Progress Report 4

(For the Period Covering 06/09/2010 to 09/08/2010)

Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading

FDOT Contract No. BDK75 977-21

UF Contract No. 82153

FDOT Project Manager:	Rick Renna, P.E.
UF Principal Investigator:	Dr. David Bloomquist, Ph.D., P.E.
Co-Principal Investigator:	Dr. Timothy J. McGrath, Ph.D., P.E.
Graduate Student:	Kenneth Pasken, E.I.
Undergraduate Students:	Zachary Faraone

Date of Submittal: October 7, 2010

1. Work Accomplished This Quarter

   This quarter, preparation work continued on the FDOT Soil Box to complete it for the proposed testing program. This involved numerous tasks, ranging from ordering new materials and machining parts for the project, to doing research on a number of different testing techniques. The first test also commenced during this quarter. Specifically, the following was accomplished this quarter:

   a. Review of new triaxial test data performed at lower confining pressures and lower standard proctor densities.

   b. Preparation work on the Soil Box, for the first test, was continued and finalized.

   c. The design of the laser mounting system was finalized, and the system itself was fabricated.

   d. String potentiometers were ordered and subsequently installed on the laser mounting system.

   e. Construction of the instrumentation room along the East Wall of the Soil Box was completed.

   f. The instrumentation wiring was simplified to provide for less clutter in the instrumentation room and to reduce electrical noise.

   g. The first test began on Monday, August 23, 2010 with two pre-deflected 36 inch M294 HDPE pipes inside the Soil Box.

   h. Earth pressure cell readings were taken.

   i. Displacement laser readings were taken.

   j. Numerous visits to the Lab to photograph newly delivered materials, newly machined parts, and project progress in general.

   k. Literature review.

A discussion of the completed activities follows.

a. Review of new triaxial test data performed at lower confining pressures and lower standard proctor densities.

As discussed in Progress Report 3, new triaxial tests were in the process of being performed to assess the test soil's response under conditions similar to those existing in the Soil Box. At the time of submittal of Progress Report 3, only the results for the sample compacted at 90 percent standard density and tested at 3 and 5 psi confining pressures were ready. Shortly thereafter, the results for the samples tested at 80 and 85 percent standard densities were received. As stated in previous progress reports, these tests were performed courtesy of the FDOT SMO. The results for those samples compacted at 80 and 85 percent standard densities can be viewed in *Appendix A: Triaxial Test Results for Sample with 80% Standard Density* and *Appendix B: Triaxial Test Results for Sample with 85% Standard Density*, respectively.

b. Preparation work on the Soil Box, for the first test, was continued and finalized.

This particular task followed a work sequence similar to that discussed in Progress Report 3 for preparation of the Soil Box. It was accomplished in a number of stages. First, four to six inches of soil were added to close the eventual gap between the bottom of the Soil Box top and the lift bags that would be placed on top of the load plates. The final soil level can be seen in Figure 1 below.

Figure 1: Final soil level in Soil Box.

The next step was to install the load plates on top of the soil. The load plates were lifted individually and set in their appropriate locations. As per the AutoCAD drawings submitted with Progress Report 2, six five-foot by five-foot and four two-and-a-half-foot by five-foot load plates were installed. This step can be seen in Figure 2 below.

Figure 2: Load plates in the process of installation.

After the load plates were successfully installed, the lift bags needed to be set in place. They were hoisted into place in the same manner as the load plates. See Figure 3 below. The smaller lift bags seen towards the end of the long dimension of the Soil Box are so sized to account for the smaller load plates. This is to avoid eccentric loading of the soil.

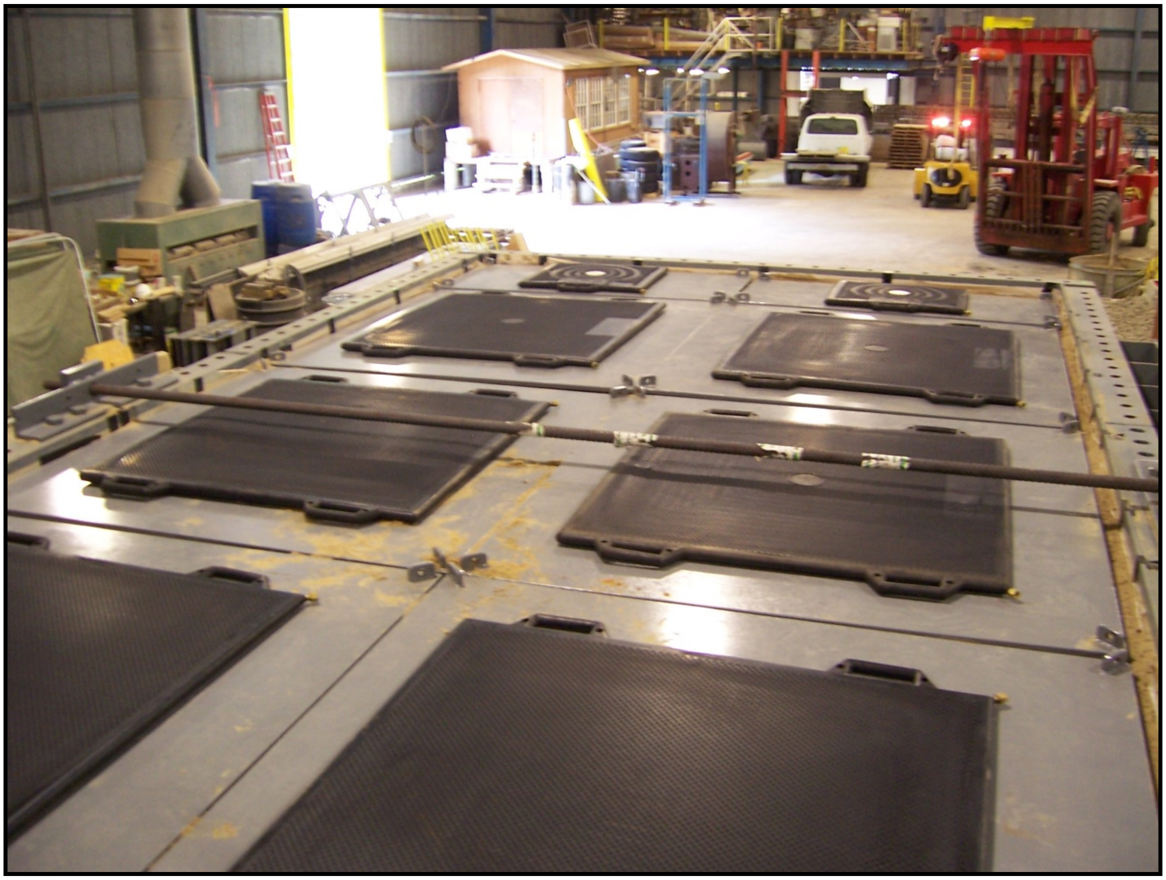

Figure 3: Lift bags after placement directly over center of the load plates.

The next step in the process was to connect all the necessary equipment for pressurizing the lift bags, as seen in the figures below. The air hoses were connected to the lift bags, routed through drilled holes in the Soil Box East wall and down the wall into a flange, connecting all the air hoses to one air supply.

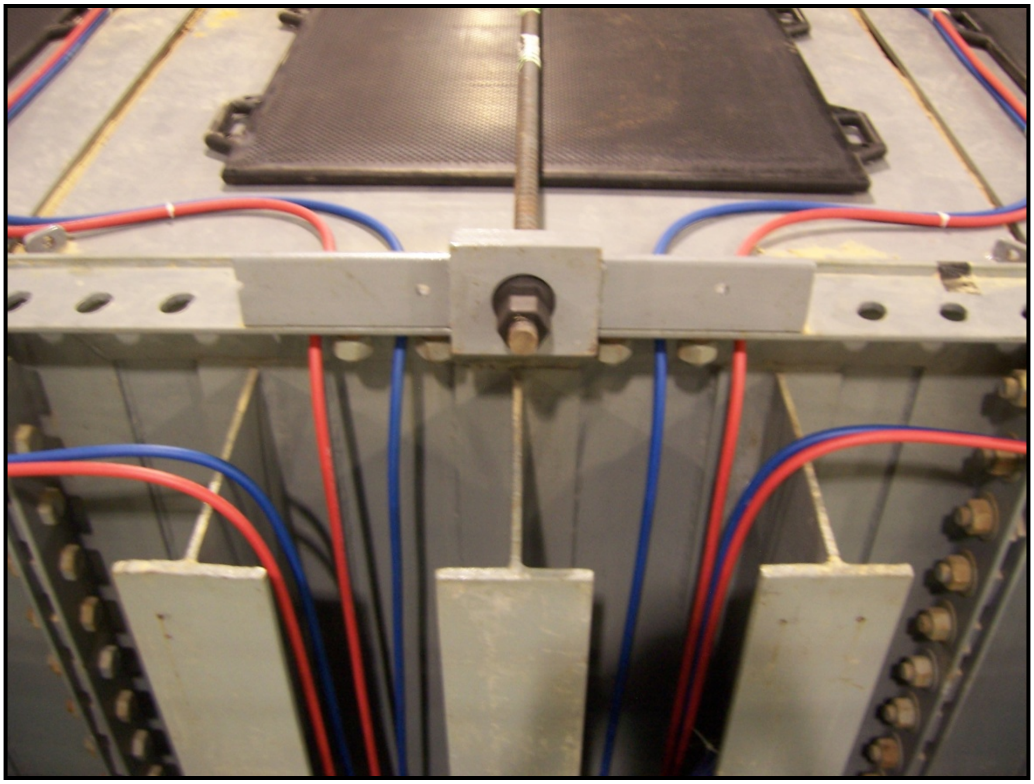

Figure 4: Air hoses routed through and down Soil Box East wall.

Figure 5: Air hoses connected to lift bags.

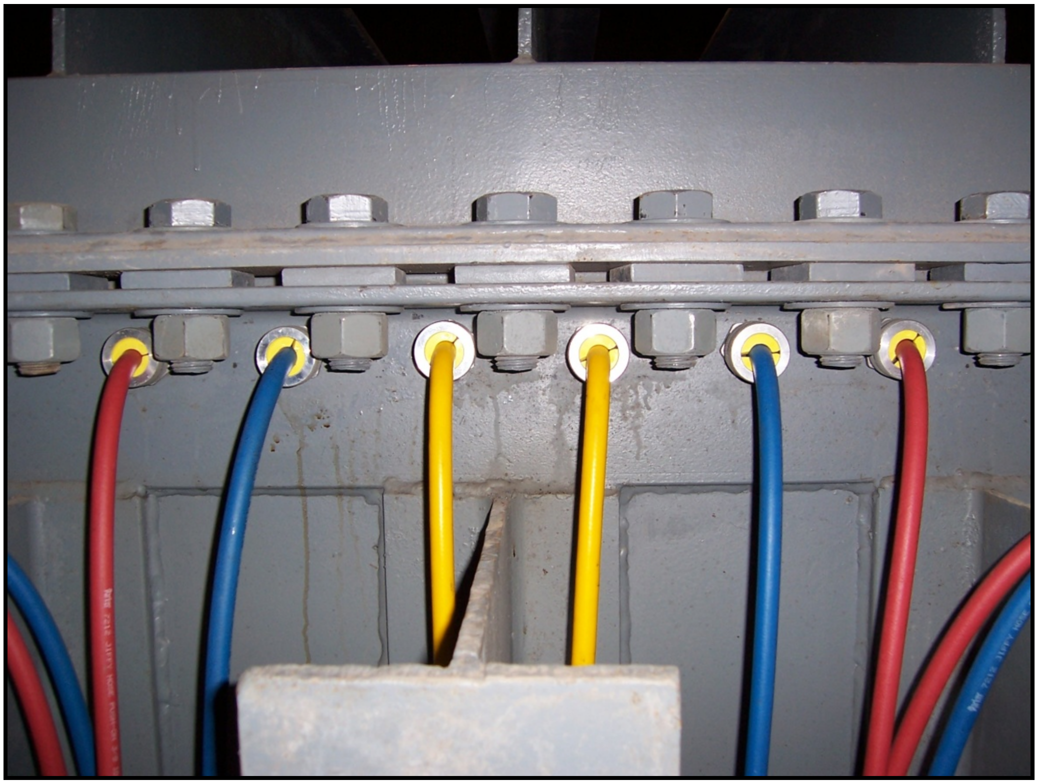

Figure 6: Close-up of air hoses being routed through Soil Box East wall.

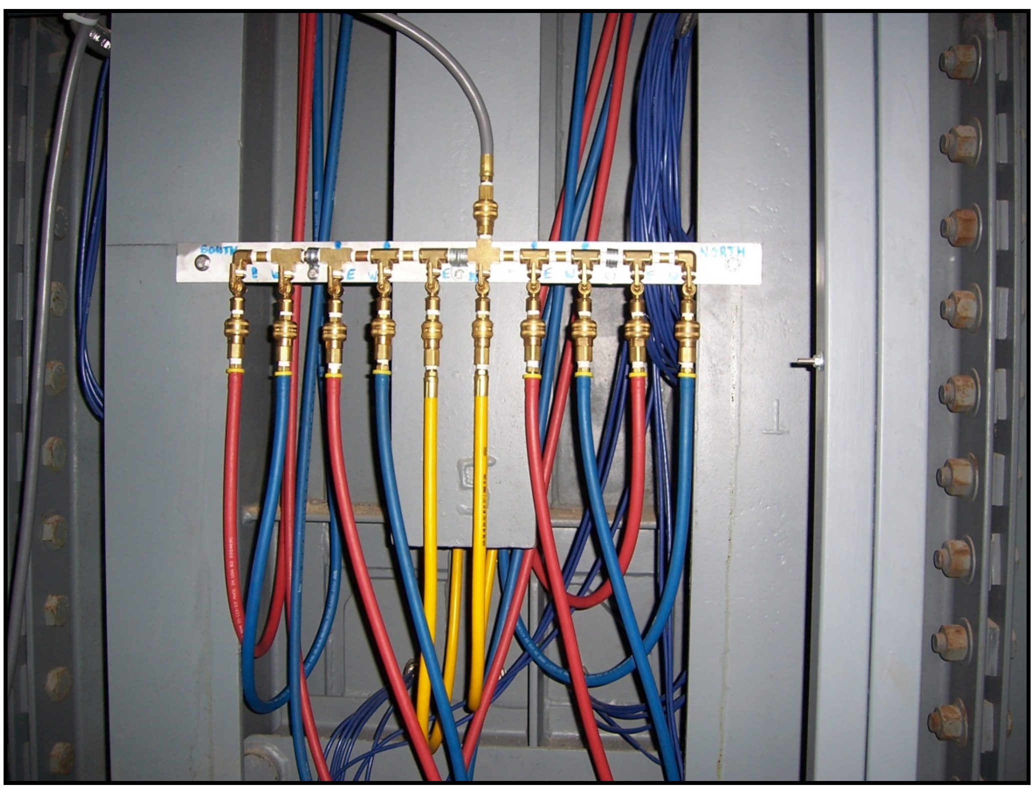

Figure 7: Air hoses connected to pressure source.

Following the installation of the lift bags and air pressurizing equipment, the Soil Box top was ready to be installed. The top is comprised of three sections, the outer two being wider than the middle section. This particular task proved especially difficult due to the need to line up all the holes on the top with the vertical walls. The objects lying on top of the lift bags, seen in Figures 8 and 9 below, were used to temporarily hold the sections in place while the holes were lined up. These two figures also show the South section after placement.

