Condition Investigations of HDPE Pipe In-Service In the United States (Six States)

for

The American Concrete Pipe Association

Irving, Texas

WJE No. 991592

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EXECUTIVE SUMMARY

This study consisted of inspecting 39 High Density Polyethylene (HDPE) Pipes located in 6 different states. The diameters of the pipes ranged from 28 to 60-in. The inspections consisted of diameter measurements, distress documentation, alignment measurements, and still and video photography. The tables below present a list of the pipes inspected by state. The state names have been omitted in this report at the request of the American Concrete Pipe Association (ACPA) in respect for the states that assisted in identifying the HDPE pipe locations. Pipe deflection, distress, and misalignment problems are listed. If the pipe had deflections greater than 5% then a "yes" was entered in the pipe deflection column, and the percent of total pipe deflection measurements greater than 5% is shown in the parenthesis. If buckling (swelling), bulging, or cracking was apparent in the pipe then a "yes" was entered . If the pipe had joint separations that exceed 1-in. or if the misalignment of the pipe was apparent then a "yes" was entered in the appropriate column. Also, the pipes that were installed as test or pilot installations are identified in the table.

Table 1: Pipe Summary - State 1

Pipe #	Diameter (in)	Year	Pipe Deflection (>5%)	Buckling, Cracking, Bulging	Joint Separation	Test Installation	Misalignment
1	36	1992	Yes (11%)	Yes	Yes	No	No
2	60	1995	Yes (13%)	No	Yes	No	Yes
3	42	1996	Yes (7%)	No	Yes	No	Yes
4	30	1998	Yes (9%)	Yes	No	No	No
5	30	1997	Yes (2%)	Yes	Yes	No	No
6	48	1999	Yes (23%)	Yes	Yes	No	No
7	42	1992	Yes (15%)	Yes	No	No	No
8	42	1999	Yes (35%)	Yes	Yes	No	No
9	42	1994	Yes (28%)	Yes	Yes	No	No
10	48	1999	Yes (32%)	Yes	Yes	No	No
11	42	1999	Yes (30%)	No	Yes	No	Yes
12	48	1999	Yes (13%)	Yes	Yes	No	No
13	42	1999	Yes (39%)	Yes	Yes	No	Yes

Table 2: Pipe Summary - State 2

Pipe #	Diameter (in)	Year	Pipe Deflection (>5%)	Buckling, Cracking, Bulging	Joint Separation	Test Installation	Misalignment
1	48	1999	Yes (9%)	Yes	Yes	No	Yes
2	36	1997	Yes (10%)	No	Yes	No	Yes
3	36	1997	No	Yes	Yes	No	Yes
4	30	1998	No	Yes	Yes	No	No
5	48	1998	Yes (7%)	Yes	No	No	No
6	60	1996	Yes (28%)	Yes	Yes	No	No
7	60	1996	Yes (2%)	Yes	Yes	No	Yes

Table 3: Pipe Summary - State 3

Pipe #	Diameter (in)	Year	Pipe Deflection (>5%)	Buckling, Cracking, Bulging	Joint Separation	Test Installation	Misalignment
1	54	1996	No	No	Yes	Yes	No
2	48	1998	No	No	No	No	No
3	42	1994	Yes (18%)	Yes	No	No	Yes
4	30	1991	Yes (30%)	No	Yes	No	Yes

Table 4: Pipe Summary - State 4

Pipe #	Diameter (in)	Year	Pipe Deflection (>5%)	Buckling, Cracking, Bulging	Joint Separation	Test Installation	Misalignment
1	42	1997	No	No	Yes	Yes	No
2	42	1997	No	No	Yes	Yes	No
3	48	1998	No	No	Yes	No	No
4	36	1998	Yes (25%)	No	Yes	No	Yes
5	36	1998	Yes (18%)	No	Yes	No	Yes
6	30	1987	Yes (8%)	Yes	Yes	No	Yes

Table 5: Pipe Summary - State 5

Pipe #	Diameter (in)	Year	Pipe Deflection (>5%)	Buckling, Cracking, Bulging	Joint Separation	Test Installation	Misalignment
1	48	1996	No	Yes	No	Yes	Yes
2	36	1996	No	No	No	No	No
3	30	1996	Yes (6%)	Yes	Yes	No	Yes
4	36	1989	Yes (4%)	Yes	Yes	Yes	Yes

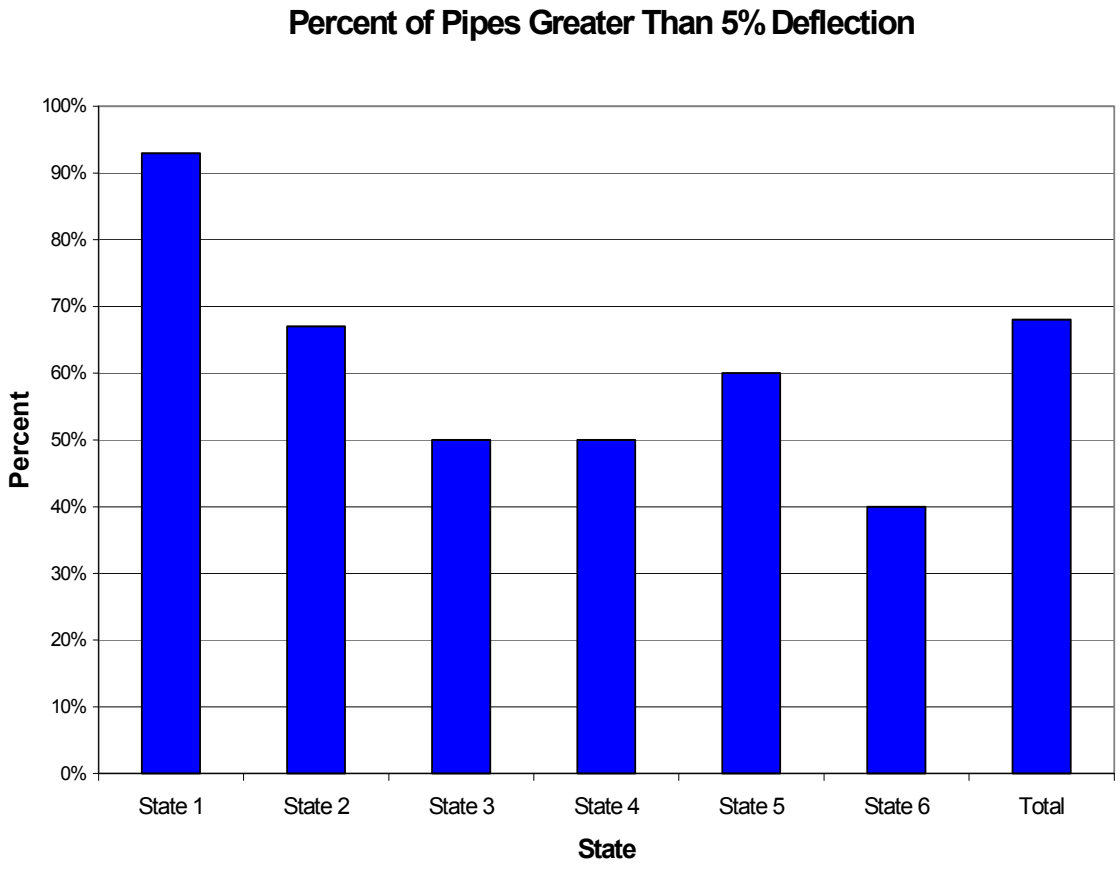
Table 6: Pipe Summary - State 6

Pipe #	Diameter (in)	Year	Pipe Deflection (>5%)	Buckling, Cracking, Bulging	Joint Separation	Test Installation	Misalignment
1	30	1992	Yes (4%)	Yes	Yes	No	No
2	24	1999	No	No	No	No	No
3	36	1999	No	No	Yes	No	No
4	30	19981999	No	Yes	No	No	No
5	42	1999	Yes (45%)	Yes	No	No	No

Twenty-nine out of 39 pipes (74%) had joint separations greater than 1-in. Twenty-seven pipes (69%) had deflections greater than 5%. Twenty-four of the pipes (62%) had developed buckling, crackling, or bulging. Sixteen of the pipes (41%) had noticeable misalignment.

Of the 27 pipes that exhibited deflections greater than 5%, seventy-four percent (20 pipes) also had cracking or buckling. Thus, twenty-six percent (7 pipes) of the pipes with deflections greater than 5% had no cracking or buckling. These pipes had few deflections greater than 7.5% .

The following chart shows the percent of pipes that had deflections greater than 5%, by state and overall.

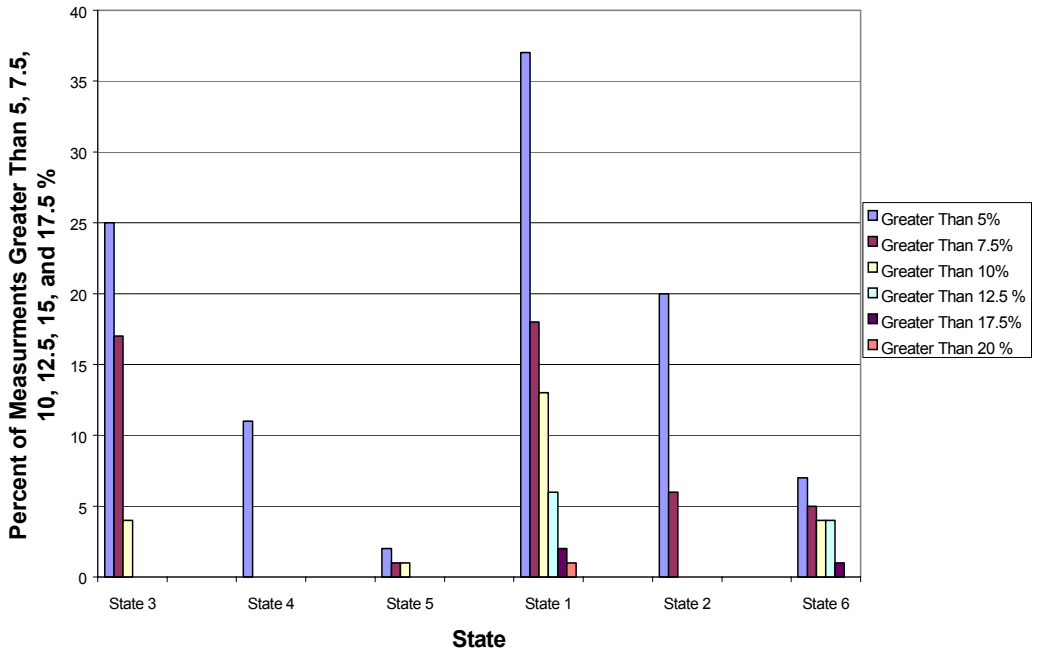


Of all the pipes inspected, 68% of the pipes had deflections greater than 5%, with State 6 having the least with 40% and State 1 having the highest with 93%.

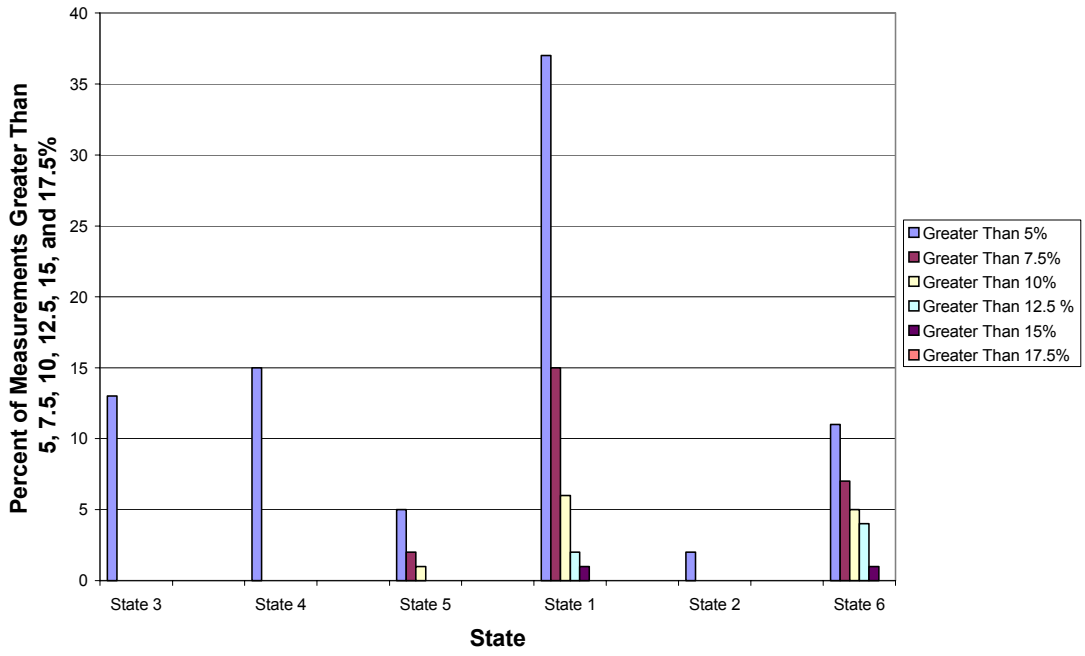
The deflection measurement data for all the pipes in each state is summarized in the following charts. The horizontal and vertical measurements are shown on separate charts. Each bar in the chart represents the percent of all measurements that have a deflection percent greater than or equal to 5 %, 7.5%, 10 %, 15% and 17.5%.

Approximately 18% of all horizontal and 16% of vertical diameter measurements exceed the 5% deflection criteria. Less than 5% of the 45° and 135° measurements exceed the 5% deflection criteria.

Summary of Horizontal Deflection Measurements by State



Summary of Vertical Deflection Measurements by State



INSPECTION OF HIGH DENSITY POLYETHYLENE PIPES FOR THE AMERICAN CONCRETE PIPE ASSOCIATION IRVING, TEXAS WJE No. 991592

BACKGROUND

In the spring of 2000, Wiss, Janney, Elstner Associates, Inc. (WJE) was contracted by the American Concrete Pipe Association (ACPA) to study HDPE piping systems in selected states throughout the United States. The goal of this study was to inspect and evaluate HDPE pipe performance under a variety of installation conditions. Determination of the causes of distress was not investigated. The focal point of the study is pipe of 30-in. diameter and greater, and pipes used in culvert/cross drain applications. The scope of work involves inspecting and documenting pipes in six different states.

In each state, the pipe locations were found by contacting the states Departments of Transportation or similar department. Due to the difficulty in finding pipe locations, every location provided by each state was inspected.

INSPECTION PROTOCOL

The inspection protocol for each installation included the following four tasks: (a) diameter measurements, (b) still and video photography, (c) alignment measurements and (d) distress documentation.

Diameter measurements - Diameter measurements were typically made every 5-ft. along the length of the pipe starting at the inlet of the pipes. At each measurement location, the vertical, horizontal, and each 45-degree angle diameters were measured. The diameters were measured to the nearest 1/8-in. with internal diameter measuring equipment. All measurements were recorded on field data sheets. ASTM D 2412 allows up to 5 % deflection tolerance in the diameter of the pipe. This 5 % tolerance was used as the deflection criteria. The percent deflection is based on the nominal diameter of the pipe.

Still and video photography - Any areas of distress inside the pipes, such as buckling, cracking, and joint separation and misalignment was photographed. Photographs were taken of the site conditions and surrounding area. All photographs were documented, detailing the location of picture and picture description. The entire length of each pipe was videotaped highlighting any areas of distress.

Alignment measurements - A laser level was set up at the end of the pipes (either the inlet or outlet), and the distance from the crown of the pipe to the level was measured. Measurements were than taken from the crown of the pipe every 5-ft. along the length of the pipe.

Distress documentation - All areas of distress were recorded emphasizing location and type of distress. The types of distress encountered were as follows: joint separation, exfiltration or infiltration at joints, wall buckling, cracking, horizontal and vertical misalignment, bulging and swelling of the pipe, undermining, and pipe deflection. All joints and pipe sections were labeled in ascending order starting from the inlet of the pipe, unless noted.

ANALYSIS OF DATA

During the inspections, the diameter measurements, alignment measurements, and distress documentation was recorded on data sheets. These data sheets have been compiled in an Appendix that has been bound separately and is available upon request. Pertinent information in the appendices has been reproduced in this report.

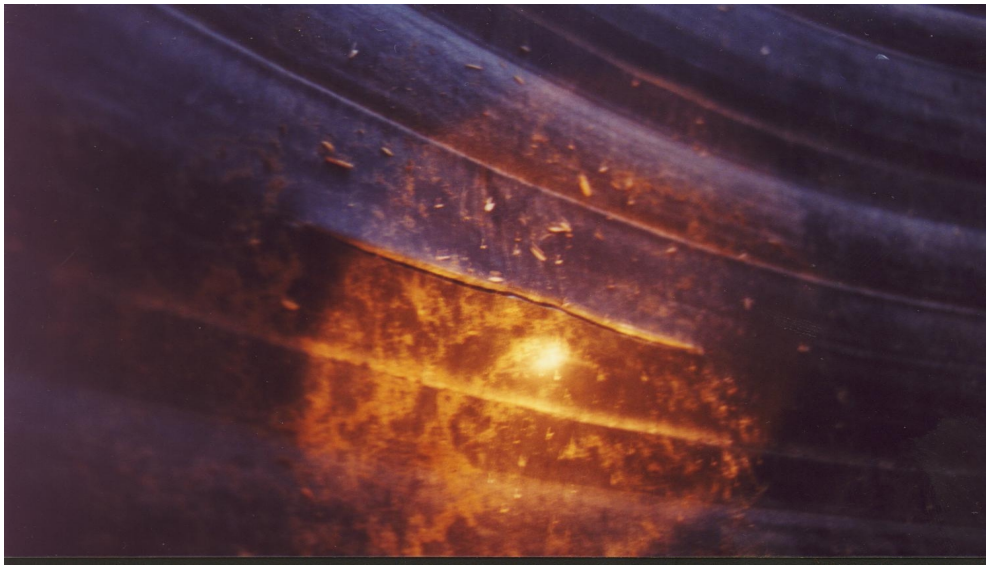
Deflection calculations were performed with all the diameter measurements, and the percent deflection of each measurement was calculated. The nominal diameter of the pipes was used to calculate the deflections of the pipes. These calculations can be found in the Appendix and most are also presented below in the Inspection Findings section of this document. All percent deflections greater than or equal to 5% are highlighted in bold print.

Vertical alignment measurements were typically taken at 5-ft intervals along the length of the pipe. The measurements were used to chart the grade of the pipe.

STATE 1 INSPECTION FINDINGS

The following sections will present the highlights of each individual pipe inspection, and in some cases the diameter measurements, photographs and alignment graphs are presented.

Pipe 1 - This 36-in diameter pipe was installed in 1992 and has a maximum depth of cover of 5-ft. A swell in the pipe is present from 37-ft to 42-ft, where water is ponding. A 7-in long crack has also formed at 38-ft. From 40-ft to 55-ft, the deflection of the pipe is easily noticed (see picture below). Wall buckling (rippling) has occurred from 37-ft to 39-ft at about 270 degrees. Joint separations range from 1 1/2-in to 2-in.



Crack in pipe at 38-ft – Pipe 1

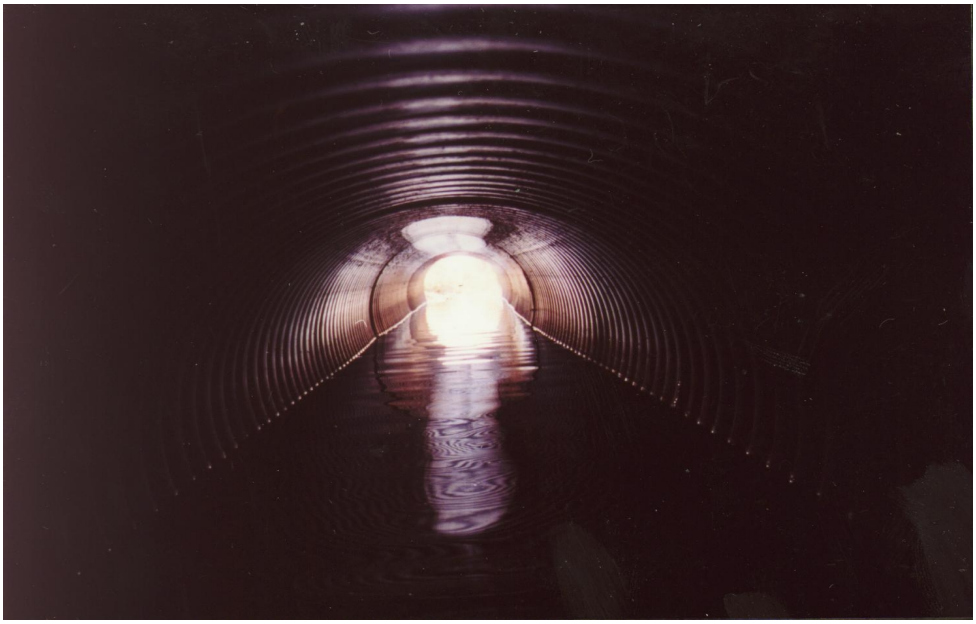
Obvious deflection of the pipe- Pipe 1

Diameter measurements were taken every 5-ft along the 60-ft of pipe. Eleven percent of the deflections exceed 5%, all occurring in the vertical and horizontal directions.

