To: Jed Friesen, PREDL Systems.
From: Alonso Vidal, P.E. Bowman Consulting
Date: August 9, 2018
Subject: 3ASC Phase 1 Submittal 27 Predl PVC Riser Test Manhole response, Item No. 8 Buckling calculations

Background

In response to the request to provide with buckling calculations. The calculations follow the recommendations given on ASTM F 1759 – 97 (Reapproved 2004) Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications, sections *7.1.2.3 Axial Buckling* and *7.1.2.9 Interaction of Axial and Radial Buckling.*

All formulae for table come form the above ASMT standard.

Content/Review

PVC Material Information	
PVC Pipe ID	60.000
Wall Thickness	1.208
I of Wall	0.147
Material Modulus	400000.000
Poisson Ratio	0.380
Tensile Strength	1000.000
Comp. strength	4000.000
axial strain limit	0.035
ring strain limit	**0.050**
Other	
Critical R.T,Dry	2721.393
Critical Axial Strain at axial buckling (calculated)	**0.025**
H20 wheel load	16000

		Ring Buckling			Axial Buckling		
Manhole Depth	**PVC Length**	**Critical. Ring Trust**	**Ring Trust stress**	**Safety Factor**	**Axial Strain**	**Critical Axial Strain at axial buckling**	**Safety Factor**
ft	ft	lbf/in	lbf/in		in/in	in/in	
4.00	1.00	1080.10	48.71	22	0.00018	0.025	139
5.00	2.00	1107.36	68.20	16	0.00019	0.025	133
6.00	3.00	1134.87	87.68	13	0.00020	0.025	124
7.00	4.00	1162.60	107.17	11	0.00021	0.025	115
8.00	5.00	1190.53	126.65	9	0.00023	0.025	105
9.00	6.00	1218.61	146.14	8	0.00026	0.025	95
10.00	7.00	1246.81	165.62	8	0.00029	0.025	86
11.00	8.00	1275.10	185.11	7	0.00032	0.025	78
12.00	9.00	1303.43	204.59	6	0.00035	0.025	70
13.00	10.00	1331.76	224.08	6	0.00039	0.025	63
14.00	11.00	1360.07	243.56	6	0.00044	0.025	57
15.00	12.00	1388.30	263.05	5	0.00048	0.025	51
16.00	13.00	1416.41	282.53	5	0.00053	0.025	46
17.00	14.00	1444.37	302.02	5	0.00059	0.025	42
18.00	15.00	1472.13	321.50	5	0.00065	0.025	38
19.00	16.00	1499.64	340.99	4	0.00071	0.025	35
20.00	17.00	1526.88	360.47	4	0.00077	0.025	32
21.00	18.00	1553.80	379.96	4	0.00084	0.025	29
22.00	19.00	1580.36	399.44	4	0.00092	0.025	27
23.00	20.00	1606.53	418.93	4	0.00100	0.025	25
24.00	21.00	1632.27	438.41	4	0.00108	0.025	23
25.00	22.00	1657.55	457.90	4	0.00116	0.025	21

Conclusions

The buckling potential, as calculated with the Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications is very low, as shown by the safety factor in the table.

PVC Material Information

PVC Pipe ID	60.000	inch
Wall Thickness	1.208	inch
I of Wall	0.147	Inch^4/in
Material Modulus	352000.000	psi
Poisson Ratio	0.334	
Tensile Strength	880.000	psi
Comp. strength	3520.000	psi
axial strain limit	0.035	
ring strain limit	0.050	

Soil Information

soil dry density	120.000	lbf/sq.f
soil sat. density	135.000	lbf/sq.f
soil intet.friction angle	30.000	
friction coefficient	0.400	
Soil Modulus	1000.000	psi,E'
active Earth pres. Coe.	0.333	

Other

Critical R.T,Dry	2607.867	lbf/in
Critcal Axial Strain	0.024	
H20 wheel load	16000	lbs

Design Calculation Sheet For 60" PVC Manhole Riser - TEMPERATURE DE-RATED

Considerations and Assumptions to ASTM F 1759-97 (2004)