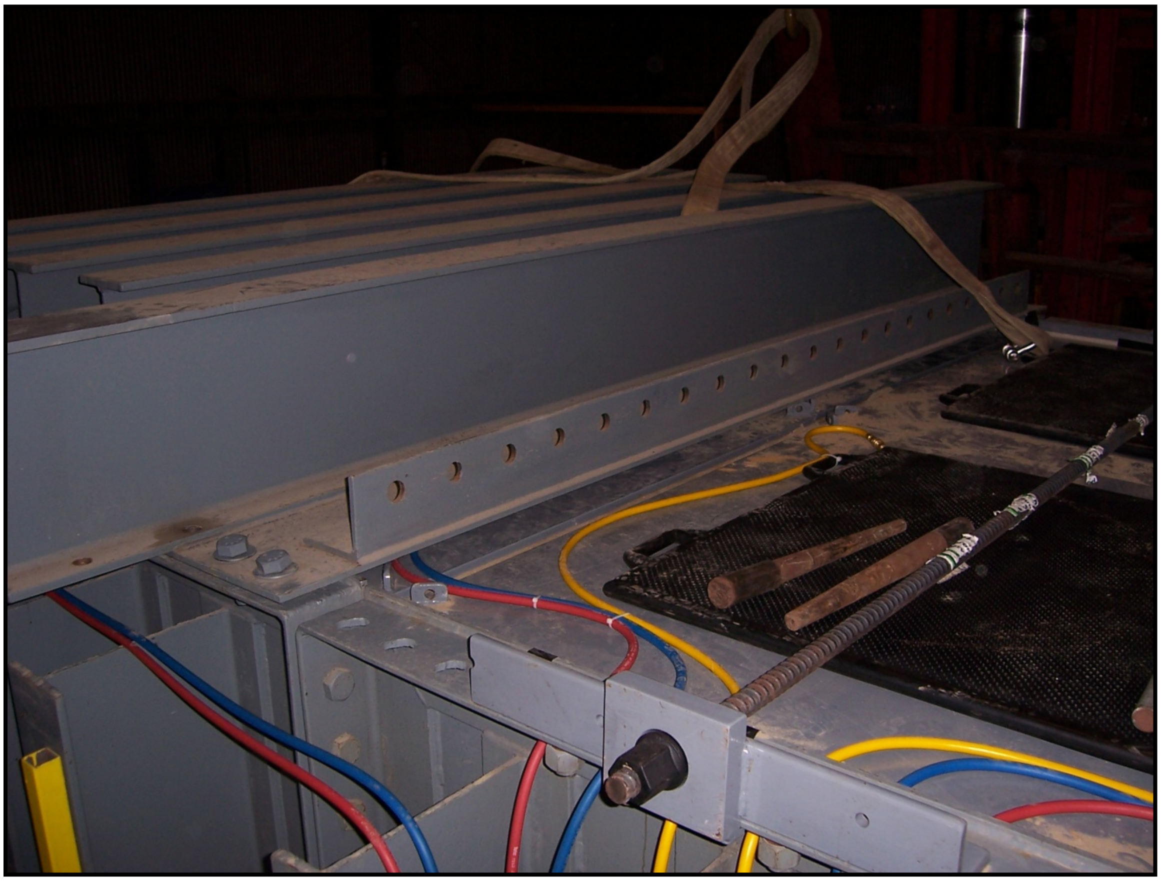

Figure 8: Partial installation of the Soil Box top.

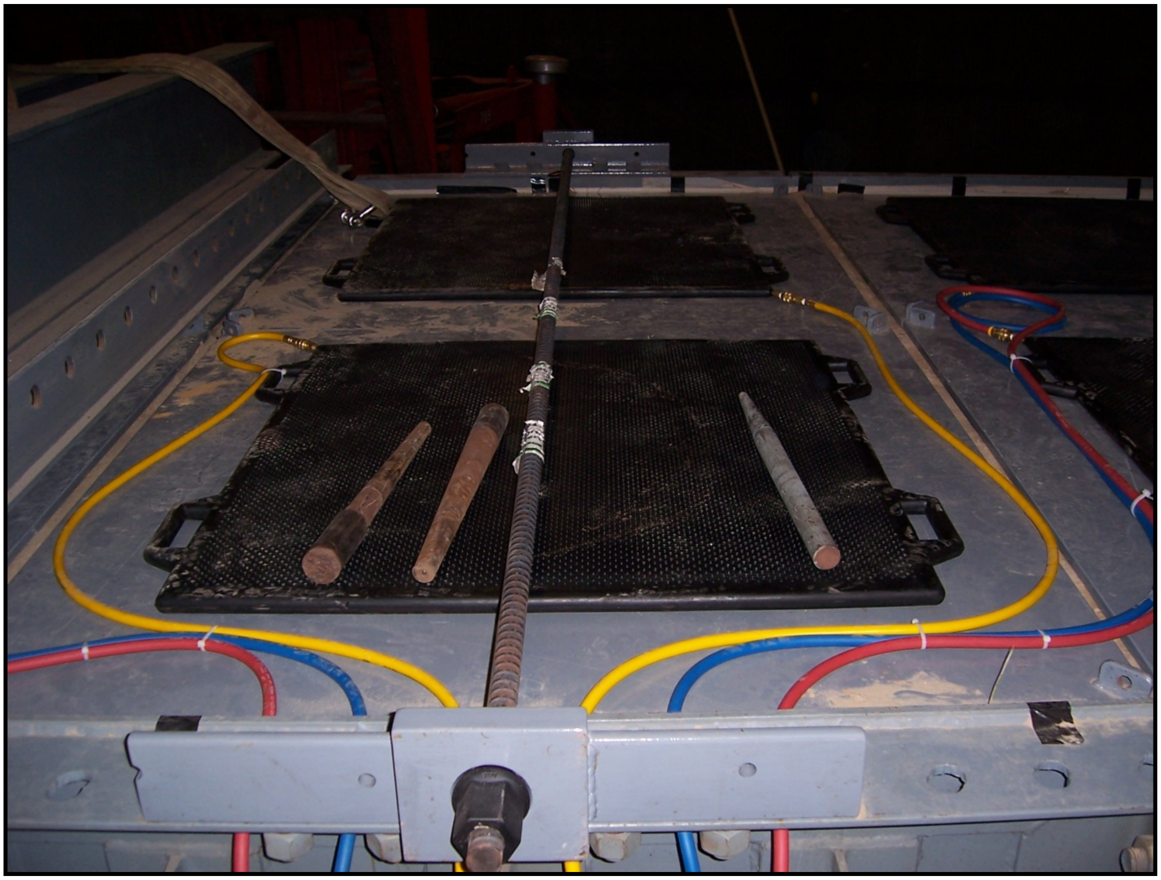

Figure 9: Partial installation of the Soil Box top.

Due to complications with correctly lining up all three sections, an end of the South section needed to be slightly trimmed. The alteration can be seen in Figure 10 below.

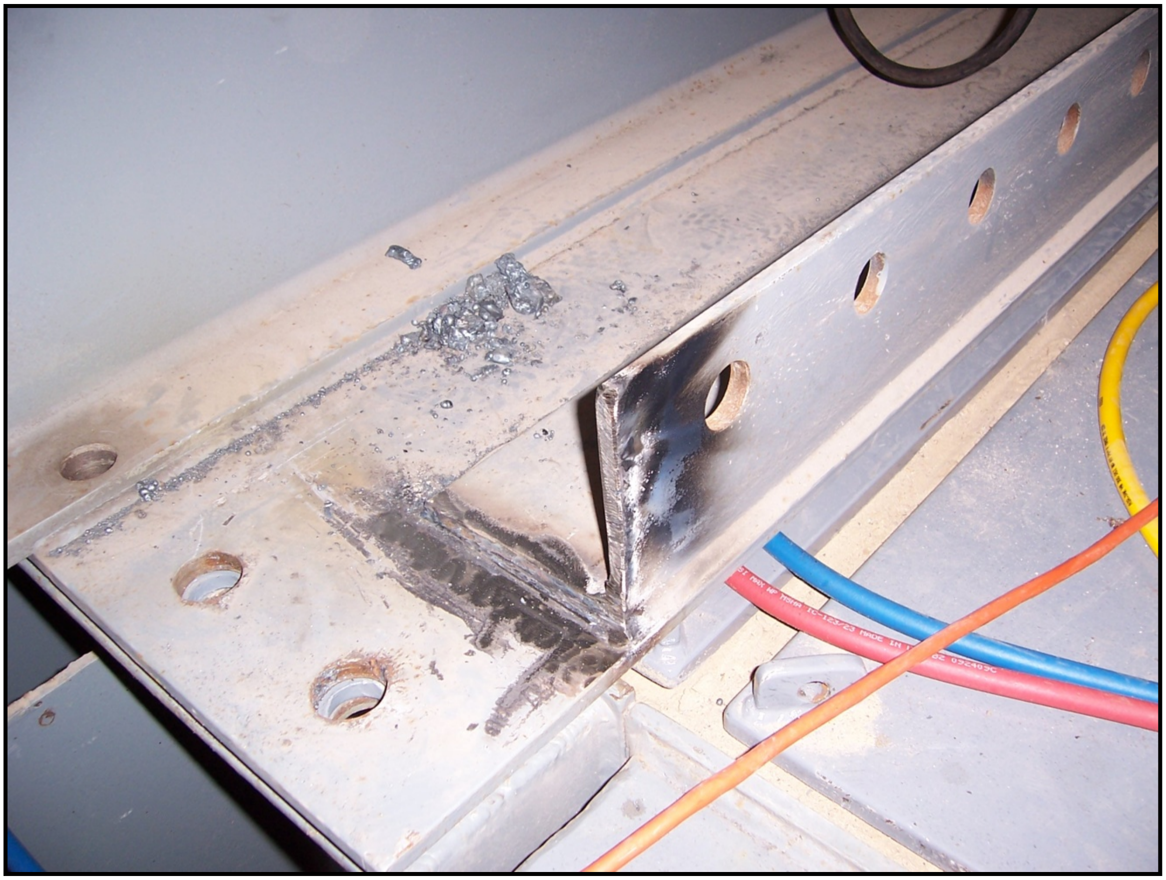

Figure 10: Trimmed end of South section of Soil Box top.

Once this was performed, the top could be properly put in place and fastened with all the necessary hardware, seen below in Figure 11. This was the last step in preparing the Soil Box itself for the first test.

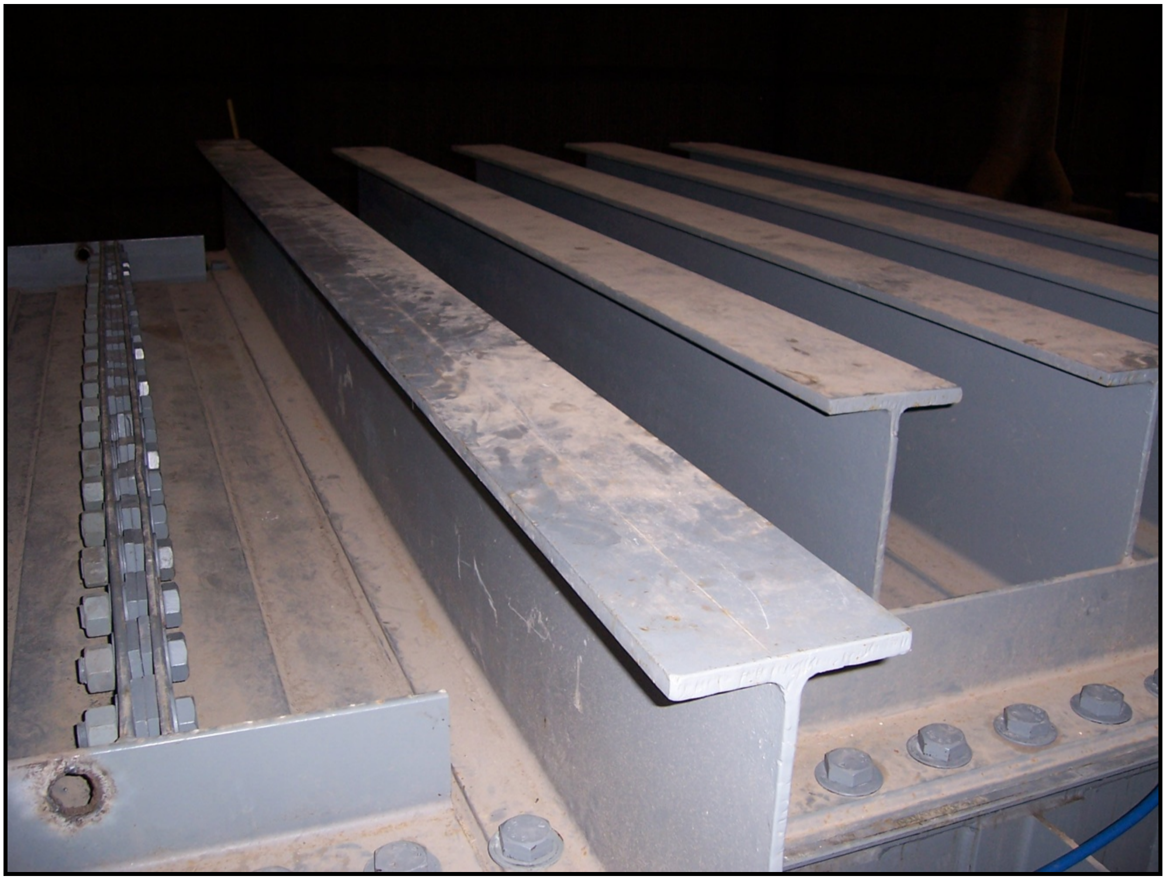

Figure 11: Completed installation of Soil Box top.

The construction of the instrumentation room along the East Wall of the Soil Box will be discussed in Section e.

c. The design of the laser mounting system was finalized, and the system itself was fabricated.

The laser mounting system was finally completed during this quarter, allowing for extremely precise deflection measurements. The process is accomplished by means of a beam that is fixed to the Soil Box walls at each end of the pipes. The laser is attached to a cart which moves along the length of the beam with the use of a hand-crank, attached on the West end of the Soil Box. Attached to the cart is a string which is spooled inside of the string potentiometer. As the cart moves along the length of the pipe, both displacement measurements from the laser and horizontal distance along the pipe from the string potentiometer are output to a data acquisition program. The hardware can be seen in Figures 12 and 13 below.

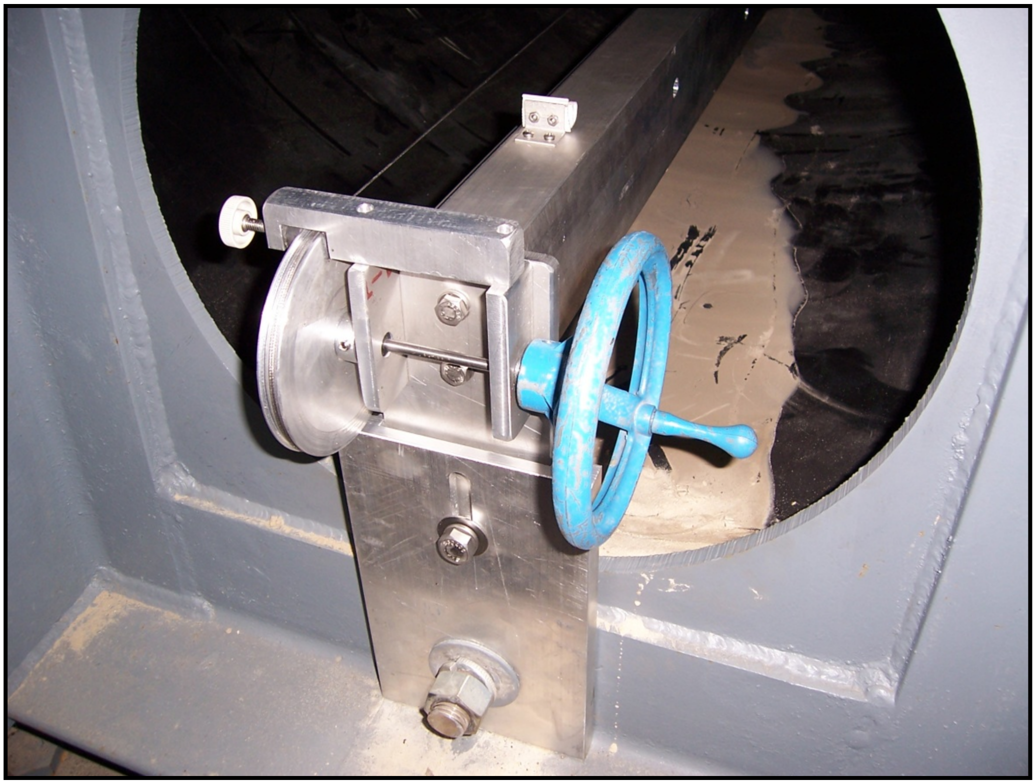

Figure 12: Hand-crank and reel on West end of Soil Box.

