CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 88 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 4/13/2020 Page 8	AFT Fathom Model	

Valve	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
7								
10								
17								
18								

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 89 of 180
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Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 4/13/2020 Page 1	AFT Fathom Model	

Model Reference Information

General

Title: AFT Fathom Model
Analysis run on: 4/13/2020 10:36:42 AM
Application version: AFT Fathom Version 10 (2018.05.21)
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\VV Files\LERF TransferRev0.fth
Scenario: Base Scenario/Run 2/Low Basin Level High DP
Output File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\VV Files\LERF TransferRev0_F1.out

Execution Time= 0.27 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 91
Total Number Of Temperature Iterations= 0
Number Of Pipes= 27
Number Of Junctions= 27
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300
Total Inflow= 84.08 gal/min
Total Outflow= 84.08 gal/min
Maximum Static Pressure is 102.3 psia at Pipe 50 Inlet
Minimum Static Pressure is 1.918 psia at Pipe 56 Inlet

Warnings

No Warnings

Applied Standards

===== ANSI/HI 9.6.3-2017 - Rotodynamic Pumps - Guideline for Operating Regions =====
Pump 5 set to specific speed <=4500 (US Customary), with lower POR 70% and upper POR 120% of BEP

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 90 of 180
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AFT Fathom 10 (Output) 4/13/2020 Page 2	AFT Fathom Model	

Pump Summary

Jct	Results Diagram	Name	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)
5	Show	Pump	84.08	11.68	87.68	202.4	N/A	100.0	4.300	N/A	N/A	N/A

Jct	NPSHR (feet)
5	N/A

Valve Summary

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Static In (psia)	Cv	K
7	Valve	REGULAR	84.08	11.68	0.023088	0.053302	87.63	553.4	0.7638
10	Valve	REGULAR	84.08	11.68	0.023731	0.054785	86.63	545.8	0.7650
X17	60M-43B	REGULAR	0.00	0.00	N/A	N/A	86.61	N/A	N/A
18	60M-43A	REGULAR	84.08	11.68	0.001221	0.002820	86.61	2,405.8	0.6300
56	Control Valve	FCV	84.08	11.68	0.036971	0.085351	87.68	437.3	1.2231
63 [P5]	Three Way Valve	THREE-WAY	84.08	11.68	0.022463	0.051859	87.61	561.0	0.7241
X63 [P55]	Three Way Valve	THREE-WAY	0.00	0.00	N/A	N/A	87.61	N/A	N/A

Jct	Valve State
7	Open
10	Open
X17	Closed By User
18	Open
56	Opened By User
63 [P5]	Open
X63 [P55]	Closed By User

Pipe Output Table

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
2	Pipe	84.08	8.0391	89.252	87.514	605.5	605.5	1.73839211	1.73839211	0.0000
3	Pipe	84.08	2.1190	87.684	87.679	605.5	605.5	0.00506283	0.00506283	0.0000
5	Pipe	84.08	2.1467	87.567	86.634	605.5	606.0	0.93272644	0.93272644	0.2166
10	Pipe	84.08	0.5367	86.639	86.613	606.0	606.0	0.02657444	0.02657444	0.0000
12	Pipe	0.00	0.0000	86.615	86.615	606.0	606.0	0.00000000	0.00000000	0.0000

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 91 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
4/13/2020
Page 3

AFT Fathom Model

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
2	4.0132821	89.252	87.514	89.687	87.949
3	0.0116881	87.684	87.679	87.714	87.709
5	1.6533084	87.567	86.634	87.598	86.665
10	0.0613502	86.639	86.613	86.641	86.615
12	0.0000000	86.615	86.615	86.615	86.615

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
13	Pipe	0.00	0.0000	86.615	86.615	606.0	606.0	0.00000000	0.00000000	0.0000
14	Pipe	84.08	0.5367	86.613	86.613	606.0	606.0	0.00006694	0.00006694	0.0000
28	Pipe	84.08	2.1467	86.516	78.967	606.0	623.3	7.54907915	7.54907915	7.4937
29	Pipe	84.08	2.1467	83.567	78.957	623.3	606.0	-4.60995993	-4.60995993	-7.4937
32	Pipe	0.00	0.0000	83.225	75.731	606.0	623.3	7.49365768	7.49365768	7.4937
33	Pipe	84.08	3.2319	102.303	102.298	576.6	576.6	0.00546056	0.00546056	0.0000
36	Pipe	84.08	2.1467	86.540	86.527	606.0	606.0	0.01293168	0.01293168	0.0000
38	Pipe	84.08	3.6490	83.497	75.855	606.0	623.3	7.64128353	7.64128353	7.4937
39	Pipe	84.08	3.6490	75.823	75.749	623.3	623.3	0.07381292	0.07381292	0.0000
41	Pipe	0.00	0.0000	75.731	75.731	623.3	623.3	0.00000000	0.00000000	0.0000
44	Pipe	84.08	3.6490	14.696	9.037	623.3	609.0	-5.65941897	-5.65941897	-6.1942
45	Pipe	84.08	3.6490	75.642	75.240	623.3	623.3	0.40145639	0.40145639	0.0000
47	Pipe	84.08	8.0391	74.822	74.399	623.3	623.3	0.42290375	0.42290375	0.0000
48	Pipe	84.08	8.0391	14.399	13.976	623.3	623.3	0.42290375	0.42290375	0.0000
49	Pipe	84.08	3.6490	14.193	13.933	623.3	623.3	0.26013687	0.26013687	0.0000
50	Pipe	84.08	2.1190	102.329	100.847	576.6	580.0	1.48238796	1.48238796	1.4728
51	Pipe	84.08	1.8926	100.853	89.663	580.0	605.5	11.19003338	11.19003338	11.0456
52	Pipe	84.08	2.1190	87.642	87.632	605.5	605.5	0.00963438	0.00963438	0.0000
54	Pipe	84.08	2.1190	87.609	87.590	605.5	605.5	0.01926875	0.01926875	0.0000
55	Pipe	0.00	0.0000	1.918	1.918	605.5	605.5	0.00000000	0.00000000	0.0000
56	Pipe	0.00	0.0000	14.696	1.918	605.5	576.0	-12.77821141	-12.77821141	-12.7782
58	Pipe	84.08	0.5367	86.611	86.576	606.0	606.0	0.03546957	0.03546957	0.0000

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 92 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
4/13/2020
Page 4

AFT Fathom Model

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
13	0.0000000	86.615	86.615	86.615	86.615
14	0.0001545	86.613	86.613	86.615	86.614
28	0.1279470	86.516	78.967	86.547	78.998
29	6.6573545	78.957	83.567	78.988	83.598
32	0.0000000	83.225	75.731	83.225	75.731
33	0.0126063	102.303	102.298	102.373	102.368
36	0.0298543	86.540	86.527	86.571	86.558
38	0.3408116	83.497	75.855	83.586	75.945
39	0.1704058	75.823	75.749	75.913	75.839
41	0.0000000	75.731	75.731	75.731	75.731
44	1.2345552	9.037	14.696	9.126	14.786
45	0.9268092	75.642	75.240	75.731	75.330
47	0.9763229	74.822	74.399	75.257	74.834
48	0.9763229	14.399	13.976	14.834	14.411
49	0.6005565	14.193	13.933	14.282	14.022
50	0.0222421	102.329	100.847	102.360	100.877
51	0.3335047	100.853	89.663	100.877	89.687
52	0.0222421	87.642	87.632	87.672	87.662
54	0.0444842	87.609	87.590	87.639	87.620
55	0.0000000	1.918	1.918	1.918	1.918
56	0.0000000	1.918	14.696	1.918	14.696
58	0.0818857	86.611	86.576	86.613	86.578

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
5	Pump	14.626	102.303	14.696	102.373	84.08	11.68	0.0000
7	Valve	87.632	87.609	87.662	87.639	84.08	11.68	0.7638
10	Valve	86.634	86.639	86.665	86.641	84.08	11.68	0.7650
15	Tee or Wye	86.614	86.614	86.615	86.615	N/A	N/A	See Mult. Losses
16	Area Change	86.615	86.615	86.615	86.615	0.00	0.00	0.0000
X17	60M-43B	86.615	83.225	86.615	83.225	0.00	0.00	0.0000
18	60M-43A	86.613	86.611	86.614	86.613	84.08	11.68	0.6300
31	Bend	86.527	86.516	86.558	86.547	84.08	11.68	0.3400
32	Bend	78.967	78.957	78.998	78.988	84.08	11.68	0.3400
35	Area Change	102.298	102.329	102.368	102.360	84.08	11.68	0.1180
37	Area Change	86.576	86.540	86.578	86.571	84.08	11.68	3.6738
38	Area Change	83.567	83.497	83.598	83.586	84.08	11.68	0.3642
39	Area Change	75.731	75.731	75.731	75.731	0.00	0.00	0.0000

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 93 of 180
Title: Leachate and Basin Pump Flow Calculation			
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AFT Fathom 10 (Output)
4/13/2020
Page 5

AFT Fathom Model

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
40	Tee or Wye	75.692	75.692	75.731	75.731	N/A	N/A	See Mult. Losses
42	Bend	75.855	75.823	75.945	75.913	84.08	11.68	0.3586
47	Assigned Pressure	14.696	14.606	14.786	14.696	84.08	11.68	1.0000
49	General Component	74.399	14.399	74.834	14.834	84.08	11.68	137.9188
50	Area Change	75.240	74.822	75.330	75.257	84.08	11.68	0.8114
51	Area Change	13.976	14.193	14.411	14.282	84.08	11.68	0.2967
54	Orifice	13.933	9.037	14.022	9.126	84.08	11.68	54.6231
56	Control Valve	87.679	87.642	87.709	87.672	84.08	11.68	1.2231
59	Branch	89.663	89.252	89.687	89.687	84.08	11.68	0.0000
60	Branch	100.847	100.853	100.877	100.877	84.08	11.68	0.0000
61	Area Change	87.514	87.684	87.949	87.714	84.08	11.68	0.5396
63	Three Way Valve	87.606	87.606	87.620	87.620	N/A	N/A	See Mult. Losses
64	Bend	1.918	1.918	1.918	1.918	0.00	0.00	0.0000
65	Assigned Pressure	14.696	14.696	14.696	14.696	0.00	0.00	0.0000

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 94 of 180
Title: Leachate and Basin Pump Flow Calculation			
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LOW BASIN LEVEL/HIGH OPERATING FILTER DP

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 95 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 4/13/2020 Page 1	AFT Fathom Model	

General

Title: AFT Fathom Model
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\VV Files\LERF TransferRev0.fth
Scenario: Base Scenario/Run 2/Low Basin Level High Operating DP

Number Of Pipes= 27
Number Of Junctions= 27

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Pipes

Pipe	Name	Pipe Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam. Units	Friction Data Set	Roughness	Roughness Units	Losses (K)
2	Pipe	Yes	30	feet	2.067	inches	Standard	0.0018	inches	0.301856
3	Pipe	Yes	2	feet	4.026	inches	Standard	0.0018	inches	0.04
5	Pipe	Yes	378	feet	4	inches	Unspecified	0.000204	inches	0.5749724
10	Pipe	Yes	350	feet	8	inches	Unspecified	0.000204	inches	1.622009
12	Pipe	Yes	2	feet	8	inches	Unspecified	0.000204	inches	0
13	Pipe	Yes	1	feet	8	inches	Unspecified	0.000204	inches	0
14	Pipe	Yes	1	feet	8	inches	Unspecified	0.000204	inches	0
28	Pipe	Yes	30	feet	4	inches	Unspecified	0.000204	inches	0
29	Pipe	Yes	1521	feet	4	inches	Unspecified	0.000204	inches	2.38
32	Pipe	Yes	1221	feet	3	inches	Unspecified	0.000204	inches	4.702397
33	Pipe	Yes	1	feet	3.26	inches	Standard	0.0018	inches	0
36	Pipe	Yes	7	feet	4	inches	Unspecified	0.000204	inches	0
38	Pipe	Yes	20	feet	3.068	inches	Standard	0.0018	inches	0

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 96 of 180
Title: Leachate and Basin Pump Flow Calculation			
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AFT Fathom 10 (Model)
4/13/2020
Page 2

AFT Fathom Model

Pipe	Initial Flow	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Size	Type	Special Condition
2			59, 61	Cylindrical Pipe	Steel - ANSI	2 inch	schedule 40	None
3			61, 56	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
5			63, 10	Cylindrical Pipe	User Specified			None
10			10, 15	Cylindrical Pipe	User Specified			None
12			15, 16	Cylindrical Pipe	User Specified			None
13			16, 17	Cylindrical Pipe	User Specified			None
14			15, 18	Cylindrical Pipe	User Specified			None
28			31, 32	Cylindrical Pipe	User Specified			None
29			32, 38	Cylindrical Pipe	User Specified			None
32			17, 39	Cylindrical Pipe	User Specified			None
33			5, 35	Cylindrical Pipe	Steel - ANSI	3 inch	Schedule 10	None
36			37, 31	Cylindrical Pipe	User Specified			None
38			38, 42	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None

Pipe	Name	Pipe Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam. Units	Friction Data Set	Roughness	Roughness Units	Losses (K)
39	Pipe	Yes	10	feet	3.068	inches	Standard	0.0018	inches	0
41	Pipe	Yes	15	feet	2.067	inches	Standard	0.0018	inches	0.8678359
44	Pipe	Yes	50	feet	3.068	inches	Standard	0.0018	inches	2.606288
45	Pipe	Yes	30	feet	3.068	inches	Standard	0.0018	inches	2.008384
47	Pipe	Yes	1	feet	2.067	inches	Standard	0.0018	inches	0.8489699
48	Pipe	Yes	1	feet	2.067	inches	Standard	0.0018	inches	0.8489699
49	Pipe	Yes	20	feet	3.068	inches	Standard	0.0018	inches	1.25524
50	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
51	Pipe	Yes	98.93	feet	4.26	inches	Standard	0.0018	inches	0
52	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
54	Pipe	Yes	10	feet	4.026	inches	Standard	0.0018	inches	0
55	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
56	Pipe	Yes	46	feet	4.026	inches	Standard	0.0018	inches	0.4752721
58	Pipe	Yes	350	feet	8	inches	Unspecified	0.000204	inches	6.21

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 97 of 180
Title: Leachate and Basin Pump Flow Calculation			
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AFT Fathom 10 (Model)
4/13/2020
Page 3

AFT Fathom Model

Pipe	Initial Flow	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Size	Type	Special Condition
39			42, 40	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None
41			39, 40	Cylindrical Pipe	Steel - ANSI	2 inch	STD (schedule 40)	None
44			54, 47	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None
45			40, 50	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None
47			50, 49	Cylindrical Pipe	Steel - ANSI	2 inch	STD (schedule 40)	None
48			49, 51	Cylindrical Pipe	Steel - ANSI	2 inch	STD (schedule 40)	None
49			51, 54	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None
50			35, 60	Cylindrical Pipe	Steel - ANSI	4 inch	STD (schedule 40)	None
51			60, 59	Cylindrical Pipe	Steel - ANSI	4 inch	Schedule 10	None
52			56, 7	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
54			7, 63	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
55			63, 64	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
56			64, 65	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
58			18, 37	Cylindrical Pipe	User Specified			None

Pipe Fittings & Losses

Pipe	Total K	Elbow/Bend Standard Threaded	Elbow/Bend Smooth Flanged	Valve Butterfly	Valve Plug	Other Tee
2	0.3	1 (0.3)				
3	0.04					1 (0.04)
5	0.57		3 (0.57)			
10	1.62		3 (0.48)			2 (1.14)
29	2.38		7 (2.38)			
32	4.7		8 (1.94)	2 (1.62)		2 (1.14)
41	0.87		2 (0.53)		1 (0.34)	
44	2.61		6 (1.51)			1 (1.1)
45	2.01		8 (2.01)			
47	0.85			1 (0.85)		
48	0.85			1 (0.85)		
49	1.26		5 (1.26)			
56	0.48		2 (0.48)			
58	6.21		10 (1.96)	3 (1.89)		6 (2.36)

Area Change Table

Area Change	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type
16	Area Change	Yes	606	feet				Conical
35	Area Change	Yes	576.6	feet				Conical
37	Area Change	Yes	606	feet				Conical

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 98 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
4/13/2020
Page 4

AFT Fathom Model

Area Change	Geometry	Angle	Loss Factor
16	Expansion	45	0
35	Expansion	45	0.1179652
37	Contraction	45	3.673761

Area Change	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type
38	Area Change	Yes	606	feet				Conical
39	Area Change	Yes	623.3	feet				Conical
50	Area Change	Yes	623.3	feet				Conical
51	Area Change	Yes	623.3	feet				Conical
61	Area Change	Yes	605.5	feet				Conical

Area Change	Geometry	Angle	Loss Factor
38	Contraction	45	0.3642007
39	Contraction	45	0.7135802
50	Contraction	45	0.8114334
51	Expansion	45	0.2967157
61	Expansion	45	0.5395717

Assigned Pressure Table

Assigned Pressure	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
47	Assigned Pressure	Yes	609	feet	1.000	atm	
65	Assigned Pressure	Yes	576	feet	1.000	atm	

Assigned Pressure	Pressure	Pressure Units	Pressure Type	Balance Energy	Balance Concentration	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out
47	1	atm	Stagnation	No	No	(P44) 0, 1		
65	1	atm	Stagnation	No	No	(P56) 0, 1		

Assigned Pressure	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out
47								
65								

Assigned Pressure	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out
47								
65								

Assigned Pressure	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
47						
65						

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 99 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 4/13/2020 Page 5	AFT Fathom Model	

Bend Table

Bend	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type	Angle (Degrees)	R/D
31	Bend	Yes	606	feet				Smooth Bend	90	1
32	Bend	Yes	623.3	feet				Smooth Bend	90	1
42	Bend	Yes	623.3	feet				Smooth Bend	90	1
64	Bend	Yes	605.5	feet				Smooth Bend	90	1.5

Bend	Loss Factor
31	0.34
32	0.34
42	0.35864
64	0.237636

Branch Table

Branch	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Boundary Flow (+ = in/- = out)
59	Branch	Yes	605.5	feet				None	
60	Branch	Yes	580	feet				None	

Branch	Boundary Flow Units	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out
59		(P2) 0, 0	(P51) 0, 0					
60		(P50) 0, 0	(P51) 0, 0					

Branch	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out
59									
60									

Branch	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
59									
60									

Control Valve Table

Control Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
56	Control Valve	Yes	605.5	feet			

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 100 of 180
Title: Leachate and Basin Pump Flow Calculation			
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AFT Fathom 10 (Model)
4/13/2020
Page 6

AFT Fathom Model

Control Valve	Special Condition	Valve Type	Control Setting	Control Units	Pressure/ Head Type	Inlet Failure Type	Outlet Failure Type	Full Open Loss Type
56	Fully Open - No Control	FCV	10	gal/min	N/A	Fully Open	N/A	Cv Table

Control Valve	Full Open Loss
56	437.29

General Component Table

General Component	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
49	General Component	Yes	623.3	feet			

General Component	Special Condition	Loss Model	Loss Value	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units
49	None	Resistance Curve	Variable	Vol. Flow Rate	gal/min	Pressure Loss	psid

General Component	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
49	40	0	0	0	0

Orifice Table

Orifice	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Orifice Type	Flow Area Type
54	Orifice	Yes	623.3	feet				Sharp-Edged	Diameter

Orifice	Dimension	Dimension Units	R/D	Restricted Area	Restricted Area Units	Loss Model	Loss Value	Independent Variable	Ind. Variable Units
54	1.361	inches				K Constant	54.62305		

Orifice	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
54							

Pump Table

Pump	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Pump Type
5	Pump	Yes	576.6	feet				None	Pump Curve

Pump	Design Flow Rate	Design Flow Rate Units	Current Configuration	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Pump Curve Constant a
5				Vol. Flow Rate	gal/min	Head Rise	feet	221.5061

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 101 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
4/13/2020
Page 7

AFT Fathom Model

Pump	Pump Curve Constant b	Pump Curve Constant c	Pump Curve Constant d	Pump Curve Constant e	Runout Flow Rate	Runout Flow Rate Units	Speed	Control When Exceeded Only
5	-0.03898634	-0.002236957	0	0			100	

Pump	Heat Added To Fluid	Heat Added Units	Submerged Pump Pressure	Submerged Pump Pressure Units
5	0	Percent	576.6	feet

Tee or Wye Table

Tee or Wye	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Tee/Wye Type
15	Tee or Wye	Yes	606	feet				Sharp Straight
40	Tee or Wye	Yes	623.3	feet				Sharp Straight

Tee or Wye	Loss Type	Angle	Pipes A, B, C
15	Detailed	90	14, 10, 12
40	Detailed	90	39, 41, 45

Three Way Valve Table

Three Way Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
63	Three Way Valve	Yes	605.5	feet			

Three Way Valve	Special Condition	Loss Model	Percent Open	Cv Pipe #1	Cv Pipe #2
63	Pipe #2 Closed	Cv	100	561	0

Valve Table

Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Exit Valve	Exit Pressure
7	Valve	Yes	605.5	feet				None	No	
10	Valve	Yes	606	feet				None	No	
17	60M-43B	Yes	606	feet				Closed	No	
18	60M-43A	Yes	606	feet				None	No	

Valve	Exit Pressure Units	Restricted Area	Restricted Area Units	Loss Model	Loss Source	Loss Factor	Percent Open	Open Pct. Data Exists	Independent Variable
7				K Constant	N/A	0.76383		No	
10				K Constant	N/A	0.765		No	
17				K Constant	N/A	0.63		No	
18				K Constant	N/A	0.63		No	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 102 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 4/13/2020 Page 8	AFT Fathom Model	

Valve	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
7								
10								
17								
18								

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 103 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 4/13/2020 Page 1	AFT Fathom Model	

Model Reference Information

General

Title: AFT Fathom Model
Analysis run on: 4/13/2020 10:36:53 AM
Application version: AFT Fathom Version 10 (2018.05.21)
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\VV Files\LERF TransferRev0.fth
Scenario: Base Scenario/Run 2/Low Basin Level High Operating DP
Output File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\VV Files\LERF TransferRev0_F3.out

Execution Time= 0.10 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 38
Total Number Of Temperature Iterations= 0
Number Of Pipes= 27
Number Of Junctions= 27
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300
Total Inflow= 118.2 gal/min
Total Outflow= 118.2 gal/min
Maximum Static Pressure is 95.02 psia at Pipe 50 Inlet
Minimum Static Pressure is 1.918 psia at Pipe 56 Inlet

Warnings

No Warnings

Applied Standards

===== ANSI/HI 9.6.3-2017 - Rotodynamic Pumps - Guideline for Operating Regions =====
Pump 5 set to specific speed <=4500 (US Customary), with lower POR 70% and upper POR 120% of BEP

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 104 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 4/13/2020 Page 2	AFT Fathom Model	

Pump Summary

Jct	Results Diagram	Name	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)
5	Show	Pump	118.2	16.43	80.41	185.6	N/A	100.0	5.544	N/A	N/A	N/A

Jct	NPSHR (feet)
5	N/A

Valve Summary

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Static In (psia)	Cv	K
7	Valve	REGULAR	118.2	16.43	0.045635	0.105353	78.30	553.4	0.7638
10	Valve	REGULAR	118.2	16.43	0.046905	0.108285	76.63	545.8	0.7650
X17	60M-43B	REGULAR	0.0	0.00	N/A	N/A	76.60	N/A	N/A
18	60M-43A	REGULAR	118.2	16.43	0.002414	0.005573	76.59	2,405.8	0.6300
56	Control Valve	FCV	118.2	16.43	0.073074	0.168700	78.39	437.3	1.2231
63 [P5]	Three Way Valve	THREE-WAY	118.2	16.43	0.044399	0.102501	78.25	561.0	0.7241
X63 [P55]	Three Way Valve	THREE-WAY	0.0	0.00	N/A	N/A	78.25	N/A	N/A

Jct	Valve State
7	Open
10	Open
X17	Closed By User
18	Open
56	Opened By User
63 [P5]	Open
X63 [P55]	Closed By User

Pipe Output Table

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
2	Pipe	118.2	11.3021	81.414	78.062	605.5	605.5	3.3515086	3.3515086	0.0000
3	Pipe	118.2	2.9792	78.399	78.389	605.5	605.5	0.0096261	0.0096261	0.0000
5	Pipe	118.2	3.0180	78.170	76.630	605.5	606.0	1.5394681	1.5394681	0.2166
10	Pipe	118.2	0.7545	76.641	76.592	606.0	606.0	0.0490976	0.0490976	0.0000
12	Pipe	0.0	0.0000	76.596	76.596	606.0	606.0	0.0000000	0.0000000	0.0000

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 105 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
4/13/2020
Page 3

AFT Fathom Model

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
2	7.7373508	81.414	78.062	82.274	78.922
3	0.0222230	78.399	78.389	78.458	78.449
5	3.0540427	78.170	76.630	78.231	76.692
10	0.1133475	76.641	76.592	76.645	76.596
12	0.0000000	76.596	76.596	76.596	76.596

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)
13	Pipe	0.0	0.0000	76.596	76.596	606.0	606.0	0.0000000	0.0000000	0.0000
14	Pipe	118.2	0.7545	76.592	76.592	606.0	606.0	0.0001225	0.0001225	0.0000
28	Pipe	118.2	3.0180	76.406	68.811	606.0	623.3	7.5958509	7.5958509	7.4937
29	Pipe	118.2	3.0180	70.956	68.790	623.3	606.0	-2.1665350	-2.1665350	-7.4937
32	Pipe	0.0	0.0000	70.299	62.806	606.0	623.3	7.4936577	7.4936577	7.4937
33	Pipe	118.2	4.5437	94.969	94.958	576.6	576.6	0.0103313	0.0103313	0.0000
36	Pipe	118.2	3.0180	76.451	76.427	606.0	606.0	0.0238451	0.0238451	0.0000
38	Pipe	118.2	5.1301	70.818	63.045	606.0	623.3	7.7735968	7.7735968	7.4937
39	Pipe	118.2	5.1301	62.981	62.841	623.3	623.3	0.1399695	0.1399695	0.0000
41	Pipe	0.0	0.0000	62.806	62.806	623.3	623.3	0.0000000	0.0000000	0.0000
44	Pipe	118.2	5.1301	14.696	9.608	623.3	609.0	-5.0877765	-5.0877765	-6.1942
45	Pipe	118.2	5.1301	62.628	61.853	623.3	623.3	0.7757195	0.7757195	0.0000
47	Pipe	118.2	11.3021	61.026	60.193	623.3	623.3	0.8330673	0.8330673	0.0000
48	Pipe	118.2	11.3021	20.193	19.360	623.3	623.3	0.8330673	0.8330673	0.0000
49	Pipe	118.2	5.1301	19.788	19.285	623.3	623.3	0.5023209	0.5023209	0.0000
50	Pipe	118.2	2.9792	95.021	93.530	576.6	580.0	1.4908444	1.4908444	1.4728
51	Pipe	118.2	2.6609	93.542	82.226	580.0	605.5	11.3163144	11.3163144	11.0456
52	Pipe	118.2	2.9792	78.316	78.298	605.5	605.5	0.0180908	0.0180908	0.0000
54	Pipe	118.2	2.9792	78.252	78.216	605.5	605.5	0.0361816	0.0361816	0.0000
55	Pipe	0.0	0.0000	1.918	1.918	605.5	605.5	0.0000000	0.0000000	0.0000
56	Pipe	0.0	0.0000	14.696	1.918	605.5	576.0	-12.7782114	-12.7782114	-12.7782
58	Pipe	118.2	0.7545	76.589	76.523	606.0	606.0	0.0666791	0.0666791	0.0000

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 106 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
4/13/2020
Page 4

AFT Fathom Model

Pipe	dH (feet)	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
13	0.0000000	76.596	76.596	76.596	76.596
14	0.0002829	76.592	76.592	76.596	76.596
28	0.2359251	76.406	68.811	76.468	68.872
29	12.2982876	68.790	70.956	68.851	71.018
32	0.0000000	70.299	62.806	70.299	62.806
33	0.0238511	94.969	94.958	95.108	95.097
36	0.0550492	76.451	76.427	76.512	76.489
38	0.6462722	70.818	63.045	70.995	63.222
39	0.3231361	62.981	62.841	63.158	63.018
41	0.0000000	62.806	62.806	62.806	62.806
44	2.5542589	9.608	14.696	9.785	14.873
45	1.7908394	62.628	61.853	62.806	62.030
47	1.9232336	61.026	60.193	61.886	61.053
48	1.9232336	20.193	19.360	21.053	20.220
49	1.1596667	19.788	19.285	19.965	19.463
50	0.0417647	95.021	93.530	95.081	93.590
51	0.6250393	93.542	82.226	93.590	82.274
52	0.0417647	78.316	78.298	78.376	78.357
54	0.0835295	78.252	78.216	78.312	78.276
55	0.0000000	1.918	1.918	1.918	1.918
56	0.0000000	1.918	14.696	1.918	14.696
58	0.1539365	76.589	76.523	76.593	76.527

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
5	Pump	14.557	94.969	14.696	95.108	118.2	16.43	0.0000
7	Valve	78.298	78.252	78.357	78.312	118.2	16.43	0.7638
10	Valve	76.630	76.641	76.692	76.645	118.2	16.43	0.7650
15	Tee or Wye	76.594	76.594	76.596	76.596	N/A	N/A	See Mult. Losses
16	Area Change	76.596	76.596	76.596	76.596	0.0	0.00	0.0000
X17	60M-43B	76.596	70.299	76.596	70.299	0.0	0.00	0.0000
18	60M-43A	76.592	76.589	76.596	76.593	118.2	16.43	0.6300
31	Bend	76.427	76.406	76.489	76.468	118.2	16.43	0.3400
32	Bend	68.811	68.790	68.872	68.851	118.2	16.43	0.3400
35	Area Change	94.958	95.021	95.097	95.081	118.2	16.43	0.1180
37	Area Change	76.523	76.451	76.527	76.512	118.2	16.43	3.6738
38	Area Change	70.956	70.818	71.018	70.995	118.2	16.43	0.3642
39	Area Change	62.806	62.806	62.806	62.806	0.0	0.00	0.0000

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 107 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
4/13/2020
Page 5

AFT Fathom Model

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
40	Tee or Wye	62.727	62.727	62.806	62.806	N/A	N/A	See Mult. Losses
42	Bend	63.045	62.981	63.222	63.158	118.2	16.43	0.3586
47	Assigned Pressure	14.696	14.519	14.873	14.696	118.2	16.43	1.0000
49	General Component	60.193	20.193	61.053	21.053	118.2	16.43	46.5188
50	Area Change	61.853	61.026	62.030	61.886	118.2	16.43	0.8114
51	Area Change	19.360	19.788	20.220	19.965	118.2	16.43	0.2967
54	Orifice	19.285	9.608	19.463	9.785	118.2	16.43	54.6231
56	Control Valve	78.389	78.316	78.449	78.376	118.2	16.43	1.2231
59	Branch	82.226	81.414	82.274	82.274	118.2	16.43	0.0000
60	Branch	93.530	93.542	93.590	93.590	118.2	16.43	0.0000
61	Area Change	78.062	78.399	78.922	78.458	118.2	16.43	0.5396
63	Three Way Valve	78.249	78.249	78.276	78.276	N/A	N/A	See Mult. Losses
64	Bend	1.918	1.918	1.918	1.918	0.0	0.00	0.0000
65	Assigned Pressure	14.696	14.696	14.696	14.696	0.0	0.00	0.0000

CALCULATION SHEET

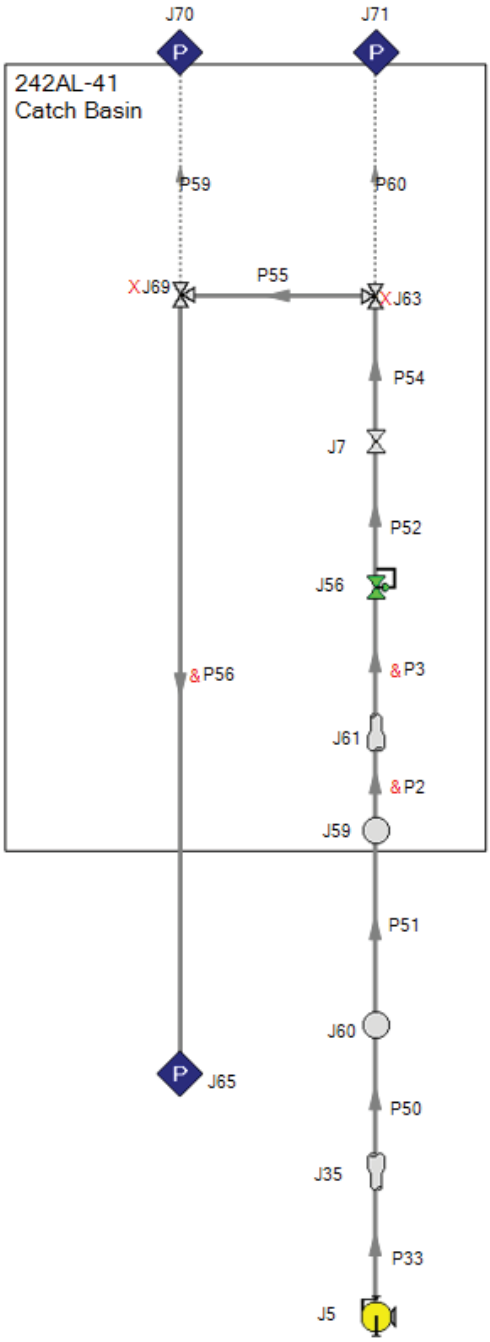
Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 108 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

APPENDIX D

BASIN PUMP RECIRCULATION MODEL

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 109 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 110 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

APPENDIX E

BASIN PUMP RECIRCULATION FATHOM INPUTS AND OUTPUTS

Control Valve Cavitation

Pump Run-Out

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 111 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Control Valve Cavitation

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 112 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 1	AFT Fathom Model	

General

Title: AFT Fathom Model
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF TransferRev0.fth
Scenario: Base Scenario/RecircRunHighBasin/Cavitation Check

Number Of Pipes= 11
Number Of Junctions= 12

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Pipes

Pipe	Name	Pipe Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam. Units	Friction Data Set	Roughness	Roughness Units	Losses (K)
2	Pipe	Yes	30	feet	4.026	inches	Standard	0.0018	inches	0.271584
3	Pipe	Yes	2	feet	2.067	inches	Standard	0.0018	inches	0.04
33	Pipe	Yes	1	feet	3.26	inches	Standard	0.0018	inches	0
50	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
51	Pipe	Yes	98.93	feet	4.26	inches	Standard	0.0018	inches	0
52	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
54	Pipe	Yes	10	feet	4.026	inches	Standard	0.0018	inches	0
55	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
56	Pipe	Yes	46	feet	4.026	inches	Standard	0.0018	inches	0.4752721
59	Pipe	Yes	1	feet	3.068	inches	Standard	0.0018	inches	0
60	Pipe	Yes	1	feet	3.068	inches	Standard	0.0018	inches	0

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 113 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 2

AFT Fathom Model

Pipe	Initial Flow	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Size	Type	Special Condition
2			59, 61	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
3			61, 56	Cylindrical Pipe	Steel - ANSI	2 inch	schedule 40	None
33			5, 35	Cylindrical Pipe	Steel - ANSI	3 inch	Schedule 10	None
50			35, 60	Cylindrical Pipe	Steel - ANSI	4 inch	STD (schedule 40)	None
51			60, 59	Cylindrical Pipe	Steel - ANSI	4 inch	Schedule 10	None
52			56, 7	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
54			7, 63	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
55			63, 69	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
56			69, 65	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
59			69, 70	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None
60			63, 71	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None

Pipe Fittings & Losses

Pipe	Total K	Elbow/Bend Standard Threaded	Elbow/Bend Smooth Flanged	Other Tee
2	0.27	1 (0.27)		
3	0.04			1 (0.04)
56	0.48		2 (0.48)	

Area Change Table

Area Change	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type
35	Area Change	Yes	576.6	feet				Conical
61	Area Change	Yes	605.5	feet				Conical

Area Change	Geometry	Angle	Loss Factor
35	Expansion	45	0.1179652
61	Contraction	45	3.244747

Assigned Pressure Table

Assigned Pressure	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
65	Assigned Pressure	Yes	602	feet	1.000	atm	
70	Assigned Pressure	Yes	606	feet	1.000	atm	
71	Assigned Pressure	Yes	606	feet	1.000	atm	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 114 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 3	AFT Fathom Model	

Assigned Pressure	Pressure	Pressure Units	Pressure Type	Balance Energy	Balance Concentration	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out
65	1	atm	Stagnation	No	No	(P56) 0, 1		
70	1	atm	Stagnation	No	No	(P59) 0, 0		
71	1	atm	Stagnation	No	No	(P60) 0, 0		

Assigned Pressure	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out
65								
70								
71								

Assigned Pressure	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out
65								
70								
71								

Assigned Pressure	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
65						
70						
71						

Branch Table

Branch	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Boundary Flow (+ = in/- = out)
59	Branch	Yes	605.5	feet				None	
60	Branch	Yes	580	feet				None	

Branch	Boundary Flow Units	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out
59		(P2) 0, 0	(P51) 0, 0					
60		(P50) 0, 0	(P51) 0, 0					

Branch	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out
59									
60									

Branch	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
59									
60									

Control Valve Table

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 115 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 4

AFT Fathom Model

Control Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Valve Type
56	Control Valve	Yes	605.5	feet				None	FCV

Control Valve	Control Setting	Control Units	Pressure/ Head Type	Inlet Failure Type	Outlet Failure Type	Full Open Loss Type	Full Open Loss
56	125	gal/min	N/A	Fully Open	N/A	Cv Table	437.29

Pump Table

Pump	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Pump Type
5	Pump	Yes	576.6	feet				None	Pump Curve

Pump	Design Flow Rate	Design Flow Rate Units	Current Configuration	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Pump Curve Constant a
5				Vol. Flow Rate	gal/min	Head Rise	feet	221.5061

Pump	Pump Curve Constant b	Pump Curve Constant c	Pump Curve Constant d	Pump Curve Constant e	Runout Flow Rate	Runout Flow Rate Units	Speed	Control When Exceeded Only
5	-0.03898634	-0.002236957	0	0			100	

Pump	Heat Added To Fluid	Heat Added Units
5	0	Percent

Three Way Valve Table

Three Way Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
63	Three Way Valve	Yes	605.5	feet			
69	Three Way Valve	Yes	605.5	feet			

Three Way Valve	Special Condition	Loss Model	Percent Open	Cv Pipe #1	Cv Pipe #2
63	Pipe #2 Closed	Cv	100	561	0
69	Pipe #2 Closed	Cv	0	409	0

Valve Table

Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Exit Valve	Exit Pressure
7	Valve	Yes	605.5	feet				None	No	

Valve	Exit Pressure Units	Restricted Area	Restricted Area Units	Loss Model	Loss Source	Loss Factor	Percent Open	Open Pct. Data Exists	Independent Variable
7				K Constant	N/A	0.76383		No	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 116 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 5	AFT Fathom Model	

Valve	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
7								

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 117 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 1	AFT Fathom Model	

Model Reference Information

General

Title: AFT Fathom Model
Analysis run on: 3/26/2020 3:25:48 PM
Application version: AFT Fathom Version 10 (2018.05.21)
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF TransferRev0.fth
Scenario: Base Scenario/RecircRunHighBasin/Cavitation Check
Output File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF TransferRev0_F7.out

Execution Time= 0.05 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 2
Total Number Of Temperature Iterations= 0
Number Of Pipes= 11
Number Of Junctions= 12
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300
Total Inflow= 125.0 gal/min
Total Outflow= 125.0 gal/min
Maximum Static Pressure is 103.9 psia at Pipe 50 Inlet
Minimum Static Pressure is 13.40 psia at Pipe 56 Inlet

Warnings

No Warnings

Applied Standards

===== ANSI/HI 9.6.3-2017 - Rotodynamic Pumps - Guideline for Operating Regions =====
Pump 5 set to specific speed <=4500 (US Customary), with lower POR 70% and upper POR 120% of BEP

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 118 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 2	AFT Fathom Model	

Pump Summary

Jct	Results Diagram	Name	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)
5	Show	Pump	125.0	17.37	78.70	181.7	N/A	100.0	5.737	N/A	N/A	N/A

