Appendix C.2

Geomembrane Tensile Strength and Anchor Trench Calculations

Calc. FOS for Tensile Failure and Anchor Pull-out due to self-weight.
Based on methods presented in "Designing With Geosynthetics" 4 th edition
Robert M. Koerner, 1998 Prentice-Hall

SWC
SMITH WILLIAMS CONSULTANTS, INC.

Project: CC&V Phase 5 2.5 Slope w/ 300 slope length
Date: August 2007
By: J. F. Lupo
CHECKED: WITTNER 8/6/07

Input Parameters

Height of Slope (ft):	300	ft
Slope (Z:1):	2.5	
FML Thickness (mil):	80	mil
FML Yield Stress (psi):	2200	psi [redacted]
FML Specific Gravity:	0.935	
Soil Friction Angle	30	degrees
Liner-Soil Interface Friction Angle (degrees):	15	degrees
Anchor Trench Depth (ft):	3	ft
Anchor Trench Width (ft):	3	ft
Anchor Set-Back (ft)	3	ft
Soil Depth over Setback	2	ft
Soil Unit Weight (pcf):	110	pcf

TENSILE FAILURE OF LINER FROM SELF-WT CALC'S

FML Density =	[redacted]	pcf	
Slope Length =	[redacted]	ft	
Slope Angle =	[redacted]	degrees	
Liner Total Wt./ Unit ft. =	[redacted]	lbs/ft	
Max. Tensile Force From Self-Wt. =	[redacted]	lbs/ft	
Frictional Resistance =	[redacted]	lbs/ft	
Tensile Stress (neg. frictional resistance)	[redacted]	psi	
Tensile Stress (w/ frictional resistance)	[redacted]	psi	
FOS Tensile failure (MIN)	[redacted]	PASS	FOS must be greater than 10 to pass
FOS Tensile failure (MAX)	[redacted]	PASS	FOS must be greater than 10 to pass
Max. Heat/Cool Force:	[redacted]	lbs/ft	
Max. Tensile Stress Developed +	[redacted]	psi	
FOS Tensile Failure =	[redacted]	PASS	FOS must be greater than 5 to pass

LINER ANCHOR CALC'S

At Rest Coeff.	[redacted]	
Active Pressure Coeff.	[redacted]	
Passive Pressure Coeff.	[redacted]	
Allowable Liner Force	[redacted]	lbs/ft
Shear Force Above Membrane Due to Soil Cover	[redacted]	lbs/ft
Shear Force Below Liner Due to Soil Cover	[redacted]	lbs/ft
Shear Force Below Liner Due to Liner Pull-Down	[redacted]	lbs/ft
Active Pressure Anchor Backfill Side	[redacted]	lbs/ft
Passive Pressure Anchor InSitu Side	[redacted]	lbs/ft
Sum of Forces	[redacted]	lbs/ft
FOS Pull-out	[redacted]	PASS

Calc. FOS for Tensile Failure and Anchor Pull-out due to self-weight.
Based on methods presented in "Designing With Geosynthetics" 4 th edition
Robert M. Koerner, 1998 Prentice-Hall

SWC
SMITH WILLIAMS CONSULTANTS, INC.

Project: CC&V Phase 5 2.0 Slope w/ 300 slope length
Date: August 2007
By: J. F. Lupo
CHECKED: WITTWER 8/6/07

Input Parameters

Height of Slope (ft):	300 ft
Slope (Z:1):	2
FML Thickness (mil):	80 mil
FML Yield Stress (psi):	2200 psi [illegible] ppi
FML Specific Gravity:	0.935
Soil Friction Angle	30 degrees
Liner-Soil Interface Friction Angle (degrees):	15 degrees
Anchor Trench Depth (ft):	3 ft
Anchor Trench Width (ft):	3 ft
Anchor Set-Back (ft)	3 ft
Soil Depth over Setback	2 ft
Soil Unit Weight (pcf):	110 pcf

TENSILE FAILURE OF LINER FROM SELF-WT CALC'S

FML Density =	[illegible]	pcf	
Slope Length =	[illegible]	ft	
Slope Angle =	26.57	degrees	
Liner Total Wt./ Unit ft. =	260.92	lbs/ft	
Max. Tensile Force From Self-Wt. =	116.69	lbs/ft	
Frictional Resistance =	162.53	lbs/ft	
Tensile Stress (neg. frictional resistance)	[illegible]	psi	
Tensile Stress (w/ frictional resistance)	[illegible]	psi	
FOS Tensile failure (MIN)	[illegible]	PASS	FOS must be greater than 10 to pass
FOS Tensile failure (MAX)	[illegible]	PASS	FOS must be greater than 10 to pass
Max. Heat/Cool Force:	[illegible]	lbs/ft	
Max. Tensile Stress Developed +	[illegible]	psi	
FOS Tensile Failure =	[illegible]	PASS	FOS must be greater than 5 to pass

LINER ANCHOR CALC'S

At Rest Coeff.	[illegible]	
Active Pressure Coeff.	[illegible]	
Passive Pressure Coeff.	[illegible]	
Allowable Liner Force	[illegible]	lbs/ft
Shear Force Above Membrane Due to Soil Cover	[illegible]	lbs/ft
Shear Force Below Liner Due to Soil Cover	[illegible]	lbs/ft
Shear Force Below Liner Due to Liner Pull-Down	[illegible]	lbs/ft
Active Pressure Anchor Backfill Side	[illegible]	lbs/ft
Passive Pressure Anchor InSitu Side	[illegible]	lbs/ft
Sum of Forces	[illegible]	lbs/ft
FOS Pull-out	[illegible]	PASS

Appendix C.3.1

Phases I Through 5 Primary Solution Collection Pipe Burial Calculations

SWC

SMITH WILLIAMS CONSULTANTS, INC.

Project: CC&V Phase 5 VLF	**Job No. 1125**
Calculation Title: **Ore Loading Effects on solution collection piping**	
Prepared By: JFL	**Date: March 14, 2008**
Checked By: DTW	**Date: March 19, 2008**

OBJECTIVE:

Assess the effect of ore loading on solution collection piping deformation for the Phase 5 VLF extension, and existing pipes within the VLF (including underdrains).

METHOD:

The method for PE pipe deformation under high loads is based on the work presented in Lupo (2001).

Traditional methods for pipe design are based on stress theory, whereby the stress conditions within the pipe wall are evaluated based on assumed loading conditions. This design approach was initially developed for concrete and steel pipe and has been extended for PE pipe design. The stress theory method was developed assuming the pipe materials are very stiff compared to the pipe envelope material (the material surrounding the pipe). Under these conditions, the loads are carried entirely by the pipe, not by the pipe envelope.

Pipe design employing stress theory requires the pipe to be designed to account for the following performance criteria:

- Wall Crushing : Wall crushing occurs when the wall stress exceeds the long-term compressive strength of pipe material;

- Wall Buckling: Wall buckling occurs when the total soil pressure exceeds the pipe critical buckling pressure; and

- Ring Deflection: Ring deflection is defined as the ratio between the vertical change in diameter to the original pipe diameter. Typically, pipe deflection is calculated using the Modified Iowa method (USDA, 1990). The design limit for ring deflection is typically assumed to be approximately 5 percent. Krizek (1990) reports that this value was derived from the inspections of numerous pipe installations, where the average deflection before failure was determined to about 20 percent of the pipe diameter. Assuming a safety factor of 4, results in design ring deflection of 5 percent.

For design, the applied stress on the pipe is based on an assumed prism of ore above the pipe, so the vertical stress can be calculated as:

$$\sigma_v = \gamma_o * h$$

where:

γ_o = unit of ore, and
h = height of ore over the pipe.

This applied stress, plus any additional stresses, are applied as an external pressure to the pipe to assess wall crushing and pipe buckling. The pipe-ore interaction is not accounted for in these calculations.

The pipe ring deflection is typically evaluated using the Modified Iowa method. This method relates pipe deflection to the stiffness of the pipe and ore. In the modified Iowa method, the pipe and ore stiffness are addressed separately; the pipe-ore interaction is not accounted for in this method.

While the traditional approach can be used for PE pipe design, field and laboratory studies have shown that the traditional approach for pipe design may result in overly conservative designs. For leach facility design this can lead to limits on ore height over the pipe, or special pipe bedding/trenching design.

The reason the traditional design approach may be overly conservative is that PE pipes are significantly more flexible than steel or concrete pipes. Field and laboratory studies conducted by Watkins and Reeve (1979), Watkins (1987), Watkins (1990), Sargand et al (1993) and Reeve et al (1981) have shown that flexible pipe performance is strongly influenced by the pipe-envelope interaction. A schematic illustrating the pipe-envelope interaction with respect to pipe performance limits is shown in Figure 1.

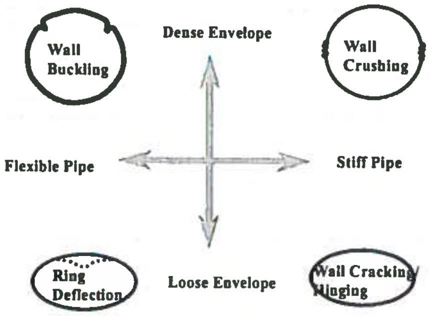


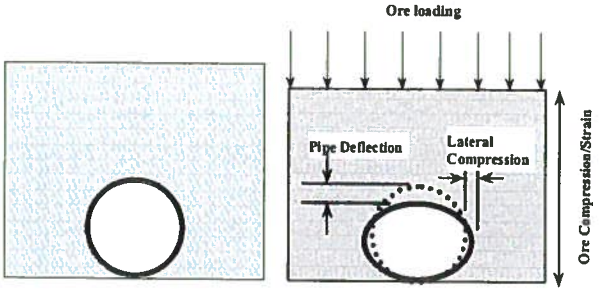
Figure 1. Schematic of Pipe Performance Limits (after Watkins and Reeve, 1979).

Field and laboratory performance tests have shown that the primary performance limit for PE pipes is ring deflection (Watkins and Reeve, 1979). Excessive ring deflection in PE pipes may lead to:

- Restricted flow within the pipe, and
- Excessive dimpling leading to pipe buckling.

Compared to stiff pipe (i.e. steel and concrete), flexible pipe, such as PE, interacts differently with the surrounding ore. PE pipe readily deforms under load, interacting closely with the ore. Furthermore, PE material is a viscoelastic material, which has the beneficial property of creeping or stress relaxation under load. This means that after the pipe is loaded, the stress in the wall of the pipe will decrease (relax) over time as the pipe deforms.

The flexibility of PE pipe can lead to the development of a stress arch within the ore. A stress arch transfers a portion of the vertical stress around the flexible pipe and into the adjacent ore. PE pipe deformation and stress arch development are illustrated in Figures 2 and 3, respectively.



Pre-Loading Condition

Post Loading Condition

Figure 2. Flexible Pipe Deformation

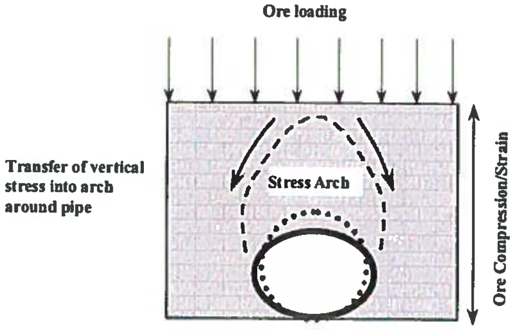


Figure 3. Stress Arch Development

Several laboratory and field test programs have been conducted to assess the actual performance of

PE pipes. The results of these test programs have been instrumental in the understanding of PE pipe performance. A summary of pipe test results is presented in Figure 4.

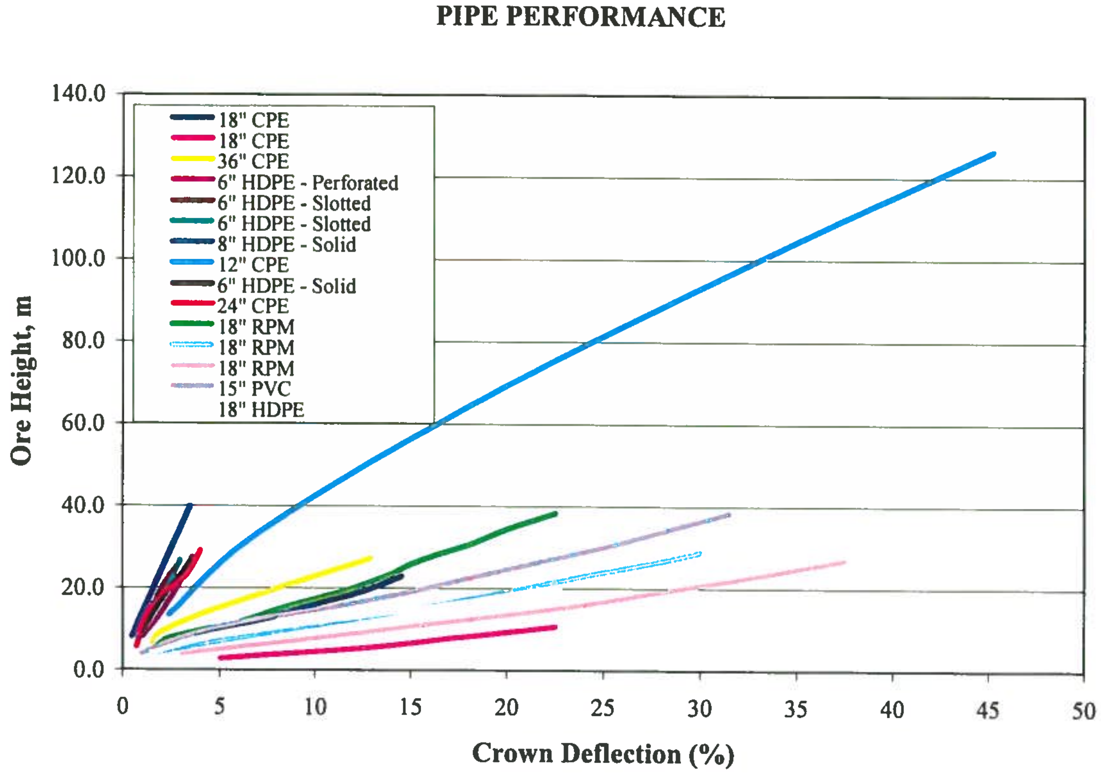


Figure 4. Pipe Test Data

When reviewing the test data presented in Figure 4, it is important to note that none of the PE pipes failed in these tests. All of the tests were terminated before failure of the pipes could be reached because of limitations to the test apparatus or fill height.