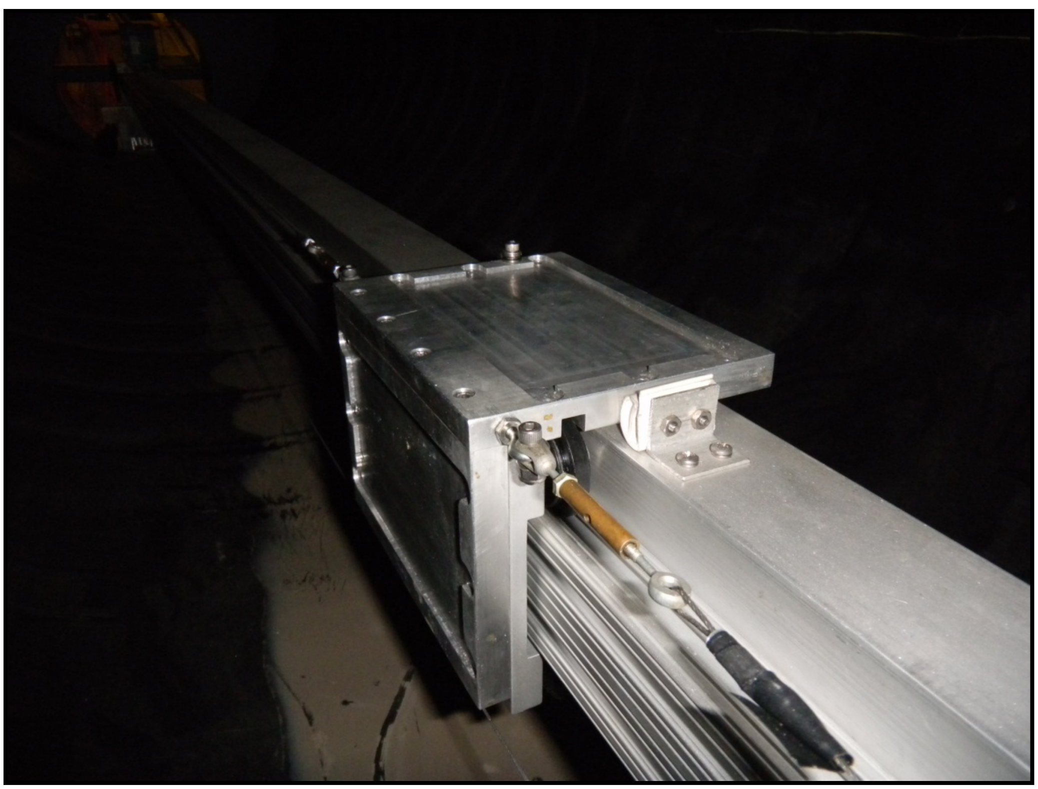

Figure 13: The cart on which the displacement laser mounts.

d. String potentiometers were ordered and subsequently installed on the laser mounting system.

Each pipe being tested has the setup shown in Figure 14 below. This makes the data acquisition process much quicker when compared to having to move the entire rig from one pipe to the other.

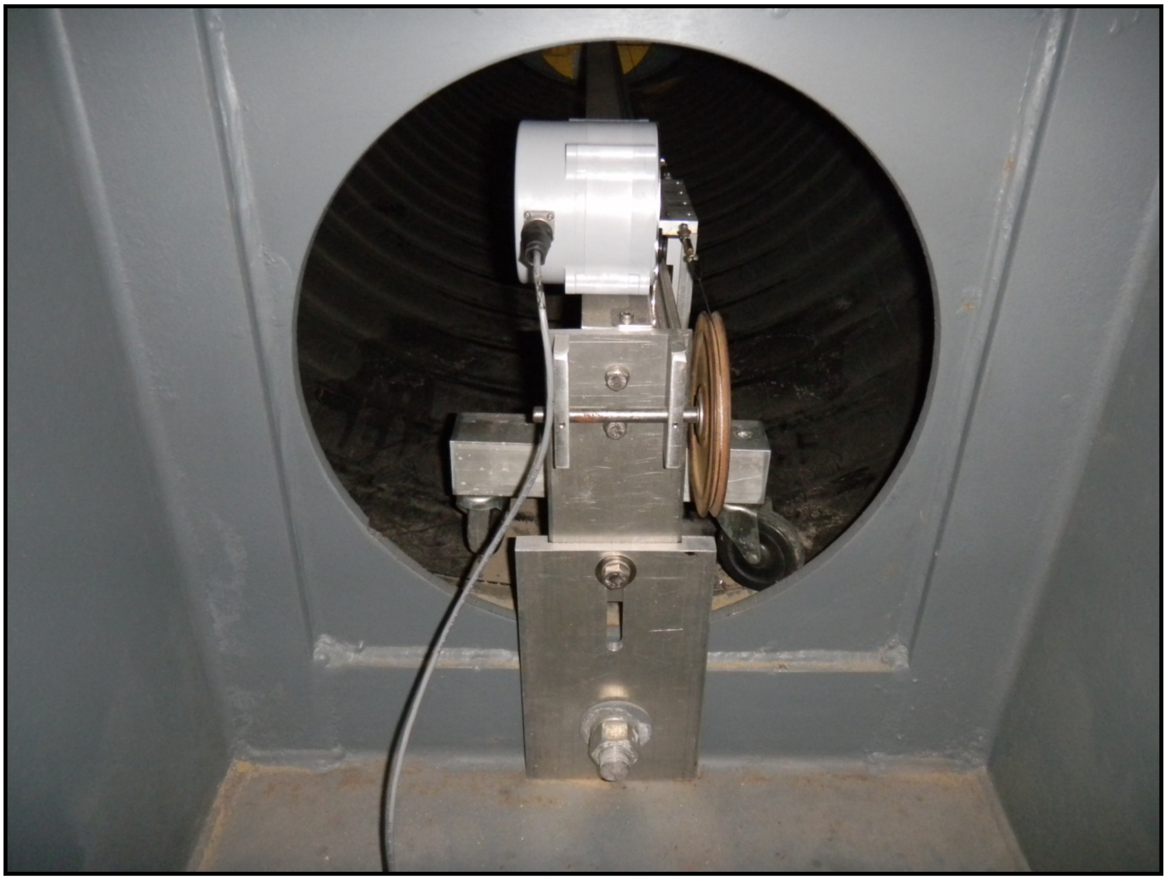

Figure 14: String potentiometer attached on the East end of the track.

e. Construction of the instrumentation room along the East Wall of the Soil Box was completed.

The instrumentation room was required for protection of all data acquisition hardware and the various pieces of instrumentation. There is a window on the East face of the room to allow for air ventilation. It also provides ease of communication between the person operating the laser and the person sitting at the computer at which the data is collected. Exterior and interior views of the completed instrumentation room can be seen in Figures 15 and 16 below.

Figure 15: Completed exterior of instrumentation room.

Figure 16: Completed interior of instrumentation room.

f. The instrumentation wiring was simplified to provide for less clutter in the instrumentation room and to reduce electrical noise.

One of the major concerns in the final phases before testing was electrical noise present in the instrumentation signals for the displacement laser and string potentiometers. Figure 17 below represents the initial condition which had a great deal of clutter. Absent from that figure is the power source for the displacement laser. Figure 18 represents the current condition for the instrumentation wiring. The two circuit boards have been replaced, and all connections have been soldered and heat-shrunk. Performing this upgrade to the instrumentation wiring has proved to be very successful in eliminating most, if not all, of the noise.

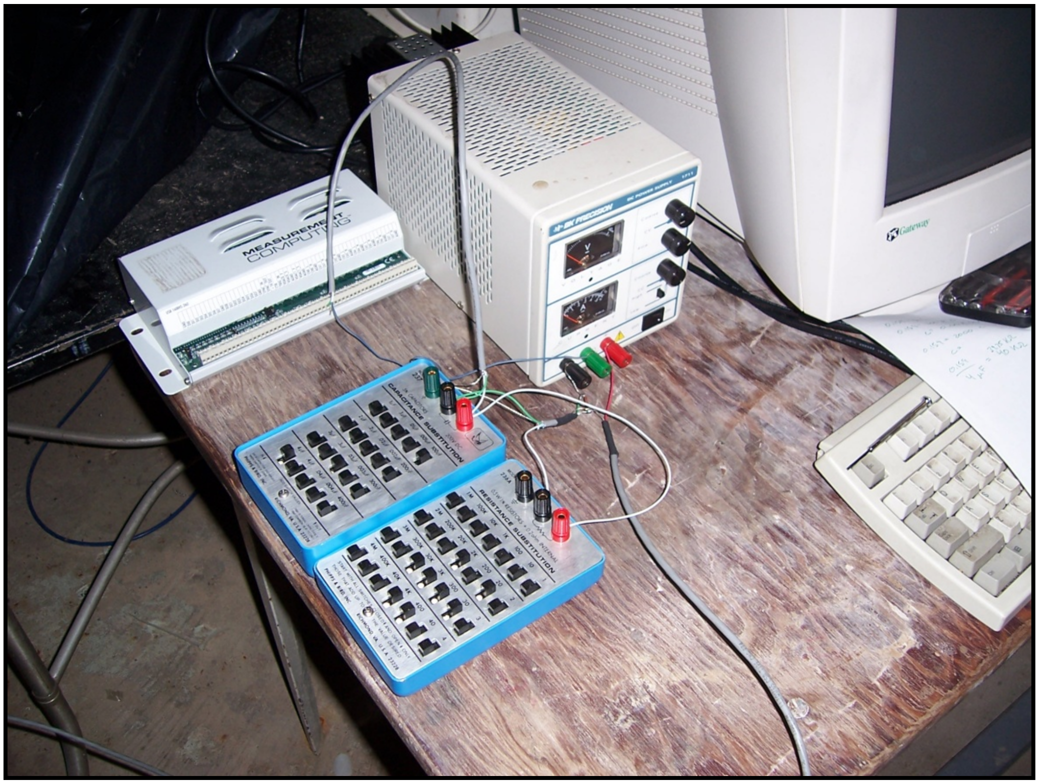

Figure 17: Instrumentation wiring prior to refining.

Figure 18: Simplified instrumentation wiring, decreasing the amount of electrical noise.

g. The first test began on Monday, August 23, 2010 with two pre-deflected 36 inch M294 HDPE pipes inside the Soil Box.

Zero readings were taken on all of the earth pressure cells and with the displacement laser on Thursday, August 19, 2010. On Monday the 23rd, the system began to be pressurized, starting off at 2 psi and increasing by 2 psi increments until 8.33 psi was reached. This specific pressure correlated to a surcharge load of 10 feet. The increments were then raised to 3.33 psi until a pressure of 16.67 psi was reached, simulating a surcharge depth of 20 feet. For the range of 20 feet to 50 feet of surcharge, or 16.67 psi to 41.67 psi, respectively, the pressure increment was increased to 5 psi. As of the end of this quarter, a pressure of 26.67 psi was being applied.

Based on the earth pressure cell readings and displacement laser readings, discussed below in Sections h and i, some discussion began about what the actual pressures were that were being applied. In reality, when the lift bags are inflated, the footprint they have on the load plates is diminished because they expand in the vertical direction. It is because of this reduced contact area that the pressures being recorded throughout the soil were much less than what was being measured as the applied pressure from the air source. Because this realization happened after the end of the quarter, this topic will be covered in greater detail in Progress Report 5, as well as being touched upon in Section 2 below.

h. Earth pressure cell readings were taken.

Earth pressure cell readings were taken on a number of dates. A summary of each of the recording sessions for this quarter can be found in *Appendix C: Earth Pressure Cell Data 36" HDPE without Trench Box*. In printed form the earth pressure cell data collected for this quarter is over 450 pages in length. The data is being provided to Mr. Bryan P. Strohman of Simpson Gumpertz & Heger in Microsoft Excel format every two weeks. This is for the purposes of the Finite Element Analysis to be performed based on the pressure readings. Electronic copies of the Excel worksheets can be sent via email upon request.

i. Displacement laser readings were taken.

Displacement laser readings were likewise taken on a number of dates. A summary of data for this quarter can be found in *Appendix D: Displacement Laser Data 36" HDPE without Trench Box*. As with the earth pressure cell data, the displacement laser data collected for this quarter is over 100 pages in length. Electronic copies of the Excel worksheets can be sent via email upon request.

Of special note are Figures K through P in *Appendix D*. These figures show the deflection measurement of each pipe quadrant, except for the bottom, plotted against the length dimension of the pipes for the pressures being applied during this quarter. There are noticeable changes in the plots as the pressure is increased. However, the deflections from the zero readings are not actually that large. This fact is what first sparked doubts regarding the actual pressure being applied in the soil. The graphic in Figure 19 below shows the quadrant orientations when looking from the East end of the pipe to the West end. Therefore, Quadrant

1 points North, Quadrant 2 points to the top of the pipe, Quadrant 3 points South, and Quadrant 4 points to the bottom of the pipe.

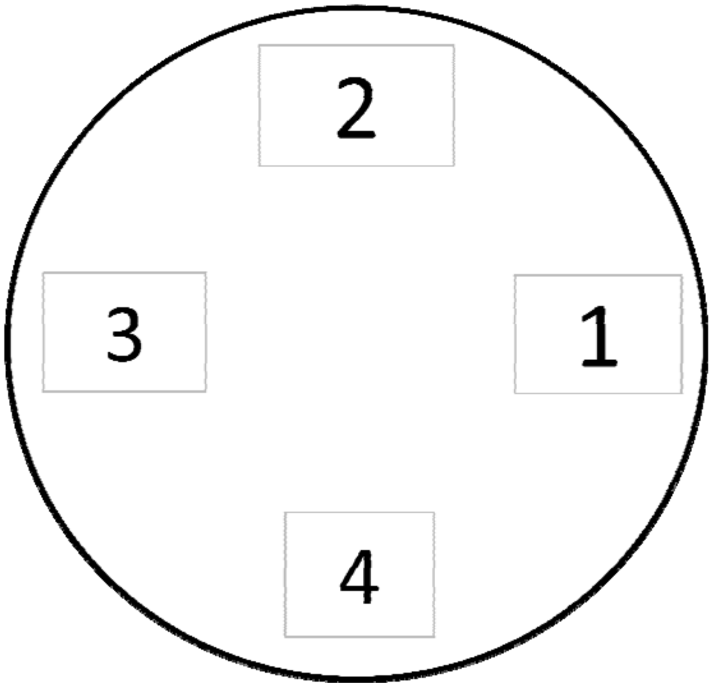

Figure 19: Quadrant orientations, viewing from East end to West end.

j. Numerous visits to the Lab to photograph newly delivered materials, newly machined parts, and project progress in general.

Each week, pictures are taken of all the new steps that have progressed. This process will continue throughout the duration of the project.

k. Literature review.