1. Dry soil and Satuated soil conditions
2. H20 live load
3. Soil modulus 1000 psi
4. Backfill Width 24" minimum.
5. Ring Thrust Compression and Bending
6. Axial soil down drag load
7. PVC Pipe Material to *"Hand Book of PVC PIPE DESIGN AND CONSTRUCTION", 5TH*
7. PVC Pipe Material strengh properties reduced to 88% for a potential 80 degree temperature

Note: Cells in yellow are the input variables. Outputs are the safety factors which are reflecting the performance of Pipe Ring Deformation, Ring Stress, Axial Deformation respectively. All safety factors should be greater than 2 except Bouyancy effect.

Calculation Sheet

Manhole Depth	PVC Length	Dry radial Pres.	Wet.radial Pres.	Down Drag Load	D.D. Force	R.T. Stress	R. B. Stress	Strain of T+B	Strain of Axial	C.R.T Stress	Safety Factor Index			
ft	ft	lb/sf	lbf/sf	lbf/sf	lbs	lbf/in	lbf/in	%	%	lbf/in	Ring Deform.	Ring Stess	Axial Deform.	Bouyancy effect
4.00	1.00	121.00	229.21	27.23	444.87	48.71	14.91	0.029%	0.020%	1013.22	173	21	120	0.8
5.00	2.00	169.40	320.89	38.12	1245.63	68.20	20.87	0.040%	0.021%	1038.79	124	15	115	0.8
6.00	3.00	217.80	412.57	49.01	2402.29	87.68	26.83	0.052%	0.023%	1064.60	96	12	107	0.8
7.00	4.00	266.20	504.25	59.90	3914.85	107.17	32.80	0.064%	0.024%	1090.62	79	10	99	0.9
8.00	5.00	314.60	595.93	70.79	5783.30	126.65	38.76	0.075%	0.027%	1116.81	67	9	91	1.0
9.00	6.00	363.00	687.62	81.68	8007.65	146.14	44.72	0.087%	0.029%	1143.16	58	8	82	1.1
10.00	7.00	411.40	779.30	92.57	10587.89	165.62	50.69	0.098%	0.033%	1169.61	51	7	74	1.2
11.00	8.00	459.80	870.98	103.46	13524.03	185.11	56.65	0.110%	0.036%	1196.15	46	6	67	1.3
12.00	9.00	508.20	962.66	114.35	16816.06	204.59	62.61	0.121%	0.040%	1222.72	41	6	60	1.4
13.00	10.00	556.60	1054.34	125.24	20463.99	224.08	68.58	0.133%	0.045%	1249.31	38	6	54	1.6
14.00	11.00	605.00	1146.03	136.13	24467.81	243.56	74.54	0.144%	0.049%	1275.86	35	5	49	1.7
15.00	12.00	653.40	1237.71	147.02	28827.53	263.05	80.50	0.156%	0.055%	1302.34	32	5	44	1.8
16.00	13.00	701.80	1329.39	157.91	33543.15	282.53	86.47	0.167%	0.061%	1328.71	30	5	40	2.0
17.00	14.00	750.20	1421.07	168.80	38614.66	302.02	92.43	0.179%	0.067%	1354.94	28	4	36	2.1
18.00	15.00	798.60	1512.75	179.69	44042.06	321.50	98.39	0.191%	0.073%	1380.98	26	4	33	2.2
19.00	16.00	847.00	1604.44	190.58	49825.36	340.99	104.36	0.202%	0.081%	1406.79	25	4	30	2.4
20.00	17.00	895.40	1696.12	201.47	55964.56	360.47	110.32	0.214%	0.088%	1432.34	23	4	27	2.5
21.00	18.00	943.80	1787.80	212.36	62459.65	379.96	116.28	0.225%	0.096%	1457.60	22	4	25	2.6
22.00	19.00	992.20	1879.48	223.25	69310.64	399.44	122.25	0.237%	0.104%	1482.51	21	4	23	2.8
23.00	20.00	1040.60	1971.16	234.14	76517.52	418.93	128.21	0.248%	0.113%	1507.06	20	4	21	2.9
24.00	21.00	1089.00	2062.85	245.03	84080.30	438.41	134.17	0.260%	0.122%	1531.21	19	3	20	3.1
25.00	22.00	1137.40	2154.53	255.92	91998.97	457.90	140.13	0.271%	0.132%	1554.92	18	3	18	3.2