Jct	NPSHR (feet)
5	N/A

Valve Summary

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Static In (psig)	Cv	K
7	Valve	REGULAR	125.0	17.37	0.05103	0.1178	-1.045	553.35	0.7638
56	Control Valve	FCV	125.0	17.37	76.73226	177.1454	74.812	14.27	79.8046
63 [P55]	Three Way Valve	THREE-WAY	125.0	17.37	0.04965	0.1146	-1.099	561.00	0.7432
X63 [P60]	Three Way Valve	THREE-WAY	0.0	0.00	N/A	N/A	-1.099	N/A	N/A
69 [P56]	Three Way Valve	THREE-WAY	125.0	17.37	0.09341	0.2156	-1.169	409.00	1.3982
X69 [P59]	Three Way Valve	THREE-WAY	0.0	0.00	N/A	N/A	-1.169	N/A	N/A

Jct	Valve State	Open Percentage (Percent)
7	Open	N/A
56	Open	30.86
63 [P55]	Open	100.00
X63 [P60]	Closed By User	N/A
69 [P56]	Open	0.00
X69 [P59]	Closed By User	N/A

Pipe Output Table

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psig)	P Static Min (psig)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)	dH (feet)
2	Pipe	125.0	3.150	76.3304	76.192	605.5	605.5	0.13858	0.13858	0.0000	0.31992
3	Pipe	125.0	11.951	75.0804	74.812	605.5	605.5	0.26807	0.26807	0.0000	0.61886
33	Pipe	125.0	4.805	89.1103	89.099	576.6	576.6	0.01148	0.01148	0.0000	0.02650
50	Pipe	125.0	3.150	89.1691	87.676	576.6	580.0	1.49283	1.49283	1.4728	0.04634
51	Pipe	125.0	2.814	87.6898	76.344	580.0	605.5	11.34587	11.34587	11.0456	0.69327
52	Pipe	125.0	3.150	-1.0253	-1.045	605.5	605.5	0.02007	0.02007	0.0000	0.04634
54	Pipe	125.0	3.150	-1.0964	-1.137	605.5	605.5	0.04014	0.04014	0.0000	0.09268

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 119 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
3/26/2020
Page 3

AFT Fathom Model

Pipe	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
2	91.03	90.89	91.09	90.95
3	89.78	89.51	90.74	90.47
33	103.81	103.79	103.96	103.95
50	103.87	102.37	103.93	102.44
51	102.39	91.04	102.44	91.09
52	13.67	13.65	13.74	13.72
54	13.60	13.56	13.67	13.63

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psig)	P Static Min (psig)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)	dH (feet)
55	Pipe	125.0	3.150	-1.1862	-1.206	605.5	605.5	0.02007	0.02007	0.0000	0.04634
56	Pipe	125.0	3.150	0.0000	-1.300	605.5	602.0	-1.29964	-1.29964	-1.5161	0.49962
59	Pipe	0.0	0.000	0.2166	0.000	605.5	606.0	0.21658	0.21658	0.2166	0.00000
60	Pipe	0.0	0.000	0.2166	0.000	605.5	606.0	0.21658	0.21658	0.2166	0.00000

Pipe	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
55	13.51	13.49	13.58	13.56
56	13.40	14.70	13.46	14.76
59	14.91	14.70	14.91	14.70
60	14.91	14.70	14.91	14.70

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
5	Pump	25.11	103.81	25.27	103.96	125.0	17.37	0.0000
7	Valve	13.65	13.60	13.72	13.67	125.0	17.37	0.7638
35	Area Change	103.79	103.87	103.95	103.93	125.0	17.37	0.1180
56	Control Valve	89.51	13.67	90.47	13.74	125.0	17.37	79.8046
59	Branch	91.04	91.03	91.09	91.09	125.0	17.37	0.0000
60	Branch	102.37	102.39	102.44	102.44	125.0	17.37	0.0000
61	Area Change	90.89	89.78	90.95	90.74	125.0	17.37	3.2447
63	Three Way Valve	13.60	13.60	13.63	13.63	N/A	N/A	See Mult. Losses
65	Assigned Pressure	14.70	14.63	14.76	14.70	125.0	17.37	1.0000
69	Three Way Valve	13.53	13.53	13.56	13.56	N/A	N/A	See Mult. Losses
70	Assigned Pressure	14.70	14.70	14.70	14.70	0.0	0.00	0.0000
71	Assigned Pressure	14.70	14.70	14.70	14.70	0.0	0.00	0.0000

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 120 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Pump Run-Out

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 121 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 1	AFT Fathom Model	

General

Title: AFT Fathom Model
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF TransferRev0.fth
Scenario: Base Scenario/RecircRunHighBasin/Run-Out Check

Number Of Pipes= 11
Number Of Junctions= 12

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Pipes

Pipe	Name	Pipe Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam. Units	Friction Data Set	Roughness	Roughness Units	Losses (K)
2	Pipe	Yes	30	feet	4.026	inches	Standard	0.0018	inches	0.271584
3	Pipe	Yes	2	feet	2.067	inches	Standard	0.0018	inches	0.04
33	Pipe	Yes	1	feet	3.26	inches	Standard	0.0018	inches	0
50	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
51	Pipe	Yes	98.93	feet	4.26	inches	Standard	0.0018	inches	0
52	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
54	Pipe	Yes	10	feet	4.026	inches	Standard	0.0018	inches	0
55	Pipe	Yes	5	feet	4.026	inches	Standard	0.0018	inches	0
56	Pipe	Yes	46	feet	4.026	inches	Standard	0.0018	inches	0.4752721
59	Pipe	Yes	1	feet	3.068	inches	Standard	0.0018	inches	0
60	Pipe	Yes	1	feet	3.068	inches	Standard	0.0018	inches	0

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 122 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 2

AFT Fathom Model

Pipe	Initial Flow	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Size	Type	Special Condition
2			59, 61	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
3			61, 56	Cylindrical Pipe	Steel - ANSI	2 inch	schedule 40	None
33			5, 35	Cylindrical Pipe	Steel - ANSI	3 inch	Schedule 10	None
50			35, 60	Cylindrical Pipe	Steel - ANSI	4 inch	STD (schedule 40)	None
51			60, 59	Cylindrical Pipe	Steel - ANSI	4 inch	Schedule 10	None
52			56, 7	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
54			7, 63	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
55			63, 69	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
56			69, 65	Cylindrical Pipe	Steel - ANSI	4 inch	schedule 40	None
59			69, 70	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None
60			63, 71	Cylindrical Pipe	Steel - ANSI	3 inch	STD (schedule 40)	None

Pipe Fittings & Losses

Pipe	Total K	Elbow/Bend Standard Threaded	Elbow/Bend Smooth Flanged	Other Tee
2	0.27	1 (0.27)		
3	0.04			1 (0.04)
56	0.48		2 (0.48)	

Area Change Table

Area Change	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type
35	Area Change	Yes	576.6	feet				Conical
61	Area Change	Yes	605.5	feet				Conical

Area Change	Geometry	Angle	Loss Factor
35	Expansion	45	0.1179652
61	Contraction	45	3.244747

Assigned Pressure Table

Assigned Pressure	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
65	Assigned Pressure	Yes	602	feet	1.000	atm	
70	Assigned Pressure	Yes	606	feet	1.000	atm	
71	Assigned Pressure	Yes	606	feet	1.000	atm	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 123 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 3	AFT Fathom Model	

Assigned Pressure	Pressure	Pressure Units	Pressure Type	Balance Energy	Balance Concentration	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out
65	1	atm	Stagnation	No	No	(P56) 0, 0		
70	1	atm	Stagnation	No	No	(P59) 0, 0		
71	1	atm	Stagnation	No	No	(P60) 0, 0		

Assigned Pressure	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out
65								
70								
71								

Assigned Pressure	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out
65								
70								
71								

Assigned Pressure	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
65						
70						
71						

Branch Table

Branch	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Boundary Flow (+ = in/- = out)
59	Branch	Yes	605.5	feet				None	
60	Branch	Yes	580	feet				None	

Branch	Boundary Flow Units	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out
59		(P2) 0, 0	(P51) 0, 0					
60		(P50) 0, 0	(P51) 0, 0					

Branch	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out
59									
60									

Branch	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
59									
60									

Control Valve Table

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 124 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 4

AFT Fathom Model

Control Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Valve Type
56	Control Valve	Yes	605.5	feet				None	FCV

Control Valve	Control Setting	Control Units	Pressure/ Head Type	Inlet Failure Type	Outlet Failure Type	Full Open Loss Type	Full Open Loss
56	280	gal/min	N/A	Fully Open	N/A	Cv Table	437.29

Pump Table

Pump	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Pump Type
5	Pump	Yes	576.6	feet				None	Pump Curve

Pump	Design Flow Rate	Design Flow Rate Units	Current Configuration	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Pump Curve Constant a
5				Vol. Flow Rate	gal/min	Head Rise	feet	221.5061

Pump	Pump Curve Constant b	Pump Curve Constant c	Pump Curve Constant d	Pump Curve Constant e	Runout Flow Rate	Runout Flow Rate Units	Speed	Control When Exceeded Only
5	-0.03898634	-0.002236957	0	0			100	

Pump	Heat Added To Fluid	Heat Added Units
5	0	Percent

Three Way Valve Table

Three Way Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
63	Three Way Valve	Yes	605.5	feet			
69	Three Way Valve	Yes	605.5	feet			

Three Way Valve	Special Condition	Loss Model	Percent Open	Cv Pipe #1	Cv Pipe #2
63	Pipe #2 Closed	Cv	100	561	0
69	Pipe #2 Closed	Cv	0	409	0

Valve Table

Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Exit Valve	Exit Pressure
7	Valve	Yes	605.5	feet				None	No	

Valve	Exit Pressure Units	Restricted Area	Restricted Area Units	Loss Model	Loss Source	Loss Factor	Percent Open	Open Pct. Data Exists	Independent Variable
7				K Constant	N/A	0.76383		No	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 125 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 5	AFT Fathom Model	

Valve	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
7								

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 126 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 1	AFT Fathom Model	

Model Reference Information

General

Title: AFT Fathom Model
Analysis run on: 3/26/2020 3:25:53 PM
Application version: AFT Fathom Version 10 (2018.05.21)
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF TransferRev0.fth
Scenario: Base Scenario/RecircRunHighBasin/Run-Out Check
Output File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF TransferRev0_F8.out

Execution Time= 0.03 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 2
Total Number Of Temperature Iterations= 0
Number Of Pipes= 11
Number Of Junctions= 12
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 S.G. water
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300
Total Inflow= 280.0 gal/min
Total Outflow= 280.0 gal/min
Maximum Static Pressure is 40.04 psia at Pipe 50 Inlet
Minimum Static Pressure is 13.85 psia at Pipe 56 Inlet

Warnings

No Warnings

Applied Standards

===== ANSI/HI 9.6.3-2017 - Rotodynamic Pumps - Guideline for Operating Regions =====
Pump 5 set to specific speed <=4500 (US Customary), with lower POR 70% and upper POR 120% of BEP

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 127 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 2	AFT Fathom Model	

Pump Summary

Jct	Results Diagram	Name	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)	NPSHA (feet)
5	Show	Pump	280.0	38.91	15.25	35.21	N/A	100.0	2.491	N/A	N/A	N/A

Jct	NPSHR (feet)
5	N/A

Valve Summary

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Static In (psia)	Cv	K
7	Valve	REGULAR	280.0	38.91	0.2560	0.5911	15.10	553.35	0.7638
56	Control Valve	FCV	280.0	38.91	7.8426	18.1056	18.54	99.98	1.6256
63 [P55]	Three Way Valve	THREE-WAY	280.0	38.91	0.2491	0.5751	14.84	561.00	0.7432
X63 [P60]	Three Way Valve	THREE-WAY	0.0	0.00	N/A	N/A	14.84	N/A	N/A
69 [P56]	Three Way Valve	THREE-WAY	280.0	38.91	0.4687	1.0820	14.50	409.00	1.3982
X69 [P59]	Three Way Valve	THREE-WAY	0.0	0.00	N/A	N/A	14.50	N/A	N/A

Jct	Valve State	Open Percentage (Percent)
7	Open	N/A
56	Open	58.55
63 [P55]	Open	100.00
X63 [P60]	Closed By User	N/A
69 [P56]	Open	0.00
X69 [P59]	Closed By User	N/A

Pipe Output Table

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)	dH (feet)
2	Pipe	280.0	7.057	26.06	25.42	605.5	605.5	0.64178	0.64178	0.0000	1.4816
3	Pipe	280.0	26.771	19.84	18.54	605.5	605.5	1.29876	1.29876	0.0000	2.9983
33	Pipe	280.0	10.762	39.74	39.68	576.6	576.6	0.05344	0.05344	0.0000	0.1234
50	Pipe	280.0	7.057	40.04	38.47	576.6	580.0	1.56454	1.56454	1.4728	0.2119
51	Pipe	280.0	6.303	38.54	26.13	580.0	605.5	12.41226	12.41226	11.0456	3.1551
52	Pipe	280.0	7.057	15.19	15.10	605.5	605.5	0.09179	0.09179	0.0000	0.2119
54	Pipe	280.0	7.057	14.84	14.66	605.5	605.5	0.18358	0.18358	0.0000	0.4238

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 128 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
3/26/2020
Page 3

AFT Fathom Model

Pipe	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
2	26.06	25.42	26.40	25.75
3	19.84	18.54	24.67	23.37
33	39.74	39.68	40.52	40.46
50	40.04	38.47	40.37	38.81
51	38.54	26.13	38.81	26.40
52	15.19	15.10	15.52	15.43
54	14.84	14.66	15.18	14.99

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)	dH (feet)
55	Pipe	280.0	7.057	14.41	14.32	605.5	605.5	0.09179	0.09179	0.0000	0.2119
56	Pipe	280.0	7.057	14.36	13.85	605.5	602.0	-0.51227	-0.51227	-1.5161	2.3174
59	Pipe	0.0	0.000	14.91	14.70	605.5	606.0	0.21658	0.21658	0.2166	0.0000
60	Pipe	0.0	0.000	14.91	14.70	605.5	606.0	0.21658	0.21658	0.2166	0.0000

Pipe	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
55	14.41	14.32	14.74	14.65
56	13.85	14.36	14.18	14.70
59	14.91	14.70	14.91	14.70
60	14.91	14.70	14.91	14.70

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
5	Pump	24.49	39.74	25.27	40.52	280.0	38.91	0.0000
7	Valve	15.10	14.84	15.43	15.18	280.0	38.91	0.7638
35	Area Change	39.68	40.04	40.46	40.37	280.0	38.91	0.1180
56	Control Valve	18.54	15.19	23.37	15.52	280.0	38.91	1.6256
59	Branch	26.13	26.06	26.40	26.40	280.0	38.91	0.0000
60	Branch	38.47	38.54	38.81	38.81	280.0	38.91	0.0000
61	Area Change	25.42	19.84	25.75	24.67	280.0	38.91	3.2447
63	Three Way Valve	14.84	14.84	14.99	14.99	N/A	N/A	See Mult. Losses
65	Assigned Pressure	14.36	14.36	14.70	14.70	280.0	38.91	0.0000
69	Three Way Valve	14.50	14.50	14.65	14.65	N/A	N/A	See Mult. Losses
70	Assigned Pressure	14.70	14.70	14.70	14.70	0.0	0.00	0.0000
71	Assigned Pressure	14.70	14.70	14.70	14.70	0.0	0.00	0.0000

CALCULATION SHEET

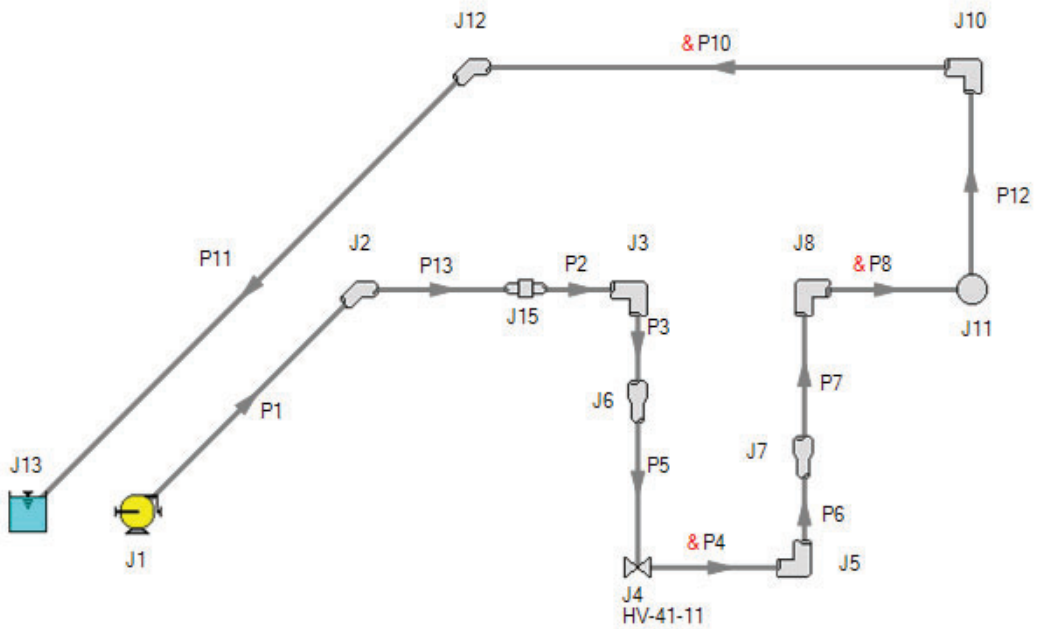
Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 129 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

APPENDIX F

LEACHATE PUMP FATHOM MODEL

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 130 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 131 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

APPENDIX G

LEACHATE PUMP FATHOM INPUTS AND OUTPUTS

Minimum Flow

Maximum Flow

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 132 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Minimum Flow

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 133 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 1	AFT Fathom Model	

General

Title: AFT Fathom Model
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF.fth
Scenario: Base Scenario/Goulds Pump/Minimum Flow

Number Of Pipes= 12
Number Of Junctions= 13

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 lbm/ft3
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Pipes

Pipe	Name	Pipe Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam. Units	Friction Data Set	Roughness	Roughness Units	Losses (K)
1	Pipe	Yes	116	feet	1.682	inches	Standard	0.0018	inches	0
2	Pipe	Yes	1.5	feet	1.61	inches	Standard	0.0018	inches	0.04
3	Pipe	Yes	0.75	feet	1.61	inches	Standard	0.0018	inches	0
4	Pipe	Yes	0.5	feet	0.622	inches	Standard	0.0018	inches	0.364336
5	Pipe	Yes	0.75	feet	0.622	inches	Standard	0.0018	inches	0
6	Pipe	Yes	0.75	feet	0.546	inches	Standard	0.0018	inches	0
7	Pipe	Yes	0.75	feet	1.61	inches	Standard	0.0018	inches	0
8	Pipe	Yes	5	inches	1.61	inches	Standard	0.0018	inches	0.04
10	Pipe	Yes	9.8	feet	1.61	inches	Standard	0.0018	inches	0.06168
11	Pipe	Yes	116	feet	1.61	inches	Standard	0.0018	inches	0
12	Pipe	Yes	17	inches	1.61	inches	Standard	0.0018	inches	0
13	Pipe	Yes	1.5	feet	1.61	inches	Standard	0.0018	inches	0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 134 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 2

AFT Fathom Model

Pipe	Initial Flow	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Size	Type	Special Condition
1			1, 2	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	Schedule 10	None
2			15, 3	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
3			3, 6	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
4			4, 5	Cylindrical Pipe	Steel - ANSI	1/2 inch	schedule 40	None
5			6, 4	Cylindrical Pipe	Steel - ANSI	1/2 inch	schedule 40	None
6			5, 7	Cylindrical Pipe	Steel - ANSI	1/2 inch	schedule 80	None
7			7, 8	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
8			8, 11	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
10			10, 12	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
11			12, 13	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
12			11, 10	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
13			2, 15	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None

Pipe Fittings & Losses

Pipe	Total K	Elbow/Bend Smooth Flanged	Valve Ball	Other Tee
2	0.04			1 (0.04)
4	0.36	1 (0.36)		
8	0.04			1 (0.04)
10	0.06		1 (0.06)	

Area Change Table

Area Change	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type
6	Area Change	Yes	605.6	feet				Conical
7	Area Change	Yes	605.6	feet				Conical

Area Change	Geometry	Angle	Loss Factor
6	Contraction	90	16.05661
7	Expansion	90	0.7832083

Branch Table

Branch	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Boundary Flow (+ = in/- = out)
11	Branch	Yes	605.6	feet				None	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 135 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 3

AFT Fathom Model

Branch	Boundary Flow Units	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out
11		(P8) 1.1, 0	(P12) 0, 0					

Branch	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out
11									

Branch	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
11									

Pump Table

Pump	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Pump Type
1	Pump	Yes	574.5	feet				None	Pump Curve

Pump	Design Flow Rate	Design Flow Rate Units	Current Configuration	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Pump Curve Constant a
1				Vol. Flow Rate	gal/min	Head Rise	feet	173.1132

Pump	Pump Curve Constant b	Pump Curve Constant c	Pump Curve Constant d	Pump Curve Constant e	Runout Flow Rate	Runout Flow Rate Units	Speed	Control When Exceeded Only
1	-3.244979	-0.2765802	0	0			100	

Pump	Heat Added To Fluid	Heat Added Units
1	0	Percent

Valve Table

Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Exit Valve	Exit Pressure
4	HV-41-11	Yes	605.6	feet				None	No	

Valve	Exit Pressure Units	Restricted Area	Restricted Area Units	Loss Model	Loss Source	Loss Factor	Percent Open	Open Pct. Data Exists	Independent Variable
4				Cv	Cv From Table	0.52	30	Yes	

Valve	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
4								

Bend Table

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 136 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 4

AFT Fathom Model

Bend	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type	Angle (Degrees)	R/D
2	Bend	Yes	605.6	feet				Smooth Bend	45	1.5
3	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
5	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
8	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
10	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
12	Bend	Yes	605.6	feet				Smooth Bend	45	1.5

Bend	Loss Factor
2	0.2009148
3	0.28784
5	0.364336
8	0.28784
10	0.28784
12	0.2037692

General Component Table

General Component	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
15	General Component	Yes	605.6	feet			

General Component	Special Condition	Loss Model	Loss Value	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units
15	None	Resistance Curve	Variable	Vol. Flow Rate	gal/min	Pressure Loss	psid

General Component	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
15	5.551115E-17	0	0.0002777778	0	0

Reservoir Table

Reservoir	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Liquid Elev.	Liquid Elev. Units
13	Reservoir	Yes						601	feet

Reservoir	Surface Pressure	Surface Pressure Units	Balance Energy	Balance Concentration	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out
13	1	atm	No	No	(P11) 0, 0			

Reservoir	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out
13									

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 137 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 5

AFT Fathom Model

Reservoir	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out
13									

Reservoir	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out	(Pipe #1) Depth	(Pipe #2) Depth	(Pipe #3) Depth	(Pipe #4) Depth	(Pipe #5) Depth	(Pipe #6) Depth
13				(P11) 576.6					

Reservoir	(Pipe #7) Depth	(Pipe #8) Depth	(Pipe #9) Depth	(Pipe #10) Depth	(Pipe #11) Depth	(Pipe #12) Depth	(Pipe #13) Depth	(Pipe #14) Depth	(Pipe #15) Depth
13									

Reservoir	(Pipe #16) Depth	(Pipe #17) Depth	(Pipe #18) Depth	(Pipe #19) Depth	(Pipe #20) Depth	(Pipe #21) Depth	(Pipe #22) Depth	(Pipe #23) Depth	(Pipe #24) Depth
13									

Reservoir	(Pipe #25) Depth	Pipe Depth Units
13		feet

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 138 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 1	AFT Fathom Model	

Model Reference Information

General

Title: AFT Fathom Model
Analysis run on: 3/26/2020 3:28:03 PM
Application version: AFT Fathom Version 10 (2018.05.21)
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF.fth
Scenario: Base Scenario/Goulds Pump/Minimum Flow
Output File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF_F1.out

Execution Time= 0.11 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 37
Total Number Of Temperature Iterations= 0
Number Of Pipes= 12
Number Of Junctions= 13
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 lbm/ft3
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300
Total Inflow= 3.699 gal/min
Total Outflow= 3.699 gal/min
Maximum Static Pressure is 15.79 psia at Pipe 1 Inlet
Minimum Static Pressure is 14.68 psia at Pipe 11 Inlet

Warnings

No Warnings

Applied Standards

===== ANSI/HI 9.6.3-2017 - Rotodynamic Pumps - Guideline for Operating Regions =====
Pump 1 set to specific speed <=4500 (US Customary), with lower POR 70% and upper POR 120% of BEP

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 139 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 2	AFT Fathom Model	

Pump Summary

Jct	Results Diagram	Name	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
1	Show	Pump	3.699	8.242E-03	1.093	157.3	N/A	100.0	2.357E-03	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
1	N/A	N/A

Valve Summary

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Static In (psia)	Cv	K	Valve State	Open Percentage (Percent)
4	HV-41-11	REGULAR	3.699	8.242E-03	0.8114	116.8	15.53	0.5200	492.8	Open	30.00

Reservoir Summary

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
13	Reservoir	Infinite	N/A	601.0	14.70	N/A	N/A	3.699	8.242E-03

Pipe Output Table

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)	dH (feet)
1	Pipe	3.699	0.5342	15.79	15.56	574.5	605.6	0.2306098	0.2306098	0.2160	2.10784
2	Pipe	3.699	0.5830	15.55	15.55	605.6	605.6	0.0002655	0.0002655	0.0000	0.03823
3	Pipe	3.699	0.5830	15.55	15.55	605.6	605.6	0.0001127	0.0001127	0.0000	0.01623
4	Pipe	3.699	3.9061	14.72	14.71	605.6	605.6	0.0082990	0.0082990	0.0000	1.19505
5	Pipe	3.699	3.9061	15.54	15.53	605.6	605.6	0.0050608	0.0050608	0.0000	0.72876
6	Pipe	3.699	5.0692	14.70	14.70	605.6	605.6	0.0085234	0.0085234	0.0000	1.22737
7	Pipe	3.699	0.5830	14.68	14.68	605.6	605.6	0.0001127	0.0001127	0.0000	0.01623
8	Pipe	3.699	0.5830	14.68	14.68	605.6	605.6	0.0001026	0.0001026	0.0000	0.01478
10	Pipe	3.699	0.5830	14.68	14.68	605.6	605.6	0.0015348	0.0015348	0.0000	0.22102
11	Pipe	3.699	0.5830	14.87	14.68	605.6	576.6	-0.1845451	-0.1845451	-0.2014	2.42551
12	Pipe	3.699	0.5830	14.68	14.68	605.6	605.6	0.0002130	0.0002130	0.0000	0.03067
13	Pipe	3.699	0.5830	15.56	15.56	605.6	605.6	0.0002255	0.0002255	0.0000	0.03247

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 140 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
3/26/2020
Page 3

AFT Fathom Model

Pipe	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
1	15.79	15.56	15.79	15.56
2	15.55	15.55	15.55	15.55
3	15.55	15.55	15.55	15.55
4	14.72	14.71	14.72	14.71
5	15.54	15.53	15.54	15.53
6	14.70	14.70	14.71	14.70
7	14.68	14.68	14.68	14.68
8	14.68	14.68	14.68	14.68
10	14.68	14.68	14.68	14.68
11	14.68	14.87	14.68	14.87
12	14.68	14.68	14.68	14.68
13	15.56	15.56	15.56	15.56

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
1	Pump	14.70	15.79	14.70	15.79	3.699	8.242E-03	0.000
2	Bend	15.56	15.56	15.56	15.56	3.699	8.242E-03	5.786
3	Bend	15.55	15.55	15.55	15.55	3.699	8.242E-03	7.849
4	HV-41-11	15.53	14.72	15.53	14.72	3.699	8.242E-03	492.791
5	Bend	14.71	14.70	14.71	14.71	3.699	8.242E-03	2.991
6	Area Change	15.55	15.54	15.55	15.54	3.699	8.242E-03	437.854
7	Area Change	14.70	14.68	14.70	14.68	3.699	8.242E-03	5.441
8	Bend	14.68	14.68	14.68	14.68	3.699	8.242E-03	7.849
10	Bend	14.68	14.68	14.68	14.68	3.699	8.242E-03	7.849
11	Branch	14.68	14.68	14.68	14.68	3.699	8.242E-03	0.000
12	Bend	14.68	14.68	14.68	14.68	3.699	8.242E-03	5.557
13	Reservoir	14.70	14.87	14.70	14.87	3.699	8.242E-03	0.000
15	General Component	15.56	15.55	15.56	15.55	3.699	8.242E-03	103.638

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 141 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Maximum Flow

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 142 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 1	AFT Fathom Model	

General

Title: AFT Fathom Model
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF.fth
Scenario: Base Scenario/Goulds Pump/Maximum Flow

Number Of Pipes= 12
Number Of Junctions= 13

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 lbm/ft3
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300

Pipes

Pipe	Name	Pipe Defined	Length	Length Units	Hydraulic Diameter	Hydraulic Diam. Units	Friction Data Set	Roughness	Roughness Units	Losses (K)
1	Pipe	Yes	116	feet	1.682	inches	Standard	0.0018	inches	0
2	Pipe	Yes	1.5	feet	1.61	inches	Standard	0.0018	inches	0.04
3	Pipe	Yes	0.75	feet	1.61	inches	Standard	0.0018	inches	0
4	Pipe	Yes	0.5	feet	0.622	inches	Standard	0.0018	inches	0.364336
5	Pipe	Yes	0.75	feet	0.622	inches	Standard	0.0018	inches	0
6	Pipe	Yes	0.75	feet	0.546	inches	Standard	0.0018	inches	0
7	Pipe	Yes	0.75	feet	1.61	inches	Standard	0.0018	inches	0
8	Pipe	Yes	5	inches	1.61	inches	Standard	0.0018	inches	0.04
10	Pipe	Yes	9.8	feet	1.61	inches	Standard	0.0018	inches	0.06168
11	Pipe	Yes	116	feet	1.61	inches	Standard	0.0018	inches	0
12	Pipe	Yes	17	inches	1.61	inches	Standard	0.0018	inches	0
13	Pipe	Yes	1.5	feet	1.61	inches	Standard	0.0018	inches	0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 143 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model) 3/26/2020 Page 2	AFT Fathom Model	

Pipe	Initial Flow	Initial Flow Units	Junctions (Up,Down)	Geometry	Material	Size	Type	Special Condition
1			1, 2	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	Schedule 10	None
2			15, 3	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
3			3, 6	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
4			4, 5	Cylindrical Pipe	Steel - ANSI	1/2 inch	schedule 40	None
5			6, 4	Cylindrical Pipe	Steel - ANSI	1/2 inch	schedule 40	None
6			5, 7	Cylindrical Pipe	Steel - ANSI	1/2 inch	schedule 80	None
7			7, 8	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
8			8, 11	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
10			10, 12	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
11			12, 13	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
12			11, 10	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None
13			2, 15	Cylindrical Pipe	Steel - ANSI	1-1/2 inch	schedule 40	None

Pipe Fittings & Losses

Pipe	Total K	Elbow/Bend Smooth Flanged	Valve Ball	Other Tee
2	0.04			1 (0.04)
4	0.36	1 (0.36)		
8	0.04			1 (0.04)
10	0.06		1 (0.06)	

Area Change Table

Area Change	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type
6	Area Change	Yes	605.6	feet				Conical
7	Area Change	Yes	605.6	feet				Conical

Area Change	Geometry	Angle	Loss Factor
6	Contraction	90	16.05661
7	Expansion	90	0.7832083

Branch Table

Branch	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Boundary Flow (+ = in/- = out)
11	Branch	Yes	605.6	feet				None	

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 144 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 3

AFT Fathom Model

Branch	Boundary Flow Units	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out
11		(P8) 1.1, 0	(P12) 0, 0					

Branch	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out
11									

Branch	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out
11									

General Component Table

General Component	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source
15	General Component	Yes	605.6	feet			

General Component	Special Condition	Loss Model	Loss Value	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units
15	None	Resistance Curve	Variable	Vol. Flow Rate	gal/min	Pressure Loss	psid

General Component	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
15	5.551115E-17	0	0.0002777778	0	0

Pump Table

Pump	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Pump Type
1	Pump	Yes	574.5	feet				None	Pump Curve

Pump	Design Flow Rate	Design Flow Rate Units	Current Configuration	Independent Variable	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Pump Curve Constant a
1				Vol. Flow Rate	gal/min	Head Rise	feet	173.1132

Pump	Pump Curve Constant b	Pump Curve Constant c	Pump Curve Constant d	Pump Curve Constant e	Runout Flow Rate	Runout Flow Rate Units	Speed	Control When Exceeded Only
1	-3.244979	-0.2765802	0	0			100	

Pump	Heat Added To Fluid	Heat Added Units
1	0	Percent

Reservoir Table

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 145 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 4

AFT Fathom Model

Reservoir	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Liquid Elev.	Liquid Elev. Units
13	Reservoir	Yes						576.6	feet

Reservoir	Surface Pressure	Surface Pressure Units	Balance Energy	Balance Concentration	(Pipe #1) K In, K Out	(Pipe #2) K In, K Out	(Pipe #3) K In, K Out	(Pipe #4) K In, K Out
13	1	atm	No	No	(P11) 0, 0			

Reservoir	(Pipe #5) K In, K Out	(Pipe #6) K In, K Out	(Pipe #7) K In, K Out	(Pipe #8) K In, K Out	(Pipe #9) K In, K Out	(Pipe #10) K In, K Out	(Pipe #11) K In, K Out	(Pipe #12) K In, K Out	(Pipe #13) K In, K Out
13									

Reservoir	(Pipe #14) K In, K Out	(Pipe #15) K In, K Out	(Pipe #16) K In, K Out	(Pipe #17) K In, K Out	(Pipe #18) K In, K Out	(Pipe #19) K In, K Out	(Pipe #20) K In, K Out	(Pipe #21) K In, K Out	(Pipe #22) K In, K Out
13									

Reservoir	(Pipe #23) K In, K Out	(Pipe #24) K In, K Out	(Pipe #25) K In, K Out	(Pipe #1) Depth	(Pipe #2) Depth	(Pipe #3) Depth	(Pipe #4) Depth	(Pipe #5) Depth	(Pipe #6) Depth
13				(P11) 576.6					

Reservoir	(Pipe #7) Depth	(Pipe #8) Depth	(Pipe #9) Depth	(Pipe #10) Depth	(Pipe #11) Depth	(Pipe #12) Depth	(Pipe #13) Depth	(Pipe #14) Depth	(Pipe #15) Depth
13									

Reservoir	(Pipe #16) Depth	(Pipe #17) Depth	(Pipe #18) Depth	(Pipe #19) Depth	(Pipe #20) Depth	(Pipe #21) Depth	(Pipe #22) Depth	(Pipe #23) Depth	(Pipe #24) Depth
13									

Reservoir	(Pipe #25) Depth	Pipe Depth Units
13		feet

Valve Table

Valve	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Special Condition	Exit Valve	Exit Pressure
4	HV-41-11	Yes	605.6	feet				None	No	

Valve	Exit Pressure Units	Restricted Area	Restricted Area Units	Loss Model	Loss Source	Loss Factor	Percent Open	Open Pct. Data Exists	Independent Variable
4				Cv	Cv From Table	1.8	100	Yes	

Valve	Ind. Variable Units	Dependent Variable	Dep. Variable Units	Loss Constant a	Loss Constant b	Loss Constant c	Loss Constant d	Loss Constant e
4								

Bend Table

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 146 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Model)
3/26/2020
Page 5

AFT Fathom Model

Bend	Name	Object Defined	Inlet Elevation	Elevation Units	Initial Pressure	Initial Pressure Units	Database Source	Type	Angle (Degrees)	R/D
2	Bend	Yes	605.6	feet				Smooth Bend	45	1.5
3	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
5	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
8	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
10	Bend	Yes	605.6	feet				Smooth Bend	90	1.5
12	Bend	Yes	605.6	feet				Smooth Bend	45	1.5

Bend	Loss Factor
2	0.2009148
3	0.28784
5	0.364336
8	0.28784
10	0.28784
12	0.2037692

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 147 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 1	AFT Fathom Model	

Model Reference Information

General

Title: AFT Fathom Model
Analysis run on: 3/26/2020 1:06:56 PM
Application version: AFT Fathom Version 10 (2018.05.21)
Input File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF.fth
Scenario: Base Scenario/Goulds Pump/Maximum Flow
Output File: P:\Clients\Washington River Protection Solutions - WRPS 544\S54413.024 - LERF Basin 41 Design\Calculations\Mech\M-002 Flow\Rev 0\LERF_F2.out

Execution Time= 0.07 seconds
Total Number Of Head/Pressure Iterations= 0
Total Number Of Flow Iterations= 14
Total Number Of Temperature Iterations= 0
Number Of Pipes= 12
Number Of Junctions= 13
Matrix Method= Gaussian Elimination

Pressure/Head Tolerance= 0.0001 relative change
Flow Rate Tolerance= 0.0001 relative change
Temperature Tolerance= 0.0001 relative change
Flow Relaxation= (Automatic)
Pressure Relaxation= (Automatic)

Constant Fluid Property Model
Fluid Database: User Specified
Fluid= User Specified
Density= 1 lbm/ft3
Viscosity= 1 centipoise
Vapor Pressure= Unspecified
Viscosity Model= Newtonian
Apply laminar and non-Newtonian correction to: Pipe Fittings & Losses, Junction K factors, Junction Special Losses, Junction Polynomials
Corrections applied to the following junctions: Branch, Reservoir, Assigned Flow, Assigned Pressure, Area Change, Bend, Tee or Wye, Spray Discharge, Relief Valve

Ambient Pressure (constant)= 1 atm
Gravitational Acceleration= 1 g
Turbulent Flow Above Reynolds Number= 4000
Laminar Flow Below Reynolds Number= 2300
Total Inflow= 10.04 gal/min
Total Outflow= 10.04 gal/min
Maximum Static Pressure is 15.49 psia at Pipe 1 Inlet
Minimum Static Pressure is 14.54 psia at Pipe 11 Inlet

Warnings

No Warnings

Applied Standards

===== ANSI/HI 9.6.3-2017 - Rotodynamic Pumps - Guideline for Operating Regions =====
Pump 1 set to specific speed <=4500 (US Customary), with lower POR 70% and upper POR 120% of BEP

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 148 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output) 3/26/2020 Page 2	AFT Fathom Model	

Pump Summary

Jct	Results Diagram	Name	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP (psid)	dH (feet)	Overall Efficiency (Percent)	Speed (Percent)	Overall Power (hp)	BEP (gal/min)	% of BEP (Percent)
1	Show	Pump	10.04	0.02237	0.7822	112.6	N/A	100.0	4.581E-03	N/A	N/A

Jct	NPSHA (feet)	NPSHR (feet)
1	N/A	N/A

Valve Summary

Jct	Name	Valve Type	Vol. Flow (gal/min)	Mass Flow (lbm/sec)	dP Stag. (psid)	dH (feet)	P Static In (psia)	Cv	K	Valve State
4	HV-41-11	REGULAR	10.04	0.02237	0.4990	71.85	15.14	1.800	41.13	Open

Reservoir Summary

Jct	Name	Type	Liq. Height (feet)	Liq. Elevation (feet)	Surface Pressure (psia)	Liquid Volume (feet3)	Liquid Mass (lbm)	Net Vol. Flow (gal/min)	Net Mass Flow (lbm/sec)
13	Reservoir	Infinite	N/A	576.6	14.70	N/A	N/A	10.04	0.02237

Pipe Output Table

Pipe	Name	Vol. Flow Rate (gal/min)	Velocity (feet/sec)	P Static Max (psia)	P Static Min (psia)	Elevation Inlet (feet)	Elevation Outlet (feet)	dP Stag. Total (psid)	dP Static Total (psid)	dP Gravity (psid)	dH (feet)
1	Pipe	10.04	1.450	15.49	15.24	574.5	605.6	0.2557054	0.2557054	0.2160	5.72161
2	Pipe	10.04	1.583	15.21	15.21	605.6	605.6	0.0007207	0.0007207	0.0000	0.10378
3	Pipe	10.04	1.583	15.21	15.21	605.6	605.6	0.0003060	0.0003060	0.0000	0.04407
4	Pipe	10.04	10.603	14.64	14.62	605.6	605.6	0.0225270	0.0225270	0.0000	3.24389
5	Pipe	10.04	10.603	15.15	15.14	605.6	605.6	0.0137373	0.0137373	0.0000	1.97817
6	Pipe	10.04	13.760	14.59	14.57	605.6	605.6	0.0231362	0.0231362	0.0000	3.33161
7	Pipe	10.04	1.583	14.55	14.55	605.6	605.6	0.0003060	0.0003060	0.0000	0.04407
8	Pipe	10.04	1.583	14.55	14.55	605.6	605.6	0.0002786	0.0002786	0.0000	0.04012
10	Pipe	10.04	1.583	14.55	14.54	605.6	605.6	0.0041662	0.0041662	0.0000	0.59994
11	Pipe	10.04	1.583	14.70	14.54	605.6	576.6	-0.1535787	-0.1535787	-0.2014	6.88467
12	Pipe	10.04	1.583	14.55	14.55	605.6	605.6	0.0005781	0.0005781	0.0000	0.08324
13	Pipe	10.04	1.583	15.24	15.24	605.6	605.6	0.0006121	0.0006121	0.0000	0.08814