The following articles have been collected and are being reviewed. Literature review will continue throughout the duration of the project.

Abolmaali, Ali. "Experimental Verification of CUES Laser Profiler Deformation Analysis Results." Arlington, TX: University of Texas, 2008. Print.

CleanFlow Systems. "Analyzing the Accuracy of Profiler Equipment and Software." 29 June 2010. Web.

CleanFlow Systems. "Profiler Reporting For Flexible Pipes." 8 Apr. 2010. Web.

Moser, A.P. Buried Pipe Design. Second Edition. New York, NY: McGraw-Hill, 2001. Print.

Motahari, Ardavan, and Jorge Forteza. "Accuracy of Laser Profiling of Flexible Pipes Using CUES System." Arlington, TX: University of Texas, 2008. Print.

Palmer, Michael. "Results of Full-Scale Test on 16-inch HDPE Pipe." 2005. Web. 25 Jan. 2010.

Sargand, Shad M., and Teruhisa Masada. "Soil Arching Over Deeply Buried Thermoplastic Pipe." 15 Nov. 2002. Web.

2. Activities Planned for Next Quarter

The primary task to accomplish next quarter, other than the completion of the first test, is to determine the actual pressures that were being exerted on the soil. The process of how this will be done will be discussed in more detail in Progress Report 5. One of the Soil Box top sections will be removed, and new pressure cells will be placed directly beneath a couple of the load plates. The system will then be sealed back up and pressurized. This will allow for a more accurate measurement of exactly what pressure is being applied by the lift bags.

Also of importance in determining why the pipe deflections have been so small is the issue of soil arching. This particular aspect was introduced after conclusion of this quarter, and is currently being investigated. More information will follow on this matter in Progress Report 5.

The current compressor being used to pressurize the system will be replaced with a more powerful, higher capacity compressor during the next quarter. This will allow for greater pressures to be reached, a necessity that became apparent because of the lift bag contact area issues discussed above.

Finally, the first test will be concluded next quarter. Once the test is done, the process of taking the entire setup apart will begin. Careful attention will be paid to ensure that every aspect of the takedown is well documented, and that the utmost care is given to removing the pipes, instrumentation, soil, etc. from the Soil Box.

3. Activities Beyond the Next Quarter

Once the first test is complete, the process is repetitious. Pending the outcome of the proposed method for measuring the true pressures being applied, the testing process will have been standardized, and the continuation of this process relies on repeating the same steps over again.

4. Summary of Requested Modifications

No changes or modifications are requested.

5. Project Schedule

A table of tasks to be completed with current status is provided on the next page.

FLORIDA DEPARTMENT OF TRANSPORTATION
RESEARCH CENTER

PROJECT SCHEDULE

Project Title	Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading					
FDOT Project No.	BDK75 977-21	FY	2010	Months	June-September	
Research Agency	University of Florida					
Principal Investigator	Dr. David Bloomquist, Dr. Timothy McGrath					

RESEARCH TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	ESTIMATED % COMPLETION
Task 1																									5
Install Visqueen Sheeting/Purchase Lift Bags																									
Task 2a																									7
Install Bedding Material/Earth Pressure Cells																									
Task 3a																									4
Install Two 36" HDPE Pipes/Backfill/Flooding																									
Task 4a																									10
Fill Box/Install Pressure Cells/Lift Bags																									
Task 5																									4
Conduct Triaxial/1D Compression Tests																									
Task 6																									3
Finalize Design/Construction of LVDT Profiler																									
Task 7																									6
Conduct Staged Load Tests on Dual 36" HDPE Pipe																									
Task 8A																									10
Repeat Tests on Single Pipes w/ Trench Boxes																									
Task 8B																									8
Repeat Test Series on 36" Corrugated Steel Pipe																									
Task 8C																									8
Repeat Test Series on 36" Corrugated Aluminum Pipe																									
Task 8D																									8
Repeat Test Series on 36" PVC Pipe																									
Task 8E																									8
Repeat Test Series on 24" HDPE Pipe																									
Task 8F																									8
Repeat Test Series on 24" Corrugated Steel Pipe																									
Task 9																									10
Perform FEM modeling																									
Task 10																									1
Preparation of Final Report																									
																									100%
Overall % Complete Projected	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	85%	90%	95%	100%	
Overall % Complete Actual	4%	7%	11%	14%	18%	22%																			

FIG. A -- OVERALL PROJECT SCHEDULE

Appendix

Appendix A

Triaxial Test Results for

Sample with 80% Standard Density

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE	Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
			By: SH	Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-1
Date:	6/3/2010
Test By:	Dan Pitocchi
Description:	80% std proctor @ 3 psi confining
Strain Rate:	0.006 in/min

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**139.93**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1090.14**
Mass of sample (g)	950.21
Mass of sample (lbs)	2.09

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.1405**	**0.5160**
2	**6.1005**	**0.5215**
3	**6.1490**	**0.5185**
Average	6.130	0.519
Average Height minus pore stones and filter paper	5.6113	

Diameter (in)	
Top	**2.883**
Middle	**2.881**
Bottom	**2.891**
Average (minus membrane)	2.861
Area (in^2)	6.4287

	Initial	Final
Tare	**59.64**	
Wet	**231.95**	
Dry	**212.50**	
moisture (%)	12.7	#DIV/0!

Optimum Dry Density, pcf	**109.5**
Optimum Moisture, %	**12.5**
Target Density, pcf	87.6
Actual Dry Density, pcf	89.0
Percentage of Optimum	**81.3**

Actual Volume, ft^3	0.0209
Volume Start of Test, cm3	591.1434
Volume After Consol, cm3	581.0812

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	10
	B =	0

Height before saturation (in)	**0.0483**
Height after saturation (in)	**0.0773**
Δ Hs (in)	0.029
Height after consolidation (in)	**0.1062**
Δ Height after sat. and consol. (in)	0.0579
Average height ΔHc+ΔHs (in)	5.5534
Vo (in^3)	36.0738
ΔVs (in^3)	0.5591
ΔVc (cm^3)	**0.9000**
(in^3)	0.0549
ΔV_T (in^3)	0.6140
Ac (in^2)	6.3852
Volume after consolidation, Vc, (cm^3)	581.0812
Confining Pressure (psi)	**3**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-2
Date:	5/20/2010
Test By:	dp
Description:	80% std proctor @ 5 psi confining
	0.006 in/min

Membrane Thickness (in)	0.012
Mass of 2 pore stones, 2 papers & mem. (g)	147.80
Mass of 2 ps, 2fp, 1 mem + sample (g)	1102.41
Mass of sample (g)	954.61
Mass of sample (lbs)	2.10

Height	Sample + pore stones + papers	Pore Stones & Papers
1	6.0210	0.5350
2	6.0135	0.5250
3	6.0695	0.5365
Average	6.035	0.532
Average Height minus pore stones and filter paper	5.5025	

Diameter (in)	
Top	2.900
Middle	2.910
Bottom	2.900
Average (minus membrane)	2.879
Area (in^2)	6.5114

	Initial	Final
Tare	68.50	
Wet	239.05	
Dry	219.94	
moisture (%)	12.6	#DIV/0!

Optimum Dry Density, pcf	109.5
Optimum Moisture, %	12.5
Target Density, pcf	87.6
Actual Dry Density, pcf	90.1
Percentage of Optimum	**82.3**

Actual Volume, ft^3	0.0207
Volume Start of Test, cm3	587.1309
Volume After Consol, cm3	567.4245

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	10
	B =	0

Height before saturation (in)	0.0607
Height after saturation (in)	0.1207
Δ Hs (in)	0.060
Height after consolidation (in)	0.1282
Δ Height after sat. and consol. (in)	0.0675
Average height $\Delta Hc+\Delta Hs$ (in)	5.4350
Vo (in^3)	35.8289
ΔVs (in^3)	1.1721
ΔVc (cm^3)	0.5
(in^3)	0.0305
ΔV_T (in^3)	1.2026
Ac (in^2)	6.3710
Volume after consolidation, Vc, (cm^3)	567.4245
Confining Pressure (psi)	5

Test Notes:

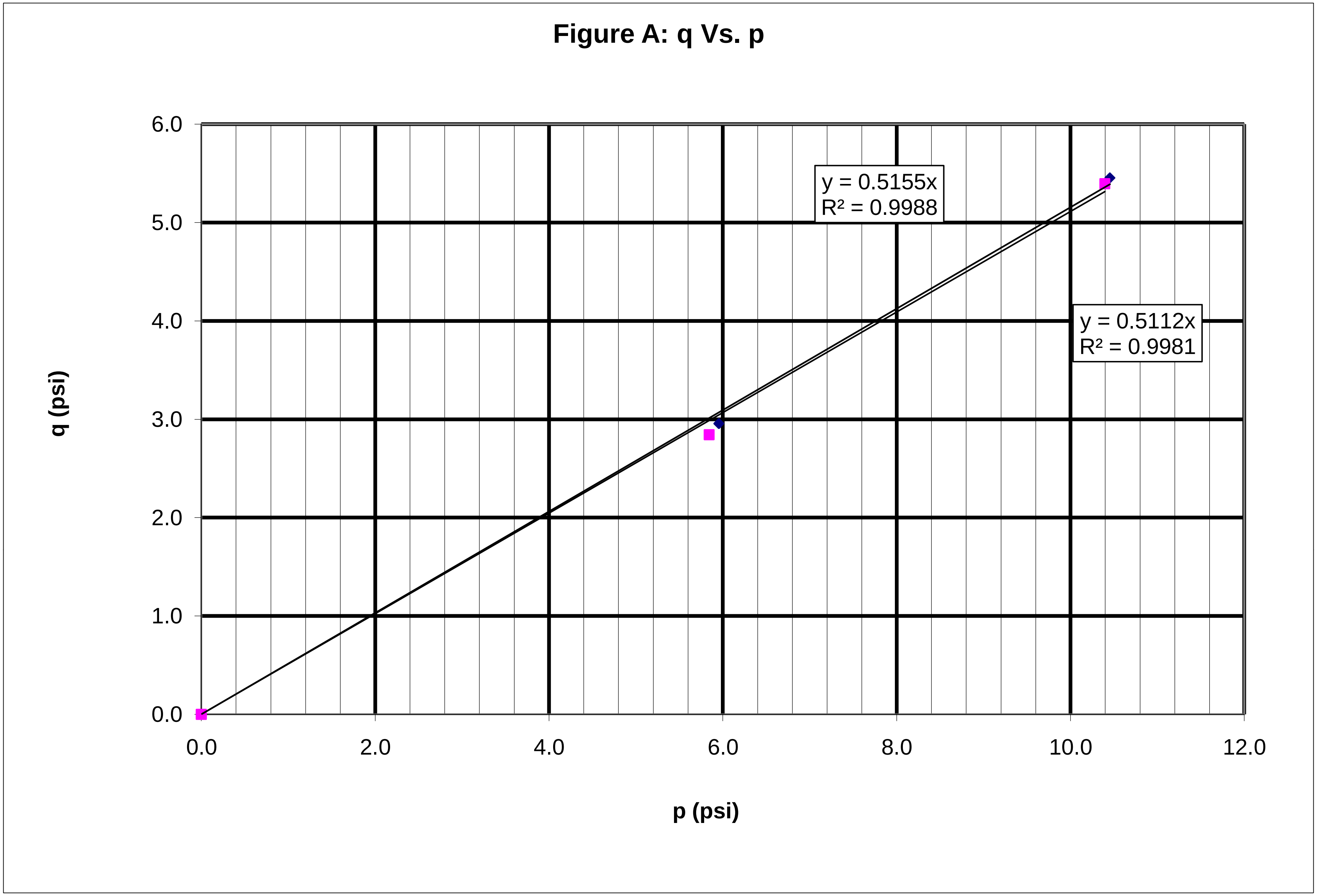

Figure A: q Vs. p
y = 0.5155x
R² = 0.9988
y = 0.5112x
R² = 0.9981
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
q (psi)
p (psi)

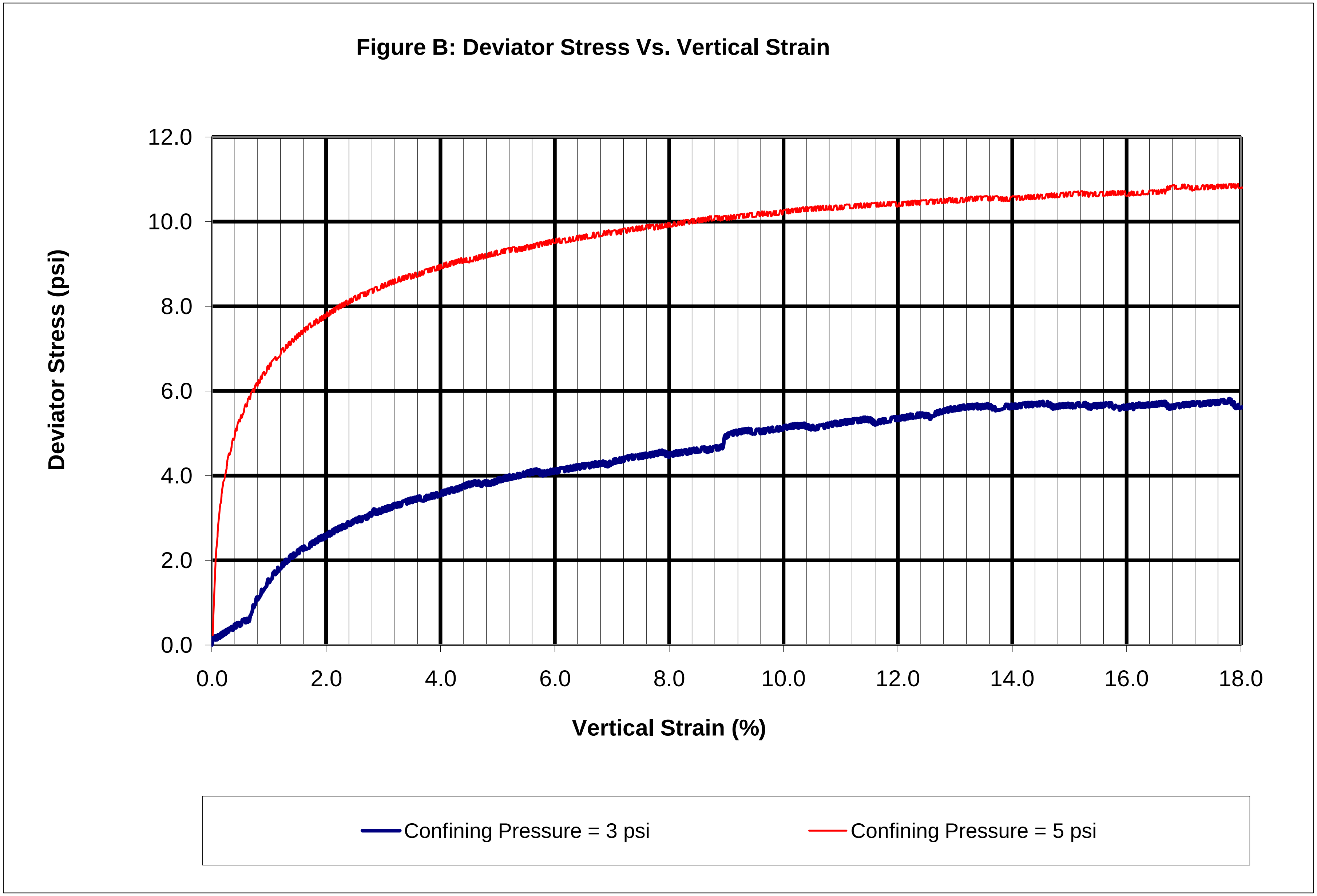
Figure B: Deviator Stress Vs. Vertical Strain
Deviator Stress (psi)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Vertical Strain (%)
Confining Pressure = 3 psi
Confining Pressure = 5 psi