The results from these tests clearly show that PE pipes can remain stable and functional with ring deflections in excess of 20 percent. These results also agree well with observations from actual leach pads, as illustrated in Figure 5 which shows a functional solution collection pipe from a leach pad, with approximately 20 percent ring deflection.

Project: CC&V Phase 5 VLF	**Job No. 1125**
Calculation Title: **Ore Loading Effects on solution collection piping**	
Prepared By: JFL	**Date: March 14, 2008**
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Figure 5 Functioning Solution Collection Pipe w/ 20% Ring Deflection (Binocular Shape)

Watkins (1990) has shown that the pipe deflection is closely associated with the compression of the material surrounding the pipe (termed the pipe envelope). Therefore, the pipe design approach should account for the compression characteristics of the pipe envelope.

The recommended approach for flexible pipe design is based on the work of Burns & Richard (1964) and Höeg (1968), which present closed form plane-strain solutions for thin, circular, elastic conduits buried in an elastic soil. These equations include the interaction of the pipe with the surrounding material. To provide a more suitable solution for flexible pipe design, these equations have been modified to account for the following:

- Non-linear compression of ore during loading,
- Viscoelastic nature of the PE pipe material, and
- A more thorough accounting for the stress arch effect due rotation of principle stresses.

ASSUMPTIONS:

- The corrugated PE pipe characteristics are defined by those presented by Advanced Drainage Systems (ADS).
- Solid PE pipe characteristics are defined by Drisco-Pipe.
- The pipe envelope behavior is based on compression tests conducted on actual Cresson Project Drain Cover Fill (DCF). The compression curve is defined as that presented in

Figure 6. The parameters of the ore/DCF were based on test data, and have the following properties:

Property	**Value**
Unit Wt.	118 pcf
Elastic Modulus	Varies according to Fig. 6
Friction Angle	40 degrees

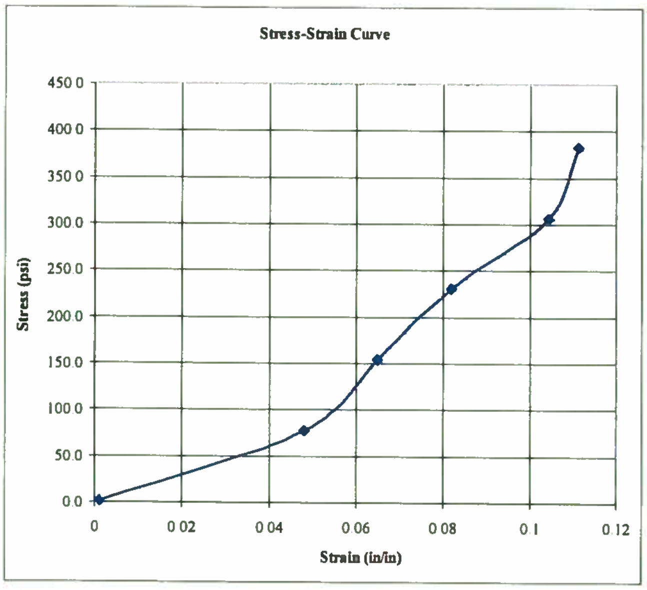

Figure 6. DCF Compression Curve

CALCULATIONS:

Pipe deformation calculations were conducted for the following scenarios, which cover the Primary, Secondary, LVSC, Leak Detection, and the Arequa Gulch Spring pipes under the maximum applicable ore depths.

Pipe Deformation Analyses

VLF Phase	**Pipe**	**Ore Depth (ft)**
5	Primary Pipe – 26" OD, DR 11 Solid HDPE Pipe	590
5	Secondary Pipe – 16" OD PCPE	590
5	Secondary Pipe – 12" OD PCPE	590
IV	Primary Pipe – 26" OD, DR 11 Solid HDPE Pipe	800
IV	Secondary Pipe – 18" OD PCPE	800
I,II	Primary Pipe – 15" OD PCPE	800
I,II,III	LVSC, Leak Detection Pipe – 4" OD PCPE	800
Arequa Gulch Spring Pipe	4" OD SDR 17 Solid HDPE	800

The results of the pipe deformation analyses are presented in Attachment A.

<u>CONCLUSIONS:</u>

The pipe deformation analyses indicate that the pipes, under the maximum ore load, will deform between 10 to 22 percent, as summarized below. It is noted that pipes undergoing deformations in the range of 20% should be sized for twice the flow capacity, as the pipe will likely take on a binocular shape (see Figure 5). In the case of VLF (all Phases I-IV and 5), all pipes were sized assuming a binocular shape, therefore the pipes will function as designed, even under 22% crown deflection.

SMITH WILLIAMS CONSULTANTS, INC.

Project: CC&V Phase 5 VLF	**Job No. 1125**
Calculation Title: **Ore Loading Effects on solution collection piping**	
Prepared By: JFL	**Date: March 14, 2008**
Checked By: DTW	**Date: March 19, 2008**

VLF Phase	Pipe	Crown Deflection	Acceptable (y/n)
5	Primary Pipe – 26" OD, DR 11 Solid HDPE Pipe	10-12%	Yes
5	Secondary Pipe – 16" OD PCPE	18%	Yes. Size pipe for twice the flow to accommodate deformation
5	Secondary Pipe – 12" OD PCPE	18%	Yes. Size pipe for twice the flow to accommodate deformation
IV	Primary Pipe – 26" OD, DR 11 Solid HDPE Pipe	12-15%	Yes
IV	Secondary Pipe – 18" OD PCPE	22%	Yes. In original design, these pipes were sized for twice the flow assuming a binocular pipe section.
I,II	Primary Pipe – 15" OD PCPE	22%	Yes. In original design, these pipes were sized for twice the flow assuming a binocular pipe section.
I,II,III	LVSC, Leak Detection Pipe – 4" OD PCPE	22%	Yes. In original design, these pipes were sized for twice the flow assuming a binocular pipe section.
Arequa Gulch Spring Pipe	4" OD SDR 17 Solid HDPE	16%	Yes

References

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SMITH WILLIAMS CONSULTANTS, INC.

Project: CC&V Phase 5 VLF	**Job No. 1125**
Calculation Title: **Ore Loading Effects on solution collection piping**	
Prepared By: JFL	**Date: March 14, 2008**
Checked By: DTW	**Date: March 19, 2008**

Attachment A
Pipe Deformation Analyses

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

(With Incremental Stress Analysis (non-linear))

SAC

Project: CCAV Phase 5 Primary Pipe 24" OD SDR 11 HDPE

By: [illegible]
Date: March 2008

Pipe Compression [illegible]

SOIL and PIPE Input Data

Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	Lateral Pressure Parameters B	 C
Pipe	n/a	n/a				
Pipe Envelope	0	40	5194	0.38	0.459	0.41

Pipe Diameter (in)	24		
Pipe ID (in)	20.99		
Weight of Pipe (lb/ft):	74.57	DR=	10.28
Pipe Corrugated (y/n)	n		45.00
Prescribed Constrained Modulus (y/n)	n		0.22
Prescribed Constrained Modulus (psi)	2000		
Pipe Wall Thickness (in)	2.534		
Pipe Area (in^2/in)	2.513		
Flexural Modulus (psi), E =	30,000		
Ring Compression Modulus (psi), E =	30,000		
C value (in)	1.300		
Moment of Inertia (in^4/in) non-corrugated	1.7515		
Moment of Inertia (in^4/in) corrugated (input from manufacturer data)	0.0660	selected I	1.7515
Stiffness Coefficients			
Flexural Stiffness	194.2		
Ring Compression Stiffness	6418.1		

Ring Stiffness Factor 11.4 Pipe Stiffness Less Than Envelope

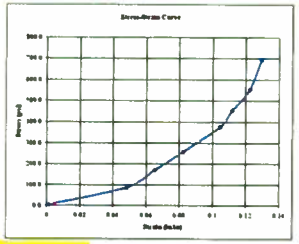
Shell-Medium Parameters		
UF	0.90	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	11.4	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in)	11.75	
Depth of Burial (ft)	900	
Applied Surface Stress (psi)	0	
Soil Density (pcf)	118	
Total Vertical Stress Component (psf)	69520	Free Field Stress Values
Total Vertical Stress Component (psi)	482.8	

Critical Stress For Buckling Failure (psi): 67310.4

Quality: 0.3

Corrected Stress (psi) 20193.1



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
255.0	0.0819	3114
375.0	0.1044	3592
450.0	0.1114	4039
580.0	0.121	4900.1
690.0	0.129	5349.0
		#DIV/0!
		#DIV/0!

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	483.7	495.1	0.0	-1.398	0.00E+00	6287.4	1972.0	2501.8	0.0834	0.1710	1955	-1813	4457	688
10	476.9	398.6	181.0	-1.373	4.73E-01	6171.6	1844.0	2456.7	0.0819	0.1678	1848	-1715	4304	741
20	457.5	379.4	193.6	-0.911	8.09E-01	5830.2	1596.0	2323.1	0.0774	0.1588	1543	-1431	3866	892
30	427.7	350.0	260.8	-0.399	1.20E+00	5317.4	1083.0	2119.8	0.0707	0.1449	1076	-996	3195	1124
40	393.3	353.9	296.5	0.330	1.34E+00	4700.8	583.0	1870.5	0.0623	0.1278	498	-462	2369	1408
50	352.4	275.4	296.5	1.041	1.34E+00	4034.0	-114.7	1609.3	0.0535	0.1097	-114	106	1495	1715
60	319.8	239.5	260.0	1.720	1.20E+00	3407.4	-495.0	1359.5	0.0453	0.0927	-489	439	867	1795
70	286.1	210.1	193.6	2.273	8.09E-01	2896.6	-1168.0	1152.6	0.0384	0.0788	-1150	1076	-3	2227
80	266.6	190.9	181.0	2.634	4.73E-01	2563.2	-1474.8	1019.9	0.0340	0.0697	-1464	1358	-444	2378
90	259.9	184.3	0.0	2.759	1.07E-16	2447.4	-1584.0	973.8	0.0325	0.0666	-1570	1457	-596	2430

Vertical Deflection (%):	10.61
Horizontal Deflection (%)	-11.90
Radial Soil Pressure at Crown (psi):	259.9
Circumferential Shortening (in)	0.75
Arc length of each sector (in) =	2.05

37423

Max. Compressive Stress (psi) 4457

Max. Tensile Stress (psi) -596

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	324.0	48.2	0.0	-1.780	0.00E+00	4544.0	2301.4	1809.2	0.0603	0.1236	2281	-2117	4091	-307
10	329.7	55.5	276.9	-1.635	8.79E-01	4534.0	2174.3	1804.9	0.0602	0.1234	2155	-2000	3960	-195
20	336.7	91.7	520.4	-1.287	1.65E+00	4904.8	1882.5	1792.5	0.0598	0.1225	1793	-1663	3585	129
30	348.9	167.6	701.1	-0.562	2.23E+00	4457.1	1267.0	1773.8	0.0591	0.1212	1237	-1147	3010	626
40	363.8	250.5	797.3	0.253	2.53E+00	4290.9	960.0	1750.3	0.0583	0.1196	555	-515	2305	1235
50	379.7	339.0	797.3	1.100	2.53E+00	4336.2	-172.0	1726.4	0.0575	0.1179	-170	158	1555	1884
60	394.7	432.0	701.1	1.911	2.23E+00	4277.7	-539.0	1702.1	0.0567	0.1163	-852	791	850	2493
70	406.9	489.8	520.4	2.848	1.65E+00	4229.9	-1420.9	1683.1	0.0561	0.1150	-1408	1306	275	2989
80	414.8	534.0	276.9	2.996	8.79E-01	4178.8	-1786.5	1670.7	0.0557	0.1143	-1771	1643	-100	3314
90	417.6	549.3	0.0	3.144	3.15E-16	4187.9	-1911.6	1666.4	0.0555	0.1139	-1997	1760	-330	3426

Vertical Deflection (%):	11.09
Horizontal Deflection (%)	-13.18
Radial Soil Pressure at Crown (psi):	417.6
Circumferential Shortening (in):	4.73
Arc length of each sector (in) =	2.05