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 149 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

AFT Fathom 10 (Output)
3/26/2020
Page 3

AFT Fathom Model

Pipe	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)
1	15.49	15.24	15.49	15.24
2	15.21	15.21	15.21	15.21
3	15.21	15.21	15.21	15.21
4	14.64	14.62	14.65	14.63
5	15.15	15.14	15.16	15.15
6	14.59	14.57	14.61	14.59
7	14.55	14.55	14.55	14.55
8	14.55	14.55	14.55	14.55
10	14.55	14.54	14.55	14.54
11	14.54	14.70	14.54	14.70
12	14.55	14.55	14.55	14.55
13	15.24	15.24	15.24	15.24

All Junction Table

Jct	Name	P Static In (psia)	P Static Out (psia)	P Stag. In (psia)	P Stag. Out (psia)	Vol. Flow Rate Thru Jct (gal/min)	Mass Flow Rate Thru Jct (lbm/sec)	Loss Factor (K)
1	Pump	14.71	15.49	14.71	15.49	10.04	0.02237	0.000
2	Bend	15.24	15.24	15.24	15.24	10.04	0.02237	2.131
3	Bend	15.21	15.21	15.21	15.21	10.04	0.02237	2.892
4	HV-41-11	15.14	14.64	15.15	14.65	10.04	0.02237	41.127
5	Bend	14.62	14.59	14.63	14.61	10.04	0.02237	1.102
6	Area Change	15.21	15.15	15.21	15.16	10.04	0.02237	161.306
7	Area Change	14.57	14.55	14.59	14.55	10.04	0.02237	2.004
8	Bend	14.55	14.55	14.55	14.55	10.04	0.02237	2.892
10	Bend	14.55	14.55	14.55	14.55	10.04	0.02237	2.892
11	Branch	14.55	14.55	14.55	14.55	10.04	0.02237	0.000
12	Bend	14.54	14.54	14.54	14.54	10.04	0.02237	2.047
13	Reservoir	14.70	14.70	14.70	14.70	10.04	0.02237	0.000
15	General Component	15.24	15.21	15.24	15.21	10.04	0.02237	103.638

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 150 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 1

LEACHATE PUMP CURVE

CALCULATION SHEET

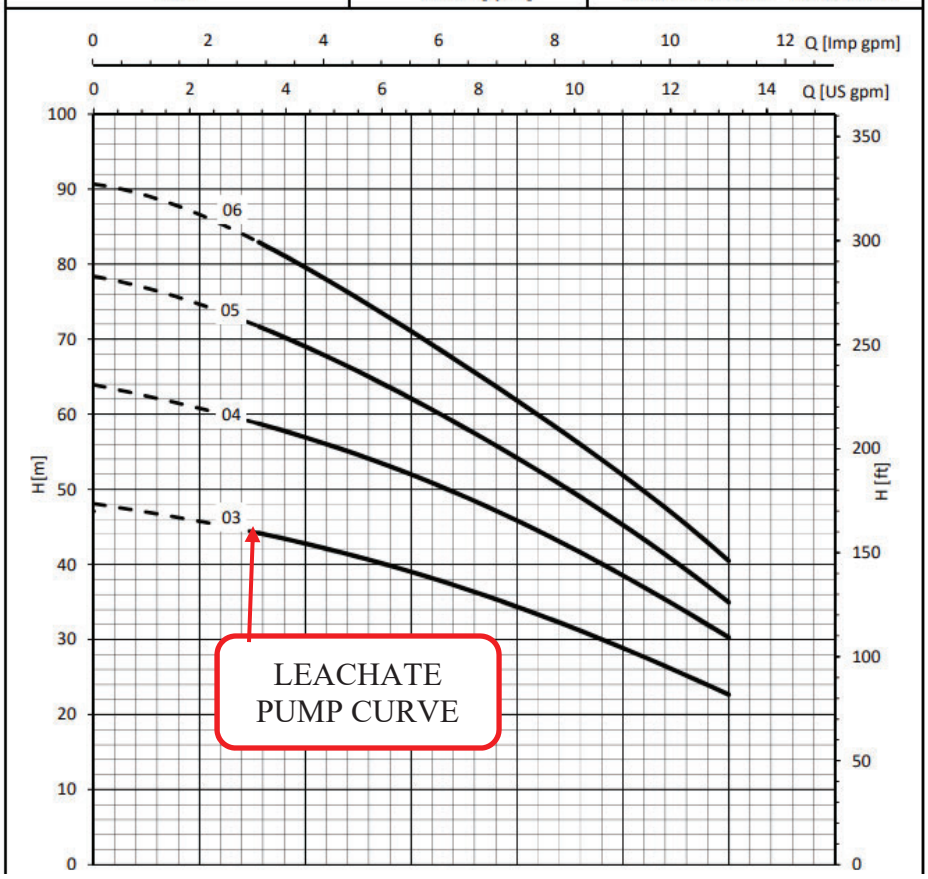
Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 151 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Minimum Continuous Operating Flow Rate = 3.2 GPM
Maximum Continuous Operating Flow Rate = 13.3 GPM

LOWARA
a xylem brand

1SC SERIES - SINGLE PHASE VERSION
OPERATING CHARACTERISTICS

1SC	~ 3500 [rpm]	ISO 9906:2012 - Grade 3B



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 152 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 2

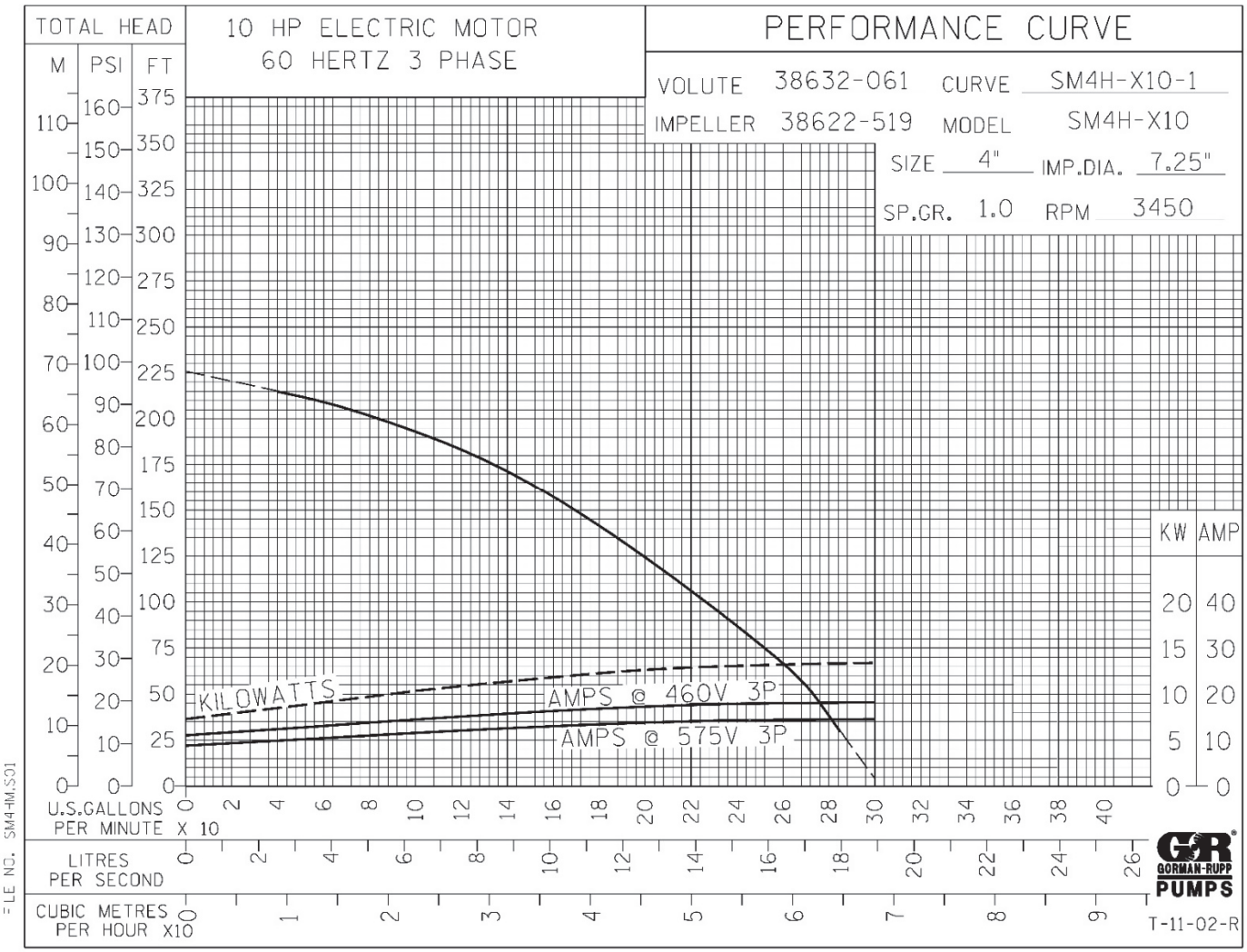
BASIN PUMP CURVE

RPP-CALC-63650, Rev. 0

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 153 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Minimum Continuous Operating Flow Rate = 40 GPM
Maximum Continuous Operating Flow Rate = 280 GPM



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 154 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 3

CAVITATION CALCULATION

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 155 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Control Valve Sizing

$\Delta P_{maxL} = F_L^2 \cdot (P_1 - F_F \cdot P_V)$ — Allowable sizing pressure drop for control valves without fittings (Control Valve Handbook, Pg. 115).

$F_F = 0.96 - 0.28 \cdot \sqrt{\frac{P_V}{P_C}}$ — Liquid critical pressure ratio factor (Control Valve Handbook, Pg. 115).

P_1 = "Upstream absolute static pressure"

P_2 = "Downstream absolute static pressure"

P_C = "Absolute thermodynamic critical pressure"

P_V = "Vapor pressure absolute of liquid at inlet temperature"

Flow Control Valve Sizing

$\Delta P := 76.73 psi$ ("Low Head Loss") — Calculated differential pressure across MOV-41-1 for the high basin level recirculation scenario

$P_1 := 74.81 psi + 1 atm = 89.5 psi$ — Upstream absolute static pressure of MOV-41-1 for the high basin level recirculation scenario.

$P_2 := P_1 - \Delta P = 12.8 psi$ — Downstream absolute static pressure of MOV-41-1 for the high basin level recirculation scenario.

$P_C := 3208 psi$ — Absolute thermodynamic critical pressure (Control Valve Handbook, Pg 205).

$P_V := 2.226 psi$ — Absolute vapor pressure at 130 °F, which is a bounding temperature (Lindeburg, Appendix 23.A, Attachment 9).

$\%O := 30.86\%$ — Percent open high head loss scenarios (Fathom Model Output).

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 156 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

$$F_L(x) := \text{linterp}\left[\begin{pmatrix}0\\10\\20\\30\\40\\50\\60\\70\\80\\90\\100\end{pmatrix}\%, \begin{pmatrix}0\\0.96\\0.95\\0.94\\0.93\\0.92\\0.90\\0.89\\0.86\\0.82\\0.75\end{pmatrix}, x\right]$$

Linear inerpolation of the V-Control Valve liquid pressure recovery factor (Attachment 1).

$$F_F := 0.96 - 0.28\cdot\sqrt{\frac{P_V}{P_C}} = 0.95$$

Liquid critical pressure ratio factor (Control Valve Handbook, Pg. 115) for the high basin level recirculation scenario.

$$\Delta P_{maxL} := F_L(\%O)^2\cdot\left(P_1 - F_F\cdot P_V\right) = 77\cdot psi$$

Allowable sizing pressure drop for control valves without fittings (Control Valve Handbook, Pg. 115) for the high basin level recirculation scenario.

$$\Delta P_{maxL} = 77\cdot psi$$

Calculated MOV-41-1 allowable pressure drop.

$$Check := \begin{cases}\text{"Design OK"} & \text{if } \Delta P_{maxL} \ge \Delta P \\ \text{"Redesign"} & \text{otherwise}\end{cases} = \text{"Design OK"}$$

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 157 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 4

FLOWTEK CUTSHEET

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 158 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

FlowTek®
A Subsidiary of BRAY INTERNATIONAL, Inc.

V-Control Ball Valve Selection Guide
Technical Bulletin No. 1006
Date: September 2008 / Pg. 3 of 6

V-CONTROL BALL VALVE FLOW COEFFICIENT C_V CHARTS

Full Port 1/2" to 4" Triad and 1/2" to 12" F15/3

		Percent and Angle of Ball Rotation										
Valve Size	V-Port Angle	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1/2"	15°	0	0.04	0.17	0.43	0.68	0.98	1.62	2.09	2.84	3.61	4.18
1/2"	30°	0	0.04	0.23	0.47	0.77	1.19	1.83	2.47	3.43	4.65	5.55
1/2"	60°	0	0.04	0.28	0.73	1.11	1.83	2.92	4.29	7.00	9.43	12.78
1/2"	90	0	0.06	0.47	0.85	1.28	2.05	3.24	4.74	8.26	11.61	14.72
3/4"	15°	0	0.05	0.20	0.51	0.88	1.30	2.13	2.75	3.74	4.75	5.51
3/4"	30°	0	0.07	0.30	0.61	0.99	1.57	2.42	3.25	4.52	6.12	7.30
3/4"	60°	0	0.07	0.35	0.93	1.46	2.42	3.85	5.64	9.21	12.41	16.25
3/4"	90°	0	0.08	0.59	1.11	1.69	2.69	4.27	6.24	10.85	15.28	19.37
1"	15°	0	0.06	0.30	0.93	1.49	2.31	3.75	4.67	6.47	8.46	9.84
1"	30°	0	0.08	0.45	1.25	2.06	3.54	5.30	7.70	10.49	12.84	15.48
1"	60°	0	0.09	0.68	1.74	2.78	5.13	8.00	11.88	18.71	23.22	32.81
1"	90°	0	0.11	0.93	2.78	5.09	7.74	12.20	17.33	22.50	31.40	43.89
1-1/4"	15°	0	0.03	0.27	0.83	1.64	2.78	4.07	5.88	7.99	10.81	12.82
1-1/4"	30°	0	0.05	0.48	1.37	2.47	4.12	6.08	8.82	11.76	14.87	17.37
1-1/4"	60°	0	0.07	0.67	2.04	3.41	6.47	10.80	15.39	22.35	33.37	43.45
1-1/4"	90°	0	0.08	0.78	2.92	5.41	10.23	17.28	25.50	35.60	51.76	65.81
1-1/2"	15°	0	0.05	0.37	1.15	2.26	3.82	5.59	8.08	10.99	14.86	17.62
1-1/2"	30°	0	0.07	0.65	1.88	3.39	5.66	8.36	12.12	16.17	20.44	23.88
1-1/2"	60°	0	0.09	0.92	2.81	4.69	8.89	14.85	21.16	30.73	45.88	59.74
1-1/2"	90°	0	0.10	1.07	4.01	7.44	14.06	22.60	31.90	48.03	71.17	90.49
2"	15°	0	0.06	0.69	2.23	4.45	7.24	10.68	15.38	21.39	28.75	34.69
2"	30°	0	0.09	1.18	3.79	7.53	12.26	17.83	26.44	36.45	48.09	55.85
2"	60°	0	0.11	1.51	5.80	10.39	20.60	33.98	48.75	69.04	104.23	135.75
2"	90°	0	0.16	1.89	7.28	13.58	25.38	42.30	55.56	87.04	129.75	167.34
2-1/2"	15°	0	0.07	0.77	2.40	5.23	8.06	11.73	16.42	22.31	27.24	31.30
2-1/2"	30°	0	0.09	1.15	4.42	7.91	13.39	20.05	30.43	41.92	56.30	76.95
2-1/2"	60°	0	0.13	1.46	5.91	11.90	23.24	37.92	59.31	83.29	113.65	162.50
2-1/2"	90°	0	0.17	1.83	7.29	16.45	31.16	53.53	77.89	118.29	177.32	239.45
3"	15°	0	0.08	0.89	2.96	6.65	9.58	13.42	19.47	26.67	31.79	38.31
3"	30°	0	0.12	1.20	4.15	9.49	15.96	26.78	38.91	53.31	69.77	85.91
3"	60°	0	0.15	2.89	6.70	15.82	29.36	46.32	73.60	106.74	149.88	193.20
3"	90°	0	0.20	4.12	8.65	21.09	41.09	69.27	105.91	161.04	237.23	359.21
4"	15°	0	0.11	1.40	3.73	8.86	16.76	27.91	41.85	59.24	75.49	96.37
4"	30°	0	0.16	1.75	7.84	18.59	35.21	58.60	87.89	124.41	158.53	196.35
4"	60°	0	0.26	2.20	12.44	33.67	62.98	106.26	160.49	233.96	329.50	437.29
4"	90°	0	0.35	4.37	19.68	50.29	91.83	157.43	240.51	365.15	546.62	830.86
6"	15°	0	0.20	2.50	6.64	15.77	29.85	49.70	74.54	105.51	134.44	171.62
6"	30°	0	0.29	3.12	13.97	33.11	62.70	104.37	156.53	221.56	282.33	349.69
6"	60°	0	0.46	5.41	22.15	59.97	112.16	189.24	285.82	416.68	586.83	800.80
6"	90°	0	0.66	7.79	35.05	89.56	163.55	280.37	428.34	650.32	973.50	1479.70
8"	15°	0	0.34	4.23	11.32	26.84	50.80	84.58	126.84	195.00	345.50	692.07
8"	30°	0	0.49	5.32	23.77	56.35	106.70	177.62	266.39	377.06	480.47	595.11
8"	60°	0	0.79	6.66	23.81	102.06	190.87	322.06	486.41	709.11	998.69	1325.38
8"	90°	0	1.05	13.26	59.64	152.42	278.33	477.14	728.96	1106.69	1656.77	2518.18
10"	15°	0	0.53	6.62	17.69	41.94	79.38	132.15	198.20	350.00	545.00	856.36
10"	30°	0	0.77	8.31	37.14	88.05	166.73	277.53	416.24	589.16	750.74	929.87
10"	60°	0	1.23	10.41	37.20	159.47	298.23	503.22	760.02	1107.99	1560.45	2070.90
10"	90°	0	1.64	20.72	93.20	238.16	434.90	745.53	1139.00	1729.20	2588.70	3934.65
12"	15°	0	0.74	9.26	24.76	58.72	111.13	185.01	277.47	564.00	1101.07	1638.90
12"	30°	0	1.07	11.63	52.00	123.27	233.42	388.54	582.73	824.82	1051.03	1301.81
12"	60°	0	1.72	14.57	52.08	223.25	417.52	704.51	1064.03	1551.19	2184.63	2899.26
12"	90°	0	2.29	29.00	130.47	333.42	608.85	1043.74	1594.59	2420.88	3624.18	5508.51

Fl	0	0.96	0.95	0.94	0.93	0.92	0.90	0.89	0.86	0.82	0.75
Xt	0	0.98	0.77	0.71	0.67	0.64	0.63	0.62	0.55	0.43	0.40

Fl = Liquid Pressure Recovery Factor Xt= Pressure Drop Ratio Factor (Gas)

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 159 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

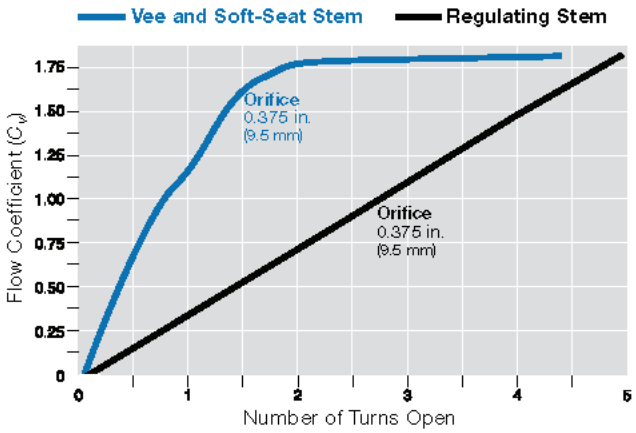
ATTACHMENT 5

SWAGELOK NEEDLE VALVE CUTSHEET

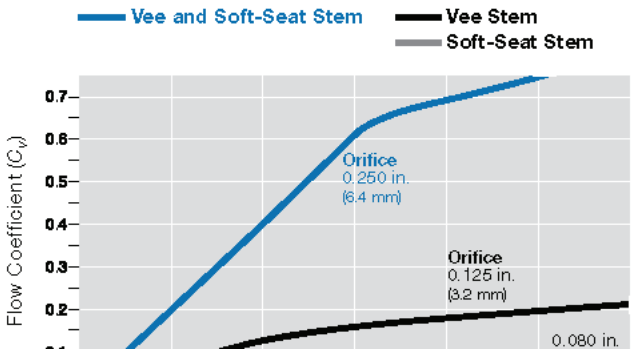
CALCULATION SHEET

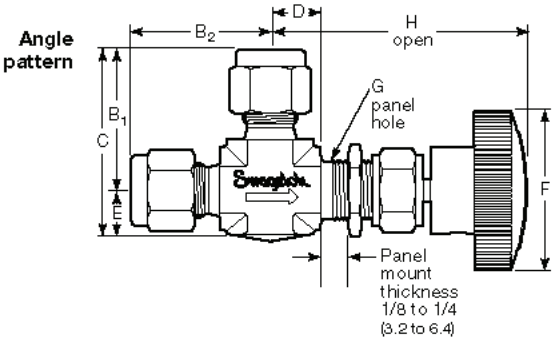
Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 160 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

18 Series



20 and 26 Series





Stainless Steel Valves with Regulating Stems

Select an ordering number.

Alloy 400, Brass, and Steel Valves with Regulating Stems

Replace **SS** in the ordering number with a material designator.

Example: **M**-ORS2

Material	Designator
Alloy 400	M
Brass	B
Steel	S

Vee and Soft-Seat Stems

Replace **R** in the ordering number with **V** for a vee stem or **K** for a soft-seat stem with PCTFE stem tip.

Examples: SS-O**V**S2
SS-O**K**S2

Angle-Pattern Valves

Add **-A** to the ordering number.

Example: SS-ORS2-**A**

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 161 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 6

LEACHATE STRAINER DATA

RPP-CALC-63650, Rev. 0

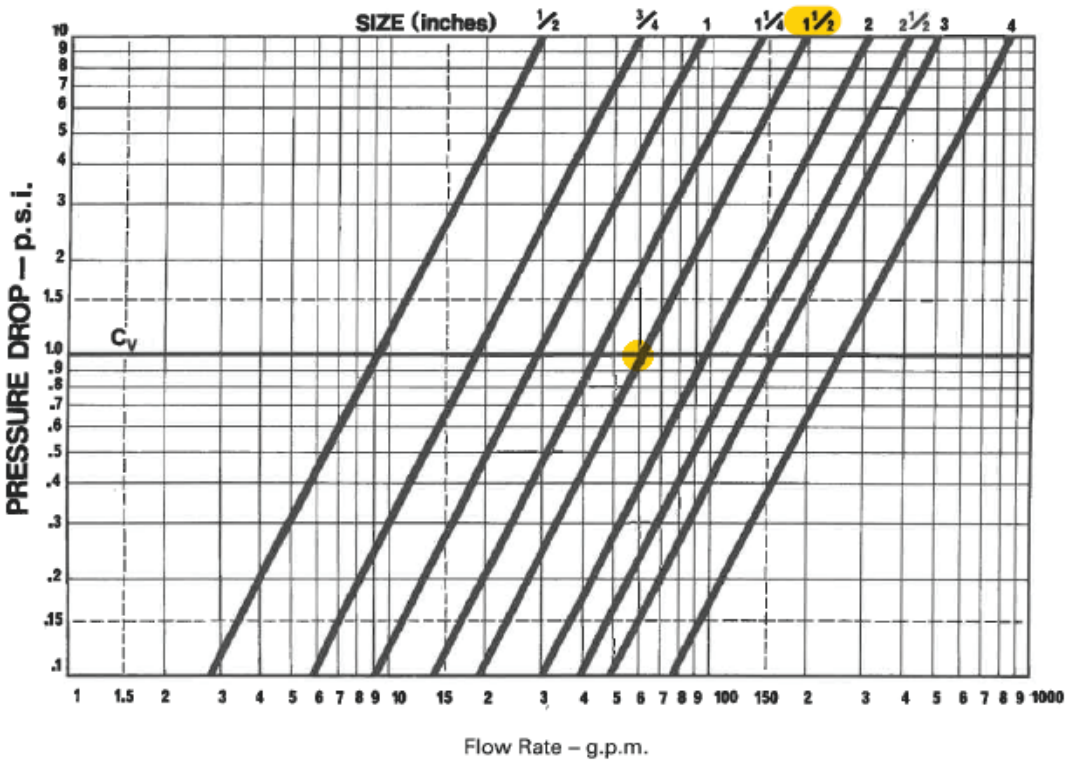
CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 162 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

S-MS-PressureDrop-Y

Pressure Drop Chart

Y Strainers Screwed End



Above based on the flow of clean water through .033: - ¼" perforated metal screens. Consult our Engineering Department for pressure drop information on steam, gases or viscous fluids. See Theoretical Pressure Drop Curves for Screen Clogging In the Technical Data Section for multiplying factors for clogged screens.

Mueller Steam Specialty™

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 163 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 7

3-WAY VALVE DATA SHEET

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 164 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

DIMENSIONS - MODEL MPF - CLASSES 150/300

SIZE ins (mm)	A 150	A1 300	øB	D	E	F	G	øH	øI*	J	K	L*	MPF150 Flange Dimensions M	N	S	T	MPF300 Flange Dimensions M1	N1	S1	T1
1/2 (15)	5.98 (152)	6.30 (160)	0.59 (15)	5.12 (130)	2.44 (62)	1.61 (41)	0.43 (11)	1.42 (36)	1.65 (42)	0.35 (9)	0.24 (6)	0.24 (6)	3.50 (89)	4	2.38 (60.5)	0.63 (16)	3.75 (95)	4	2.62 (66.5)	0.63 (16)
3/4 (20)	6.57 (167)	6.97 (177)	0.79 (20)	6.50 (165)	3.23 (82)	1.93 (49)	0.55 (14)	1.65 (42)	1.97 (50)	0.43 (11)	0.24 (6)	0.28 (7.1)	3.88 (98.5)	4	2.75 (69.8)	0.63 (16)	4.62 (117)	4	3.25 (82.5)	0.75 (19)
1 (25)	7.48 (190)	7.87 (200)	0.98 (25)	6.50 (165)	3.50 (89)	2.17 (55)	0.55 (14)	1.65 (42)	1.97 (50)	0.43 (11)	0.24 (6)	0.28 (7.1)	4.25 (108)	4	3.12 (79.2)	0.63 (16)	4.88 (124)	4	3.50 (89)	0.75 (19)
11/4 (32)	8.19 (208)	8.19 (208)	1.26 (32)	8.07 (205)	3.86 (98)	2.48 (63)	0.71 (18)	1.97 (50)	2.76 (70)	0.55 (14)	0.28 (7.1)	0.36 (9.2)	4.62 (117)	4	3.50 (89)	0.63 (16)	5.25 (133)	4	3.88 (98.5)	0.75 (19)
11/2 (40)	8.66 (220)	9.21 (234)	1.50 (38)	8.07 (205)	4.25 (108)	2.91 (74)	0.71 (18)	1.97 (50)	2.76 (70)	0.55 (14)	0.28 (7.1)	0.36 (9.2)	5.00 (127)	4	3.88 (98.5)	0.63 (16)	6.12 (155)	4	4.50 (114)	0.87 (22)
2 (50)	9.96 (253)	10.75 (273)	1.97 (50)	12.80 (325)	5.51 (140)	3.66 (93)	0.91 (23)	2.76 (70)	4.02 (102)	0.67 (17)	0.36 (9.2)	0.45 (11.4)	6.00 (152)	4	4.75 (120.6)	0.75 (19)	6.50 (165)	8	5.00 (127)	0.75 (19)
21/2 (65)	11.81 (300)	11.81 (300)	2.44 (62)	15.75 (400)	7.87 (200)	4.69 (119)	0.98 (25)	4.02 (102)	—	0.87 (22)	0.43 (11)	—	7.00 (177.8)	4	5.50 (139.7)	0.75 (19)	7.50 (190.5)	8	5.88 (149.4)	0.88 (22.4)
3 (80)	12.01 (305)	13.01 (330.4)	2.99 (76)	19.69 (500)	8.27 (210)	5.39 (137)	0.98 (25)	4.02 (102)	—	0.87 (22)	0.43 (11)	—	7.50 (190.5)	4	6.00 (152.4)	0.75 (19)	8.25 (209.6)	8	6.62 (168.2)	0.88 (22.4)
4 (100)	14.51 (368.5)	15.49 (393.5)	3.78 (96)	25.59 (650)	9.06 (230)	6.18 (157)	0.98 (25)	4.02 (102)	—	0.87 (22)	0.43 (11)	—	9.00 (228.6)	8	7.50 (190.5)	0.75 (19)	10.00 (254)	8	7.88 (200.2)	0.88 (22.4)
6 (150)	16.81 (427)	18.43 (468.1)	5.91 (150)	47.24 (1200)	8.66 (220)	6.28 (159.5)	2.40 (61)	4.92 (125)	—	1.42 (36)	M12	—	11.00 (279.4)	8	9.50 (241.3)	0.88 (22.4)	12.50 (317.5)	12	10.62 (269.8)	0.88 (22.4)
8 (200)	20.94 (532)	—	7.87 (200)	59.06 (1500)	10.31 (262)	7.91 (201)	2.40 (61)	4.92 (125)	—	1.42 (36)	M12	—	13.50 (342.9)	8	11.75 (298.5)	0.88 (22.4)	15.00 (381)	12	13.00 (330.2)	1.00 (25.4)

*Outer mounting bolt circle (I) and hole diameter (L) for 1/2"–2" valves not shown in drawing.

TORQUE – Models MPF150/MPF300

SIZE ins (mm)	1/2 (15)	3/4 (20)	1 (25)	1 1/4 (32)	1 1/2 (40)	2 (50)	2 1/2 (65)	3 (80)	4 (100)	6 (150)	8 (200)
Lbs-In (Nm)	124 (14)	159 (18)	301 (34)	381 (43)	513 (58)	885 (100)	1239 (140)	2213 (250)	2830 (320)	6000 (678)	8000 (904)

Torque at maximum rated pressure, clean water, TFM seating material.

CV – Models MPF150/MPF300

SIZE ins (mm)	1/2 (15)	3/4 (20)	1 (25)	1 1/4 (32)	1 1/2 (40)	2 (50)	2 1/2 (65)	3 (80)	4 (100)	6 (150)	8 (200)
90°	8.1	15	24	40	65	106	171	255	409	1083	2007
180°	11	21	33	54	92	147	240	356	561	1509	2817

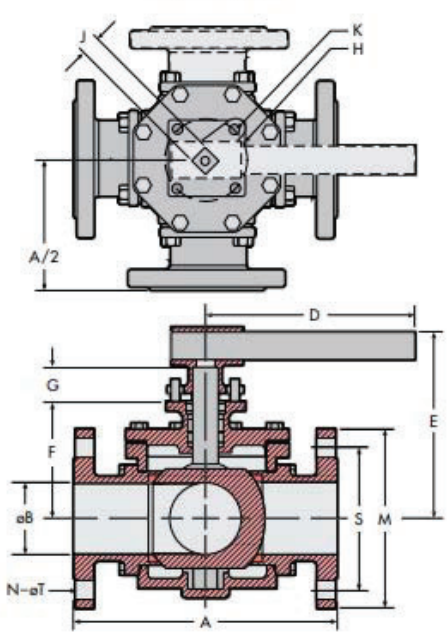
WEIGHT – Models MPF150 (4-Way, T Port)

SIZE ins (mm)	1/2 (15)	3/4 (20)	1 (25)	1 1/4 (32)	1 1/2 (40)	2 (50)	2 1/2 (65)	3 (80)	4 (100)	6 (150)	8 (200)
lbs (Kg)	8.7 (3.9)	10.3 (4.7)	14.9 (6.7)	20.8 (9.4)	30.3 (13.7)	51.3 (23.3)	70.1 (31.8)	88.4 (40.1)	160.5 (72.8)	290.4 (131.7)	543 (246.3)

WEIGHT – Models MPF300 (4-Way, T Port)

SIZE ins (mm)	1/2 (15)	3/4 (20)	1 (25)	1 1/4 (32)	1 1/2 (40)	2 (50)	2 1/2 (65)	3 (80)	4 (100)	6 (150)
lbs (Kg)	11.2 (5.1)	16 (7.3)	21.8 (9.9)	29.1 (13.2)	42.9 (19.5)	61 (27.7)	86.4 (39.2)	108.3 (49.1)	184.2 (83.6)	456.2 (206.9)

MPF150/MPF300
2-1/2" – 8" shown



10

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 165 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 8

FRP DATA SHEET

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 166 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Conley Composites
an ANDRONACO INDUSTRIES company

EPOXY SCHEDULE 40/30
DOUBLE CONTAINED PIPING

ASTM DESIGNATION CODE RTRP-11FW1-2113

Conley Product Data

RUGGED TOP OF THE LINE PERFORMANCE ~ AFFORDABLE COST

Description

- Extra heavy duty filament wound piping for service up to 150 psi
- 60 mil double Nexus® reinforced corrosion barrier (inner liner)
- Premium aromatic amine cured product for operating temperatures up to 275°F
- Sizes available from 2" through 30"
- Complete line of filament wound fittings available
- In house fabrication facilities "From your blueprints to pipe assemblies"
- Color coding available
- Patented interlocking union for thermal expansion (US Patent #5449204 & 5368338)
- See Sch 40/30 Specification
- See Sch 40 Product Data
- See Sch 30 Product Data

Typical Applications

- Waste water treatment
- Steel pickling
- Automotive
- Petrochemical
- Pharmaceutical
- Chemical processing
- Brine and brackish water
- Jet fuel
- Gasoline – Diesel – Fuel Oil
- Cooling water
- Odor control
- Industrial waste
- Food and beverages
- Bridge, roof and floor drains

Performance

- Excellent chemical resistance inside and outside to a variety of caustics, acids, brines and petroleum products ~ See the chemical resistance chart for fluid services
- External UV/Corrosion barrier minimum 10/20 mil on all pipe and fittings
- 25 year guarantee against *'fiber blooming'* on all pipe and fittings
- Straight socket joining system (No expensive tapering tools required)

Specifications

- ASTM D2996 Filament-Wound "Fiberglass" Pipe
- ASTM D2310 Classification for Machine-Made "Fiberglass" Pipe
- ASTM D3567 Determining Dimensions of "Fiberglass" Pipe and Fittings
- ASTM D4024 Machine Made "Fiberglass" Flanges
- ASTM D5685 "Fiberglass" Pressure Pipe Fittings

Codes & Standards

- AWWA C950 Fiberglass Pressure Pipe Standards
- ASME B31.1 Power Piping Code
- ASME B31.3 Process Piping Code

Listings

- U.S. Federal Regulations FDA 21 CFR 175.300

Application Legislation

- 40 CFR 280. RCRA, Subtitle 1
- 40 CFR 264/5
- CERCLA "Superfund Act"

PDS4030E (12/14) 1

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 167 of 180
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Schedule 40/30 Pipe Dimensional Data* and Pressure Ratings(1) from –50° to 275°F

(1) Static pressure rating; steady (stationary) pressure is created when using a gear pump, turbine pump, centrifugal pump, etc.
(2) Vacuum Service: A full vacuum within the pipe is equivalent to 14.7 psi external pressure at sea level. Contact Conley for higher external pressure ratings.

NOM SIZE	ANNULUS CLEAR (IN)	SPIDER MIN OPENING (IN)	ANNULUS VOLUME (GAL/FT)	COMBINED WEIGHT (LB/FT)	ANNULUS PRESS (PSI)	ANNULUS VAC PRESS (PSI)(2)
2"/4"	0.81	0.6	0.51	3.14	150	24.1
2"/6"	1.81	1.6	1.32	4.32	150	13.8
3"/6"	1.27	1.0	1.10	4.89	150	13.8
3"/8"	2.27	2.0	2.24	5.85	150	6.1
4"/6"	0.76	0.5	0.82	5.54	150	13.8
4"/8"	1.76	1.5	1.96	6.50	150	6.1
6"/8"	0.72	0.5	1.14	8.45	150	6.1
6"/10"	1.72	1.5	2.61	10.86	150	10.2
8"/10"	0.70	0.5	1.47	12.63	150	10.2
8"/12"	1.83	1.6	3.51	14.02	100	5.7
10"/12"	0.79	0.5	2.04	16.61	100	5.7
10"/14"	1.79	1.5	4.20	18.60	100	3.6
12"/14"	0.63	0.4	2.16	21.67	100	3.6
12"/16"	1.63	1.4	4.65	23.01	100	2.5
14"/16"	0.63	0.4	2.49	24.91	100	2.5
14"/18"	1.63	1.4	5.30	27.91	100	4.2
16"/18"	0.63	0.4	2.82	29.80	100	4.2
16"/20"	1.63	1.4	5.96	31.32	100	3.1
18"/20"	0.63	0.4	3.14	33.21	100	3.1
18"/24"	2.63	2.0	10.40	39.70	100	3.5
20"/24"	1.65	1.4	7.26	40.54	100	3.5
20"/30"	4.77	2.0	21.22	50.49	100	3.1
24"/30"	2.70	2.0	13.96	58.82	100	3.1

*All values are nominal. Minimum wall thickness shall not be less than 87.5% of nominal wall thickness in accordance with ASTM D2996.

NOTES:
For carrier pipe dimensions, see Schedule 40 Pipe Dimensional Data Table
For containment pipe dimensions, see Schedule 30 Pipe Dimensional Data Table

2 PDS4030E (12/14)

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 168 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Support Spans (FT)

NOM SIZE	CARRIER PIPE TEMPERATURE							
	75	100	125	150	175	200	225	250
2"/4"	15.3	15.3	15.3	15.3	15.2	15.2	15.1	15.1
2"/6"	19.6	19.6	19.6	19.6	19.5	19.5	19.5	19.5
3"/6"	18.3	18.3	18.3	18.3	18.3	18.2	18.2	18.1
3"/8"	21.5	21.5	21.5	21.5	21.4	21.4	21.4	21.4
4"/6"	17.9	17.9	17.9	17.9	17.8	17.7	17.5	17.5
4"/8"	20.5	20.5	20.5	20.5	20.5	20.4	20.3	20.3
6"/8"	19.9	19.9	19.9	19.9	19.8	19.6	19.3	19.3
6"/10"	23.1	23.1	23.1	23.1	23.1	22.9	22.8	22.8
8"/10"	22.5	22.5	22.5	22.5	22.4	22.1	21.9	21.8
8"/12"	24.5	24.5	24.5	24.5	24.4	24.3	24.1	24.1
10"/12"	23.8	23.8	23.8	23.8	23.7	23.4	23.2	23.1
10"/14"	25.3	25.3	25.3	25.3	25.2	25.0	24.8	24.7
12"/14"	25.4	25.4	25.4	25.4	25.2	24.9	24.6	24.5
12"/16"	26.6	26.6	26.6	26.6	26.5	26.2	25.9	25.9
14"/16"	26.4	26.4	26.4	26.4	26.3	25.9	25.6	25.5
14"/18"	28.6	28.6	28.6	28.6	28.5	28.2	28.0	27.9
16"/18"	28.3	28.3	28.3	28.3	28.1	27.8	27.5	27.4
16"/20"	29.4	29.4	29.4	29.4	29.3	29.0	28.7	28.7
18"/20"	29.1	29.1	29.1	29.1	29.0	28.6	28.3	28.2
18"/24"	32.4	32.4	32.4	32.4	32.3	32.0	31.8	31.7
20"/24"	31.9	31.9	31.9	31.9	31.7	31.5	31.2	31.1
20"/30"	36.8	36.8	36.8	36.8	36.7	36.5	36.4	36.3
24"/30"	35.7	35.7	35.7	35.7	35.6	35.3	35.0	34.9

NOTE: These spans are valid for the containment pipe operating at ambient temperatures.