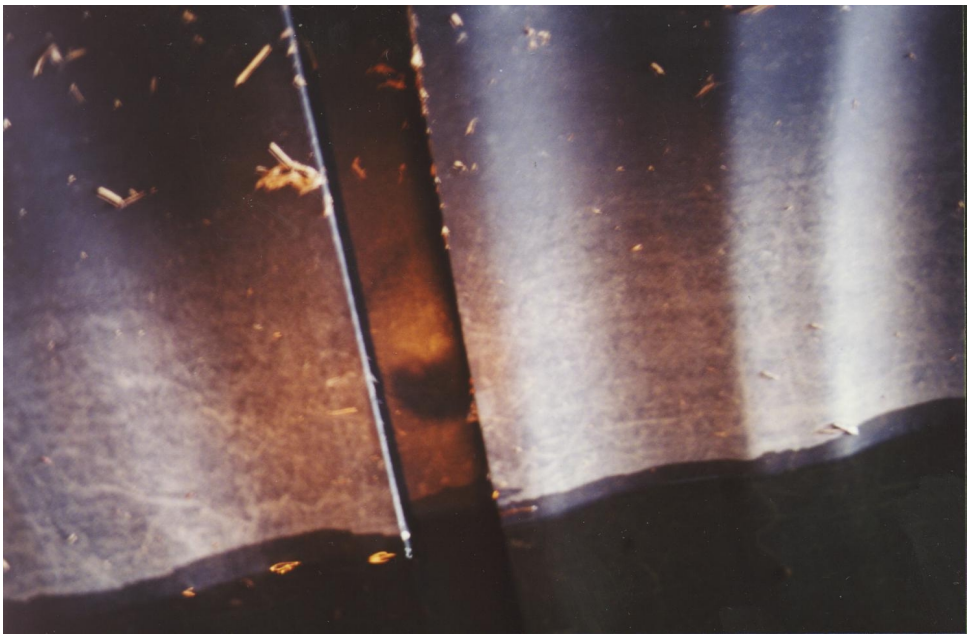
	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	35.38	35.25	36.50	35.75	1.74	2.08	1.39	0.69
5	35.63	36.25	37.00	36.75	1.04	0.69	2.78	2.08
10	35.75	36.13	36.63	36.50	0.69	0.35	1.74	1.39
15	35.50	36.50	36.88	36.50	1.39	1.39	2.43	1.39
20	35.63	36.63	37.25	36.75	1.04	1.74	3.47	2.08
25	35.50	36.63	37.00	36.75	1.39	1.74	2.78	2.08
30	35.50	36.88	37.13	36.63	1.39	2.43	3.13	1.74
35	35.38	36.50	37.25	36.63	1.74	1.39	3.47	1.74
40	34.13	37.25	38.50	37.38	**5.21**	3.47	**6.94**	3.82
45	34.38	36.88	37.75	36.88	4.51	2.43	4.86	2.43
50	31.75	37.50	40.13	36.75	**11.81**	4.17	**11.46**	2.08
55	31.75	37.00	40.00	37.25	**11.81**	2.78	**11.11**	3.47
60	35.00	35.88	37.25	37.50	2.78	0.35	3.47	4.17
	% of Measurements above Tolerance				*23.07*	*0*	*23.01*	*0*

Pipe 2 - This pipe was installed in 1995. The pipe is 75-ft long and has a diameter of 60-in. At the time of inspection, the pipe had 7 to 10 inches for water in it and had about 3 to 4 inches of soil deposits on the bottom of the pipe. Therefore, no vertical diameter measurements were taken. Significant joint separations have occurred at all joints. The following table summarizes the joint separations.

Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
1	1.5	2.0	1/2-in drop off
2	1.0	4.0	Repair patch near bottom of pipe
3	1.75	3.5	



Profile of pipe – Pipe 2

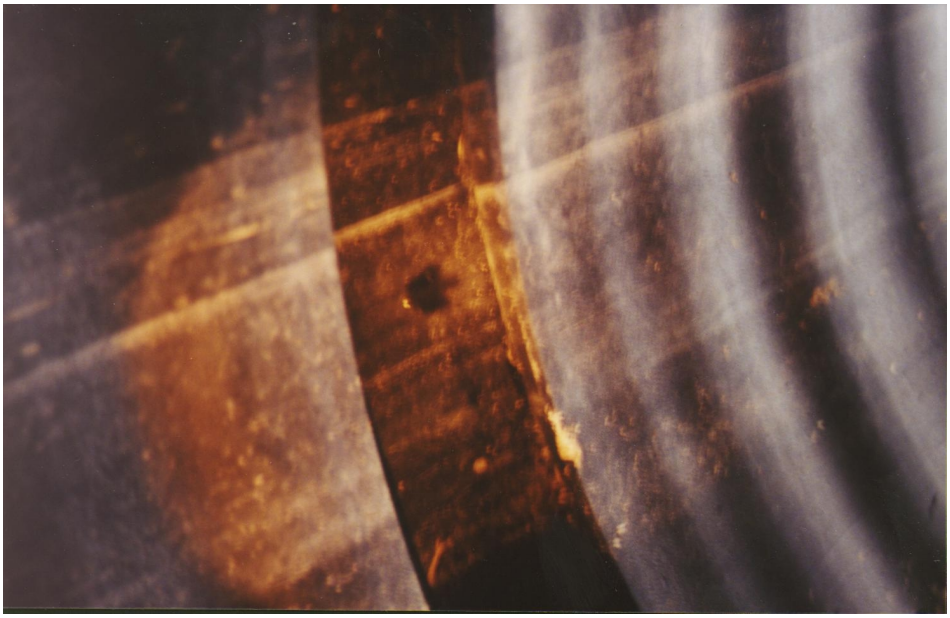


Separation at Joint 1 – Pipe 2

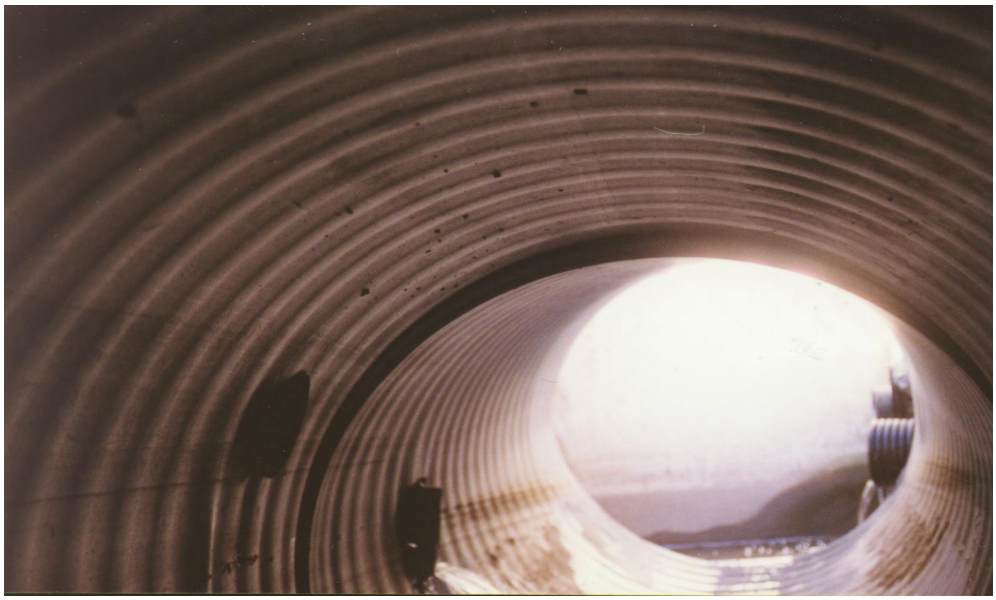
Diameter measurements were taken every 5-ft along the length of the pipe, except no vertical diameters were measured. Thirteen percent of the deflection calculations exceed the 5% criteria, all occurring in the horizontal diameter measurements.

	Diameter			***% Deflection***		
	(45-225)	(90-270)	(135-315)	(45-225)	(90-270)	(135-315)
0	57.50	59.38	59.00	4.17	1.04	1.67
5	58.75	62.50	60.25	2.08	4.17	0.42
10	59.50	62.25	59.75	0.83	3.75	0.42
15	60.75	62.50	60.00	1.25	4.17	0.00
20	59.88	64.25	60.00	0.21	**7.08**	0.00
25	59.88	63.25	59.50	0.21	**5.42**	0.83
30	59.25	60.75	59.75	1.25	1.25	0.42
35	60.00	60.25	59.88	0.00	0.42	0.21
40	59.75	61.25	60.00	0.42	2.08	0.00
45	60.50	60.75	60.50	0.83	1.25	0.83
50	61.25	60.75	60.50	2.08	1.25	0.83
55	60.25	63.25	61.75	0.42	**5.42**	2.92
60	60.25	63.75	60.50	0.42	**6.25**	0.83
65	60.38	64.00	60.50	0.63	**6.67**	0.83
70	59.75	64.50	62.25	0.42	**7.50**	3.75
75	60.88	61.50	60.75	1.46	2.50	1.25
	% of Measurements above Tolerance			*0*	*37.5*	*0*

Pipe 3 - This 42-in. diameter pipe was installed in 1996. The pipe is 70-ft. long and has approximately 5-ft. of cover. This pipe is a storm drain that empties from a concrete box culvert. Separations as large as 5 1/2-in have developed at the joints (see picture below). There is a 2-in. drop from pipe 3 to 4 (see picture below). No other areas of distress were found.



5 1/2 -in separation at Joint 3 – Pipe 3

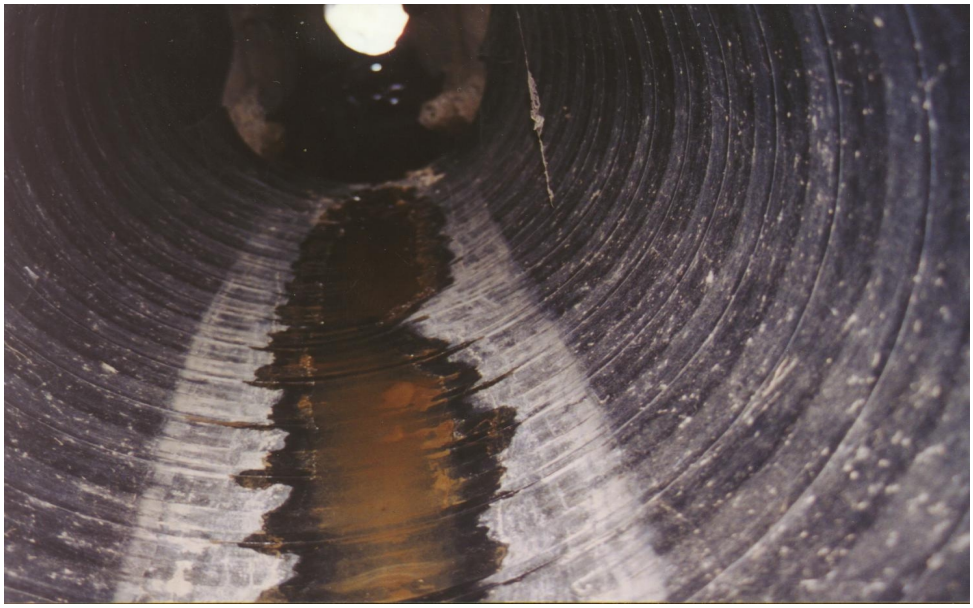


Two-inch drop – Pipe 3

Diameter measurements were taken every 5-ft. along the 70-ft. of pipe. Seven percent of the deflection measurements exceeded 5%, with most occurring in the horizontal direction.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	40.25	42.38	44.00	42.25	4.17	0.89	4.76	0.60
5	39.50	43.25	45.00	42.75	**5.95**	2.98	**7.14**	1.79
10	40.38	42.88	44.25	43.50	3.87	2.08	**5.36**	3.57
15	40.75	42.50	43.25	42.38	2.98	1.19	2.98	0.89
20	41.88	42.25	44.50	42.75	0.30	0.60	**5.95**	1.79
25	41.50	42.38	42.88	42.50	1.19	0.89	2.08	1.19
30	42.00	42.38	42.50	42.25	0.00	0.89	1.19	0.60
35	42.25	42.38	42.25	42.63	0.60	0.89	0.60	1.49
40	41.88	42.38	42.25	42.00	0.30	0.89	0.60	0.00
45	42.00	42.25	42.88	42.25	0.00	0.60	2.08	0.60
50	42.13	42.38	42.50	42.25	0.30	0.89	1.19	0.60
55	42.25	42.25	42.75	42.13	0.60	0.60	1.79	0.30
60	41.38	42.00	42.75	42.75	1.49	0.00	1.79	1.79
65	41.75	43.00	42.75	41.88	0.60	2.38	1.79	0.30
70	42.88	42.50	42.25	42.50	2.08	1.19	0.60	1.19
	% of Measurements above Tolerance				***6.67***	***0***	***20***	***0***

Pipe 4 - This pipe was installed in 1998. The pipe consists of two 15-ft. lengths of pipe that are connected by a 40-ft. concrete pipe. The pipe has a diameter of 30-in, and the depth of cover is about 4-ft. Wall buckling has developed on the sidewalls of the south pipe from 12 to 13-ft. In the north pipe, a bulge in the bottom of the pipe is apparent at 10-ft. (see picture below), and a crack was found at 11-ft. extending from 45 to 135 degrees.



Bulge in the bottom of the north pipe – Pipe 4

The following presents the deflection data for the two 15-ft. lengths of pipe. Nine percent of the deflections exceed the 5% criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	29.75	30.25	30.75	30.25	0.83	0.83	2.50	0.83
5	29.75	29.25	30.88	30.38	0.83	2.50	2.92	1.25
10	29.38	30.25	30.25	30.50	2.08	0.83	0.83	1.67
15	28.50	30.25	32.25	30.50	**5.00**	0.83	**7.50**	1.67
	40' concrete culvert in center							
0	30.13	30.38	30.50	30.38	0.42	1.25	1.67	1.25
5	29.25	30.50	31.25	30.13	2.50	1.67	4.17	0.42
10	29.25	30.38	31.75	30.13	2.50	1.25	**5.83**	0.42
15	30.50	30.25	30.13	30.25	1.67	0.83	0.42	0.83
	% of Measurements above Tolerance				*12.5*	*0*	*25*	*0*

Pipe 5 - This pipe was installed in 1997. The pipe is 60-ft. long and has a diameter of 30-in. Separations less than 2-in. have developed in the two joints of this pipe. A crack was found at 10-ft. extending from 80 to 110 degrees. No other areas of distress were found. Only one diameter measurement or 2 % exceeded 5% deflection.

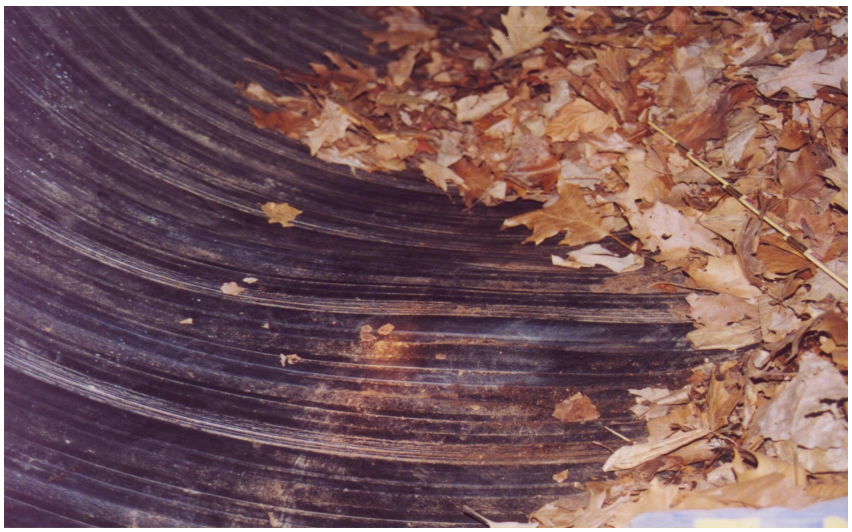
Crack at 10-ft. – Pipe 5

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	29.88	30.50	30.75	30.25	0.42	1.67	2.50	0.83
5	29.75	30.38	30.68	30.50	0.83	1.25	2.25	1.67
10	29.88	30.38	30.88	30.38	0.42	1.25	2.92	1.25
15	29.25	30.38	31.00	30.25	2.50	1.25	3.33	0.83
20	29.00	30.38	31.25	30.50	3.33	1.25	4.17	1.67
25	29.63	30.38	31.00	30.50	1.25	1.25	3.33	1.67
30	29.50	30.00	31.00	31.75	1.67	0.00	3.33	**5.83**
35	29.38	30.38	31.13	29.63	2.08	1.25	3.75	1.25
40	29.25	30.50	31.00	30.50	2.50	1.67	3.33	1.67
45	29.25	29.75	30.88	30.50	2.50	0.83	2.92	1.67
50	29.25	30.50	31.00	30.75	2.50	1.67	3.33	2.50
55	29.88	30.13	30.50	30.50	0.42	0.42	1.67	1.67
60	30.38	30.13	30.25	30.38	1.25	0.42	0.83	1.25
	% of Measurements Above Tolerance				*0*	*0*	*0*	*7.69*

Pipe 6 - This 48-in. diameter pipe was installed in 1999. The pipe is 70-ft. long and has a maximum 2-ft. depth of cover. Significant separations have occurred in all the joints.

Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
1	0.0	1.5	Joint repaired/Repair is Bad
2	1.5	2.0	Joint repaired/Repair is Bad
3	2.5	2.0	

Three bulges have developed in the bottom of this pipe, at 12, 34, and 45-ft. Cracks have developed on the tops of these bulges (see picture below). The deflection of the pipe was easily noticed. Twenty-three percent of all the deflection calculations exceeded the 5% criteria. Five percent of the measurements exceeded 10% deflection with a maximum of 15% deflection occurring at 50-ft.



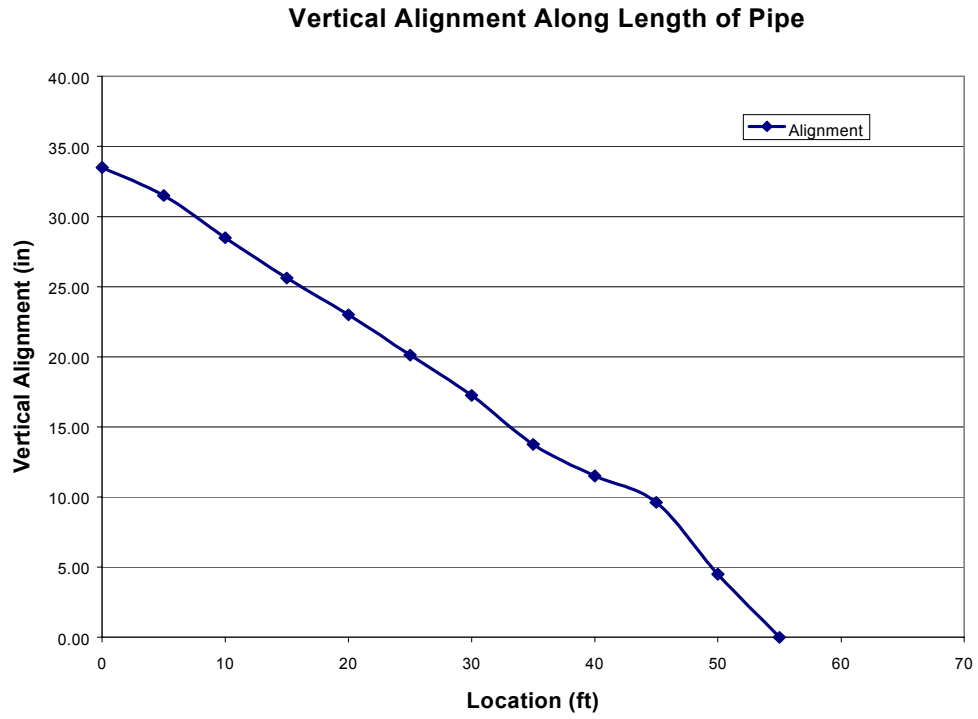
Bulge in bottom of pipe –Pipe 6

Crack on top of the bulge at 34-ft – Pipe 6

Diameter measurements were taken at 5-ft intervals starting at the inlet as shown below. Twenty-five percent of the measurements exceeded the 5% criteria.