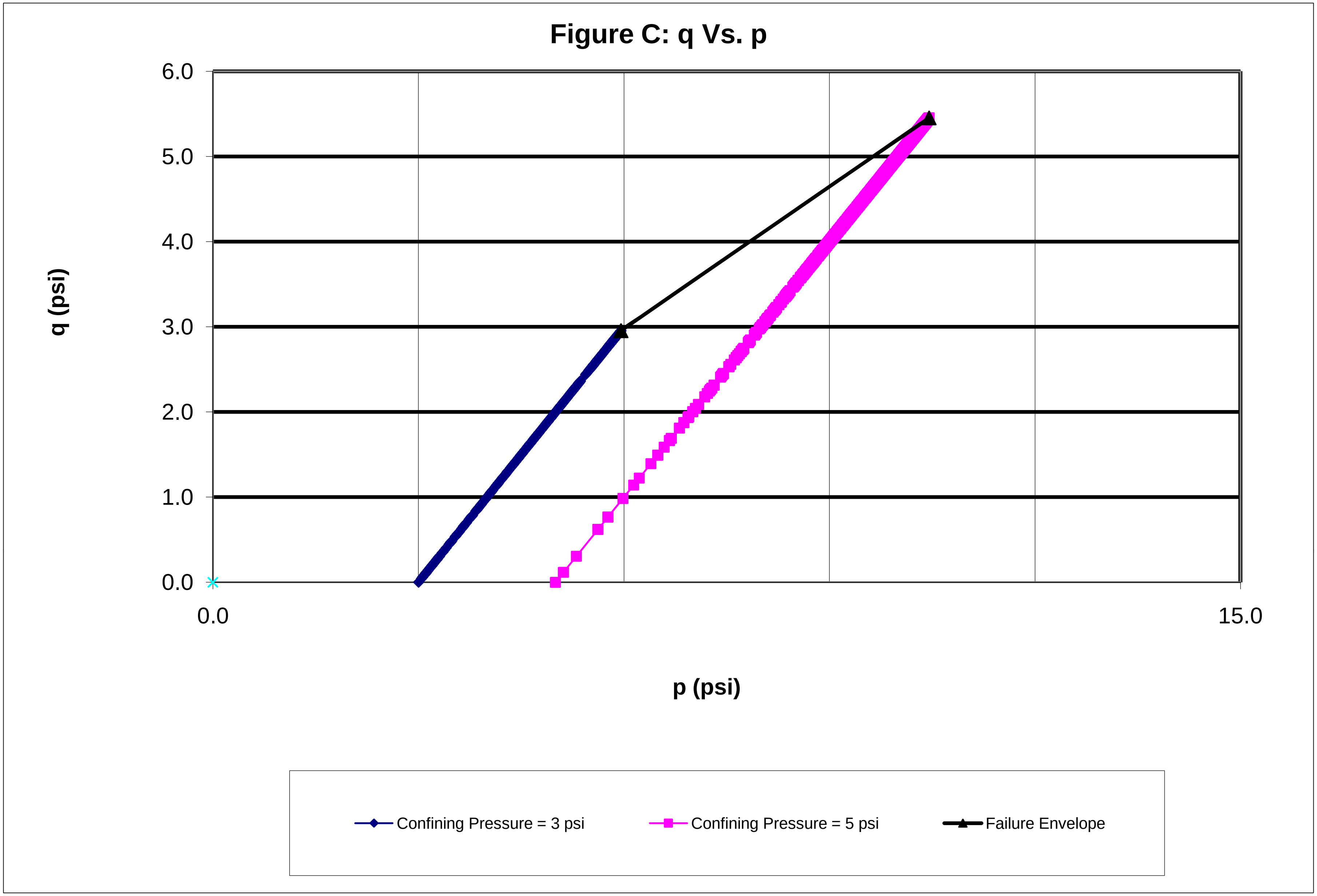

Figure C: q Vs. p
q (psi)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
15.0
p (psi)
Confining Pressure = 3 psi
Confining Pressure = 5 psi
Failure Envelope

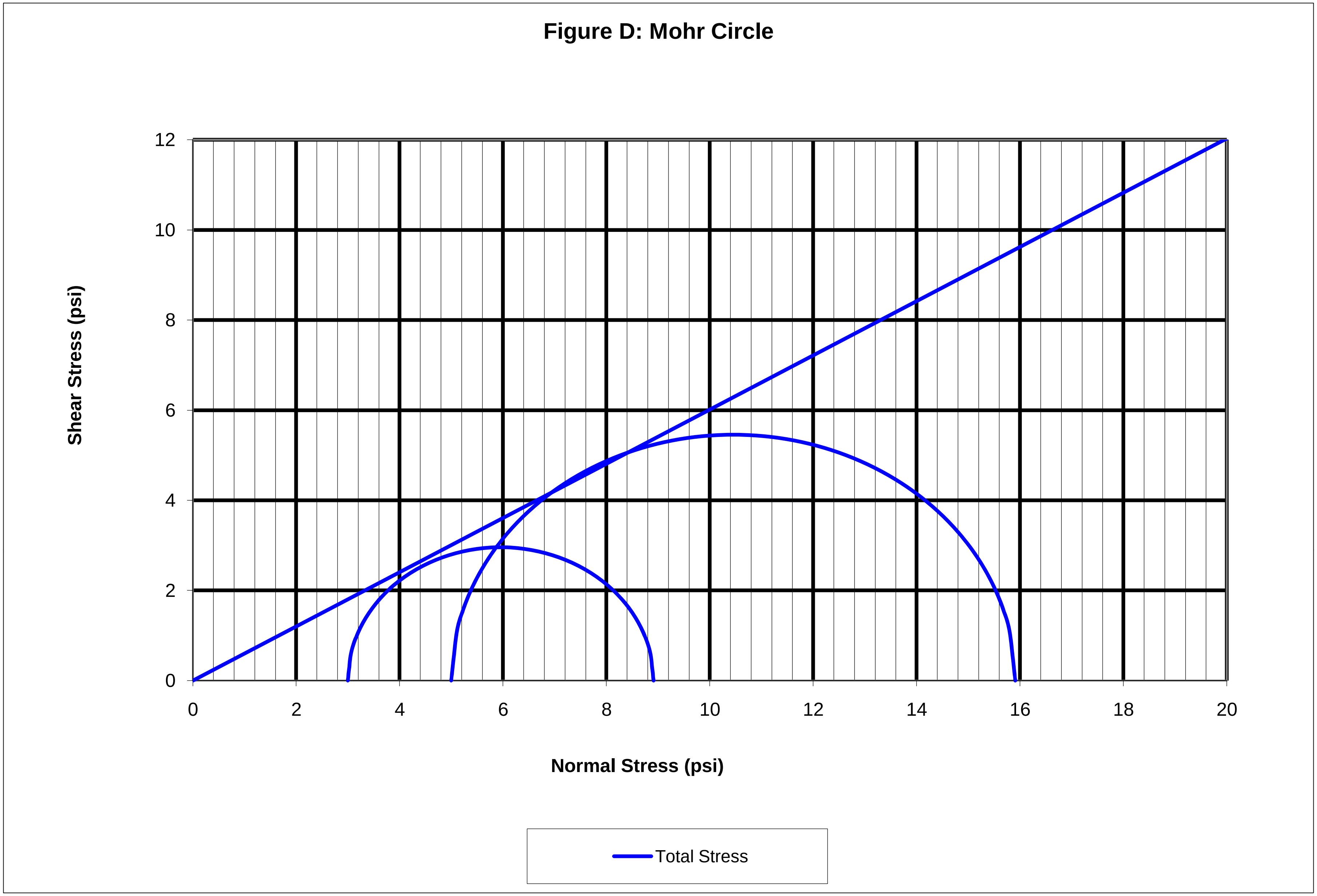
Figure D: Mohr Circle
Shear Stress (psi)
0
2
4
6
8
10
12
0
2
4
6
8
10
12
14
16
18
20
Normal Stress (psi)
Total Stress

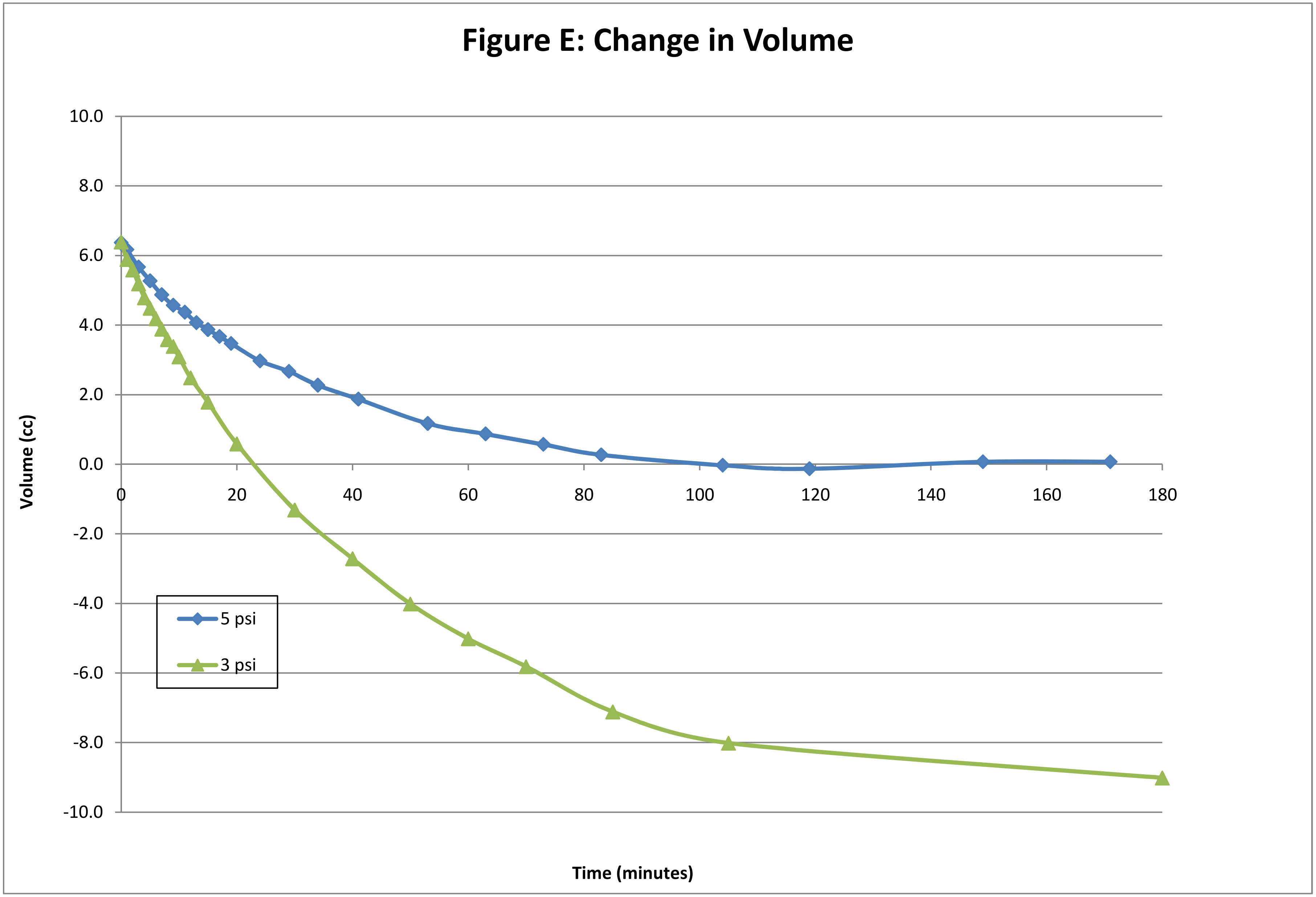
Figure E: Change in Volume
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0
20
40
60
80
100
120
140
160
180
Volume (cc)
Time (minutes)
5 psi
3 psi

Appendix B

Triaxial Test Results for

Sample with 85% Standard Density

prep.______
setup______
consol.______
shear______

	STATE MATERIALS OFFICE Foundations Laboratory	Consolidated Drained Triaxial Compression Test	Revised Date: 2/8/06	
			By: SH	Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-1 (re-run)
Date:	5/25/2010
Test By:	Dan Pitocchi
Description:	85% std proctor @ 3 psi confining
Strain Rate:	0.006 in/min

Membrane Thickness (in)	0.012
Mass of 2 pore stones, 2 papers & mem. (g)	132.60
Mass of 2 ps, 2fp, 1 mem + sample (g)	1143.96
Mass of sample (g)	1011.36
Mass of sample (lbs)	2.23

Height	Sample + pore stones + papers	Pore Stones & Papers
1	6.0990	0.5275
2	6.1285	0.5275
3	6.1030	0.5295
Average	6.110	0.528
Average Height minus pore stones and filter paper	5.5820	

Diameter (in)	
Top	2.905
Middle	2.906
Bottom	2.904
Average (minus membrane)	2.881
Area (in^2)	6.5189

	Initial	Final
Tare	68.83	531.40
Wet	234.37	1582.00
Dry	216.00	1385.30
moisture (%)	12.48	23.0

Optimum Dry Density, pcf	109.5
Optimum Moisture, %	12.5
Target Density, pcf	93.1
Actual Dry Density, pcf	94.1
Percentage of Optimum	**86.0**

Actual Volume, ft^3	0.0211
Volume Start of Test, cm3	596.3035
Volume After Consol, cm3	591.9744

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	10
	B =	0.96

Height before saturation (in)	0.0271
Height after saturation (in)	0.0378
Δ Hs (in)	0.011
Height after consolidation (in)	0.0388
Δ Height after sat. and consol. (in)	0.0117
Average height ΔHc+ΔHs (in)	5.5703
Vo (in^3)	36.3887
ΔVs (in^3)	0.2093
ΔVc (cm^3)	0.9000
(in^3)	0.0549
ΔV_T (in^3)	0.2642
Ac (in^2)	6.4852
Volume after consolidation, Vc, (cm^3)	591.9744
Confining Pressure (psi)	3

Test Notes:

prep._______
setup_______
consol._______
shear_______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06	
		By: SH	Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-2R
Date:	6/8/2010
Test By:	Dan Pitocchi
Description:	85% std proctor @ 5 psi confining
Strain Rate:	0.006 in/min

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**143.31**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1157.83**
Mass of sample (g)	1014.52
Mass of sample (lbs)	2.24

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.0870**	**0.5285**
2	**6.1260**	**0.5280**
3	**6.0845**	**0.5290**
Average	6.099	0.529
Average Height minus pore stones and filter paper	5.5707	

Diameter (in)	
Top	**2.903**
Middle	**2.904**
Bottom	**2.906**
Average (minus membrane)	2.880
Area (in^2)	6.5159

	Initial	Final
Tare	**68.51**	
Wet	**261.91**	
Dry	**240.58**	
moisture (%)	12.40	#DIV/0!