Span multipliers for fluids of different specific gravities

FLUID SPECIFIC GRAVITY							
AIR	0.75	0.9	**1.0**	1.1	1.25	1.5	2.0
1.40	1.07	1.02	**1.0**	0.98	0.95	0.90	0.84
(MULTIPLIER FOR CORRECTED SPAN LENGTHS)							

Span multipliers for fluids at different temperatures

FLUID TEMPERATURE						
75°F	100°F	150°F	200°F	225°F	250°F	275°F
1.0	0.98	0.93	0.88	0.84	0.80	0.75
(MULTIPLIER FOR CORRECTED SPAN LENGTHS)						

FDS4030E (12/14) 3

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 169 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Anchor Loads Due to Restrained Thermal Expansion (LBS)

NOM SIZE	TEMPERATURE CHANGE IN CONTAINMENT PIPE			
	1°F	25°F	50°F	75°F
2"/4"	519	1,535	2,592	3,650
2"/6"	547	2,232	3,987	5,742
3"/6"	751	2,436	4,191	5,946
3"/8"	774	3,003	5,325	7,647
4"/6"	981	2,666	4,421	6,176
4"/8"	1,004	3,233	5,555	7,877
6"/8"	1,697	3,926	6,248	8,570
6"/10"	1,754	5,349	9,095	12,841
8"/10"	2,379	5,975	9,721	13,466
8"/12"	2,412	6,798	11,366	15,934
10"/12"	3,330	7,716	12,284	16,852
10"/14"	3,377	8,888	14,628	20,367
12"/14"	4,469	9,979	15,719	21,459
12"/16"	4,500	10,770	17,301	23,831
14"/16"	5,172	11,441	17,972	24,503
14"/18"	5,243	13,215	21,519	29,824
16"/18"	5,914	13,886	22,191	30,495
16"/20"	5,950	14,782	23,981	33,181
18"/20"	6,621	15,453	24,653	33,853
18"/24"	6,775	19,288	32,323	45,357
20"/24"	7,071	19,584	32,618	45,653
20"/30"	7,306	25,461	44,372	63,284
24"/30"	10,258	28,413	47,325	66,236

NOTE: Thermal end loads on anchors are independent of the carrier pipe temperature. The loads are based on the change in temperature of the containment pipe plus 10% or the maximum load from the carrier pipe at 150°F with uninsulated containment pipe.

4 PDS4030E (12/14)

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 170 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Typical Properties

TEMPERATURE	75°F	250°F	
PROPERTY	VALUE	VALUE	METHOD
AXIAL TENSILE STRENGTH	14,200 psi	10,650 psi	ASTM D2105
AXIAL TENSILE DESIGN STRENGTH	3,550 psi	2,660 psi	ASTM D2105
AXIAL MODULUS OF ELASTICITY	1.75×10^6 psi	1.30×10^6 psi	ASTM D2105
COMPRESSIVE STRENGTH	22,750 psi	17,000 psi	ASTM D695
COMPRESSIVE DESIGN STRENGTH	5,685 psi	4,250 psi	ASTM D695
COMPRESSION MODULUS	2.80×10^6 psi	2.10×10^6 psi	ASTM D695
POISSON'S RATIO $V_{a/h}$ ($V_{h/a}$)	0.33 (0.23)		*CONLEY METHOD #20
BEAM BENDING, ULTIMATE STRESS	30,000 psi	22,500 psi	CONLEY METHOD 8
BEAM BENDING, DESIGN STRESS[1]	3,750 psi	2,810 psi	CONLEY METHOD 8
SHEAR MODULUS	1.30×10^6 psi	1.00×10^6 psi	*CONLEY METHOD #9
HYDROSTATIC DESIGN BASIS	16,000 psi	8,000 psi	ASTM D2992 PROCEDURE B
HYDROSTATIC BURST (WALL STRESS @ 72°F)	32,000 psi	24,000 psi	ASTM D1599
CIRCUMFERENTIAL MODULUS OF ELASTICITY	2.50×10^6 psi	1.87×10^6 psi	ASTM D1599
FLEXURAL MODULUS OF ELASTICITY	1.75×10^6 psi	1.30×10^6 psi	ASTM 2790
COEFFICIENT OF LINEAR THERMAL EXPANSION	$9.5 \times \frac{10^{-6}\ \text{IN}}{\text{IN-}^\circ\text{F}}$		CONLEY METHOD 3
COEFFICIENT OF THERMAL CONDUCTIVITY	$2.9\ \frac{\text{BTU/HR-IN}}{\text{FT}^2\text{-}^\circ\text{F}}$		CONLEY METHOD 16
SPECIFIC GRAVITY	1.85		
DENSITY	0.067 LB/CU IN		
DIELECTRIC STRENGTH	$535\ \frac{\text{VOLTS}}{\text{MIL}}$		ASTM D149
DEGREE OF CURE	175°C (347°F) Tg		DMA
HEAT DEFLECTION TEMPERATURE	150°C (302°F)		ISO 75-3
FLOW FACTOR (HAZEN-WILLIAMS)	150		
SURFACE ROUGHNESS	1.7×10^{-5} FEET		
MANNING'S "n"	0.009 INCH		

[1]Beam bending design stress is 1/8 of ultimate to allow for combined stress (bending and pressure)

PDS4030E (12/14) 5

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 171 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ATTACHMENT 9

67246-024-RFI-002-R0

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 172 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

REQUEST FOR INFORMATION

Section 1 ***(Subcontractor)***

Subcontract No.: 67246 Rel No.: 024 RFI No. *(Subcontract No.-Rel. No.-RFI-Seq. No.-Rev. No.)*: 67246-024-RFI-002-R0

Subcontract Title: LERF Basin 41 Engineering Design

Project Title: LERF Basin 41 Design Project No.: T1P226

RFI Title/Description: Basin 41 pump design criteria

RFI Initiated By: Paul Dorsh Phone: 946-3300 Date of Request: 12/2/2019

E-Mailed To: Phone: Response Requested By: 12/9/2019

Section 2 ***(Subcontractor)***

Reference Drawing or Document:

N/A

Proposed Change to Document(s)? ☐ Yes ☒ No

Description of Request/Recommendation:

The currently installed LERF Basin pumps consist of a Berkeley submersible pump mounted a 6" Franklin submersible motor. The design requires the motor to be mounted below the pump to ensure proper motor cooling has occurred. This inherently locates the pump suction approximately 31" above the basin floor. To perform a full basin pump down this configuration requires Operations to remove the pump assembly and replace with a temporary pump that has a lower suction elevation.

As a part of the Basin 41 design, a new pump assembly will be designed to facilitate a full basin pump down. To aid in the pump selection a few pump design requirements need to be determined:

1. What is the target flow rate of the new pump?
2. What is the maximum operating design temperature?
3. What is the orifice size of FO-60A-001 on H-2-88974? Where is this located on H-2-89183?
4. What is the maximum and minimum differential pressure of Influent Filter(s) 60B-FL-1A? Where are they located on H-2-89183?
5. What is the fluid density to be used in the flow calculation?
6. What is the fluid viscosity to be used in the flow calculation?

Recommendation:

It appears that previous LERF pump designs target flow rates were nominally 140gpm. Industry standard process fluid temperatures are nominally 100F. Flow rates and temperatures above these values are achievable but will reduce the pump options available.

For the 30% submittal 40psid, 1SpG, and 1cP was used for questions #4, #5, and #6 respectively. All values need to be confirmed and/or updated for the 60% design submittal.

Requestor: Paul Dorsh Date: 12/2/2019

Page 1 of 2 A-6003-417 (REV 10)

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 173 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

REQUEST FOR INFORMATION (Continued)

Page 2 of 2

Section 1 ***(Subcontractor)***

Subcontract No.: 67246 Rel No.: 024 RFI No. *(Subcontract No.-Rel. No.-RFI-Seq. No.-Rev. No.)*: 67246-024-RFI-002-R0

Subcontract Title: LERF Basin 41 Engineering Design

Project Title: LERF Basin 41 Design Project No.: T1P226

RFI Title/Description: Basin 41 pump design criteria

Section 3 (WRPS)

Response to Request:

Basin pump design criteria is as follows:

1. Target flow rate for basin pump is 75 gpm (normal) and 150 gpm (max).

2. Nominal process liquid temperature at the LERF basins is 60 deg. F.

3. Orifice size of FO-60A-001 is 1.361" (ref. FO-60A-001 tag details in SmartPlant Foundation (SPF), ECN-642756, and H-2-88974, Sheet 1, Rev 19, Zone F6; see attached). This flow-restricting orifice is located on H-2-89183, Sheet 1, Rev 7 in Zone C3 and on Sheet 2, Rev 1 in Zone C4 (see attached).

4. Maximum differential pressure across influent filters is 60 psid, but filters are normally changed when they reach 40 psid. Assume a differential pressure across clean filters of 2 psid.

5. Use 1.0 specific gravity for fluid density.

6. Use 1.0 cP for fluid viscosity.

Engineer/Position *(if applicable)*: Nathaniel Wilson (PRJ DA) Date:

Contract Change Required?	☐ Yes	☒ No	Contract Change Request/CAL No.:
Engineering Review Necessary?	☒ Yes	☐ No	Date Sent to Engineering: 12/6/2019
DCN/ECN/EDT Required?	☐ Yes	☒ No	DCN/ECN/EDT No.:
Applicable TOC-MT Required?	☒ Yes	☐ No	TOC-MT No.: MT-50497
Clarification Only?	☒ Yes	☐ No	

Responder:

Nathaniel Wilson (PRJ DA) — *Print First and Last Name* — Signature — 12/16/19 *Date*

Buyer's Technical Representative (BTR):

Steven Shepherd — *Print First and Last Name* — Signature — 12/16/19 *Date*

Page 2 of 2 A-6003-417 (REV 10)

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 174 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

67246-024-RFI-002-R0 (Basin 41 pump design criteria)
Attachment

FO-60A-001 tag details in SPF,
ECN-642756,
H-2-88974, Sheet 1, Rev 19, Zone F6,
H-2-89183, Sheet 1, Rev 7, Zone C3, and
H-2-89183, Sheet 2, Rev 1, Zone C4, all referenced in Item 3 response:

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 175 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Details - ORIFICE ON 60A INLET ANALYZERS

Page 1

Main Details

Equipment/Component ID No. (EIN):	FO-60A-001
Equipment Title :	ORIFICE ON 60A INLET ANALYZERS

Project Details

Tag Classification Details

Classification Name:	MECHANICAL/PROCESS EQUIP
Tag Type:	FO, FLOW ORIFICE
Tag Sub-Type:	FO, FLOW ORIFICE

Structures, Systems, and Components

Primary Building/Facility:	2025E, 200 AREA EFFLUENT TREATMENT FACILITY
Secondary Building/Facility No./s:	
Primary System:	ETF-60A, INFLUENT RECEIVING/STAGING
Secondary System:	
Room:	
Parent EIN (Assembly):	

Technical Baseline Details

Technical Baseline?:	Y
Design Authority:	

General details

Creation Date:	10/22/2015 6:20:01 PM
Creation User:	superuser
Last Updated Date:	9/26/2017 8:09:43 PM

Configuration details

Object configuration:	PL_TOC
Object query configuration:	

Component Details

MEL Validated:	
Discontinued:	False
Status:	OPR
Asset Class:	Equipment
Department:	POPS
Manufacturer/Make:	
Model Number:	

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 176 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Details - ORIFICE ON 60A INLET ANALYZERS

Page 2

Serial Number:
Spare Parts Catalog ID:

Safety Equipment Compliance

Safety Compliance Status: N/A

End of Service Life/Expiration Date
:
Next TSR Surveillance Late Due Date
:

Safety Classification

Safety Class: GS

DSA Safety SSC ID:

Hazardous Area Classification Details

Equipment Status (Active/Inactive):
Hazardous-area classification:
Comments/Basis:

Additional Details

Description (Key Words): ORIFICE = 1.361", LABELED A1249, 304SS, 150 PSI, 200 F

Description (Location): Location Room: 131

Size (Hp, KW, Dimensions, etc.):
Additional Information:
QA Level: Commercial

Regulatory Driver:
Suspect/Counterfeit Item: False

Label Details

Label size code (see TFC-ENG-STD-12
):
Number of sides:
Title:
Subtitle: ORIFICE ON 60A INLET ANALYZERS

Fed from (breakers, panels, etc.):
Label barcode (auto generated by SP
F): S166745WT

Vendor and Purchase Order Details

Vendor:
Vendor Phone No.:
VIN (Vendor Identification Number):
Purchase Order No.:
Purchase Order Date:
Date Acquired:
Date Installed:

Work Log Details

Work Log Type: 2 - Modify

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 177 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

Details - ORIFICE ON 60A INLET ANALYZERS

Page 3

Work Log Entry: Initial SmartPlant Foundation data import.

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 178 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ENGINEERING CHANGE NOTICE **ESSENTIAL**

CPR 18

Page 1 of 4

1. ECN 642756

Proj. ECN

2. ECN Category (mark one) Supplemental [X] Direct Revision [] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	3. Originator's Name, Organization, MSIN, and Telephone No. LL Lin, 32230, S6-72, 372-2759	4. USQ Required? [] Yes [X] No	5. Date 1/15/98
	6. Project Title/No./Work Order No. Install Restricting Orifice Plate In Influent Line/A4055	7. Bldg./Sys./Fac. No. 2025E/60A	8. Approval Designator NA
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) H-2-88974 Rev 8, Sh 1	10. Related ECN No(s). NA	11. Related PO No. None

12a. Modification Work [X] Yes (fill out Blk. 12b) [] No (NA Blks. 12b, 12c, 12d)	12b. Work Package No. EL-98-00031/M	12c. Modification Work Complete Design Authority/Cog. Engineer Signature & Date	12d. Restored to Original Condition (Temp. or Standby ECN only) NA Design Authority/Cog. Engineer Signature & Date

13a. Description of Change 13b. Design Baseline Document? [X] Yes [] No

Description of Changes:

Affected document: H-2-88974 Rev 8, Sh 1 P&ID Influent Reception System

See pages 3 and 4 of this ECN for details.

14a. Justification (mark one)

Criteria Change	[]	Design Improvement	[X]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

14b. Justification Details

The current configuration results in discharging process water from the influent instrument loop to Sump 1. This discharge presents a major impact to the STT due to excessive quantity of waste to be reprocessed. Installing the restricting orifice will route the return from the instrument loop to process stream.

15. Distribution (include name, MSIN, and no. of copies)

L. L. Lin, S6-72, 1	J. E. Geary, S6-71, 1
N. J. Sullivan, S6-72, 1	E. A. McNamar, S6-72, 1
B. S. Darling, T4-05, 1	R. N. Wagner, S6-72, 1
D. L. Tubbs, S6-74, 1	D. L. Flyckt, S6-72, 1
N. A. Ballantyne, S6-72, 1	M. W. Bowman, S6-72, 1

RELEASE STAMP
JAN 20 1998
DATE: HANFORD RELEASE ID:
STA: 30 25

A-7900-013-2 (05/96) GEF095

A-7900-013-1

Sargent & Lundy Engineering Services, Inc

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 179 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ENGINEERING CHANGE NOTICE

Page 2 of 4

1. ECN (use no. from pg. 1): 642756

16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
[X] Yes	Additional	[na] $	Additional	[na] $	Improvement	[na]
[] No	Savings	[na] $	Savings	[na] $	Delay	[na]

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[na]	Seismic/Stress Analysis	[na]	Tank Calibration Manual	[na]
Functional Design Criteria	[na]	Stress/Design Report	[na]	Health Physics Procedure	[na]
Operating Specification	[na]	Interface Control Drawing	[na]	Spares Multiple Unit Listing	[na]
Criticality Specification	[na]	Calibration Procedure	[na]	Test Procedures/Specification	[na]
Conceptual Design Report	[na]	Installation Procedure	[na]	Component Index	[x]
Equipment Spec.	[na]	Maintenance Procedure	[na]	ASME Coded Item	[na]
Const. Spec.	[na]	Engineering Procedure	[na]	Human Factor Consideration	[na]
Procurement Spec.	[na]	Operating Instruction	[na]	Computer Software	[na]
Vendor Information	[na]	Operating Procedure	[x]	Electric Circuit Schedule	[na]
OM Manual	[na]	Operational Safety Requirement	[na]	ICRS Procedure	[na]
FSAR/SAR	[na]	IEFD Drawing	[x]	Process Control Manual/Plan	[na]
Safety Equipment List	[na]	Cell Arrangement Drawing	[na]	Process Flow Chart	[na]
Radiation Work Permit	[na]	Essential Material Specification	[na]	Purchase Requisition	[na]
Environmental Impact Statement	[na]	Fac. Proc. Samp. Schedule	[na]	Tickler File	[na]
Environmental Report	[na]	Inspection Plan	[na]		[]
Environmental Permit	[na]	Inventory Adjustment Request	[na]		[]

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision
POP 55F-001		
~~WHG~~-SD-ETF-OCD-001 HNF		

21. Approvals

	Signature	Date		Signature	Date
Design Authority	L. L. Lin	1-15-98	Design Agent	L. L. Lin	1-15-98
Cog. Eng.	L. L. Lin	1-15-98	PE		
Cog. Mgr.	N. J. Sullivan (informal review)	1-16-98	QA		
QA			Safety		
Safety			Design		
Environ.			Environ.		
Other			Other		

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

A-7900-013-3 (05/96) GEF096

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-M-002	**Rev.** 0	**Page No.** 180 of 180
Title: Leachate and Basin Pump Flow Calculation			
Prepared By: Gallegos, JF, P.E.	**Date:** 4/10/2020	**Checked By:** Dixon, KW, P.E.	**Date:** 4/10/2020

ENGINEERING CHANGE NOTICE CONTINUATION SHEET Page 3 of 4

ECN 642756
Date 1/15/98

1. Install orifice plate FO-60A001 at the flange immediate upstream of valve 60A-035. The orifice plate shall be for 3" pipe, 1/8" in thickness, 1.361" inside diameter, 304 SS, and 150 psi rating.

2. Orifice plate installation is to meet the requirements of ETF piping spec class 153S. Test the new installation in accordance with ASME B31.3-1993 edition and addenda for Category D Fluid Service.

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE: May 28,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63660 **Rev.** 00

2. **Title:**
LERF Basin 41 Liner Anchor Wall Design

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Harrison, Sarah E	*Harrison, Sarah E*	05/28/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/24/2020
Checker	Santos, Peter P	*Davidson, Ronald W for Santos, Peter P per email*	04/08/2020
Document Control Approval	Meinecke, Kathryn R	*Meinecke, Kathryn R*	05/26/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/29/2020
Originator	Davidson, Ronald W	*Davidson, Ronald W*	04/08/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	04/23/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	04/29/2020

8. **Description of Change and Justification**

Initial Release.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
ETF FACILITIES LERF FACILITIES	ETF LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
McFerran, Brandon E	242-A/AW/ETF OPERATIONS
McShane, Michael P	ENGINEERING PROGRAMS
Nelson, Richard L	
Omberg Carro, Susan K	NUCLEAR SAFETY
Powers, Daniel J	ETF ENGINEERING
Roosendaal, Gene D	TFP PROJECT MANAGEMENT
Rutherford, Wally	ETF ENGINEERING
Sackett, Tom E	TANK FARM PROJECTS
Samoska, Jerry A	INSTRUMENT & CNTRL ENGINEERING
Shultz, Milton V	NUCLEAR SAFETY
Smith, Gregory E	TANK FARM PROJECTS ENGINEERING

DOCUMENT RELEASE AND CHANGE FORM	**Doc No:** RPP-CALC-63660 **Rev.** 00

14. **Distribution**

Name	**Organization**
Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63660
Revision 0

LERF Basin 41 Liner Anchor Wall Design

Prepared by

RW Davidson
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
April 2020

5/19/2020

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

Sargent & Lundy Engineering Services, Inc.	**RPP-CALC-63660, Rev. 0** **CALCULATION COVER SHEET**	**Page No.** 1 of 40 **Date** 4/3/2020 **Rev. No.** 0 **Calculation No:** S54413.024-S-001

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions, LLC

Title:

LERF Basin 41 Liner Anchor Wall Design

Purpose and Objective:

The purpose of this calculation is to analyze the concrete wall footing and the anchor bolts for the LERF Basin 41 Liner Anchor Wall.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	40	Print Name/ Sign:	RW Davidson, P.E.	PP Santos, P.E.	PM Dorsh, P.E.
		Date:	4/3/2020	4/7/2020	4/7/2020

Revision Description (Revision Description/Affected Pages):

Initial Release.

		Print Name/ Sign:			
		Date:			

Revision Description (Revision Description/Affected Pages):

Sargent & Lundy Engineering Services, Inc.

RPP-CALC-63660, Rev. 0

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev.	Page No.
S54413.024	S54413.024-S-001	0	2 of 40

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	All Pages
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
RW Davidson, P.E.	4/3/2020
Checker (Print Name and Sign):	**Date:**
PP Santos, P.E.	4/7/2020

Signatures obtained only after discrepancies are corrected and comments are resolved.

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63660, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 3 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020

TABLE OF CONTENTS

1.0 PURPOSE 4
2.0 METHODOLOGY 4
3.0 DESIGN INPUTS 4
4.0 ASSUMPTIONS 4
5.0 COMPUTER SOFTWARE 4
6.0 RESULTS 5
7.0 REFERENCES 5
7.0 REFERENCES, CONT'D 6
8.0 CALCULATIONS 7

Attachments

Attachment 1

Attachment 2

Acronyms

ACI	American Concrete Institute
ADH	Adhesive Anchor
AHR	Anchor
ASCE	American Society of Civil Engineers
DCR	Demand-to-Capacity Ratio
IBC	International Building Code
NDC	Natural Phenomena Design Category
WDC	Wind Design Category

1.0 PURPOSE

The purpose of this calculation is to analyze the concrete wall footing and the anchor bolts for the LERF Basin 41 Liner Anchor Wall.

2.0 METHODOLOGY

Wind, seismic and live loads on the anchor wall are calculated using ASCE 7-10, *Minimum Design Loads on Buildings and Other Structures* and TFC-ENG-STD-06, *Design Loads for Tank Farm Facilities*.

The concrete adhesive anchor bolts are analyzed using Chapter 17 of ACI 318, *Building Code Requirements for Structural Concrete and Commentary* and ESR-3187 for Hilti *HIT-HY 200 Adhesive Anchors and Post Installed Reinforcing Bar Connections in Concrete*. Stability of the concrete wall footing on soil is checked using IBC and *Principles of Foundation Engineering*.

The mechanically tensioned tower system is procured from an off the shelf manufacturer and is not analyzed in this calculation.

3.0 DESIGN INPUTS

1. The REVOC®[1] cover system is supplied as a pre-manufactured system installed by Layfield Group as shown in Attachment 1. Layfield has recommended to increase the counter weight and height of the tension towers to promote better cover folding. This design considers a counter weight of steel weighing approximately 160 lbf and a tensioning tower height of 6'-0" per drawing H-2-838750, SH 5.
2. The anchor wall is General Service per MT-50497.
3. The minimum concrete compressive strength is 4500 psi, (See RPP-SPEC-63632, Section 03 30 00).
4. The anchor rods are based on fractional stainless steel threaded rods using ASTM F593 material per ESR-3187, Table 11.
5. Dimension for the anchor wall are based on Drawings H-2-838750, SH 3.

4.0 ASSUMPTIONS

None.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Mathcad®[2] 15.0 was used for the hand calculations. Calculations are checked using a handheld calculator.

---

1 REVOC is a registered trademark of LAYFIELD Group. Ltd., Richmond, B.C. Canada.
2 Mathcad is a registered trademark of PTC, Inc., Needham, Massachusetts.

6.0 RESULTS

The Hilti®[3] HIT-HY 200 adhesive anchors are adequate using a 1/2" stainless steel anchor bolts with a 2 3/4" minimum effective embedment depth and maximum embedment of 3 ½". The anchor wall is adequate with #4 rebar spaced 10" on-center longitudinally and 12" on-center transversely, each face.

TABLE: Results Summary

Tension Post Adhesive Anchors	**DCR**
DCR (tension)	0.27
DCR (shear)	0.02
DCR (per ACI 318, Equation 17.6.3)	0.27
Anchor Wall	**DCR**
DCR (shear)	0.006
DCR (torsion)	0.014
DCR (soil bearing)	0.24
Tension Post	**DCR**
DCR (weld)	0.23
DCR (combined axial, flexure, shear and torsion)	0.03

7.0 REFERENCES

ACI 318-14, *Building Code Requirements for Structural Concrete and Commentary*, 2014, American Concrete Institute, Farmington Hills, MI.

ACI SP-17 (14), "*The Reinforced Concrete Design Handbook, A Companion to ACI 318-14",* Volume 1, American Concrete Institute, Farmington Hills, MI.

ASCE 7-2010, *Minimum Design Loads for Buildings and Other Structures*, 2010, American Society of Civil Engineers, Reston, VA.

Das, Braja M., *Principles of Foundation Engineering*, Sixth Ed., 2007, Cengage Learning, Stamford, CT.

ESR-3187, Hilti *HIT-HY 200 Adhesive Anchors and Post Installed Reinforcing Bar Connections in Concrete*, Issued March 2018, Revised April 2019, ICC Evaluation Services, Whittier, CA., (See Attachment 2 for Excerpt).

3 Hilti and HIT-HY are registered trademarks of Hilti Aktiengesellschaft, Schaan, Liechtenstein

7.0 REFERENCES, CONT'D

H-2-838750, Rev. 0, Sheets 1-5, *LERF Basin 41 Civil Top Liner, Top Liner Details,* U.S. Department of Energy, Richland, WA.

IBC 2015*, International Building Code*, International Code Council, 2015, Country Club Hills, IL.

MT-50497, Rev 00, Liquid Effluent Retention Facility (LERF) Basin 41, U.S. Department of Energy, Richland, WA.

RPP-SPEC-63632, Rev. 0, *Construction Specification For: LERF Basin 41 Design*, U.S. Department of Energy, Richland, WA.

TFC-ENG-STD-06, Rev. D-2, *Design Loads for Tank Farm Facilities*, U.S. Department of Energy, Richland, WA.

8.0 CALCULATIONS

8.1 Determine Wind Loads

$V := 110mph$ — Wind Speed (TFC-ENG-STD-06, Table 3, WDC-1/NDC-1).

$K_d := 0.90$ — Wind Direction factor (ASCE 7-10, Section 26.6 and Table 26.6-1 for Chimneys, Tanks and Similar Structures).

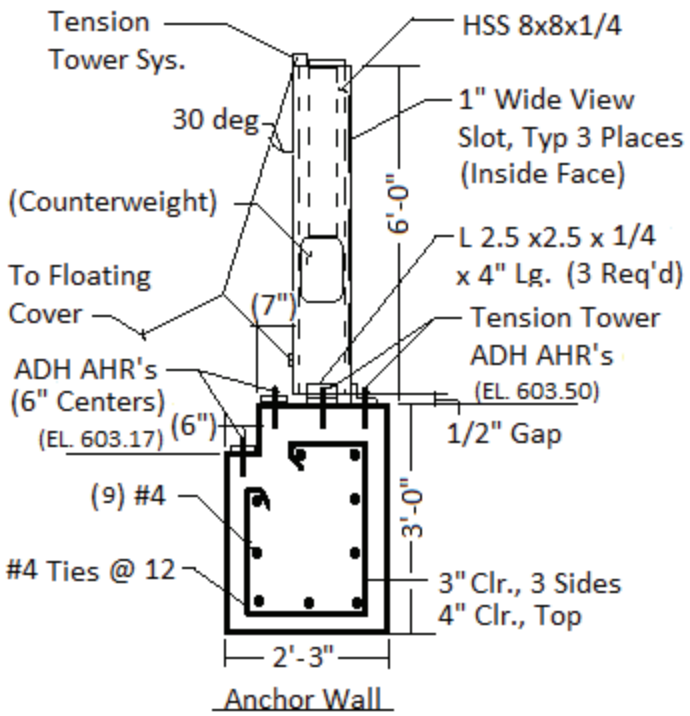
$K_z := 0.85$ — Velocity Pressure coefficient for Design Exposure C. (ASCE 7-10, Table 29.3-1 for 0-15 ft)

$K_{zt} := 1.0$ — Topographic factor. (ASCE 7-10, Section 26.8.2)

$G := 0.85$ — Gust Effect factor. (ASCE 7-10, Section 26.9.1)

$h := 6 \cdot ft = 6.0\,ft$ — Height of the tension tower.

$D := 8in$ — Nominal width of the tension tower.



See Attachment 1 for additional details on REVOC cover system/mechanical tension tower.

$q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot \left(\frac{V}{mph}\right)^2 \cdot psf = 23.7 \cdot psf$ — Velocity pressure calculated at mean height h. (ASCE 7-10, Equation 29.3-1)

$\frac{h}{D} = 9.0$ — Ratio of height of tension tower post to width of post.

$C_f := 1.5$ — Net force coefficient (interpolated) for square, wind normal to face, (ASCE 7-10, Figure 29.5-1)

$A_f := h \cdot D = 4.0 \cdot ft^2$ — Projected area normal to the wind.

$F_w := q_z \cdot G \cdot C_f \cdot A_f = 120.9\ lbf$ — Design wind load on other structures. (ASCE 7-10, Equation 29.5-1)

8.2 Determine Seismic Loads

$\gamma_{stl} := 490 \cdot pcf$ — Density of steel, (AISC 14th Ed., Table 17-12).

$Wt_{tower} := 19.61 \cdot \frac{lbf}{ft} \cdot h = 117.7\ lbf$ — Weight of tension tower member, (HSS 8x8x3/16), (AISC 14th Ed.,Table 1-12).

$Wt_{cwt} := (7in \cdot 7in \cdot 12in) \cdot \gamma_{stl} = 166.7\ lbf$ — Approximate weight of tension tower steel counterweight.

$Wt_{tot} := \left(Wt_{tower} + Wt_{cwt}\right) \cdot 1.15 = 327.1\ lbf$ — Total weight of tension tower system, (includes 15% contingency for misc. components, pulleys, cables etc.).

$S_{DS} := 0.588$ — Horizontal five-percent damped design spectral response acceleration at short periods. (TFC-ENG-STD-06)

$z_h := 0.0$ — Ratio of the height in structure of point of attachment of component to the average roof height of structure.

$I_p := 1.0$ — Component importance factor for SDC-1 loading. (TFC-ENG-STD-06)

$a_p := 1.0$ — Component amplification factor for other rigid components, limited deformability. (ASCE 7-10, Table 13.5-1)

$R_p := 2.5$ — Component response modification factor for other rigid components, limited deformability.. (ASCE 7-10, Table 13.5-1)

$$F_{pnom} := \frac{0.4 \cdot a_p \cdot S_{DS} \cdot \left(Wt_{tot}\right)}{\frac{R_p}{I_p}} [1 + 2(z_h)] = 30.8 \cdot lbf$$

The horizontal seismic force. (ASCE 7-10, Equation 13.3-1)

$F_{pmax} := 1.6 S_{DS} \cdot I_p \cdot \left(Wt_{tot}\right) = 307.7\ lbf$ — The maximum lateral seismic force. (ASCE 7-10, Equation 13.3-2)

$F_{pmin} := 0.3 S_{DS} \cdot I_p \cdot \left(Wt_{tot}\right) = 57.7\ lbf$ — The minimum lateral seismic force. (ASCE 7-10, Equation 13.3-3)

$$F_p := \begin{cases} F_{pmin} & \text{if } F_{pnom} < F_{pmin} \\ F_{pmax} & \text{if } F_{pnom} > F_{pmax} \\ F_{pnom} & \text{otherwise} \end{cases}$$

The minimum lateral force to use for design purposes.

$F_p = 57.7\ lbf$

$F_v := 0.2 S_{DS} \cdot Wt_{tot} = 38.5\ lbf$ — The design vertical seismic force. (ASCE 7-10, Section 13.3.1)

8.3 Determine Tension Tower Loads on the Anchor Bolts

The following section determines the anchor forces to withstand the worst case loading.

$\Omega_o := 2.5$ — Overstrength factor. (ASCE 7-10, Table 13-5.1, Supplement 1, required for anchorage to concrete).

$R_{cable} := \frac{Wt_{cwt}}{\cos(30 \cdot deg)} = 192.5\ lbf$ — Tension force on the top liner cable based on a 30 deg angle of cable from vertical plane of tension tower.

$F_{h_cable} := \sqrt{R_{cable}^2 - Wt_{cwt}^2} = 96.3\ lbf$ — Horizontal component of the tension cable force.

$F_h := \max\left(1.6F_{h_cable}, 1.0F_w + 1.0 \cdot F_{h_cable}, 1.0 \cdot F_p \cdot \Omega_o + 1.0 \cdot F_{h_cable}\right) = 240.5 \cdot lbf$ — LRFD horizontal load combinations per ASCE 7-10, Section 2.3.2.

$F_{v_comb} := \max\left(1.4 \cdot Wt_{tot}, 1.2 \cdot Wt_{tot} + 1.0 \cdot F_v\right) = 457.9\ lbf$ — LRFD vertical load combinations per ASCE 7-10, Section 2.3.2.

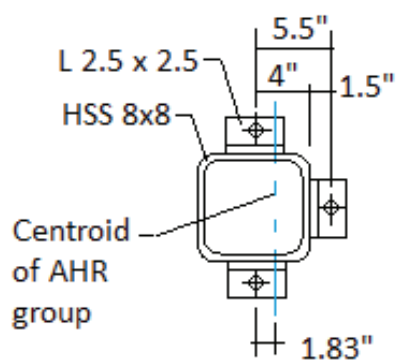
$M_{ot} := 1.0 \cdot F_p \cdot \Omega_o \cdot \frac{2}{3} \cdot h + 1.0 \cdot F_{h_cable} \cdot h = 13854.2 \cdot in \cdot lbf$ — Use LRFD seismic horizontal load combination, previously defined.

$M_{res} := \left(0.9Wt_{tot} - 1.0 \cdot F_v \cdot \Omega_o\right) \cdot 2 \cdot in = 396.4 \cdot in \cdot lbf$ — Use minimum LRFD vertical load combination per ASCE 7-10, Section 2.3.2.

$n := 3$ — Number of anchors in group

$Centroid_{ahrs} := \frac{[(n-1) \cdot 0 \cdot in + (n-2) \cdot 5.5 \cdot in]}{n}$

$Centroid_{ahrs} = 1.83 \cdot in$



Plan View

$T_{stud} := \frac{M_{ot} - M_{res}}{3 \cdot \left(2 \cdot in + \frac{5.5 \cdot in}{3}\right)} = 1170.2\ lbf$ — Tension load per stud, 3 studs, based on the distance from the centroid of the tension tower anchor group to edge of L2.5 x 2.5 x 4 inch long clip in direction of applied load.

$V_{stud} := \frac{F_h}{3} = 80.2\ lbf$ — Shear load per stud, 3 studs.

8.4 Check Anchor Bolts in Accordance with ACI 318-14, Chapter 17

Define Constants

Based on 1/2" diameter ASTM F593 stainless steel threaded rods with 3 1/2" embedment depth

$n_a := 3$	The number of anchors per post.
$s_a := 5.5 \cdot in$	Minimum spacing of the tension tower anchors.
$h_{ef} := 2.75in$	The effective minimum embedment. (ESR-3187, Table 12 & 14)
$n_{a_t} := 3$	Number of anchors resisting tension. (Moment Couple)
$n_{a_v} := n_a = 3.0$	Number of anchors resisting shear.
$f'_c := 4500psi$	Compressive strength of concrete. (See Inputs)
$k_c := 17$	Effectiveness factor for cracked concrete. (ESR-3187, Table 12)
$\psi_{c_N} := 1.0$	Cracked concrete factor for post-installed anchor in cracked concrete. (ACI 318-14, Section 17.4.2.6)
$\phi_{t_s} := 0.65$	Strength reduction factor for steel failure in tension. (ESR-3187, Table 11)
$\phi_{t_c} := 0.65$	Strength reduction factor for concrete breakout failure in tension. (ESR-3187, Table 12)
$\phi_{v_s} := 0.60$	Strength reduction factor for steel failure in shear. (ESR-3187, Table 11).
$\phi_{v_c} := 0.70$	Strength reduction factor for concrete breakout failure in shear. (ESR-3187, Table 12)
$\phi_e := 0.75$	Tensile strength reduction factor for anchors in moderate or high seismic risk zones. (ACI 318-14 Section 17.2.3.4.4)
$\alpha_{v_seis} := 0.70$	Seismic shear reduction factor, (ESR-3187, Table 11).
$\phi_d := 0.65$	Bond strength reduction factor, (ESR-3187, Table 14 for dry & water saturated concrete installation conditions).
$c_{ac} := 2 \cdot h_{ef} = 5.5 \cdot in$	Critical edge distance factor for adhesive anchors. (ACI 318-14, Section 17.7.6)
$c_{a1} := 6 \cdot in - 1.5 \cdot in = 4.5 \cdot in$	Distance from center of anchor to edge of concrete in the direction of applied shear. (See ACI 318-14, Section 17.5.2.1 for illustration)
$c_{a2} := c_{ac} = 5.5 \cdot in$	Distance from center of anchor to edge of concrete in the direction perpendicular to applied shear (and c_{a1}). (See ACI 318-14, Section 17.5.2.1 for illustration)
$c_{a_min} := \min(c_{a1}, c_{a2}) = 4.5 \cdot in$	The minimum edge distance between the edge of the concrete and the nearest anchor. (primary tension tower anchor)
$h_{min} := h_{ef} + 1.25 \cdot in = 4.0 \cdot in$	The minimum member thickness. (ESR-3187, Table 12)
$h_a := 30in$	Actual concrete thickness. (H-2-838750)
$d := 0.5in$	The anchor diameter. (ESR-3187, Table 11)

Determine Steel Strength of Anchor in Tension

$$Individual_Group := \begin{cases} \text{"Analyze anchors individually according to ACI 318, Chapter 17"} & \text{if } 3 \cdot h_{ef} \le s_a \\ \text{"Analyze anchors as a group according to ACI 318, Chapter 17"} & \text{otherwise} \end{cases}$$

Individual_Group = "Analyze anchors as a group according to ACI 318, Chapter 17"

$N_{sa} := 14190 lbf$

The tensile capacity of the anchor is based on ICC-ES Evaluation Report ESR-3187, Table 11, for ASTM F593, stainless steel threaded anchor rods, conservative.

$\phi N_{sa} := \phi_{t_s} \cdot N_{sa} = 9223.5\ lbf$

Tensile steel strength incorporating strength reduction factors.

Determine Concrete Breakout Strength of Anchorage in Tension

$$\psi_{ed_N} := \begin{cases} 1 & \text{if } c_{a_min} \ge 1.5 \cdot h_{ef} \\ 0.7 + 0.3 \cdot \dfrac{c_{a_min}}{1.5 \cdot h_{ef}} & \text{otherwise} \end{cases} = 1.0$$

The modification factor for edge effects. (ACI 318-14, Section 17.4.2.5)

$$\psi_{cp_N} := \begin{cases} 1 & \text{if } c_{a_min} \ge c_{ac} \\ \dfrac{\max(c_{a_min}, 1.5 \cdot h_{ef})}{c_{ac}} & \text{otherwise} \end{cases} = 0.8$$

Uncracked concrete pullout factor for post-installed anchors. (ACI 318-14, Section 17.4.2.7)

$\lambda := 1.0$

Modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$$N_b := k_c \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot \left(\frac{h_{ef}}{in}\right)^{1.5} lbf = 5200.6\ lbf$$

Basic concrete breakout strength of a single anchor in tension in cracked concrete. (ACI 318-14, Equation 17.4.2.2a)

$A_{Nco} := 9 \cdot h_{ef}^2 = 68.1 \cdot in^2$

Projected concrete failure area of a single anchor with an edge distance equal to or greater than 1.5 x h_{ef}. (ACI 318-14, Equation 17.4.2.1c)

$$A_{Nc} := \left(\min(1.5 \cdot h_{ef}, c_{a1}) + s_a + 1.5 \cdot h_{ef}\right) \cdot \left(\min(1.5 \cdot h_{ef}, c_{a2}) + 2 \cdot s_a + 1.5 \cdot h_{ef}\right) = 264.7 \cdot in^2$$

$A_{Nc} := \min(n_a \cdot A_{Nco}, A_{Nc}) = 204.2 \cdot in^2$

Projected concrete failure area of the anchorage group. (ACI 318-14, Section 17.4.2.1 and Figure R17.4.2.1(b))

Set: $e'_N := 1.83 \cdot in$

Set the resultant tension force eccentricity with respect to centroid of the anchors in tension, previously defined. (ACI 318-14, Fig R17.4.2.4)

$$\psi_{ec_N} := \frac{1}{\left(1 + \dfrac{2 \cdot e'_N}{3 \cdot h_{ef}}\right)} = 0.7$$

Modification factor for anchor groups loaded eccentrically in tension. (ACI 318-14, Section 17.4.2.4, Equation 17.4.2.4)

$$N_{cbg} := \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ec_N} \cdot \psi_{ed_N} \cdot \psi_{c_N} \cdot \psi_{cp_N} \cdot N_b = 8842.3 \cdot lbf$$

Concrete breakout strength of the anchorage in tension. (ACI 318-14, Equation 17.4.2.1b)

$\phi N_{cb} := \phi_e \cdot \phi_{t_c} \cdot N_{cbg} = 4310.6\ lbf$

Tensile breakout strength incorporating strength reduction factors.