D.D.FORCE: *Down Drag Force*
R.T.Stress: *Ring Thrust stress*
R.B.Stress: *Ring bending Stress*
Stain of T+B: *Combine strain of Ring Thrust and Bending*
C.R.T Stress: *Critical Ring Thrust Stress*
Counter weight (base and lid) *3500lbs*

EXPIRES 9/20/2020

BUCKLING CALCULATION PVC RISER- TEMPERATURE DERATED

*Values used in this calculation are from Design Calculation Sheet for PVC Riser-Temperature Derated

h properties reduced to 88% for a poter

PVC Material Information	
PVC Pipe ID	60.000
Wall Thickness	1.208
I of Wall	0.147
Material Modulus	352000.000
Poisson Ratio	0.334
Tensile Strength	1000.000
Comp. strength	4000.000
axial strain limit	**0.035**

ring strain limit 0.05

EXPIRES 9/20/2020

Other	
Critical R.T,Dry	**2607.867**
Critical Axial Strain at axial	0.02418123

H20 wheel load 16000

		Ring Buckling			**Axial Buckling**		
Manhole Depth	PVC Length	Critical .Ring Trust	Ring Trust stress	Safety Factor	Axial Strain	Critical Axial Strain	Safety Factor
ft	ft	lbf/in	lbf/in		in/in	in/in	
4.00	1.00	1013.22	48.71	21	0.00020	0.024	120
5.00	2.00	1038.79	68.20	15	0.00021	0.024	115
6.00	3.00	1064.60	87.68	12	0.00023	0.024	107
7.00	4.00	1090.62	107.17	10	0.00024	0.024	99
8.00	5.00	1116.81	126.65	9	0.00027	0.024	91
9.00	6.00	1143.16	146.14	8	0.00029	0.024	82
10.00	7.00	1169.61	165.62	7	0.00033	0.024	74
11.00	8.00	1196.15	185.11	6	0.00036	0.024	67
12.00	9.00	1222.72	204.59	6	0.00040	0.024	60
13.00	10.00	1249.31	224.08	6	0.00045	0.024	54
14.00	11.00	1275.86	243.56	5	0.00049	0.024	49
15.00	12.00	1302.34	263.05	5	0.00055	0.024	44
16.00	13.00	1328.71	282.53	5	0.00061	0.024	40
17.00	14.00	1354.94	302.02	4	0.00067	0.024	36
18.00	15.00	1380.98	321.50	4	0.00073	0.024	33
19.00	16.00	1406.79	340.99	4	0.00081	0.024	30
20.00	17.00	1432.34	360.47	4	0.00088	0.024	27
21.00	18.00	1457.60	379.96	4	0.00096	0.024	25
22.00	19.00	1482.51	399.44	4	0.00104	0.024	23
23.00	20.00	1507.06	418.93	4	0.00113	0.024	21
24.00	21.00	1531.21	438.41	3	0.00122	0.024	20
25.00	22.00	1554.92	457.90	3	0.00132	0.024	18

PERFORMANCE LIM	CRITERIA	REFERENCE
Ring Buckling	If the ring compressive thrust stress ε	ASTM F 1759-97 (2004)
Axial Buckling	The critical axial strain at axial buckling > Axial Strair	ASTM F 1759-97 (2004)

Temperature Derating considerations

Background

This submittal is to address the request to assess the temperature effects or derating on the PREDL's Hybrid PVC Manhole System.

The author considers the subject a very specialized one given the application in question: a sewer manhole, and could not find any directly related published study or testing standard on the matter.