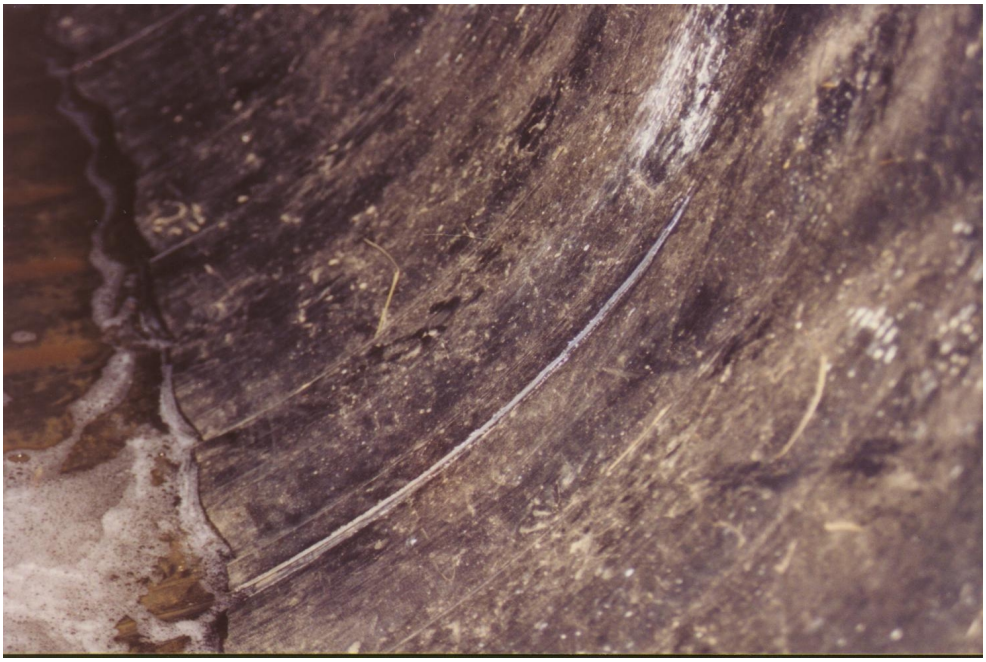
	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	45.75	47.50	48.75	47.25	4.69	1.04	1.56	1.56
5	45.88	46.75	48.50	47.75	4.43	2.60	1.04	0.52
10	45.75	45.50	48.75	48.63	4.69	**5.21**	1.56	1.30
15	45.75	47.50	48.75	46.75	4.69	1.04	1.56	2.60
20	45.00	47.25	49.13	47.00	**6.25**	1.56	2.34	2.08
25	44.50	47.63	49.50	47.25	**7.29**	0.78	3.13	1.56
30	44.25	47.38	49.00	47.75	**7.81**	1.30	2.08	0.52
35	43.00	48.00	51.63	47.50	**10.42**	0.00	**7.55**	1.04
40	44.38	48.25	50.75	47.00	**7.55**	0.52	**5.73**	2.08
45	42.75	47.25	49.38	48.25	**10.94**	1.56	2.86	0.52
50	40.88	46.25	52.50	48.25	**14.84**	3.65	**9.38**	0.52
55	47.63	46.25	51.75	48.00	0.78	3.65	**7.81**	0.00
60	43.25	46.13	50.25	48.50	**9.90**	3.91	4.69	1.04
65	45.00	46.50	48.75	47.75	**6.25**	3.13	1.56	0.52
	% of Measurements above Tolerance				*60*	*7.14*	*26.67*	*0*

The following graph charts the vertical alignment of the pipe. As can be seen from the chart, the grade of the pipe is generally good, with only minor bulges or swells.

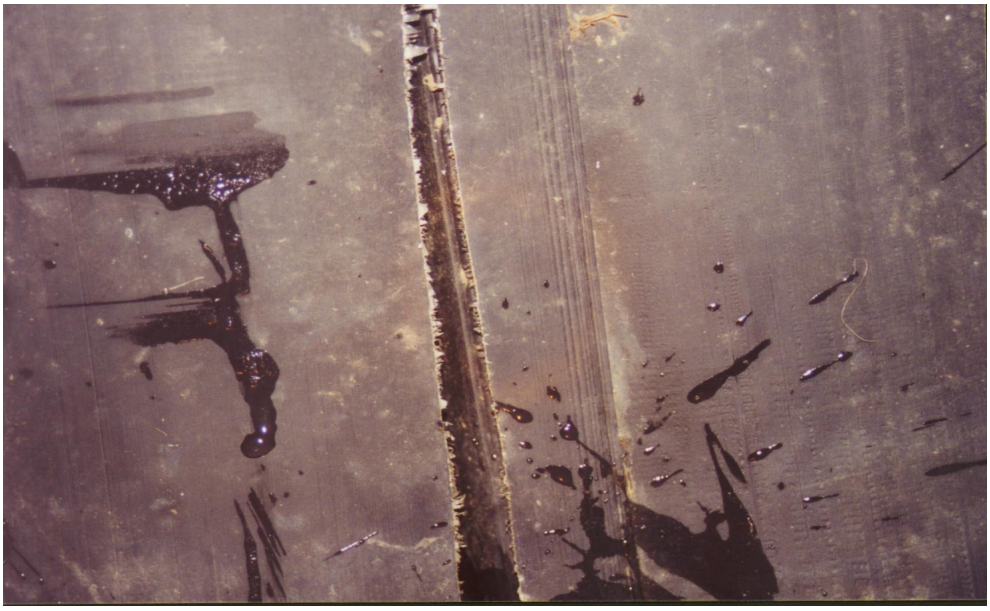


Pipe 7 - This pipe was installed in 1992. The pipe is 20-ft. long and has a diameter of 42-in. A 15-in. drainage pipe drains into this pipe at 10-ft. Rippling of the sidewalls is apparent from 4-fto 15-ft. A bulge has developed at the bottom of the pipe at 8-ft. Numerous cracks have formed in this pipe and are summarized in the chart below.

Location along Pipe (ft)	Length of Crack (in)	Width of Crack (in)
4	24	0.5
7	24	0.75
10	12	Hairline
13	24	Hairline



Crack at 4-ft. – Pipe 7



Crack at 7-ft. – Pipe 7

Bulge at the bottom of the pipe and cracks in the top of the pipe – Pipe 7

The vertical deflection at 10-ft. was found to be 11.6% of the diameter. The rest of the deflection data is presented below. Fifteen percent of the deflection calculations exceed the 5% criteria.

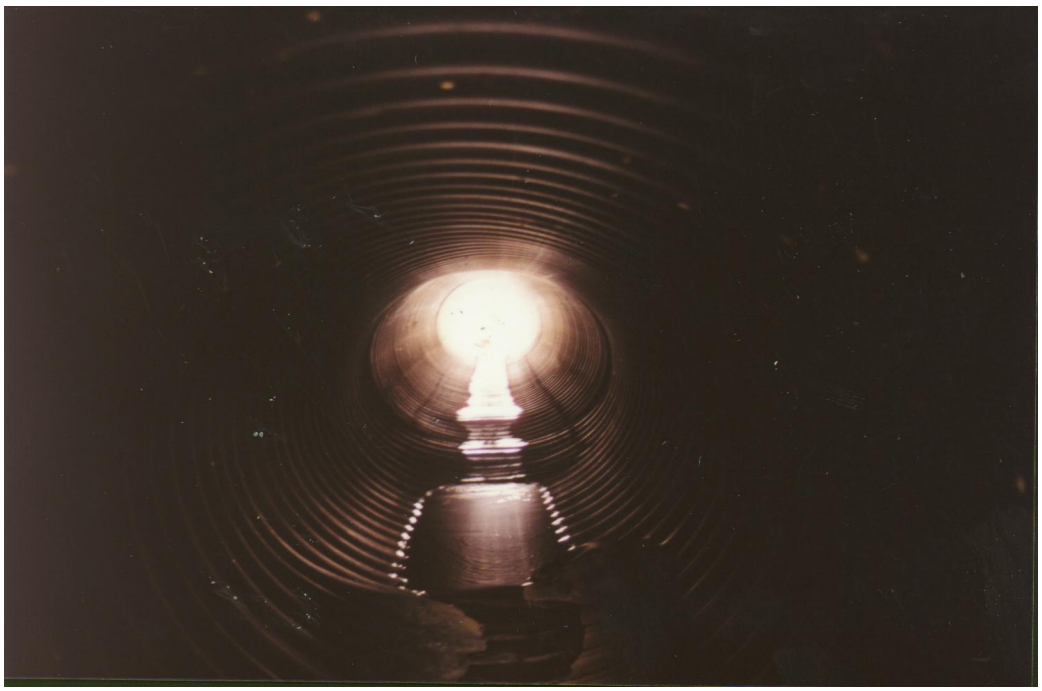
	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	41.00	40.50	41.88	42.38	2.38	3.57	0.30	0.89
5	39.75	41.63	43.25	41.75	**5.36**	0.89	2.98	0.60
10	37.13	41.25	45.50	41.00	**11.61**	1.79	**8.33**	2.38
15	40.63	42.00	42.50	41.25	3.27	0.00	1.19	1.79
20	41.13	41.50	41.88	41.25	2.08	1.19	0.30	1.79
	% of Measurements above Tolerance				*40*	*0*	*20*	*0*

Pipe 8 - This 42-in. diameter pipe was installed in 1999. The pipe is 60-ft. long and has a maximum cover of 3-ft. An obvious bulge and crack has developed in the bottom of the pipe at 10-ft. The bulge elevates the pipe about 3 to 4-in. and has an area of about 1/2-ft^2 (see picture below). Beyond the bulge, a swell in the pipe has occurred, creating ponding of the water. Three wall cracks were found: at 16-ft, 17-ft and 50-ft. The deflection of the pipe was easily noticed. Significant separations of the joints have also occurred.

Bulge and crack in bottom of pipe – Pipe 8

Crack at 50-ft. - Pipe 8

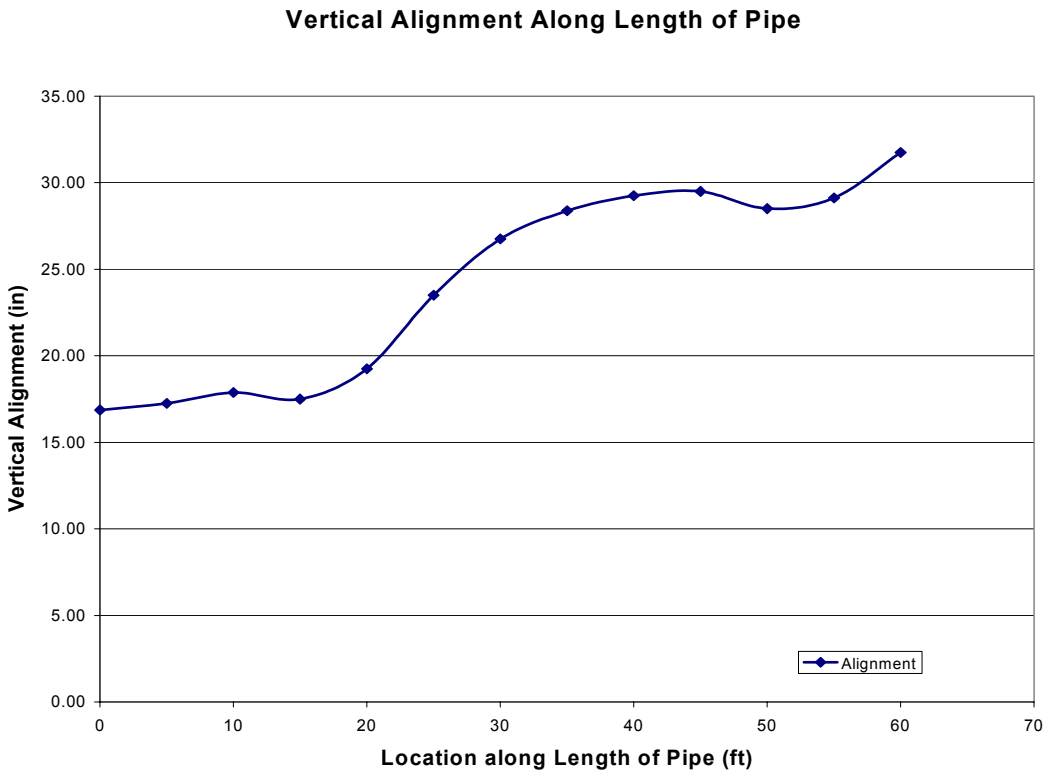
Separation at Joint 1 – Pipe 8



Note oval shape of pipe, swell in bottom of pipe, and bulge – Pipe 8

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	41.88	42.25	42.75	42.25	0.30	0.60	1.79	0.60
5	41.25	42.88	43.13	41.88	1.79	2.08	2.68	0.30
10	39.38	44.25	45.25	41.25	**6.25**	**5.36**	**7.74**	1.79
15	38.88	41.88	44.63	42.88	**7.44**	0.30	**6.25**	2.08
20	36.38	43.88	47.38	44.00	**13.39**	4.46	**12.80**	4.76
25	39.00	42.50	45.25	42.75	**7.14**	1.19	**7.74**	1.79
30	39.88	42.50	44.25	42.50	**5.06**	1.19	**5.36**	1.19
35	40.38	42.75	44.00	42.50	3.87	1.79	4.76	1.19
40	40.50	42.38	44.00	42.25	3.57	0.89	4.76	0.60
45	39.38	42.25	44.75	42.75	**6.25**	0.60	**6.55**	1.79
50	37.25	42.63	46.25	42.88	**11.31**	1.49	**10.12**	2.08
55	39.13	43.50	45.38	42.25	**6.85**	3.57	**8.04**	0.60
	% of Measurements above Tolerance				*66.67*	*8.33*	*66.67*	*0*

Thirty five percent of the deflections exceeded the 5% criteria, with the most deflection occurring in the horizontal and vertical directions. The following chart presents the vertical alignment of the pipe. A significant bulge in the pipe is apparent between 20 and 50-ft. creating two swells on either side of the bulge.



Pipe 9 - This 42-in. diameter pipe was installed in 1994. The pipe is 80-ft. long and has a maximum cover of about 9-ft. A bulge has developed near Joint 1. A total of 10 cracks were found in this pipe as summarized below.

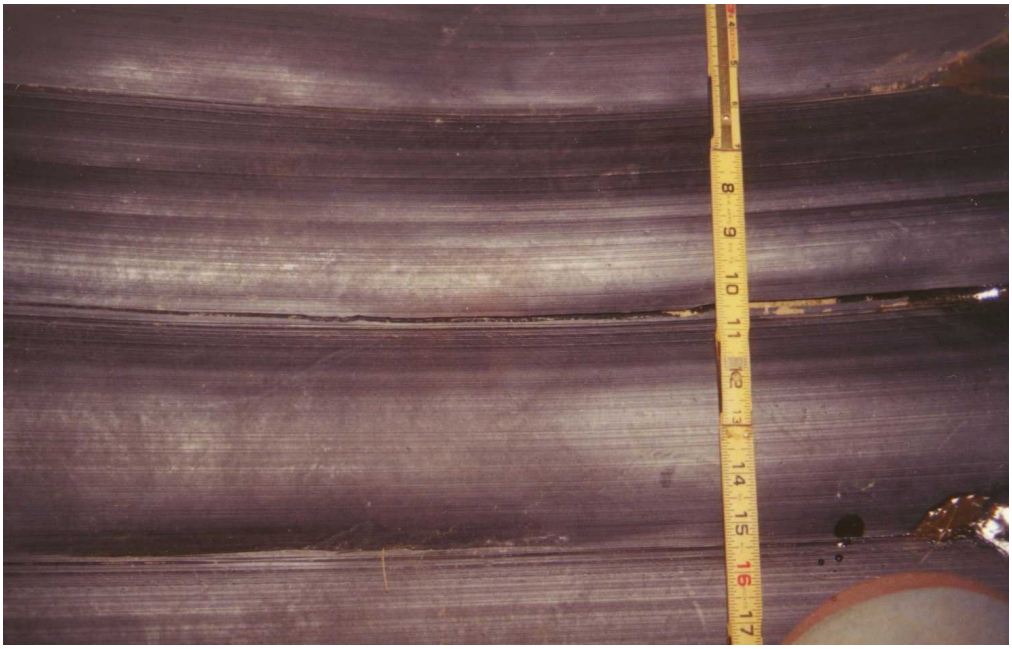
Location of Crack	Length of Crack (in)	Width of Crack (in)
54 '	60	0.5
52 '	2	0.5
59'	30	Hairline
63'	70	Hairline
67'	45	Hairline
68'	3	0.5
70'	60	0.5
73'	50	0.5
75'	30	Hairline
79'	5	Hairline

Separations of the joints ranged from 1 to 3-in. Rippling of the sidewalls is apparent throughout the length of the pipe (see picture).

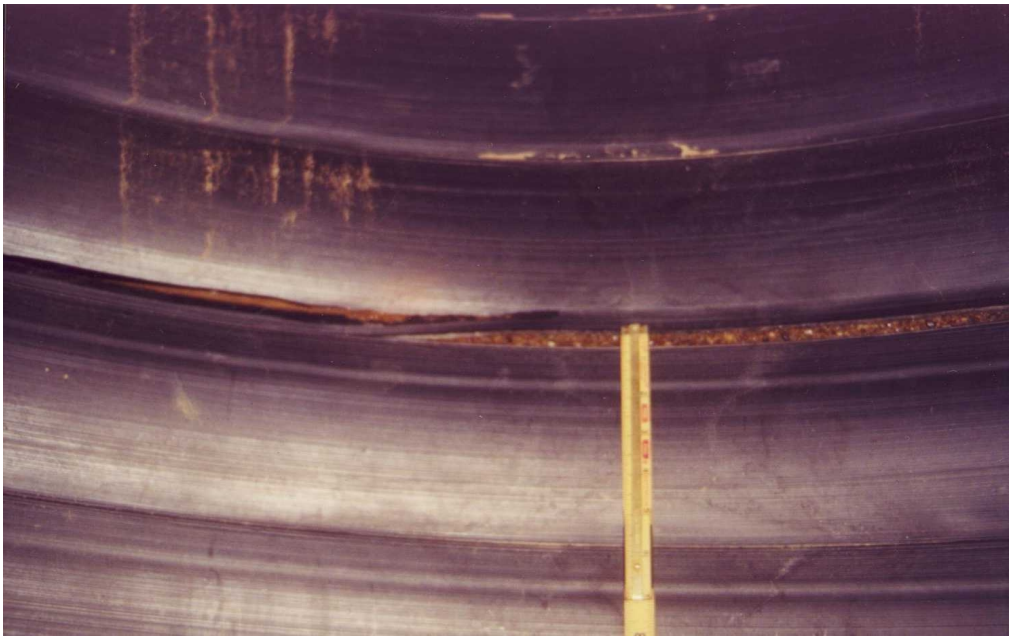
Profile of pipe: Note wall buckling and obvious oval shape – Pipe 9

