RESEARCH

Report No. UT-13.14

MONITORING OF DUROMAXX PIPES INSTALLED ON MANHEAD ROAD IN RICH COUNTY, UTAH

Prepared For:

Utah Department of Transportation
Research Division

Submitted By:

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Final Report
September 2013

udot.utah.gov
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ACKNOWLEDGMENTS

The authors acknowledge the Utah Department of Transportation (UDOT) for funding this research, and the following individuals from UDOT on the Technical Advisory Committee for helping to initiate and guide the research:

- Michael Fazio
- Marjorie Rasmussen
- Rodney Terry
- Denis Stuhff
- Jeff Erdman
- Jerry Chaney
- David Stevens
- Zack Andrus
- Barry Sharp

Bill Cox, Rich County Commissioner, as well as CONTECH Construction Products are also acknowledged for their coordination and support on the federally funded, local government project.

TECHNICAL REPORT ABSTRACT

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UT-13.14	N/A	N/A

4. Title and Subtitle	5. Report Date
MONITORING OF DUROMAXX PIPES INSTALLED ON MANHEAD ROAD IN RICH COUNTY, UTAH	September 2013
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Steven L. Folkman and Scott Rowley	
9. Performing Organization Name and Address	10. Work Unit No.
Utah State University Buried Structures Laboratory 4130 Old Main Hill Logan, UT 84322-4130	8RD1492H
	11. Contract or Grant No. 11-9009
12. Sponsoring Agency Name and Address	13. Type of Report & Period Covered
Utah Department of Transportation 4501 South 2700 West P.O. Box 148410 Salt Lake City, UT 84114-8410	Final Report July 2010 to July 2013
	14. Sponsoring Agency Code PIC No. MP10.003

15. Supplementary Notes

Prepared in cooperation with the Utah Department of Transportation.

16. Abstract

This report documents the performance of two different culvert materials in an installation in northern Utah. The culverts are described as a DuroMaxx pipe made by CONTECH Construction Products, Inc. and an N-12 HDPE culvert made by ADS Corporation. Both culvert types are 24 inches in diameter. The DuroMaxx pipe was the type receiving actual evaluation; the ADS pipe installed nearby was used for comparison. A total of five inspections were made over a three year period. Culvert deflections at five locations along four culverts were measured each visit. The deflections and general observations about the pipe are reported. With the exception of two locations, both the ADS and DuroMaxx pipes have performed adequately. The ADS pipe in one location has a deflection of 7%, but is holding steady at that deflection which is described as marginal. Also damage has been done on the west entrance to the DuroMaxx pipe. The cause of the damage is unknown. Deflections are higher in the ADS pipe than in the DuroMaxx pipe. The magnitude of the deflections is primarily attributed to the small spacing and low soil compaction between adjacent pipes. The DuroMaxx pipe does achieve a smaller deflection in this situation.

17. Key Words	18. Distribution Statement	23. Registrant's Seal
Culvert, ADS, DuroMaxx, deflection, monitoring	Not restricted. Available through: UDOT Research Division 4501 South 2700 West P.O. Box 148410 Salt Lake City, UT 84114-8410 www.udot.utah.gov/go/research	N/A

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	45	N/A

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EXECUTIVE SUMMARY

Utah State University was asked by the Utah Department of Transportation (UDOT) to monitor two different types of culverts installed on Manhead road in Rich County. The objective was to examine the performance of a new HDPE drainage culvert utilizing a steel spiral rib. This new pipe is called DuroMaxx and made by CONTECH Construction Products, Inc. The DuroMaxx culverts were compared with a conventional N-12 HDPE pipe manufactured by ADS Corporation. Actual pipe stiffness values were not provided for the DuroMaxx and ADS pipes. Both pipes are manufactured to the same minimum pipe stiffness specification. The DuroMaxx culverts were initially installed on July 19, 2010. The ADS culvert was installed within the same month. Both culvert types were 24 inches in diameter. In each installation location, two pipes (either ADS or DuroMaxx) were installed beside each other with a gap between them.

The authors were not present when the culverts were installed. However, photographs of the installation are available. All available evidence indicates both types of pipe had nearly identical installation procedures. Nevertheless, there is insufficient documentation of the pipe installation procedures to guarantee that the procedures where identical. In the author’s opinion, the pipe installation procedure was less than ideal. A single trench was dug and both pipes were placed side by side. The distance between the pipe walls and the trench walls is difficult to determine from available photographs. However, the distance between adjacent pipes is approximately 5.0 inches. This is approximately half the minimum clearance specified in ASTM D2321. When installing a flexible pipe, one should have sufficient clearance on each side of a pipe to allow compaction equipment to work the soil into the pipe haunch regions. Soil below the spring line of the pipe would have been in an “as dumped” state.

The research contract required measuring culvert deflections and condition during five visits over a three year period. Low soil compaction in the pipe haunches and a small soil column between pipes resulted in large deflections in the ADS pipe. Significantly, one station of the ADS culvert is at 7% deflection which borders on the 7.5% deflection limit at which the culvert should be replaced. Nevertheless, the ADS deflections appear to have stabilized. The results show that the DuroMaxx pipe did produce smaller deflections. An anomaly occurred in the

measured deflections of the DuroMaxx pipe between the 1-month inspection and the year-1 inspection. This anomaly was a small overall reduction in pipe deflections which was not expected. The final (year-3) inspection correlates well with the year-2 and year-1 results. The cause of the anomaly is believed to be associated with settlement of the ribs into the granular fill during the winter and spring when the water table was high. With regard to pipe deflections, the DuroMaxx culverts have had excellent performance so far.

In the final inspection there was some damage observed in the DuroMaxx pipes in the west entrance to both pipes. The damage is localized to the portion extending past the soil. This may be a concern if the additional damage causes erosion of the shoulder material.

1.0 INTRODUCTION

UDOT asked Buried Structures Laboratory at Utah State University to monitor a new pipe installation in Rich County, Utah. The pipe installed is manufactured by CONTECH Construction Products, Inc. and is described as DuroMaxx pipe. This is a steel reinforced polyethylene pipe. This pipe was installed on July 19, 2010 on Manhead Road (Latitude 41°49'56.71"N, Longitude 111° 4'37.06"W), north of Randolph, as part of a Federal aid, local government road rehabilitation and widening project (STP-0357(2)). This was the only location along the project where DuroMaxx pipe was used.

To give a relative comparison of the performance of this pipe, measurements were also taken on conventional HDPE pipe manufactured by Advanced Drainage System Corporation (ADS). The monitored ADS pipe was installed within the same month approximately 270 feet south of the DuroMaxx pipe. The installations are essentially identical with two lengths of 24 inch pipe at each location with approximately 3 feet of soil cover over the pipes. Figure 1 shows photographs of the two pipe installations.

The objective of this study is to monitor deflections in these two pipe installations over a 3 year period. The results of this study would be used by UDOT to judge the suitability of DuroMaxx pipe for installation in other locations in Utah.

With the exception of two locations, both the ADS and DuroMaxx pipes have performed adequately. The ADS pipe in one location has a deflection of 7%, but is holding steady at that deflection which is described as marginal. Damage has been done on the west entrance to the DuroMaxx pipe. The cause of the damage is unknown.

Figure 1. Photographs of the DuroMaxx (left) and ADS (right) pipe installations.

2.0 RESEARCH METHODS

Pipe health and/or distress of flexible pipe can be inferred from pipe deflections. If a flexible pipe is installed properly, deflections should be less than 5% of the pipe diameter. Thermoplastic pipes with deflections in excess of 5% should be reviewed by a professional engineer, and AASHTO recommends pipes with deflections in excess of 7.5% be removed from service. For deflections greater than 7%, joint leakage might occur. Infiltration or exfiltration at the joint can lead to destabilization of the backfill material and pipe collapse. High deflections increase pipe stress and thereby make them more susceptible to failure by slow crack growth. Initial pipe deflection in flexible pipe is primarily governed by the quality of the installation. A secondary effect is pipe stiffness. Actual pipe stiffness values were not provided for the DuroMaxx and ADS pipes. Both pipes are manufactured to the same minimum pipe stiffness specification. One might expect smaller pipe deflections from the stiffer pipe if identical installation procedures were followed. However, there is insufficient data available to assure that both pipes had identical installation procedures.

A UDOT representative observed the installation of the DuroMaxx pipe on July 19, 2010 and prepared the installation memorandum included in Appendix A of this report. Utah State University researchers did not observe installation of either pipe type at the project site. Figure 2 shows photographs supplied by UDOT of the DuroMaxx pipe installation. The authors were not present when the culverts were installed, but photographs similar to those in Figure 2 were supplied by UDOT and reviewed.

The measured gap between adjacent pipes of both types was nominally 5.0 inches. UDOT project plans called for positioning the DuroMaxx pipes on 4.5 foot centers and the ADS pipes to the south on 4.0 foot centers. The outside diameter of the ADS pipe is 27.8 inches, and the gap between the adjacent pipes should have resulted in 20 inches of clearance between the two pipes. The gap between the DuroMaxx pipes should have been even greater. ASTM D2321 gives guidance for installation for thermoplastic pipes. The ASTM D2321 recommendation for minimum trench width is 1.25 x (Outside Diameter) + 12 inches = 47 inches (for the ADS pipe), indicating the need for 9 to 10 inches of clearance on each side of a pipe. Other guidelines are available from AASHTO and pipe manufactures, but in this case ASTM D2321 gives the smallest trench width specification. It is difficult to determine from the available photographs of the installation what the overall trench width was. Nevertheless, the clearance between adjacent pipes did not meet UDOT project plans or ASTM D2321 guidelines. When a trench width is too small, compaction equipment cannot move compacted soil into the haunch regions. The crushed stone backfill material was an excellent material, if properly compacted. In the region between the pipes and particularly in the pipe haunch regions, the fill would have been in an "as dumped" condition with very low compaction and would lead to increased pipe deflections.