Determine Bond Strength of Adhesive Anchors in Tension

$\lambda_a := \lambda = 1.0$

ACI 318-14, Section 17.2.6 and modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$\tau_{cr} := 1170 \cdot psi$

Characteristic bond stress in cracked concrete, temperature range A, (ESR-3187, Table 14).

$\tau_{uncr} := 2220 \cdot psi$

Characteristic bond stress in uncracked concrete, temperature range A, (ESR-3187, Table 14).

$d_a := d = 0.5 \cdot in$

Anchor diameter, previously defined.

$N_{ba} := \lambda_a \cdot \tau_{cr} \cdot \pi \cdot d_a \cdot h_{ef} = 5054.0\ lbf$

Basic bond strength of adhesive anchor, (ACI 318-14, Section 17.4.5.2)

$c_{Na} := 10 \cdot d_a \cdot \sqrt{\frac{\tau_{uncr}}{1100 \cdot psi}} = 7.1 \cdot in$

Critical edge distance, (ACI 318-14, Equation 17.4.5.1d).

$A_{Nao} := \left(2 \cdot c_{Na}\right)^2 = 201.8 \cdot in^2$

Projected influence area for a single anchor, (ACI 318-14, Equation 17.4.5.1c).

$A_{Na} := \left(2 \cdot c_{Na} + 2s_a\right) \cdot \left(c_{Na} + c_{a_min} + s_a\right) = 431.1 \cdot in^2$

Projected influence area for a group of anchors, (ACI 318-14, Figure R17.4.5.1).

$A_{Na} := n_a \cdot A_{Nao} = 605.5 \cdot in^2$

Limiting value of A.Na per ACI 318-14, Section 17.4.5.1).

$\psi_{ed_Na} := 1.0 \qquad c_{a_min} = 4.5 \cdot in \quad > \quad c_{Na} = 7.1 \cdot in$

Modification factor for edge effects, (ACI 318-14, Equation 17.4.5.4a).

$\psi_{cp_Na} := \frac{c_{a_min}}{c_{ac}} \qquad c_{a_min} = 4.5 \cdot in \quad < \quad c_{ac} = 5.5 \cdot in$

Modification factor for adhesive anchors designed for uncracked concrete, (ACI 318-14, Equation 17.4.5.5a).

$e'_N := 1.83 \cdot in$

Previously defined.

$\psi_{ec_Na} := \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} = 0.8$

Modification factor for adhesive anchor group loaded eccentrically in tension. (ACI 318-14, Equation 17.4.5.3)

$N_{ag} := \frac{A_{Na}}{A_{Nao}} \cdot \psi_{ec_Na} \cdot \psi_{ed_Na} \cdot \psi_{cp_Na} \cdot N_{ba} = 9864.1\ lbf$

Nominal bond strength of group of adhesive anchors in tension, (ACI 318-14, Equation 17.4.5.1b).

$\phi N_{ag} := \phi_e \cdot \phi_d \cdot N_{ag} = 4808.7\ lbf$

Nominal bond strength in tension for a group of adhesive anchors in tension incorporating strength reduction factors, (ACI 318-14, Equation 17.4.5.1b).

Determine Steel Strength of the Anchorage in Shear

$$\text{Individual_Group} := \begin{cases} \text{"Analyze anchors individually in shear according to ACI 318, Chapter 17"} & \text{if } 3\cdot c_{a1} \le s_a \\ \text{"Analyze anchors as a group in shear according to ACI 318, Chapter 17"} & \text{otherwise} \end{cases}$$

Individual_Group = "Analyze anchors as a group in shear according to ACI 318, Chapter 17"

$V_{sa} := 8515\cdot lbf$ — The steel strength in shear. (ESR-3187, Table 11, ASTM F593)

$\phi V_{sa} := \alpha_{v_seis}\cdot\phi_{v_s}\cdot V_{sa} = 3576.3\ lbf$ — Steel shear strength incorporating strength reduction factors.

Determine Concrete Breakout Strength of the Anchorage in Shear

$$\psi_{ed_V} := \begin{cases} 1.0 & \text{if } c_{a2} \ge 1.5\cdot c_{a1} \\ 0.7 + 0.3\cdot\dfrac{c_{a2}}{1.5\cdot c_{a1}} & \text{otherwise} \end{cases} = 0.9$$

Edge distance factor (Anchors not on a corner). (ACI 318-14, Section 17.5.2.6)

$\psi_{c_V} := 1.0$ — Cracked concrete factor without supplementary reinforcement, (ACI 318-14, Section 17.5.2.7)

$$\psi_{h_V} := \begin{cases} \sqrt{\dfrac{1.5\cdot c_{a1}}{h_a}} & \text{if } h_a < 1.5\cdot c_{a1} \\ 1 & \text{otherwise} \end{cases} = 1.00$$

Thickness modification factor. (ACI 318-14, Section 17.5.2.8)

$d_a := d = 0.5\cdot in$ — The outside diameter of the anchor.

$l_e := \min(8\cdot d_a, h_{ef}) = 2.8\cdot in$ — The load bearing length of anchor for shear. (ACI 318-14, Section 17.5.2.2)

$$V_b := \min\left[7\cdot\left(\frac{l_e}{d_a}\right)^{0.2}\cdot\sqrt{\frac{d_a}{in}}\cdot\lambda\cdot\sqrt{\frac{f'_c}{psi}}\cdot\left(\frac{c_{a1}}{in}\right)^{1.5}\cdot lbf,\ 9\cdot\lambda\cdot\sqrt{\frac{f'_c}{psi}}\cdot\left(\frac{c_{a1}}{in}\right)^{1.5}\cdot lbf\right] = 4457.4\cdot lbf$$

Basic concrete breakout strength of a single anchor in shear in cracked concrete. (ACI 318-14, Section 17.5.2.2)

$A_{Vco} := 4.5\cdot c_{a1}^2 = 91.1\cdot in^2$ — The projected area for a single anchor in a deep member with a distance from edges equal or greater than 1.5 x c_{a1}. (ACI 318-14, Equation 17.5.2.1c)

$A_{Vc} := \left[\left(2\cdot 1.5\cdot c_{a1}\right) + 2s_a\right]\cdot\min\left(1.5\cdot c_{a1}, h_a\right) = 165.4\cdot in^2$ — Projected concrete failure area of the anchorage. (ACI 318-14, Section 17.5.2.1 and Figure R17.5.2.1b)

$e'_V := 1.83\cdot in$ — Previously defined and is taken same as value for eccentricity of anchor group in tension.

$$\psi_{ec_V} := \frac{1}{\left(1 + \dfrac{2\cdot e'_V}{3\cdot c_{a1}}\right)} = 0.8$$

Modification factor for anchor group loaded eccentrically in shear. (ACI 318-14, Equation 17.5.2.5)

$$V_{cbg} := \frac{A_{Vc}}{A_{Vco}}\cdot\psi_{ec_V}\cdot\psi_{ed_V}\cdot\psi_{c_V}\cdot\psi_{h_V}\cdot V_b = 6010.4\cdot lbf$$

Nominal concrete breakout strength of anchorage in shear. (ACI 318-14, Equation 17.5.2.1a)

$\phi V_{cb} := \phi_{v_c}\cdot V_{cbg} = 4207.3\ lbf$ — Shear breakout strength incorporating strength reduction factors.

Determine Pryout Strength of the Anchorage in Shear

$k_{cp} := \begin{cases} 1 & \text{if } h_{ef} < 2.5\text{in} \\ 2 & \text{otherwise} \end{cases} = 2.0$

Coefficient for pryout strength. (ACI 318-14, Section 17.5.3.1)

$N_{cbg} = 8842.3\ \text{lbf}$ $N_{ag} = 9864.1\ \text{lbf}$

Use the lesser of N_{cbg} from Equation 17.4.2.1b or N_{ag} from 17.4.5.1b per ACI 318-14, Section 17.5.3.1).

$V_{cp} := k_{cp} \cdot N_{cbg} = 17684.7\ \text{lbf}$

The nominal pryout strength of the anchorage in shear per ACI 318-14, Equation 17.5.3.1a.

$\phi V_{cp} := \phi_{v_c} \cdot V_{cp} = 12379.3\ \text{lbf}$

Shear pryout strength incorporating strength reduction factors.

Determine Governing Failure Strength

$\text{Govern}_v := \begin{cases} \text{"Steel failure governs (Ductile Failure)."} & \text{if } \phi V_{sa} \le \min(\phi V_{cb}, \phi V_{cp}) \\ \text{"Concrete breakout governs (Brittle Failure)."} & \text{if } \phi V_{cb} < \min(\phi V_{sa}, \phi V_{cp}) \\ \text{"Concrete pryout governs (Brittle Failure)."} & \text{otherwise} \end{cases}$

$\text{Govern}_v = \text{"Steel failure governs (Ductile Failure)."}$

$\text{Shear}_{govern} := \begin{cases} \phi V_{sa} & \text{if } \phi V_{sa} \le \min(\phi V_{cb}, \phi V_{cp}) \\ \phi V_{cb} & \text{if } \phi V_{cb} < \min(\phi V_{sa}, \phi V_{cp}) \\ \phi V_{cp} & \text{otherwise} \end{cases}$

The governing allowable shear capacity of the anchorage.

$\text{Shear}_{govern} = 3576\ \text{lbf}$

$\text{Shear_Check} := \begin{cases} \text{"Anchor capacity in shear is OK."} & \text{if } \text{Shear}_{govern} > V_{stud} \\ \text{"Anchor capacity in shear is NOT OK"} & \text{otherwise} \end{cases}$

$V_{stud} = 80.2\ \text{lbf}$

$\text{Shear_Check} = \text{"Anchor capacity in shear is OK."}$

Check to determine the adequacy of the anchors in shear.

$\text{Govern}_t := \begin{cases} \text{"Steel failure governs (Ductile Failure)."} & \text{if } \phi N_{sa} \le \min(\phi N_{cb}, \phi N_{ag}) \\ \text{"Concrete breakout governs (Brittle Failure)."} & \text{if } \phi N_{cb} \le \min(\phi N_{sa}, \phi N_{ag}) \\ \text{"Bond strength governs (Brittle Failure)."} & \text{otherwise} \end{cases}$

$\text{Govern}_t = \text{"Concrete breakout governs (Brittle Failure)."}$

$\text{Tensile}_{govern} := \begin{cases} \phi N_{sa} & \text{if } \phi N_{sa} \le \min(\phi N_{cb}, \phi N_{ag}) \\ \phi N_{cb} & \text{if } \phi N_{cb} \le \min(\phi N_{sa}, \phi N_{ag}) \\ \phi N_{ag} & \text{otherwise} \end{cases}$

The governing allowable tensile capacity of the anchorage.

$\text{Tensile}_{govern} = 4311\ \text{lbf}$

$$Tension_Check := \begin{cases} \text{"Anchor capacity in tension is OK."} & \text{if } Tensile_{govern} > T_{stud} \\ \text{"Anchor capacity in tension is NOT OK"} & \text{otherwise} \end{cases}$$

$T_{stud} = 1170\ lbf$

Tension_Check = "Anchor capacity in tension is OK."

Check to determine the adequacy of the anchors in tension.

$$DCR_{tens} := \frac{T_{stud}}{Tensile_{govern}} = 0.27$$

$$DCR_{shear} := \frac{V_{stud}}{Shear_{govern}} = 0.02$$

$$DCR := \begin{cases} DCR_{tens} & \text{if } DCR_{shear} \le 0.2 \\ DCR_{shear} & \text{if } DCR_{tens} \le 0.2 \\ \frac{1}{1.2} \cdot \left(DCR_{tens} + DCR_{shear}\right) & \text{otherwise} \end{cases} = 0.27$$

The DCR ratio is less than 1.0; therefore, **OK**
ACI 318-14, Section 17.6.

8.5 Check Temperature and Shrinkage Reinforcement (based on ACI 318-14, Section 24.4.3.2)

Due to the (minimal) loads, the anchor wall is adequate for flexure and only temperature and shrinkage reinforcement is required for the rebar in the wall.

Table 24.4.3.2—Minimum ratios of deformed shrinkage and temperature reinforcement area to gross concrete area

Reinforcement type	f_y, psi	Minimum reinforcement ratio	
Deformed bars	< 60,000	0.0020	
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of:	$\frac{0.0018 \times 60,000}{f_y}$
			0.0014

$h_c := 36in$ Thickness of the concrete wall.

$b := 27in$ Width of the wall for rebar design.

$A_{steel} := 0.0018 \cdot b \cdot h_c = 1.75 \cdot in^2$ Area of steel required by temperature and shrinkage. (ACI 318-14, Table 7.6.1.1)

$A_4 := 0.20in^2$ $n := 9$ Area and number of #4 bars. (ACI 318-14, Appendix A)

$A_{s_provided} := A_4 \cdot n = 1.8 \cdot in^2 > A_{steel} = 1.75 \cdot in^2$ The current design is adequate as designed with (9) #4 bars, continuous, w/# 4 ties @ 12".

24.4.3.3 The spacing of deformed shrinkage and temperature reinforcement shall not exceed the lesser of ***5h*** and 18 in.

$s_{long} := 10 \cdot in$ < $18 \cdot in$ OK

$s_{trans} := 12 \cdot in$ < $18 \cdot in$ OK

8.6 Check Minimum Reinforcement (based on ACI 318-14, Section 13.3.5 for Walls as Grade Beams)

$b_w := 27 \cdot in$ Width of wall.

$s_{long} = 10.0 \cdot in$ Rebar spacing for longitudinal bars, previously defined.

$s_{trans} = 12.0 \cdot in$ Rebar spacing for transverse bars, previously defined.

per ACI 318-14, Section 13.3.5 & 11.6:

Min long reinf $A_{s.l} := 0.0012 \cdot b_w \cdot s_{long} = 0.3 \cdot in^2$ Min transverse reinf $A_{s.t} := 0.0020 \cdot b_w \cdot s_{trans} = 0.6 \cdot in^2$

Table 11.6.1—Minimum reinforcement for walls with in-plane $V_u \leq 0.5\phi V_c$

Wall type	Type of nonprestressed reinforcement	Bar/wire size	f_y, psi	Minimum longitudinal[1], ρ_ℓ	Minimum transverse, ρ_t
Cast-in-place	Deformed bars	≤ No. 5	≥ 60,000	0.0012	0.0020
			< 60,000	0.0015	0.0025
		> No. 5	Any	0.0015	0.0025
	Welded-wire reinforcement	≤ W31 or D31	Any	0.0012	0.0020
Precast[2]	Deformed bars or welded-wire reinforcement	Any	Any	0.0010	0.0010

$n := 4$ Minimum number of bars provided per rebar spacing.

$A_{s_prov_long} := A_4 \cdot n = 0.8 \cdot in^2$ #4 bars @ 10" spg OK > $A_{s.l} = 0.3 \cdot in^2$

$A_{s_prov_trans} := A_4 \cdot n = 0.8 \cdot in^2$ #4 ties @ 12" spg OK > $A_{s.t} = 0.6 \cdot in^2$

8.7 Check Shear Capacity of Anchor Wall

Table 7.4.2.2—Shear reinforcement requirements

Condition	Spacing		Provision in ACI 318-14
$V_u \le \phi V_c/2$	No shear reinforcement required		9.6.3.1
$\phi V_c/2 < V_u \le \phi V_c$	Minimum shear reinforcement $s \le \frac{d}{2} \le 24$ in.		9.6.3.1
$\phi V_c < V_u \le \phi V_c + \phi 4\sqrt{f'_c} b_w d$	Nonprestressed	$s \le \frac{d}{2} \le 24$ in.	9.7.6.2.2
	Prestressed	$s \le \frac{3h}{4} \le 24$ in.	
$\phi V_c + \phi 4\sqrt{f'_c} b_w d < V_u \le \phi V_c + \phi 8\sqrt{f'_c} b_w d$	Nonprestressed	$s \le \frac{d}{4} \le 12$ in.	9.7.6.2.2
	Prestressed	$s \le \frac{3h}{8} \le 12$ in.	
$V_u > \phi V_c + \phi 8\sqrt{f'_c} b_w d$	Increase cross section		22.5.1.2

$d := 36 \cdot in - 3 \cdot in - 0.5 \cdot in - \frac{0.5 \cdot in}{2} = 32.3 \cdot in$

Distance from extreme compression fiber to centroid of longitudinal tension reinf.

$\phi_{shear} := 0.75$

Shear reduction factor. (ACI 318-14, Table 21.2.1)

$\lambda = 1.0$

Modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$\phi V_c := \phi_{shear} \cdot 2\lambda \cdot psi \cdot \sqrt{\frac{f'_c}{psi}} \cdot b_w \cdot d = 88 \cdot kip$

Shear strength of the evaluated concrete anchor wall section. (ACI 318-14, Section 22.5.5.1)

$V_u := \sqrt{F_{v_comb}^2 + F_h^2} = 517.2\ lbf$

Resultant shear demand.

$\frac{\phi V_c}{2} = 43808.8\ lbf \quad > \quad V_u$

No shear reinforement is required per ACI 318-14 Table 7.4.2.2

$DCR_{shear} := \frac{V_u}{\phi V_c} = 0.006$

8.8 Check Torsional Shear on Anchor Wall

$A_{cp} := b_w \cdot h = 1944.0 \cdot in^2$ — Area enclosed by outside perimeter of section per SP-17 (14), Volume 1, Chapter 7, Figure 7.4.3a.

$P_{cp} := 2 \cdot (b_w + h) = 198.0 \cdot in$ — Outside perimeter of concrete section per SP-17 (14), Volume 1, Chapter 7, Figure 7.4.3a.

$\phi_t := 0.75$ — ACI 318-14, Table 21.2.1

$\phi T_{th} := \phi_t \cdot \lambda \cdot psi \cdot \sqrt{\frac{f'_c}{psi}} \cdot \frac{A_{cp}^2}{P_{cp}} = 80022.8 \cdot ft \cdot lbf$ — Threshold torsion ACI 318-14, Table 22.7.4.1 (a), nonprestressed member

$T_u := M_{ot} = 1154.5 \cdot ft \cdot lbf$ — Torsional moment on anchor wall, previously defined.

$\phi T_{th} = 80022.8 \cdot ft \cdot lbf \quad > \quad T_u = 1154.5 \cdot ft \cdot lbf$ — Torsional effects can be neglected, ACI 318-14, Section 22.7

$$DCR_{torsion} := \frac{T_u}{\phi T_{th}} = 0.014$$

8.9 Check Soil Bearing Pressure

The following section will determine if the concrete anchor wall is adequately sized to distribute the load to the soil at an adequate pressure

$l_{cf} := 36 \cdot in \cdot 2 + 8 \cdot in + 2.5 \cdot in \cdot 2 = 7.1\,ft$ — Length of the concrete wall considered (based on 45 deg distribution).

$w_{cf} := 27 \cdot in$ — The width of the concrete wall footing. (H-2-838750)

$t_{cf} := 36in$ — The depth of the concrete wall footing. (H-2-838750)

$\rho_c := 150pcf$ — Typical density of concrete.

$W_{cf} := \rho_c \cdot w_{cf} \cdot l_{cf} \cdot t_{cf} = 7171.9 \cdot lbf$ — The weight of a concrete footing.

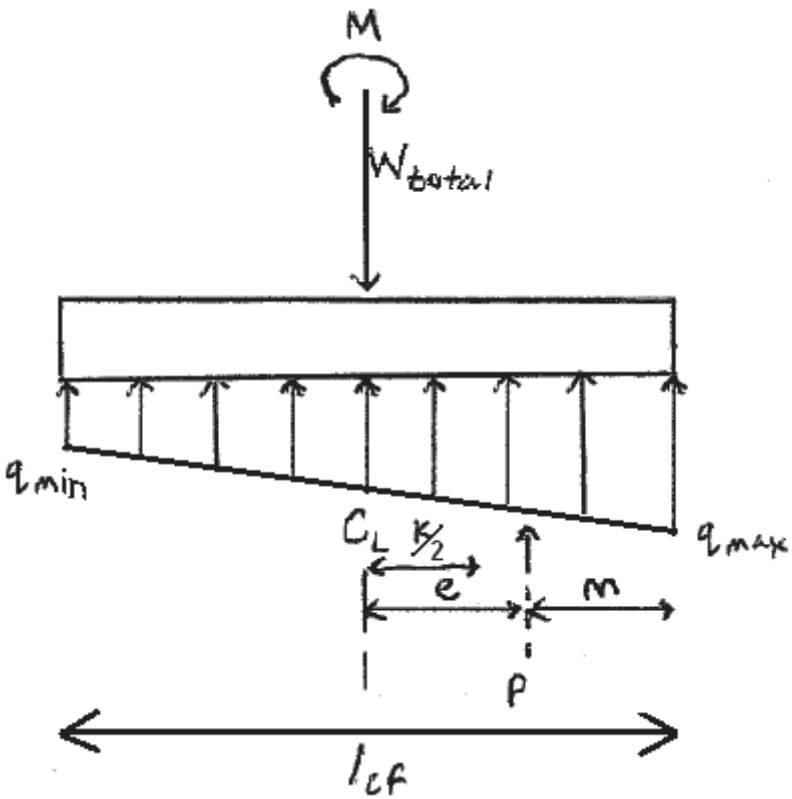
$M_1 := 0.6F_w \cdot \frac{h}{2} = 217.5 \cdot ft \cdot lbf$ — In-plane moment on the footing. (ASCE 7-10, Section 2.4.1 Equation 5)

$M_2 := 0.7 \cdot F_p \cdot \frac{2}{3} \cdot h = 161.5 \cdot lbf \cdot ft$ — In-plane moment on the footing. (ASCE 7-10, Section 2.4.1 Equation 5)

$M := \max(M_1, M_2) = 217.5 \cdot ft \cdot lbf$ — Maximum in-plane moment on the anchor wall footing.

$Q := Wt_{tot} + W_{cf} = 7498.9\,lbf$ — The total vertical force bearing on the soil at each tower column.

$e := \frac{M}{Q} = 0.3 \cdot in$ — The resulting eccentricity, which is the moment divided by total bearing load. (Das, pg. 147, Equation 3.51)



$$q_{min} := \max\left(\frac{Q}{w_{cf} \cdot l_{cf}} - \frac{6 \cdot M}{l_{cf}^2 w_{cf}}, 0psf\right) = 459.0 \cdot psf$$

Minimum Soil Pressure under footing. (Principles of Foundation Engineering, Das, Eq 3.53, pg 147)

$$q_{max} := \frac{Q}{w_{cf} \cdot l_{cf}} + \frac{6 \cdot M}{l_{cf}^2 w_{cf}} = 482.1 \cdot psf$$

Maximum Soil Pressure under footing. (Principles of Foundation Engineering, Das, Eq 3.52, pg 147)

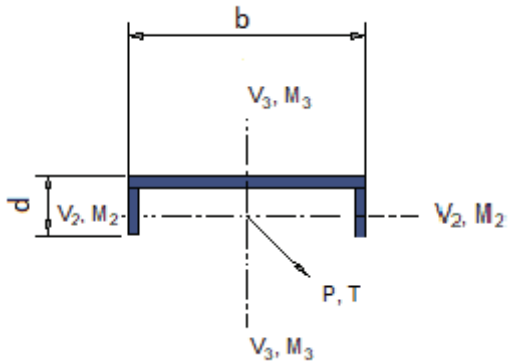
$$p_{allow_sb} := 2000psf$$

The allowable bearing pressure of the soil. (IBC 2015, Table 1806.2, material class 3)

$$DCR_{sb} := \frac{q_{max}}{p_{allow_sb}} = 0.24$$

The demand capacity ratio for the soil bearing pressure. The footing has a DCR lower than 1.0, therefore it is **OK**.

8.9 Check Connection Clip Welds at Base of Tension Tower



Weld Geometry:

$b := 4 \cdot in$ Weld width.

$d := 2 \cdot in$ Weld length.

$w_{act} := \frac{3}{16} \cdot in$ Weld size.

$F_{EXX} := 70 \cdot ksi$ Ultimate stress of the weld metal.

Envelope connection forces and moments, (conservative since loads are based on LRFD load combinations for AHR's)

$F_h = 240.5\ lbf$ Maximum horizontal load, previously defined.

$F_{v_comb} = 457.9\ lbf$ Maximum vertical load, previously defined.

$M_{ot} = 13854.2 \cdot in \cdot lbf$ Maximum moment, previously defined.

$P := 0 \cdot lbf$ $V_2 := \frac{F_h}{2} = 120.2\ lbf$ $V_3 := \frac{F_{v_comb}}{2} = 228.9\ lbf$

$T := \frac{M_{ot}}{2} = 6927.1 \cdot in \cdot lbf$ $M_2 := 0 \cdot in \cdot lbf$ $M_3 := 0 \cdot in \cdot lbf$

Weld Properties Per Blodgett 1991, Table 5, Page 7.4-7.

$C_2 := \frac{b}{2}$ $C_2 = 2.0 \cdot in$ The distance from the neutral axis to the outer fiber along the 2-2 axis.

$C_3 := \frac{d^2}{2d + b}$ $C_3 = 0.5 \cdot in$ The distance from the neutral axis to the outer fiber along the 3-3 axis.

$A_{w2} := b$ $A_{w2} = 4.0 \cdot in$ The linear shear area of the weld along the 2-2 axis.

$A_{w3} := 2 \cdot d$ $A_{w3} = 4.0 \cdot in$ The linear shear area of the weld along the 3-3 axis. (AISC SPEC, Eqn. C-G4-1)

$$J_w := \frac{(b + 2d)^3}{12} - \frac{d^2 \cdot (b + d)^2}{(b + 2 \cdot d)} \qquad J_w = 24.7 \cdot in^3$$

The linear polar moment of inertia.

$$A_{lin} := \sqrt{\left(\frac{V_2}{A_{w2}} + \frac{T \cdot C_3}{J_w}\right)^2 + \left(\frac{V_3}{A_{w3}} + \frac{T \cdot C_2}{J_w}\right)^2} \qquad A_{lin} = 641.9 \cdot \frac{lbf}{in}$$

Linear weld stress.

Check weld strength:

$\Omega_w := 2$ weld metal

AISC SPEC., Table J2.5

$$R_n := \frac{0.6 \cdot F_{EXX}}{\Omega_w} \qquad R_n = 21.0 \cdot ksi$$

Allowable weld stress.

$$R_u := \frac{A_{lin}}{0.707 w_{act}} \qquad R_u = 4.8 \cdot ksi$$

Actual stress in the weld.

$$DCR := \frac{R_u}{R_n} = 0.23$$

The demand/capacity ratio is < 1; therefore, OK.

8.10 Check the Adequacy of the HSS Tension Tower Posts

Note: The HSS tension towers incorporate three narrow cutouts on the inside face of the posts for view ports. The cutouts are approximately 1" wide by 1'-6" long. Compression and shear checks are performed based on these net section areas.

8.10.1 HSS Tension Tower Posts Loaded in Compression (Column)

This section analyzes the tension tower HSS posts for compression under gravity and earthquake loading. This force will be included with the bending of the columns due to earthquake loading and cable tension loads.

Envelope connection forces and moments, (conservative since loads are based on LRFD load combinations for AHR's)

$F_{v_comb} = 457.9\ lbf$ Maximum vertical load, previously defined.

Common Steel Properties:

$\nu := 0.3$ Poisson ratio

$E := 29000 \cdot ksi$ Steel modulus of elasticity. (AISC 14th Ed., Table B4.1b)

Steel - rectangular HSS:

Rectangular HSS shall be fabricated from ASTM A500 Gr B:

$f_{y500} := 46000 \cdot psi$ minimum yield stress, AISC, Table 5-5.

$f_{u500} := 58000 \cdot psi$ minimum ultimate tensile stress, AISC Table 5-5.

Let: $F_y := f_{y500} = 46.0 \cdot ksi$ $F_u := f_{u500} = 58.0 \cdot ksi$

$$G := \frac{E}{2 \cdot (1 + \nu)} = 11153.8 \cdot ksi$$

Member properties ref AISC [2014]

Section input table (all sections in Manual of Steel Construction, Allowable Stress Design, Fourteenth Edition)

Member := "HSS8X8X1/4"

Variables in data file

Sect = "HSS8X8X1/4"

$H_t = 8.0 \cdot in$

$t_{des} = 0.2 \cdot in$

$I_x = 70.7 \cdot in^4$

$I_y = 70.7 \cdot in^4$

$J = 111.0 \cdot in^4$

$Wt = 25.8 \cdot plf$

$b = 8.0 \cdot in$

$b_t = 31.3$

$Z_x = 20.5 \cdot in^3$

$Z_y = 20.5 \cdot in^3$

$C = 28.1 \cdot in^3$

$A = 7.10 \cdot in^2$

$t_{nom} = 0.3 \cdot in$

$Ht_t = 31.3$

$S_x = 17.7 \cdot in^3$

$S_y = 17.7 \cdot in^3$

$r_x = 3.2 \cdot in$

$r_y = 3.2 \cdot in$

Nominal strength for compression members. (ANSI/AISC 360-14 Chapter E)

$\Omega_c := 1.67$ Safety factor for compression, AISC 14th Ed., Section B 3.7.

Flexural Buckling - E-3

Determine governing slenderness ratio

$r_x = 3.2 \cdot in$ HSS strong axis radius of gyration.

$r_y := r_x$ HSS weak axis radius of gyration.

Buckling over entire length of column:

$K := 2.1$ Estimated length factor for end fixity conditions of the column, (AISC 14th Ed., Comm. 7.2, Table C-A-7.1, Case (e))

$L := h$ Column height (previously defined).

$SR := \frac{K \cdot L}{r_x} = 48.0$ Slenderness ratio.

$\lambda_{cx} := SR = 48.0$ $\lambda_{cy} := SR = 48.0$

Limits for b/t ratio - Table B4.1

$\lambda_p := 1.12 \cdot \sqrt{\frac{E}{F_y}}$ $\lambda_p = 28.1$ Check for compact section - AISC 14th Ed., Table B4.1.

$\lambda_r := 1.40 \cdot \sqrt{\frac{E}{F_y}}$ $\lambda_r = 35.2$ Check for non-compact section - AISC 14th Ed., Table B4.1.

$b_t = 31.3$ $Ht_t = 31.3$ Width-to-thickness ratios.

$r_{b_t} := \begin{cases} b_t & \text{if } b_t \ge Ht_t \\ Ht_t & \text{otherwise} \end{cases}$ $r_{b_t} = 31.3$

$SECTION := \begin{cases} \text{"COMPACT"} & \text{if } r_{b_t} \le \lambda_p \\ \text{"NONCOMPACT"} & \text{if } \lambda_p < r_{b_t} \le \lambda_r \\ \text{"SLENDER"} & \text{otherwise} \end{cases}$ SECTION = "NONCOMPACT"

$\lambda_c := \max(\lambda_{cx}, \lambda_{cy})$ $\lambda_c = 48.0$ Maximum slenderness ratio.

$F_e := \frac{\pi^2 \cdot E}{\lambda_c^2}$ $F_e = 124.2 \cdot ksi$ Elastic buckling stress, AISC 14th Ed., Eq. E3-4.

$$F_{cr} := \begin{cases} 0.658^{\frac{F_y}{F_e}} \cdot F_y & \text{if } \lambda_c \le 4.71 \cdot \sqrt{\frac{E}{F_y}} \\ 0.877 \cdot F_e & \text{otherwise} \end{cases}$$

$F_{cr} = 39.4 \cdot ksi$ AISC 14th Ed., Eq's E3-2 and E3-3.

$A_{g_net} := A - (t_{des} \cdot 1 \cdot in) = 6.9 \cdot in^2$ Net section area including the 1" wide by 1'-6" long view ports.

$P_n := F_{cr} \cdot A_{g_net}$ $P_n = 270.5 \cdot kip$ Nominal compressive strength, AISC 14th Ed., Eq. E3-1.

$P_c := \frac{P_n}{\Omega_c} = 162.0 \cdot kip$ Axial capacity of HSS 8x8x1/4

8.10.2 HSS Tension Tower Posts Loaded in Bending (Column)

Envelope connection forces and moments, (conservative since loads are based on LRFD load combinations for AHR's)

$M_{ot} = 13854.2 \cdot in \cdot lbf$ Maximum moment, previously defined.

Nominal strength for Square and Rectangular HSS and Box-Shaped Members in flexure. (ANSI/AISC 360-10 Chapter F-F7.)

$\Omega_b := 1.67$ Safety factor for flexure, AISC 14th Ed., Section F1.

SECTION = "NONCOMPACT"

Note: HSS is noncompact section. Limit state of local flange buckling and local web buckling apply. AISC 14th Ed., F7.2, F2.3

$M_n := (F_y \cdot Z_x) = 943.0 \cdot kip \cdot in$ Nominal flexural strength, AISC 14th Ed., Eq F7-1

$M_p := M_n$ AISC 14th Ed., Eq F7-1.

$M_{n_fb} := M_p - \left[(M_p - F_y \cdot S_x) \left(3.57 \cdot b_t \cdot \sqrt{\frac{F_y}{E}} - 4.0 \right) \right] = 885.0 \cdot kip \cdot in$ Nominal flexural strength for flange buckling, AISC 14th Ed., Eq. F7-2.

$M_{n_wb} := M_p - \left[(M_p - F_y \cdot S_x) \left(0.305 \cdot Ht_t \cdot \sqrt{\frac{F_y}{E}} - 0.738 \right) \right] = 989.1 \cdot kip \cdot in$ Nominal flexural strength for web buckling, AISC 14th Ed., Eq. F7-5.

$M_n := \min(M_{n_fb}, M_{n_wb}, M_p) = 885.0 \cdot kip \cdot in$ Nominal flexural strength, AISC 14th Ed., Section F7.

$M_c := \frac{M_n}{\Omega_b}$ $M_c = 529.9 \cdot kip \cdot in$ Flexural capacity of HSS 8x8x1/4.

$DCR_{vc} := \frac{F_{v_comb}}{P_c} = 0.003$ The demand to capacity ratio for the tension tower posts in compression. Since the DCR is less than 1.0, the posts are adequate in compression.

$DCR_f := \frac{M_{ot}}{M_c} = 0.03$ The demand to capacity ratio for the tension tower posts in bending. Since the DCR is less than 1.0, the posts are adequate in bending.

8.10.3 HSS Tension Tower Posts Loaded in Shear (Column)

Envelope connection forces and moments, (conservative since loads are based on LRFD load combinations for AHR's)

$F_h = 240.5\ lbf$ Maximum horizontal load, previously defined.

Nominal strength for hollow rectangular members in shear (AISC 14th Edition Chapter G-G5);

The nominal shear strength, Vn, of rectangular HSS and box members shall be determined using the provisions of Section G2.1 with $A_w = 2ht$ where h for the width resisting the shear force shall be taken as the clear distance between the flanges less the inside corner radius on each side and $t_w = t_{des}$ and $k_v = 5$. If the corner radius is not known, h shall be taken as the corresponding outside dimension minus three times the thickness.

$h_{v.HSS} := H_t - 3 \cdot t_{des}$ $A_{wx.HSS_net} := 2 \cdot h_{v.HSS} \cdot t_{des} - t_{des} \cdot 1 \cdot in = 3.2 \cdot in^2$

$b_{v.HSS} := b - 3 \cdot t_{des}$ $A_{wy.HSS_net} := 2 \cdot b_{v.HSS} \cdot t_{des} - t_{des} \cdot 1 \cdot in = 3.2 \cdot in^2$

Net section areas including the 1" wide x 1'-6" lg. view ports.

Based on AISC 14th Eq's G2-3, G2-4 and G2-5 $k_{v.HSS} := 5$

$$\lambda_{v.HSS} := \sqrt{\frac{k_{v.HSS} \cdot E}{F_y}} = 56.1$$

$$C_{vx.HSS} := \begin{cases} 1 & \text{if } \frac{b_{v.HSS}}{t_{des}} \le 1.10 \cdot (\lambda_{v.HSS}) \\ \frac{t_{des}}{b_{v.HSS}} \cdot 1.10 \cdot \sqrt{\frac{(k_{v.HSS}) \cdot E}{F_y}} & \text{if } 1.10 \cdot (\lambda_{v.HSS}) < \frac{b_{v.HSS}}{t_{des}} \le 1.37 \cdot \lambda_{v.HSS} \\ \left[\frac{1.51 \cdot E \cdot (k_{v.HSS})}{F_y} \cdot \left(\frac{t_{des}}{b_{v.HSS}}\right)^2\right] & \text{otherwise} \end{cases}$$

$\frac{b_{v.HSS}}{t_{des}} = 31.3$

$1.10 \cdot (\lambda_{v.HSS}) = 61.8$

$C_{vx.HSS} = 1.0$

$$C_{vy.HSS} := \begin{cases} 1 & \text{if } \dfrac{h_{v.HSS}}{t_{des}} \le 1.10\cdot(\lambda_{v.HSS}) \\ \dfrac{t_{des}}{h_{v.HSS}}\cdot 1.10\cdot\sqrt{\dfrac{(k_{v.HSS})\cdot E}{F_y}} & \text{if } 1.10\cdot\lambda_{v.HSS} < \dfrac{h_{v.HSS}}{t_{des}} \le 1.37\cdot\lambda_{v.HSS} \\ \left[\dfrac{1.51\cdot E\cdot(k_{v.HSS})}{F_y}\cdot\left(\dfrac{t_{des}}{h_{v.HSS}}\right)^2\right] & \text{otherwise} \end{cases}$$

$$\frac{h_{v.HSS}}{t_{des}} = 31.3$$

$$C_{vy.HSS} = 1.0$$

The nominal shear strength, V_n, of unstiffened or stiffened webs, according to the limit states of shear yielding and shear buckling AISC 14th Ed., Eq. G2-1, is:

$\Omega_v := 1.5$ ASD reduction factor for members in shear AISC 14th, Section G1

$V_{nx.HSS} := 0.6\cdot(F_y)\cdot(A_{wx.HSS_net})\cdot(C_{vx.HSS}) = 87.5\cdot kip$ AISC 14th Ed., Section G2-1.

$V_{ny.HSS} := 0.6\cdot(F_y)\cdot(A_{wy.HSS_net})\cdot(C_{vy.HSS}) = 87.5\cdot kip$ AISC 14th Ed., Section G2-1.

$V_{cx.HSS} := \dfrac{V_{nx.HSS}}{\Omega_v} = 58.3\cdot kip$ Factored allowable shear load for HSS strong axis.

$V_{cy.HSS} := \dfrac{V_{ny.HSS}}{\Omega_v} = 58.3\cdot kip$ Factored allowable shear load for HSS weak axis.

$DCR_{hs} := \dfrac{F_h}{V_{cx.HSS}} = 0.004$ The demand to capacity ratio for the tension tower posts in shear. Since the DCR is less than 1.0, the posts are adequate in shear.

8.10.4 HSS Tension Tower Posts Loaded in Torsion (Column)

Torsional Strength of Round and Rectangular HSS (AISC 14th Edition Chapter H-H3):

$$h_t_{HSS} := \max\left(\frac{b_{v.HSS}}{t_{des}}, \frac{h_{v.HSS}}{t_{des}}\right) = 31.3$$

AISC 14th Eq's H3-3, H3-4 and H3-5

$$2.45\cdot\sqrt{\frac{E}{F_y}} = 61.5$$

$$F_{cr.HSS.tor} := \begin{cases} 0.6\cdot(F_y) & \text{if } h_t_{HSS} \le 2.45\cdot\sqrt{\frac{E}{F_y}} \\ 0.6\cdot(F_y)\cdot\left(2.45\cdot\sqrt{\frac{E}{F_y}}\right)\cdot\frac{1}{h_t_{HSS}} & \text{if } 2.45\cdot\sqrt{\frac{E}{F_y}} < h_t_{HSS} \le 3.07\cdot\sqrt{\frac{E}{F_y}} \\ 0.458\cdot\pi^2\cdot E\cdot h_t_{HSS}^{-2} & \text{otherwise} \end{cases}$$

$$F_{cr.HSS.tor} = 27.6\cdot ksi$$

The nominal torsional strength, T_n, according to the limit states of torsional yielding and torsional buckling is:

$C_{HSS} := C = 28.1\cdot in^3$ HSS torsional constant, previously defined.