40125

Max. Compressive Stress (psi) 4091

Max. Tensile Stress (psi) -307

Free Field Stress 483.5 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
11.75	417.6	259.9	549.3	184.3	326.0	483.7	40.2	405.2
12.25	393.1	280.7	490.3	181.3	344.3	456.7	184.6	414.4
12.75	375.7	290.7	442.3	179.0	376.2	433.3	190.8	423.1
13.25	363.7	314.3	403.1	177.3	363.4	413.8	203.9	428.6
13.75	355.6	328.0	370.8	176.1	367.2	394.8	229.5	434.2
14.25	350.6	340.1	344.0	175.2	368.3	378.8	270.3	438.9
14.75	347.8	350.8	321.6	174.6	367.6	364.6	296.1	443.8
15.25	346.7	360.3	303.8	174.2	365.5	351.9	318.8	446.6
15.75	346.9	368.8	287.0	173.9	362.9	340.6	336.7	449.7
16.25	348.1	376.5	273.6	173.9	358.8	330.3	352.7	452.5
16.75	349.9	383.4	262.1	173.7	354.9	321.8	366.5	454.9
17.25	352.2	389.6	252.3	173.7	350.0	312.6	378.5	457.1
17.75	355.0	395.3	243.9	173.8	345.3	305.0	388.9	459.0
18.25	357.9	400.4	236.6	173.9	340.5	298.0	398.8	460.7
18.75	361.1	405.2	230.3	174.1	335.7	291.6	405.9	462.2
19.25	364.3	409.5	224.9	174.2	330.9	285.8	413.8	463.6
19.75	367.6	413.4	220.1	174.4	326.2	280.6	419.3	464.9
20.25	370.9	417.1	216.0	174.6	321.6	275.4	424.6	466.0
20.75	374.2	420.4	212.3	174.8	317.0	270.8	429.5	467.0
21.25	377.6	423.6	209.1	175.0	312.7	266.5	433.9	468.0
21.75	380.6	426.4	206.3	175.2	308.4	262.6	437.8	468.9
22.25	383.7	429.1	203.8	175.4	304.3	258.9	441.3	469.6
22.75	386.7	431.6	201.6	175.6	300.3	255.5	444.4	470.4
23.25	389.7	433.9	199.6	175.8	296.5	252.3	447.3	471.0
23.75	392.5	436.1	197.9	176.0	292.8	249.3	449.8	471.7
Avg Values	368.4	379.7	417.3	178.3	336.7	325.3	187.6	436.6
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Positive Arch	Negative Arch	Negative Arch	Positive Arch	Positive Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

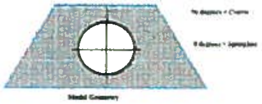
[With Incremental Stress Analysis (non-linear)]

SAC

Project: CCAV Phase 5 Secondary Pipes - 16" OD PCPE Pipes

By: Lupo
Date: March 2006

Note: [illegible]



Model Geometry

SOIL and PIPE Input Data

Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	Lateral Pressure Parameters B	C
Pipe	n/a	n/a				
Pipe Envelope	0	40	4134	0.39	1.489	0.21

Pipe Diameter (in)	17.87
Pipe ID (in)	14.98
Weight of Pipe (lb/ft)	4.62
Pipe Corrugated (y/n)	n
Prescribed Constrained Modulus (y/n)	n
Prescribed Constrained Modulus (psi)	2000
Pipe Wall Thickness (in)	1.375
Pipe Area (in^2/in)	0.219
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	0.450
Moment of Inertia (in^4/in) non-corrugated	0.2070
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0440

DR= 12.99

48.00

5.33

selected I [illegible]

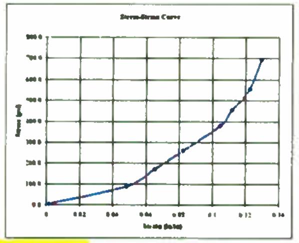
Stiffness Coefficients	
Flexural Stiffness	22.0
Ring Compression Stiffness	200.7

Ring Stiffness Factor 5.7 Pipe Stiffness Less Than Envelope

Shell-Medium Parameters		
VF	7.15	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	115.1	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in)	8.14
Depth of Burial (ft)	590
Applied Surface Stress (psf)	0
Soil Density (pcf)	118
Total Vertical Stress Component (psf)	69620
Total Vertical Stress Component (psi)	483.5

Free Field Stress Values



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
255.0	0.0819	3114
375.0	0.1044	3592
450.0	0.1116	4039
550.0	0.122	4508.2
690.0	0.129	5348.8
		#DIV/0!
		#DIV/0!

Critical Stress For Buckling Failure (psi): 3661.2

Ovality 6.3

Corrected Stress (psi) 1198.4

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	220.5	866.4	0.0	-0.254	0.00E+00	1935.9	199.1	8825.3	0.2943	0.4170	1350	-2549	10183	6276
10	213.6	826.7	61.0	-0.172	2.84E-01	1891.0	189.0	8620.4	0.2873	0.4081	1294	-2430	9914	6193
20	209.3	770.1	114.6	0.140	5.34E-01	1761.7	162.8	8030.9	0.2677	0.3882	1110	-2085	9141	5946
30	187.5	683.3	154.5	0.609	7.20E-01	1563.6	121.6	7127.8	0.2376	0.3374	829	-1557	7957	5571
40	160.7	576.8	175.4	1.173	8.19E-01	1320.6	71.0	6019.9	0.2007	0.2850	484	-909	6504	5111
50	132.1	463.5	175.6	1.773	8.19E-01	1061.9	17.1	4840.8	0.1614	0.2292	117	-219	4958	4621
60	105.3	357.0	154.5	2.337	7.20E-01	818.9	-33.5	3732.9	0.1244	0.1767	-228	429	3505	4162
70	83.5	270.2	114.6	2.797	5.34E-01	620.8	-74.8	2829.8	0.0943	0.1340	-510	957	2320	3787
80	69.2	213.6	61.0	3.090	2.84E-01	491.4	-101.7	2240.3	0.0747	0.1061	-693	1302	1547	3542
90	64.2	193.9	0.0	3.202	1.02E-16	446.5	-111.0	2035.5	0.0679	0.0964	-757	1432	1279	3457

Vertical Deflection (%):	10.22
Horizontal Deflection (%).	-3.10
Radial Soil Pressure at Crown (psi)	64.2
Circumferential Shortening (in:	10.39
Arc length of each sector (in) =	1.42

9251

Max. Compressive Stress (psi) 10183

Max. Tensile Stress (psi) No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	130.6	227.5	0.0	-0.439	0.00E+00	1312.3	215.9	5982.4	0.1962	0.3616	1470	-2760	6996	2767
10	139.1	345.2	302.9	-0.334	4.50E-01	1311.0	205.2	5975.6	0.1868	0.2616	1399	-2627	6920	2893
20	140.4	296.0	569.3	0.000	1.24E+00	1297.4	175.4	5913.9	0.1825	0.2606	1196	-2246	6700	3258
30	143.5	373.0	767.0	0.517	1.67E+00	1281.8	129.0	5842.4	0.1826	0.2594	885	-1662	6363	3817
40	149.0	469.3	873.3	1.141	1.90E+00	1194.9	73.8	5447.0	0.1816	0.2579	503	-945	5990	4503
50	147.7	571.0	872.2	1.805	1.90E+00	1187.6	14.3	5413.7	0.1805	0.2563	97	-183	5511	5231
60	150.3	666.5	767.0	2.439	1.67E+00	1180.7	-41.7	5382.3	0.1794	0.2548	-284	534	5098	5916
70	152.3	744.3	569.3	2.938	1.24E+00	1179.1	-87.3	5374.8	0.1796	0.2534	-595	1118	4781	6475
80	153.7	795.1	302.9	3.270	4.50E-01	1173.4	-117.1	5348.1	0.1780	0.2528	-798	1499	4542	6839
90	154.3	812.0	0.0	3.389	3.36E-16	1170.3	-127.5	5334.3	0.1778	0.2525	-869	1632	4465	6966

Vertical Deflection (%):	19.24
Horizontal Deflection (%)	-5.39
Radial Soil Pressure at Crown (psi)	154.3
Circumferential Shortening (in:	10.28
Arc length of each sector (in) =	1.41

22199

Max. Compressive Stress (psi) 6996

Max. Tensile Stress (psi) No Tensile Stress

Free Field Stress 481.5 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
8.14	154.2	64.2	818.0	193.9	138.6	229.9	227.9	866.4
8.64	167.8	93.8	697.8	310.2	187.8	161.0	300.5	788.0
9.14	149.6	122.1	609.8	280.3	220.5	248.0	351.1	742.4
9.64	158.1	148.6	541.4	256.8	247.0	251.5	391.6	704.3
10.14	169.8	173.0	487.3	238.4	259.9	252.7	430.0	677.0
10.64	183.3	195.6	444.1	232.1	266.4	252.4	441.2	653.1
11.14	197.5	215.9	409.0	231.7	269.5	251.2	457.0	633.6
11.64	211.9	234.5	380.3	233.3	272.0	249.3	469.0	616.9
12.14	225.9	251.9	356.5	231.5	272.7	247.1	478.0	603.0
12.64	239.4	266.9	336.7	230.3	272.1	244.7	484.8	591.3
13.14	252.4	281.0	320.0	228.9	270.7	242.1	490.0	581.1
13.64	264.7	293.8	305.7	227.3	268.8	239.6	493.9	572.3
14.14	276.3	305.6	293.6	225.7	266.4	237.1	496.8	564.7
14.64	287.1	316.3	283.1	224.0	263.9	234.7	498.9	558.0
15.14	297.3	326.1	274.1	222.4	261.2	232.4	500.5	552.2
15.64	306.8	335.2	266.1	220.8	258.5	230.1	501.6	547.0
16.14	315.8	343.5	259.2	219.2	255.7	228.0	502.4	542.4
16.64	324.1	351.1	253.1	217.7	253.0	226.0	502.8	538.3
17.14	331.9	358.3	247.7	216.2	250.4	224.1	503.1	534.6
17.64	339.2	364.7	242.9	214.9	247.8	222.2	503.3	531.2
18.14	346.0	370.8	238.6	213.5	245.3	220.5	503.1	528.2
18.64	352.4	376.4	234.8	212.3	242.9	218.9	503.0	525.5
19.14	358.3	381.6	231.3	211.1	240.6	217.4	502.8	523.0
19.64	363.9	386.4	228.2	210.0	238.4	215.9	502.5	520.8
20.14	369.2	391.0	225.4	208.9	236.3	214.5	502.1	518.7
Avg Values	264.9	277.9	371.8	230.9	247.8	234.8	378.1	730.9
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

[With Incremental Stress Analysis (non-linear)]

SAC

Project: CC&V Phase 5 Secondary Pipes - 12" OD PCPK Pipes

By: Lopo

Date: March 2008

Note: [illegible]

SOIL and PIPE Input Data

					Lateral Pressure Parameters	
Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
Pipe	N/A	N/A				
Pipe Envelope	0	40	4194	0.38	0.689	0.31

Pipe Diameter (in)	14.45
Pipe ID (in)	12.19
Weight of Pipe (lb/ft):	3.19
Pipe Corrugated (y/n)	y
Prescribed Constrained Modulus (y/n)	n
Prescribed Constrained Modulus (psi):	2000
Pipe Wall Thickness (in)	1.13
Pipe Area (in^2/in):	0.113
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	0.350
Moment of Inertia (in^4/in) non-corrugated:	0.2509
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0410

DR = 12.79

45.00

6.12

selected I: 0.0410

Stiffness Coefficients	
Flexural Stiffness	28.1
Ring Compression Stiffness	834.6

Ring Stiffness Factor 4.2 Pipe Stiffness Less Than Envelope

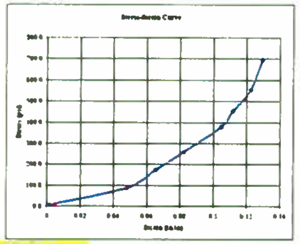
Shell-Medium Parameters		
UF	6.93	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	182.9	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in):	6.66	
Depth of Burial (ft)	590	
Applied Surface Stress (psf)	0	
Soil Density (pcf)	118	
Total Vertical Stress Component (psf)	69639	Free Field Stress Values
Total Vertical Stress Component (psi)	483.5	

Critical Stress For Buckling Failure (psi): 2783.1

Ovality: 0.3

Corrected Stress (psi): 834.9



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
255.0	0.0819	3114
375.0	0.1044	3592
450.0	0.1114	4039
560.0	0.122	4590.2
690.0	0.129	5348.8
		#DIV/0!
		#DIV/0!