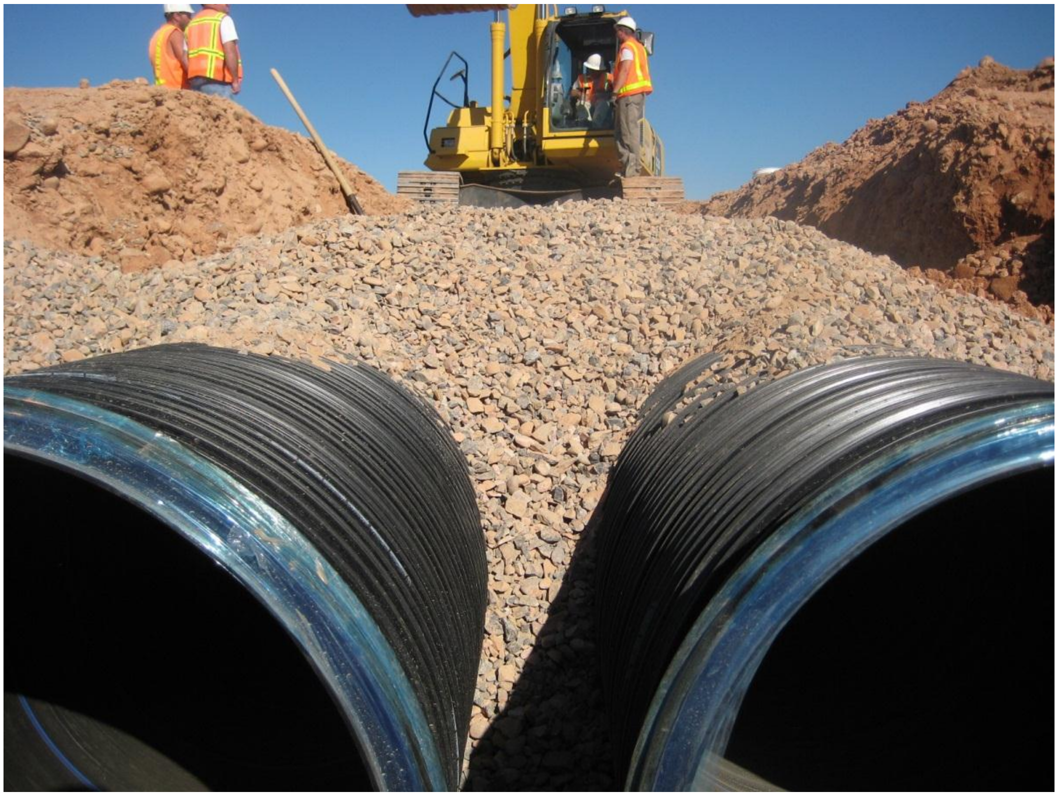

Figure 2. Photographs of the DuroMaxx pipe installation (photos from UDOT).

3.0 DATA COLLECTION

3.1 Pipe Deflections

Pipe deflections were determined by measuring vertical and horizontal inside diameters at five positions along each pipe. Figure 3 illustrates the measurement locations. It was desired to have three locations under the traffic lanes and two on the soft shoulder areas. Table 1 lists the specific locations for the measurements relative to the west end of each pipe. Only Station 1 for the South ADS pipe was slightly adjusted to avoid measuring directly on top of a pipe joint. The inside pipe diameters were measured with a Bosch Distance Measurer, model DLR130, with a resolution of 1/16 inch.

On the initial inspection of each pipe, the measurement locations were clearly marked with paint on the inside of the pipes. Figure 4 shows a photograph of the base and target marks made at one station. The base locations for horizontal and vertical measurements are the location to place the Bosch distance sensor. The target marks are the location where the laser dot is placed, prior to making the distance measurement. Past experience has shown that the paint used is quite durable. During each subsequent visit, the markings were checked for decay or being rubbed off. The initial markings did not require a reapplication of the paint during the entire project. Thus the measurements are consistently made from the same locations in the pipe.

A schedule of the pipe inspections is given in Table 2. At the first inspection visit, only the ADS pipe was inspected. The DuroMaxx pipe had water in it, due to the sprinkler system used in the alfalfa field adjacent to the pipe. This water prevented applying the measurement markers. A special pipe squeegee was fabricated to push out remaining pipe water on the subsequent inspection visit a week later.

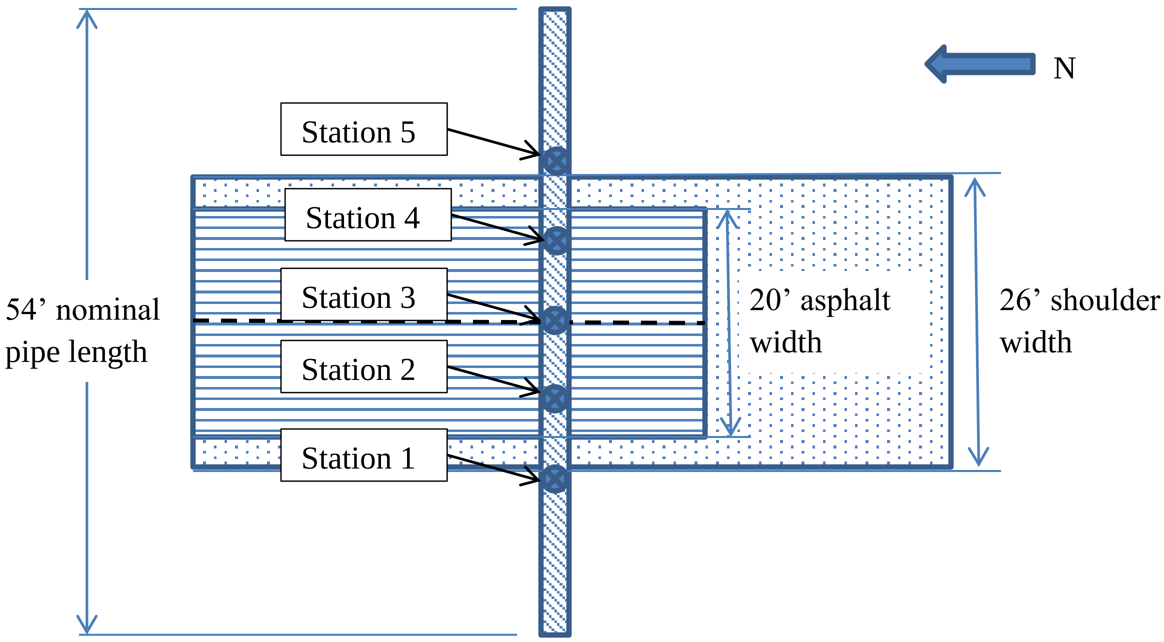

Figure 3. Illustration of the measurement station locations with respect to the road.

Table 1. Station locations in feet from the west end of the pipe

Station	DuroMaxx South Pipe	DuroMaxx North Pipe	ADS South Pipe	ADS North Pipe
1	13	13	14	13
2	20	20	20	20
3	27	27	27	27
4	34	34	34	34
5	41	41	41	41

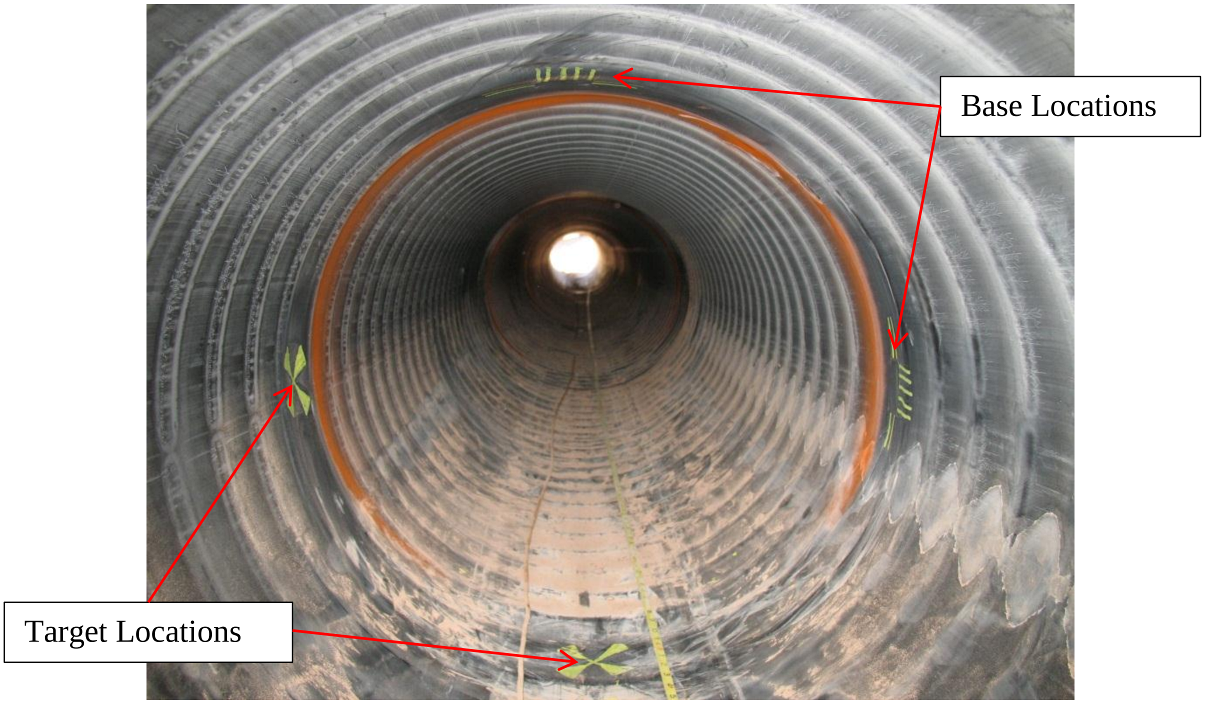

Figure 4. Base and target marking at a measurement station.