Rippling of the sidewalls – Pipe 9

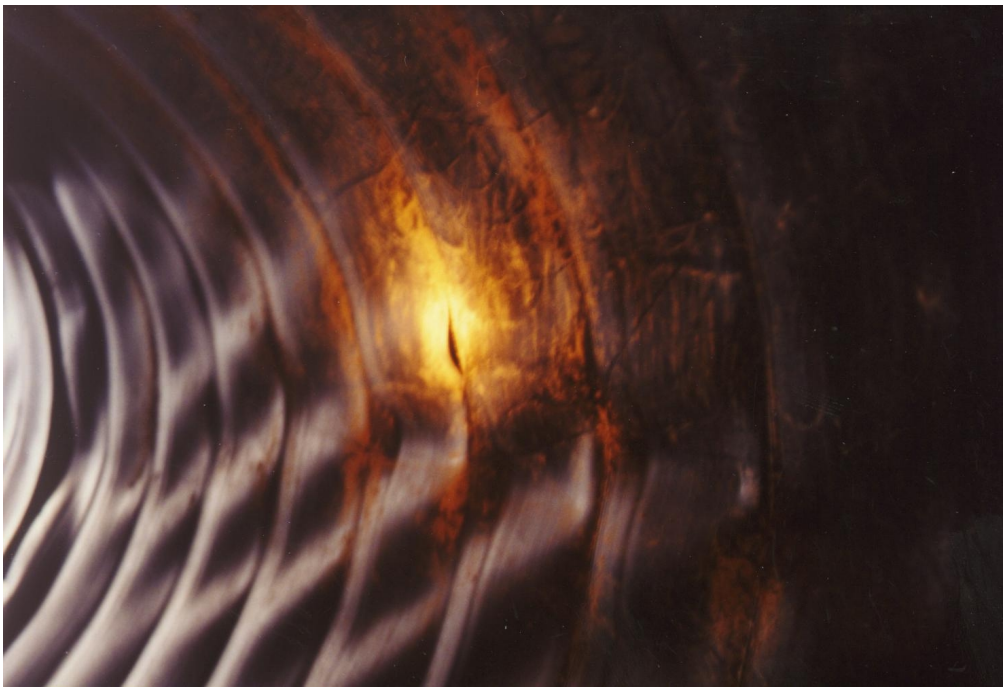
Separation at Joint 1 – Pipe 9



Crack at 63-ft. – Pipe 9



Crack at 75-ft. – Pipe 9



Small crack at 57-ft. Note wall rippling – Pipe 9

Diameter measurements were taken at 5-ft. intervals throughout the pipe. Deflections greater than 10 % occurred at multiple locations. Twenty eight percent of the deflection calculations exceed the 5% criteria, and ten percent of the measurements exceed 10% deflection.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	41.50	41.38	41.25	41.00	1.19	1.49	1.79	2.38
5	41.25	41.63	41.88	41.13	1.79	0.89	0.30	2.08
10	41.25	41.63	42.00	42.13	1.79	0.89	0.00	0.30
15	40.88	41.50	42.25	41.88	2.68	1.19	0.60	0.30
20	40.38	41.00	42.75	41.00	3.87	2.38	1.79	2.38
25	39.50	42.00	43.50	41.38	**5.95**	0.00	3.57	1.49
30	37.75	41.63	44.75	42.00	**10.12**	0.89	**6.55**	0.00
35	38.75	41.75	44.38	42.00	**7.74**	0.60	**5.65**	0.00
40	39.38	40.75	43.50	42.75	**6.25**	2.98	3.57	1.79
45	38.75	40.75	44.63	42.00	**7.74**	2.98	**6.25**	0.00
50	38.13	40.75	44.88	41.75	**9.23**	2.98	**6.85**	0.60
55	41.25	41.25	45.25	42.13	1.79	1.79	**7.74**	0.30
60	36.75	43.50	46.00	42.50	**12.50**	3.57	**9.52**	1.19
65	36.50	43.50	46.25	41.50	**13.10**	3.57	**10.12**	1.19
70	36.00	42.13	46.25	42.00	**14.29**	0.30	**10.12**	0.00
75	37.75	41.50	44.88	42.50	**10.12**	1.19	**6.85**	1.19
80	40.50	41.75	43.13	41.88	3.57	0.60	2.68	0.30
	% of Measurements above Tolerance				*58.82*	*0*	*52.94*	*0*

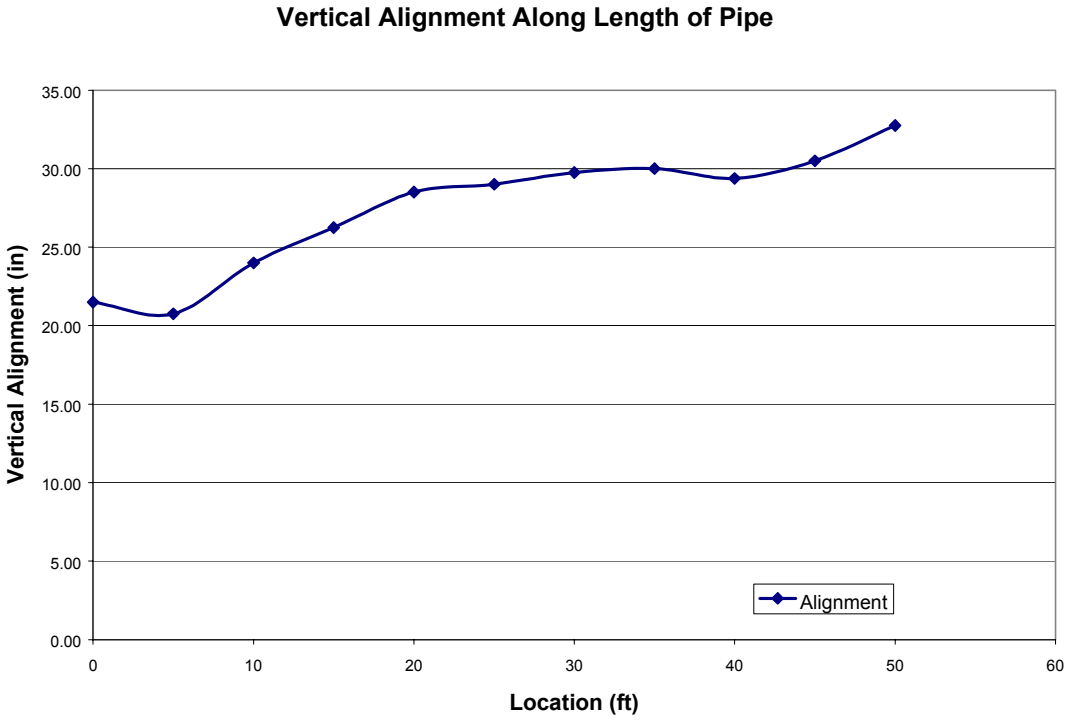
Pipe 10 - This 48-in. diameter pipe was installed in 1999. The pipe is 50-ft. long and has a maximum cover of 1 1/2-ft. The overall alignment of this pipe was pretty good, and the joint separations were less than 1 1/4-in. A bulge in the top of the pipe was found at 22-ft. Thirty two percent of the deflection calculations exceed 5%.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	47.25	48.75	48.88	48.63	1.56	1.56	1.82	1.30
5	46.88	48.88	49.25	48.75	2.34	1.82	2.60	1.56
10	46.88	48.50	49.13	48.38	2.34	1.04	2.34	0.78
15	44.88	50.75	51.50	47.75	**6.51**	**5.73**	**7.29**	0.52
20	43.75	49.50	51.88	48.50	**8.85**	3.13	**8.07**	1.04
25	44.75	48.63	51.00	48.38	**6.77**	1.30	**6.25**	0.78
30	45.50	48.00	51.38	48.50	**5.21**	0.00	**7.03**	1.04
35	45.00	48.50	50.75	49.25	**6.25**	1.04	**5.73**	2.60
40	45.13	48.88	50.88	48.50	**5.99**	1.82	**5.99**	1.04
45	46.25	48.25	50.13	49.25	3.65	0.52	4.43	2.60
50	47.38	48.50	49.25	48.75	1.30	1.04	2.60	1.56
	% of Measurements above Tolerance				*60*	*10*	*60*	*0*

Pipe 11 - This pipe was installed in 1999. The pipe is 50-ft. long and has a diameter of 42-in. Joint separation ranged from 1/4-in. to 1 1/4-in. No other areas of distress were found. Significant deflection has occurred near the outlet of the pipe.

All the deflection data and the vertical alignment of the pipe is presented below. Thirty percent of the measurements exceed the 5% criteria, and seven percent of the deflections exceed the 10% deflection. The maximum deflection of 19% occurred at 5-ft.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	36.38	43.13	44.25	42.75	**13.39**	2.68	**5.36**	1.79
5	34.00	44.50	46.25	42.50	**19.05**	**5.95**	**10.12**	1.19
10	39.88	43.50	44.75	41.75	**5.06**	3.57	**6.55**	0.60
15	40.25	42.63	44.13	42.13	4.17	1.49	**5.06**	0.30
20	40.13	43.13	44.00	42.25	4.46	2.68	4.76	0.60
25	40.38	42.38	43.75	42.63	3.87	0.89	4.17	1.49
30	40.13	42.38	44.13	42.25	4.46	0.89	**5.06**	0.60
35	39.50	42.38	44.63	42.50	**5.95**	0.89	**6.25**	1.19
40	39.75	43.00	44.75	43.25	**5.36**	2.38	**6.55**	2.98
45	40.88	42.00	43.63	42.75	2.68	0.00	3.87	1.79
50	41.88	42.00	42.75	42.63	0.30	0.00	1.79	1.49
	% of Measurements above Tolerance				*45.45*	*9.09*	*63.63*	*0*



Pipe 12 - This 48-in. diameter pipe was installed in 1999. This pipe is 53-ft. long and has a maximum cover of about 7-ft. Wall rippling was apparent from 5 to 15-ft, and two bulges had developed in the bottom of the pipe; one at 10-ft. and one at 51-ft. The alignment of the pipe was good, and separations of the joints ranged from 1 to 2-in. Significant deflection was noticed near the inlet of the pipe. Thirteen percent of the deflections exceed 5%.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	44.88	49.75	50.88	48.63	**6.51**	3.65	**5.99**	1.30
5	43.25	51.50	52.38	46.75	**9.90**	**7.29**	**9.11**	2.60
10	45.63	50.25	49.13	46.50	4.95	4.69	2.34	3.13
15	46.38	49.50	48.75	47.50	3.39	3.13	1.56	1.04
20	47.00	48.63	49.00	47.75	2.08	1.30	2.08	0.52
25	47.50	48.88	49.50	47.50	1.04	1.82	3.13	1.04
30	47.00	49.25	49.38	46.13	2.08	2.60	2.86	3.91
35	47.13	49.25	49.38	47.25	1.82	2.60	2.86	1.56
40	45.88	49.00	50.75	47.63	4.43	2.08	**5.73**	0.78
47	45.88	49.50	50.13	47.75	4.43	3.13	4.43	0.52
53	46.25	49.38	50.00	47.25	3.65	2.86	4.17	1.56
	% of Measurements above Tolerance				*18.18*	*9.09*	*27.27*	*0*

Pipe 13 - This pipe was installed in 1999. The pipe is 80-ft. long and has a diameter of 42-in. This pipe has developed severe deflection throughout most of the pipe. Reverse curvature of the top of pipe has occurred from 10 to 22-ft (see picture below). A bulge in the side of the pipe is elevated up to an inch from 5 to 15-ft. Wall buckling has developed from 17 to 20-ft. and from 65 to 75-ft. A crack was found at 16-ft. extending from 180 to 270 degrees. Numerous small bulges and swells have developed in the bottom of the pipe, creating water ponding.

The deflection calculations are presented below. Thirty-nine percent of the deflection measurements exceed 5%. Thirteen percent of the deflections exceed 10%, with a maximum of 18.8% deflection occurring at 15-ft.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	39.50	43.00	44.75	42.50	**5.95**	2.38	**6.55**	1.19
5	39.88	40.38	44.75	44.75	**5.06**	3.87	**6.55**	**6.55**
10	36.88	39.50	46.38	45.25	**12.20**	**5.95**	**10.42**	**7.74**
15	34.13	42.25	48.38	42.75	**18.75**	0.60	**15.18**	1.79
20	35.63	40.50	47.75	44.50	**15.18**	3.57	**13.69**	**5.95**
25	38.88	43.25	44.88	42.50	**7.44**	2.98	**6.85**	1.19
30	39.13	42.25	45.00	42.88	**6.85**	0.60	**7.14**	2.08
35	38.88	42.50	45.50	42.75	**7.44**	1.19	**8.33**	1.79
40	38.50	43.00	45.63	42.00	**8.33**	2.38	**8.63**	0.00
45	40.75	42.75	43.63	41.75	2.98	1.79	3.87	0.60
50	40.88	42.38	43.00	42.25	2.68	0.89	2.38	0.60
55	40.75	42.63	43.50	42.00	2.98	1.49	3.57	0.00
60	41.13	41.25	42.88	43.25	2.08	1.79	2.08	2.98
65	40.25	43.00	43.50	41.75	4.17	2.38	3.57	0.60
70	37.13	43.25	46.63	42.50	**11.61**	2.98	**11.01**	1.19
75	36.75	44.13	45.88	42.00	**12.50**	**5.06**	**9.23**	0.00
80	41.63	42.75	42.88	42.25	0.89	1.79	2.08	0.60
	% of Measurements above Tolerance				*64.7*	*11.76*	*64.7*	*17.65*

STATE 2 INSPECTION FINDINGS

Pipe 1 - This pipe was installed in 1999. This pipe is 110-ft. long and has a diameter of 48-in. The pipe had up to 6-in. of frozen water near the outlet of the pipe, therefore some diameter measurements could not be taken. A bulge in the pipe was apparent from 22 to 30-ft on the bottom of the pipe. The top of the pipe was flattened from 25 to 35-ft and from 72 to 75-ft. A rip in joint 3 had developed. Separations of the joints ranged from 1/2 to 2-in. and are summarized below.

Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
1	1.75	1.75	Weld Separation
2	1.0	2.5	Infiltration
3	0.5	1.0	Rip in Joint
4	1.75	2.5	Infiltration
5	1.0	1.5	Joint Weld Split

The diameter measurements are summarized below. Nine percent of the deflection calculations exceed 5%.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	-	47.25	47.50	46.63	-	1.56	1.04	2.86
5	-	47.13	47.25	46.38	-	1.82	1.56	3.39
10	-	46.75	47.38	46.38	-	2.60	1.30	3.39
15	45.75	46.25	47.25	47.88	4.69	3.65	1.56	0.26
20	46.25	47.00	47.13	47.25	3.65	2.08	1.82	1.56
25	45.75	47.25	47.63	47.25	4.69	1.56	0.78	1.56
30	44.50	47.25	49.00	46.88	**7.29**	1.56	2.08	2.34
35	43.75	48.50	49.00	46.50	**8.85**	1.04	2.08	3.13
40	46.38	47.13	48.00	46.75	3.39	1.82	0.00	2.60
45	-	46.25	46.75	47.50	-	3.65	2.60	1.04
50	47.00	46.75	47.00	47.13	2.08	2.60	2.08	1.82
55	45.25	46.50	47.25	47.63	**5.73**	3.13	1.56	0.78
60	-	46.00	46.50	47.25	-	4.17	3.13	1.56
65	-	46.50	46.38	47.25	-	3.13	3.39	1.56
70			-				-	
75			48.88				1.82	
80			-				-	
85			-				-	
90			-				-	
95			48.50				1.04	
	% of Measurements above Tolerance				*37.5*	*0*	*0*	*0*

Pipe 2 - This pipe was installed in 1997. The pipe is 325-ft. long and has a diameter of 36-in. Minor corrugation deflections (not measurable) have occurred throughout the length of the pipe. Separations at the joint and misalignment of the pipe was evident throughout the pipe. The joint separations are summarized below.

Joint No.	**Separation at Top (in)**	**Separation at Bottom (in)**	**Description**
1	0.5	1.25	1-in step up from pipe 1 to 2
2	1.0	0.0	1 1/2-in step down
3	0.25	0.0	1 1/2-in step down
4	1.0	0.25	Joint Buckling
5	1.0	0.25	1-in step-down
6	1.0	1.0	1-in step-down
7	1.5	1.25	Step out at 270
8	1.5	1.5	Step out at 270
9	0.5	0.0	1-in step out at 270
10	1.25	0.0	Split in joint weld
11	0.75	0.5	1-in step down
12	0.25	0.0	1-in step out at 270
13	0.25	0.75	1-in step-down
14	0.0	0.0	1-in step out at 250 - 280
15	0.25	0.5	1-in step out at 270
16	0.5	0.5	

No major areas of distress were noted, however many small swells and bulges in the bottom of the pipe were apparent. Deflection measurements were taken at 10-ft. intervals along the length of the pipe. The deflection calculations are presented below. Ten percent of the deflection measurements exceed 5% deflection with most occurring in the vertical diameter.

	Diameter				***% Deflection***			
0	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
5	34.13	35.75	36.88	36.13	**5.21**	0.69	2.43	0.35
15	35.00	36.00	36.75	35.88	2.78	0.00	2.08	0.35
25	33.25	35.63	37.75	36.00	**7.64**	1.04	4.86	0.00
35	34.38	36.13	37.00	35.50	4.51	0.35	2.78	1.39
45	33.50	36.50	37.25	35.88	**6.94**	1.39	3.47	0.35
55	35.50	36.75	36.25	35.00	1.39	2.08	0.69	2.78
65	34.25	36.50	36.75	35.50	4.86	1.39	2.08	1.39
75	35.50	36.13	36.00	35.50	1.39	0.35	0.00	1.39
85	34.13	36.00	36.75	36.25	**5.21**	0.00	2.08	0.69
95	34.50	36.13	37.00	34.75	4.17	0.35	2.78	3.47
105	33.75	36.25	37.25	36.00	**6.25**	0.69	3.47	0.00
115	35.13	36.25	36.50	35.88	2.43	0.69	1.39	0.35
125	33.75	36.00	37.13	36.38	**6.25**	0.00	3.13	1.04
135	34.50	37.00	37.25	35.50	4.17	2.78	3.47	1.39
145	33.00	36.88	38.00	35.25	**8.33**	2.43	**5.56**	2.08
155	34.38	36.50	37.13	34.88	4.51	1.39	3.13	3.13
165	34.00	36.63	37.13	35.00	**5.56**	1.74	3.13	2.78
175	35.38	35.88	36.25	35.75	1.74	0.35	0.69	0.69
185	34.50	35.63	36.75	36.13	4.17	1.04	2.08	0.35
195	34.88	36.25	37.00	36.00	3.13	0.69	2.78	0.00
205	34.13	36.25	36.88	36.13	**5.21**	0.69	2.43	0.35
215	34.00	37.75	37.75	36.13	**5.56**	4.86	4.86	0.35
225	33.88	36.00	37.13	35.00	**5.90**	0.00	3.13	2.78
235	34.50	36.63	37.00	35.75	4.17	1.74	2.78	0.69
245	34.00	36.38	36.875	35.25	**5.56**	1.04	2.43	2.08
255	35.625	37	35.5	34	1.04	2.78	1.39	5.56
265	35.25	37	36	34.75	2.08	2.78	0.00	3.47
275	36.875	35.75	34.75	35.125	2.43	0.69	3.47	2.43
285	35.75	36	35.375	35.25	0.69	0.00	1.74	2.08
295	36.5	36.75	35.25	34.75	1.39	2.08	2.08	3.47
305	36.25	36.125	35.25	35.125	0.69	0.35	2.08	2.43
315	36.375	35.75	35.25	35.75	1.04	0.69	2.08	0.69
325	36.25	35.875	35.5	35.875	0.69	0.35	1.39	0.35
	% of Measurements above Tolerance				*36.36*	*0.00*	*3.03*	*3.03*

Pipe 3 - This storm drain was installed in 1997. The pipe is 335-ft. long and has a diameter of 36-in. The depth of cover ranges from 3 to 10-ft. Three swells in the bottom of the pipe were apparent: 265 to 315-ft, 135 to 160-ft, and 25 to 45-ft. Water was ponding at these locations. The alignment of the pipe is good, however, numerous small bulges had developed in the bottom of the pipe. Significant separations of most of the joints is evident. The joint separations are summarized in the following table.

Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
1	2.0	2.0	Alignment Good
2	2.0	2.5	Alignment Good
3	2.25	2.5	Alignment Good
4	1.5	2.0	Alignment Good
5	1.5	2.0	Alignment Good
6	1.0	1.5	Alignment Good
7	1.0	1.5	Step down 1/2-in
8	0.5	0.75	Alignment Good
9	0.0	0.0	Step down
10	0.0	1.0	Step down
11	0.5	1.0	Alignment Good
12	0.0	0.5	Alignment Good
13	0.25	0.5	Alignment Good
14	0.75	1.0	Alignment Good
15	0.25	1.0	Alignment Good
16	1.0	1.5	Alignment Good

Deflection measurements were taken at 10-ft. intervals along the length of the pipe. No deflections exceed 5%.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	35.50	36.13	36.38	35.75	1.39	0.35	1.04	0.69
10	35.75	35.63	36.00	36.25	0.69	1.04	0.00	0.69
20	35.25	36.13	36.50	35.88	2.08	0.35	1.39	0.35
30	36.00	36.00	35.75	35.88	0.00	0.00	0.69	0.35
40	36.50	36.00	35.25	35.75	1.39	0.00	2.08	0.69
50	35.75	36.00	35.88	35.75	0.69	0.00	0.35	0.69
60	36.13	36.00	35.75	35.88	0.35	0.00	0.69	0.35
70	35.50	36.13	36.00	35.88	1.39	0.35	0.00	0.35
80	35.88	36.00	36.00	35.75	0.35	0.00	0.00	0.69
90	36.25	36.00	35.75	36.00	0.69	0.00	0.69	0.00
100	36.25	35.88	36.00	36.00	0.69	0.35	0.00	0.00
110	36.25	35.88	36.00	35.88	0.69	0.35	0.00	0.35
120	36.25	35.75	35.75	36.13	0.69	0.69	0.69	0.35
130	36.50	36.00	35.50	35.75	1.39	0.00	1.39	0.69
140	37.00	36.25	35.75	34.50	2.78	0.69	0.69	4.17
150	36.88	35.75	35.63	35.25	2.43	0.69	1.04	2.08
160	36.75	35.25	35.00	35.25	2.08	2.08	2.78	2.08
170	36.00	35.88	35.75	35.75	0.00	0.35	0.69	0.69
180	36.50	35.88	35.25	35.50	1.39	0.35	2.08	1.39
190	35.75	36.00	36.00	35.75	0.69	0.00	0.00	0.69
200	35.25	36.25	36.50	36.00	2.08	0.69	1.39	0.00
210	35.75	36.13	36.00	35.88	0.69	0.35	0.00	0.35
220	36.50	35.75	35.50	35.75	1.39	0.69	1.39	0.69
230	35.00	36.63	36.75	35.75	2.78	1.74	2.08	0.69
240	36.25	35.75	35.50	36.25	0.69	0.69	1.39	0.69
250	36.50	35.25	35.00	36.00	1.39	2.08	2.78	0.00
260	36.75	35.00	35.13	36.38	2.08	2.78	2.43	1.04
270	36.88	35.25	34.88	36.00	2.43	2.08	3.13	0.00
280	36.88	35.13	35.00	36.50	2.43	2.43	2.78	1.39
290	35.88	35.88	35.63	36.25	0.35	0.35	1.04	0.69
300	36.38	35.75	35.38	35.50	1.04	0.69	1.74	1.39
310	36.13	35.88	35.50	35.75	0.35	0.35	1.39	0.69
320	35.50	35.63	36.00	36.25	1.39	1.04	0.00	0.69
330	35.38	35.50	36.00	36.13	1.74	1.39	0.00	0.35
340	34.75	35.50	36.88	36.00	3.47	1.39	2.43	0.00
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 4 - This 30-in. diameter pipe was installed in 1998 and drains from a concrete catch basin. This pipe is approximately 100-ft. in length, however, only 35-ft. of the pipe was inspected due to thick ice in the bottom of the pipe. A bulge had developed near the bottom of the pipe at 30-ft. Severe separations have developed in all of the joints. The follow table presents a summary of the joint separations.

Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
1	8.0	4.0	1-in drop, infiltration
2	5.0	6.0	1 1/2-in drop
3	4.75	4.75	Infiltration
4	.025	4.0	

Diameter measurements were taken every 5-ft. up to 35-ft. No deflection measurements exceed 5% deflection criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0								
5								
10	29.38	29.75	30.50	30.13	2.08	0.83	1.67	0.42
15	30.13	29.25	30.00	30.50	0.42	2.50	0.00	1.67
20	30.50	29.88	29.75	30.25	1.67	0.42	0.83	0.83
25	30.50	29.88	29.50	29.75	1.67	0.42	1.67	0.83
30	29.50	29.88	29.75	29.38	1.67	0.42	0.83	2.08
35	30.13	29.88	30.00	30.25	0.42	0.42	0.00	0.83
	% of measurement above tolerance				*0*	*0*	*0*	*0*

Pipe 5 - This 48-in. pipe is 70-ft. long. Two cracks have developed in this pipe: one at 10-ft. extending around the entire circumference of the pipe and another at 10.5-ft. extending from 270 to 300 degrees. Corrugation deflection of 3/8-in. were measured at 15-ft. and at 35-ft. A small swell was apparent in the bottom of the pipe at 35-ft. followed by a bulge at 40-ft. Wall rippling has developed in the sidewalls along the entire length of pipe. Joint separations ranged from 0.5 to 1.5-in.

Two cracks that have developed in the pipe – Pipe 5

Deflection measurements were taken at 5-ft. intervals along the 70-ft. pipe. Seven percent of the deflection calculations exceed the 5% criteria, with all occurring at the 45° measurement.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	47.25	47.13	47.00	48.50	1.56	1.82	2.08	1.04
5	47.00	45.50	46.75	48.63	2.08	**5.21**	2.60	1.30
10	47.75	45.25	45.75	48.88	0.52	**5.73**	4.69	1.82
15	47.00	45.13	46.75	48.88	2.08	**5.99**	2.60	1.82
20	46.50	46.00	47.50	48.75	3.13	4.17	1.04	1.56
25	46.50	46.38	47.75	48.25	3.13	3.39	0.52	0.52
30	46.50	46.00	48.00	48.63	3.13	4.17	0.00	1.30
35	45.75	46.00	48.25	48.50	4.69	4.17	0.52	1.04
40	45.88	46.00	48.25	48.50	4.43	4.17	0.52	1.04
45	46.00	45.38	48.50	49.38	4.17	**5.47**	1.04	2.86
50	46.13	45.63	48.25	48.00	3.91	4.95	0.52	0.00
55	46.00	46.63	49.25	49.00	4.17	2.86	2.60	2.08
60	46.13	47.00	48.75	49.13	3.91	2.08	1.56	2.34
65	46.00	46.88	48.75	48.50	4.17	2.34	1.56	1.04
70	47.63	48.00	48.25	48.00	0.78	0.00	0.52	0.00
	% of Measurements above Tolerance				*0*	*26.67*	*0*	*0*

Pipe 6 and 7 - These two pipes were installed in 1996. These pipes both have a diameter of 60-in. and a combined length of 165-ft. This first pipe drains from a catch basin to a retention pond, and the second drains into the catch basin and runs perpendicular to the first pipe. In the first pipe, the oval shape of the pipe is easily noticed (see picture below). Rippling of the sidewalls is apparent from 4 to 15-ft (see picture below) and from 15 to 30-ft. Corrugation deflections of 1-in. were measured at numerous locations along the pipe. Numerous cracks and splits have developed, specifically near the inlet and outlet of the pipe. The following table summarizes the locations of the cracks in the first pipe.

Number of Cracks	Location of Crack	Width (in)	Length (in)
8	0 to 2-ft	> 2	4 to 8
1	2-ft	2.5	24
1	10-ft	hairline	12
1	11-ft	hairline	2
6	25 - 30 -ft	0.25	1.5
1	30-ft	3.0	3.0
1	30-ft	2.0	5.0
6	30-ft	hairline	60

In the second pipe, similar cracking of the inlet and outlet of the pipe has occurred. Wall rippling has developed from 0 to 12-ft. Numerous bulges were observed in the bottom of the pipe, typically raising the bottom of the pipe 2-in. Corrugation deflections of 0.5-in. were common with a maximum of 7/8-in. The cracking of the pipe is summarized below.

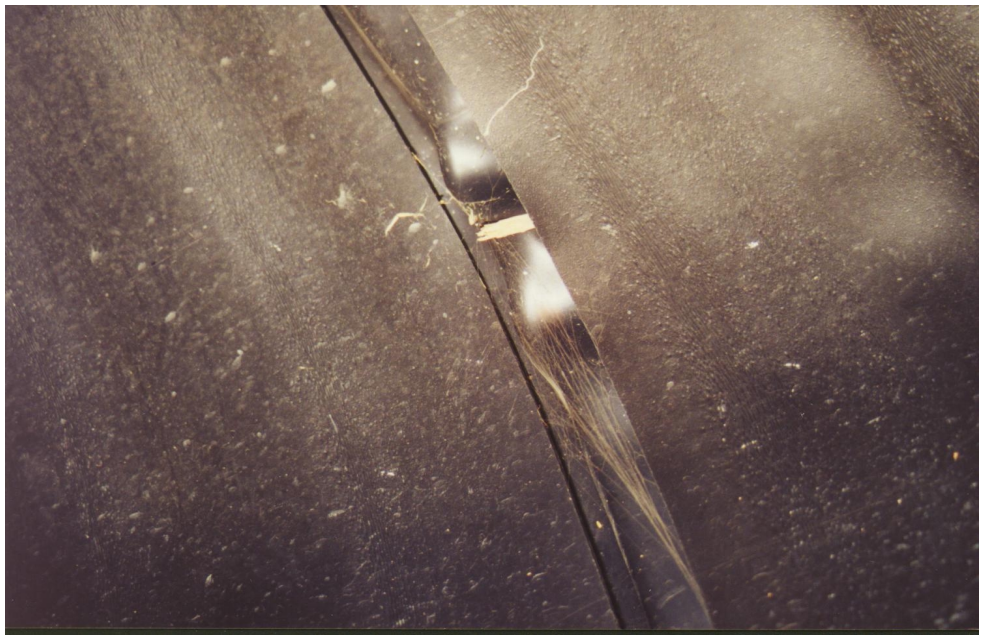
Number of Cracks	Location of Crack	Width (in)	Length (in)
3	2-ft	2 to 3	6 to 9
5	2-ft	2 to 3	4

Separations were significant in most of the joints in the two pipes. A summary of the joint separations is presented below.

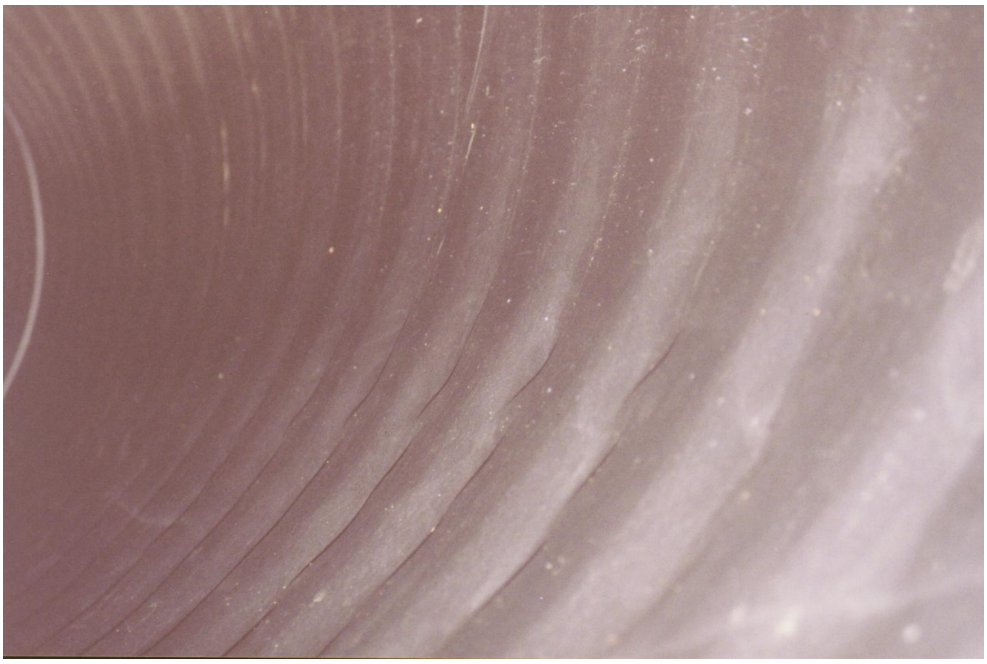
Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
Pipe 6			
1	1.5	2.0	2-in step down, joint buckling
2	1.5	1.5	1-in step-down joint buckling
Pipe 7			
1	3.5	3.0	Step-up
1	0.5	3.5	
3	3.5	3.5	Signs of infiltration
2	2.0	2.5	0.5-in step-down
3	2.0	2.5	1.5-in step-down
4	2.5	3.75	

Profile of Pipe 6

Bulge in the bottom of Pipe 6

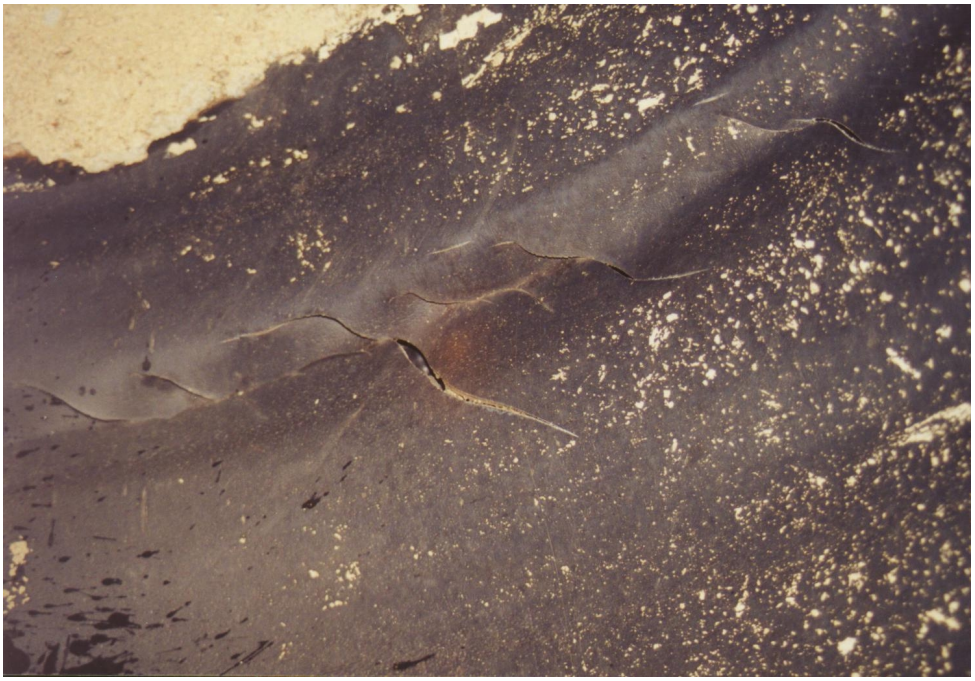


Separation of Joint 1, Pipe 6

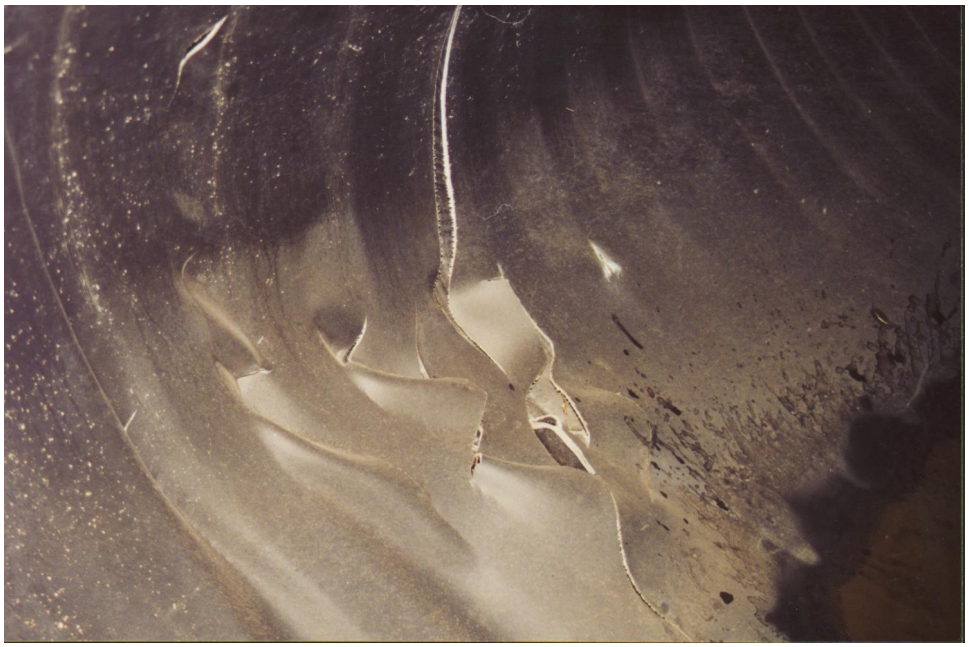


Wall rippling of Pipe 7

Splitting of Pipe 6



Cracking of Pipe 7



Cracking of Pipe 7

Cracking at outlet of Pipe 7

Deflection measurements were taken every 5-ft. along the length of the pipe. The deflection calculations are summarized below. Twenty-eight percent of the deflection calculations exceed 5% in Pipe 6. Two percent of the deflections exceed 5% in Pipe 7.

Pipe 6:

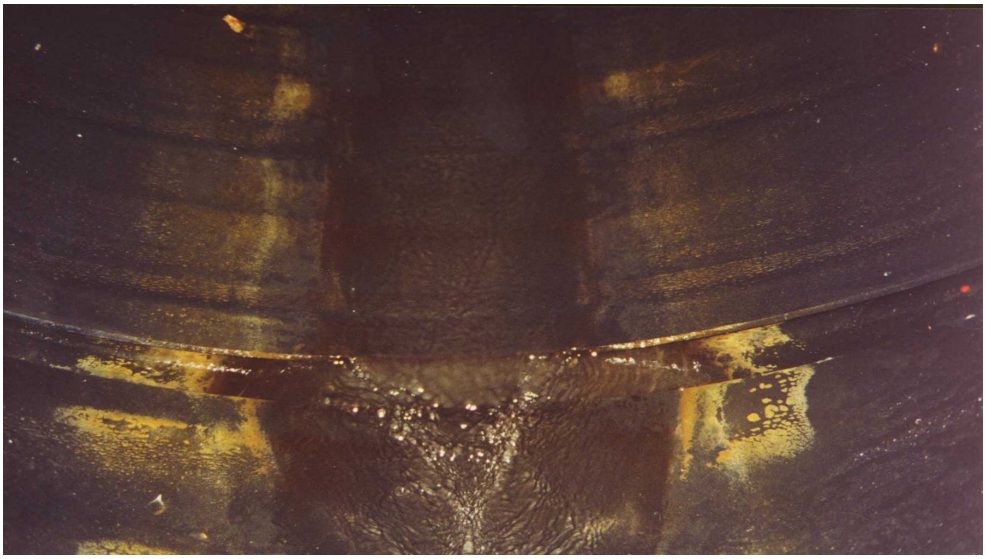
	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	54.50	61.25	62.50	59.25	**9.17**	2.08	4.17	1.25
5	56.25	56.75	63.50	61.75	**6.25**	**5.42**	**5.83**	2.92
10	56.50	64.13	62.50	59.25	**5.83**	**6.88**	4.17	1.25
15	55.00	59.25	65.00	59.75	**8.33**	1.25	**8.33**	0.42
20	57.25	59.00	60.75	61.25	4.58	1.67	1.25	2.08
25	58.00	58.75	60.75	60.50	3.33	2.08	1.25	0.83
30	55.38	59.00	60.13	59.75	**7.71**	1.67	0.21	0.42
35	58.50	59.25	62.75	59.88	2.50	1.25	4.58	0.21
	% of Measurements above Tolerance				*62.5*	*25*	*25*	*0*

Pipe 7:

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	56.75	61.00	62.75	59.25	**5.42**	1.67	4.58	1.25
10	58.25	59.13	62.00	58.25	2.92	1.46	3.33	2.92
20	58.00	61.00	60.75	59.25	3.33	1.67	1.25	1.25
30	60.75	61.00	60.25	58.75	1.25	1.67	0.42	2.08
40	60.88	60.50	59.13	59.38	1.46	0.83	1.46	1.04
50	57.38	60.00	61.50	60.75	4.38	0.00	2.50	1.25
60	60.75	60.00	59.50	59.75	1.25	0.00	0.83	0.42
70	59.25	60.00	59.75	59.50	1.25	0.00	0.42	0.83
80	59.75	60.00	60.38	59.75	0.42	0.00	0.63	0.42
90	59.25	60.25	59.75	60.13	1.25	0.42	0.42	0.21
100	59.00	59.13	60.50	60.38	1.67	1.46	0.83	0.63
110	58.75	60.25	60.75	60.13	2.08	0.42	1.25	0.21
120	58.75	59.25	61.00	59.75	2.08	1.25	1.67	0.42
130	58.50	60.25	64.38	58.75	2.50	0.42	7.29	2.08
	% of Measurements above Tolerance				*7.14*	*0*	*0*	*0*

STATE 3 INSPECTION FINDINGS

Pipe 1 - This 54-in. diameter pipe was installed as a test installation in 1996 as a cross drain. The maximum depth of cover is about 9.5 ft. The overall condition of pipe appeared to be good. However, separations ranging up to 2-in, and exfiltration was noticed at both joints in the pipe. The photograph below shows the joint separation.