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	231.9	838.9	0.0	-0.215	0.00E+00	1612.6	150.5	8719.2	0.2906	0.3373	1285	-2937	10004	5783
10	226.9	819.5	61.0	-0.130	2.33E-01	1575.3	143.9	8517.7	0.2839	0.3295	1225	-2799	9742	5718
20	212.6	763.6	116.1	0.114	4.38E-01	1468.0	125.1	7937.3	0.2646	0.3071	1051	-2401	8988	5536
30	190.7	678.0	156.6	0.488	5.90E-01	1303.5	91.8	7048.0	0.2349	0.2727	784	-1793	7832	5256
40	163.8	572.9	177.9	0.960	6.71E-01	1101.8	53.5	5957.2	0.1986	0.2305	457	-1045	6414	4913
50	135.2	461.1	177.9	1.436	6.71E-01	887.1	13.0	4796.4	0.1599	0.1856	109	-249	4905	4547
60	108.6	356.0	156.6	1.895	5.90E-01	685.3	-25.9	3705.6	0.1235	0.1434	-218	498	3487	4204
70	86.5	270.4	116.1	2.270	4.38E-01	520.9	-54.0	2816.3	0.0939	0.1090	-485	1109	2332	3926
80	72.2	214.5	61.0	2.516	2.33E-01	413.9	-77.2	2237.9	0.0746	0.0865	-659	1506	1577	3741
90	67.2	193.1	0.0	2.599	0.36E-17	376.1	-84.2	2034.3	0.0678	0.0787	-719	1646	1315	3678

Vertical Deflection (%):	17.98
Horizontal Deflection (%)	-3.23
Radial Soil Pressure at Crown (psi)	67.2
Circumferential Shortening (in):	0.33
Arc length of each sector (in) =	1.16

9676

Max. Compressive Stress (psi) 10004

Max. Tensile Stress (psi) No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	140.7	328.4	0.0	-0.366	0.00E+00	1014.0	163.1	5482.9	0.1827	0.2121	1393	-3183	6875	2299
10	141.3	343.0	302.2	-0.273	9.37E-01	1013.0	155.3	5476.1	0.1825	0.2119	1326	-3030	6802	2446
20	142.8	353.6	568.0	-0.081	1.01E+00	1009.4	132.7	5457.7	0.1819	0.2111	1133	-2590	6591	2868
30	145.1	371.3	765.2	0.413	1.34E+00	1004.2	98.1	5429.6	0.1810	0.2101	838	-1915	6267	3515
40	148.0	466.4	870.2	0.921	1.55E+00	997.8	55.7	5395.1	0.1798	0.2087	476	-1087	5871	4308
50	151.1	567.6	870.2	1.443	1.55E+00	991.0	10.6	5358.4	0.1786	0.2073	90	-206	5449	5152
60	153.9	661.0	765.2	1.971	1.34E+00	984.7	-31.8	5323.9	0.1775	0.2060	-272	621	5051	5945
70	156.3	760.4	568.0	2.389	1.01E+00	979.5	-66.4	5296.2	0.1765	0.2049	-567	1296	4729	6592
80	157.8	791.0	302.2	2.656	9.37E-01	976.1	-89.0	5277.5	0.1759	0.2041	-760	1736	4518	7014
90	158.4	808.6	0.0	2.790	1.73E-16	974.9	-96.8	5271.1	0.1757	0.2039	-827	1889	4445	7160

Vertical Deflection (%):	19.03
Horizontal Deflection (%)	-5.50
Radial Soil Pressure at Crown (psi):	158.4
Circumferential Shortening (in):	0.32
Arc length of each sector (in) =	1.16

22883

Max. Compressive Stress (psi) 7160

Max. Tensile Stress (psi) No Tensile Stress

Free Field Stress 483.5 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
6.65	193.4	67.2	808.6	199.1	148.7	231.9	225.4	838.9
7.15	190.7	103.3	672.6	213.5	198.0	245.1	311.8	770.9
7.65	154.2	137.1	574.2	223.8	232.6	251.7	370.0	720.4
8.15	168.7	168.1	501.2	229.3	253.2	253.0	410.0	681.9
8.65	184.5	195.9	446.8	231.7	264.8	253.4	437.7	652.1
9.15	201.6	220.8	403.6	232.2	270.8	251.6	457.3	628.4
9.65	218.9	243.0	369.9	231.6	273.1	249.1	471.1	609.5
10.15	235.7	262.7	343.3	230.3	273.1	246.1	480.9	594.0
10.65	251.6	280.3	321.9	228.6	271.6	242.9	487.9	581.3
11.15	266.6	296.0	304.3	226.7	269.3	239.8	492.9	570.6
11.65	280.5	310.1	289.8	224.7	266.3	236.7	496.4	561.6
12.15	293.4	322.7	277.7	222.7	263.1	233.7	498.9	553.9
12.65	305.3	334.1	267.6	220.7	259.7	230.9	500.9	547.4
13.15	316.3	344.3	258.9	218.8	256.3	228.2	501.6	541.7
13.65	326.3	353.6	251.4	217.0	253.0	225.7	502.2	536.8
14.15	335.6	362.0	245.2	215.3	249.7	223.4	502.5	532.6
14.65	344.2	369.6	239.7	213.6	246.6	221.3	502.6	528.6
15.15	352.1	376.6	234.9	212.1	243.6	219.2	502.5	525.3
15.65	359.4	382.9	230.6	210.6	240.8	217.3	502.2	522.2
16.15	366.1	388.7	226.9	209.3	238.1	215.5	501.9	519.6
16.65	372.4	394.0	223.6	208.0	235.5	213.9	501.5	517.2
17.15	378.3	398.9	220.7	206.8	233.1	212.3	501.1	515.0
17.65	383.8	403.5	218.0	205.7	230.9	210.9	500.7	513.0
18.15	388.8	407.6	215.7	204.6	228.7	209.6	500.3	511.2
18.65	393.1	411.5	213.6	203.6	226.7	208.3	499.7	509.6
Avg Values:	287.5	301.4	329.6	221.4	246.8	230.9	463.3	708.1
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

(With Incremental Stress Analysis (non-linear))

Project: CCAV Phase IV Primary Pipe 24" OD SDR 11

By: Lopa
Date: March 2008

SOIL and PIPE Input Data

Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
					Lateral Pressure Parameters	
Pipe	n/a	n/a				
Pipe Envelope	0	40	5452	0.38	0.489	0.31

Pipe Diameter (in)	24
Pipe ID (in)	19.99
Weight of Pipe (lb/ft):	56.37
Pipe Corrugated (y/n)	n
Prescribed Constrained Modulus (y/n)	n
Prescribed Constrained Modulus (psi):	2000
Pipe Wall Thickness (in)	2.504
Pipe Area (in^2/in)	2.512
Flexural Modulus (psi), E =	80,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	1.000
Moment of Inertia (in^4/in) non-corrugated.	1.7716
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0410

D/t = 10.80

48.00

0.22

selected I: 1.7716

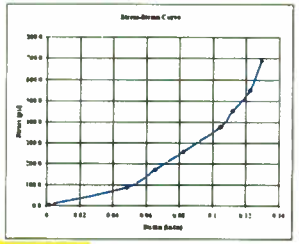
Stiffness Coefficients	
Flexural Stiffness	394.6
Ring Compression Stiffness	6410.1

Ring Stiffness Factor 32.4 Pipe Stiffness Less Than Envelope

Multi-Modulus Parameters		
UF	1.10	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	20.4	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then = perfectly rigid embedded pipe

Pipe Mean Radius (in)	10.75
Depth of Burial (ft)	900
Applied Surface Stress (psf)	0
Soil Density (pcf)	110
Total Vertical Stress Component (psf)	96400
Total Vertical Stress Component (psi)	673.6

Free Field Stress Values



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
255.0	0.0819	3114
375.0	0.1044	3592
450.0	0.1114	4039
590.0	0.122	4908.2
690.0	0.129	5349.0
		#DIV/0!
		#DIV/0!

Critical Stress For Buckling Failure (psi): 67316.6

Ovality: 0.3

Corrected Stress (psi): 30193.1

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psf)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	648.8	583.3	0.0	-1.574	0.00E+00	8244.4	2359.2	3280.5	0.1094	0.2243	2339	-2169	5619	1111
10	631.4	573.4	157.8	-1.438	8.49E-01	8090.9	2232.2	3219.5	0.1073	0.2200	2213	-2053	5433	1167
20	604.4	544.8	298.9	-0.998	1.03E+00	7648.9	1866.5	3043.6	0.1015	0.2080	1850	-1716	4894	1327
30	563.8	501.8	348.8	-0.343	1.39E+00	6971.8	1310.2	2770.2	0.0923	0.1893	1299	-1201	4069	1569
40	512.3	447.2	396.7	0.448	1.58E+00	6143.2	618.9	2443.7	0.0815	0.1670	613	-569	3057	1875
50	458.1	390.0	396.7	1.316	1.58E+00	5257.3	-112.5	2091.9	0.0697	0.1430	-113	103	1980	2195
60	407.4	336.3	348.8	2.119	1.39E+00	4426.7	-799.8	1761.4	0.0587	0.1204	-793	736	969	2497
70	366.0	293.5	298.9	2.776	1.03E+00	3749.5	-1360.1	1492.0	0.0497	0.1020	-1348	1251	144	2743
80	338.9	263.9	157.8	3.203	8.49E-01	3307.6	-1735.8	1316.1	0.0439	0.0899	-1721	1587	-405	2903
90	329.5	253.9	0.0	3.350	1.96E-16	3154.1	-1852.9	1255.1	0.0418	0.0858	-1837	1704	-582	2959

Vertical Deflection (%):	12.89
Horizontal Deflection (%)	-13.40
Radial Soil Pressure at Crown (psf)	329.5
Circumferential Shortening (in)	6.20
Arc length of each sector (in) =	2.09

47455

Max. Compressive Stress (psi) 5619

Max. Tensile Stress (psi) -582

FULL SLIPPAGE

Angle	Soil Stresses (psf)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	431.8	65.4	0.0	-2.034	0.00E+00	5911.3	2744.3	2353.3	0.0784	0.1608	2720	-2524	5073	-171
10	434.3	86.7	380.9	-1.849	1.03E+00	5898.5	2594.1	2347.1	0.0782	0.1604	2571	-2385	4918	-38
20	443.7	140.1	715.9	-1.343	1.94E+00	5861.7	2161.5	2332.4	0.0777	0.1594	2143	-1988	4475	345
30	458.1	242.0	964.5	-0.568	2.62E+00	5805.3	1498.8	2310.0	0.0770	0.1579	1486	-1378	3796	931
40	478.0	357.3	1096.8	0.382	2.97E+00	5736.0	685.8	2282.4	0.0761	0.1560	680	-631	2962	1651
50	494.6	479.9	1096.8	1.394	2.97E+00	5662.6	-179.4	2253.1	0.0751	0.1540	-178	165	2075	2418
60	512.3	595.2	964.5	2.344	2.62E+00	5593.1	-992.6	2225.6	0.0742	0.1521	-984	913	1242	3138
70	526.7	689.2	715.9	3.119	1.94E+00	5536.0	-1659.2	2203.2	0.0734	0.1506	-1641	1522	562	3725
80	536.1	750.5	380.9	3.625	1.03E+00	5498.9	-2087.7	2188.5	0.0729	0.1496	-2069	1920	119	4108
90	539.3	771.8	0.0	3.800	3.70E-16	5487.2	-2238.8	2183.4	0.0728	0.1493	-2218	2058	-35	4241

Vertical Deflection (%):	14.63
Horizontal Deflection (%)	-17.23
Radial Soil Pressure at Crown (psf)	539.3
Circumferential Shortening (in)	6.20
Arc length of each sector (in) =	2.09

77662

Max. Compressive Stress (psi) 5073

Max. Tensile Stress (psi) -171

Free Field Stress 659.6 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
11.75	530.3	329.5	771.8	353.9	431.0	640.0	69.4	983.3
12.25	507.6	373.5	688.9	350.6	457.6	606.9	153.6	991.9
12.75	489.6	383.7	621.6	348.1	474.7	576.6	225.7	999.2
13.25	470.6	405.7	566.4	346.2	485.5	550.4	285.1	605.3
13.75	461.0	429.3	520.0	344.7	491.6	527.1	334.4	610.5
14.25	455.3	442.4	483.0	343.6	493.7	506.6	375.6	614.9
14.75	452.7	457.7	451.3	342.8	493.3	488.3	410.3	618.7
15.25	452.2	471.4	424.7	342.2	491.1	471.8	439.6	622.1
15.75	453.4	483.8	402.1	341.8	487.6	457.1	464.6	625.0
16.25	455.9	494.9	383.0	341.5	482.7	443.7	486.0	627.5
16.75	459.3	504.9	366.7	341.3	477.3	431.6	504.4	629.7
17.25	463.2	514.0	352.4	341.2	471.9	420.6	520.3	631.7
17.75	467.6	522.3	340.3	341.1	465.6	410.6	534.1	633.5
18.25	472.3	529.9	330.1	341.1	459.1	401.5	546.3	635.1
18.75	477.1	536.9	321.0	341.2	452.8	393.1	556.6	636.5
19.25	482.1	543.3	313.1	341.2	446.5	385.3	565.9	637.8
19.75	487.1	549.1	306.2	341.3	440.2	378.1	574.0	638.9
20.25	492.1	554.5	300.1	341.4	434.1	371.7	581.3	639.9
20.75	497.0	559.5	294.8	341.6	428.1	365.6	587.7	640.9
21.25	501.8	564.2	290.1	341.7	422.3	359.9	593.4	641.7
21.75	506.6	568.5	285.9	341.8	416.6	354.7	598.4	642.5
22.25	511.3	572.5	282.2	342.0	411.2	349.8	603.0	643.2
22.75	515.7	576.2	279.0	342.1	405.9	345.3	607.1	643.9
23.25	520.0	579.7	276.0	342.3	400.8	341.0	610.8	644.5
23.75	524.2	583.0	273.4	342.6	395.9	337.1	614.1	645.1
Avg. Values	484.4	500.5	386.3	347.1	452.6	436.4	464.3	683.4
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Positive Arch	Negative Arch	Negative Arch	Positive Arch	Positive Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

[With Incremental Stress Analysis [illegible]]

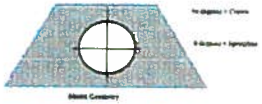
SAC

Project: CCAV Phase IV Secondary Pipe 18" OD PCPE

By: [illegible]

Date: March 2008

Note: [illegible]



SOIL and PIPE Input Data

				Lateral Pressure Parameters		
Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
Pipe	n/a	n/a				
Pipe Envelope	0	40	5142	0.38	0.499	0.31

Pipe Diameter (in)	21.2
Pipe ID (in):	18.07
Weight of Pipe (lb/ft):	6.43
Pipe Corrugated (y/n):	y
Prescribed Constrained Modulus (y/n):	n
Prescribed Constrained Modulus (psi):	2000
Pipe Wall Thickness (in):	1.563
Pipe Area (in^2/in):	1.563
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	0.500
Moment of Inertia (in^4/in) non-corrugated:	0.3984
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0090

DR = 13.99

65.06

0.25

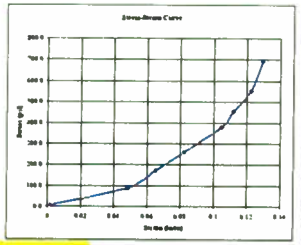
selected I 0.0090

Stiffness Coefficients	
Flexural Stiffness	14.9
Ring Compression Stiffness	771.6

Ring Stiffness Factor = 2.0 Pipe Stiffness Less Than Envelope

Shell-Medium Parameters		
UF	0.19	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	180.7	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in):	9.82	
Depth of Burial (ft)	300	
Applied Surface Stress (psf)	0	
Soil Density (pcf)	110	
Total Vertical Stress Component (psf)	94600	Free Field Stress Values
Total Vertical Stress Component (psi)	655.6	



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
255.0	0.0819	3114
375.0	0.1044	3592
450.0	0.1114	4039
550.0	0.122	4508.2
690.0	0.129	5349.5
		#DIV/0!
		#DIV/0!