Table 2. Summary of pipe inspection dates

	Date
Installation	July 19, 2010
First Inspection (ADS Pipe)	Aug. 23, 2010
First Inspection (DuroMaxx Pipe)	Aug. 27, 2010
Second Inspection (1-month)	Sep. 28, 2010
Third Inspection (year-1)	July 8, 2011
Fourth Inspection (year-2)	June 29, 2012
Fifth Inspection (year-3)	June 28, 2013

The dimensional data collected is given in Appendices B, C, D, E and F. Appendix B lists the dimensions measured during the initial visits. Appendices C, D, E and F list the dimensions measured on the second, third, fourth, and fifth inspections, respectively. The nominal inside pipe diameter was not measured prior to installation. Since pipe deflections are small in the initial pipe inspections, an estimate of the unburied pipe diameter is computed by averaging the vertical and horizontal pipe dimensions. This estimate of the initial inside pipe diameter is summarized in Table 3. Note that the DuroMaxx pipe is 0.6 inch smaller in diameter. These initial inside diameter values were used to compute the percent deflection of each pipe as:

$$\%\ deflection = \frac{ID - ID_{initial}}{ID_{initial}} \times 100 \qquad (1)$$

Where, ID is the current inside diameter and $ID_{initial}$ is the appropriate value from Table 3. Negative deflection values indicate a decrease in diameter and positive deflection values indicate an increase in diameter.

Table 3. Estimate of initial pipe diameters

	Inside Diameter (inches)
DuroMaxx	23.532
ADS	24.135

A summary of the initial pipe deflections as a percentage of the diameter at each measurement station is given in Table 4. Deflections measured in the second inspection (one-month) are summarized in Table 5. The red values in Table 5 are used to highlight deflections that are different from the initial values. Similarly, Tables 6, 7, and 8 list the measured deflections after the third (one-year), fourth (two-year), and fifth (three-year) visits, respectively, with red values again highlighting changes from the previous visit.

Table 4. Pipe deflections from the initial inspection

		South Pipe		North Pipe	
	Station	Vert. Def (%)	Hori. Def (%)	Vert. Def (%)	Hori. Def (%)
ADS	1	-6.77%	6.90%	-3.29%	3.42%
	2	-5.03%	4.66%	-4.04%	3.67%
	3	-3.05%	3.17%	-2.30%	2.18%
	4	-5.03%	4.41%	-4.54%	4.91%
	5	-1.31%	1.18%	-3.29%	4.16%
	Average	-4.24%	4.06%	-3.49%	3.67%
DuroMaxx	1	-1.58%	1.99%	-0.82%	0.97%
	2	-1.33%	2.50%	-1.58%	0.97%
	3	-2.86%	3.01%	-2.86%	2.24%
	4	-2.35%	3.01%	-2.86%	2.75%
	5	-1.07%	0.71%	-1.84%	0.97%
	Average	-1.84%	2.24%	-1.99%	1.58%

Table 5. Pipe deflections from the second inspection (~1 month after installation)

	Station	South Pipe		North Pipe	
		Vert. Def (%)	Hori. Def (%)	Vert. Def (%)	Hori. Def (%)
ADS	1	-7.02%	7.15%	-3.29%	3.42%
	2	-5.03%	4.66%	-4.29%	3.67%
	3	-3.29%	3.17%	-2.55%	2.18%
	4	-5.03%	4.41%	-4.79%	4.91%
	5	-1.31%	1.18%	-3.29%	4.16%
	Average	-4.34%	4.11%	-3.64%	3.67%
DuroMaxx	1	-1.84%	1.99%	-0.82%	0.97%
	2	-1.58%	2.50%	-1.58%	0.97%
	3	-2.86%	3.01%	-2.86%	2.24%
	4	-2.35%	3.01%	-2.86%	2.75%
	5	-1.07%	0.97%	-1.84%	1.22%
	Average	-1.94%	2.29%	-1.99%	1.63%

Note: red values indicate readings that differ from the previous inspection results.

Table 6. Pipe deflections from the third inspection (~1 year after installation)

	Station	South Pipe		North Pipe	
		Vert. Def (%)	Hori. Def (%)	Vert. Def (%)	Hori. Def (%)
ADS	1	-6.53%	6.40%	-2.80%	3.17%
	2	-5.03%	4.66%	-4.04%	3.67%
	3	-3.05%	3.17%	-2.30%	2.18%
	4	-5.03%	4.41%	-4.79%	5.16%
	5	-1.31%	1.18%	-3.29%	4.16%
	Average	-4.19%	3.97%	-3.44%	3.67%
DuroMaxx	1	-1.07%	1.48%	-0.82%	0.71%
	2	-0.82%	1.99%	-1.07%	0.97%
	3	-2.09%	2.24%	-2.35%	1.73%
	4	-2.09%	2.50%	-2.35%	2.24%
	5	-1.07%	0.71%	-1.58%	0.97%
	Average	-1.43%	1.78%	-1.63%	1.33%

Note: red values indicate readings that differ from the previous inspection results.

Table 7. Pipe deflections from the fourth inspection (~2 years after installation)

	Station	South Pipe		North Pipe	
		Vert. Def (%)	Hori. Def (%)	Vert. Def (%)	Hori. Def (%)
ADS	1	-6.53%	6.65%	-3.05%	3.17%
	2	-5.28%	4.66%	-4.29%	3.67%
	3	-3.05%	3.17%	-2.55%	2.18%
	4	-5.03%	4.41%	-5.03%	5.16%
	5	-1.31%	0.93%	-3.29%	3.92%
	Average	-4.24%	3.97%	-3.64%	3.62%
DuroMaxx	1	-1.07%	1.22%	-0.56%	0.71%
	2	-0.82%	1.73%	-1.33%	0.71%
	3	-2.09%	2.24%	-2.09%	1.73%
	4	-2.09%	2.50%	-2.35%	2.24%
	5	-1.07%	0.71%	-1.58%	0.97%
	Average	-1.43%	1.68%	-1.58%	1.27%

Note: red values indicate readings that differ from the previous inspection results.

Table 8. Pipe deflections from the fifth inspection (~3 years after installation)

	Station	South Pipe		North Pipe	
		Vert. Def (%)	Hori. Def (%)	Vert. Def (%)	Hori. Def (%)
ADS	1	-6.53%	6.65%	-3.05%	3.42%
	2	-5.28%	4.91%	-4.29%	3.67%
	3	-3.29%	3.17%	-2.80%	2.42%
	4	-5.03%	4.66%	-5.03%	5.41%
	5	-1.31%	1.18%	-3.29%	3.92%
	Average	-4.29%	4.11%	-3.69%	3.77%
DuroMaxx	1	-1.33%	1.22%	-0.56%	0.71%
	2	-0.82%	1.73%	-1.33%	0.71%
	3	-2.09%	2.24%	-2.09%	1.48%
	4	-2.09%	2.50%	-2.35%	2.24%
	5	-1.07%	0.71%	-1.58%	1.22%
	Average	-1.48%	1.68%	-1.58%	1.27%

Note: red values indicate readings that differ from the previous inspection results.

3.2 Visual Inspections

Visual inspections and measurements were made by traversing the length of the pipe. Given the tight fit in a 24-inch pipe, a skateboard covered with a foam pad aided the process. Figure 5 is a photograph of a student preparing to enter the pipe on the skateboard. The inspector can move along by pulling with their hands or pushing with their feet.

Photographs of the pipes made during the initial visit are shown in Figure 6 for the DuroMaxx pipe and in Figure 7 for the ADS pipe. Figures 8 and 9 are DuroMaxx and ADS photos made at the one-year visit. Similarly, Figures 10, 11, 12, and 13 are DuroMaxx and ADS photos made at the two-year and three-year visits. Note that all the pipes showed that water levels up to about 1.0 inch deep are present at certain times of the year.

An effort was made to identify any localized deflections that could be identified visually on the interior of the pipe. No significant issues were observed during the visual inspections of the inside pipe surfaces. However, on the two-year visit, minor rock impingement bumps were observed in the haunch region of the north DuroMaxx pipe between stations 1 and 2. Figure 14 is a photo of the "bumps." Please note that it is difficult to capture these minor bumps if the camera flash is operating. Figure 14 has the flash turned off requiring a long shutter time (causing some blurring) and the pipe exit cropped out to better highlight the bumps. These very minor bumps did not change between the year-2 and year-3 visits and likely have been present all along. Minor damage was also observed during the final inspection in the blue plastic seals that cover the spiral weld seams in the south DuroMaxx pipe. Figure 15 has a photograph of the damage. After careful inspection it was determined that the loops were pulled away from the pipe during our inspections. It is believed that in process of pushing ourselves through the pipes that our feet pulled these seals out as shown. Since these are located above the spring-line of the pipe, no leakage or soil migration issues are expected.