Separation at Joint 2 –Pipe 1

WJE's diameter measurements were taken at 0, 20, 25, 40, 50, 75, and 100-ft. along the length of the pipe. These diameter measurements are presented below. No measurements exceeded the 5 % deflection failure criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	53.50	54.13	52.63	52.50	0.93	0.23	2.55	2.78
20	55.50	53.50	51.88	53.38	2.78	0.93	3.94	1.16
25	54.13	52.75	52.25	52.50	0.23	2.31	3.24	2.78
40	54.88	54.75	52.88	53.25	1.62	1.39	2.08	1.39
50	54.50	53.00	52.50	53.75	0.93	1.85	2.78	0.46
75	53.38	53.25	53.50	54.25	1.16	1.39	0.93	0.46
100	52.38	53.75	55.00	54.00	3.01	0.46	1.85	0.00
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 2 - This 48-in. diameter pipe is 66-ft. long and was installed approximately two years ago. This pipe was installed as a cross drain under a farmer's driveway due to a wash out of a steel pipe. The maximum depth of cover is 4 ft.

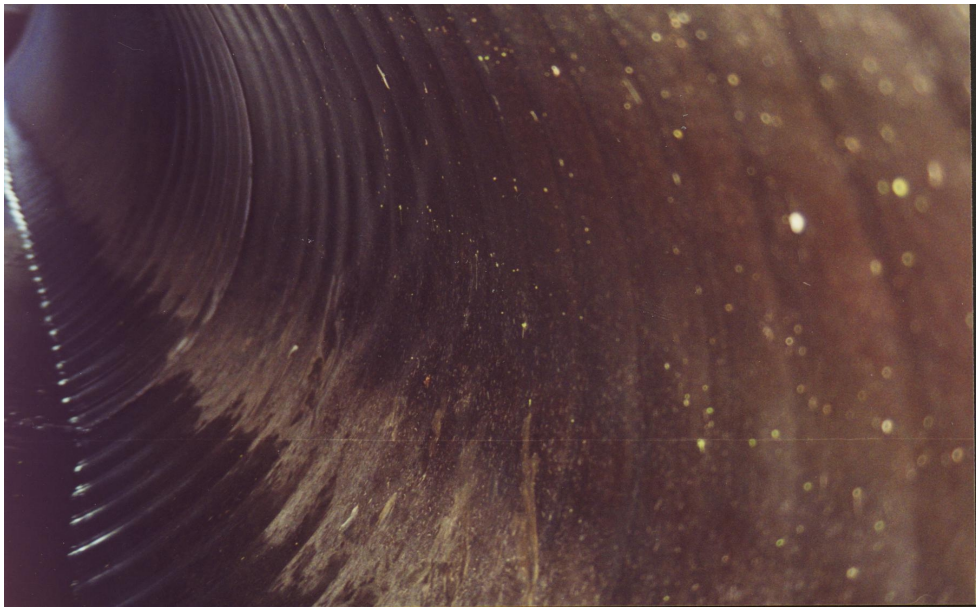
Some undermining upstream of Joint 1 and a 1-in. separation at this joint were observed. The pipe appeared to be in overall good condition. No cracks or wall buckling were observed.

Diameter measurements were at 0, 20, 40, 60, and 66-ft along the pipe. The largest deflection change measured was 2.6 % occurring at the midlength of the pipe. None of the deflections of this pipe exceed the 5 % criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	47.50	48.00	48.00	48.50	1.04	0.00	0.00	1.04
20	48.13	48.63	48.00	47.75	0.26	1.30	0.00	0.52
40	48.75	47.75	46.75	48.50	1.56	0.52	2.60	1.04
60	48.25	48.75	47.88	48.00	0.52	1.56	0.26	0.00
66	48.50	48.38	47.63	48.13	1.04	0.78	0.78	0.26
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 3 - This 42-in. diameter pipe was installed in 1994 as a cross-drain culvert. The maximum depth of cover is between 2 to 3 ft. Significant deflection changes have occurred in this pipe, and the oval shape of the pipe is easily noticed. Pipe vibrations were noticed during traffic. The springlines of the pipe showed a few local bucking wrinkles (ripples) along the pipe lengths. Exfiltration was observed at Joint 1, and a 4-in. bulge was observed upstream of Joint 2 in the crown.

Oval shape of the pipe – Pipe 3



Wall buckling – Pipe 3

Diameters were measured at 0, 10, 20, 30, 40, 50, and 60-ft. along the length of the pipe, starting at the inlet as shown in the following table. Eighteen percent of the diameter measurements exceeded the 5 % deflection criteria with the maximum deflection occurring at 40-ft.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	40.75	41.00	42.00	42.25	2.98	2.38	0.00	0.60
10	39.50	41.25	43.00	43.25	**5.95**	1.79	2.38	2.98
20	38.25	43.25	43.75	42.75	**8.93**	2.98	4.17	1.79
30	40.00	42.88	43.00	40.50	4.76	2.08	2.38	3.57
40	37.75	39.88	44.50	40.75	**10.12**	**5.06**	**5.95**	2.98
50	40.25	41.31	41.50	41.00	4.17	1.64	1.19	2.38
60	41.00	42.25	42.00	41.31	2.38	0.60	0.00	1.64
	% of Measurements above Tolerance				*42.86*	*14.29*	*14.29*	*0*

Pipe 4 - This 30-in. diameter pipe was installed as a cross-drain culvert. The amount of soil cover ranges from about 6-ft. at the inlet to about 9-ft. at the outlet. An oval shape to the pipe is apparent throughout the entire length of the pipe, and horizontal misalignment is easily noticed (see picture below). Separation of all joints was apparent.

Note oval shape of profile – Pipe 4

Diameter measurements were made at 0, 20, 40, 60, and 86-ft. as shown in the following table. Thirty percent of the diameter measurements exceed the 5 % deflection criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	30.39	29.50	28.50	29.00	1.30	1.67	**5.00**	3.33
20	27.50	29.50	31.75	29.25	**8.33**	1.67	**5.83**	2.50
40	27.50	29.75	31.25	30.50	**8.33**	0.83	4.17	1.67
60	27.75	28.25	31.00	30.25	**7.50**	**5.83**	3.33	0.83
86	30.00	29.50	29.25	29.75	0.00	1.67	2.50	0.83
	% of Measurements above Tolerance				*60*	*20*	*40*	*0*

STATE 4 INSPECTION FINDINGS

Pipe 1 and 2 - (Twin Installation) - These 42–in. diameter twin-pipe installations were installed as test installations in 1997. This installation consists of two parallel 80-ft. long pipes that form a cross-line culvert. The pipe is covered with 3 to 5-ft. of soil and is in overall good condition. Separations of the joints have developed up to 2-in. No significant areas of distress were noted in either of the pipes.

Diameters were measured at 0, 10, 20, 30, 40, 50, 60, 70, and 80-ft. along both pipes. The diameter measurements can be found in the tables below. All the diameter measurements, for both pipes, meet the 5 % deflection criteria.

South Pipe:

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	40.25	40.13	41.50	41.00	4.17	4.46	1.19	2.38
10	41.50	41.75	41.75	40.88	1.19	0.60	0.60	2.68
20	41.38	42.00	42.00	41.50	1.49	0.00	0.00	1.19
30	40.88	41.75	41.38	41.75	2.68	0.60	1.49	0.60
40	40.75	40.88	41.88	41.75	2.98	2.68	0.30	0.60
50	40.00	40.75	41.75	41.50	4.76	2.98	0.60	1.19
60	40.50	41.50	42.00	41.25	3.57	1.19	0.00	1.79
70	40.00	41.75	41.50	41.25	4.76	0.60	1.19	1.79
80	40.88	41.25	41.50	41.25	2.68	1.79	1.19	1.79
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

North Pipe:

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	40.88	40.00	40.50	40.38	2.68	4.76	3.57	3.87
10	41.50	40.75	41.50	40.75	1.19	2.98	1.19	2.98
20	4.00	40.50	41.38	41.00	4.76	3.57	1.49	2.38
30	40.88	40.50	41.50	41.75	2.68	3.57	1.19	0.60
40	40.13	40.00	40.88	40.50	4.46	4.76	2.68	3.57
50	40.50	41.00	41.50	41.75	3.57	2.38	1.19	0.60
60	40.50	40.75	40.38	41.75	3.57	2.98	3.87	0.60
70	41.38	41.00	41.38	41.00	1.49	2.38	1.49	2.38
80	41.13	41.25	41.75	41.50	2.08	1.79	0.60	1.19
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

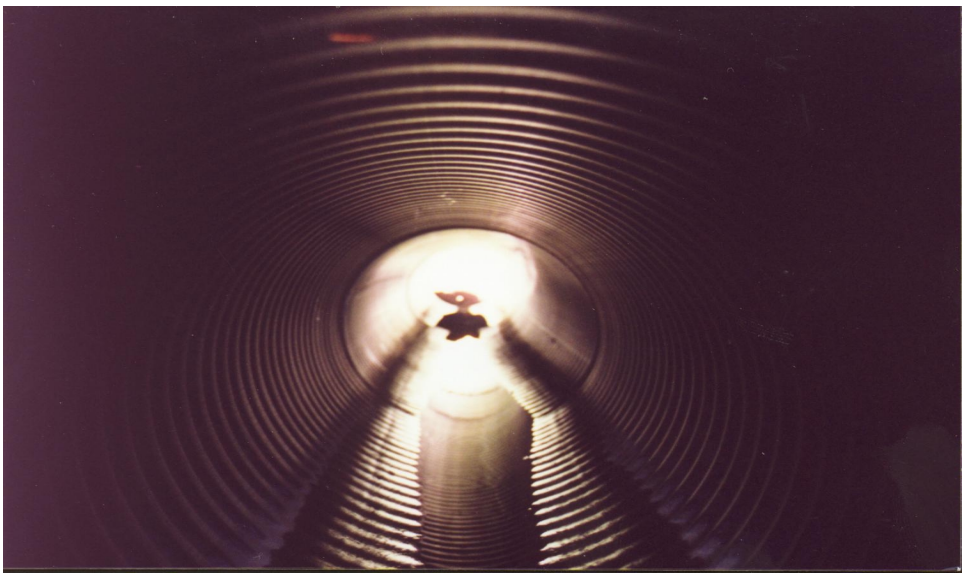
Pipe 3 - This 48-in. diameter pipe was installed as a cross-drain culvert, due to a previous wash out of a steel pipe during a hurricane. The pipe is 45-ft. long and has about 2-ft. of cover. The pipe is in overall good condition. However, Joints 1 and 2 have separations as large as 1½ in. Both ends of the pipe are exposed, and the outlet end appears to be slightly delaminated due to exposure to the sun. No other areas of distress were observed. The traffic volume over the pipe is very low.

Good shape and alignment – Pipe 3

Diameter measurements were taken at 0, 5, 10, 15, 20, 25, 30, 35, 40, and 45-ft. and can be found in the following table. All measurements of deflection are less than the 5 % deflection criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	47.63	46.50	46.75	47.25	0.78	3.13	2.60	1.56
5	47.88	47.00	46.50	47.13	0.26	2.08	3.13	1.82
10	48.00	46.63	46.38	47.50	0.00	2.86	3.39	1.04
15	47.75	46.88	46.50	47.00	0.52	2.34	3.13	2.08
20	47.38	47.50	46.75	46.38	1.30	1.04	2.60	3.39
25	47.38	48.00	46.50	46.50	1.30	0.00	3.13	3.13
30	48.00	47.63	46.00	46.38	0.00	0.78	4.17	3.39
35	48.50	47.25	46.25	46.13	1.04	1.56	3.65	3.91
40	48.25	47.38	46.13	46.75	0.52	1.30	3.91	2.60
45	48.13	47.00	46.50	47.50	0.26	2.08	3.13	1.04
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 4 and Pipe 5 (Twin-pipe installation) - These two 36-in. diameter parallel pipes were installed in 1998 as a cross-drain culvert. The pipes are 60-ft. long and have about 2-ft. of cover. The pipes run north and south. Pipe deflection and the vertical misalignment were easily noticed (see picture below). Four lacerations of the east pipe were found in the top of the pipe near Joint 2. It is probable that these lacerations are from the forks of a backhoe. In the east pipe, exfiltration and a 2-in. gap was observed at Joint 1, and undermining was apparent upstream of Joint 2. In the west pipe, a 1 1/2-in. separation was measured at Joint 1, and 3/4-in. elevation difference at Joint 1 was apparent. A gap of 1/2-in. has developed at Joint 2 and exfiltration was occurring.



Profile of east pipe – Pipe 4

Lacerations in top of pipe – Pipe 5

Diameter measurements were taken at 0, 10, 20, 30, 40, 50, 60-ft and along the length of both pipes and can be found in the following tables. In the east pipe, 25 %of the diameter measurements exceed the 5 % deflection criteria, while in the west pipe, 18 % of the measurements exceed the criteria. The diameters that exceeded the failure criteria all occurred in the vertical and horizontal direction.

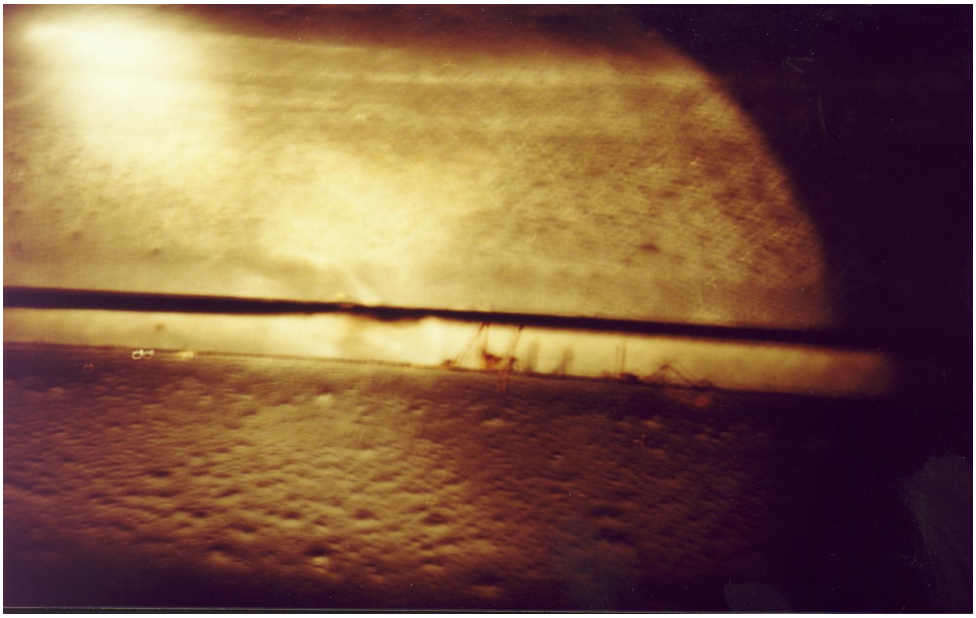
Pipe 4:

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	36.13	36.00	36.13	35.88	0.35	0.00	0.35	0.35
10	34.63	38.00	38.00	35.50	3.82	**5.56**	**5.56**	1.39
20	34.75	37.75	37.50	35.75	3.47	4.86	4.17	0.69
30	33.88	37.63	38.50	36.50	**5.90**	4.51	**6.94**	1.39
40	33.88	36.25	38.13	37.25	**5.90**	0.69	**5.90**	3.47
50	33.50	36.50	37.75	37.75	**6.94**	1.39	4.86	4.86
60	35.63	35.75	35.88	35.75	1.04	0.69	0.35	0.69
	% of Measurements above Tolerance				*42.86*	*14.29*	*42.86*	*0*

Pipe 5:

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	35.75	35.75	35.63	35.50	0.69	0.69	1.04	1.39
10	35.00	35.75	37.50	37.00	2.78	0.69	4.17	2.78
20	34.75	37.75	38.00	36.50	3.47	4.86	**5.56**	1.39
30	34.63	36.75	37.50	36.75	3.82	2.08	4.17	2.08
40	33.88	37.00	38.13	37.25	**5.90**	2.78	**5.90**	3.47
50	34.00	36.50	38.25	37.75	**5.56**	1.39	**6.25**	4.86
60	35.38	36.50	37.25	36.75	1.74	1.39	3.47	2.08
	% of Measurements above Tolerance				*28.57*	*0*	*42.86*	*0*

Pipe 6 - This 120-ft. long, 30-in diameter pipe was installed in 1987 as a test pilot for use of HDPE as a culvert material. The depth of soil cover ranges from 4-ft. at the inlet to 15-ft. at the outlet. At the time of the inspection no water was present. Every joint in the pipe has experienced some separation with 1 3/4-in. as the maximum separation. The pipe has significant vertical and horizontal alignment problems. A sag of about 3-in. was apparent upstream of Joint 4. Some sections of the pipe liner were missing near the inlet of the pipe.



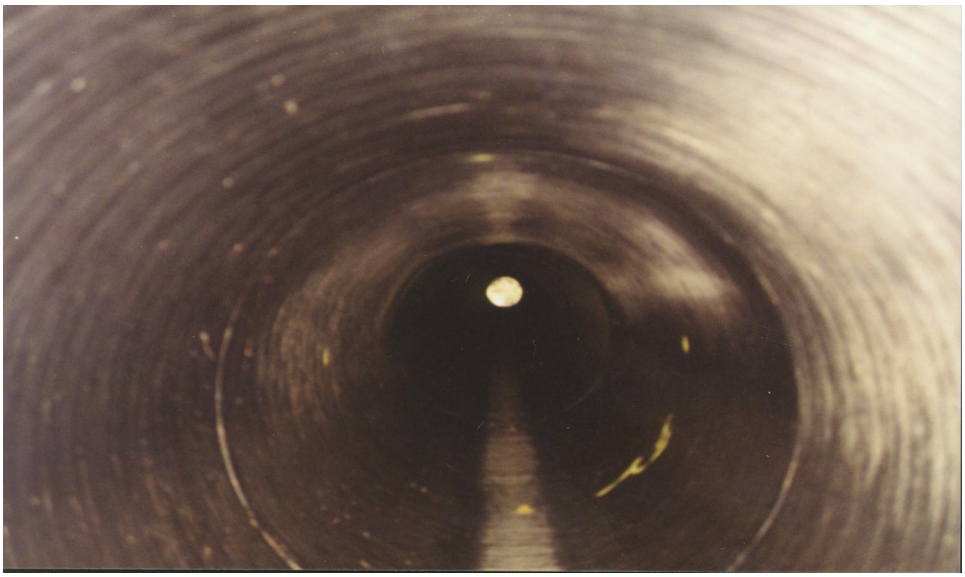
Typical joint separation – Pipe 6

Diameter measurements were taken at 10-ft. increments as shown in the following table. Eight percent of the diameter measurements exceeded 5 % deflection criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	30.50	30.25	30.25	30.25	1.67	0.83	0.83	0.83
10	28.88	31.50	31.38	31.00	3.75	**5.00**	4.58	3.33
20	29.50	31.00	31.25	30.50	1.67	3.33	4.17	1.67
30	29.75	30.75	31.00	30.75	0.83	2.50	3.33	2.50
40	28.63	30.50	31.88	31.50	4.58	1.67	**6.25**	**5.00**
50	30.25	30.13	29.75	30.00	0.83	0.42	0.83	0.00
60	30.25	30.13	30.25	30.25	0.83	0.42	0.83	0.83
70	30.38	30.50	30.00	30.13	1.25	1.67	0.00	0.42
80	30.25	30.75	30.75	31.00	0.83	2.50	2.50	3.33
90	29.50	30.63	30.75	30.63	1.67	2.08	2.50	2.08
100	29.63	31.00	30.75	30.50	1.25	3.33	2.50	1.67
110	30.00	30.75	30.50	30.00	0.00	2.50	1.67	0.00
120	29.75	30.88	31.00	31.50	0.83	2.92	3.33	**5.00**
	% of Measurements above Tolerance				*0*	*7.69*	*7.69*	*15.38*

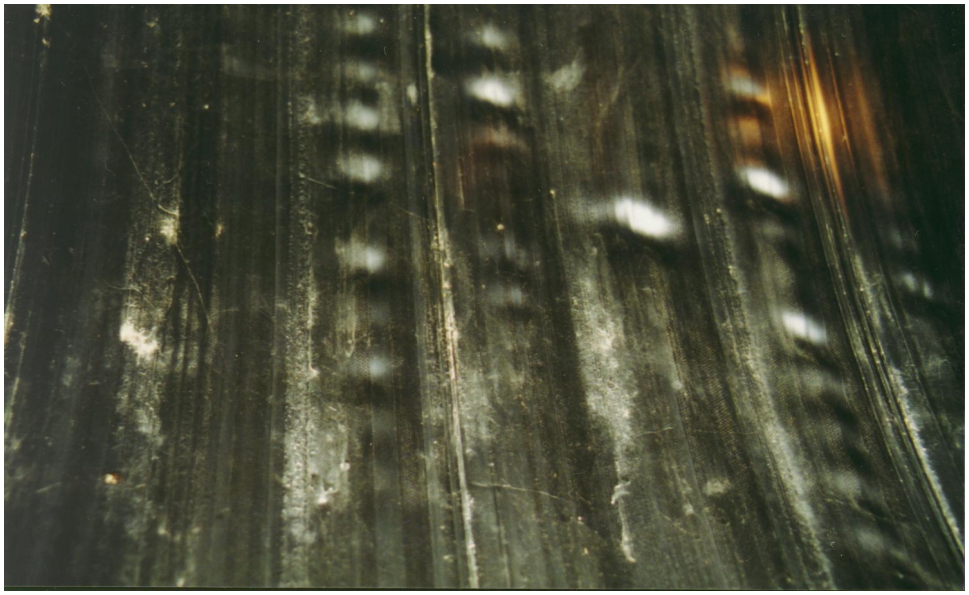
STATE 4 INSPECTION FINDINGS

Pipe 1 - This 48-in. diameter pipe is approximately 215-ft. long and was installed as a test installation in 1996. The maximum soil cover is about 20-ft. A 1-in long crack has developed in this pipe at 73-ft. (see picture below). Rippling (buckling) of the sidewalls has occurred from 82 to 86-ft. The alignment of the pipe is pretty good except for at joint 5 where the pipe dropped 3-in., and minimal joint separation has occurred. Three splits were found at 99-ft. at the top of the pipe. These splits were caused during installation (as documented by construction records).