Critical Stress For Buckling Failure (psi) 4452.2

Ovality: 0.3

Corrected Stress (psi) 1227.7

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	275.3	1211.1	0.0	-0.273	0.00E+00	2736.0	265.3	10833.0	0.3611	0.6382	1690	-3174	12523	7659
10	269.1	1192.3	79.0	-0.179	3.89E-01	2719.0	252.9	10770.9	0.3590	0.6193	1421	-3006	12192	7765
20	251.1	1099.0	141.0	0.303	7.31E-01	2529.3	217.3	10016.3	0.3320	0.5721	1221	-2601	11237	7416
30	225.7	971.4	189.9	0.990	9.89E-01	2237.6	162.9	8860.3	0.2953	0.5061	915	-1950	9776	6911
40	189.9	815.0	216.0	1.761	1.12E+00	1879.3	94.2	7442.1	0.2481	0.4251	540	-1151	7982	6291
50	154.1	648.5	216.0	2.616	1.12E+00	1498.2	25.1	5933.0	0.1978	0.3309	141	-300	6074	5633
60	120.4	492.1	189.9	3.419	9.89E-01	1149.1	-41.7	4516.0	0.1505	0.2579	-234	497	4281	5013
70	91.9	366.6	141.0	4.074	7.31E-01	848.1	-96.1	3359.0	0.1120	0.1918	-540	1150	2819	4509
80	75.0	281.3	79.0	4.502	3.89E-01	657.6	-131.4	2604.2	0.0868	0.1407	-739	1575	1865	4179
90	68.7	252.4	0.0	4.650	1.39E-16	591.4	-144.0	2342.1	0.0781	0.1330	-809	1723	1533	4065

Vertical Deflection (%):	11.93
Horizontal Deflection (%)	-1.78
Radial Soil Pressure at Crown (psi)	68.7
Circumferential Shortening (in:	15.28
Arc length of each sector (in) =	1.71

9090

Max. Compressive Stress (psi) 12523

Max. Tensile Stress (psi) No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	165.0	511.6	0.0	-0.509	0.00E+00	1711.6	284.0	6778.0	0.2259	0.3871	1600	-3408	8378	3370
10	165.5	595.6	413.2	-0.346	9.27E-01	1710.2	271.3	6772.5	0.2258	0.3868	1524	-3244	8296	3527
20	166.7	625.1	776.5	0.112	1.74E+00	1706.3	232.3	6756.8	0.2252	0.3859	1305	-2780	8062	3977
30	168.5	531.6	1066.2	0.860	2.35E+00	1700.1	172.7	6732.8	0.2244	0.3845	970	-2067	7703	4666
40	170.8	643.3	1189.7	1.729	2.67E+00	1692.7	99.5	6703.2	0.2234	0.3829	560	-1191	7263	5512
50	173.2	781.3	1189.7	2.687	2.67E+00	1684.8	21.7	6671.8	0.2224	0.3811	122	-260	6794	6412
60	175.5	931.9	1066.2	3.537	2.35E+00	1677.3	-51.5	6642.3	0.2214	0.3794	-289	616	6353	7258
70	177.4	1038.3	776.5	4.253	1.74E+00	1671.2	-111.1	6618.3	0.2206	0.3780	-624	1329	5994	7947
80	178.4	1100.6	413.2	4.723	9.27E-01	1667.3	-150.0	6602.6	0.2201	0.3771	-843	1795	5760	8398
90	179.0	1132.1	0.0	4.806	1.32E-16	1665.9	-162.8	6597.1	0.2199	0.3768	-919	1957	5678	8554

Vertical Deflection (%):	23.05
Horizontal Deflection (%)	-5.18
Radial Soil Pressure at Crown (psi)	179.0
Circumferential Shortening (in:	15.28
Arc length of each sector (in) =	1.71

25774

Max. Compressive Stress (psi) 8554

Max. Tensile Stress (psi) No Tensile Stress

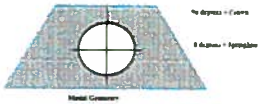
Free Field Stress: 695.6 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
9.82	179.0	48.7	1132.1	252.4	164.0	275.3	331.6	1231.1
10.32	173.3	100.6	996.8	275.0	224.6	296.1	413.0	1129.0
10.82	179.3	133.3	898.5	291.7	267.4	310.6	476.3	1073.1
11.32	184.6	163.6	808.9	302.7	298.1	319.9	524.1	1022.3
11.82	197.5	191.6	729.1	310.1	320.8	325.9	561.0	980.0
12.32	212.9	218.9	669.8	314.8	335.3	329.3	589.6	944.6
12.82	229.5	244.6	620.3	317.9	345.9	331.0	611.9	914.6
13.32	246.7	268.2	578.7	318.9	352.9	331.3	629.3	889.1
13.82	264.0	290.4	543.6	319.3	357.2	330.8	642.9	867.1
14.32	281.0	311.0	513.3	318.9	359.6	329.6	653.6	848.1
14.82	297.6	330.1	487.6	318.0	360.5	328.0	662.0	831.9
15.32	313.6	347.8	465.1	316.7	360.3	326.1	668.6	817.1
15.82	328.9	364.2	445.7	315.1	359.2	323.9	673.7	804.3
16.32	343.5	379.5	428.7	313.4	357.6	321.7	677.7	793.0
16.82	357.5	393.6	413.7	311.6	355.6	319.4	680.8	783.0
17.32	370.7	406.8	400.6	309.7	353.2	317.0	683.1	774.0
17.82	383.2	419.1	388.9	307.8	350.7	314.7	684.9	765.9
18.32	395.0	430.5	378.5	305.9	348.0	312.4	686.1	758.7
18.82	406.2	441.2	369.2	304.0	345.2	310.2	687.0	752.2
19.32	416.8	451.2	360.8	302.1	342.5	308.0	687.5	746.2
19.82	426.7	460.5	353.3	300.3	339.7	305.9	687.9	740.8
20.32	436.2	469.2	346.5	298.5	336.9	303.9	688.0	735.9
20.82	445.1	477.4	340.3	296.8	334.2	301.9	687.9	731.4
21.32	453.5	485.0	334.8	295.2	331.5	300.0	687.7	727.3
21.82	461.5	492.2	329.7	293.6	328.9	298.2	687.5	723.5
Avg Values:	319.1	333.5	813.9	295.0	329.2	314.9	581.2	1040.1
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

(With Incremental Stress Analysis (non-linear))

SAC



Model Geometry

Project: CCAV Phase 1B Primary Pipe 18" OD PCPE

By: Lago

Date: March 2008

Note: Compression is positive, tension is negative

SOIL and PIPE Input Data

Lateral Pressure Parameters

Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
Pipe	n/a	n/a				
Pipe Envelope	0	40	3143	0.30	0.699	0.31

Pipe Diameter (in)	17.87
Pipe ID (in).	16.98
Weight of Pipe (lb/ft):	4.63
Pipe Corrugated (y/n)	n
Prescribed Constrained Modulus (y/n):	n
Prescribed Constrained Modulus (psi):	2000
Pipe Wall Thickness (in)	1.295
Pipe Area (in^2/in):	0.119
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	0.450
Moment of Inertia (in^4/in) non-corrugated:	0.1778
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0440

DR = 13.97

62.00

0.22

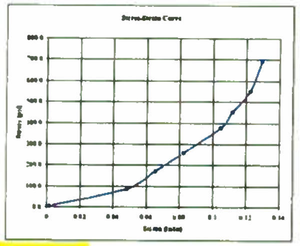
selected I: 0.0440

Stiffness Coefficients	
Flexural Stiffness	22.0
Ring Compression Stiffness	888.7

Ring Stiffness Factor 3.7 Pipe Stiffness Less Than Envelope

Soil-Medium Parameters		
UF	0.77	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	144.9	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential load
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in):	8.34	
Depth of Burial (ft):	800	
Applied Surface Stress (psf):	0	
Soil Density (pcf):	110	
Total Vertical Stress Component (psf):	88000	Free Field Stress Values
Total Vertical Stress Component (psi):	615.4	



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.063	2615
255.0	0.0819	3114
375.0	0.1044	3592
450.0	0.1114	4039
550.0	0.122	4508.2
690.0	0.129	5349.0
		#DIV/0!
		#DIV/0!

Critical Stress For Buckling Failure (psi): 3661.2

Quality: 0.3

Corrected Stress (psi): 1098.4

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	281.6	1194.5	0.0	-0.237	0.00E+00	2381.1	235.6	10856.7	0.3618	0.5139	1605	-3014	12460	7840
10	278.4	1148.1	76.6	-0.119	3.24E-01	2316.9	224.5	10599.1	0.3531	0.5017	1530	-2874	12129	7724
20	257.4	1086.4	143.9	0.237	6.09E-01	2162.8	192.9	9859.6	0.3286	0.4668	1315	-2469	11174	7390
30	229.8	981.3	191.9	0.776	8.20E-01	1916.5	144.9	8727.6	0.2909	0.4133	985	-1850	9713	6878
40	195.9	887.6	220.5	1.430	9.33E-01	1610.0	85.1	7339.3	0.2444	0.3475	580	-1090	7920	6249
50	159.9	644.1	220.5	2.143	9.33E-01	1285.9	21.9	5861.8	0.1954	0.2775	190	-281	6051	5581
60	126.1	498.5	191.9	2.884	8.20E-01	981.3	-37.4	4473.5	0.1491	0.2118	-255	479	4218	4953
70	98.5	365.3	143.9	3.366	6.09E-01	733.1	-85.0	3341.7	0.1114	0.1582	-585	1099	2757	4440
80	80.5	283.6	76.6	3.696	3.24E-01	571.0	-117.4	2603.0	0.0868	0.1232	-800	1503	1803	4106
90	74.8	255.3	0.0	3.818	1.16E-16	516.7	-128.4	2346.5	0.0782	0.1111	-875	1644	1471	3990

Vertical Deflection (%):	31.73
Horizontal Deflection (%):	-1.93
Radial Soil Pressure at Crown (psi):	74.8
Circumferential Shortening (in):	11.50
Arc length of each sector (in) =	1.42

10651

Max. Compressive Stress (psi) 12460

Max. Tensile Stress (psi) No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	168.9	327.6	0.0	-0.636	0.00E+00	1472.5	253.3	6712.4	0.2237	0.3178	1726	-3243	8439	3471
10	169.4	351.6	411.5	-0.301	7.66E-01	1471.0	241.3	6704.7	0.2235	0.3175	1644	-3088	8350	3618
20	171.0	420.7	773.9	0.095	1.44E+00	1466.7	206.3	6686.3	0.2229	0.3165	1408	-2644	8094	4042
30	173.6	526.7	1042.6	0.677	1.94E+00	1460.3	153.4	6656.5	0.2219	0.3151	1044	-1964	7703	4693
40	176.4	654.7	1187.6	1.404	2.20E+00	1452.2	88.2	6620.0	0.2207	0.3134	601	-1129	7221	5491
50	179.8	799.0	1185.6	2.177	2.20E+00	1443.7	18.9	6581.1	0.2194	0.3116	129	-241	6710	6340
60	182.5	935.0	1042.6	2.903	1.94E+00	1435.7	-46.3	6544.6	0.2182	0.3098	-316	593	6229	7137
70	184.9	1080.9	773.9	3.496	1.44E+00	1429.1	-99.4	6514.9	0.2172	0.3084	-678	1273	5837	7788
80	186.4	1100.1	411.0	3.882	7.66E-01	1424.9	-134.1	6495.4	0.2165	0.3075	-914	1717	5581	8211
90	187.0	1134.1	0.0	4.016	2.74E-16	1423.6	-146.3	6488.7	0.2163	0.3072	-996	1871	5493	8360

Vertical Deflection (%):	22.06
Horizontal Deflection (%):	-3.35
Radial Soil Pressure at Crown (psi):	187.0
Circumferential Shortening (in):	12.89
Arc length of each sector (in) =	1.42