Some significant damage was observed on the final, year-3 inspection on the west entrance of the DuroMaxx pipes. Figures 16 and 17 are photographs of the pipe at the west entrance. Figure 17 shows the tear at a rib location that occurred. The soil above the pipe may be more subject to erosion because of this. No damage was observed on the exterior of the ADS pipe. The cause of this damage is unknown.

Figure 5. Photograph of the padded skate board used during pipe inspections.

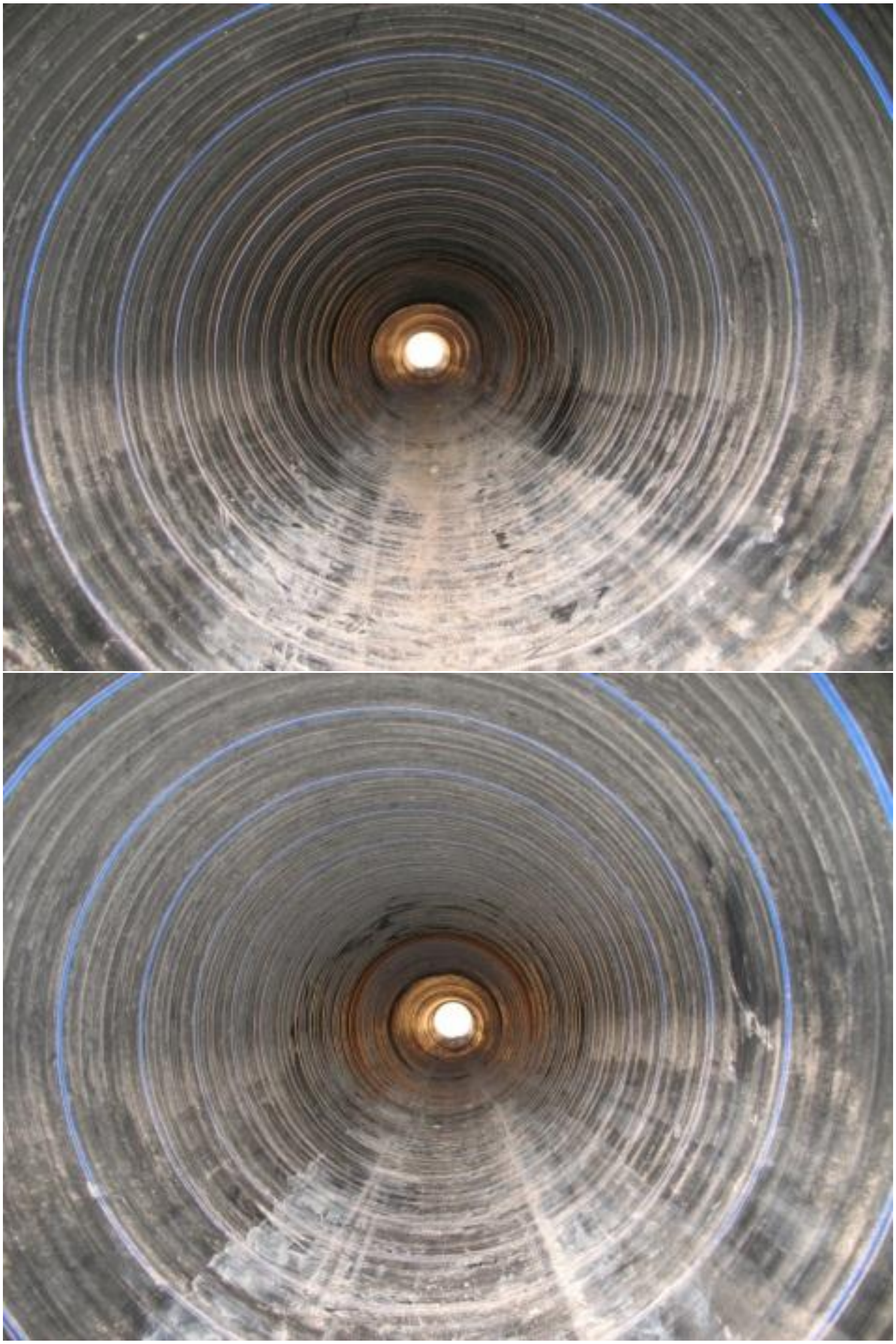

Figure 6. DuroMaxx pipe photos at initial visit; north pipe (top) and south pipe (bottom).

Figure 7. ADS pipe photos at initial visit; north pipe (top) and south pipe (bottom).

Figure 8. DuroMaxx pipe photos after 1 year; north pipe (top) and south pipe (bottom).

Figure 9. ADS pipe photos after 1 year; north pipe (top) and south pipe (bottom).

Figure 10. DuroMaxx pipe photos after 2 years; north pipe (top) and south pipe (bottom).

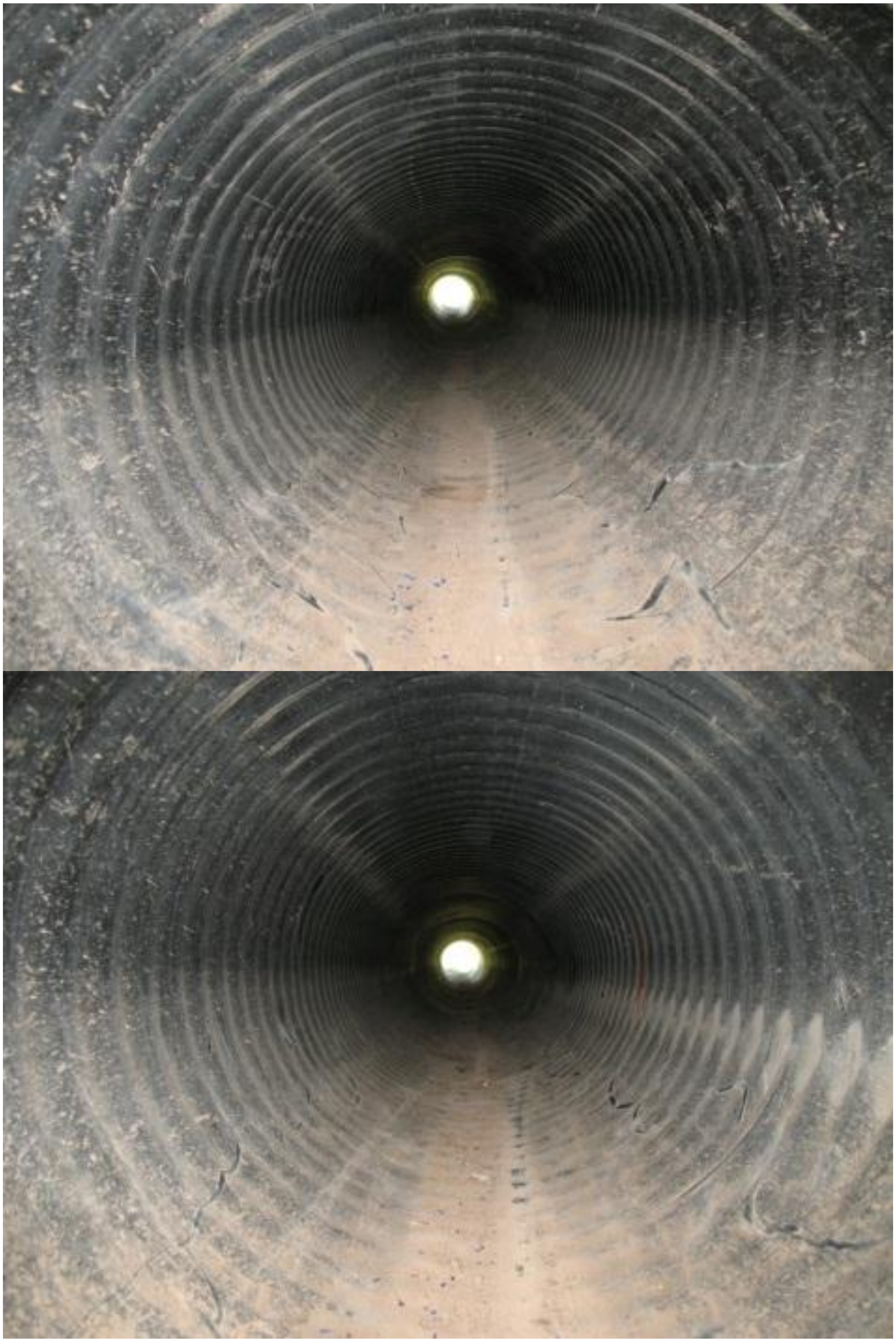

Figure 11. ADS pipe photos after 2 years; north pipe (top) and south pipe (bottom).