Profile of pipe – Pipe 1

Small crack that has developed – Pipe 1



Rippling of the side walls – Pipe 1

Diameter measurements were taken at 5-ft. intervals along the 215-ft. length of the pipe. The measurements are presented below. No deflection measurements exceed the 5% criteria.

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	47.63	47.00	47.00	47.00	0.78	2.08	2.08	2.08
5	46.88	47.00	47.75	46.88	2.34	2.08	0.52	2.34
10	47.38	46.75	47.00	47.50	1.30	2.60	2.08	1.04
15	47.25	47.00	47.50	47.88	1.56	2.08	1.04	0.26
20	47.25	47.25	47.00	47.25	1.56	1.56	2.08	1.56
25	47.25	47.00	47.75	47.00	1.56	2.08	0.52	2.08
30	47.00	47.50	47.50	47.75	2.08	1.04	1.04	0.52
35	46.63	47.25	47.50	47.50	2.86	1.56	1.04	1.04
40	46.75	47.00	47.50	47.63	2.60	2.08	1.04	0.78
45	46.50	47.75	47.50	47.00	3.13	0.52	1.04	2.08
50	46.25	47.88	47.88	47.50	3.65	0.26	0.26	1.04
55	46.13	47.50	47.75	47.50	3.91	1.04	0.52	1.04
60	46.25	47.50	47.50	47.00	3.65	1.04	1.04	2.08
65	46.38	47.00	47.25	47.00	3.39	2.08	1.56	2.08
70	46.00	46.88	47.50	47.25	4.17	2.34	1.04	1.56
75	46.38	47.50	47.50	46.50	3.39	1.04	1.04	3.13
80	46.50	46.75	47.88	47.25	3.13	2.60	0.26	1.56
85	47.50	47.00	46.75	46.25	1.04	2.08	2.60	3.65
90	47.75	46.88	46.00	46.00	0.52	2.34	4.17	4.17
95	46.00	46.75	47.00	46.88	4.17	2.60	2.08	2.34
100	46.50	47.00	46.88	46.75	3.13	2.08	2.34	2.60
105	47.50	47.00	46.50	46.63	1.04	2.08	3.13	2.86
110								
115	47.25	46.50	46.75	46.88	1.56	3.13	2.60	2.34
120	46.25	47.00	46.88	47.00	3.65	2.08	2.34	2.08
125	46.50	47.00	47.25	46.75	3.13	2.08	1.56	2.60
130	46.5	47	47	46.875	3.13	2.08	2.08	2.34
135	46.75	47.125	46.875	47	2.60	1.82	2.34	2.08
140	46.125	46.75	47.25	46.75	3.91	2.60	1.56	2.60
145	46.5	46.5	46.75	47	3.13	3.13	2.60	2.08
150	46.625	46.5	46.875	47	2.86	3.13	2.34	2.08
155	46.75	46.75	47	47.25	2.60	2.60	2.08	1.56
160	46.75	47	47	47.25	2.60	2.08	2.08	1.56
165	46.5	47	47	47.25	3.13	2.08	2.08	1.56
170	47.25	46.5	46.5	47	1.56	3.13	3.13	2.08
175	46.75	46.5	46.875	47.25	2.60	3.13	2.34	1.56
180	47.5	46.875	46.75	47	1.04	2.34	2.60	2.08
185	47.75	46.5	46.375	46.75	0.52	3.13	3.39	2.60
190	47.5	46.75	46.875	47	1.04	2.60	2.34	2.08
195	47	46.75	46.875	47	2.08	2.60	2.34	2.08
200	47.375	47	47	47.25	1.30	2.08	2.08	1.56
205	47.375	46.875	46.375	46.5	1.30	2.34	3.39	3.13
210	46.875	47.5	47.375	47.25	2.34	1.04	1.30	1.56
215	46.5	47.75	47.375	46.75	3.13	0.52	1.30	2.60
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 2 - This pipe was installed in 1996. The pipe has a diameter of 36-in. and a length of 100-ft. The maximum soil cover is about 15-ft. The alignment of the pipe is good and the joints are in pretty good condition. The maximum joint separation of 1/2-in. occurred at Joint 4.

Deflection measurements were taking every 5-ft. along the length of the pipe. No deflections exceeded 5%.

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	36.25	35.75	35.63	36.25	0.69	0.69	1.04	0.69
5	36.00	36.25	36.00	35.75	0.00	0.69	0.00	0.69
10	36.25	35.75	35.88	35.13	0.69	0.69	0.35	2.43
15	36.00	36.13	35.75	36.25	0.00	0.35	0.69	0.69
20	36.25	35.88	35.75	35.88	0.69	0.35	0.69	0.35
25	35.75	35.88	36.00	36.13	0.69	0.35	0.00	0.35
30	35.50	36.00	36.38	36.50	1.39	0.00	1.04	1.39
35	35.63	36.00	36.13	36.25	1.04	0.00	0.35	0.69
40	35.50	36.13	36.38	36.25	1.39	0.35	1.04	0.69
45	35.75	35.88	36.13	36.25	0.69	0.35	0.35	0.69
50	35.38	35.75	35.88	36.25	1.74	0.69	0.35	0.69
55	36.25	35.75	35.88	36.13	0.69	0.69	0.35	0.35
60	36.00	35.88	36.25	35.88	0.00	0.35	0.69	0.35
65	35.75	36.25	36.38	36.25	0.69	0.69	1.04	0.69
70	35.75	36.13	36.25	36.50	0.69	0.35	0.69	1.39
75	36.00	36.25	36.13	35.75	0.00	0.69	0.35	0.69
80	35.50	36.50	36.50	35.75	1.39	1.39	1.39	0.69
85	36.00	36.50	36.25	35.63	0.00	1.39	0.69	1.04
90	35.75	36.50	36.50	35.75	0.69	1.39	1.39	0.69
95	35.63	36.63	36.50	35.88	1.04	1.74	1.39	0.35
100	35.50	37.25	36.88	35.75	1.39	3.47	2.43	0.69
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 3 - This 30-in. diameter pipe was installed in 1996. The pipe is approximately 146-ft. long and has a maximum depth of cover of 10-ft. Due to a significant amount of water in the end of the pipe, no diameter measurements or distress documentation was done on the last 20-ft. of pipe. Joint separations were consistently bad at every joint. The separations ranged from 1 to 5-in. The following table shows the separations at each joint.

Joint No.	Separation at Top (in)	Separation at Bottom (in)	Description
1	1.5	2.25	Exfiltration
2	2.5	2.5	1 1/2-in misalignment of pipes
3	1.0	2.5	
4	0.0	5.0	Fill Soil Visible
5	3.5	3.5	Exfiltration
6	2.0	2.0	
7	2.0	2.5	

A bulge in the pipe was apparent in the bottom of the pipe at 100-ft, possibly due to a rock. A 1/8-in. wide crack had opened up at 16-ft. extending from 270 to 0 degrees. Also, a 6-in. long crack in the pipe was found at 98-ft.

Diameter measurements were taken at every 5 feet to 126-ft. Six percent of the diameter measurements exceeded the 5% criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	29.50	30.75	30.50	29.75	1.67	2.50	1.67	0.83
6	29.00	30.50	31.00	30.25	3.33	1.67	3.33	0.83
11	29.00	30.50	30.88	30.25	3.33	1.67	2.92	0.83
16	29.25	29.75	30.50	30.75	2.50	0.83	1.67	2.50
21	29.63	29.75	30.25	30.50	1.25	0.83	0.83	1.67
26	29.88	30.50	30.25	30.50	0.42	1.67	0.83	1.67
31	30.00	30.25	30.13	30.25	0.00	0.83	0.42	0.83
36	29.88	30.25	30.25	30.13	0.42	0.83	0.83	0.42
41	29.50	29.88	30.50	30.50	1.67	0.42	1.67	1.67
46	30.00	30.25	30.50	30.25	0.00	0.83	1.67	0.83
51	29.75	30.50	30.75	30.13	0.83	1.67	2.50	0.42
56	29.13	30.25	30.50	30.13	2.92	0.83	1.67	0.42
61	29.75	30.25	30.75	30.75	0.83	0.83	2.50	2.50
66	29.75	30.75	32.50	31.25	0.83	2.50	**8.33**	4.17
71	28.25	30.75	31.13	31.25	**5.83**	2.50	3.75	4.17
76	29.25	30.25	31.50	30.50	2.50	0.83	**5.00**	1.67
81	29.25	30.50	31.25	30.88	2.50	1.67	4.17	2.92
86	28.75	30.50	31.50	30.75	4.17	1.67	**5.00**	2.50
91	29.50	30.75	31.25	30.25	1.67	2.50	4.17	0.83
96	28.75	30.75	31.25	30.88	4.17	2.50	4.17	2.92
101	28.75	30.75	31.50	31.00	4.17	2.50	**5.00**	3.33
106	29.25	30.50	31.25	30.75	2.50	1.67	4.17	2.50
111	28.88	30.50	31.50	31.00	3.75	1.67	**5.00**	3.33
116	29.25	30.75	31.00	30.38	2.50	2.50	3.33	1.25
121	28.88	30.50	31.00	30.63	3.75	1.67	3.33	2.08
126	29.50	30.50	31.13	30.25	1.67	1.67	3.75	0.83
	% of Measurements above Tolerance				*3.85*	*0*	*19.2*	*0*

Pipe 4 - This pipe was installed as a test installation. The pipe has a diameter of 36-in. and is 100-ft. long. The pipe consists of a 20-ft. length of pipe, followed by a storm drain, another 70-ft. of pipe, another storm drain, and then ends with a 15-ft. length of pipe. Two major cracks were found: a 1/8-in. crack at 49-ft. extending from 45 to 180 degrees, and a 1/8-in. crack at 50-ft. extending around the entire circumference of the pipe. Also, a small crack had developed at 1-ft. Rippling of the sidewalls was apparent from 5 to 12-ft. Severe deflection was noted in the last 15-ft. of pipe.

Diameter measurements were taken at 5-ft. intervals along the length of the pipe. Due to 4-in. thick layer of sediment at the bottom of the pipe, vertical diameter measurements were not taken along the middle 70-ft. of pipe. The diameter measurements are presented below. Four percent of the deflection calculations exceed 5%.

	Diameter				*% Deflection*			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	35.63	36.50	36.25	35.75	1.04	1.39	0.69	0.69
5	35.00	36.38	36.75	35.75	2.78	1.04	2.08	0.69
10	35.50	36.00	36.50	36.25	1.39	0.00	1.39	0.69
15	34.75	36.25	37.00	35.38	3.47	0.69	2.78	1.74
20	35.25	35.75	36.50	36.63	2.08	0.69	1.39	1.74
0	-	36.38	36.75	36.00	-	1.04	2.08	0.00
5	-	36.25	36.75	36.50	-	0.69	2.08	1.39
10	-	36.00	36.00	36.25	-	0.00	0.00	0.69
15	-	36.25	36.50	36.38	-	0.69	1.39	1.04
20	-	36.50	36.75	35.75	-	1.39	2.08	0.69
25	-	35.63	36.75	36.13	-	1.04	2.08	0.35
30	-	36.25	36.50	36.25	-	0.69	1.39	0.69
35	-	35.50	36.50	36.00	-	1.39	1.39	0.00
40	-	36.75	37.25	36.50	-	2.08	3.47	1.39
45	-	37.50	37.38	36.75	-	4.17	3.82	2.08
50	-	37.00	37.50	36.75	-	2.78	4.17	2.08
55	-	37.38	37.25	36.50	-	3.82	3.47	1.39
60	-	37.00	37.38	36.50	-	2.78	3.82	1.39
65	-	36.25	37.50	36.75	-	0.69	4.17	2.08
70	-	36.25	36.50	36.75	-	0.69	1.39	2.08
0	35.25	36.00	37.25	36.88	2.08	0.00	3.47	2.43
5	32.00	37.75	40.50	38.50	**11.11**	4.86	**12.50**	6.94
10	-	-	-	-	-	-	-	-
15	35.38	36.25	37.00	36.25	1.74	0.69	2.78	0.69
	% of Measurements above Tolerance				*12.5*	*0*	*4.35*	*0*

STATE 5 INSPECTION FINDINGS

Pipe 1 - This pipe was installed in 1992. This pipe is 120-ft. long and has a diameter of 30-in. Since the pipe was 3/4 full of water, the pipe ends were blocked and the water was pumped until 3 to 4-in. of water was left. The pipe was in good condition and no major areas of distress were noted. A few small bulges and swells were observed in the bottom of the pipe. Separations of the joints ranged from 1 to 2-in.

Deflection measurements were taken every 5-ft. along the length of the pipe. Four percent of the deflection calculations exceed 5%.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	30.13	30.25	30.00	30.13	0.42	0.83	0.00	0.42
5	30.25	30.50	30.63	30.50	0.83	1.67	2.08	1.67
10	30.13	30.50	30.00	30.13	0.42	1.67	0.00	0.42
15	31.00	30.13	29.50	29.25	3.33	0.42	1.67	2.50
20	30.50	30.00	29.88	30.75	1.67	0.00	0.42	2.50
25	30.25	30.00	30.13	30.50	0.83	0.00	0.42	1.67
30	30.13	30.13	30.50	30.63	0.42	0.42	1.67	2.08
35	30.00	30.13	30.50	30.50	0.00	0.42	1.67	1.67
40	29.38	30.13	30.50	30.38	2.08	0.42	1.67	1.25
45	30.00	30.50	30.25	30.13	0.00	1.67	0.83	0.42
50	29.25	30.25	31.13	30.13	2.50	0.83	3.75	0.42
55	29.38	30.25	31.13	30.25	2.08	0.83	3.75	0.83
60	30.00	30.00	31.00	29.75	0.00	0.00	3.33	0.83
65	29.38	30.00	31.25	30.13	2.08	0.00	4.17	0.42
70	28.75	29.50	32.00	30.13	4.17	1.67	**6.67**	0.42
75	28.63	29.13	31.63	30.00	4.58	2.92	**5.42**	0.00
80	29.63	30.00	31.00	30.63	1.25	0.00	3.33	2.08
85	29.25	30.13	31.00	30.13	2.50	0.42	3.33	0.42
90	29.63	30.00	30.75	30.38	1.25	0.00	2.50	1.25
95	29.75	30.13	30.63	30.50	0.83	0.42	2.08	1.67
100	29.50	29.25	30.63	30.50	1.67	2.50	2.08	1.67
105	29.25	30.00	31.00	30.50	2.50	0.00	3.33	1.67
110	29.50	29.75	30.38	30.75	1.67	0.83	1.25	2.50
115	29.75	30.00	30.38	30.25	0.83	0.00	1.25	0.83
120	28.50	29.75	31.5	29.88	**5.00**	0.83	**5.00**	*0.42*
	% of Measurements above Tolerance				*4*	*0*	*12*	*0*

Profile of pipe – Pipe 1

Pipe 2 – This pipe was installed in 1999. The pipe has a diameter of 24-in. and is 75-ft. long. The overall condition and the alignment of the pipe is good. No significant areas of distress were found. Separations of the joint ranged from 0.5 to 1-in.

Diameter measurements were taken every 5-ft. No deflection measurements exceed the 5% deflection criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	24.75	24.13	23.75	24.13	3.13	0.52	1.04	0.52
5	24.63	24.25	23.25	24.00	2.60	1.04	3.13	0.00
10	24.13	24.38	24.00	24.25	0.52	1.56	0.00	1.04
15	24.25	24.38	24.25	23.88	1.04	1.56	1.04	0.52
20	24.13	23.75	24.50	24.38	0.52	1.04	2.08	1.56
25	24.50	24.13	24.00	24.25	2.08	0.52	0.00	1.04
30	24.50	24.25	24.00	24.25	2.08	1.04	0.00	1.04
35	24.13	24.13	24.25	24.38	0.53	0.52	1.04	1.56
40	24.25	24.38	24.38	24.50	1.04	1.56	1.56	2.08
45	24.50	24.00	24.00	24.25	2.08	0.00	0.00	1.04
50	24.13	24.38	24.25	24.38	0.52	1.56	1.04	1.56
55	23.25	25.00	25.13	24.63	3.13	4.17	4.69	2.60
60	24.25	24.38	24.50	24.13	1.04	1.56	2.08	0.52
65	24.50	24.50	23.75	24.00	2.08	2.08	1.04	0.00
70	24.25	24.38	23.88	23.75	1.04	1.56	0.52	1.04
75	24.38	24.13	24.25	24.13	1.56	0.52	1.04	0.52
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

View of pipe - Pipe 2

Pipe 3 - This pipe was installed in 1998. The pipe is 70-ft. long and has a diameter of 30-in. The maximum depth of cover is 18-in. The condition of the pipe is good, and no areas of distress were observed. The joint separations at the three joints are as follows:

Joint No.	Separation at Top (in)	Separation at Bottom (in)
1	1.5	0.5
2	0.5	0.5
3	0.5	1.25

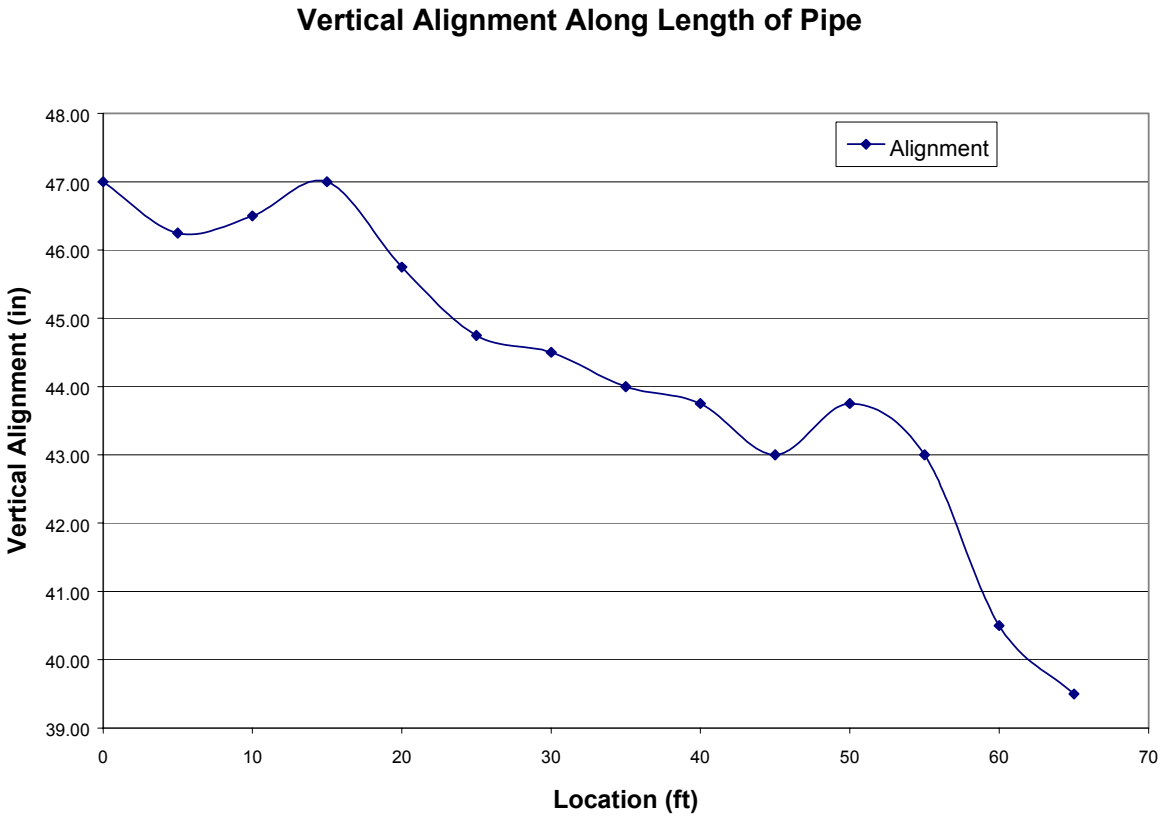
Deflection measurements were taken every 5-ft along the 70-ft. of pipe. No measurements exceed the 5% deflection criteria.