Optimum Dry Density, pcf	**109.5**
Optimum Moisture, %	**12.5**
Target Density, pcf	**93.1**
Actual Dry Density, pcf	94.7
Percentage of Optimum	**86.5**

Actual Volume, ft^3	0.0210
Volume Start of Test, cm3	594.8175
Volume After Consol, cm3	590.4501

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	10
	B =	0.94

Height before saturation (in)	**0.0647**
Height after saturation (in)	**0.0749**
Δ Hs (in)	0.010
Height after consolidation (in)	**0.0773**
Δ Height after sat. and consol. (in)	0.0126
Average height ΔHc+ΔHs (in)	5.5581
Vo (in^3)	36.2980
ΔVs (in^3)	0.1994
ΔVc (cm^3)	**1.1000**
(in^3)	0.0671
ΔV_T (in^3)	0.2665
Ac (in^2)	6.4827
Volume after consolidation, Vc, (cm^3)	590.4501
Confining Pressure (psi)	**5**

Test Notes:

prep.______
setup______
consol.______
shear______

STATE MATERIALS OFFICE Foundations Laboratory	**Consolidated Drained Triaxial Compression Test**	Revised Date: 2/8/06
		By: SH / Page 1 of 1

Project:	UF Soil Box
Sample No.:	S-1
Date:	5/25/2010
Test By:	Dan Pitocchi
Description:	85% std proctor @ 3 psi confining
Strain Rate:	0.006 in/min

Membrane Thickness (in)	**0.012**
Mass of 2 pore stones, 2 papers & mem. (g)	**140.86**
Mass of 2 ps, 2fp, 1 mem + sample (g)	**1146.40**
Mass of sample (g)	1005.54
Mass of sample (lbs)	2.22

Height	Sample + pore stones + papers	Pore Stones & Papers
1	**6.1220**	**0.5280**
2	**6.1295**	**0.5225**
3	**6.1145**	**0.5280**
Average	6.122	0.526
Average Height minus pore stones and filter paper	5.5958	

Diameter (in)	
Top	**2.895**
Middle	**2.903**
Bottom	**2.907**
Average (minus membrane)	2.878
Area (in^2)	6.5039

	Initial	Final
Tare	**59.50**	
Wet	**244.14**	
Dry	**223.40**	
moisture (%)	12.7	22.6

Optimum Dry Density, pcf	**109.5**
Optimum Moisture, %	**12.5**
Target Density, pcf	93.1
Actual Dry Density, pcf	93.4
Percentage of Optimum	**85.3**

Actual Volume, ft^3	0.0211
Volume Start of Test, cm3	596.3988
Volume After Consol, cm3	584.2581

Shear Failure Sketch	B value	
	u1 =	
	u2 =	
	Δs =	
	B =	0.95

Height before saturation (in)	**0.0687**
Height after saturation (in)	**0.1054**
Δ Hs (in)	0.037
Height after consolidation (in)	**0.1071**
Δ Height after sat. and consol. (in)	0.038
Average height ΔHc+ΔHs (in)	5.5574
Vo (in^3)	36.3945
ΔVs (in^3)	0.7165
ΔVc (cm^3)	**0.4000**
(in^3)	0.0244
ΔV_T (in^3)	0.7409
Ac (in^2)	6.4155
Volume after consolidation, Vc, (cm^3)	584.2581
Confining Pressure (psi)	**3**

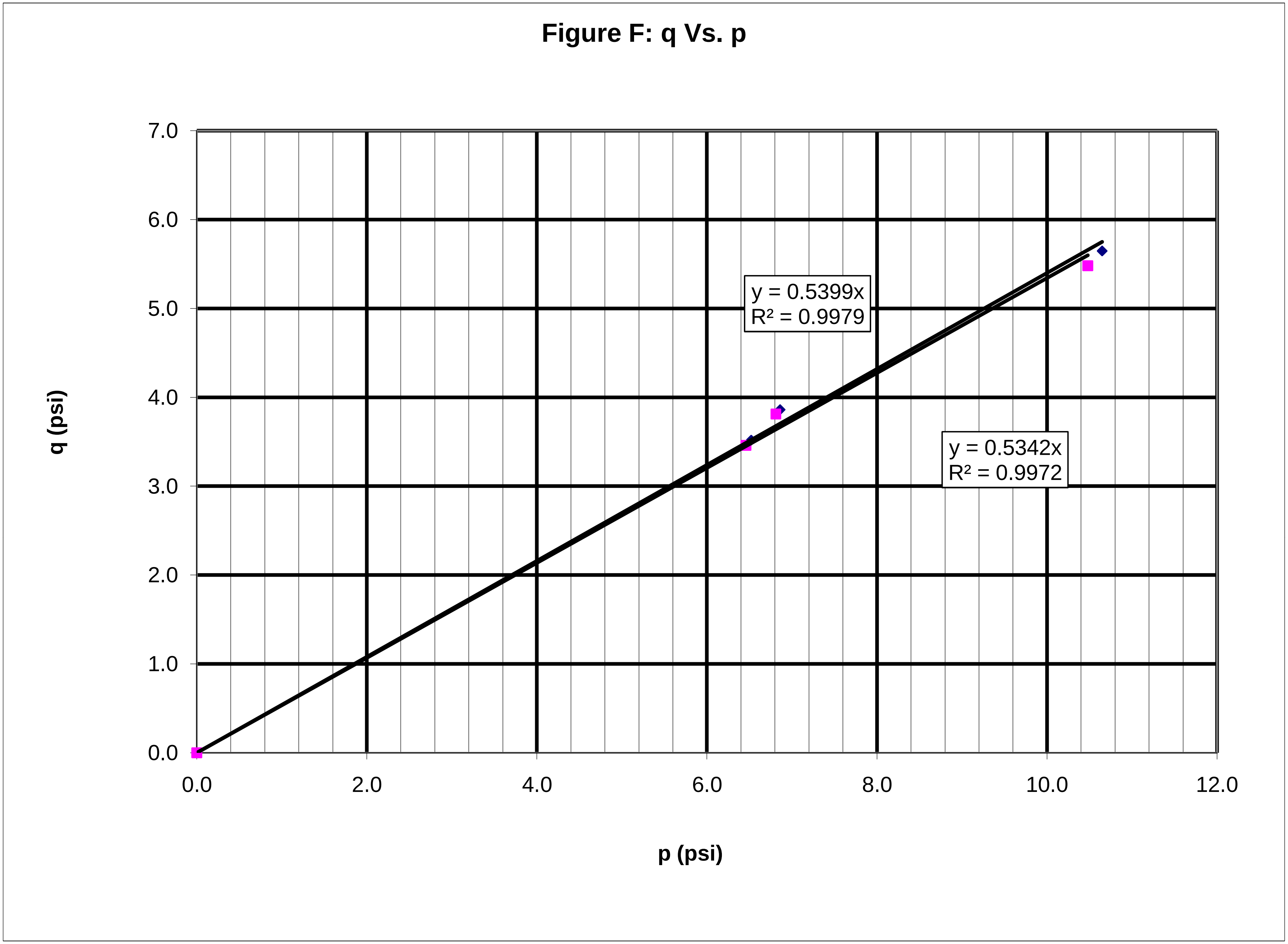

Figure F: q Vs. p
q (psi)
p (psi)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
y = 0.5399x
R² = 0.9979
y = 0.5342x
R² = 0.9972

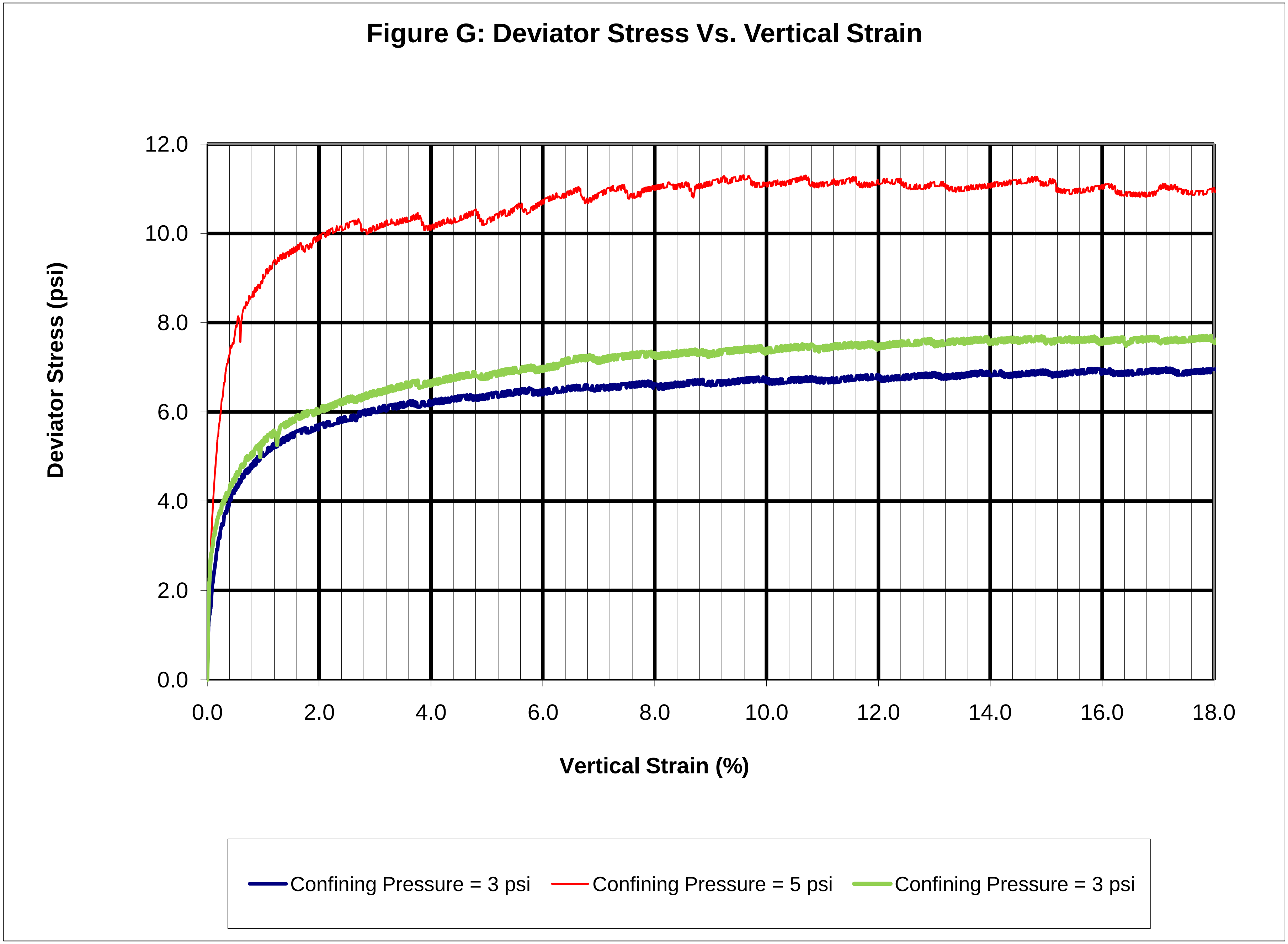
Figure G: Deviator Stress Vs. Vertical Strain
Deviator Stress (psi)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Vertical Strain (%)
Confining Pressure = 3 psi
Confining Pressure = 5 psi
Confining Pressure = 3 psi

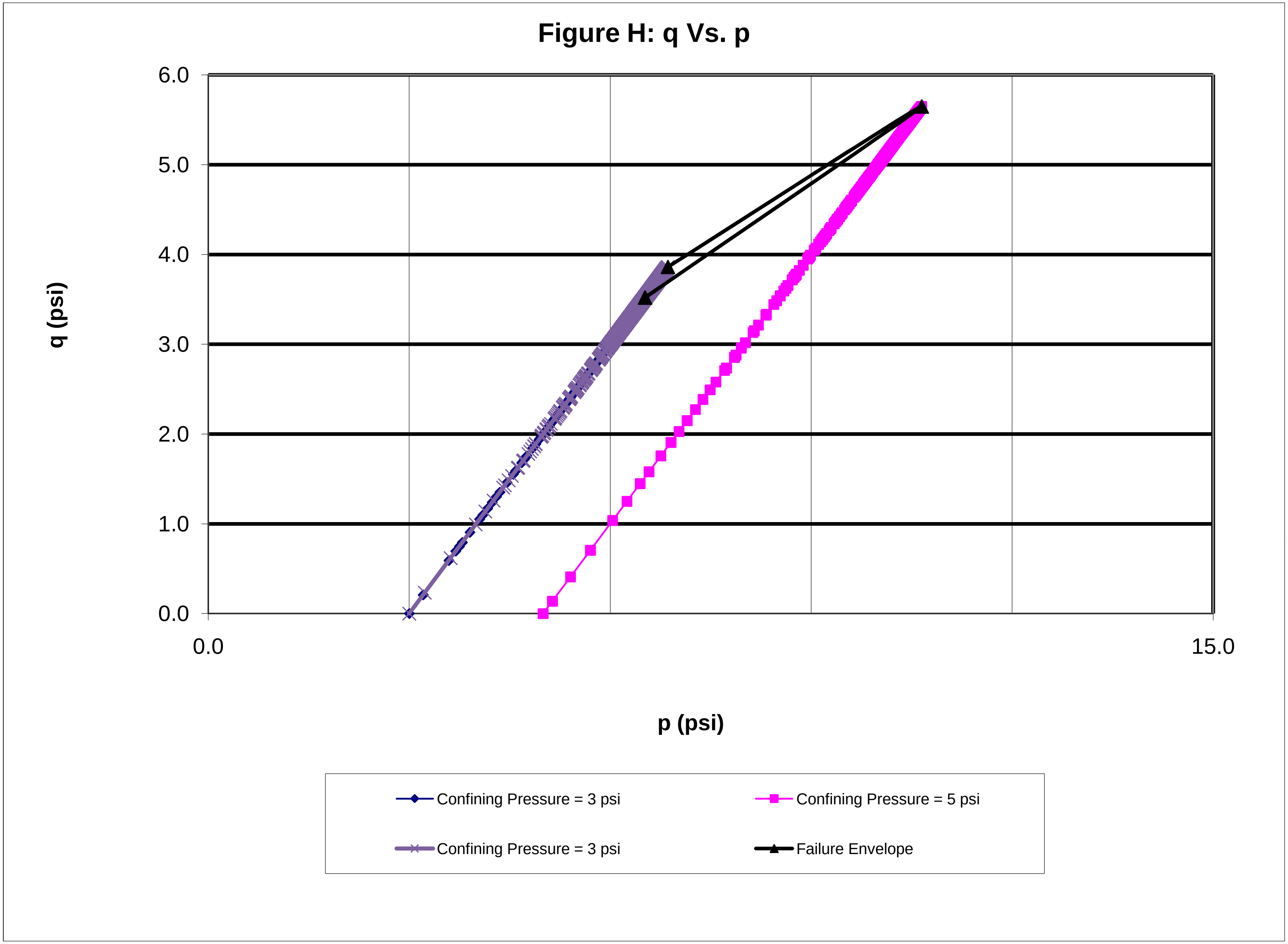

Figure H: q Vs. p
q (psi)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
15.0
p (psi)
Confining Pressure = 3 psi
Confining Pressure = 5 psi
Confining Pressure = 3 psi
Failure Envelope