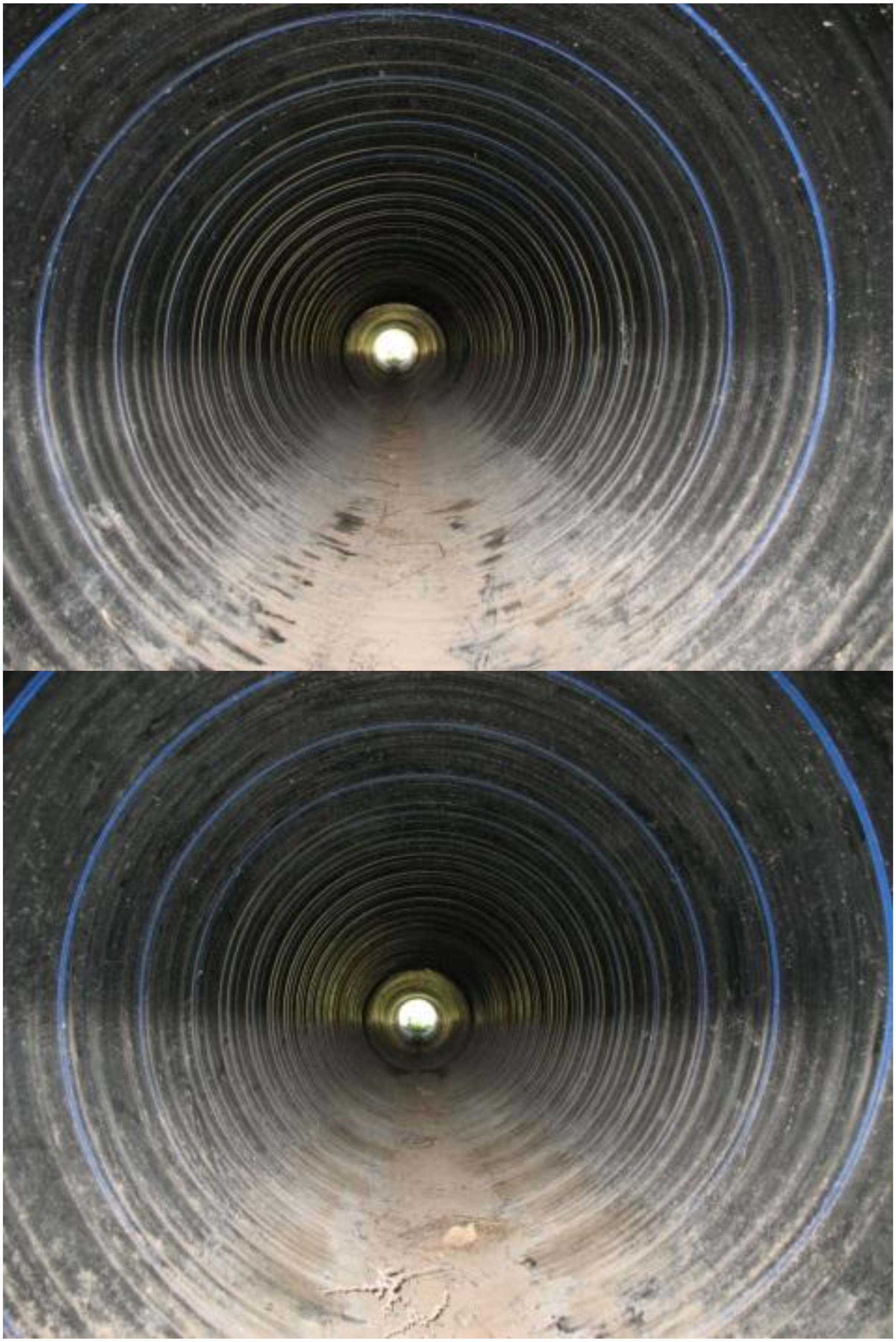

Figure 12. DuroMaxx pipe photos after 3 years; north pipe (top) and south pipe (bottom).

Figure 13. ADS pipe photos after 3 years; north pipe (top) and south pipe (bottom).

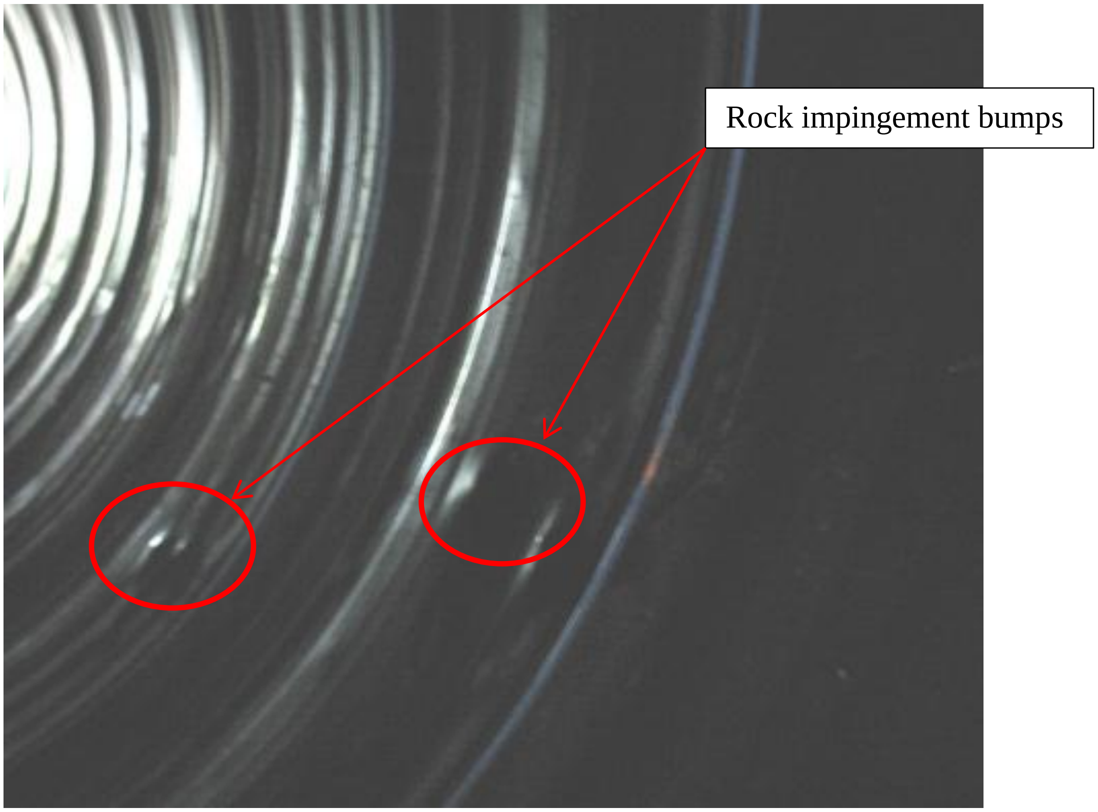

Figure 14. Rock impingement bumps in the north DuroMaxx pipe.

Figure 15. Minor damage to plastic seal at spiral weld locations.

Figure 16. Damage to the west entrance to the DuroMaxx pipe.

Figure 17. Close up view of damage to the west entrance to the north DuroMaxx pipe.

4.0 DATA EVALUATION/ANALYSIS

Looking at Table 4 from the initial visit, and Tables 5, 6, 7, and 8 from subsequent visits, we see that the deflections of the DuroMaxx pipe are approximately half those of the ADS pipe. From our experience, if the trench was wider and the backfill was more uniformly worked into the haunches, the difference in the deflections would not be as great. Over the inspection period the deflections at station 1 in the south ADS pipe have been near 7% in both the vertical and horizontal directions. AASHTO LRFD requirements state that pipes exhibiting deflection over 5% after 30 days should be evaluated by a Professional Engineer and that over 7.5% should be removed from service. Thus this is a reason for concern. Again, the cause of these large deflections was too small of spacing between pipes and the resulting low soil compaction.

To better visualize the data in Tables 4, 5, 6, 7, and 8, the deflections were plotted as a function of station number (roughly at 7 foot intervals) and a bar color is drawn for each visit, thereby showing variations in deflections with time. The cyan (light blue) bars are for the most recent visit. Figure 18 presents the results for the ADS pipe. Figure 18 shows little to no changes in the ADS pipe deflection with time and the system seems very stable. The small changes seen are consistent with soil consolidation and pipe stress relaxation. Figure 19 gives a corresponding set of plots for the DuroMaxx pipe. The initial and one-month deflections of the DuroMaxx pipe are nearly identical. However, the one-year observation of the DuroMaxx pipe shows a change from previous measurements. The one-year inspection is surprising in that the pipe deflections in both horizontal and vertical directions are in most cases slightly reduced! However, the two-year and three-year inspections closely follow the one-year data. The readings on the DuroMaxx pipe were double checked and the measurement sensor calibration accuracy was verified after the one-year visit and again prior to the two-year visit, so we are confident in the measured data. The reduction in pipe deflections is not a cause for concern, but they are opposite to the trend that is normally expected. It is important to note that a 0.25% change in deflection is slightly less than 1/16-inch error which is the resolution of the sensor. Thus, changes in the readings on this level are quite small deflections.

The cause of the slight re-rounding of pipe between the one-month and one-year inspections is believed to be attributed to penetration of the pipe ribs on the bottom of the pipe into the very granular soil. Figure 20 shows the DuroMaxx pipe ribs and the approximate clearance around the ribs. The granular nature of the soil is also shown in Figure 2. As previously mentioned, the pipes were laid too close together and in a narrow trench preventing adequate compaction of the soil in the haunch regions. However, it is believed that the soil above the pipe spring-line was highly compacted, allowing formation of a stiff soil arch. As shown in Figures 6 through 13, the water table does exceed the bottom of the pipe, probably during snow melt in the spring. During the first winter and spring, the high water table lubricated the soil particles and allowed the DuroMaxx ribs to penetrate more deeply into the loose granular material they were sitting on while the highly compacted soil bridge over the top of the pipe remained secure. Thus a small amount of re-rounding of the pipe occurred. Although we have no proof of this scenario, it does appear as a likely candidate.