$T_{n.HSS} := (F_{cr.HSS.tor})\cdot(C_{HSS}) = 775.6\cdot kip\cdot in$ AISC 14th Ed., Eq. H3-1

The allowable torsional strength, Tn/Ω_T , for round and rectangular HSS shall be determined as follows:

$\Omega_T := 1.67$ ASD reduction factor for members in torsion AISC 14th Ed., Section H3.1.

$T_{c.HSS} := \frac{T_{n.HSS}}{\Omega_T} = 464.4\cdot kip\cdot in$ Factored allowable torsion on HSS

$ecc_{cable} := 2\cdot in$ Eccentricity of applied tension cable force at top of HSS post, conservative.

$DCR_t := \frac{F_h\cdot ecc_{cable}}{T_{c.HSS}} = 0.001$ The demand to capacity ratio for the tension tower posts in torsion. Since the DCR is less than 1.0, the posts are adequate in torsion.

8.10.5 HSS Tension Tower Posts Subject to Combined Axial, Flexure, Shear and Torsion

$DCR_{HSS} := DCR_{vc} + DCR_f + (DCR_{hs} + DCR_t)^2 = 0.03$ The DCR for members subject to combined torsion, shear, flexure and axial force is less than 1.0; Therefore, **OK**. (AISC 14th Ed., Eq. H3-6)

ATTACHMENT 1

REVOC® COVER TENSIONING TOWER SYSTEM

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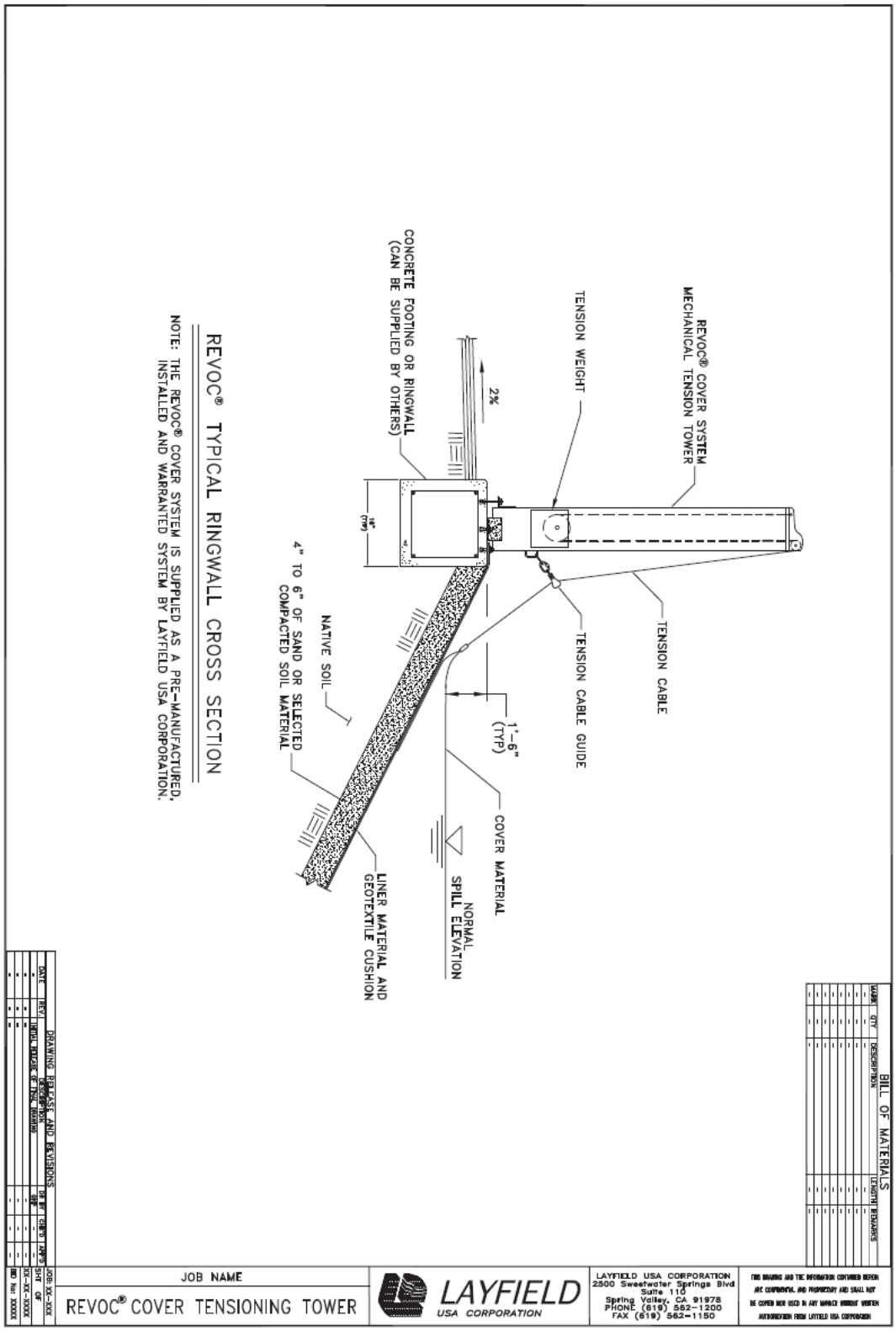
CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 31 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020



ATTACHMENT 2

ICC-ES EVALUATION REPORT

ESR -3187

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

(EXCERPT)

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63660, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 33 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020

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ESR-3187

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DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

HILTI, INC.

EVALUATION SUBJECT:

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

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Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 34 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
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DIVISION: 03 00 00—CONCRETE
Section: 03 16 00—Concrete Anchors

DIVISION: 05 00 00—METALS
Section: 05 05 19—Post-installed Concrete Anchors

REPORT HOLDER:

HILTI, INC.

EVALUATION SUBJECT:

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2018, 2015, 2012, and 2009 *International Building Code®* (IBC)
- 2018, 2015, 2012, and 2009 *International Residential Code®* (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

For evaluation for compliance with codes adopted by the Los Angeles Department of Building and Safety (LADBS), see ESR-3187 LABC and LARC Supplement.

For evaluation for compliance with the *National Building Code of Canada®* (NBCC), see listing report ELC-3187.

Property evaluated:

Structural

2.0 USES

Adhesive anchors and reinforcing bars installed using the Hilti HIT-HY 200 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are used to resist static, wind and earthquake (Seismic Design Categories A through F) tension and shear loads in cracked and uncracked normal-weight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

The anchor system complies with anchors as described in Section 1901.3 of the 2018 and 2015 IBC, Section 1909 of the 2012 IBC and is an alternative to cast-in-place anchors described in Section 1908 of the 2012 IBC, and Sections 1911 and 1912 of the 2009 IBC. The anchor systems may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

The post-installed reinforcing bar system is an alternative to cast-in-place reinforcing bars governed by ACI 318 and IBC Chapter 19.

3.0 DESCRIPTION

3.1 General:

The Hilti HIT-HY 200 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are comprised of the following components:

- Hilti HIT-HY 200 adhesive packaged in foil packs (either Hilti HIT-HY 200-A or Hilti HIT-HY 200-R)
- Adhesive mixing and dispensing equipment
- Equipment for hole cleaning and adhesive injection

The Hilti HIT-HY 200 Adhesive Anchoring System may be used with continuously threaded rod, Hilti HIT-Z(-R) anchor rods, Hilti HIS-(R)N internally threaded inserts or deformed steel reinforcing bars as depicted in Figure 1. The Hilti HIT-HY 200 Post-Installed Reinforcing Bar System may only be used with deformed steel reinforcing bars as depicted in Figure 2. The primary components of the Hilti Adhesive Anchoring and Post-Installed Reinforcing Bar Systems, including the Hilti HIT-HY 200 Adhesive, HIT-RE-M static mixing nozzle and steel anchoring elements, are shown in Figure 6 of this report.

The manufacturer's printed Installation instructions (MPII), as included with each adhesive unit package, are replicated as Figure 9.

3.2 Materials:

3.2.1 Hilti HIT-HY 200 Adhesive: Hilti HIT-HY 200 Adhesive is an injectable, two-component hybrid adhesive. The two components are separated by means of a dual-cylinder foil pack attached to a manifold. The two components combine and react when dispensed through a static mixing nozzle attached to the manifold. Hilti HIT-HY 200 is available in 11.1-ounce (330 mL) and 16.9-ounce (500 mL) foil packs. The manifold attached to each foil pack is stamped with the adhesive expiration date. The shelf life, as indicated by the expiration date, applies to an unopened foil pack stored in a dry, dark environment and in accordance with Figure 9.

Hilti HIT-HY 200 Adhesive is available in two options, Hilti HIT-HY 200-A and Hilti HIT-HY 200-R. Both options are subject to the same technical data as set forth in this report. Hilti HIT-HY 200-A will have shorter working times

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Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63660, Rev. 0 CALCULATION SHEET		
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 35 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020

and curing times than Hilti HIT-HY 200-R. The packaging for each option employs a different color, which helps the user distinguish between the two adhesives.

3.2.2 Hole Cleaning Equipment:

3.2.2.1 Standard Equipment: Standard hole cleaning equipment, comprised of steel wire brushes and air nozzles, is described in Figure 9 of this report.

3.2.2.2 Hilti Safe-Set™ System: The Hilti Safe-Set™ with Hilti HIT-HY 200 consists of one of the following:

- For the Hilti HIT-Z and HIT-Z-R anchor rods, hole cleaning is not required after drilling the hole, except if the hole is drilled with a diamond core drill bit.
- For the elements described in Sections 3.2.4.2 through 3.2.4.4 and Section 3.2.5, the Hilti TE-CD or TE-YD hollow carbide drill bit with a carbide drilling head conforming to ANSI B212.15. Used in conjunction with a Hilti vacuum with a minimum value for the maximum volumetric flow rate of 129 CFM (61 ℓ/s), the Hilti TE-CD or TE-YD drill bit will remove the drilling dust, automatically cleaning the hole.

3.2.3 Hole Preparation Equipment:

3.2.3.1 Hilti Safe-Set™ System: TE-YRT Roughening Tool: For the elements described in Sections 3.2.5.2 through 3.2.5.4 and Tables 12, 13, 16, 17, 21, and 23, the Hilti TE-YRT roughening tool with a carbide roughening head is used for hole preparation in conjunction with holes core drilled with a diamond core bit as illustrated in Figure 4.

3.2.4 Dispensers: Hilti HIT-HY 200 must be dispensed with manual or electric dispensers provided by Hilti.

3.2.5 Anchor Elements:

3.2.5.1 Hilti HIT-Z and HIT-Z-R Anchor Rods: Hilti HIT-Z and HIT-Z-R anchor rods have a conical shape on the embedded section and a threaded section above the concrete surface. Mechanical properties for the Hilti HIT-Z and HIT-Z-R anchor rods are provided in Table 2. The rods are available in diameters as shown in Table 7 and Figure 1. Hilti HIT-Z anchor rods are produced from carbon steel and furnished with a 0.005-millimeter-thick (5 μm) zinc electroplated coating. Hilti HIT-Z-R anchor rods are fabricated from grade 316 stainless steel.

3.2.5.2 Threaded Steel Rods: Threaded steel rods must be clean, continuously threaded rods (all-thread) in diameters as described in Tables 11 and 15 and Figure 1 of this report. Steel design information for common grades of threaded rods is provided in Table 3. Carbon steel threaded rods must be furnished with a 0.0002-inch-thick (0.005 mm) zinc electroplated coating complying with ASTM B633 SC 1 or must be hot-dipped galvanized complying with ASTM A153, Class C or D. Stainless steel threaded rods must comply with ASTM F593 or ISO 3506 A4. Threaded steel rods must be straight and free of indentations or other defects along their length. The ends may be stamped with identifying marks and the embedded end may be blunt cut or cut on the bias to a chisel point.

3.2.5.3 Steel Reinforcing Bars for use in Post-Installed Anchor Applications: Steel reinforcing bars are deformed bars as described in Table 4 of this report. Tables 11, 15, and 19 and Figure 1 summarize reinforcing bar size ranges. The embedded portions of reinforcing bars must be straight, and free of mill scale, rust, mud, oil and other coatings (other than zinc) that may impair the bond with the adhesive. Reinforcing bars must not be bent after installation except as set forth in ACI 318-14 26.6.3.1(b) or ACI 318-11 7.3.2, as applicable, with the additional condition that the bars must be bent cold, and heating of reinforcing bars to facilitate field bending is not permitted.

3.2.5.4 Hilti HIS-N and HIS-RN Inserts: Hilti HIS-N and HIS-RN inserts have a profile on the external surface and are internally threaded. Mechanical properties for Hilti HIS-N and HIS-RN inserts are provided in Table 5. The inserts are available in diameters and lengths as shown in Table 22 and Figure 1. Hilti HIS-N inserts are produced from carbon steel and furnished with a 0.005-millimeter-thick (5 μm) zinc electroplated coating complying with ASTM B633 SC 1. The stainless steel Hilti HIS-RN inserts are fabricated from X5CrNiMo17122 K700 steel conforming to DIN 17440. Specifications for common bolt types that may be used in conjunction with Hilti HIS-N and HIS-RN inserts are provided in Table 6. Bolt grade and material type (carbon, stainless) must be matched to the insert. Strength reduction factors, ϕ, corresponding to brittle steel elements must be used for Hilti HIS-N and HIS-RN inserts.

3.2.5.5 Ductility: In accordance with ACI 318-14 2.3 or ACI 318-11 D.1, as applicable, in order for a steel element to be considered ductile, the tested elongation must be at least 14 percent and reduction of area must be at least 30 percent. Steel elements with a tested elongation of less than 14 percent or a reduction of area of less than 30 percent, or both, are considered brittle. Values for various steel materials are provided in Tables 2, 3, and 6 of this report. Where values are nonconforming or unstated, the steel must be considered brittle.

3.2.6 Steel Reinforcing Bars for Use in Post-Installed Reinforcing Bar Connections: Steel reinforcing bars used in post-installed reinforcing bar connections are deformed bars (rebar) as depicted in Figures 2 and 3. Tables 25, 26, 27, and Figure 9 summarize reinforcing bar size ranges. The embedded portions of reinforcing bars must be straight, and free of mill scale, rust and other coatings that may impair the bond with the adhesive. Reinforcing bars must not be bent after installation, except as set forth in Section 26.6.3.1(a) of ACI 318-14 or Section 7.3.2 of ACI 318-11, as applicable, with the additional condition that the bars must be bent cold, and heating of reinforcing bars to facilitate field bending is not permitted.

3.3 Concrete:

Normal-weight concrete must comply with Sections 1903 and 1905 of the IBC, as applicable. The specified compressive strength of the concrete must be from 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

4.0 DESIGN AND INSTALLATION

4.1 Strength Design of Post-Installed Anchors:

Refer to Table 1 for the design parameters for specific installed elements, and refer to Figure 4 and Section 4.1.4 for a flowchart to determine the applicable design bond strength or pullout strength.

4.1.1 General: The design strength of anchors under the 2018 and 2015 IBC and 2018 and 2015 IRC must be determined in accordance with ACI 318-14 and this report. The design strength of anchors under the 2012 and 2009 IBC, as well as the 2012 and 2009 IRC must be determined in accordance with ACI 318-11 and this report.

A design example according to the 2012 and 2009 IBC based on ACI 318-11 is given in Figure 7 of this report.

Design parameters are based on ACI 318-14 for use with the 2018 and 2015 IBC, and ACI 318-11 for use with the 2012 and 2009 IBC unless noted otherwise in Sections 4.1.1 through 4.1.11 of this report.

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63660, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 36 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020

TABLE 1—DESIGN TABLE INDEX

Design Table		Fractional		Metric	
		Table	Page	Table	Page
Hilti HIT-Z and HIT-Z-R Anchor Rod	Steel Strength - N_{sa}, V_{sa}	7	14	7	14
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	8	15	8	15
	Pullout Strength – N_p	10	19	10	19
Standard Threaded Rod	Steel Strength - N_{sa}, V_{sa}	11	20	15	25
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	12	22	16	26
	Bond Strength - N_a, N_{ag}	14	24	18	28
Hilti HIS-N and HIS-RN Internally Threaded Insert	Steel Strength - N_{sa}, V_{sa}	22	32	22	32
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	23	33	23	33
	Bond Strength - N_a, N_{ag}	24	34	24	34

Design Table		Fractional		EU Metric		Canadian	
		Table	Page	Table	Page	Table	Page
Steel Reinforcing Bars	Steel Strength - N_{sa}, V_{sa}	11A	21	15	25	19	29
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	12	22	16	26	20	30
	Bond Strength - N_a, N_{ag}	13	23	17	27	21	31
	Determination of development length for post-installed reinforcing bar connections	25	35	26	36	27	36

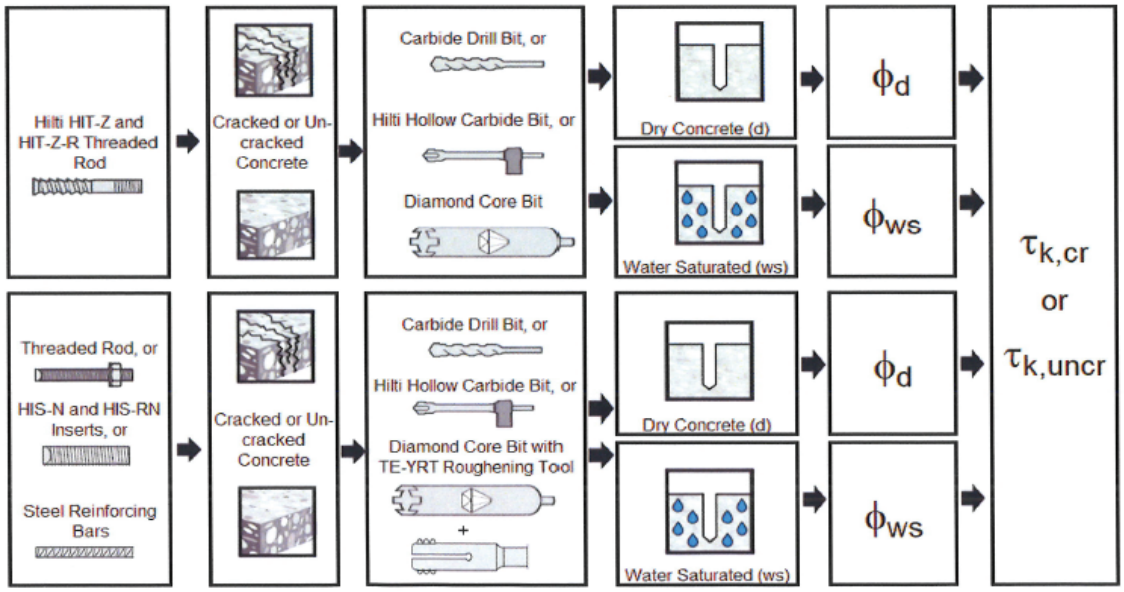

FIGURE 4—FLOWCHART FOR THE ESTABLISHMENT OF DESIGN BOND OR PULLOUT STRENGTH FOR POST-INSTALLED ADHESIVE ANCHORS

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63660, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 37 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020

Fractional Threaded Rod

Steel Strength

TABLE 11—STEEL DESIGN INFORMATION FOR FRACTIONAL THREADED ROD

DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)[1]						
				3/8	1/2	5/8	3/4	7/8	1	1 1/4
Rod O.D.		d	in. (mm)	0.375 (9.5)	0.5 (12.7)	0.625 (15.9)	0.75 (19.1)	0.875 (22.2)	1 (25.4)	1.25 (31.8)
Rod effective cross-sectional area		A_{se}	in.^{2} (mm^2)	0.0775 (50)	0.1419 (92)	0.2260 (146)	0.3345 (216)	0.4617 (298)	0.6057 (391)	0.9691 (625)
ISO 898-1 Class 5.8	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	5,620 (25.0)	10,290 (45.8)	16,385 (72.9)	24,250 (107.9)	33,470 (148.9)	43,910 (195.3)	70,260 (312.5)
		V_{sa}	lb (kN)	3,370 (15.0)	6,175 (27.5)	9,830 (43.7)	14,550 (64.7)	20,085 (89.3)	26,345 (117.2)	42,155 (187.5)
	Reduction for seismic shear	$\alpha_{V,seis}$	-	0.70						
	Strength reduction factor ϕ for tension[2]	ϕ	-	0.65						
	Strength reduction factor ϕ for shear[2]	ϕ	-	0.60						
ASTM A193 B7	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	9,685 (43.1)	17,735 (78.9)	28,250 (125.7)	41,810 (186.0)	57,710 (256.7)	75,710 (336.8)	121,135 (538.8)
		V_{sa}	lb (kN)	5,810 (25.9)	10,640 (47.3)	16,950 (75.4)	25,085 (111.6)	34,625 (154.0)	45,425 (202.1)	72,680 (323.3)
	Reduction for seismic shear	$\alpha_{V,seis}$	-	0.70						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F1554 Gr. 36	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	- -	8,230 (36.6)	13,110 (58.3)	19,400 (86.3)	26,780 (119.1)	35,130 (156.3)	56,210 (250.0)
		V_{sa}	lb (kN)	- -	4,940 (22.0)	7,865 (35.0)	11,640 (51.8)	16,070 (71.5)	21,080 (93.8)	33,725 (150.0)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.6						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F1554 Gr. 55	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	- -	10,645 (47.4)	16,950 (75.4)	25,090 (111.6)	34,630 (154.0)	45,430 (202.1)	72,685 (323.3)
		V_{sa}	lb (kN)	- -	6,385 (28.4)	10,170 (45.2)	15,055 (67.0)	20,780 (92.4)	27,260 (121.3)	43,610 (194.0)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.7						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F1554 Gr. 105	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	- -	17,740 (78.9)	28,250 (125.7)	41,815 (186.0)	57,715 (256.7)	75,715 (336.8)	121,135 (538.8)
		V_{sa}	lb (kN)	- -	10,645 (47.4)	16,950 (75.4)	25,090 (111.6)	34,630 (154.0)	45,430 (202.1)	72,680 (323.3)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.7						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F593, CW Stainless	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	7,750 (34.5)	14,190 (63.1)	22,600 (100.5)	28,435 (126.5)	39,245 (174.6)	51,485 (229.0)	- -
		V_{sa}	lb (kN)	4,650 (20.7)	8,515 (37.9)	13,560 (60.3)	17,060 (75.9)	23,545 (104.7)	30,890 (137.4)	- -
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.7						-
	Strength reduction factor ϕ for tension[2]	ϕ	-	0.65						-
	Strength reduction factor ϕ for shear[2]	ϕ	-	0.60						-
ASTM A193, Gr. B(M), Class 1 Stainless	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	-						55,240 (245.7)
		V_{sa}	lb (kN)	-						33,145 (147.4)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	-						0.6
	Strength reduction factor ϕ for tension[2]	ϕ	-	-						0.75
	Strength reduction factor ϕ for shear[2]	ϕ	-	-						0.65

For **SI**: 1 inch = 25.4 mm, 1 lbf = 4.448 N. For **pound-inch** units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf

[1] Values provided for common rod material types are based on specified strengths and calculated in accordance with ACI 318-14 Eq. (17.4.1.2) and Eq (17.5.1.2b) or ACI 318-11 Eq. (D-2) and Eq. (D-29). Nuts and washers must be appropriate for the rod.

[2] For use with the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 9.2, as set forth in ACI 318-14 17.3.3 or ACI 318-11 D.4.3. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. Values correspond to a brittle steel element.

[3] For use with the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 9.2, as set forth in ACI 318-14 17.3.3 or ACI 318-11 D.4.3. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. Values correspond to a ductile steel element.

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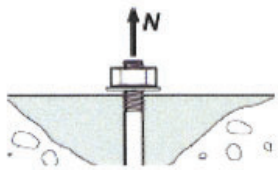
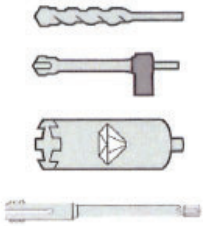
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 39 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020

Fractional Threaded Rod and Reinforcing Bars



Concrete Breakout Strength



Carbide Bit or
Hilti Hollow Carbide Bit or
Diamond Core Bit + Roughening Tool

TABLE 12—CONCRETE BREAKOUT DESIGN INFORMATION FOR FRACTIONAL THREADED ROD AND REINFORCING BARS IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT (OR HILTI HOLLOW CARBIDE DRILL BIT) OR CORE DRILLED WITH A DIAMOND CORE BIT AND ROUGHENED WITH A HILTI ROUGHENING TOOL[1]

DESIGN INFORMATION	Symbol	Units	Nominal rod diameter (in.) / Reinforcing bar size							
			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1 1/4 or #10
Effectiveness factor for cracked concrete	$k_{c,cr}$	in-lb (SI)	17 (7.1)							
Effectiveness factor for uncracked concrete	$k_{c,uncr}$	in-lb (SI)	24 (10)							
Minimum Embedment	$h_{ef,min}$	in. (mm)	2 3/8 (60)	2 3/4 (70)	3 1/8 (79)	3 1/2 (89)	3 1/2 (89)	4 (102)	4 1/2 (114)	5 (127)
Maximum Embedment	$h_{ef,max}$	in. (mm)	7 1/2 (191)	10 (254)	12 1/2 (318)	15 (381)	17 1/2 (445)	20 (508)	22 1/2 (572)	25 (635)
Min. anchor spacing[3]	s_{min}	in. (mm)	1 7/8 (48)	2 1/2 (64)	3 1/8 (79)	3 3/4 (95)	4 3/8 (111)	5 (127)	5 5/8 (143)	6 1/4 (159)
Min. edge distance (Threaded rods)	c_{min}	in. (mm)	1¾ (45)	1¾ (45)	2 (3) (50) (3)	2 1/8 (3) (55) (3)	2¼ (3) (60) (3)	2¾ (3) (70) (3)	n/a	3 1/8 (3) (80) (3)
Min. edge distance (Reinforcing bars)[3]	c_{min}	-	5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances							
Minimum concrete thickness	h_{min}	in. (mm)	h_{ef} + 1 1/4 (h_{ef} + 30)		$h_{ef} + 2d_0$ (4)					
Critical edge distance – splitting (for uncracked concrete)	c_{ac}	-	See Section 4.1.10.2 of this report.							
Strength reduction factor for tension, concrete failure modes, Condition B[2]	ϕ	-	0.65							
Strength reduction factor for shear, concrete failure modes, Condition B[2]	ϕ	-	0.70							

For **SI**: 1 inch ≡ 25.4 mm, 1 lbf = 4.448 N, 1 psi = 0.006897 MPa.
For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf, 1 MPa = 145.0 psi

[1] Additional setting information is described in Figure 9, Manufacturers Printed Installation Instructions (MPII).
[2] Values provided for post-installed anchors under Condition B without supplementary reinforcement as defined in ACI 318-14 17.3.3 or ACI 318-11 D.4.3.
[3] For installations with 1 3/4-inch edge distance, refer to Section 4.1.9.2 for spacing and maximum torque requirements.
[4] d_0 = hole diameter.

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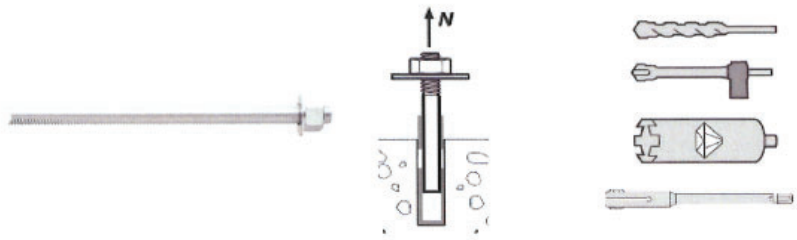
Project No. S54413.024	**Calculation No.** S54413.024-S-001	**Rev.** 0	**Page No.** 40 of 40
Title: LERF Basin 41 Liner Anchor Wall Design			
Prepared By: RW Davidson	**Date:** 4/3/2020	**Checked By:** PP Santos	**Date:** 4/3/2020



Fractional Threaded Rod | Bond Strength | Carbide Bit or Hilti Hollow Carbide Bit or Diamond Core Bit + Roughening Tool

TABLE 14—BOND STRENGTH DESIGN INFORMATION FOR FRACTIONAL THREADED ROD IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT (OR HILTI HOLLOW CARBIDE DRILL BIT) OR CORE DRILLED WITH A DIAMOND CORE BIT AND ROUGHENED WITH A HILTI ROUGHENING TOOL[1]

DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)						
				3/8	1/2	5/8	3/4	7/8	1	1 1/4
Minimum Embedment		$h_{ef,min}$	in. (mm)	2 3/8 (60)	2 3/4 (70)	3 1/8 (79)	3 1/2 (89)	3 1/2 (89)	4 (102)	5 (127)
Maximum Embedment		$h_{ef,max}$	in. (mm)	7 1/2 (191)	10 (254)	12 1/2 (318)	15 (381)	17 1/2 (445)	20 (508)	25 (635)
Temperature range A[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	1,045 (7.2)	1,135 (7.8)	1,170 (8.1)	1,260 (8.7)	1,290 (8.9)	1,325 (9.1)	1,380 (9.5)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)
Temperature range B[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	1,045 (7.2)	1,135 (7.8)	1,170 (8.1)	1,260 (8.7)	1,290 (8.9)	1,325 (9.1)	1,380 (9.5)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)
Temperature range C[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	855 (5.9)	930 (6.4)	960 (6.6)	1,035 (7.1)	1,055 (7.3)	1,085 (7.5)	1,130 (7.8)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)
Permissible installation conditions	Dry and water saturated concrete	Anchor Category	-	1						
		ϕ_d, ϕ_{ws}	-	0.65						
Reduction for seismic tension	Hammer drilled	$\alpha_{N,seis}$	-	0.88	0.99	0.99	1.0	1.0	0.95	0.99
	Core drilled + roughening	$\alpha_{N,seis}$	-	N/A		0.88	0.96	0.96	1.0	0.82

For **SI**: 1 inch ≡ 25.4 mm, 1 lbf = 4.448 N, 1 psi = 0.006897 MPa.
For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf, 1 MPa = 145.0 psi

[1] Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi (17.2 MPa). For concrete compressive strength, f'_c, between 2,500 psi (17.2 MPa) and 8,000 psi (55.2 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1], the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2{,}500)^{0.1}$ [For SI: $(f'_c / 17.2)^{0.1}$]. See Section 4.1.4 of this report for bond strength determination.
[2] Temperature range A: Maximum short term temperature = 130°F (55°C), Maximum long term temperature = 110°F (43°C).
Temperature range B: Maximum short term temperature = 176°F (80°C), Maximum long term temperature = 110°F (43°C).
Temperature range C: Maximum short term temperature = 248°F (120°C), Maximum long term temperature = 162°F (72°C).
Short term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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DATE: May 26,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63664 **Rev.** 00

2. **Title:**
LERF Basin 41 Catch Basin Design

3. **Project Number:** ☐N/A
T1P226

4. **Design Verification Required:**
☐Yes ☒No

5. **USQ Number:** ☒ N/A
RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type:
public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Harrison, Sarah E	*Harrison, Sarah E*	05/26/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/28/2020
Checker	Santos, Peter P	*Santos, Peter P*	04/27/2020
Document Control Approval	Alvarez, Efren	*Alvarez, Efren*	05/26/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/29/2020
Originator	Davidson, Ronald W	*Davidson, Ronald W*	04/27/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	04/23/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	04/29/2020

8. **Description of Change and Justification**

Initial Release.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
ETF FACILITIES LERF FACILITIES	ETF LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
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RPP-CALC-63664
Revision 0

LERF Basin 41 Catch Basin Design

Prepared by

RW Davidson
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
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Sargent & Lundy Engineering Services, Inc.	**RPP-CALC-63664, Rev. 0** **CALCULATION COVER SHEET**	**Page No.** 1 of 40 **Date** 04/27/2020 **Rev. No.** 1 **Calculation No:** S54413.024-S-002

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions, LLC

Title:

LERF Basin 41 Catch Basin Design

Purpose and Objective:

The purpose of this calculation is to design the concrete Catch Basin and pipe support anchors for Liquid Effluent Retention Facility (LERF) Basin 41.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	31	**Print Name/ Sign:**	RW Davidson, P.E.	PP Santos, P.E.	PM Dorsh, P.E.
		Date:	04/03/2020	04/07/2020	04/07/2020

Revision Description (Revision Description/Affected Pages):

Initial Release.

1	40	**Print Name/ Sign:**	RW Davidson, P.E.	PP Santos, P.E.	PM Dorsh, P.E.
		Date:	04/27/2020	04/27/2020	04/27/2020

Revision Description (Revision Description/Affected Pages):

Added Section 8.12 which determines the loads on the weight anchor eye bolts and Section 8.13 which checks the 5/8” adhesive anchor rods used to attach the weight anchor eye bolts to the CB wall. Added Attachment 3 for HDPE pipe data. Added drawing reference. Table of Contents reflects addition of Attachment 3. Section 6.0 Results Table updated to add DCR results for 5/8” adhesive anchor rods for weight anchor eye bolts.

Sargent & Lundy Engineering Services, Inc.

RPP-CALC-63664, Rev. 0

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev.	Page No.
S54413.024	S54413.024-S-002	1	2 of 40

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	All Pages
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
RW Davidson, P.E.	04/27/2020
Checker (Print Name and Sign):	**Date:**
PP Santos, P.E.	04/27/2020

Signatures obtained only after discrepancies are corrected and comments are resolved.

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 3 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

TABLE OF CONTENTS

1.0 PURPOSE 4
2.0 METHODOLOGY 4
3.0 DESIGN INPUTS 4
4.0 ASSUMPTIONS 4
5.0 COMPUTER SOFTWARE 4
6.0 RESULTS 5
7.0 REFERENCES 5
8.0 CALCULATIONS 7

Attachments

Attachment 1
ICC-ES Evaluation Report - ESR-3187 (Excerpt)
Attachment 2
Pipe Wall Thickness Data Sheet
Attachment 3
HDPE Pipe Data Sheet

Acronyms

ACI	American Concrete Institute
ASCE	American Society of Civil Engineers
CB	Catch Basin
CL	Center Line
DCR	Demand-to-Capacity Ratio
IBC	International Building Code
LERF	Liquid Effluent Retention Facility
LRFD	Load and Resistance Factor Design
NDC	Natural Phenomena Hazard Design Category
SpG	Specific Gravity
WDC	Wind Design Category

1.0 PURPOSE

The purpose of this calculation is to design the concrete Catch Basin (CB) and pipe support anchors for the Liquid Effluent Retention Facility (LERF) Basin 41.

2.0 METHODOLOGY

Wind, seismic, dead and fluid loads for the CB are calculated using ASCE 7-10, *Minimum Design Loads on Buildings and Other Structures* and TFC-ENG-STD-06, *Design Loads for Tank Farm Facilities*.

The concrete adhesive anchor bolts are analyzed using Chapter 17 of ACI 318, *Building Code Requirements for Structural Concrete and Commentary* and ESR-3187, Hilti *HIT-HY 200 Adhesive Anchors and Post Installed Reinforcing Bar Connections in Concrete*. Stability of the concrete catch basin on soil is checked using IBC and *Principles of Foundation Engineering*.

3.0 DESIGN INPUTS

1. Pipe support anchor loads are calculated using ASCE 7-10.
2. The CB is General Service per MT-50497.
3. The compressive strength of the concrete is 4500 psi per RPP-SPEC-63632.
4. Specific gravity of LERF fluid flow is taken as 1.0*SpG water per RPP-CALC-63650.
5. Nominal strength of anchor rods is based on ASTM F593 CW-1, stainless steel material per ESR-3187, Table 11 and RPP-SPEC-63632.
6. Dimensions of the CB are based on Drawing H-2-838751, Sheets 1-5.
7. Tributary spacing of the pipe supports are derived from Drawing H-2-838767, *LERF Basin 41, Catch Basin Assembly*, Sheet 3.
8. Pipe diameter, support details are found in H-2-838771, *LERF Basin 41, Catch Basin Piping Notes and Parts List, Isometric, Assembly & Details.*

4.0 ASSUMPTIONS

None.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Mathcad®[1] 15.0 was used for the hand calculations. Calculations are checked using a handheld calculator.

1 Mathcad is a registered trademark of PTC, Inc., Needham, Massachusetts.

6.0 RESULTS

The Hilti®[2] HIT-HY 200 adhesive anchor system is adequate using a 1/2" stainless steel threaded anchor rods with 3 ½" embedment depth for the pipe support anchors and 5/8" stainless steel threaded anchor rods with 3 7/8" embedment depth for the weight anchors (eye bolts). The 8" concrete CB slab is adequate with #5 rebar spaced 9" on center each way.

TABLE: Results Summary

Pipe Support Adhesive Anchors	**DCR**
DCR tension	0.07
DCR shear	0.01
DCR per ACI 318, Equation 17.6.3	0.01
Weight Anchor (Eye Bolt) Adhesive Anchors	**DCR**
DCR tension	0.45
DCR shear	0.08
DCR per ACI 318, Equation 17.6.3	0.45
CB Slab	**DCR**
DCR one-way shear	0.2
DCR punching shear	0.05
DCR soil bearing	0.19
Pipe Support Post Weld	**DCR**
DCR weld	0.59

7.0 REFERENCES

ACI 318-14, *Building Code Requirements for Structural Concrete and Commentary*, 2014, American Concrete Institute, Farmington Hills, MI.

AISC 325-11, *Steel Construction Manual, American Institute of Steel Construction, 14th Edition*, 2011, Chicago, IL.

ASCE 7-2010, *Minimum Design Loads for Buildings and Other Structures*, 2010, American Society of Civil Engineers, Reston, VA.

Das, Braja M., *Principles of Foundation Engineering*, Sixth Ed., 2007, Cengage Learning, Stamford, CT

2 Hilti and HIT-HY are registered trademarks of Hilti Aktiengesellschaft, Schaan, Liechtenstein

7.0 REFERENCES CONT'D

ESR-3187, Hilti *HIT-HY 200 Adhesive Anchors and Post Installed Reinforcing Bar Connections in Concrete*, Reissued March 2016, ICC Evaluation Services, Whittier, CA., (See Attachment 1 for Excerpt).

H-2-838750, Rev. 0, Sheet 1, *LERF Basin 41 Civil Top Liner*, U.S. Department of Energy, Richland, WA.

H-2-838751, Rev. 0, Sheets 1-5, *LERF Catch Basin 41 Structural Plan & Section, Details, and Elevation & Details*, U.S. Department of Energy, Richland, WA.

H-2-838767, Rev. 0, Sheets 1-11*, LERF Basin 41, Catch Basin Notes & Parts List, Isometric, Assembly*, *Sections, Details & Weldments*, U.S. Department of Energy, Richland, WA.

H-2-838771, Rev. 0, Sheets 1-10, *LERF Basin 41, Catch Basin Piping Notes and Parts List*, *Isometric, Assembly & Details,* U.S. Department of Energy, Richland, WA.

IBC 2015*, International Building Code*, International Code Council, 2015, Country Club Hills, IL.

MT-50497, Rev 00, Liquid Effluent Retention Facility (LERF) Basin 41, U.S. Department of Energy, Richland, WA.

PH-20, *Pipe Hangers & Supports*, B-Line Series Catalog.

RPP-CALC-63650, Rev 0, *Leachate and Basin Pump Flow Calculation,* U.S. Department of Energy, Richland, WA.

RPP-SPEC-63632, Rev 0, *Construction Specification for LERF Basin 41 Design*, U.S. Department of Energy, Richland, WA.

TFC-ENG-STD-06, Rev. D-2, *Design Loads for Tank Farm Facilities*, U.S. Department of Energy, Richland, WA.

8.0 CALCULATIONS

NOTE: Use B3088S-2 1/2 Seismic Base Stand dimensions to get maximum applied loads.

8.1 Determine Wind Loads

$V := 110mph$ — Wind Speed, (TFC-ENG-STD-06, Table 3 for WDC-1/NDC-1).

$K_d := 0.95$ — Wind Direction factor for Round Chimneys, Tanks and Similar Structures, (ASCE 7-10, Section 26.6 and Table 26.6-1).

$K_z := 0.85$ — Velocity Pressure coefficient for Design Exposure C. (ASCE 7-10, Table 29.3-1)

$K_{zt} := 1.0$ — Topographic factor. (ASCE 7-10, Section 26.8.2)

$G := 0.85$ — Gust Effect factor. (ASCE 7-10, Section 26.9.1)

$D_{post} := 2.88in$ — Outside diameter of B-Line B3088S-2 1/2 Seismic Base Stand, Sch 40.