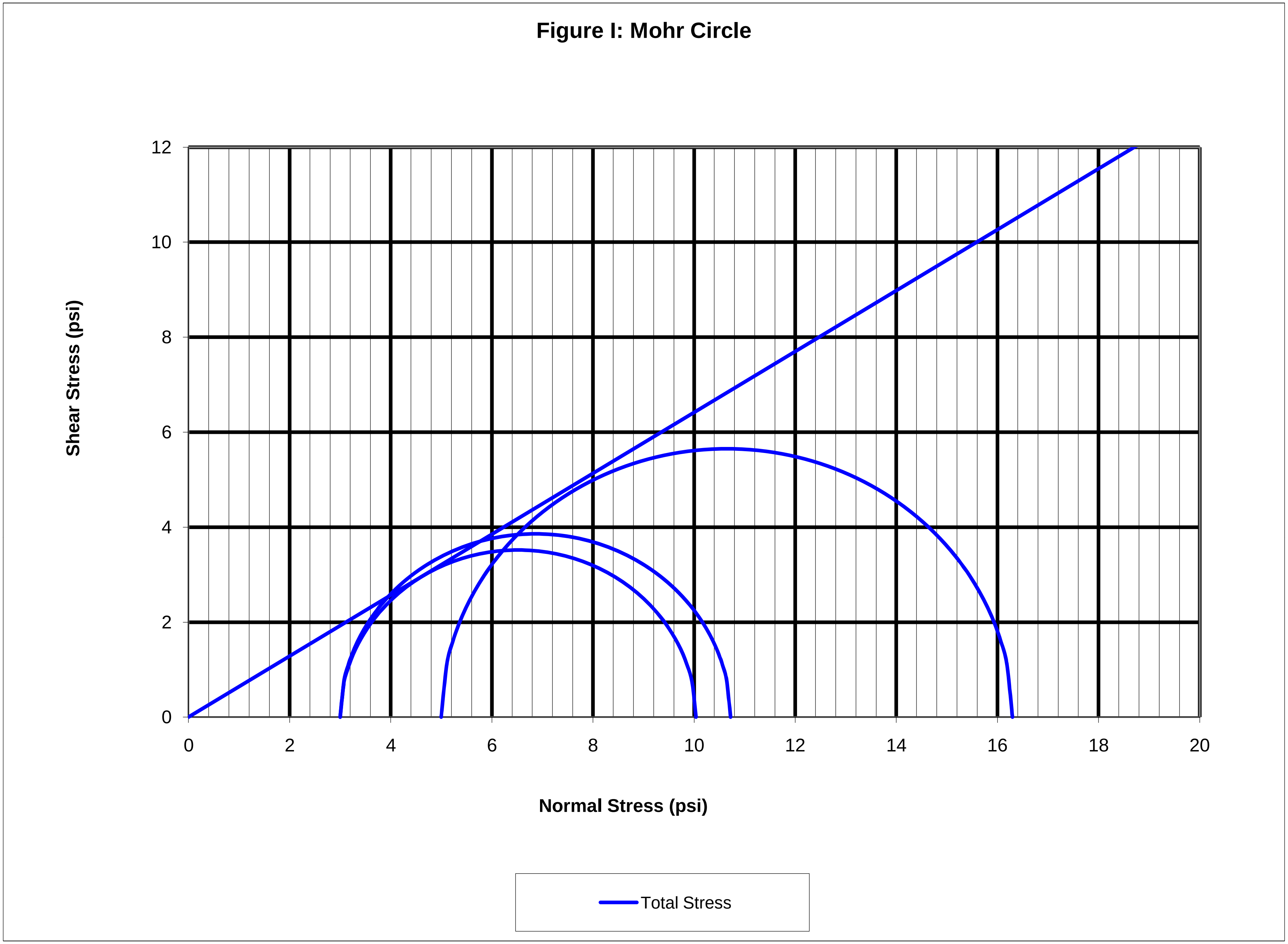
Figure I: Mohr Circle
Shear Stress (psi)
0
2
4
6
8
10
12
0
2
4
6
8
10
12
14
16
18
20
Normal Stress (psi)
Total Stress

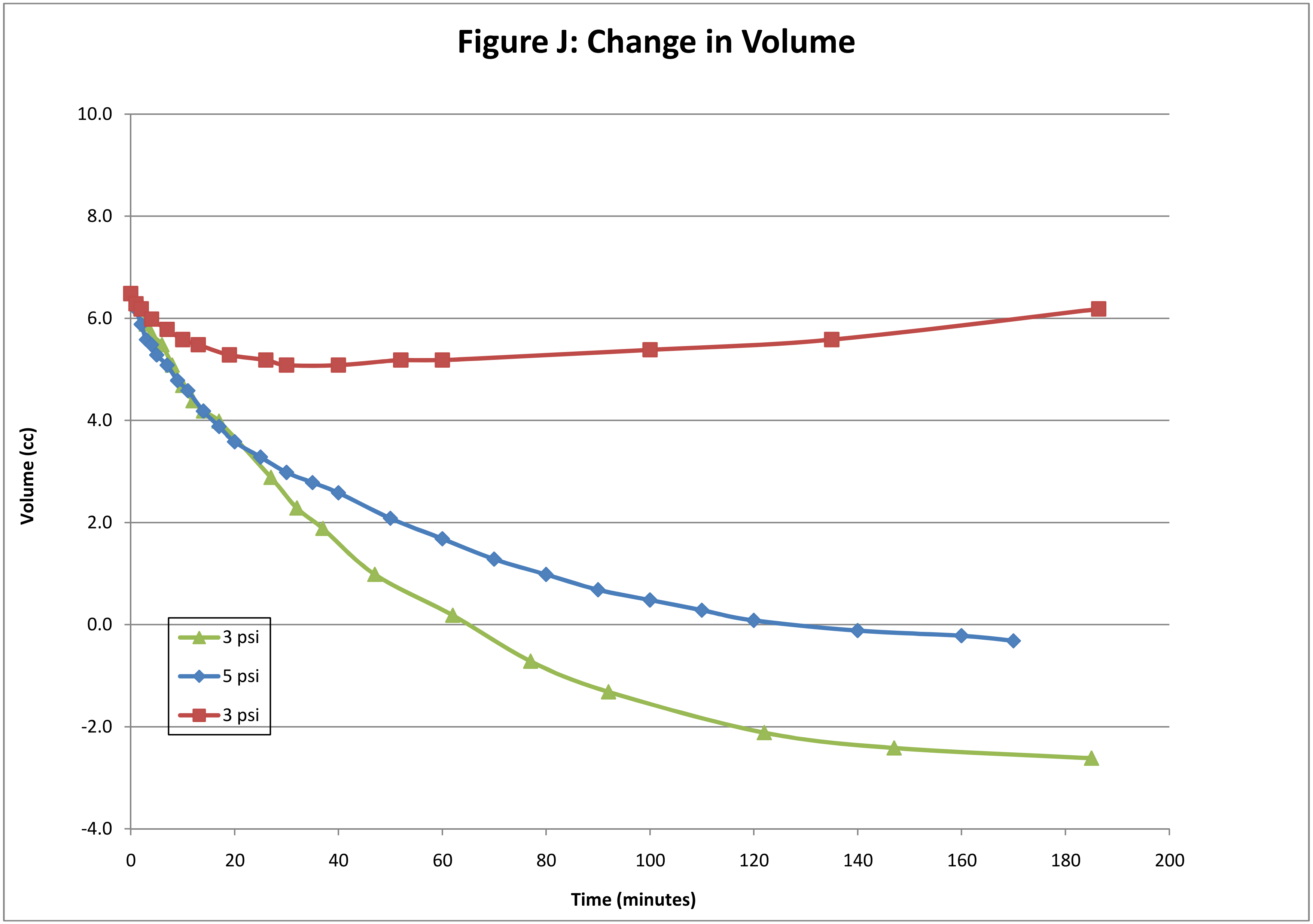
Figure J: Change in Volume
Volume (cc)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
0
20
40
60
80
100
120
140
160
180
200
Time (minutes)
3 psi
5 psi
3 psi

Appendix C

Earth Pressure Cell Data

36” HDPE without Trench Box

Appendix C Table of Contents

Appendix D

Displacement Laser Data

36” HDPE without Trench Box

Appendix D Table of Contents

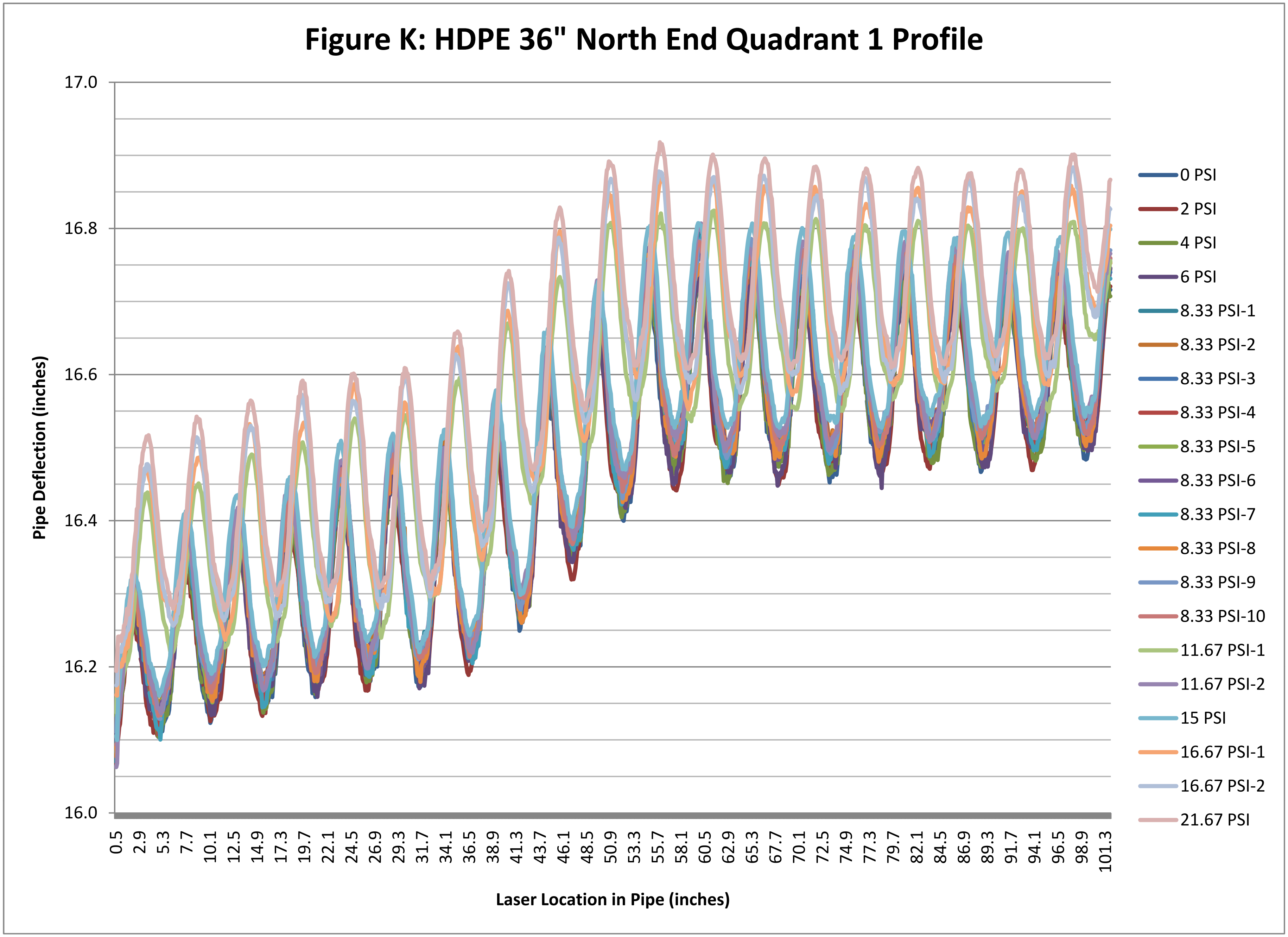
Figure K: HDPE 36" North End Quadrant 1 Profile
Pipe Deflection (inches)
17.0
16.8
16.6
16.4
16.2
16.0
0.5
2.9
5.3
7.7
10.1
12.5
14.9
17.3
19.7
22.1
24.5
26.9
29.3
31.7
34.1
36.5
38.9
41.3
43.7
46.1
48.5
50.9
53.3
55.7
58.1
60.5
62.9
65.3
67.7
70.1
72.5
74.9
77.3
79.7
82.1
84.5
86.9
89.3
91.7
94.1
96.5
98.9
101.3
Laser Location in Pipe (inches)
0 PSI
2 PSI
4 PSI
6 PSI
8.33 PSI-1
8.33 PSI-2
8.33 PSI-3
8.33 PSI-4
8.33 PSI-5
8.33 PSI-6
8.33 PSI-7
8.33 PSI-8
8.33 PSI-9
8.33 PSI-10
11.67 PSI-1
11.67 PSI-2
15 PSI
16.67 PSI-1
16.67 PSI-2
21.67 PSI

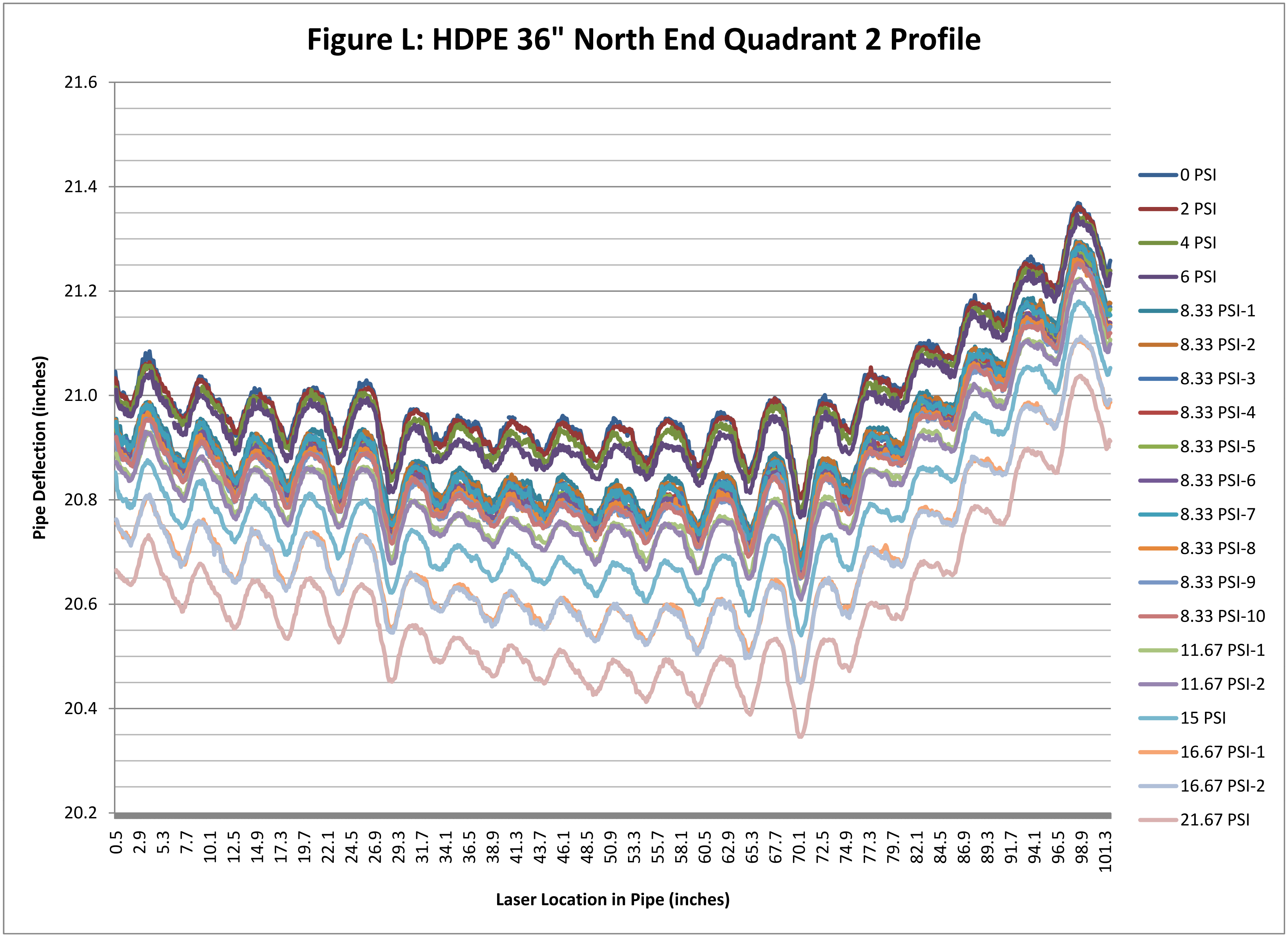
Figure L: HDPE 36" North End Quadrant 2 Profile
Pipe Deflection (inches)
21.6
21.4
21.2
21.0
20.8
20.6
20.4
20.2
0.5
2.9
5.3
7.7
10.1
12.5
14.9
17.3
19.7
22.1
24.5
26.9
29.3
31.7
34.1
36.5
38.9
41.3
43.7
46.1
48.5
50.9
53.3
55.7
58.1
60.5
62.9
65.3
67.7
70.1
72.5
74.9
77.3
79.7
82.1
84.5
86.9
89.3
91.7
94.1
96.5
98.9
101.3
Laser Location in Pipe (inches)
0 PSI
2 PSI
4 PSI
6 PSI
8.33 PSI-1
8.33 PSI-2
8.33 PSI-3
8.33 PSI-4
8.33 PSI-5
8.33 PSI-6
8.33 PSI-7
8.33 PSI-8
8.33 PSI-9
8.33 PSI-10
11.67 PSI-1
11.67 PSI-2
15 PSI
16.67 PSI-1
16.67 PSI-2
21.67 PSI