16925

Max. Compressive Stress (psi) 8439

Max. Tensile Stress (psi) No Tensile Stress

Free Field Stress 699.6 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
8.14	187.0	74.2	1134.1	236.2	168.9	281.6	327.6	1196.5
8.64	179.6	113.0	945.6	281.1	237.9	304.5	434.5	1109.0
9.14	185.2	150.7	844.1	297.6	284.1	310.5	494.3	1040.7
9.64	198.3	186.9	749.5	307.8	314.9	326.7	544.9	986.6
10.14	215.7	219.0	674.7	313.9	335.0	330.9	583.3	942.9
10.64	235.2	250.6	616.7	317.1	347.9	333.6	609.7	907.3
11.14	255.6	278.0	566.0	318.4	355.7	333.5	630.3	877.9
11.64	276.0	304.6	526.1	318.4	359.8	331.3	645.6	853.3
12.14	296.0	328.3	493.0	317.4	361.8	329.3	657.1	832.6
12.64	315.3	349.7	465.3	315.9	361.4	326.9	665.7	815.0
13.14	333.4	369.4	441.9	314.0	360.1	324.2	672.1	800.0
13.64	350.7	387.4	422.1	311.9	358.0	321.3	676.0	786.9
14.14	367.0	403.8	405.1	309.7	355.3	318.4	680.2	775.6
14.64	382.3	418.9	390.4	307.4	352.2	315.6	682.7	765.7
15.14	396.5	432.7	377.7	305.1	349.0	312.7	684.5	757.0
15.64	409.8	445.6	366.6	302.8	345.6	310.0	685.6	749.3
16.14	422.3	457.1	356.9	300.6	342.2	307.3	686.3	742.5
16.64	433.9	467.9	348.2	298.5	338.9	304.8	686.6	736.4
17.14	444.8	477.9	340.6	296.4	335.5	302.4	686.7	730.9
17.64	455.0	487.1	333.9	294.4	332.2	300.1	686.6	726.0
18.14	464.5	495.6	327.8	292.6	329.0	297.9	686.3	721.5
18.64	473.4	503.5	322.3	290.7	326.0	295.8	685.9	717.5
19.14	481.7	510.9	317.4	289.0	323.0	293.8	685.4	713.8
19.64	489.5	517.8	313.0	287.4	320.2	291.9	684.8	710.5
20.14	496.8	524.2	309.0	285.8	317.5	290.2	684.2	707.4
Avg. Values	349.8	366.3	791.2	290.7	338.5	312.0	516.3	1008.7
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

[With Incremental Stress Analysis (non-linear)]

Project: CC&V Phase I,II,III 4" OD PCPE

By: Lupo
Date: March 2003

Note: Compression is positive, tension is negative

Model Geometry

SOIL and PIPE Input Data

Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
				Lateral Pressure Parameters		
Pipe	n/a	n/a				
Pipe Envelope	0	40	3143	3.15	0.499	0.31

Pipe Diameter (in)	4.70
Pipe ID (in)	4.18
Weight of Pipe (lb/ft):	0.41
Pipe Corrugated (y/n)	n
Prescribed Constrained Modulus (y/n)	n
Prescribed Constrained Modulus (psi):	2000
Pipe Wall Thickness (in)	0.26
Pipe Area (in^2/in)	0.071
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	0.139
Moment of Inertia (in^4/in) non-corrugated:	0.0041
Moment of Inertia (in^4/in) corrugated (input from manufacturer data).	0.0014
Stiffness Coefficients	
Flexural Stiffness	23.0
Ring Compression Stiffness	912.2

D/t = 16.00
60.00
0.22

selected I: 0.0014

Ring Stiffness Factor: 1.0 Pipe Stiffness Less Than Envelope

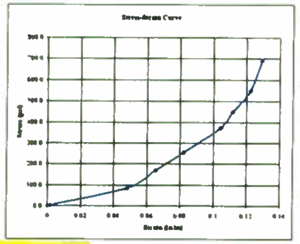
Soil-Medium Parameters		
UF	7.37	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	120.7	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in):	2.22	
Depth of Burial (ft):	800	
Applied Surface Stress (psf)	0	
Soil Density (pcf)	118	
Total Vertical Stress Component (psf):	94400	Free Field Stress Values
Total Vertical Stress Component (psi)	655.6	

Critical Stress For Buckling Failure (psi): 286.7

Ovality: 0.3

Corrected Stress (psi) 20.4



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
89.0	0.040	1771
170.0	0.065	2615
255.0	0.0819	3114
379.0	0.1060	3592
450.0	0.1114	4039
550.0	0.122	4508.2
690.0	0.129	5349.9
		#DIV/0!
		#DIV/0!

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	314.6	1142.5	0.0	-0.006	0.00E+00	723.6	18.0	10162.0	0.3387	0.1313	1783	-2579	11945	7583
10	307.7	1114.0	83.6	-0.091	9.04E-02	704.9	17.1	9927.0	0.3309	0.1282	1699	-2457	11626	7470
20	288.0	1089.6	157.1	0.044	1.70E-01	658.7	14.7	9250.1	0.3083	0.1195	1450	-2108	10700	7142
30	257.7	922.7	211.6	0.190	2.29E-01	584.6	11.0	8213.3	0.2738	0.1061	1088	-1573	9301	6640
40	220.7	779.2	240.6	0.348	2.60E-01	494.2	6.6	6941.1	0.2314	0.0896	634	-916	7575	6025
50	181.3	636.5	240.6	0.509	2.60E-01	397.9	1.9	5587.9	0.1863	0.0723	151	-118	5738	5470
60	144.1	453.0	211.6	0.738	2.29E-01	307.3	-3.1	4315.4	0.1438	0.0557	-303	439	4012	4754
70	113.9	366.1	157.1	0.883	1.70E-01	233.4	-4.8	3278.5	0.1093	0.0423	-673	976	2605	4253
80	94.1	329.0	83.6	0.979	9.04E-02	185.2	-9.2	2601.6	0.0867	0.0336	-915	1323	1687	3925
90	87.3	263.3	0.0	1.012	3.20E-17	168.9	-10.1	2366.6	0.0789	0.0306	-999	1444	1368	3811

Vertical Deflection (%):	33.16
Horizontal Deflection (%)	-3.81
Radial Soil Pressure at Crown (psi)	87.3
Circumferential Shortening (in)	3.36
Arc length of each sector (in) =	0.39

12560

Max. Compressive Stress (psi) 11945

Max. Tensile Stress (psi) No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	191.5	309.8	0.0	-0.143	0.00E+00	453.0	19.5	6362.4	0.2121	0.0822	1932	-2794	8295	3568
10	192.0	329.0	411.5	-0.107	2.09E-01	452.6	18.5	6356.5	0.2119	0.0821	1840	-2660	8196	3696
20	193.7	390.1	773.3	-0.081	3.92E-01	451.4	15.8	6339.5	0.2113	0.0819	1573	-2273	7912	4066
30	196.3	503.9	1041.9	0.160	5.29E-01	449.5	11.7	6313.4	0.2104	0.0815	1163	-1681	7476	4633
40	199.3	633.8	1180.8	0.398	6.01E-01	447.3	6.6	6281.3	0.2094	0.0811	660	-954	6941	5327
50	202.6	771.9	1180.8	0.569	6.01E-01	444.8	1.3	6247.2	0.2082	0.0807	125	-180	6372	6067
60	205.6	901.8	1041.9	0.747	5.29E-01	443.6	-3.8	6215.2	0.2072	0.0803	-370	546	5845	6762
70	208.2	1007.7	773.3	0.920	3.92E-01	440.7	-7.9	6189.1	0.2063	0.0799	-788	1139	5401	7328
80	209.0	1076.7	411.5	1.034	2.09E-01	439.5	-10.6	6172.1	0.2057	0.0797	-1055	1526	5117	7698
90	210.4	1100.7	0.0	1.070	7.48E-17	439.1	-11.4	6166.2	0.2055	0.0796	-1148	1660	5018	7826

Vertical Deflection (%):	22.39
Horizontal Deflection (%)	-4.49
Radial Soil Pressure at Crown (psi).	210.4
Circumferential Shortening (in)	3.34
Arc length of each sector (in) =	0.39

80293

Max. Compressive Stress (psi) 8295

Max. Tensile Stress (psi) No Tensile Stress

Free Field Stress 659.4 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
2.22	210.4	97.3	1100.7	263.2	191.5	314.6	305.0	1142.5
2.72	285.2	214.5	682.3	310.7	366.2	344.9	559.8	927.4
3.22	353.9	326.6	503.4	314.2	371.3	338.6	630.9	829.3
3.72	390.1	399.1	413.9	307.7	366.0	326.0	668.4	796.9
4.22	423.9	451.1	363.7	299.6	353.9	313.8	678.9	761.1
4.72	453.4	497.2	333.2	291.2	339.3	303.5	681.6	722.6
5.22	485.9	517.0	313.3	283.9	327.1	295.2	681.3	708.7
5.72	511.5	539.0	299.7	280.7	316.6	288.4	679.7	698.7
6.22	531.0	556.9	290.0	276.4	307.9	282.9	677.0	691.4
6.72	548.5	570.6	282.9	271.8	300.3	278.4	675.8	685.8
7.22	562.0	581.6	277.3	269.8	294.4	274.7	673.9	681.4
7.72	573.1	590.7	273.1	267.4	289.2	271.6	672.2	677.9
8.22	582.4	598.2	269.7	265.3	284.9	269.0	670.7	675.1
8.72	590.3	604.4	267.0	263.5	281.0	266.8	669.3	672.8
9.22	596.9	609.7	264.8	262.0	277.8	265.0	668.1	670.9
9.72	602.6	614.2	263.0	260.7	275.0	263.3	667.0	669.3
10.22	607.5	618.1	261.4	259.5	272.6	262.0	666.1	667.9
10.72	611.8	621.5	260.1	258.6	270.5	260.8	665.2	666.8
11.22	615.5	624.6	259.0	257.7	268.6	259.7	664.5	665.7
11.72	619.0	627.0	258.0	256.9	267.0	258.8	663.8	664.9
12.22	621.7	629.3	257.2	256.3	265.5	257.9	663.2	664.1
12.72	624.3	631.3	256.4	255.6	264.3	257.2	662.6	663.4
13.22	626.5	633.1	255.8	255.1	263.1	256.6	662.2	662.8
13.72	628.4	634.7	255.2	254.6	262.1	256.0	661.7	662.3
14.22	630.4	636.1	254.7	254.2	261.1	255.5	661.3	661.8
Avg Values	525.0	536.7	330.1	276.2	292.6	280.8	651.5	835.3
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

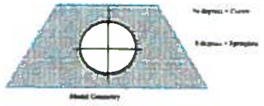
[With Incremental Stress Analysis (non-linear)]

SAC

Project: CC&V Arequa Gulch Spring Pipe 4" SDR 17 HDPE

By: Lopo
Date: March 2008

Note: Compression is positive, tension is negative



Model Geometry

SOIL and PIPE Input Data

				Lateral Pressure Parameters		
Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
Pipe	n/a	n/a				
Pipe Envelope	0	40	3542	0.39	0.449	0.31

Pipe Diameter (in):	4.5
Pipe ID (in):	3.94
Weight of Pipe (lb/ft):	1.54
Pipe Corrugated (y/n)	n
Prescribed Constrained Modulus (y/n)	n
Prescribed Constrained Modulus (psi):	2000
Pipe Wall Thickness (in):	0.281
Pipe Area (in^2/in):	0.281
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	0.200
Moment of Inertia (in^4/in) non-corrugated:	0.0018
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0014
Stiffness Coefficients	
Flexural Stiffness	42.0
Ring Compression Stiffness	4002.0

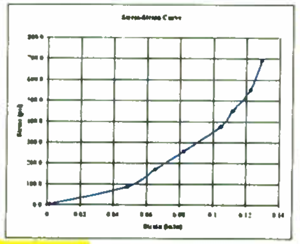
DR = [illegible]
68.09
0.33

selected I 0.0018

Ring Stiffness Factor 7.1 Pipe Stiffness Less Than Envelope

Shell-Medium Parameters		
UF	1.77	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading
VF	74.7	Bending Flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in):	2.11	
Depth of Burial (ft):	858	
Applied Surface Stress (psf):	0	
Soil Density (pcf):	110	
Total Vertical Stress Component (psf):	94380	Free Field Stress Values
Total Vertical Stress Component (psi)	655.4	



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
285.0	0.0919	3114
379.0	0.1044	3993
454.0	0.1116	4069
550.0	0.122	4508.2
690.0	0.129	5348.8
		#DIV/0!
		#DIV/0!

Critical Stress For Buckling Failure (psi) 472.2

Ovality 0.3

Corrected Stress (psi) 143.2

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	601.6	705.0	0.0	-0.264	0.00E+00	1303.3	20.9	6431.1	0.1544	0.0560	2243	-916	6093	3715
10	590.7	697.4	132.3	-0.234	9.86E-02	1278.4	19.8	6541.9	0.1514	0.0587	3144	-860	6605	3674
20	509.3	653.7	248.8	-0.150	1.85E-01	1206.1	16.7	6289.0	0.1428	0.0526	1803	-730	6088	3955
30	511.1	594.5	334.8	-0.031	2.50E-01	1095.3	11.8	5891.4	0.1297	0.0478	1280	-519	5172	3873
40	472.0	531.9	380.7	0.137	2.84E-01	959.4	5.9	3408.7	0.1126	0.0415	640	-259	4048	3190
50	389.1	444.6	380.7	0.306	2.84E-01	814.8	-0.4	2894.9	0.0965	0.0355	-42	17	2853	2912
60	330.0	372.0	334.0	0.464	2.50E-01	678.9	-6.3	2412.1	0.0806	0.0296	-683	277	1729	2689
70	281.0	312.0	248.5	0.593	1.85E-01	560.2	-11.1	2019.6	0.0673	0.0260	-1295	600	814	2507
80	250.4	276.1	132.2	0.678	9.86E-02	495.9	-14.3	1761.7	0.0587	0.0216	-1546	636	216	2180
90	239.5	260.7	0.0	0.707	3.53E-17	470.7	-15.6	1672.5	0.0558	0.0205	-1664	674	0	2347

Vertical Deflection (%):	15.71
Horizontal Deflection (%)	-13.90
Radial Soil Pressure at Crown (psi)	239.5
Circumferential Shortening (in)	1.85
Arc length of each sector (in) =	0.37