$D_{pipe} := 4.5 \cdot in$ — Outside diameter of largest pipe 4" Sch. 40 (H-2-838767, Item 18).

$t_{base_plate} := \frac{3}{8}in$ — Plate Thickness of B3088S-2 1/2.

$C_{B3090} := \left(4in + \frac{1}{16}in\right) = 0.3\,ft$ — Distance from the bottom of the B3090 gusset to the certerline of the pipe (e.g., 'C' dimension in B-Line Catalog, page 132).

$h := \left(22in + \frac{1}{8}in\right) + t_{base_plate} + C_{B3090} = 2.2\,ft$ — Maximum seismic base stand height.

$s := \max\left[\left(282in + \frac{15}{16}in\right) - \left(105in + \frac{7}{8}in\right), \left(434in + \frac{15}{16}in\right) - \left(282in + \frac{15}{16}in\right)\right] = 14.8\,ft$ — Estimated contributary pipe and insuation length supported by one seismic base stand. (H-2-838767,SH 3 Section E3-E5)

$q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot \left(\frac{V}{mph}\right)^2 \cdot psf = 25.0 \cdot psf$ — Velocity pressure calculated at mean height h. (ASCE 7-10, Equation 29.3-1)

$\frac{h}{D_{pipe}} = 5.9$ — Ratio of CL height of piping above CB floor to nominal diameter of pipe diameter used.

$\frac{D_{pipe}}{(in)} \cdot \sqrt{\frac{q_z}{(psf)}} = 22.5 > 2.5$ — ASCE 7-10, Figure 29.5-1 for Chimneys, tanks, rooftop Equipment, & Similar Structures).

$C_f := \left|\frac{(0.6 - 0.5)\cdot(7 - 1.5)}{(7 - 1)} - 0.6\right| = 0.51$ — Net force coefficient (by extrapolation), wind normal to face, (ASCE 7-10, Figure 29.5-1 for round Chimneys, tanks, rooftop Equipment, & Similar Structures).

$insul_{thk} := 5 \cdot in$ — Estimated insulation thickness.

$A_f := s \cdot \left(D_{pipe} + insul_{thk} \cdot 2\right) = 17.8 \cdot ft^2$ — Projected area normal to the wind including insulation.

$F_w := q_z \cdot G \cdot C_f \cdot A_f = 192.7\,lbf$ — Design wind load on other structures. (ASCE 7-10, Equation 29.5-1)

8.2 Determine Seismic Loads

$W_{base_stand} := \frac{1638lbf}{100} = 16.4\,lbf$

Weight of B3088S-2 1/2 Seismic Base Stand. (B-Line Catalog, page 128)

$W_{pipe_support} := \frac{586lbf}{100} = 5.9\,lbf$

Weight of B3090-4 Pipe Support with U-Bolt. (B-Line Catalog, page 132)

$W_{4_40s} := 11 \cdot plf \cdot s = 162.3\,lbf$

Estimated contributary pipe weight supported by one pipe support post based on 4" dia. Sch 40S SST pipe. (see Attachment 2)

$W_{insul} := 5 \cdot plf \cdot s = 73.8\,lbf$

Estimated weight of 5" thickness insulation.

$\rho_{waste} := 1.0 \cdot 62.4 \frac{lbf}{ft^3} = 62.400 \cdot \frac{lbf}{ft^3}$

Specific weight of basin fluid is based on RPP-CALC-63650, "Leachate and Basin Pump Flow Calculation" which uses the specific gravity of water.

$F_{wt} := \left[\frac{\pi \cdot \left[\left(D_{pipe} - 0.237 \cdot in \cdot 2\right)^2\right]}{4} \cdot s\right] \cdot \rho_{waste} = 81.4\,lbf$

Fluid weight is based on the full flow area of a Sch 40S 4-inch dia.stainless steel pipe (see Attachment 2), conservative.

$W_{tot} := \begin{pmatrix} W_{base_stand} \cdots \\ + W_{pipe_support} \cdots \\ + W_{4_40s} + W_{insul} + F_{wt} \end{pmatrix} \cdot 1.15 = 390.7\,lbf$

Estimated total dead load on one pipe support post including 15% contingency for miscellaneous pipe support fittings and pipe couplings etc.

$S_{DS} := 0.588$

Horizontal five-percent damped design spectral response acceleration at short periods. (TFC-ENG-STD-06)

$z_h := 1.0$

Ratio of the height in structure of point of attachment of component to the average roof height of structure.

$I_p := 1.0$

Component importance factor for SDC-1 loading. (TFC-ENG-STD-06)

$a_p := 2.5$

Component amplification factor for piping in accordance with ASME B31, joint made by welding or brazing. (ASCE 7-10, Table 13.6-1)

$R_p := 12$

Component response modification factor for piping in accordance with ASME B31, joint made by welding or brazing. (ASCE 7-10, Table 13.6-1)

$F_{pnom} := \frac{0.4 \cdot a_p \cdot S_{DS} \cdot \left(W_{tot}\right)}{\frac{R_p}{I_p}} [1 + 2(z_h)] = 57.4 \cdot lbf$

The horizontal seismic force. (ASCE 7-10, Equation 13.3-1)

$F_{pmax} := 1.6 S_{DS} \cdot I_p \cdot \left(W_{tot}\right) = 367.5\,lbf$

The maximum lateral seismic force. (ASCE 7-10, Equation 13.3-2)

$F_{pmin} := 0.3 S_{DS} \cdot I_p \cdot \left(W_{tot}\right) = 68.9\,lbf$

The minimum lateral seismic force. (ASCE 7-10, Equation 13.3-3)

$F_p := \begin{cases} F_{pmin} & \text{if } F_{pnom} < F_{pmin} \\ F_{pmax} & \text{if } F_{pnom} > F_{pmax} \\ F_{pnom} & \text{otherwise} \end{cases} \qquad F_p = 68.9\,lbf$

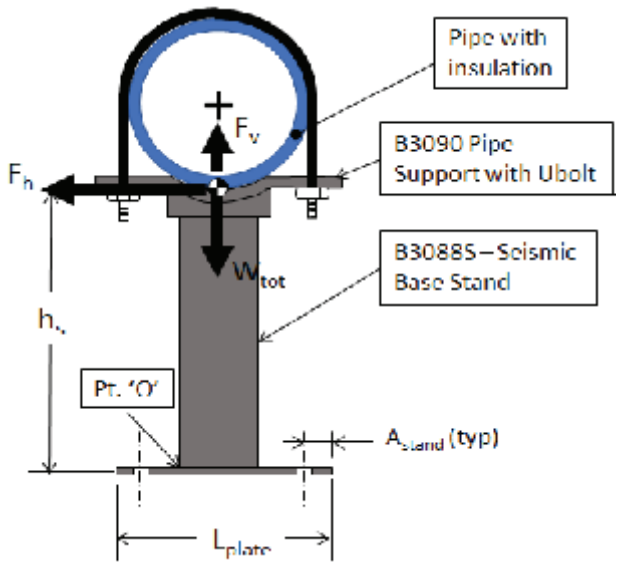
The minimum lateral force to use for design purposes.

$F_v := 0.2 S_{DS} \cdot W_{tot} = 45.9\,lbf$

The design vertical seismic force, (ASCE 7-10, Section 13.3.1).

8.3 Determine Piping Loads on the Anchors

The following section determines the anchor forces to withstand the worst case loading.



NOTE: Use B3088S-2 1/2 seismic base stand dimensions to get max moments, shears and axial force reactions, conservative.

$L_{plate} := 8.5in$ — Plate Size Length of B3088S-2 1/2 seismic base stand. (B-Line Catalog, page 128)

$A_{stand} := 1.25in$ — Edge distance/edge margin of plate fastening hole for B3088S-2 seismic base stand. (B-Line Catalog, page 128)

$D_{stand} := 2.88 \cdot in$ — Diameter of base stand -B3088S-2 1/2 seismic base stand. (B-Line Catalog, page 128)

$\Omega_o := 2.5$ — Overstrength factor, (ASCE 7-10, Table 13-5.1, Supplement 1 is required for anchorage to concrete)

$F_{h_calc} := \max(1.0F_w, 1.0 \cdot F_p \cdot \Omega_o) = 192.7 \cdot lbf$ — Calculated horizontal piping load combination per ASCE 7-10, Section 2.3.2 including overstrength factor.

$F_{h_B31.3} := 2107 \cdot lbf$ — Horizontal piping load combination per RPP-CALC-63779, Appendix H including overstrength factor.

$F_{h_comb} := \max(F_{h_calc}, F_{h_B31.3}) = 2107.0\ lbf$ — Governing horizontal piping load combination.

$F_{v_calc} := \max(1.4 \cdot W_{tot}, 1.2 \cdot W_{tot} + 1.0 \cdot F_v \cdot \Omega_o) = 583.7\ lbf$ — Calculated vertical piping load combination per ASCE 7-10, Section 2.3.2 load including overstrength factor.

$F_{v_B31.3} := 479 \cdot lbf$ — Vertical piping load combination per RPP-CALC-63779, Appendix H including overstrength factor.

$F_{v_comb} := \max(F_{v_calc}, F_{v_B31.3}) = 583.7\ lbf$ — Governing vertical piping load combination.

$h_s := h - \frac{D_{pipe}}{2} = 2.0\ ft$ — Base stand height.

$M_{ot_calc} := F_{h_calc} \cdot h_s = 390.4 \cdot ft \cdot lbf$ — Calculated overturning moment.

$M_{ot_B31.3} := 1899 \cdot ft \cdot lbf$ — Overturning moment combination per RPP-CALC-63779, Appendix H.

$$M_{ot} := \max\left(M_{ot_calc}, M_{ot_B31.3}\right) = 1899.0 \cdot ft \cdot lbf$$

$$T_{stud} := \frac{M_{ot}}{2 \cdot \left[\left(\frac{L_{plate}}{2} + \frac{D_{stand}}{2}\right) - A_{stand}\right]} = 2566.2\ lbf$$

Tension load per stud, 2 studs in tension, (moment arm is taken to face of seismic base stand, Pt. 'O', from tension side bolts, conservative).

$$V_{stud} := \frac{F_{h_comb}}{4} = 526.8\ lbf$$

Shear load per stud, 4 studs in shear.

8.4 Check Anchors in Accordance with ACI 318-14, Chapter 17

Define Constants

Use (4) 1/2" diameter fractional threaded rods with 3 1/2" minimum embedment depth

$n_a := 4$	The number of anchors per post.
$s_a := L_{plate} - A_{stand} \cdot 2 = 6.0 \cdot in$	The spacing of the anchors.
$h_{ef} := 2.75in$	The effective minimum embedment. (ESR-3187, Table 12 & 14)
$n_{a_t} := 2$	Number of anchors resisting tension. (Moment Couple)
$n_{a_v} := n_a = 4.0$	Number of anchors resisting shear.
$f'_c := 4500psi$	Compressive strength of concrete. (See Inputs)
$k_c := 17$	Effectiveness factor for cracked concrete. (ESR-3187, Table 12)
$\psi_{c_N} := 1.0$	Cracked concrete factor for post-installed anchor in cracked concrete. (ACI 318-14, Section 17.4.2.6)
$\phi_{t_s} := 0.65$	Strength reduction factor for steel failure in tension. (ESR-3187, Table 11, for ASTM F593 CW stainless steel material).
$\phi_{t_c} := 0.65$	Strength reduction factor for concrete breakout failure in tension. (ESR-3187, Table 12)
$\phi_{v_s} := 0.60$	Strength reduction factor for steel failure in shear. (ESR-3187, Table 11, for ASTM F593 CW stainless steel material).
$\phi_{v_c} := 0.70$	Strength reduction factor for concrete breakout failure in shear. (ESR-3187, Table 12)
$\phi_e := 0.75$	Tensile strength reduction factor for anchors in moderate or high seismic risk zones. (ACI 318-14 Section 17.2.3.4.4)
$\alpha_{v_seis} := 0.70$	Seismic shear reduction factor, (ESR-3187, Table 11).
$\phi_d := 0.75$	Bond strength reduction factor, (ESR-3187, Table 14).
$c_{ac} := 2 \cdot h_{ef} = 5.5 \cdot in$	Critical edge distance factor for adhesive anchors. (ACI 318-14, Section 17.7.6)
$c_{a1} := 6in$	Set minimum distance from the center of an anchor shaft to the edge of concrete in the direction of the applied shear. (See ACI 318-14, Section 17.5.2.1 for illustration)
$c_{a2} := 6in$	Set minimum distance from the center of an anchor shaft to the edge of concrete in the direction perpendicular to the applied shear (and c_{a1}). (See ACI 318-14, Section 17.5.2.1 for illustration)
$c_{a_min} := \min(c_{a1}, c_{a2}) = 6.0 \cdot in$	The minimum edge distance between the edge of the concrete and the nearest anchor.
$h_{min} := h_{ef} + 1.25 \cdot in = 4.0 \cdot in$	The minimum member thickness. (ESR-3187, Table 12)
$h_a := 8in$	Actual concrete thickness. (H-2-79571)
$d := 0.5in$	Anchor rod diameter.

Determine Steel Strength of Anchors in Tension

$c_{Na} := 5.0 \cdot in$ See bond strength of anchors in tension.

$$Individual_Group := \begin{cases} \text{"Analyze anchors individually according to ACI 318, Section 17.2.1.1"} & \text{if } 3 \cdot h_{ef} \le s_a \vee 2 \cdot c_{Na} \le s_a \\ \text{"Analyze anchors as a group according to ACI 318, Section 17.2.1.1"} & \text{otherwise} \end{cases}$$

$Individual_Group = \text{"Analyze anchors as a group according to ACI 318, Section 17.2.1.1"}$

$N_{sa} := 14190 lbf$ The nominal tensile strength of the threaded anchor rods is based on ASTM F593 CW, stainless steel material per ESR-3187, Table 11).

$\phi N_{sa} := \phi_{t_s} \cdot N_{sa} = 9223.5\ lbf$ Tensile steel strength incorporating strength reduction factors.

Determine Concrete Breakout Strength of Anchors in Tension

$$\psi_{ed_N} := \begin{cases} 1 & \text{if } c_{a_min} \ge 1.5 \cdot h_{ef} \\ 0.7 + 0.3 \cdot \dfrac{c_{a_min}}{1.5 \cdot h_{ef}} & \text{otherwise} \end{cases} = 1.0$$

The modification factor for edge effects. (ACI 318-14, Section 17.4.2.5)

$$\psi_{cp_N} := \begin{cases} 1 & \text{if } c_{a_min} \ge c_{ac} \\ \dfrac{\max(c_{a_min}, 1.5 \cdot h_{ef})}{c_{ac}} & \text{otherwise} \end{cases} = 1.0$$

Uncracked concrete pullout factor for post-installed anchors. (ACI 318-14, Section 17.4.2.7)

$\lambda := 1.0$ Modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$N_b := k_c \cdot \lambda \cdot \sqrt{\dfrac{f'_c}{psi}} \cdot \left(\dfrac{h_{ef}}{in}\right)^{1.5} lbf = 5200.6\ lbf$ Basic concrete breakout strength of a single anchor in tension in cracked concrete. (ACI 318-14, Equation 17.4.2.2a)

$A_{Nco} := 9 \cdot h_{ef}^2 = 68.1 \cdot in^2$ Projected concrete failure area of a single anchor with an edge distance equal to or greater than 1.5 x h_{ef}. (ACI 318-14, Equation 17.4.2.1c)

$A_{Nc} := (\min(1.5h_{ef}, c_{a1}) + s_a + 1.5 \cdot h_{ef}) \cdot (\min(1.5h_{ef}, c_{a2}) + s_a + 1.5 \cdot h_{ef}) = 203.1 \cdot in^2$

$A_{Nc} := \min(n_a \cdot A_{Nco}, A_{Nc}) = 203.1 \cdot in^2$

Projected concrete failure area of the anchorage. (ACI 318-14, Section 17.4.2.1 and Figure R17.4.2.1(b))

$N_{cb} := \dfrac{A_{Nc}}{A_{Nco}} \cdot \psi_{ed_N} \cdot \psi_{c_N} \cdot \psi_{cp_N} \cdot N_b = 15515.9 \cdot lbf$ Concrete breakout strength of the anchorage in tension. (ACI 318-14, Equation 17.4.2.1a)

$\phi N_{cb} := \phi_e \cdot \phi_{t_c} \cdot N_{cb} = 7564.0\ lbf$ Tensile breakout strength incorporating strength reduction factors.

Determine Bond Strength of Anchors in Tension

$\lambda_a := \lambda = 1.0$ — ACI 318-14, Section 17.2.6 and modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$\tau_{cr} := 1170 \cdot psi$ — Characteristic bond stress in cracked concrete, temperature range A, (ESR-3187, Table 14).

$\tau_{uncr} := 2220 \cdot psi$ — Characteristic bond stress in uncracked concrete, temperature range A, (ESR-3187, Table 14).

$d_a := d = 0.5 \cdot in$ — Anchor diameter, previously defined.

$N_{ba} := \lambda_a \cdot \tau_{cr} \cdot \pi \cdot d_a \cdot h_{ef} = 5054.0\ lbf$ — Basic bond strength of adhesive anchor, (ACI 318-14, Section 17.4.5.2)

$c_{Na} := 10 \cdot d_a \cdot \sqrt{\frac{\tau_{uncr}}{1100 \cdot psi}} = 7.1 \cdot in$ — Critical edge distance, (ACI 318-14, Equation 17.4.5.1d).

$A_{Nao} := (2 \cdot c_{Na})^2 = 201.8 \cdot in^2$ — Projected influence area for a single anchor, (ACI 318-14, Equation 17.4.5.1c).

$A_{Na} := (c_{Na} + s_a + c_{a_min}) \cdot (c_{Na} + s_a + c_{a_min}) = 364.9 \cdot in^2$ — Projected influence area for a group of anchors, (ACI 318-14, Fgure R17.4.5.1).

$A_{Na} := n_{a_t} \cdot A_{Nao} = 403.6 \cdot in^2$ — Limiting value of A.Na per ACI 318-14, Section 17.4.5.1).

$\Psi_{ed_Na} := 1.0$ $\quad c_{a_min} = 6.0 \cdot in > c_{Na} = 7.1 \cdot in$ — Modification factor for edge effects, ACI 318-14, Equation 17.4.5.4a).

$\Psi_{cp_Na} := 1.0$ $\quad c_{a_min} = 6.0 \cdot in > c_{ac} = 5.5 \cdot in$ — Modification factor for adhesive anchors designed for uncracked concrete, ACI 318-14, Equation 17.4.5.5a).

$N_a := \frac{A_{Na}}{A_{Nao}} \cdot \Psi_{ed_Na} \cdot \Psi_{cp_Na} \cdot N_{ba} = 10108.1\ lbf$ — Nominal bond strength in tension for a single adhesive anchor in tension, (ACI 318-14, Equation 17.4.5.1a).

$\phi N_a := \phi_e \cdot \phi_d \cdot \left(\frac{A_{Na}}{A_{Nao}} \cdot \Psi_{ed_Na} \cdot \Psi_{cp_Na} \cdot N_{ba} \right) = 5685.8\ lbf$ — Nominal bond strength in tension for a single adhesive anchor in tension incorporating strength reduction factors, (ACI 318-14, Equation 17.4.5.1a).

Determine Steel Strength of the Anchors in Shear

Individual_Group := "Analyze anchors individually in shear according to ACI 318, Section 17.2.1.1" if $3 \cdot h_{ef} \le s_a$
"Analyze anchors as a group in shear according to ACI 318, Section 17.2.1.1" otherwise

Individual_Group = "Analyze anchors as a group in shear according to ACI 318, Section 17.2.1.1"

$V_{sa} := 8515 \cdot lbf$ — The nominal shear strength of the threaded anchor rods is based on ASTM F593 CW, stainless steel material per ESR-3187, Table 11)

$\phi V_{sa} := \alpha_{v_seis} \cdot \phi_{v_s} \cdot V_{sa} = 3576.3\ lbf$ — Steel shear strength incorporating strength reduction factors.

Determine Concrete Breakout Strength of the Anchors in Shear

$\psi_{ed_V} := \begin{cases} 1.0 & \text{if } c_{a2} \geq 1.5 \cdot c_{a1} \\ 0.7 + 0.3 \cdot \dfrac{c_{a2}}{1.5 \cdot c_{a1}} & \text{otherwise} \end{cases} = 0.9$

Edge distance factor (Anchors not on a corner). (ACI 318-14, Section 17.5.2.6)

$\psi_{c_V} := 1.0$

Cracked concrete factor. (ACI 318-14, Section 17.5.2.7)

$\psi_{h_V} := \begin{cases} \sqrt{\dfrac{1.5 \cdot c_{a1}}{h_a}} & \text{if } h_a < 1.5 \cdot c_{a1} \\ 1 & \text{otherwise} \end{cases} = 1.06$

Thickness modification factor. (ACI 318-14, Section 17.5.2.8)

$d_a := d = 0.5 \cdot in$

The outside diameter of the anchor.

$l_e := \min(8 \cdot d_a, h_{ef}) = 2.8 \cdot in$

The load bearing length of anchor for shear. (ACI 318-14, Section 17.5.2.2)

$V_b := \min\left[7 \cdot \left(\frac{l_e}{d_a}\right)^{0.2} \cdot \sqrt{\frac{d_a}{in}} \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot \left(\frac{c_{a1}}{in}\right)^{1.5} \cdot lbf, 9 \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot \left(\frac{c_{a1}}{in}\right)^{1.5} \cdot lbf\right] = 6862.6 \cdot lbf$

Basic concrete breakout strength of a single anchor in shear in cracked concrete. (ACI 318-14, Section 17.5.2.2)

$A_{Vco} := 4.5 \cdot c_{a1}^2 = 162.0 \cdot in^2$

The projected area for a single anchor in a deep member with a distance from edges equal or greater than 1.5 x c_{a1}. (ACI 318-14, Equation 17.5.2.1c)

$A_{Vc} := (\min(c_{a2}, 1.5 \cdot c_{a1}) + 1.5 c_{a1}) \cdot \min(1.5 \cdot c_{a1}, h_a) = 120.0 \cdot in^2$

Projected concrete failure area of the anchorage. (ACI 318-14, Section 17.5.2.1 and Figure R17.5.2.1b)

$V_{cb} := \frac{A_{Vc}}{A_{Vco}} \cdot \psi_{ed_V} \cdot \psi_{c_V} \cdot \psi_{h_V} \cdot V_b = 4852.6 \cdot lbf$

Nominal concrete breakout strength of anchorage in shear. (ACI 318-14, Equation 17.5.2.1a)

$\phi V_{cb} := \phi_{v_c} \cdot V_{cb} = 3396.8\ lbf$

Shear breakout strength incorporating strength reduction factors.

Determine Pryout Strength of the Anchors in Shear

$k_{cp} := \begin{cases} 1 & \text{if } h_{ef} < 2.5in \\ 2 & \text{otherwise} \end{cases} = 2.0$

Coefficient for pryout strength. (ACI 318-14, Section 17.5.3.1)

$V_{cp} := k_{cp} \cdot \min(N_{cb}, N_a) = 20216.1\ lbf$

The nominal pryout strength of the anchorage in shear per ACI 318-14, Equation 17.5.3.1a.

$\phi V_{cp} := \phi_{v_c} \cdot V_{cp} = 14151.3\ lbf$

Shear pryout strength incorporating strength reduction factors.

Determine Governing Failure Strength

$$Govern_v := \begin{cases} \text{"Steel failure governs (Ductile Failure)."} & \text{if } \phi V_{sa} \le \min(\phi V_{cb}, \phi V_{cp}) \\ \text{"Concrete breakout governs (Brittle Failure)."} & \text{if } \phi V_{cb} < \min(\phi V_{sa}, \phi V_{cp}) \\ \text{"Concrete pryout governs (Brittle Failure)."} & \text{otherwise} \end{cases}$$

$Govern_v$ = "Concrete breakout governs (Brittle Failure)."

$$Shear_{govern} := \begin{cases} \phi V_{sa} & \text{if } \phi V_{sa} \le \min(\phi V_{cb}, \phi V_{cp}) \\ \phi V_{cb} & \text{if } \phi V_{cb} < \min(\phi V_{sa}, \phi V_{cp}) \\ \phi V_{cp} & \text{otherwise} \end{cases}$$

The governing allowable shear capacity of the anchorage.

$Shear_{govern} = 3397\,lbf$

$$Shear_Check := \begin{cases} \text{"Anchor capacity in shear is OK."} & \text{if } Shear_{govern} > V_{stud} \\ \text{"Anchor capacity in shear is NOT OK"} & \text{otherwise} \end{cases}$$

$V_{stud} = 526.8\,lbf$

Shear_Check = "Anchor capacity in shear is OK."

Check to determine the adequacy of the anchors in shear.

$$Govern_t := \begin{cases} \text{"Steel failure governs (Ductile Failure)."} & \text{if } \phi N_{sa} \le \min(\phi N_{cb}, \phi N_a) \\ \text{"Concrete breakout governs (Brittle Failure)."} & \text{if } \phi N_{cb} \le \min(\phi N_{sa}, \phi N_a) \\ \text{"Bond strength governs (Brittle Failure)."} & \text{otherwise} \end{cases}$$

$Govern_t$ = "Bond strength governs (Brittle Failure)."

$$Tensile_{govern} := \begin{cases} \phi N_{sa} & \text{if } \phi N_{sa} \le \min(\phi N_{cb}, \phi N_a) \\ \phi N_{cb} & \text{if } \phi N_{cb} \le \min(\phi N_{sa}, \phi N_a) \\ \phi N_a & \text{otherwise} \end{cases}$$

The governing allowable tensile capacity of the anchorage.

$Tensile_{govern} = 5686\,lbf$

$$Tension_Check := \begin{cases} \text{"Anchor capacity in tension is OK."} & \text{if } Tensile_{govern} > T_{stud} \\ \text{"Anchor capacity in tension is NOT OK"} & \text{otherwise} \end{cases}$$

$T_{stud} = 2566\,lbf$

Tension_Check = "Anchor capacity in tension is OK."

Check to determine the adequacy of the anchors in tension.

$$DCR_{tens} := \frac{T_{stud}}{Tensile_{govern}} = 0.45$$

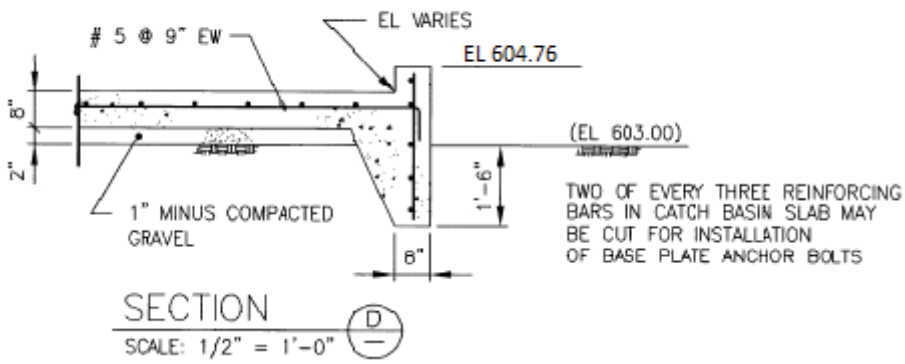
$$DCR_{shear} := \frac{V_{stud}}{Shear_{govern}} = 0.16$$

$$DCR := \begin{cases} DCR_{tens} & \text{if } DCR_{shear} \le 0.2 \\ DCR_{shear} & \text{if } DCR_{tens} \le 0.2 \\ \frac{1}{1.2}\cdot\left(DCR_{tens} + DCR_{shear}\right) & \text{otherwise} \end{cases} = 0.45$$

The DCR ratio is less than 1.0; therefore, **OK** ACI 318-14, Section 17.6.

8.5 Check Temperature and Shrinkage Reinforcement Minimum Requirements for Catch Basin Slab

(REFERENCE: H-2-838751, Rev. B, Sheet 5, Zone D2-D3)



(REFERENCE: ACI 318-14)

Table 24.4.3.2—Minimum ratios of deformed shrinkage and temperature reinforcement area to gross concrete area

Reinforcement type	f_y, psi	Minimum reinforcement ratio	
Deformed bars	< 60,000	0.0020	
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of:	$\frac{0.0018 \times 60,000}{f_y}$
			0.0014

$h_c := 8in$ — Thickness of the CB slab.

$b := 12in$ — Width of slab for rebar design.

$(A_{reqd}) := 0.0018\cdot b\cdot h_c = 0.17\cdot in^2$ — Area of steel required by temperature and shrinkage, (ACI 318-14, Table 24.4.3.2).

$A_{provided} := 0.41\cdot in^2 \quad > \quad (A_{reqd}) = 0.17\cdot in^2$ — Area of steel (#5 @ 9") for 1 ft wide section.

The design is adequate with #5 bars @ 9" EW.

8.6 Check Spacing of Shrinkage and Temperature Reinforcement

Ref: ACI 318-14

24.4.3.3 The spacing of deformed shrinkage and temperature reinforcement shall not exceed the lesser of **5*h*** and 18 in.

$5 \cdot h_c = 40.0 \cdot in$

$Spg_{bars} := 9 \cdot in$ < $18 \cdot in$ OK

8.7 Check Minimum Flexural Reinforcement (based on ACI 318-14, Section 7.6 for one-way slabs)

$h_c := 8in$ Thickness of the CB slab.

$b := 12in$ Width of the slab for rebar design.

$(A_{reqd}) := 0.0018 \cdot b \cdot h_c = 0.17 \cdot in^2$ Area of steel required for flexure. (ACI 318-14, Table 7.6.1.1)

$A_{provided} := 0.41 \cdot in^2$ > $(A_{reqd}) = 0.17 \cdot in^2$ Area of steel #5 @ 9" for 1 ft wide section.

The design is adequate for minimum flexural reinforcement with #5 bars @ 9" EW

Ref: ACI 318-14

Table 7.6.1.1—$A_{s,min}$ for nonprestressed one-way slabs

Reinforcement type	f_y, psi	$A_{s,min}$	
Deformed bars	< 60,000	$0.0020A_g$	
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of:	$\frac{0.0018 \times 60,000}{f_y} A_g$
			$0.0014A_g$

8.8 Check One-Way Shear Reinforcement

$d := 8 \cdot in - 3 \cdot in - 0.625 \cdot in - \frac{0.625 \cdot in}{2} = 4.1 \cdot in$ — Distance from extreme compression fiber to centroid of longitudinal tension reinf.

$\phi_{shear} := 0.75$ — Capacity reduction factor for shear, (ACI 318-14, Table 21.2.1)

$\lambda = 1.0$ — Modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$V_c := 2\lambda \cdot psi \cdot \sqrt{\frac{f'_c}{psi}} \cdot b \cdot d = 7 \cdot kip$ — Shear strength of the evaluated concrete CB slab section. (ACI 318-14, Section 22.5.5.1)

$f_y := 60ksi$ — Reinforcement yield strength.

$no_{bar} := 5$ — Rebar number. (H-2-838751, Sheet 5)

$d_b := \left(\frac{no_{bar}}{8}\right) \cdot in = 0.625 \cdot in$ — Rebar diameter based on rebar number.

$A_v := \frac{\pi \cdot (d_b)^2}{4}$ — Rebar Shear Area.

$spacing := 9in$ — Rebar Spacing. (H-2-838751, Sheet 5)

$V_s := \frac{f_y \cdot A_v \cdot d}{spacing} = 8309.1\ lbf$ — Steel Shear strength contribution adjusted for spacing. (ACI-318, Eqn. (22.5.10.5.3))

$V_n := V_c + V_s = 14849.6\ lbf$ — Nominal one-way shear strength. (ACI 318, Eqn. (22.5.1.1)

$\phi V_n := \phi_{shear} \cdot (V_c + V_s) = 11137.2\ lbf$ — Factored one-way shear strength.

$V_u := F_{v_comb} + \frac{M_{ot}}{\left(\frac{L_{plate}}{2}\right)} = 5945.6\ lbf$ — Shear demand.

$DCR := \frac{V_u}{\phi V_n} = 0.5$ — The DCR ratio is less than 1.0; therefore, **OK**.

8.9 Check Two-Way Punching Shear

$b_o := \left[L_{plate} + \left(\frac{d}{2}\right) \cdot 2\right] \cdot 4 = 50.3 \cdot in$ — Critical perimeter section "b_o" for two-way shear, ACI 318-14, Section 22.6.4.1 (a)

$\beta := 1.0$ — Ratio of long side to short side, square base plate.

$\alpha_s := 20$ — From Section 22.6.5.3 of ACI 318-14, define value for corner columns, conservative.

$\lambda := 1.0$ — Modification factor for normal weight concrete. (ACI 318-14, Section 19.2.4.2)

$v_{cA} := 4 \cdot \lambda \cdot \left(psi \cdot \sqrt{\frac{f'_c}{psi}} \right) = 268.3\ psi$ — Allowable shear loading, Table 22.6.5.2 from ACI 318-14.

$v_{cB} := \left(2 + \frac{4}{\beta} \right) \cdot \lambda \cdot \left(psi \cdot \sqrt{\frac{f'_c}{psi}} \right) = 402.5\ psi$ — Allowable shear loading, Table 22.6.5.2 from ACI 318-14.

$v_{cC} := \left(2 + \frac{\alpha_s \cdot d}{b_o} \right) \cdot \lambda \cdot \left(psi \cdot \sqrt{\frac{f'_c}{psi}} \right) = 242.6\ psi$ — Allowable shear loading, Table 22.6.5.2 from ACI 318-14.

$v_c := \min(v_{cA}, v_{cB}, v_{cC}) = 243\ psi$ — Nominal shear strength.

$V_{applied_punch_CB} := \frac{F_{v_comb}}{b_o \cdot d} + \frac{M_{ot}}{b_o \cdot d \cdot \frac{L_{plate}}{2}}$ — Applied punching shear load, including LRFD load factors per ACI 318-14, Table 5.3.1. Moment is applied as shear load acting at center of base plate.

where $L_{plate} = 8.5 \cdot in$

$V_{applied_punch_CB} = 29.1\ psi$

$DCR_{shear_punch_CB} := \frac{V_{applied_punch_CB}}{\phi_{shear} \cdot v_c} = 0.16$ — DCR is less than 1.0; therefore, **OK**.

8.10 Check CB Soil Bearing Pressure

The following section will determine if the concrete CB slab is adequately sized to distribute the load to the soil at an adequate pressure. Live load on CB slab ignored due to high concentration of piping systems distributed over CB floor.

$l_{cs} := L_{plate} + h_c \cdot 2 = 2.0\ ft$ — Length of CB slab section considered (based on 45 deg. distribution of loads at edges of pipe support base plate).

$w_{cs} := l_{cs}$ — Width of CB slab section considered.

$h_c = 8.0 \cdot in$ — Average thickness of the CB slab.

$\rho_c := 150 pcf$ — Typical density of concrete.

$W_{cs} := \rho_c \cdot w_{cs} \cdot l_{cs} \cdot h_c = 416.8 \cdot lbf$ — Weight of the CB slab area considered.

$M_1 := 0.6 F_w \cdot h = 255.9 \cdot ft \cdot lbf$ — In-plane moment on the slab area. (ASCE 7-10, Section 2.4.1 Equation 5)

where $h = 2.2 \cdot ft$

$M_2 := 0.7 \cdot F_p \cdot h = 106.8 \cdot lbf \cdot ft$ — In-plane moment on the slab area. (ASCE 7-10, Section 2.4.1 Equation 5)

$M_b := \max(M_1, M_2) = 255.9 \cdot ft \cdot lbf$ — Maximum in-plane moment on the slab area.

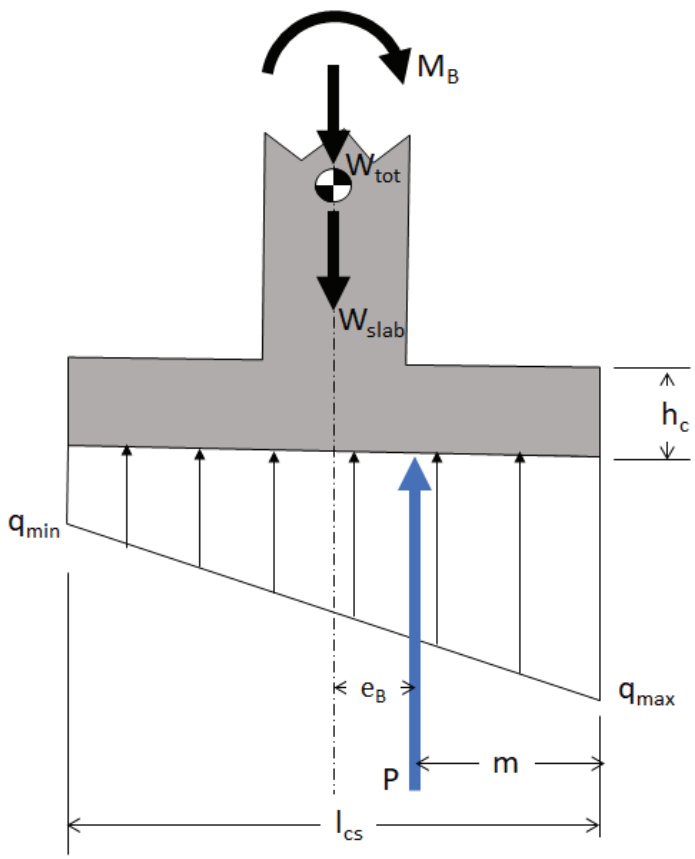
$Q := W_{tot} + 0.7 \cdot F_v + W_{cs} = 839.7\ lbf$ — The total unfactored vertical load bearing on the soil.

where $W_{tot} = 390.7\ lbf$

$$e_b := \frac{M_b}{Q} = 3.7 \cdot in$$

The resulting eccentricity, which is the moment divided by total bearing load. (Das, pg. 147, Equation 3.51)

$$m := \frac{l_{cs}}{2} - e_b = 0.7\,ft$$



$$q_{min} := \max\left(\frac{Q}{w_{cs} \cdot l_{cs}} - \frac{6 \cdot M_b}{l_{cs}^2 w_{cs}}, 0psf\right) = 21.0 \cdot psf$$

Minimum Soil Pressure under slab area. (Principles of Foundation Engineering, Das, Eq 3.53, pg 147)

$$q_{max} := \frac{Q}{w_{cs} \cdot l_{cs}} + \frac{6 \cdot M_b}{l_{cs}^2 w_{cs}} = 381.9 \cdot psf$$

Maximum Soil Pressure under slab area. (Principles of Foundation Engineering, Das, Eq 3.52, pg 147)

$$p_{allow_sb} := 2000psf$$

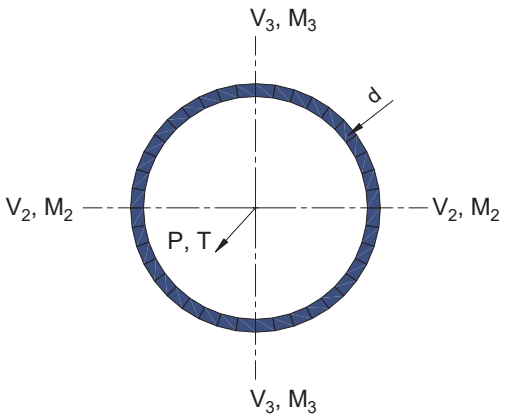
The allowable bearing pressure of the soil. (IBC 2015, Table 1806.2, material class 3)

$$DCR_{sb} := \frac{q_{max}}{p_{allow_sb}} = 0.19$$

The demand capacity ratio for the soil bearing pressure. The CB slab area has a DCR lower than 1.0, therefore **OK**.

8.11 Check Post Base Weld

NOTE: Use B3088S-2 1/2 Dimensions.



Weld Geometry:

$d := 2.88 \cdot in$ Diameter of weld.

$w_{act} := \frac{1}{4} \cdot in$ Weld size.

$F_{EXX} := 70ksi$ Ultimate stress of the weld metal.

Inputs from AISC 2010, Table J2.5:

$\Omega := 2.0$ The safety factor for welds.

$R_n := 0.6 \cdot F_{EXX}$ $R_n = 42.0 \cdot ksi$ Weld design strength.

$F_{h_comb} = 2107.0\ lbf$ Maximum horizontal load, previously defined.

$F_{v_comb} = 583.7\ lbf$ Mximum vertical load, previously defined.

$M_{ot} = 1899.0 \cdot ft \cdot lbf$ Maximum moment, previously defined.

Connection forces and moments:

$P := F_{v_comb}$ $V_2 := F_{h_comb} = 2107.0\ lbf$ $V_3 := 0 \cdot lbf$

$T := 0 \cdot in \cdot lbf$ $M_2 := M_{ot} = 1899.0 \cdot ft \cdot lbf$ $M_3 := 0 \cdot ft \cdot lbf$

Weld Properties Per Blodgett 1991, Table 5, Page 7.4-7.