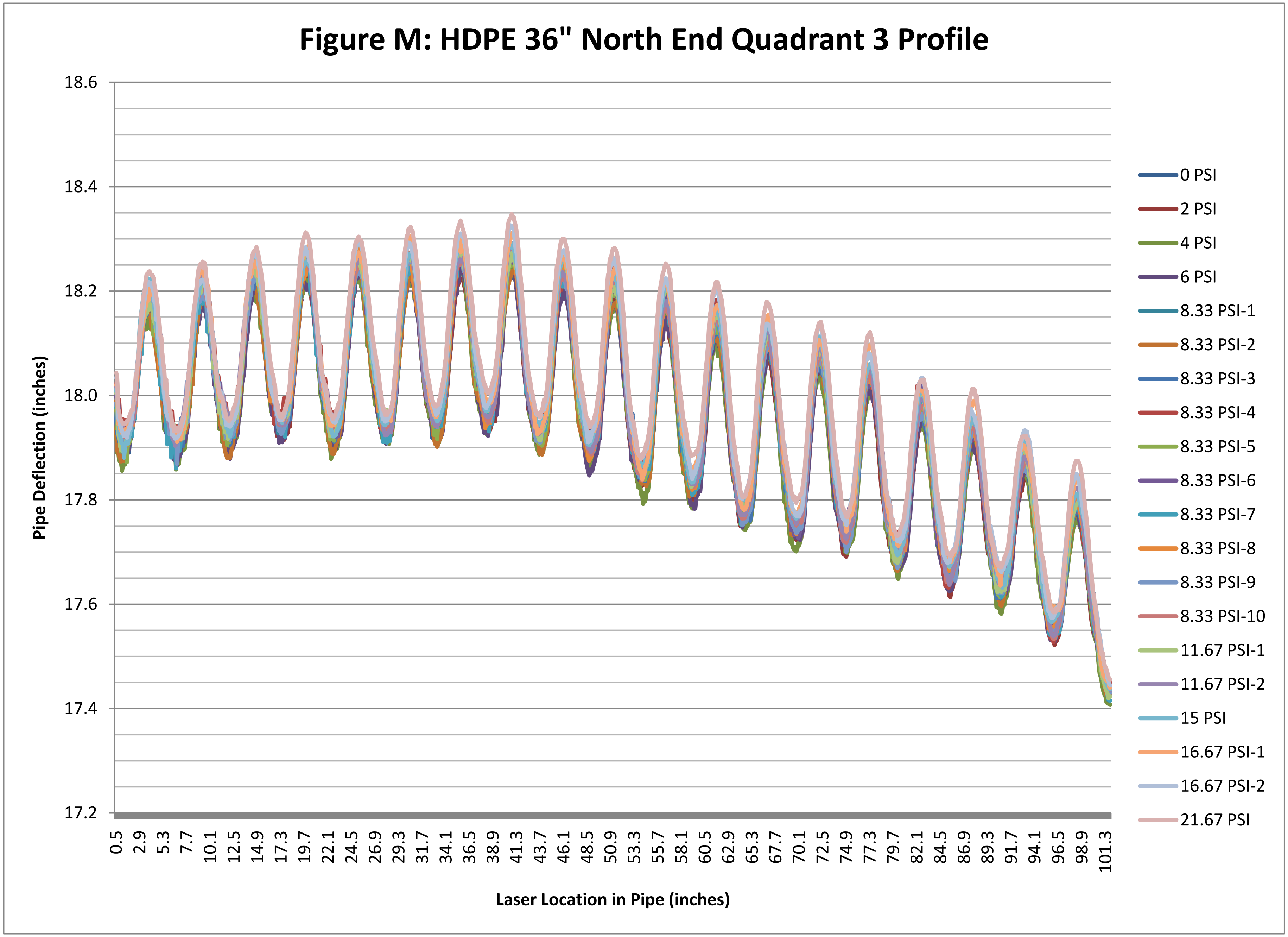

Figure M: HDPE 36" North End Quadrant 3 Profile
Pipe Deflection (inches)
Laser Location in Pipe (inches)
18.6
18.4
18.2
18.0
17.8
17.6
17.4
17.2
0.5
2.9
5.3
7.7
10.1
12.5
14.9
17.3
19.7
22.1
24.5
26.9
29.3
31.7
34.1
36.5
38.9
41.3
43.7
46.1
48.5
50.9
53.3
55.7
58.1
60.5
62.9
65.3
67.7
70.1
72.5
74.9
77.3
79.7
82.1
84.5
86.9
89.3
91.7
94.1
96.5
98.9
101.3
0 PSI
2 PSI
4 PSI
6 PSI
8.33 PSI-1
8.33 PSI-2
8.33 PSI-3
8.33 PSI-4
8.33 PSI-5
8.33 PSI-6
8.33 PSI-7
8.33 PSI-8
8.33 PSI-9
8.33 PSI-10
11.67 PSI-1
11.67 PSI-2
15 PSI
16.67 PSI-1
16.67 PSI-2
21.67 PSI

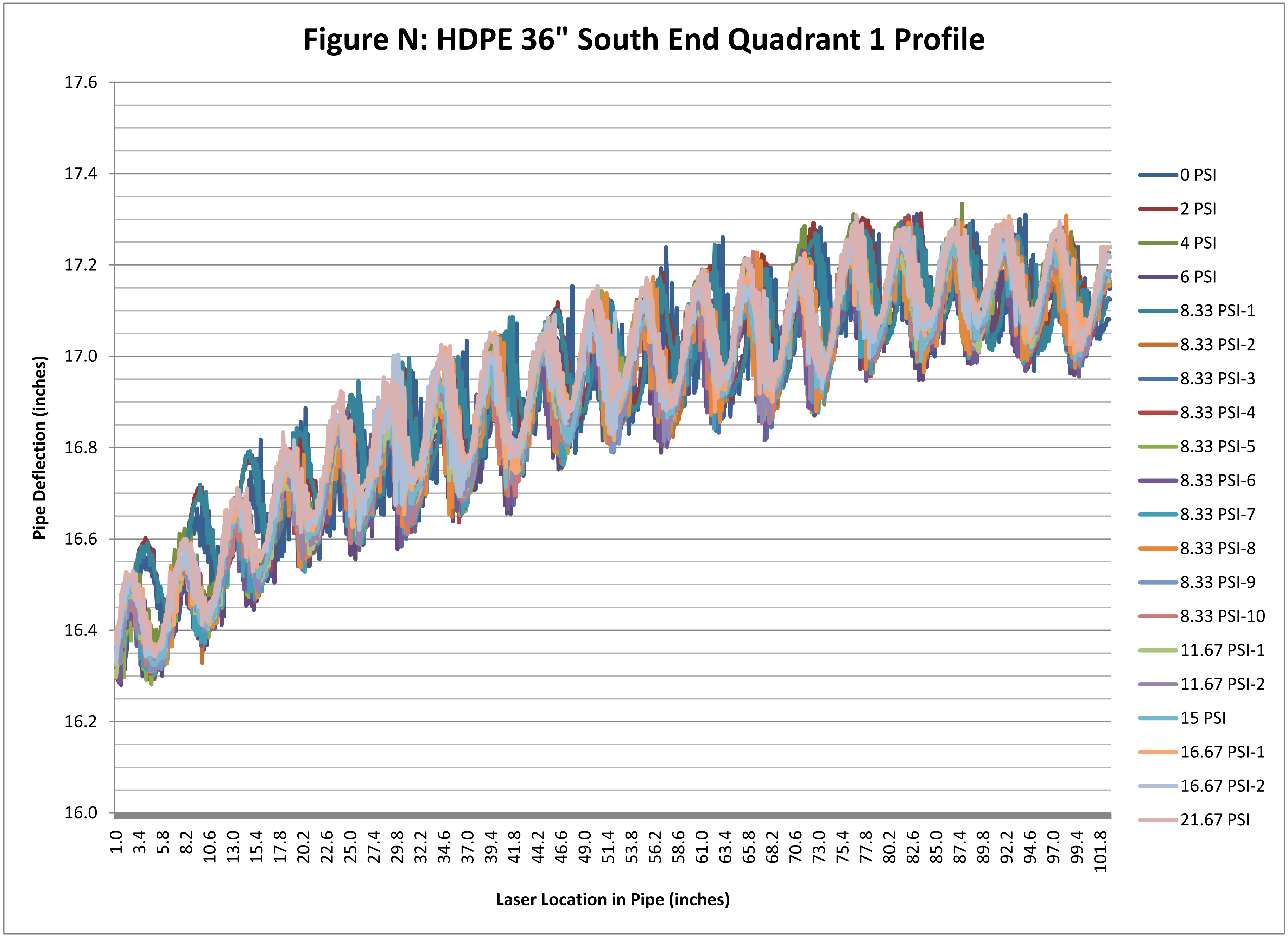
Figure N: HDPE 36" South End Quadrant 1 Profile
Pipe Deflection (inches)
17.6
17.4
17.2
17.0
16.8
16.6
16.4
16.2
16.0
Laser Location in Pipe (inches)
1.0
3.4
5.8
8.2
10.6
13.0
15.4
17.8
20.2
22.6
25.0
27.4
29.8
32.2
34.6
37.0
39.4
41.8
44.2
46.6
49.0
51.4
53.8
56.2
58.6
61.0
63.4
65.8
68.2
70.6
73.0
75.4
77.8
80.2
82.6
85.0
87.4
89.8
92.2
94.6
97.0
99.4
101.8
0 PSI
2 PSI
4 PSI
6 PSI
8.33 PSI-1
8.33 PSI-2
8.33 PSI-3
8.33 PSI-4
8.33 PSI-5
8.33 PSI-6
8.33 PSI-7
8.33 PSI-8
8.33 PSI-9
8.33 PSI-10
11.67 PSI-1
11.67 PSI-2
15 PSI
16.67 PSI-1
16.67 PSI-2
21.67 PSI

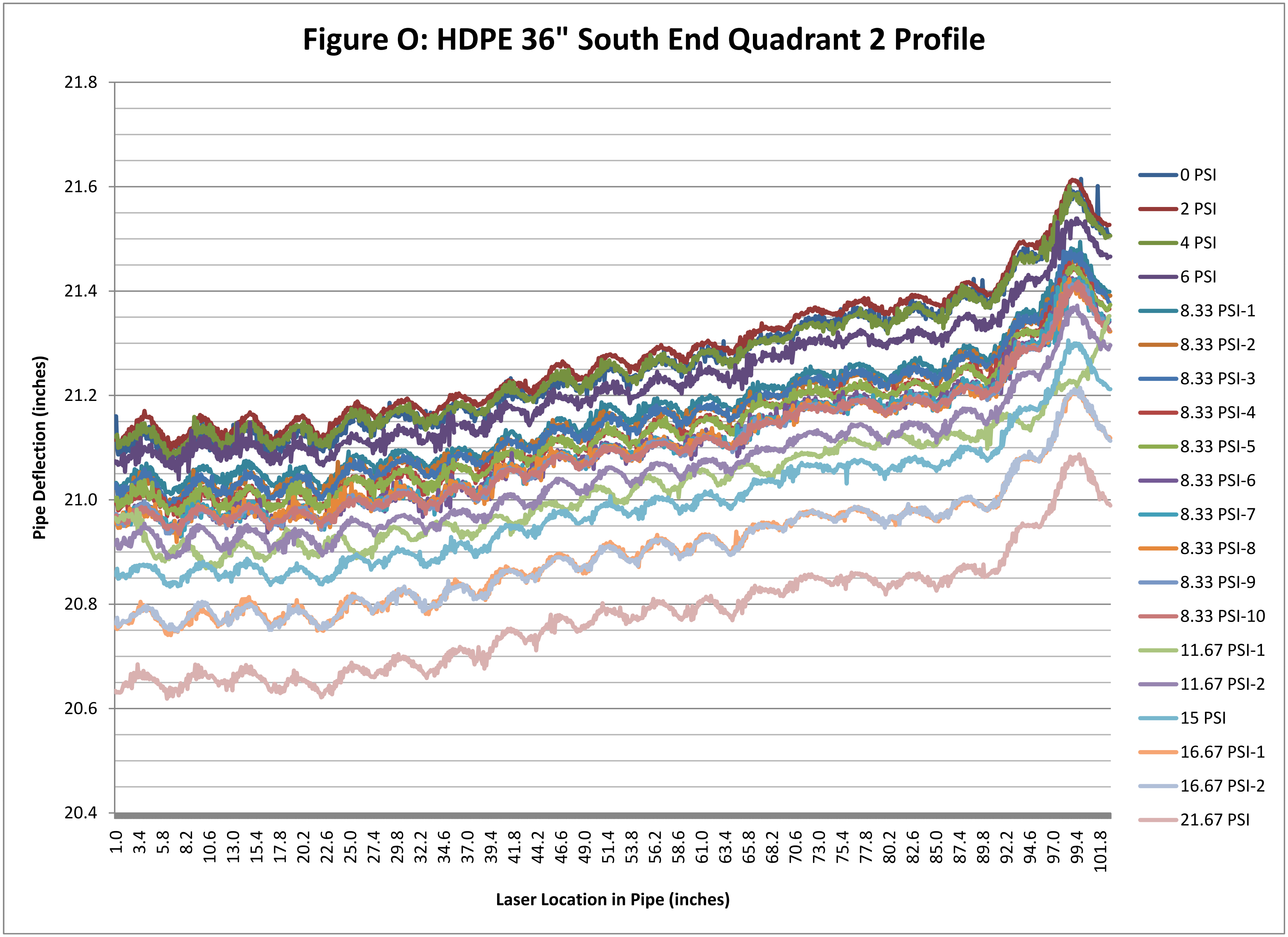
Figure O: HDPE 36" South End Quadrant 2 Profile
21.8
21.6
21.4
21.2
21.0
20.8
20.6
20.4
Pipe Deflection (inches)
1.0
3.4
5.8
8.2
10.6
13.0
15.4
17.8
20.2
22.6
25.0
27.4
29.8
32.2
34.6
37.0
39.4
41.8
44.2
46.6
49.0
51.4
53.8
56.2
58.6
61.0
63.4
65.8
68.2
70.6
73.0
75.4
77.8
80.2
82.6
85.0
87.4
89.8
92.2
94.6
97.0
99.4
101.8
Laser Location in Pipe (inches)
0 PSI
2 PSI
4 PSI
6 PSI
8.33 PSI-1
8.33 PSI-2
8.33 PSI-3
8.33 PSI-4
8.33 PSI-5
8.33 PSI-6
8.33 PSI-7
8.33 PSI-8
8.33 PSI-9
8.33 PSI-10
11.67 PSI-1
11.67 PSI-2
15 PSI
16.67 PSI-1
16.67 PSI-2
21.67 PSI

Figure P: HDPE 36" South End Quadrant 3 Profile