Given the above statements, the approach of the assessment is to first analyze the potential site conditions of the manhole installation in relation to temperature and then consider the potential effects.

Content/Review

The PREDL's Hybrid PVC Manhole for the Old Nogales Interceptor/Aerospace Corridor could be potentially exposed to soil with temperatures classified as Thermic by the NRCS, see Figure 3 Soil Temperature Regimes. The mean annual soil temperature is 60° F or higher but lower than 72° F, and the difference between mean summer and mean winter soil temperatures is more than 43° F either at a depth of 20 in. from the soil surface.
Other potential condition of the manhole installation could be contact with shallow groundwater which could be around 72° F, see Figure 2 Ground Water Temperature.
Additionally, the PREDL's Hybrid PVC Manhole could be exposed to typic ustic (Semiarid climate) or udict ustic (Humid or subhumid) climate soil moisture conditions which could affect the temperature conditions.

The manhole components with potential adverse effect to temperature could be the PVC pipe wall/barrel and the seals but given that the potential temperatures of the installation site (Nogales / Santa Cruz County) area should be below 80° F the published threshold to initiate derating or pressure pipe, temperature should not affect the manhole and there is no need to de-rate for temperature, see Figure 4 Thermal de-rating of PVC pipe, special attention to notes 3 and 4 shown below

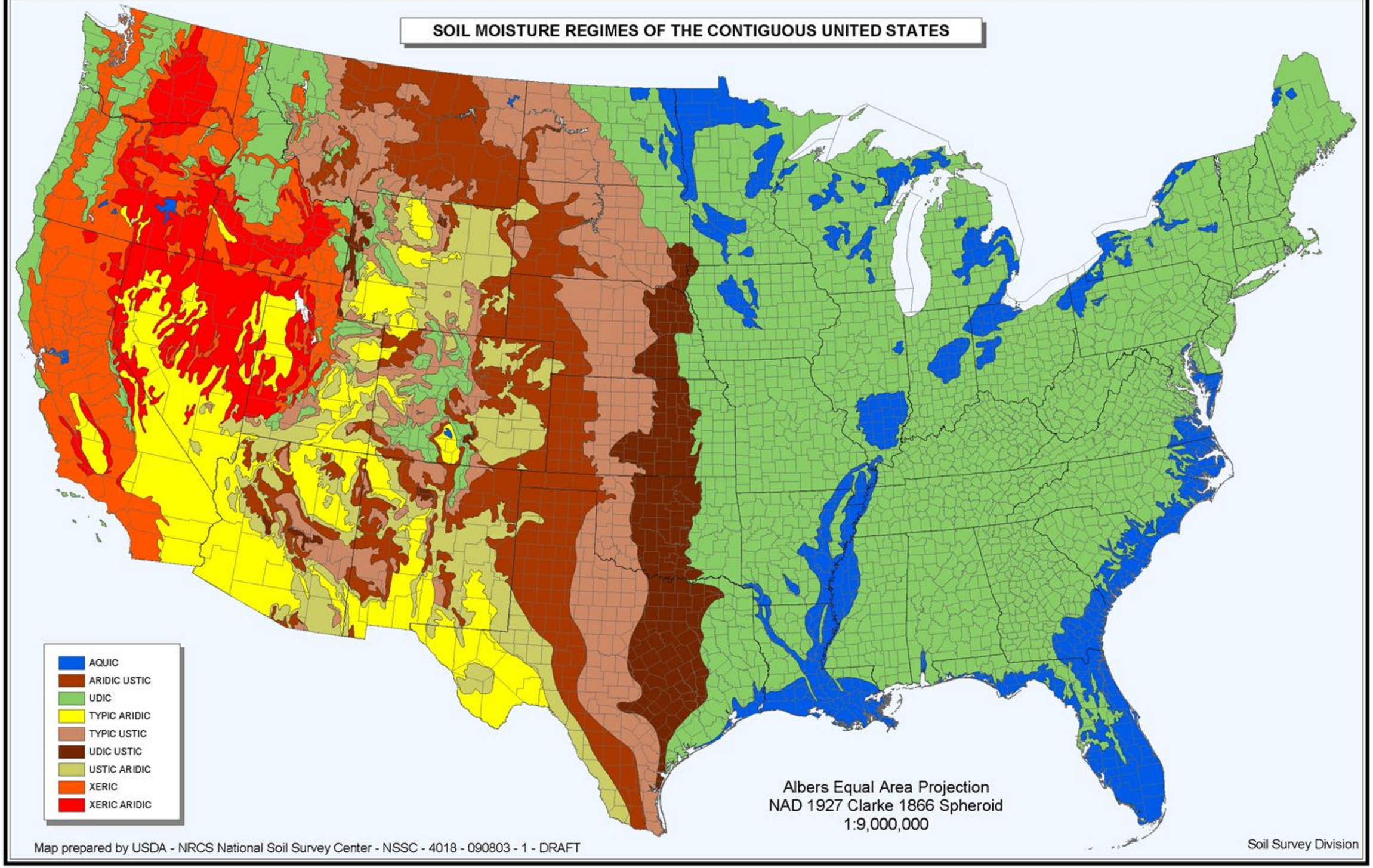
> "*3. Pipe gaskets are generally suitable for continuous use in water at the temperatures listed above.*
> *4. The de-rating factors assume sustained elevated service temperatures. When the contents of a buried PVC pressure pipe are only intermittently and temporarily raised above the service temperature shown, derating may not be needed*"
> Handbook of PVC Pipe Design and Construction 5th edition.