The high deflections in the ADS pipe are attributed to pipe spacing and soil compaction issues. The most commonly accepted formula for predicting pipe deflections is called the Iowa formula:

$$\Delta y = \frac{D_L K W_c r^3}{EI + 0.061 E' r^3} \tag{2}$$

Where: Δy = pipe deflection, D_L = 1.2 = deflection lag factor, K = 0.1 = bedding constant, W_c = 834 lb/ft = prism load for 3 feet of cover with 120 lb/ft^3 soil, r = pipe radius, E = 20 ksi = long-term Young's modulus of the pipe, $I = 0.137$ in^3 = pipe moment of inertia per unit length, and E' = soil stiffness parameter. The primary variable of concern is the soil stiffness (E'). Well compacted crushed stone can easily have $E' > 1000$ psi. Using E'=800 psi, the predicted pipe deflection for an ADS N-12 24" pipe would be 0.166 inch or about 0.7% deflection. Alternately, consider Figure 21, published by ADS Corporation and available from:
http://www.ads-pipe.com/pdf/en/technical_static/technical_note_2.130_structural_performance.pdf.
Figure 21 plots the expected pipe deflections in a 24" N-12 ADS pipe as a function of depth of cover for three soil compaction levels. There are a multitude of tests in published literature that coincide with the results of Figure 21. Thus, with correct installation, the deflections in the ADS pipe could have been less than 1%.

One might be tempted to conclude that in terms of overall pipe deflections, the DuroMaxx pipe has better performance than the ADS pipe. In Eq. 2 above, the *EI* term (pipe stiffness) in the denominator is normally small compared with the second term (soil stiffness) for a flexible pipe. That is, the quality of the soil installation process has the biggest effect on pipe deflections. As discussed above, the quality of the installation was less than ideal. One might conclude that the DuroMaxx pipe was stiffer than the ADS pipe leading to smaller deflections. Actual pipe stiffness values for both pipes have not been provided. Both are manufactured to the same minimum stiffness standard. In Appendix G, simple hand calculations are used to illustrate that one could expect the DuroMaxx pipe to be stiffer. Nevertheless, if the quality of installation of the ADS pipe were not as good as the quality of the DuroMaxx pipe, that would have a large effect on the overall results. The only conclusion that can be drawn here is that the DuroMaxx pipe deflection performance was acceptable in a less than ideal installation.

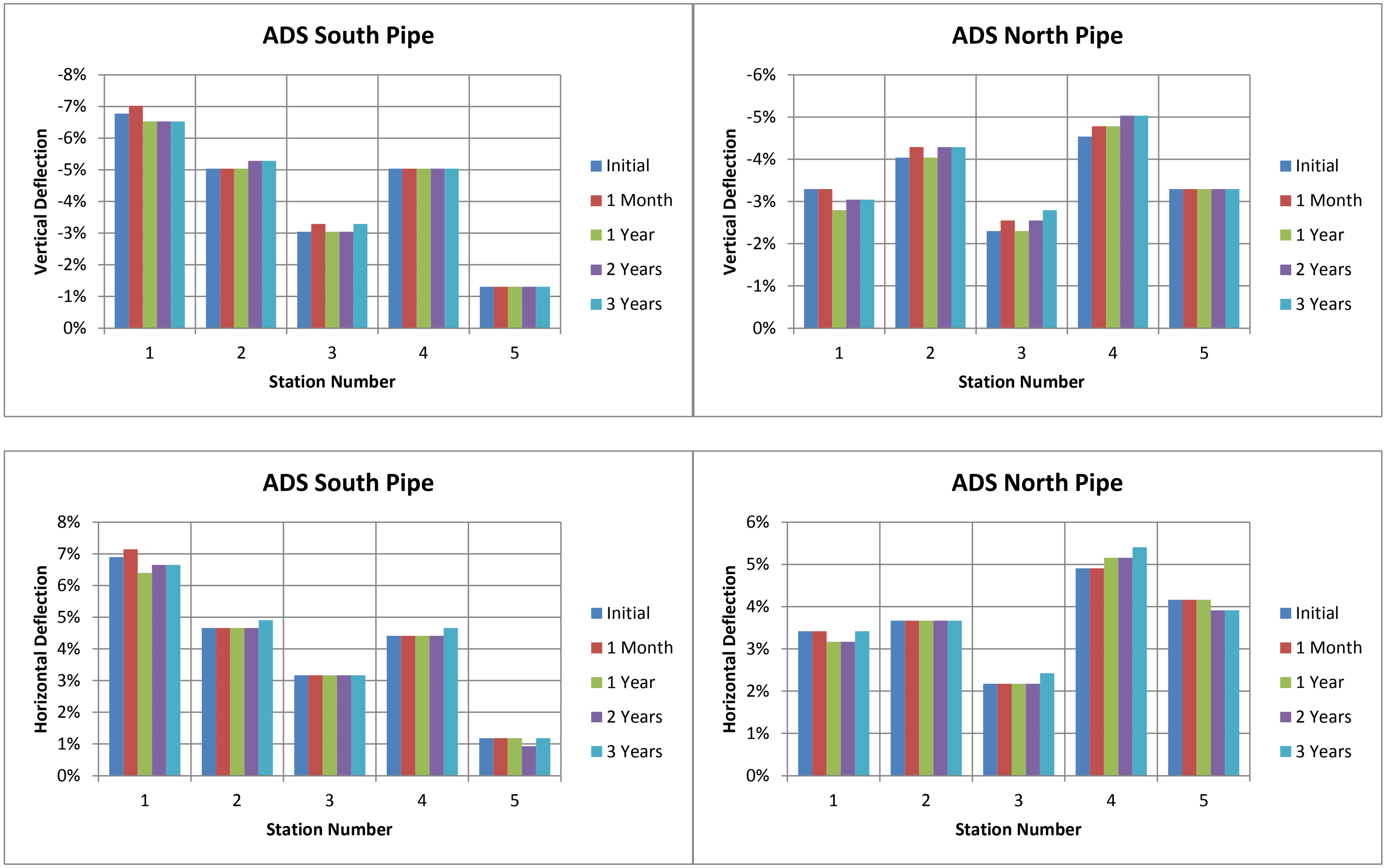

Figure 18. ADS pipe deflections as a function of station number and time.

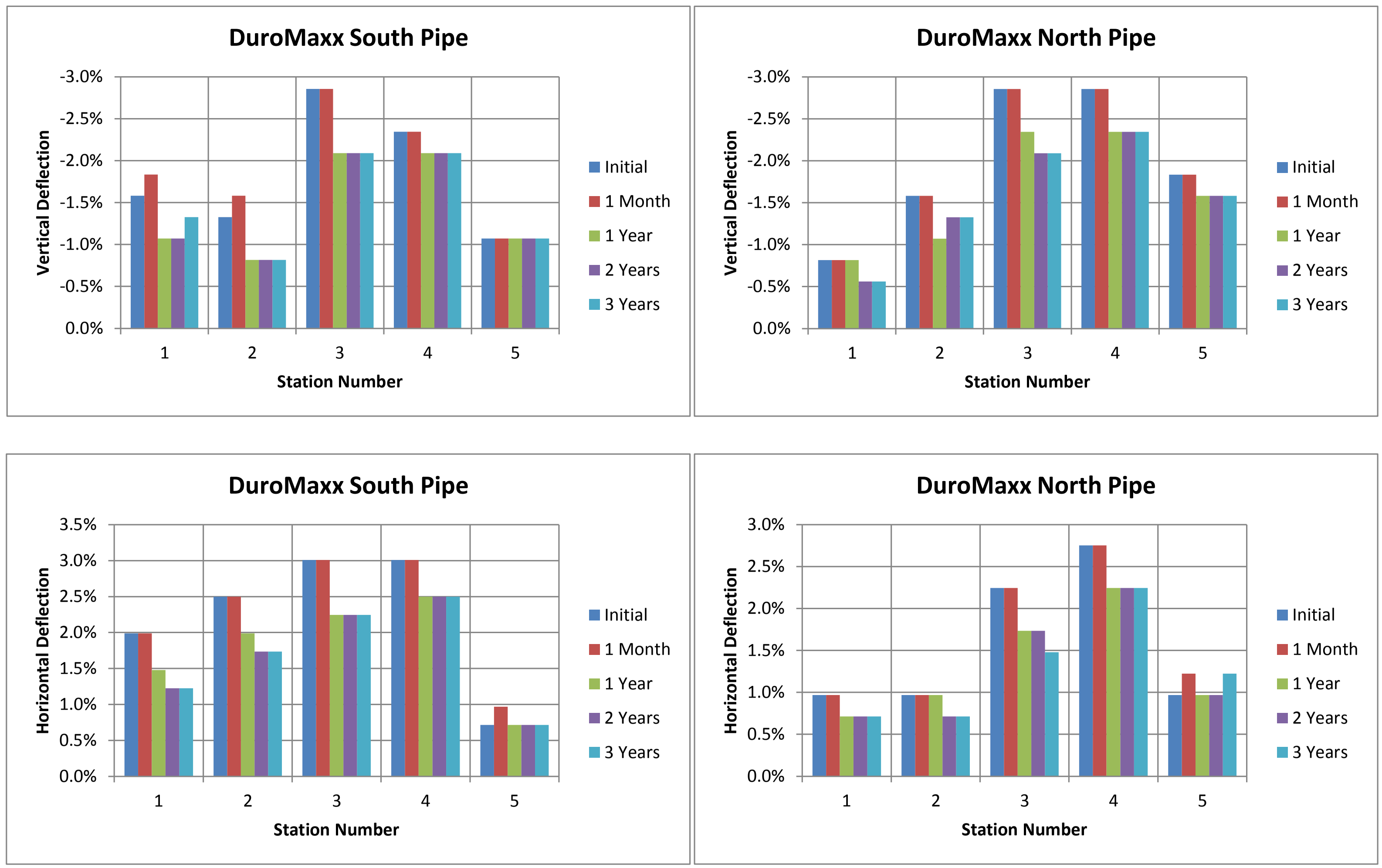

Figure 19. DuroMaxx pipe deflections as a function of station number and time.