34484

Max. Compressive Stress (psi) 6093
Max. Tensile Stress (psi) No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	406.1	90.3	0.0	-0.349	0.00E+00	897.3	24.1	3187.7	0.1063	0.0391	3607	-1896	5795	2132
10	407.0	116.0	600.1	-0.319	1.97E-01	896.6	22.0	3185.6	0.1062	0.0391	3460	-999	5653	2186
20	409.5	182.2	767.0	-0.215	3.70E-01	894.9	19.1	3179.3	0.1060	0.0390	2867	-837	5746	2242
30	413.3	284.0	1033.4	-0.064	4.99E-01	892.3	13.6	3169.8	0.1057	0.0389	1453	-580	4623	2301
40	418.0	415.0	1175.1	0.123	5.67E-01	888.9	6.5	3158.0	0.1053	0.0388	700	-231	3858	2879
50	423.0	551.5	1175.1	0.311	5.67E-01	885.6	-0.9	3145.5	0.1049	0.0386	-102	41	3044	3187
60	427.7	679.7	1033.4	0.507	4.99E-01	881.1	-7.9	3133.8	0.1045	0.0385	-855	346	2279	3480
70	431.6	784.3	767.0	0.659	3.70E-01	879.4	-13.6	3124.3	0.1041	0.0383	-1469	595	1655	3719
80	434.0	853.5	600.1	0.750	1.97E-01	877.6	-17.3	3118.0	0.1039	0.0383	-1870	757	1248	3875
90	434.9	876.3	0.0	0.792	7.05E-17	877.0	-18.6	3115.8	0.1039	0.0382	-2009	814	1107	3930

Vertical Deflection (%):	17.61
Horizontal Deflection (%)	-16.94
Radial Soil Pressure at Crown (psi)	434.9
Circumferential Shortening (in)	1.59
Arc length of each sector (in) =	0.37

43429

Max. Compressive Stress (psi) 5795
Max. Tensile Stress (psi) No Tensile Stress

Free Field Stress 659.6 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
2.11	434.9	239.5	876.2	260.7	406.1	401.6	90.3	703.8
2.61	376.3	379.4	513.5	260.7	436.9	483.4	421.3	684.3
3.11	405.0	457.6	389.0	258.7	469.1	415.5	543.6	674.0
3.61	466.0	509.3	325.5	256.7	436.3	373.2	596.7	668.5
4.11	483.6	541.3	297.9	255.2	405.6	345.0	622.4	665.1
4.61	510.6	569.3	281.0	254.0	380.1	325.4	636.0	663.0
5.11	533.6	582.8	270.9	253.0	359.5	311.1	643.6	661.6
5.61	551.9	594.4	264.6	252.3	343.0	300.5	648.1	660.4
6.11	566.6	604.8	260.4	251.7	329.7	292.3	650.8	659.6
6.61	578.5	611.4	257.6	251.3	318.9	285.9	652.6	658.9
7.11	588.3	617.6	255.6	250.8	310.0	280.8	653.7	658.5
7.61	596.3	622.2	254.3	250.6	302.7	276.7	654.4	658.1
8.11	603.0	626.3	253.1	250.3	296.5	273.3	654.9	657.8
8.61	609.6	629.5	252.3	250.0	291.4	270.5	655.3	657.5
9.11	613.6	632.3	251.6	249.9	287.0	268.1	655.5	657.3
9.61	617.6	634.6	251.1	249.7	283.2	266.1	655.7	657.1
10.11	621.1	636.7	250.7	249.6	279.9	264.4	655.8	657.0
10.61	624.2	638.4	250.4	249.4	277.1	262.9	655.9	656.8
11.11	626.9	639.9	250.1	249.3	274.7	261.6	655.9	656.7
11.61	629.2	641.2	249.9	249.2	272.8	260.5	655.9	656.6
12.11	631.3	642.6	249.7	249.2	270.6	259.5	656.0	656.5
12.61	633.2	643.6	249.6	249.1	268.9	258.6	656.0	656.4
13.11	634.8	644.3	249.4	249.0	267.4	257.8	656.0	656.4
13.61	636.3	645.1	249.3	249.0	266.0	257.2	656.0	656.3
14.11	637.6	645.9	249.2	248.9	264.8	256.5	656.0	656.3
Avg. Values	567.5	585.0	423.9	257.8	325.9	300.3	587.7	674.4
Soil Arching	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch

Appendix C.3.2

Phase 5 VLF Primary Solution Collection Pipe Burial Calculations

SWC
SMITH WILLIAMS CONSULTANTS, INC.

CALCULATION TITLE PAGE

CLIENT Cripple Creek & Victor Gold Company	**JOB NO.** 1125	**TASK NO.** A100	**PAGE** 1 **OF** 3
PROJECT Arequa VLF	**CALCULATION No.** 1	**REV. No.** 1	
SUBJECT/ TITLE Primary Pipe Design			

REV. NO.	PREPARER/ DATE	REVIEWER/ DATE	QA REVIEWER/ DATE	CONFIRMATION REQUIRED (Y/N)
1	Amanda L. Dolezal 1/8/08	Derek T. Wittwer 1/26/08	JFLupo 1/26/08	

CALCULATION OBJECTIVE

Size the primary collection pipes in order to handle the maximum flow.

CALCULATION METHODOLOGY/ LIST of ASSUMPTIONS

- Q_{total} = 14,400 gpm, distribute flow to 3 pipes.
- Consider flow only in primary pipes, not the primary / riser interaction.
- Add factor of safety of 25% for flow of 18,000 gpm for zero deformation.
- Distribute flow evenly between the three pipes for design flow in each pipe of 6,000 gpm.

REFERENCES

Watkins, R., "Plastic Pipes Under High Landfills", 1990, Buried Plastic Pipe Technology, ASTM-STP.1093.
Lupo, J., "Stability of HDPE Pipes Under High Heap Loads", 1991, SME, Denver, Colorado.

CONCLUSIONS

- 26" O.D. pipe with SDR 11 will support the necessary quantities of flow and loads without any deformation.

PROJECT: Arequa VLF	**JOB NO:** 1125	**SHEET** 2 **OF** 2
FEATURE: Primary Solution Collection Pipe	**BY:** ALD	**DATE:** 1/8/08
DETAILS: Pipe Sizing	**CHKD BY:** DTW	**DATE:** 1/26/08

- Criteria:

1) Use pressurized pipe flow calculation.

- Analysis:

Total length = 1200 feet
Average ground slope = 0.004 = 0.4%

Elevation Head = 1200 ft * 0.004 = 4.8 feet
Differential Head = calculate to get $Q \approx 6{,}000$ gpm

Use modified pipe deformation method in Lupo (1991) to test pipe deformation for both maximum and average ore height in PSSA.

Assume pipe is 26" O.D. with SDR of 11, check deformation, check flow, then verify SDR is appropriate.

Attached sheets have pipe deformation calculations for maximum ore height (590 feet). Results indicate pipe crown deflection of between 10 and 12% (less than 15% threshold), and crown pressures of between 260 and 418 psi. Tensile stresses are less than 1000 psi.

Ignore horizontal strains as these are over predicted.

Deformed pipe analysis indicates a 19% reduction in flow due to maximum crown deflection:
$Q_{def(max)} = 6{,}395$ gpm * 0.81 = 5,180 gpm (greater than 4,800 gpm)
Deformed pipe analysis indicates a 16% reduction in flow due to minimum crown deflection:
$Q_{def(min)} = 6{,}395$ gpm * 0.84 = 5,372 gpm (greater than 4,800 gpm)

Now verify SDR 11 is appropriate for loading. Use empirical approach using Watkins Equation.
$\sigma_R = 0.5P\,(1 + d)\,SDR$ per Watkins (see Lupo, 1991)

Performance of plastic pipe is governed by:
1) ring crushing
2) ring deformations

ring deflection ≈ vertical strain of pipe envelope

σ_R = ring compression (allowable is 1500psi - Driscopipe)
d = crown deflection (varies between 10 and 12%)
SDR = pipe SDR ratio

1500 psi = (0.5)*(420 psi)*(1+0.12)SDR
SDR = 6.4 ≈ 7 for maximum ore height

Therefore SDR 11 is suitable for this maximum condition in the PSSA.

8/8

Nom. Size (in)	DR	Weight lb/100ft	Dimensions, Inches			Coil/ Joint feet
			OD	Approx. ID	Min.Wall	
22	9.0	6540	22.000	17.112	2.444	20/40/50
	11.0	5482		18.000	2.000	20/40/50
	13.5	4556		18.740	1.630	20/40/50
	17.0	3680		19.412	1.294	20/40/50
	21.0	3018		19.904	1.048	20/40/50
	26.0	2461		20.308	0.846	20/40/50
24	9.0	7785	24.000	18.666	2.667	20/40/50
	11.0	6524		19.636	2.182	20/40/50
	13.5	5421		20.444	1.778	20/40/50
	17.0	4381		21.176	1.412	20/40/50
	21.0	3591		21.714	1.143	20/40/50
	26.0	2930		22.154	0.923	20/40/50
26	11.0	7657	26.000	21.272	2.364	20/40/50
	13.5	6362		22.148	1.926	20/40/50
	17.0	5139		22.942	1.529	20/40/50
	21.0	4214		23.524	1.238	20/40/50
	26.0	3439		24.000	1.000	20/40/50
28	11.0	8878	28.000	22.910	2.545	20/40/50
	13.5	7378		23.852	2.074	20/40/50
	17.0	5962		24.706	1.647	20/40/50
	21.0	4886		25.334	1.333	20/40/50
	26.0	3988		25.846	1.077	20/40/50
30	13.5	8469	30.000	25.556	2.222	20/40/50
	17.0	6845		26.470	1.765	20/40/50
	21.0	5612		27.142	1.429	20/40/50
	26.0	4578		27.692	1.154	20/40/50
800mm	13.5	9335	31.496	26.830	2.333	20/40/50
	17.0	7545		27.790	1.853	20/40/50
	21.0	6185		28.496	1.500	20/40/50
	26.0	5044		29.074	1.211	20/40/50
32	13.5	9635	32.000	27.260	2.370	20/40/50
	17.0	7786		28.236	1.882	20/40/50
	21.0	6384		28.952	1.524	20/40/50
	26.0	5210		29.538	1.231	20/40/50

Typical Physical Properties* of Driscopipe® 1000 (PE 3408) Polyethylene Pipe Resin

Property		Test Method	Unit	Value
Material Designation		PPI / ASTM	--------	PE 3408
Material Classification		ASTM D 3350	--------	Type III; PE34
Cell Classification		ASTM D 3350	--------	345464C
Density	(3)	ASTM D 1505	gms/cm^3	0.955
Melt Flow	(4)	ASTM D 1238(2.16/190)	gms/10 min.	0.11 ♦
Flex Modulus	(5)	ASTM D 790	psi	110,000
Tensile Strength	(4)	ASTM D 638	psi	3,200
PENT	(6)	ASTM F 1473	Hours	>100
HDB @ 73.4°F	(4)	ASTM D 2837	psi	1,600
U-V Stabilizer	(C)	ASTM D 1603	% C	> 2
Hardness		ASTM D 2240	Shore D	65
Tensile Strength @ Yield (Type IV Specimen)		ASTM D 638 (2"/min.)	psi	3,200
Tensile Strength @ Break (Type IV Specimen)		ASTM D 638	psi	5,000
Elongation at Break		ASTM D 638	%, minimum	750
Modulus of Elasticity (Young's Modulus)		ASTM D 638	psi	130,000
ESCR				
(Cond A,B, C: Mold. Slab)		ASTM D 1693	F$_o$, Hours	>5,000
(Compressed Ring - pipe)		ASTM F 1248	F$_o$, Hours	>3,500
PENT		ASTM F 1473	Hours	>100
Impact Strength (IZOD) (.125" Thick)		ASTM D 256 (Method A)	in-lb/in. notch	42
Linear Thermal Expansion Coeff.		ASTM D 696	in/ in/ °F	1.2 x 10^{-4}
Thermal Conductivity		ASTM D 177	BTU-in/ft^2/ hrs/°F	2.7
Brittleness Temperature		ASTM D 746	°F	< -180
Vicat Softening Temperature		ASTM D 1525	°F	257

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*This list of typical physical properties is intended for basic characterization of the material and does not represent specific determinations or specifications. The Physical properties values reported herein were determined on compression molded specimens prepared in accordance with Procedure C of ASTM D-1928 and may differ from specimens taken from the pipe.

♦ Average Melt Index value with a standard deviation of 0.01

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PIPEFLOW WORKSHEET

SWC
SMITH WILLIAMS CONSULTANTS, INC.