Note that this assessment is specific to the application/installation and summarizes empirically from interpolation of extreme pressure situations to moderate cases. If different conditions are expected such as high thermal effluents from process plants or other extreme conditions, temperature derating might be necessary.

Conclusions

The PREDL PVC manhole is a good in relationship to temperature effects for the proposed installation.

Alonso Vidal, P.E.



SOIL MOISTURE REGIMES OF THE CONTIGUOUS UNITED STATES

Figure 1 Soils Moisture Regimes

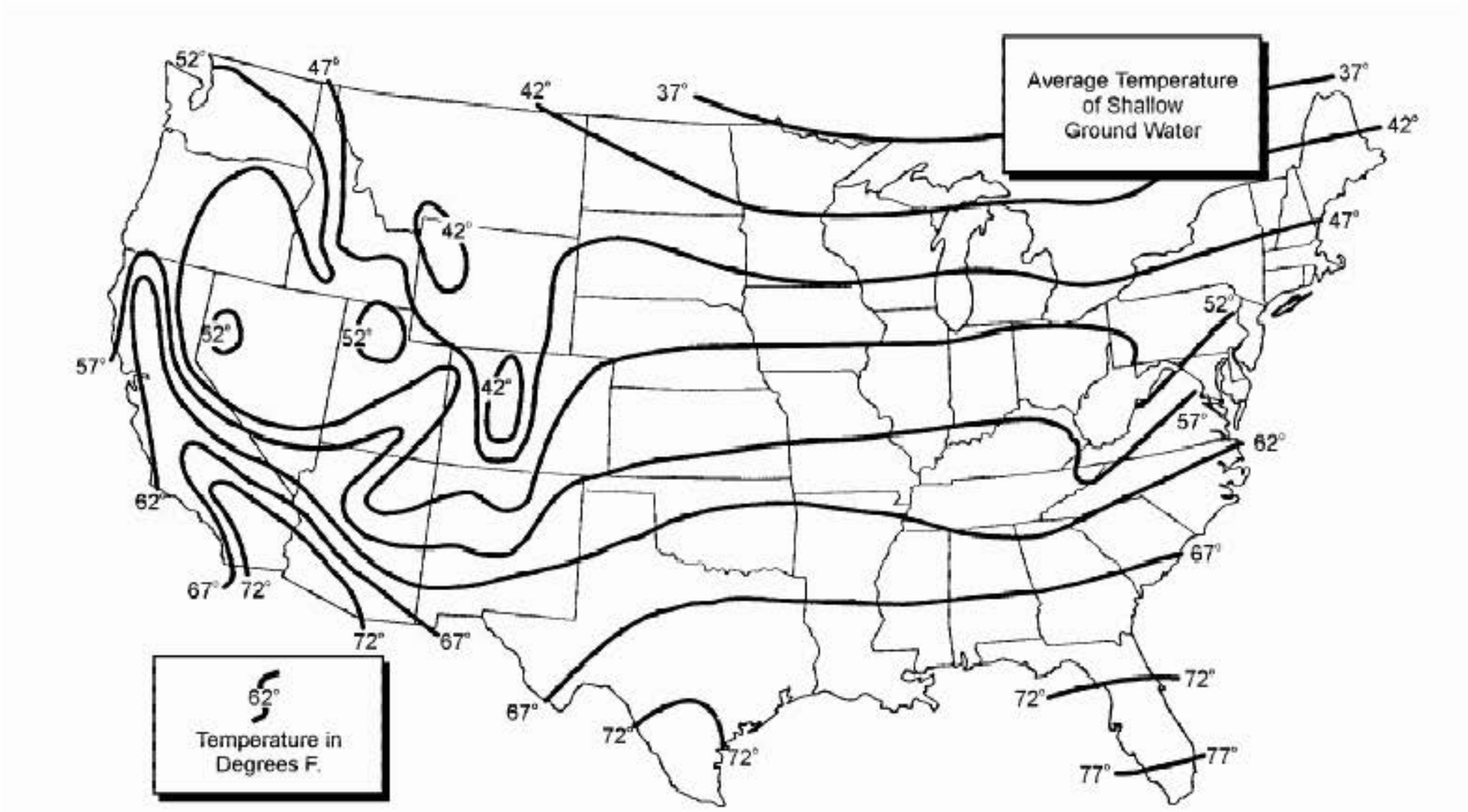


Figure 2 Ground Water Temperature

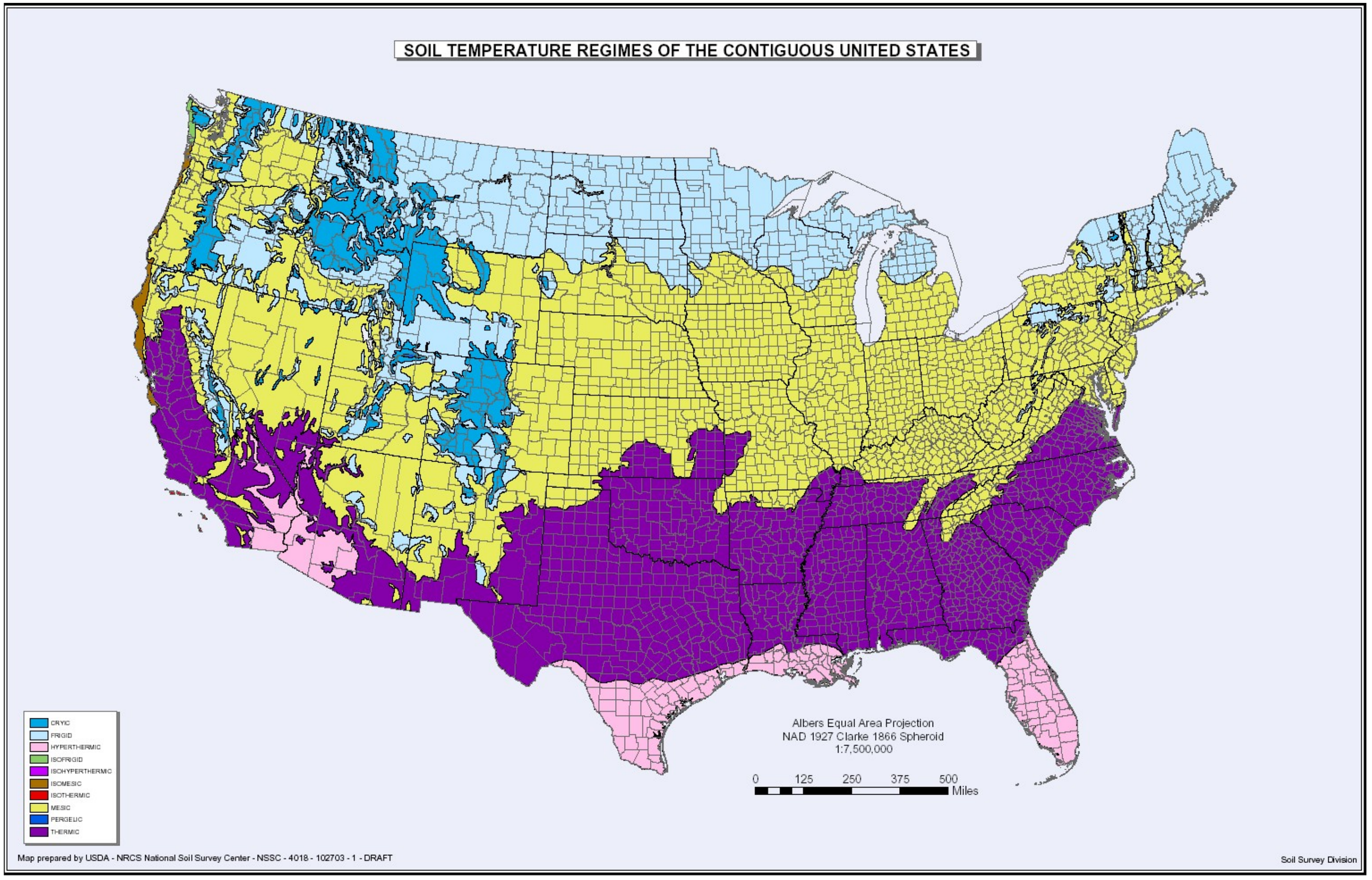


Figure 4 Thermal de-rating of PVC pipe

Table 5.3 Thermal de-rating factors for PVC pressure pipes and fittings

Maximum service temperature °F (°C)	Multiply pressure class (PC) at 73.4°F (23°C) by factor shown
80 (27)	0.88
90 (32)	0.75