Figure 20. Approximate DuroMaxx pipe rib size.

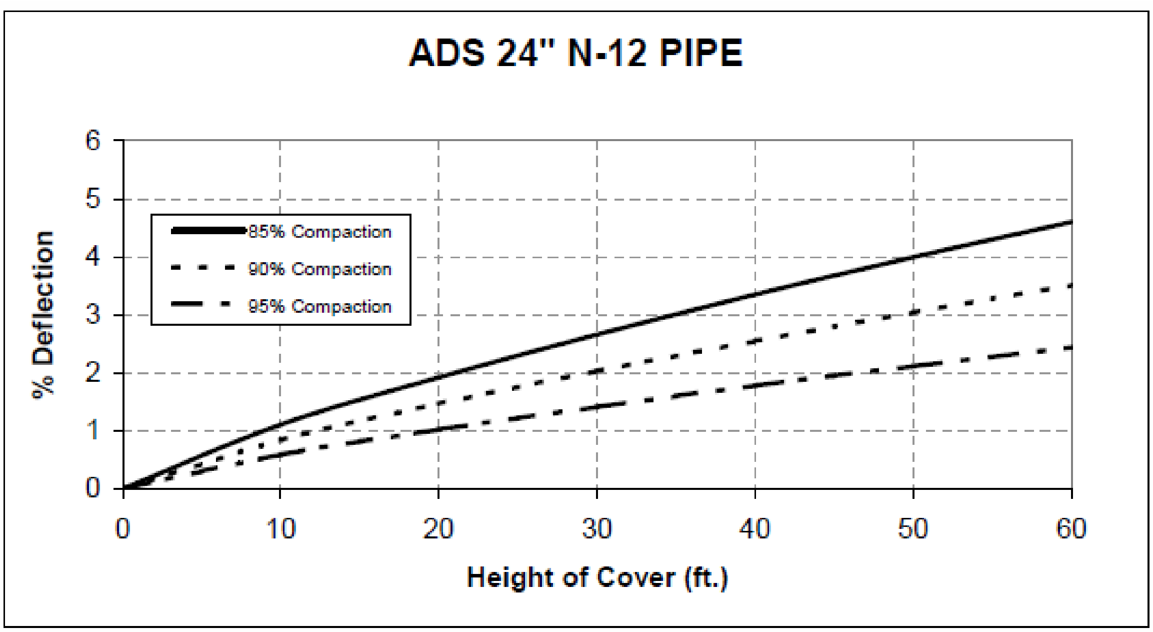

Figure 21. Expected pipe deflections from ADS Corp (see: http://www.ads-pipe.com/pdf/en/technical_static/technical_note_2.130_structural_performance.pdf).

5.0 CONCLUSIONS

Both the ADS and DuroMaxx pipes have performed adequately to date with two exceptions. Station 1 of the south ADS pipe is at a 7% deflection, but is holding steady at that deflection. Also damage has been done on the west entrance to the DuroMaxx pipe. The cause of the damage is unknown. This damage might lead to additional erosion of the road shoulder at this location. It may be wise to consider monitoring this in the future.

There were also observations of minor damage. It was noted that there are rock impingement marks in the north DuroMaxx pipe between stations 1 and 2. These marks are very small and were first observed during the year-two visit. No growth of these impingement marks was observed in the final year-three visit, and these marks were likely present during all the visits. These are of no concern at this time. The blue plastic seal at the helical weld seams was pulled out slightly at three locations in the south DuroMaxx pipe. It is believed that this damage was done during the inspection process. Again, there is no concern about this minor damage.

Deflections are higher in the ADS pipe. The magnitude of the deflections is primarily attributed to the small spacing and low soil compaction between adjacent pipes. The DuroMaxx pipe does achieve a smaller deflection in this situation.

The reduction in deflections in the DuroMaxx pipe between the one-month and the one-year visits resulted in a slight re-rounding of the pipe. This was a real effect and not attributable to measurement error. The cause is believed to be attributed to the installation procedure used to install the pipes, the pipe rib design, and the granular backfill. The narrow trench and pipe spacing result in poor compaction of fill in the haunch areas of both the ADS and DuroMaxx pipes. The DuroMaxx pipe ribs would have incomplete penetration into the granular soil at the bottom of the pipe. The soil above the spring-line of the pipe was highly compacted forming a soil bridge. The water table clearly rises above the bottom of the pipe during the spring snow melt, lubricating the soil particles and allowing the bottom of the pipe to more deeply penetrate the soil, while the soil bridge maintained the support of the road.

APPENDIX A – INSTALLATION MEMORANDUM

To: UDOT Research Division, Central Hydraulics, Region One Hydraulics

Re: STP-0357(2) Manhead Road Rehabilitation

DuroMaxx pipe installation

Date: July 29, 2010

From: Zack Andrus, UDOT Region One Design

The DuroMaxx pipe was installed on July 19, 2010 as per standard practice, back filled with ¾" crushed rock and granular borrow as per project plans. Material test results for these fill soils are available through the project file.

Two samples of the native soil were collected and submitted to the Central Materials Lab for testing.

Contech representative Russ Lakey was on site and shared pictures of the installation.

The installers mentioned that the DuroMaxx pipe differed from the ADS pipe used on the project in that the joints were much tighter. The pipe required additional effort to install and seemed to develop a very tight seal. The ADS pipe seemed to have looser tolerances and has more play at the joints. Also, the DuroMaxx pipe was lighter and more rigid than the ADS pipe of the same diameter.

It is recommended that for baseline and testing purposes that an air test be performed to check the fit and seal of the joints and that a mandrel be pulled to establish initial pipe deflection.

APPENDIX B – INITIAL INSPECTION

Table 9. Pipe dimensions from the initial inspection

ADS pipe dimension data collected on 8/23/2010

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def. (%)	Hori. Def. (%)
1	13	1.945	2.080	23.34	24.96	-3.29%	3.42%
2	20	1.930	2.085	23.16	25.02	-4.04%	3.67%
3	27	1.965	2.055	23.58	24.66	-2.30%	2.18%
4	34	1.920	2.110	23.04	25.32	-4.54%	4.91%
5	41	1.945	2.095	23.34	25.14	-3.29%	4.16%
			average	23.29	25.02	-3.49%	3.67%
		overall average		24.16			

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def.	Hori. Def.
1	14	1.875	2.15	22.50	25.80	-6.77%	6.90%
2	20	1.91	2.105	22.92	25.26	-5.03%	4.66%
3	27	1.95	2.075	23.40	24.90	-3.05%	3.17%
4	34	1.91	2.1	22.92	25.20	-5.03%	4.41%
5	41	1.985	2.035	23.82	24.42	-1.31%	1.18%
			average	23.11	25.12	-4.24%	4.06%
		overall average		24.11			

DuroMaxx pipe dimension data collected on 8/27/2010

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.945	1.98	23.34	23.76	-0.82%	0.97%
2	20	1.93	1.98	23.16	23.76	-1.58%	0.97%
3	27	1.905	2.005	22.86	24.06	-2.86%	2.24%
4	34	1.905	2.015	22.86	24.18	-2.86%	2.75%
5	41	1.925	1.98	23.10	23.76	-1.84%	0.97%
			average	23.06	23.90	-1.99%	1.58%
		overall average		23.48			

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.930	2.000	23.16	24.00	-1.58%	1.99%
2	20	1.935	2.010	23.22	24.12	-1.33%	2.50%
3	27	1.905	2.020	22.86	24.24	-2.86%	3.01%
4	34	1.915	2.020	22.98	24.24	-2.35%	3.01%
5	41	1.940	1.975	23.28	23.70	-1.07%	0.71%
			average	23.10	24.06	-1.84%	2.24%
		overall average		23.58			

APPENDIX C – SECOND INSPECTION

Table 10. Pipe dimensions from the second inspection (9/28/2010)

ADS pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def. (%)	Hori. Def. (%)
1	13	1.945	2.080	23.34	24.96	-3.29%	3.42%
2	20	1.925	2.085	23.10	25.02	-4.29%	3.67%
3	27	1.960	2.055	23.52	24.66	-2.55%	2.18%
4	34	1.915	2.110	22.98	25.32	-4.79%	4.91%
5	41	1.945	2.095	23.34	25.14	-3.29%	4.16%
			average	23.26	25.02	-3.64%	3.67%
		overall average		24.14			

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def.	Hori. Def.
1	14	1.87	2.155	22.44	25.86	-7.02%	7.15%
2	20	1.91	2.105	22.92	25.26	-5.03%	4.66%
3	27	1.945	2.075	23.34	24.90	-3.29%	3.17%
4	34	1.91	2.1	22.92	25.20	-5.03%	4.41%
5	41	1.985	2.035	23.82	24.42	-1.31%	1.18%
			average	23.09	25.13	-4.34%	4.11%
		overall average		24.11			