Project Name:	CC&V Arequa VLF
Client:	CC&V
Date:	1/18/2008
Pipe Description:	3 primary pipes 14,400gpm total
	FOS 1.25

Hazen-Williams

Parameter	Units	Units
Q	6000 gpm	379 l/s
C factor	150	
Pipe Inside Diameter	20.989 inches	
Pipe loss per 100 ft	0.1563 psi/100 ft.	
Equivalent Water Level:	0.3608 ft. of water	
Hydraulic Gradient	0.0036 ft/ft	

Pipe Inside Diameter	20.989 inches		
Upgradient Elv. (ft)	9730	2966.5	m
Upgradient Water Elv. (ft):	9745	2971.0	m
Downgradient Elv. (ft):	9725	2964.9	m
Downgradient Water Elv. (ft):	9740	2969.5	m
Pipe Elv. Change (ft):	5	1.5	m
Pipe Elevation Change	5	1.5	m
Hydraulic Elv. Change	5	1.5	m
Pipe Length	1255	382.6	m
Slope of Pipe:	0.004		
C factor	150		
Fittings Equivalent Length:	0 feet		
hydraulic gradient	0.00 ft/ft		
Q Max.	6,395 gpm		
Q	14.25 cfs		
Q	403.43 lps		
Velocity	5.93 fps		
Total Head loss (ft)	4.53		


9730
9725

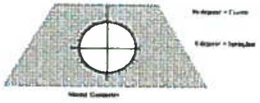
BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

(With Incremental Stress Analysis (non-linear))

Project CC&V Primary Solution Collection Phase 5 VLF 24" OD SDR 11 HDPE

By: [illegible]
Date: January [illegible]

Note: Compression is positive; tension is negative



SOIL and PIPE Input Data

Material	Cohesion	Friction Angle	Constrained Modulus (psi)	Lateral Stress Ratio	B	C
Pipe	n/a	n/a				
Pipe Envelope	0	40	4194	0.38	0.489	0.31

Pipe Diameter (in)	24
Pipe ID (in)	19.99
Weight of Pipe (lb/ft)	76.57
Pipe Corrugated (y/n)	n
Prescribed Constrained Modulus (y/n)	n
Prescribed Constrained Modulus (psi)	2000
Pipe Wall Thickness (in)	2.174
Pipe Area (in^2/in)	2.012
Flexural Modulus (psi), E =	30,000
Ring Compression Modulus (psi), E =	30,000
C value (in)	1.088
Moment of Inertia (in^4/in) non-corrugated	1.7516
Moment of Inertia (in^4/in) corrugated (input from manufacturer data)	0.0640
Stiffness Coefficients	
Flexural Stiffness	194.5
Ring Compression Stiffness	6418.1

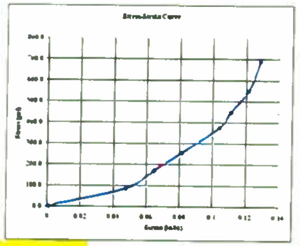
DR = 10.80
65.00
0.22

Selected I 1.7516

Ring Stiffness Factor 32.4 Pipe Stiffness Less Than Envelope

[illegible] Parameters		
UF	0.90	Extensional flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading.
VF	13.4	Bending flexibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads
		If both UF and VF are zero then a perfectly rigid embedded pipe

Pipe Mean Radius (in)	11.[illegible]	
Depth of Burial (ft)	990	
Applied Surface Stress (psf)	0	
Soil Density (pcf)	110	
Total Vertical Stress Component (psf):	69620	Free Field Stress Values
Total Vertical Stress Component (psi)	483.5	



Pipe Envelope Compression Data		
Applied Vertical Load (psi)	Vertical Strain (in/in)	Constrained Modulus (psi)
1.0	0.001	1000
85.0	0.048	1771
170.0	0.065	2615
255.0	0.0819	3114
375.0	0.1044	3593
450.0	0.1114	4039
550.0	0.122	4508.2
690.0	0.127	5433.9
		#DIV/0!
		#DIV/0!

Critical Stress For Buckling Failure (psf) 67219.4

Ovality 0.3

Corrected Stress (psf) 38193.1

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	483.7	486.1	0.0	-1.390	0.00E+00	4287.4	1971.0	2501.0	0.0834	0.1710	1986	-2013	4487	488
10	476.9	398.6	103.0	-1.273	4.73E-01	4171.6	1364.0	2405.7	0.0819	0.1670	1900	-1715	4306	761
20	457.5	379.6	153.6	-0.913	3.00E-01	3838.2	1506.0	2333.1	0.0776	0.1588	1543	-1431	3876	902
30	437.7	300.0	260.3	-0.307	1.30E+00	5327.4	1053.0	2119.0	0.0707	0.1449	1074	-995	3193	1124
40	391.1	313.9	256.5	0.220	1.36E+00	4700.8	902.0	1870.5	0.0635	0.1370	690	-462	2560	1408
50	382.4	178.4	256.5	1.041	1.36E+00	4034.0	-114.7	1605.2	0.0530	0.1097	-114	106	1491	1711
60	315.0	239.5	260.0	1.720	1.20E+00	3407.4	-693.0	1399.0	0.0452	0.0957	-430	630	967	1999
70	306.3	310.1	153.4	2.273	8.80E-01	2894.6	-1140.0	1152.6	0.0396	0.0780	-1158	1074	-5	2227
80	364.6	198.9	103.0	2.634	4.73E-01	2541.2	-1676.2	1015.9	0.0340	0.0497	-1460	1360	-444	2376
90	350.9	184.1	0.0	2.750	1.00E-14	2467.4	-2084.0	973.8	0.0325	0.0444	-1870	1457	-896	2430

Vertical Deflection (%):	10.41
Horizontal Deflection (%):	-11.98
Radial Soil Pressure at Crown (psi):	350.9
Circumferential Shortening (in):	4.78
Arc length of each meter (in) =	2.86

37423

Max. Compressive Stress (psi): 4487

Max. Tensile Stress (psi): -896

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	326.0	40.1	0.0	-1.704	0.00E+00	4844.0	2381.6	1890.2	0.0603	0.1236	3001	-2197	4891	-307
10	328.7	88.5	276.9	-1.630	8.79E-01	4834.0	2174.5	1804.9	0.0602	0.1234	2135	-2000	3940	-195
20	336.7	99.7	520.4	-1.307	1.65E+00	4904.0	1599.9	1792.0	0.0598	0.1229	1793	-1663	3585	129
30	348.9	147.9	701.1	-0.883	1.23E+00	4457.1	1347.0	1772.5	0.0591	0.1213	1257	-1147	3030	626
40	363.0	258.6	797.3	0.283	2.53E+00	6300.5	960.0	1750.2	0.0583	0.1196	900	-515	2650	1236
50	379.7	330.0	797.3	1.389	2.53E+00	4334.1	-172.0	1728.4	0.0575	0.1179	-170	126	1558	1854
60	394.7	423.0	701.1	1.913	1.23E+00	4272.7	-689.0	1703.1	0.0567	0.1163	-853	791	850	2493
70	404.9	403.0	520.4	2.060	1.65E+00	4229.9	-1430.0	1683.1	0.0561	0.1150	-1409	1306	274	2989
80	414.0	534.0	376.9	2.996	8.79E-01	4190.0	-1706.5	1670.7	0.0557	0.1143	-1771	1643	-100	3314
90	417.6	605.3	0.0	3.144	1.15E-14	4187.9	-1913.6	1666.4	0.0555	0.1139	-1897	1760	-230	3426

Vertical Deflection (%):	11.89
Horizontal Deflection (%):	-10.18
Radial Soil Pressure at Crown (psi):	417.6
Circumferential Shortening (in):	4.75
Arc length of each meter (in) =	2.69

60120

Max. Compressive Stress (psi): 4891

Max. Tensile Stress (psi): -307

Free Field Stress 483.5 psi

Radius (in)	CROWN				SPRINGLINE			
	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Radial Stress, psi (full slip)	Radial Stress, psi (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
11.75	417.6	259.9	940.3	184.3	326.0	481.7	60.2	405.2
12.25	393.1	280.7	690.3	181.5	344.3	454.7	168.4	414.4
12.75	375.7	298.7	542.3	179.0	356.2	431.3	198.9	422.1
13.25	363.7	314.5	453.1	177.3	363.4	413.8	262.9	428.6
13.75	355.6	328.0	378.8	176.1	367.2	396.8	299.5	434.3
14.25	350.4	340.1	344.0	175.2	368.3	378.8	320.2	438.9
14.75	347.0	350.8	321.4	174.6	367.6	364.6	336.1	443.0
15.25	346.7	360.3	302.8	174.2	365.5	351.9	350.0	446.6
15.75	346.9	368.8	287.0	173.9	361.9	340.4	356.7	449.7
16.25	348.1	376.5	273.6	173.8	358.8	330.3	363.7	452.5
16.75	349.9	383.4	263.1	173.7	354.5	321.0	366.5	454.9
17.25	352.2	389.6	252.3	173.7	350.0	312.4	378.6	457.1
17.75	355.0	395.3	243.9	173.8	345.3	305.0	388.9	459.0
18.25	357.9	400.4	236.4	173.9	340.5	298.0	398.0	460.7
18.75	361.1	405.2	230.3	174.1	335.7	291.6	405.9	462.3
19.25	364.3	409.5	224.9	174.2	330.9	285.8	413.0	463.6
19.75	367.6	413.4	220.1	174.4	326.2	280.4	419.2	464.9
20.25	370.9	417.1	216.0	174.6	321.6	275.4	424.6	466.0
20.75	374.3	420.4	212.3	174.8	317.0	270.9	429.5	467.0
21.25	377.4	423.6	209.1	175.0	312.7	266.5	433.9	468.0
21.75	380.6	426.4	206.3	175.2	308.4	262.6	437.8	468.9
22.25	383.7	429.1	203.8	175.4	304.3	258.9	441.3	469.6
22.75	386.7	431.6	201.6	175.6	300.3	255.5	444.4	470.4
23.25	389.7	433.9	199.6	175.8	296.5	252.3	447.2	471.0
23.75	392.5	436.1	197.9	176.0	292.8	249.3	449.8	471.7
Avg. Values	368.4	378.7	457.3	175.3	336.7	335.1	357.6	454.6
Soil Arching:	Positive Arch	Positive Arch	Negative Arch	Positive Arch	Negative Arch	Negative Arch	Positive Arch	Positive Arch

Estimate Percent Flow Reduction of Deformed Pipe (Min.)

SWC
SMITH WILLIAMS CONSULTANTS, INC.

Project: CC&V Arequa
Date: January 2008
By: Dolezal
Project #: 1125

Max. Ore Height = 590 feet

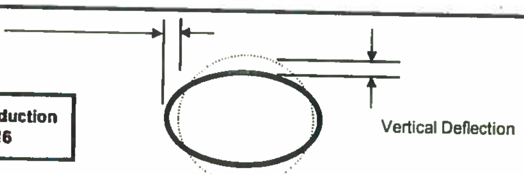
$$FlowFactor = AR^{2/3}$$

A = Flow Area
R = Hyd. Radius

Circular Pipe Flow

Inside Diameter (inches)	Area Ft^2	Hyd. Radius ft.	Flow Factor
16.00	1.40	0.33	0.67
18.00	1.77	0.38	0.92
20.00	2.18	0.42	1.22
22.00	2.64	0.46	1.57
24.00	3.14	0.50	1.98
26.00	3.69	0.54	2.45
28.00	4.28	0.58	2.99
30.00	4.91	0.63	3.59
32.00	5.59	0.67	4.26
34.00	6.31	0.71	5.01
36.00	7.07	0.75	5.83

Ellipse-Shape Pipe Flow



Max. Vertical Pipe Deflection (%): 10

Horizontal Deflection (%): 0

Flow Reduction
0.16

Circular Pipe I.D. (inches)	Vertical Axis (in.)	Horizontal Axis (in.)	Area Ft^2	Perimeter (full flow)	Hyd. Radius	Flow Factor
16.00	14.4	16.0	1.26	4.19	0.30	0.56
18.00	16.2	18.0	1.59	4.71	0.34	0.77
20.00	18.0	20.0	1.96	5.24	0.38	1.02
22.00	19.8	22.0	2.38	5.76	0.41	1.32
24.00	21.6	24.0	2.83	6.28	0.45	1.66
26.00	23.4	26.0	3.32	6.81	0.49	2.06
28.00	25.2	28.0	3.85	7.33	0.53	2.50
30.00	27.0	30.0	4.42	7.85	0.56	3.01
32.00	28.8	32.0	5.03	8.38	0.60	3.58
34.00	30.6	34.0	5.67	8.90	0.64	4.20

Estimate Percent Flow Reduction of Deformed Pipe (Max.)

Project: CC&V Arequa
Date: January 2008
By: Dolezal
Project #: 1125

Max. Ore Height = 590 feet

$$FlowFactor = AR^{2/3}$$

A = Flow Area
R = Hyd. Radius

SWC
SMITH WILLIAMS CONSULTANTS, INC.

Circular Pipe Flow

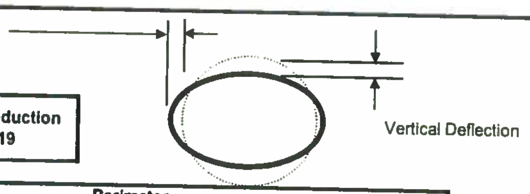
Inside Diameter (inches)	Area Ft^2	Hyd. Radius ft.	Flow Factor
16.00	1.40	0.33	0.67
18.00	1.77	0.38	0.92
20.00	2.18	0.42	1.22
22.00	2.64	0.46	1.57
24.00	3.14	0.50	1.98
26.00	3.69	0.54	2.45
28.00	4.28	0.58	2.99
30.00	4.91	0.63	3.59
32.00	5.59	0.67	4.26
34.00	6.31	0.71	5.01
36.00	7.07	0.75	5.83

Ellipse-Shape Pipe Flow

Max. Vertical Pipe Deflection (%): 12

Horizontal Deflection (%): 0

Flow Reduction
0.19



Circular Pipe I.D. (inches)	Vertical Axis (in.)	Horizontal Axis (in.)	Area Ft^2	Perimeter (full flow)	Hyd. Radius	Flow Factor
16.00	14.1	16.0	1.23	4.19	0.29	0.54
18.00	15.8	18.0	1.56	4.71	0.33	0.74
20.00	17.6	20.0	1.92	5.24	0.37	0.98
22.00	19.4	22.0	2.32	5.76	0.40	1.27
24.00	21.1	24.0	2.76	6.28	0.44	1.60
26.00	22.9	26.0	3.24	6.81	0.48	1.98
28.00	24.6	28.0	3.76	7.33	0.51	2.41
30.00	26.4	30.0	4.32	7.85	0.55	2.90
32.00	28.2	32.0	4.91	8.38	0.59	3.44
34.00	29.9	34.0	5.55	8.90	0.62	4.05