECT: HIGH POINT WATERLINE
CLIENT: VWD
ENGINEER: VIET VO
DATE: 3/11/2020
JOB NO.
SUBJECT: DUCTILE IRON PIPE THICKNESS DESIGN (TRENCH LOAD)

TRENCH LOAD CHECK:

Trench Load P_V for 12-in pipe

@ 3.5 ft depth of cover, $P_V = 7.7$

@ 5 ft depth of cover, $P_V = 7.1$

(TABLE 1, AWWA C150)

LAYING CONDITION (TABLE 2, AWWA C150)

Assume type 3 (4-in bed, loose soil, backfill lightly consolidated to top of pipe)

Use $P_V = 7.7$ (more conservative)

For $P_V = 7.7$, $D/t = 182$ (TABLE 9, AWWA C150)

$$t = \frac{D}{(D/t)} = \frac{13.20 \text{ in}}{182} = 0.073 \text{ in}$$

Add service allowance of 0.08 in (AWWA C150)

$$t_{min} = t + 0.08 = 0.153 \text{ in}$$

$$\text{min remaining wall \%} = \frac{t_{min}}{t_n} = \frac{0.153}{0.280}$$

min remain wall % = 54.6%

PROJECT: HIGH POINT WATERLINE
CLIENT: UWD
ENGINEER: VIET VO
DATE: 3/11/20
JOB NO.
SUBJECT: DIP THICKNESS DESIGN (DEFLECTION)

DEFLECTION CHECK

Use $P_v = 7.7$, D/t_1 deflection check = 200

Min thickness $t_1 = D/(D/t_1) = \frac{13.20}{200}$

$t_1 = 0.066$ in

Add service allowance of 0.08 in

$t_{min} = 0.146$ in

Min remain wall % $= \frac{t_{min}}{t_n} = \frac{0.146 \text{ in}}{0.280 \text{ in}}$

Min remain wall % = 52.1 %

Summary: Design calculations:

Pressure min wall % = 56.8%
Trench Load min wall % = 54.6%
Deflection min wall % = 52.1%

Highest wall thickness governs ∴ use pressure design

min wall % = 56.8%

round to closest 10%

Min allowable wall thickness

60%