DuroMaxx pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.945	1.98	23.34	23.76	-0.82%	0.97%
2	20	1.93	1.98	23.16	23.76	-1.58%	0.97%
3	27	1.905	2.005	22.86	24.06	-2.86%	2.24%
4	34	1.905	2.015	22.86	24.18	-2.86%	2.75%
5	41	1.925	1.985	23.10	23.82	-1.84%	1.22%
			average	23.06	23.92	-1.99%	1.63%
		overall average		23.49			

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.925	2.000	23.10	24.00	-1.84%	1.99%
2	20	1.930	2.010	23.16	24.12	-1.58%	2.50%
3	27	1.905	2.020	22.86	24.24	-2.86%	3.01%
4	34	1.915	2.020	22.98	24.24	-2.35%	3.01%
5	41	1.940	1.980	23.28	23.76	-1.07%	0.97%
			average	23.08	24.07	-1.94%	2.29%
		overall average		23.57			

APPENDIX D – THIRD INSPECTION

Table 11. Pipe dimensions from the third inspection (7/8/2011)

ADS pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def. (%)	Hori. Def. (%)
1	13	1.955	2.075	23.46	24.90	-2.80%	3.17%
2	20	1.930	2.085	23.16	25.02	-4.04%	3.67%
3	27	1.965	2.055	23.58	24.66	-2.30%	2.18%
4	34	1.915	2.115	22.98	25.38	-4.79%	5.16%
5	41	1.945	2.095	23.34	25.14	-3.29%	4.16%
			average	23.30	25.02	-3.44%	3.67%
		overall average			24.16		

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def.	Hori. Def.
1	14	1.88	2.14	22.56	25.68	-6.53%	6.40%
2	20	1.91	2.105	22.92	25.26	-5.03%	4.66%
3	27	1.95	2.075	23.40	24.90	-3.05%	3.17%
4	34	1.91	2.1	22.92	25.20	-5.03%	4.41%
5	41	1.985	2.035	23.82	24.42	-1.31%	1.18%
			average	23.12	25.09	-4.19%	3.97%
		overall average			24.11		

DuroMaxx pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.945	1.975	23.34	23.70	-0.82%	0.71%
2	20	1.94	1.98	23.28	23.76	-1.07%	0.97%
3	27	1.915	1.995	22.98	23.94	-2.35%	1.73%
4	34	1.915	2.005	22.98	24.06	-2.35%	2.24%
5	41	1.93	1.98	23.16	23.76	-1.58%	0.97%
			average	23.15	23.84	-1.63%	1.33%
		overall average			23.50		

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.940	1.990	23.28	23.88	-1.07%	1.48%
2	20	1.945	2.000	23.34	24.00	-0.82%	1.99%
3	27	1.920	2.005	23.04	24.06	-2.09%	2.24%
4	34	1.920	2.010	23.04	24.12	-2.09%	2.50%
5	41	1.940	1.975	23.28	23.70	-1.07%	0.71%
			average	23.20	23.95	-1.43%	1.78%
		overall average			23.57		

APPENDIX E – FOURTH INSPECTION

Table 12. Pipe dimensions from the fourth inspection (6/29/2012)

ADS pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def. (%)	Hori. Def. (%)
1	13	1.950	2.075	23.40	24.90	-3.05%	3.17%
2	20	1.925	2.085	23.10	25.02	-4.29%	3.67%
3	27	1.960	2.055	23.52	24.66	-2.55%	2.18%
4	34	1.910	2.115	22.92	25.38	-5.03%	5.16%
5	41	1.945	2.090	23.34	25.08	-3.29%	3.92%
			average	23.26	25.01	-3.64%	3.62%
		overall average			24.13		

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def.	Hori. Def.
1	14	1.88	2.145	22.56	25.74	-6.53%	6.65%
2	20	1.905	2.105	22.86	25.26	-5.28%	4.66%
3	27	1.95	2.075	23.40	24.90	-3.05%	3.17%
4	34	1.91	2.1	22.92	25.20	-5.03%	4.41%
5	41	1.985	2.03	23.82	24.36	-1.31%	0.93%
			average	23.11	25.09	-4.24%	3.97%
		overall average			24.10		

DuroMaxx pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.95	1.975	23.40	23.70	-0.56%	0.71%
2	20	1.935	1.975	23.22	23.70	-1.33%	0.71%
3	27	1.92	1.995	23.04	23.94	-2.09%	1.73%
4	34	1.915	2.005	22.98	24.06	-2.35%	2.24%
5	41	1.93	1.98	23.16	23.76	-1.58%	0.97%
			average	23.16	23.83	-1.58%	1.27%
		overall average			23.50		

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.940	1.985	23.28	23.82	-1.07%	1.22%
2	20	1.945	1.995	23.34	23.94	-0.82%	1.73%
3	27	1.920	2.005	23.04	24.06	-2.09%	2.24%
4	34	1.920	2.010	23.04	24.12	-2.09%	2.50%
5	41	1.940	1.975	23.28	23.70	-1.07%	0.71%
			average	23.20	23.93	-1.43%	1.68%
		overall average			23.56		

APPENDIX F – FIFTH INSPECTION

Table 13. Pipe dimensions from the fifth inspection (6/28/2013)

ADS pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def. (%)	Hori. Def. (%)
1	13	1.950	2.080	23.40	24.96	-3.05%	3.42%
2	20	1.925	2.085	23.10	25.02	-4.29%	3.67%
3	27	1.955	2.060	23.46	24.72	-2.80%	2.42%
4	34	1.910	2.120	22.92	25.44	-5.03%	5.41%
5	41	1.945	2.090	23.34	25.08	-3.29%	3.92%
			average	23.24	25.04	-3.69%	3.77%
		overall average			24.14		

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert.(in)	Horiz. (in)	Vert. Def.	Hori. Def.
1	14	1.880	2.145	22.56	25.74	-6.53%	6.65%
2	20	1.905	2.110	22.86	25.32	-5.28%	4.91%
3	27	1.945	2.075	23.34	24.90	-3.29%	3.17%
4	34	1.910	2.105	22.92	25.26	-5.03%	4.66%
5	41	1.985	2.035	23.82	24.42	-1.31%	1.18%
			average	23.10	25.13	-4.29%	4.11%
		overall average			24.10		

DuroMaxx pipe dimension data

North Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.950	1.975	23.40	23.70	-0.56%	0.71%
2	20	1.935	1.975	23.22	23.70	-1.33%	0.71%
3	27	1.920	1.990	23.04	23.88	-2.09%	1.48%
4	34	1.915	2.005	22.98	24.06	-2.35%	2.24%
5	41	1.930	1.985	23.16	23.82	-1.58%	1.22%
			average	23.16	23.83	-1.58%	1.27%
		overall average			23.50		

South Pipe

Station	Dist. (ft)	Vert. (ft)	Horiz. (ft)	Vert. (in)	Horiz. (in)	Vert. Def (%)	Hori. Def (%)
1	13	1.935	1.985	23.22	23.82	-1.33%	1.22%
2	20	1.945	1.995	23.34	23.94	-0.82%	1.73%
3	27	1.920	2.005	23.04	24.06	-2.09%	2.24%
4	34	1.920	2.010	23.04	24.12	-2.09%	2.50%
5	41	1.940	1.975	23.28	23.70	-1.07%	0.71%
			average	23.18	23.93	-1.48%	1.68%
		overall average			23.56		

APPENDIX G – ESTIMATES OF PIPE STIFFNESS

The actual stiffness values of the DuroMaxx and ADS pipes based the ASTM D2412 test procedure were not provided by the manufacturers. Both pipe designs have the same minimum pipe stiffness of 34 lb/in^2. However, pipe stiffness values can be estimated based on pipe dimensions and Young's modulus using the following equation[1]:

$$PS = 6.7 \frac{EI}{r^3} \quad \text{(G-1)}$$

where: PS = pipe stiffness (lb/in^2)

E = Young's modulus of the pipe material (psi)

I = Area moment of inertia per unit length of the cross section (in^3)

r = radius to the centroid of the pipe cross section (in)

From published ADS data[2] a 24" N-12 pipe will have I = 0.137 in^3 and r=12.506 in. The appropriate value for Young's modulus for a HDPE material is variable because of the viscoelastic behavior of the material. However, an upper range value for pipe stiffness of the ADS pipe can be estimated by using the generally accepted short-term modulus value of E=110 ksi. Using Eq. G-1, a maximum stiffness of the ADS pipe would be PS=51.6 lb/in^2.

For the DuroMaxx pipe, a lower range estimate of the pipe stiffness can be estimated by accounting for the steel only and ignoring the HDPE. Although the steel band is helically wound around the pipe, its stiffness can be estimated by treating it as circular steel bands. The approximate dimensions of the bands are 0.5 inch high and a thickness of 0.060 inch. The distance between subsequent steel bands is approximately 1.0 inch. From Table 3 the inside diameter of the DuroMaxx pipe is 23.532 inch. Using these dimensions we can obtain I= 6.23E-4 in^3 and r= 12.016 inch. Using a Young's modulus for steel of 29.E6 psi, we obtain an estimated pipe stiffness of PS=69.8 lb/in^2.

[1]A. P. Moser and S. L. Folkman, "Buried Pipe Design", McGraw Hill, 3rd Edition, p. 138.

[2]ADS N-12 Information Sheet, Product Note 3.108, Jan. 2005.