	Diameter				***% Deflection***			
0	30.38	30.25	30.00	30.00	1.25	0.83	0.00	0.00
5	30.25	30.00	29.50	30.38	0.83	0.00	1.67	1.25
10	30.63	30.13	29.50	30.38	2.08	0.42	1.67	1.25
15	29.38	30.00	30.50	30.25	2.08	0.00	1.67	0.83
20	29.75	29.88	30.25	30.50	0.83	0.42	0.83	1.67
25	30.50	29.88	29.63	30.50	1.67	0.42	1.25	1.67
30	30.38	29.75	29.75	30.50	1.25	0.83	0.83	1.67
35	30.25	30.00	30.00	30.38	0.83	0.00	0.00	1.25
40	30.13	30.25	30.00	30.00	0.42	0.83	0.00	0.00
45	30.38	30.13	29.88	30.25	1.25	0.42	0.42	0.83
50	30.13	30.00	30.13	30.25	0.42	0.00	0.42	0.83
55	30.50	30.00	29.75	30.38	1.67	0.00	0.83	1.25
60	30.50	30.38	29.88	30.25	1.67	1.25	0.42	0.83
65	30.25	30.25	29.75	29.25	0.83	0.83	0.83	2.50
70	30.25	30.13	30.13	30.25	0.83	0.42	0.42	0.83
	% of Measurements above Tolerance				*0*	*0*	*0*	*0*

Pipe 4 - This 48-in. diameter pipes is 65-ft. long and has a maximum cover of about 2-ft. Two cracks in the pipe were found at the end of the pipe extending from 30 to 45 degrees and from 280 to 290 degrees. A bulge in the pipe has developed at 60-ft around 270°. No measurements exceed the 5% deflection criteria.

	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	42.50	42.25	41.25	40.50	1.19	0.60	1.79	3.57
5	41.63	41.50	41.25	41.63	0.89	1.19	1.79	0.89
10	42.50	41.63	41.13	41.00	1.19	0.89	2.08	2.38
15	42.63	42.25	40.75	41.50	1.49	0.60	2.98	1.19
20	42.75	42.13	40.75	41.13	1.79	0.30	2.98	2.08
25	42.50	41.50	40.25	41.50	1.19	1.19	4.17	1.19
30	42.50	42.00	41.25	41.13	1.19	0.00	1.79	2.08
35	42.75	42.00	40.25	41.25	1.79	0.00	4.17	1.79
40	43.63	42.50	40.13	41.25	3.87	1.19	4.46	1.79
45	42.75	42.50	41.25	42.38	1.79	1.19	1.79	0.89
50	43.50	42.25	40.13	42.25	3.57	0.60	4.46	0.60
55	43.00	42.25	40.00	40.88	2.38	0.60	4.76	2.68
60	42.25	42.25	40.63	40.50	0.60	0.60	3.27	3.57
65	41.00	42.13	42.38	41.00	2.38	0.30	0.89	2.38
	% Measurements above Tolerance				*0*	*0*	*0*	*0*

Alignment measurements were taken every 5-ft. along the length of the pipe. These measurements are presented in the follow chart and show several vertical offsets.



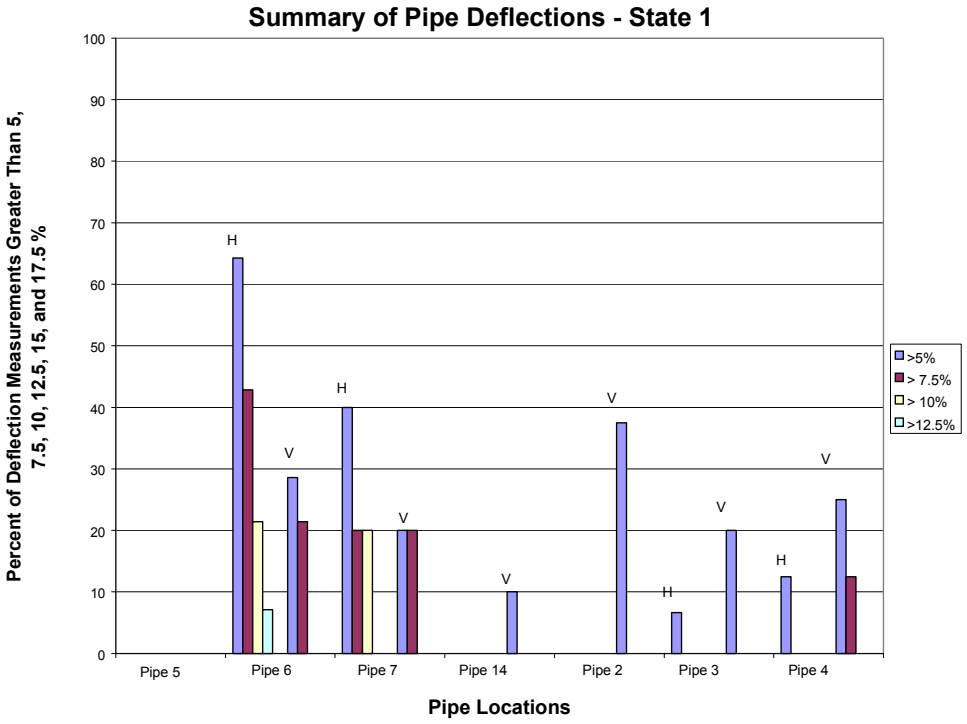
Pipe 5 - This 36-in. diameter pipe is 60-ft. long and has about 6-ft. of soil cover. Due to 18-in. of soil deposits in the last 40-ft. of pipe, only the first 20-ft. of pipe was inspected. This pipe has developed severe deflections throughout the length of pipe.

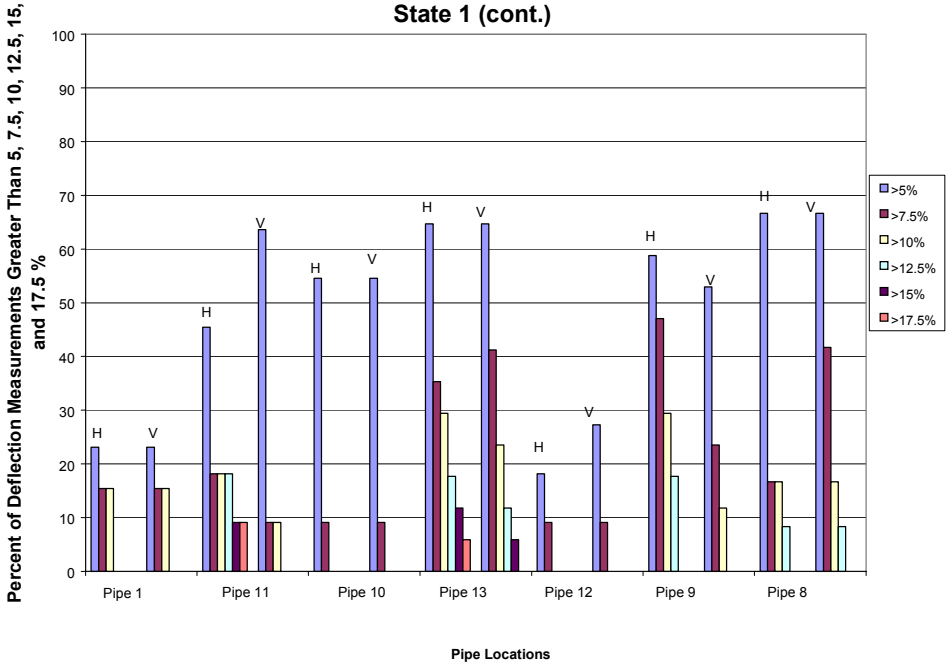
	Diameter				***% Deflection***			
	(0-180)	(45-225)	(90-270)	(135-315)	(0-180)	(45-225)	(90-270)	(135-315)
0	31.25	36.00	40.50	35.75	**13.19**	0.00	**12.50**	0.69
5	31.50	35.00	40.00	36.75	**12.50**	2.78	**11.11**	2.08
10	29.75	35.63	41.50	37.75	**17.36**	1.04	**15.28**	4.86
15	32.50	35.00	40.50	37.50	**9.72**	2.78	**12.50**	4.17
20	34.38	36.00	38.75	36.75	4.51	0.00	**7.64**	2.08
	% of Measurements above Tolerance				*80*	*0*	*100*	*0*

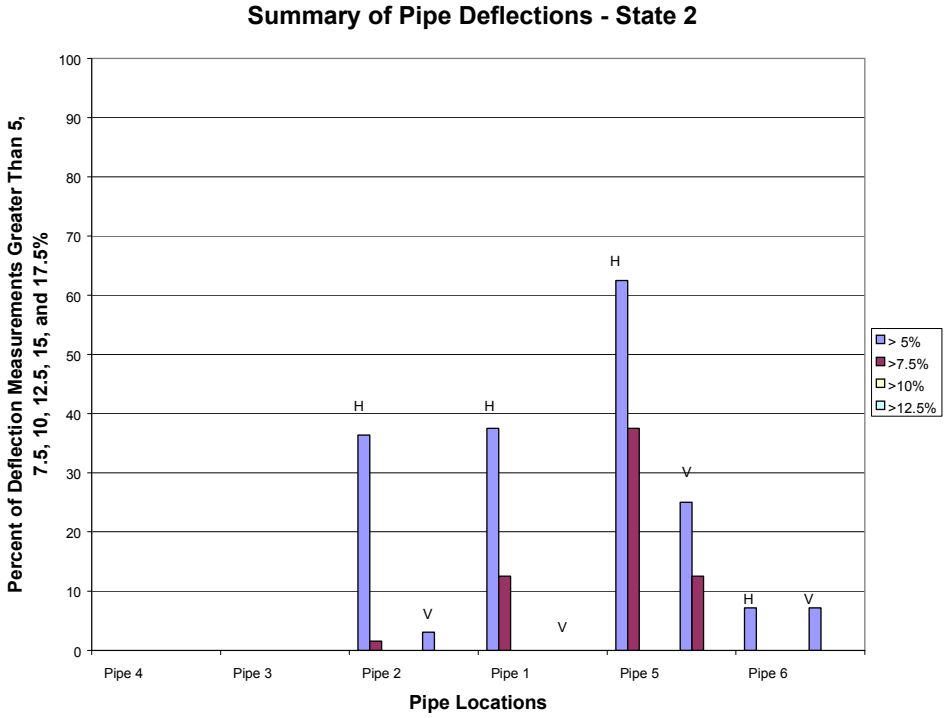
Forty -five percent of the deflection calculations exceed the 5% deflection criteria, and thirty-five percent exceed 10% deflection. The maximum deflection of 17.4% occurred at 10-ft.

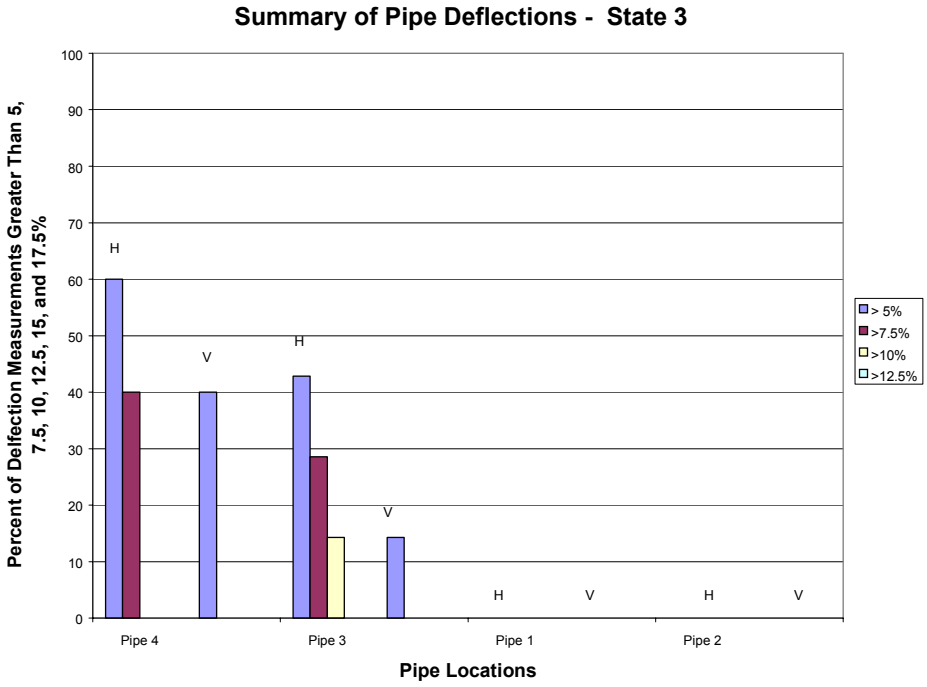
DEFLECTION SUMMARY

The following charts show the diameter measurements by state. Only the horizontal and vertical measurements are presented for each state. (H = Horizontal Deflection Measurements, V = Vertical Deflection Measurements)

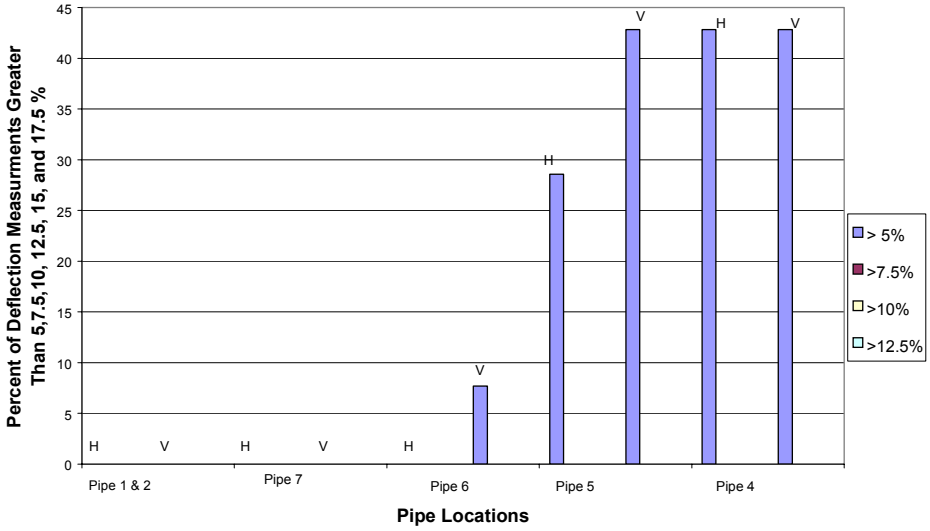




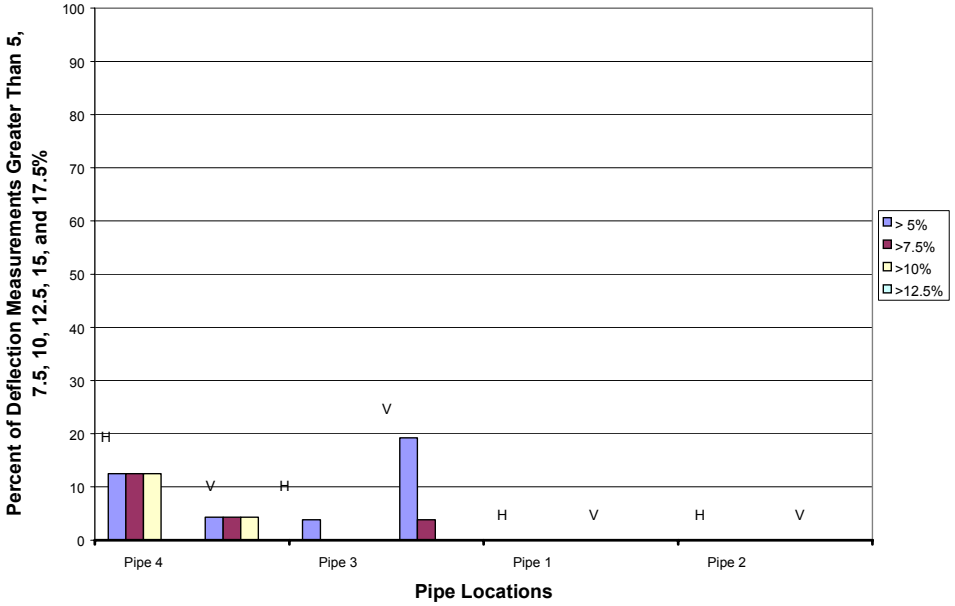

Summary of Pipe Deflections - State 2
Percent of Deflection Measurements Greater Than 5, 7.5, 10, 12.5, 15, and 17.5%
100
90
80
70
60
50
40
30
20
10
0
H
V
H
V
H
V
H
V
> 5%
>7.5%
>10%
>12.5%
Pipe 4
Pipe 3
Pipe 2
Pipe 1
Pipe 5
Pipe 6
Pipe Locations

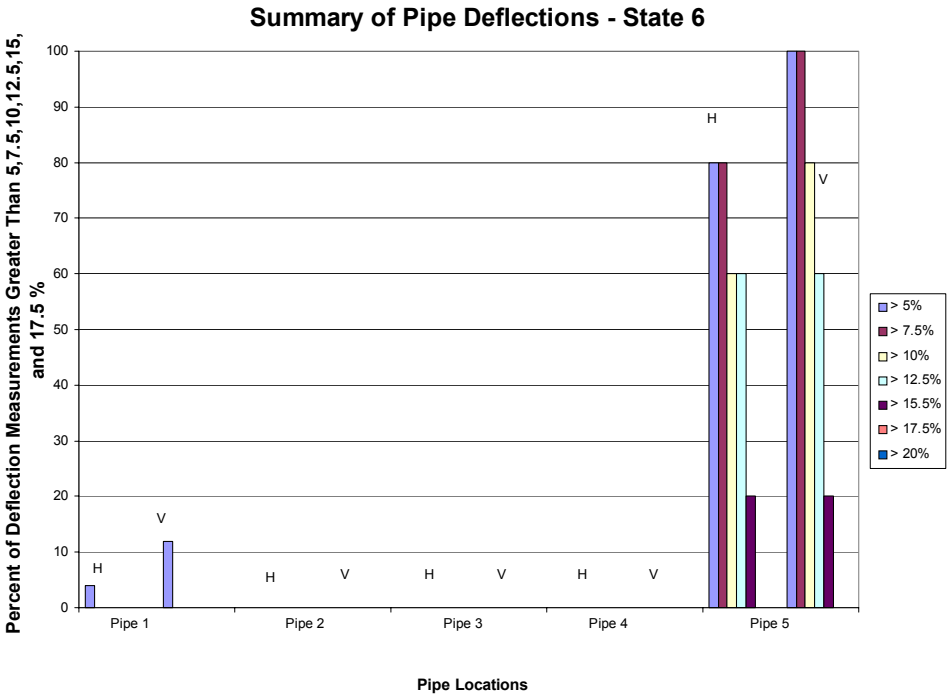

Summary of Pipe Deflections - State 3
Percent of Delfection Measurements Greater Than 5, 7.5, 10, 12.5, 15, and 17.5%
100
90
80
70
60
50
40
30
20
10
0
H
V
H
V
H
V
H
V
> 5%
>7.5%
>10%
>12.5%
Pipe 4
Pipe 3
Pipe 1
Pipe 2
Pipe Locations

Summary of Pipe Deflections - State 4



Summary of Pipe Deflections - State 5




Summary of Pipe Deflections - State 6
Percent of Deflection Measurements Greater Than 5,7.5,10,12.5,15, and 17.5 %
100
90
80
70
60
50
40
30
20
10
0
H
V
H
V
H
V
H
V
H
V
Pipe 1
Pipe 2
Pipe 3
Pipe 4
Pipe 5
Pipe Locations
> 5%
> 7.5%
> 10%
> 12.5%
> 15.5%
> 17.5%
> 20%