100 (38)	0.62
110(43)	0.50
120 (49)	0.40
130(54)	0.30
140(60)	0.22

Notes:

1. The maximum recommended sustained temperature for the wall of PVC pressure pipe and fittings is MOT (60°C).

. Interpolate between the temperatures listed to calculate other factors.

. Pipe gaskets are generally suitable for continuous use in water at the temperatures listed above.

4. The de-rating factors assume sustained elevated service temperatures. When the contents of a buried PVC pressure pipe are only intermittently and temporarily raised above the service temperature shown, de-rating may not be needed.

MEMORANDUM

To: Jed Friesen, PREDL Systems.
From: Alonso Vidal, P.E. Bowman Consulting
Date: August 9, 2018
Subject: 3ASC Phase 1 Submittal 27 Predl PVC Riser Test Manhole response – item 9 Clarification on deflections

Background

In response to the request to clarify the deflections in term of axial vs. radial.

Content/Review

The submittal contains several direct and indirect calls for deflection, to clarify we offer the following:

- Deflections in the burial depth table are all vertical-axial with pipe laying horizontal. This table is presented as an attachment of the Submittal Memo*.
- Deflection in the Manhole tests are a labeled, vertical. The manhole test are part of the attachments of the Submittal Memo*.
- The design calculation table contains elastic strain (or deflections) in both axial and radial (vertical and horizontal). This is a table also attached to the Submittal Memo* with reference to ASTM

*Revised Submittal (1) - PREDL Systems Hybrid PVC Manhole System Alternate Material for Proposed Manhole #63, Phase 1-Old Nogales Interceptor/Aerospace Corridor and Park Avenue Relief Sewer Augmentation. Revision to include 60" manhole and temperature derating.

Conclusions

Not applicable