$C := \frac{d}{2}$ $C = 1.4 \cdot in$ The distance to the outer fiber.

$A_w := \pi \cdot d$ $A_w = 9.0 \cdot in$ The linear area of the weld.

$A_{w_s} := \frac{1}{2} \cdot \pi \cdot d$ $A_{w_s} = 4.5 \cdot in$ The linear shear area of the weld (AISC 2010, Section G6-1).

$S_w := \frac{\pi \cdot d^2}{4}$ $S_w = 6.5 \cdot in^2$ The linear section modulus.

$J_w := \frac{\pi \cdot d^3}{4}$ $J_w = 18.8 \cdot in^3$ The linear polar moment of inertia.

The resultant vectors for the bending moments and shears in the directions of 2-2 and 3-3 axes are:

$M := \sqrt{M_2^2 + M_3^2}$ $M = 22788.0 \cdot in \cdot lbf$ $V := \sqrt{V_2^2 + V_3^2}$ $V = 2107.0 \cdot lbf$

$A_{lin} := \sqrt{\left(\frac{P}{A_w} + \frac{M}{S_w}\right)^2 + \left(\frac{V}{A_{w_s}} + \frac{T \cdot C}{J_w}\right)^2}$ $A_{lin} = 3592.918 \cdot \frac{lbf}{in}$ Linear weld stress.

$R_u := \frac{A_{lin}}{0.707 w_{act}}$ $R_u = 20.3 \cdot ksi$ Actual stress in the weld.

$DCR := \frac{\Omega \cdot R_u}{R_n} = 0.97$ The demand/capacity ratio is < 1; therefore, OK.

8.12 Determine Loads on CB Wall Weight Anchor Eye Bolts

$ID_{8_pipe} := 7.921 \cdot in$ $Wt_{8_pipe} := 3.80 \cdot plf$ Weight and dimensions of 8" HDPE pipe based on SDR 26 (80 psi) pressure rating, (See Attachment 3).

$Wt_{filled} := \frac{\pi \cdot ID_{8_pipe}^2}{4} \cdot 150 \cdot \frac{lbf}{ft^3} + Wt_{8_pipe} = 55.1 \cdot plf$ Weight of 8" grout filled pipe per foot length.

$Invert_{top} := 603.17 \cdot ft$ Invert elevation of 8" HPDE pipe at top of liner. (See H-2-838750 SH 2, Section D & H-838767 SH 7, Section Q-Q)

$Invert_{bot} := 576.60 \cdot ft$ Invert elevation of 8" HPDE pipe at bottom of liner, (See H-2-838750, SH 1, Plan).

$L_{riser} := \sqrt{\left[\left(Invert_{top} - Invert_{bot}\right) \cdot 3\right]^2 + \left[\left(Invert_{top} - Invert_{bot}\right)^2\right]} = 84.0\ ft$ Based on 3:1 slope of top liner. (See H-2-838750, SH 1, Plan)

$Wt_{tot_8} := L_{riser} \cdot Wt_{filled} = 4632.2\ lbf$ Total weight of 8" HDPE grout filled pipe.

$angle := \tanh\left(\frac{1}{3}\right) = 18.4 \cdot deg$ Slope angle with respect to horizontal plane.

$F_{h_8pipe} := Wt_{tot_8} \cdot \sin(angle) = 1463.8\ lbf$ Down drag component along length of the 8" HDPE grout filled pipes. Neglect friction between pipes and liner bed, conservative.

8.13 Check Weight Anchor Eye Bolts in Accordance with ACI 318-14, Chapter 17

$T_{eye_bolt} := F_{h_8pipe} \cdot \cos(angle) = 1388.8\ lbf$ — Tension load on weight anchor eye bolt.

$V_{eye_bolt} := F_{h_8pipe} \cdot \sin(angle) = 462.6\ lbf$ — Shear load on weight anchor eye bolt.

Define Constants

Based on 5/8" diameter ASTM F593 stainless steel threaded rods with 3 7/8" maximum embedment depth

$n_a := 1$ — The number of eye bolts per HPDE grouted pipe.

$s_a := 26 \cdot in$ — Minimum spacing of the eye bolts. (See H-2-838767 SH 7, Section P-P)

$h_{ef} := 3.125\,in$ — The effective minimum embedment. (ESR-3187, Table 12 & 14)

$n_{a_t} := 1$ — Number of eye bolts resisting tension.

$n_{a_v} := 1$ — Number of eye bolts resisting shear.

$f'_c := 4500psi$ — Compressive strength of concrete. (See Inputs)

$k_c := 17$ — Effectiveness factor for cracked concrete. (ESR-3187, Table 12)

$\psi_{c_N} := 1.0$ — Cracked concrete factor for post-installed anchor in cracked concrete. (ACI 318-14, Section 17.4.2.6)

$\phi_{t_s} := 0.65$ — Strength reduction factor for steel failure in tension. (ESR-3187, Table 11)

$\phi_{t_c} := 0.65$ — Strength reduction factor for concrete breakout failure in tension. (ESR-3187, Table 12)

$\phi_{v_s} := 0.60$ — Strength reduction factor for steel failure in shear. (ESR-3187, Table 11).

$\phi_{v_c} := 0.70$ — Strength reduction factor for concrete breakout failure in shear. (ESR-3187, Table 12)

$\phi_e := 0.75$ — Tensile strength reduction factor for anchors in moderate or high seismic risk zones. (ACI 318-14 Section 17.2.3.4.4)

$\alpha_{v_seis} := 0.70$ — Seismic shear reduction factor, (ESR-3187, Table 11).

$\phi_d := 0.65$ — Bond strength reduction factor, (ESR-3187, Table 14 for dry & water saturated concrete installation conditions).

$c_{ac} := 2 \cdot h_{ef} = 6.3 \cdot in$ — Critical edge distance for adhesive anchors. (ACI 318-14, Section 17.7.6)

$c_{a1} := c_{ac} = 6.3 \cdot in$ — Limiting distance from center of anchor to edge of concrete in the direction of applied load. (See ACI 318-14, Figures R17.4.2.1 and R17.5.2.1 for illustration)

$c_{a2} := c_{a1} = 6.3 \cdot in$ — Limiting distance from center of anchor to edge of concrete in the direction perpendicular to applied load. (See ACI 318-14, Figures R17.4.2.1 and R17.5.2.1 for illustration)

$c_{a_min} := \min(c_{a1}, c_{a2}) = 6.3 \cdot in$ — The minimum edge distance between the edge of the concrete and the nearest anchor. (Note: Envelopes actual edges distance)

$h_{min} := h_{ef} + 1.25 \cdot in = 4.4 \cdot in$ — The minimum member thickness. (ESR-3187, Table 12)

$h_a := 24in$ — Actual concrete thickness. (H-2-838751 SH 2)

$d := 0.625in$ — The anchor diameter. (ESR-3187, Table 11)

Determine Steel Strength of Anchor in Tension

$$Individual_Group := \begin{cases} \text{"Analyze anchors individually according to ACI 318-14, Chapter 17"} & \text{if } 3 \cdot h_{ef} \le s_a \\ \text{"Analyze anchors as a group according to ACI 318-14, Section 17.2.1.1"} & \text{otherwise} \end{cases}$$

Individual_Group = "Analyze anchors individually according to ACI 318-14, Chapter 17"

$N_{sa} := 22600lbf$ — The tensile capacity of the anchor is based on ICC-ES Evaluation Report ESR-3187, Table 11, for ASTM F593, stainless steel threaded eye anchor rods.

$\phi N_{sa} := \phi_{t_s} \cdot N_{sa} = 14690.0\ lbf$ — Tensile steel strength incorporating strength reduction factors.

Determine Concrete Breakout Strength of Anchorage in Tension

$$\psi_{ed_N} := \begin{cases} 1 & \text{if } c_{a_min} \ge 1.5 \cdot h_{ef} \\ 0.7 + 0.3 \cdot \dfrac{c_{a_min}}{1.5 \cdot h_{ef}} & \text{otherwise} \end{cases} = 1.0$$

The modification factor for edge effects. (ACI 318-14, Section 17.4.2.5)

$$\psi_{cp_N} := \begin{cases} 1 & \text{if } c_{a_min} \ge c_{ac} \\ \dfrac{\max(c_{a_min}, 1.5 \cdot h_{ef})}{c_{ac}} & \text{otherwise} \end{cases} = 1.0$$

Uncracked concrete pullout factor for post-installed anchors. (ACI 318-14, Section 17.4.2.7)

$\lambda := 1.0$ — Modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$N_b := k_c \cdot \lambda \cdot \sqrt{\dfrac{f'_c}{psi}} \cdot \left(\dfrac{h_{ef}}{in}\right)^{1.5} lbf = 6299.9\ lbf$ — Basic concrete breakout strength of a single anchor in tension in cracked concrete. (ACI 318-14, Equation 17.4.2.2a)

$A_{Nco} := 9 \cdot h_{ef}^2 = 87.9 \cdot in^2$ — Projected concrete failure area of a single anchor with an edge distance equal to or greater than 1.5 x h_{ef}. (ACI 318-14, Equation 17.4.2.1c)

$A_{Nc} := (\min(1.5 \cdot h_{ef}, c_{a1}) + s_a + 1.5 \cdot h_{ef}) \cdot (\min(1.5 \cdot h_{ef}, c_{a2}) + 1.5 \cdot h_{ef}) = 331.6 \cdot in^2$

$A_{Nc} := \min(n_a \cdot A_{Nco}, A_{Nc}) = 87.9 \cdot in^2$

Projected concrete failure area of the anchorage group. (ACI 318-14, Section 17.4.2.1 and Figure R17.4.2.1(b))

$e'_N := 0 \cdot in$ — No eccentricity of the anchors in tension. (See ACI 318-14, Fig R17.4.2.4 for illustration)

$\psi_{ec_N} := \dfrac{1}{\left(1 + \dfrac{2 \cdot e'_N}{3 \cdot h_{ef}}\right)} = 1.0$

Modification factor for anchor groups loaded eccentrically in tension. (ACI 318-14, Section 17.4.2.4, Equation 17.4.2.4)

$N_{cbg} := \dfrac{A_{Nc}}{A_{Nco}} \cdot \psi_{ec_N} \cdot \psi_{ed_N} \cdot \psi_{c_N} \cdot \psi_{cp_N} \cdot N_b = 6299.9 \cdot lbf$

Concrete breakout strength of the anchorage in tension. (ACI 318-14, Equation 17.4.2.1b)

$\phi N_{cb} := \phi_e \cdot \phi_{t_c} \cdot N_{cbg} = 3071.2\ lbf$

Tensile breakout strength incorporating strength reduction factors.

Determine Bond Strength of Adhesive Anchors in Tension

$\lambda_a := \lambda = 1.0$

ACI 318-14, Section 17.2.6 and modification factor for normalweight concrete. (ACI 318-14, Section 19.2.4.2)

$\tau_{cr} := 1170 \cdot psi$

Characteristic bond stress in cracked concrete, temperature range A, (ESR-3187, Table 14).

$d_a := d = 0.6 \cdot in$

Anchor diameter, previously defined.

$N_{ba} := \lambda_a \cdot \tau_{cr} \cdot \pi \cdot d_a \cdot h_{ef} = 7179.0\ lbf$

Basic bond strength of adhesive anchor, (ACI 318-14, Section 17.4.5.2)

$c_{Na} := 10 \cdot d_a \cdot \sqrt{\dfrac{\tau_{cr}}{1100 \cdot psi}} = 6.4 \cdot in$

Critical edge distance, (ACI 318-14, Equation 17.4.5.1d).

$A_{Nao} := \left(2 \cdot c_{Na}\right)^2 = 166.2 \cdot in^2$

Projected influence area for a single anchor, (ACI 318-14, Equation 17.4.5.1c).

$A_{Na} := \left(2 \cdot c_{Na}\right) \cdot \left(c_{Na} + c_{a_min} + s_a\right) = 498.9 \cdot in^2$

Projected influence area for a group of anchors, (ACI 318-14, Figure R17.4.5.1).

$A_{Na} := n_a \cdot A_{Nao} = 166.2 \cdot in^2$

Limiting value of A.Na per ACI 318-14, Section 17.4.5.1).

$\psi_{ed_Na} := 1.0 \qquad c_{a_min} = 6.3 \cdot in \quad > \quad c_{Na} = 6.4 \cdot in$

Modification factor for edge effects, (ACI 318-14, Equation 17.4.5.4a).

$\psi_{cp_Na} := \dfrac{c_{a_min}}{c_{ac}} \qquad c_{a_min} = 6.3 \cdot in \quad < \quad c_{ac} = 6.3 \cdot in$

Modification factor for adhesive anchors designed for uncracked concrete, (ACI 318-14, Equation 17.4.5.5a).

$e'_N := 0 \cdot in$

Previously defined.

$\psi_{ec_Na} := \dfrac{1}{\left(1 + \dfrac{e'_N}{c_{Na}}\right)} = 1.0$

Modification factor for adhesive anchor group loaded eccentrically in tension. (ACI 318-14, Equation 17.4.5.3)

$N_{ag} := \dfrac{A_{Na}}{A_{Nao}} \cdot \psi_{ec_Na} \cdot \psi_{ed_Na} \cdot \psi_{cp_Na} \cdot N_{ba} = 7179.0\ lbf$

Nominal bond strength of group of adhesive anchors in tension, (ACI 318-14, Equation 17.4.5.1b).

$\phi N_{ag} := \phi_e \cdot \phi_d \cdot N_{ag} = 3499.8\ lbf$

Nominal bond strength in tension for a group of adhesive anchors in tension incorporating strength reduction factors, (ACI 318-14, Equation 17.4.5.1b).

Determine Steel Strength of the Anchorage in Shear

$$Individual_Group := \begin{cases} \text{"Analyze anchors individually in shear according to ACI 318-14, Chapter 17"} & \text{if } 3 \cdot c_{a1} \le s_a \\ \text{"Analyze anchors as a group in shear according to ACI 318-14, Section 17.2.1.1"} & \text{otherwise} \end{cases}$$

Individual_Group = "Analyze anchors individually in shear according to ACI 318-14, Chapter 17"

$V_{sa} := 13560 \cdot lbf$ — The steel strength in shear. (ESR-3187, Table 11, ASTM F593)

$\phi V_{sa} := \alpha_{v_seis} \cdot \phi_{v_s} \cdot V_{sa} = 5695.2\ lbf$ — Steel shear strength incorporating strength reduction factors.

Determine Concrete Breakout Strength of the Anchorage in Shear

$$\psi_{ed_V} := \begin{cases} 1.0 & \text{if } c_{a2} \ge 1.5 \cdot c_{a1} \\ 0.7 + 0.3 \cdot \dfrac{c_{a2}}{1.5 \cdot c_{a1}} & \text{otherwise} \end{cases} = 0.9$$

Edge distance factor (Anchors not on a corner). (ACI 318-14, Section 17.5.2.6)

$\psi_{c_V} := 1.0$ — Cracked concrete factor without supplementary reinforcement, (ACI 318-14, Section 17.5.2.7)

$$\psi_{h_V} := \begin{cases} \sqrt{\dfrac{1.5 \cdot c_{a1}}{h_a}} & \text{if } h_a < 1.5 \cdot c_{a1} \\ 1 & \text{otherwise} \end{cases} = 1.00$$

Thickness modification factor. (ACI 318-14, Section 17.5.2.8)

$d_a := d = 0.6 \cdot in$ — The outside diameter of the anchor.

$l_e := \min(8 \cdot d_a, h_{ef}) = 3.1 \cdot in$ — The load bearing length of anchor for shear. (ACI 318-14, Section 17.5.2.2)

$$V_b := \min\left[7 \cdot \left(\frac{l_e}{d_a}\right)^{0.2} \cdot \sqrt{\frac{d_a}{in}} \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot \left(\frac{c_{a1}}{in}\right)^{1.5} \cdot lbf,\ 9 \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot \left(\frac{c_{a1}}{in}\right)^{1.5} \cdot lbf\right] = 8003.1 \cdot lbf$$

Basic concrete breakout strength of a single anchor in shear in cracked concrete. (ACI 318-14, Section 17.5.2.2)

$A_{Vco} := 4.5 \cdot c_{a1}^2 = 175.8 \cdot in^2$ — The projected area for a single anchor in a deep member with a distance from edges equal or greater than 1.5 x c_{a1}. (ACI 318-14, Equation 17.5.2.1c)

$A_{Vc} := \left[\left(2 \cdot 1.5 \cdot c_{a1}\right) + s_a\right] \cdot \min\left(1.5 \cdot c_{a1}, h_a\right) = 419.5 \cdot in^2$ — Projected concrete failure area of the anchorage. (ACI 318-14, Section 17.5.2.1 and Figure R17.5.2.1b)

$e'_V := 0 \cdot in$ — No eccentricity of anchor group in shear.

$$\psi_{ec_V} := \frac{1}{\left(1 + \dfrac{2 \cdot e'_V}{3 \cdot c_{a1}}\right)} = 1.0$$

Modification factor for anchor group loaded eccentrically in shear. (ACI 318-14, Equation 17.5.2.5)

$$V_{cbg} := \frac{A_{Vc}}{A_{Vco}} \cdot \psi_{ec_V} \cdot \psi_{ed_V} \cdot \psi_{c_V} \cdot \psi_{h_V} \cdot V_b = 17190.7 \cdot lbf$$

Nominal concrete breakout strength of anchorage in shear. (ACI 318-14, Equation 17.5.2.1a)

$\phi V_{cb} := \phi_{v_c} \cdot V_{cbg} = 12033.5\ lbf$ — Shear breakout strength incorporating strength reduction factors.

Determine Pryout Strength of the Anchorage in Shear

$k_{cp} := \begin{cases} 1 & \text{if } h_{ef} < 2.5\text{in} \\ 2 & \text{otherwise} \end{cases} = 2.0$

Coefficient for pryout strength. (ACI 318-14, Section 17.5.3.1)

$N_{cbg} = 6299.9\ \text{lbf}$ $N_{ag} = 7179.0\ \text{lbf}$

Use the lesser of N.cbg from Equation 17.4.2.1b or Nag from 17.4.5.1b per ACI 318-14, Section 17.5.3.1).

$V_{cp} := k_{cp} \cdot N_{cbg} = 12599.7\ \text{lbf}$

The nominal pryout strength of the anchorage in shear per ACI 318-14, Equation 17.5.3.1a.

$\phi V_{cp} := \phi_{v_c} \cdot V_{cp} = 8819.8\ \text{lbf}$

Shear pryout strength incorporating strength reduction factors.

Determine Governing Failure Strength

$\text{Govern}_t := \begin{cases} \text{"Steel failure governs (Ductile Failure)."} & \text{if } \phi N_{sa} \le \min(\phi N_{cb}, \phi N_{ag}) \\ \text{"Concrete breakout governs (Brittle Failure)."} & \text{if } \phi N_{cb} \le \min(\phi N_{sa}, \phi N_{ag}) \\ \text{"Bond strength governs (Brittle Failure)."} & \text{otherwise} \end{cases}$

$\text{Govern}_t = \text{"Concrete breakout governs (Brittle Failure)."}$

$\text{Tensile}_{govern} := \begin{cases} \phi N_{sa} & \text{if } \phi N_{sa} \le \min(\phi N_{cb}, \phi N_{ag}) \\ \phi N_{cb} & \text{if } \phi N_{cb} \le \min(\phi N_{sa}, \phi N_{ag}) \\ \phi N_{ag} & \text{otherwise} \end{cases}$

The governing allowable tensile capacity of the anchorage.

$\text{Tensile}_{govern} = 3071\ \text{lbf}$

$T_{eye_bolt} = 1388.8\ \text{lbf}$

$\text{Tension_Check} := \begin{cases} \text{"Anchor capacity in tension is OK."} & \text{if } \text{Tensile}_{govern} > T_{eye_bolt} \\ \text{"Anchor capacity in tension is NOT OK"} & \text{otherwise} \end{cases}$

$\text{Tension_Check} = \text{"Anchor capacity in tension is OK."}$

Check to determine the adequacy of the anchors in tension.

$$DCR_{tens} := \frac{T_{eye_bolt}}{\text{Tensile}_{govern}} = 0.45$$

$$Govern_v := \begin{cases} \text{"Steel failure governs (Ductile Failure)."} & \text{if } \phi V_{sa} \le \min(\phi V_{cb}, \phi V_{cp}) \\ \text{"Concrete breakout governs (Brittle Failure)."} & \text{if } \phi V_{cb} < \min(\phi V_{sa}, \phi V_{cp}) \\ \text{"Concrete pryout governs (Brittle Failure)."} & \text{otherwise} \end{cases}$$

$Govern_v$ = "Steel failure governs (Ductile Failure)."

$$Shear_{govern} := \begin{cases} \phi V_{sa} & \text{if } \phi V_{sa} \le \min(\phi V_{cb}, \phi V_{cp}) \\ \phi V_{cb} & \text{if } \phi V_{cb} < \min(\phi V_{sa}, \phi V_{cp}) \\ \phi V_{cp} & \text{otherwise} \end{cases}$$

The governing allowable shear capacity of the anchorage.

$Shear_{govern} = 5695\,lbf$

$V_{eye_bolt} = 462.6\,lbf$

$$Shear_Check := \begin{cases} \text{"Anchor capacity in shear is OK."} & \text{if } Shear_{govern} > V_{eye_bolt} \\ \text{"Anchor capacity in shear is NOT OK"} & \text{otherwise} \end{cases}$$

Shear_Check = "Anchor capacity in shear is OK."

Check to determine the adequacy of the anchors in shear.

$$DCR_{shear} := \frac{V_{eye_bolt}}{Shear_{govern}} = 0.08$$

$$DCR := \begin{cases} DCR_{tens} & \text{if } DCR_{shear} \le 0.2 \\ DCR_{shear} & \text{if } DCR_{tens} \le 0.2 \\ \frac{1}{1.2} \cdot (DCR_{tens} + DCR_{shear}) & \text{otherwise} \end{cases} = 0.45$$

The DCR ratio is less than 1.0; therefore, **OK**
ACI 318-14, Section 17.6.

ATTACHMENT 1

ICC-ES EVALUATION REPORT

ESR -3187

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

(EXCERPT)

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 30 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

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ESR-3187

Issued 03/2018
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DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

HILTI, INC.

EVALUATION SUBJECT:

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

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Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 31 of 40
Title: LERF Basin 41 Catch Basin Design			
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ESR-3187

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DIVISION: 03 00 00—CONCRETE
Section: 03 16 00—Concrete Anchors

DIVISION: 05 00 00—METALS
Section: 05 05 19—Post-installed Concrete Anchors

REPORT HOLDER:

HILTI, INC.

EVALUATION SUBJECT:

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2018, 2015, 2012, and 2009 *International Building Code®* (IBC)
- 2018, 2015, 2012, and 2009 *International Residential Code®* (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

For evaluation for compliance with codes adopted by the Los Angeles Department of Building and Safety (LADBS), see ESR-3187 LABC and LARC Supplement.

For evaluation for compliance with the *National Building Code of Canada®* (NBCC), see listing report ELC-3187.

Property evaluated:

Structural

2.0 USES

Adhesive anchors and reinforcing bars installed using the Hilti HIT-HY 200 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are used to resist static, wind and earthquake (Seismic Design Categories A through F) tension and shear loads in cracked and uncracked normal-weight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

The anchor system complies with anchors as described in Section 1901.3 of the 2018 and 2015 IBC, Section 1909 of the 2012 IBC and is an alternative to cast-in-place anchors described in Section 1908 of the 2012 IBC, and Sections 1911 and 1912 of the 2009 IBC. The anchor systems may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

The post-installed reinforcing bar system is an alternative to cast-in-place reinforcing bars governed by ACI 318 and IBC Chapter 19.

3.0 DESCRIPTION

3.1 General:

The Hilti HIT-HY 200 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are comprised of the following components:

- Hilti HIT-HY 200 adhesive packaged in foil packs (either Hilti HIT-HY 200-A or Hilti HIT-HY 200-R)
- Adhesive mixing and dispensing equipment
- Equipment for hole cleaning and adhesive injection

The Hilti HIT-HY 200 Adhesive Anchoring System may be used with continuously threaded rod, Hilti HIT-Z(-R) anchor rods, Hilti HIS-(R)N internally threaded inserts or deformed steel reinforcing bars as depicted in Figure 1. The Hilti HIT-HY 200 Post-Installed Reinforcing Bar System may only be used with deformed steel reinforcing bars as depicted in Figure 2. The primary components of the Hilti Adhesive Anchoring and Post-Installed Reinforcing Bar Systems, including the Hilti HIT-HY 200 Adhesive, HIT-RE-M static mixing nozzle and steel anchoring elements, are shown in Figure 6 of this report.

The manufacturer's printed Installation instructions (MPII), as included with each adhesive unit package, are replicated as Figure 9.

3.2 Materials:

3.2.1 Hilti HIT-HY 200 Adhesive: Hilti HIT-HY 200 Adhesive is an injectable, two-component hybrid adhesive. The two components are separated by means of a dual-cylinder foil pack attached to a manifold. The two components combine and react when dispensed through a static mixing nozzle attached to the manifold. Hilti HIT-HY 200 is available in 11.1-ounce (330 mL) and 16.9-ounce (500 mL) foil packs. The manifold attached to each foil pack is stamped with the adhesive expiration date. The shelf life, as indicated by the expiration date, applies to an unopened foil pack stored in a dry, dark environment and in accordance with Figure 9.

Hilti HIT-HY 200 Adhesive is available in two options, Hilti HIT-HY 200-A and Hilti HIT-HY 200-R. Both options are subject to the same technical data as set forth in this report. Hilti HIT-HY 200-A will have shorter working times

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Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 CALCULATION SHEET		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 32 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

and curing times than Hilti HIT-HY 200-R. The packaging for each option employs a different color, which helps the user distinguish between the two adhesives.

3.2.2 Hole Cleaning Equipment:

3.2.2.1 Standard Equipment: Standard hole cleaning equipment, comprised of steel wire brushes and air nozzles, is described in Figure 9 of this report.

3.2.2.2 Hilti Safe-Set™ System: The Hilti Safe-Set™ with Hilti HIT-HY 200 consists of one of the following:

- For the Hilti HIT-Z and HIT-Z-R anchor rods, hole cleaning is not required after drilling the hole, except if the hole is drilled with a diamond core drill bit.
- For the elements described in Sections 3.2.4.2 through 3.2.4.4 and Section 3.2.5, the Hilti TE-CD or TE-YD hollow carbide drill bit with a carbide drilling head conforming to ANSI B212.15. Used in conjunction with a Hilti vacuum with a minimum value for the maximum volumetric flow rate of 129 CFM (61 ℓ/s), the Hilti TE-CD or TE-YD drill bit will remove the drilling dust, automatically cleaning the hole.

3.2.3 Hole Preparation Equipment:

3.2.3.1 Hilti Safe-Set™ System: TE-YRT Roughening Tool: For the elements described in Sections 3.2.5.2 through 3.2.5.4 and Tables 12, 13, 16, 17, 21, and 23, the Hilti TE-YRT roughening tool with a carbide roughening head is used for hole preparation in conjunction with holes core drilled with a diamond core bit as illustrated in Figure 4.

3.2.4 Dispensers: Hilti HIT-HY 200 must be dispensed with manual or electric dispensers provided by Hilti.

3.2.5 Anchor Elements:

3.2.5.1 Hilti HIT-Z and HIT-Z-R Anchor Rods: Hilti HIT-Z and HIT-Z-R anchor rods have a conical shape on the embedded section and a threaded section above the concrete surface. Mechanical properties for the Hilti HIT-Z and HIT-Z-R anchor rods are provided in Table 2. The rods are available in diameters as shown in Table 7 and Figure 1. Hilti HIT-Z anchor rods are produced from carbon steel and furnished with a 0.005-millimeter-thick (5 μm) zinc electroplated coating. Hilti HIT-Z-R anchor rods are fabricated from grade 316 stainless steel.

3.2.5.2 Threaded Steel Rods: Threaded steel rods must be clean, continuously threaded rods (all-thread) in diameters as described in Tables 11 and 15 and Figure 1 of this report. Steel design information for common grades of threaded rods is provided in Table 3. Carbon steel threaded rods must be furnished with a 0.0002-inch-thick (0.005 mm) zinc electroplated coating complying with ASTM B633 SC 1 or must be hot-dipped galvanized complying with ASTM A153, Class C or D. Stainless steel threaded rods must comply with ASTM F593 or ISO 3506 A4. Threaded steel rods must be straight and free of indentations or other defects along their length. The ends may be stamped with identifying marks and the embedded end may be blunt cut or cut on the bias to a chisel point.

3.2.5.3 Steel Reinforcing Bars for use in Post-Installed Anchor Applications: Steel reinforcing bars are deformed bars as described in Table 4 of this report. Tables 11, 15, and 19 and Figure 1 summarize reinforcing bar size ranges. The embedded portions of reinforcing bars must be straight, and free of mill scale, rust, mud, oil and other coatings (other than zinc) that may impair the bond with the adhesive. Reinforcing bars must not be bent after installation except as set forth in ACI 318-14 26.6.3.1(b) or ACI 318-11 7.3.2, as applicable, with the additional condition that the bars must be bent cold, and heating of reinforcing bars to facilitate field bending is not permitted.

3.2.5.4 Hilti HIS-N and HIS-RN Inserts: Hilti HIS-N and HIS-RN inserts have a profile on the external surface and are internally threaded. Mechanical properties for Hilti HIS-N and HIS-RN inserts are provided in Table 5. The inserts are available in diameters and lengths as shown in Table 22 and Figure 1. Hilti HIS-N inserts are produced from carbon steel and furnished with a 0.005-millimeter-thick (5 μm) zinc electroplated coating complying with ASTM B633 SC 1. The stainless steel Hilti HIS-RN inserts are fabricated from X5CrNiMo17122 K700 steel conforming to DIN 17440. Specifications for common bolt types that may be used in conjunction with Hilti HIS-N and HIS-RN inserts are provided in Table 6. Bolt grade and material type (carbon, stainless) must be matched to the insert. Strength reduction factors, ϕ, corresponding to brittle steel elements must be used for Hilti HIS-N and HIS-RN inserts.

3.2.5.5 Ductility: In accordance with ACI 318-14 2.3 or ACI 318-11 D.1, as applicable, in order for a steel element to be considered ductile, the tested elongation must be at least 14 percent and reduction of area must be at least 30 percent. Steel elements with a tested elongation of less than 14 percent or a reduction of area of less than 30 percent, or both, are considered brittle. Values for various steel materials are provided in Tables 2, 3, and 6 of this report. Where values are nonconforming or unstated, the steel must be considered brittle.

3.2.6 Steel Reinforcing Bars for Use in Post-Installed Reinforcing Bar Connections: Steel reinforcing bars used in post-installed reinforcing bar connections are deformed bars (rebar) as depicted in Figures 2 and 3. Tables 25, 26, 27, and Figure 9 summarize reinforcing bar size ranges. The embedded portions of reinforcing bars must be straight, and free of mill scale, rust and other coatings that may impair the bond with the adhesive. Reinforcing bars must not be bent after installation, except as set forth in Section 26.6.3.1(a) of ACI 318-14 or Section 7.3.2 of ACI 318-11, as applicable, with the additional condition that the bars must be bent cold, and heating of reinforcing bars to facilitate field bending is not permitted.

3.3 Concrete:

Normal-weight concrete must comply with Sections 1903 and 1905 of the IBC, as applicable. The specified compressive strength of the concrete must be from 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

4.0 DESIGN AND INSTALLATION

4.1 Strength Design of Post-Installed Anchors:

Refer to Table 1 for the design parameters for specific installed elements, and refer to Figure 4 and Section 4.1.4 for a flowchart to determine the applicable design bond strength or pullout strength.

4.1.1 General: The design strength of anchors under the 2018 and 2015 IBC and 2018 and 2015 IRC must be determined in accordance with ACI 318-14 and this report. The design strength of anchors under the 2012 and 2009 IBC, as well as the 2012 and 2009 IRC must be determined in accordance with ACI 318-11 and this report.

A design example according to the 2012 and 2009 IBC based on ACI 318-11 is given in Figure 7 of this report.

Design parameters are based on ACI 318-14 for use with the 2018 and 2015 IBC, and ACI 318-11 for use with the 2012 and 2009 IBC unless noted otherwise in Sections 4.1.1 through 4.1.11 of this report.

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 33 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

TABLE 1—DESIGN TABLE INDEX

Design Table		Fractional		Metric	
		Table	Page	Table	Page
Hilti HIT-Z and HIT-Z-R Anchor Rod	Steel Strength - N_{sa}, V_{sa}	7	14	7	14
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	8	15	8	15
	Pullout Strength – N_p	10	19	10	19
Standard Threaded Rod	Steel Strength - N_{sa}, V_{sa}	11	20	15	25
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	12	22	16	26
	Bond Strength - N_a, N_{ag}	14	24	18	28
Hilti HIS-N and HIS-RN Internally Threaded Insert	Steel Strength - N_{sa}, V_{sa}	22	32	22	32
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	23	33	23	33
	Bond Strength - N_a, N_{ag}	24	34	24	34

Design Table		Fractional		EU Metric		Canadian	
		Table	Page	Table	Page	Table	Page
Steel Reinforcing Bars	Steel Strength - N_{sa}, V_{sa}	11A	21	15	25	19	29
	Concrete Breakout - N_{cb}, N_{cbg}, V_{cb}, V_{cbg}, V_{cp}, V_{cpg}	12	22	16	26	20	30
	Bond Strength - N_a, N_{ag}	13	23	17	27	21	31
	Determination of development length for post-installed reinforcing bar connections	25	35	26	36	27	36

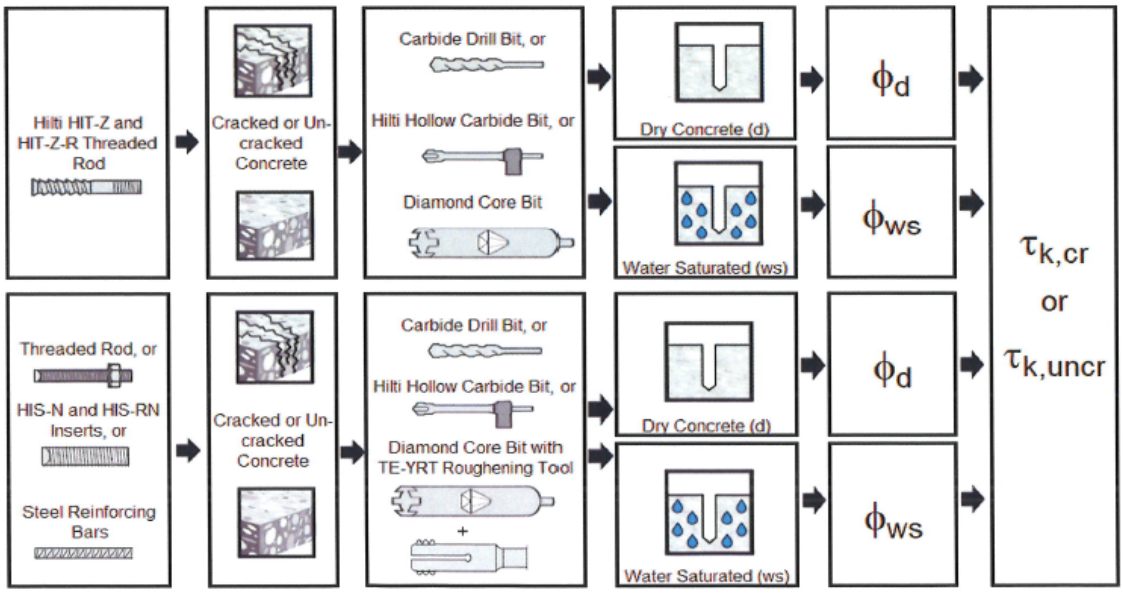


FIGURE 4—FLOWCHART FOR THE ESTABLISHMENT OF DESIGN BOND OR PULLOUT STRENGTH FOR POST-INSTALLED ADHESIVE ANCHORS

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 34 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

Fractional Threaded Rod

Steel Strength

TABLE 11—STEEL DESIGN INFORMATION FOR FRACTIONAL THREADED ROD

DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)[1]						
				3/8	1/2	5/8	3/4	7/8	1	1 1/4
Rod O.D.		d	in. (mm)	0.375 (9.5)	0.5 (12.7)	0.625 (15.9)	0.75 (19.1)	0.875 (22.2)	1 (25.4)	1.25 (31.8)
Rod effective cross-sectional area		A_{se}	in.^{2} (mm^2)	0.0775 (50)	0.1419 (92)	0.2260 (146)	0.3345 (216)	0.4617 (298)	0.6057 (391)	0.9691 (625)
ISO 898-1 Class 5.8	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	5,620 (25.0)	10,290 (45.8)	16,385 (72.9)	24,250 (107.9)	33,470 (148.9)	43,910 (195.3)	70,260 (312.5)
		V_{sa}	lb (kN)	3,370 (15.0)	6,175 (27.5)	9,830 (43.7)	14,550 (64.7)	20,085 (89.3)	26,345 (117.2)	42,155 (187.5)
	Reduction for seismic shear	$\alpha_{V,seis}$	-	0.70						
	Strength reduction factor ϕ for tension[2]	ϕ	-	0.65						
	Strength reduction factor ϕ for shear[2]	ϕ	-	0.60						
ASTM A193 B7	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	9,685 (43.1)	17,735 (78.9)	28,250 (125.7)	41,810 (186.0)	57,710 (256.7)	75,710 (336.8)	121,135 (538.8)
		V_{sa}	lb (kN)	5,810 (25.9)	10,640 (47.3)	16,950 (75.4)	25,085 (111.6)	34,625 (154.0)	45,425 (202.1)	72,680 (323.3)
	Reduction for seismic shear	$\alpha_{V,seis}$	-	0.70						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F1554 Gr. 36	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	- -	8,230 (36.6)	13,110 (58.3)	19,400 (86.3)	26,780 (119.1)	35,130 (156.3)	56,210 (250.0)
		V_{sa}	lb (kN)	- -	4,940 (22.0)	7,865 (35.0)	11,640 (51.8)	16,070 (71.5)	21,080 (93.8)	33,725 (150.0)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.6						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F1554 Gr. 55	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	- -	10,645 (47.4)	16,950 (75.4)	25,090 (111.6)	34,630 (154.0)	45,430 (202.1)	72,685 (323.3)
		V_{sa}	lb (kN)	- -	6,385 (28.4)	10,170 (45.2)	15,055 (67.0)	20,780 (92.4)	27,260 (121.3)	43,610 (194.0)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.7						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F1554 Gr. 105	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	- -	17,740 (78.9)	28,250 (125.7)	41,815 (186.0)	57,715 (256.7)	75,715 (336.8)	121,135 (538.8)
		V_{sa}	lb (kN)	- -	10,645 (47.4)	16,950 (75.4)	25,090 (111.6)	34,630 (154.0)	45,430 (202.1)	72,680 (323.3)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.7						
	Strength reduction factor ϕ for tension[3]	ϕ	-	0.75						
	Strength reduction factor ϕ for shear[3]	ϕ	-	0.65						
ASTM F593, CW Stainless	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	7,750 (34.5)	14,190 (63.1)	22,600 (100.5)	28,435 (126.5)	39,245 (174.6)	51,485 (229.0)	- -
		V_{sa}	lb (kN)	4,650 (20.7)	8,515 (37.9)	13,560 (60.3)	17,060 (75.9)	23,545 (104.7)	30,890 (137.4)	- -
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.7						-
	Strength reduction factor ϕ for tension[2]	ϕ	-	0.65						-
	Strength reduction factor ϕ for shear[2]	ϕ	-	0.60						-
ASTM A193, Gr. 8(M), Class 1 Stainless	Nominal strength as governed by steel strength	N_{sa}	lb (kN)	-						55,240 (245.7)
		V_{sa}	lb (kN)	-						33,145 (147.4)
	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	-						0.6
	Strength reduction factor ϕ for tension[2]	ϕ	-	-						0.75
	Strength reduction factor ϕ for shear[2]	ϕ	-	-						0.65

For **SI**: 1 inch = 25.4 mm, 1 lbf = 4.448 N. For **pound-inch** units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf

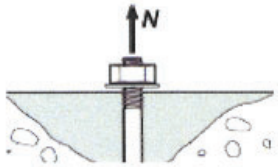
[1] Values provided for common rod material types are based on specified strengths and calculated in accordance with ACI 318-14 Eq. (17.4.1.2) and Eq (17.5.1.2b) or ACI 318-11 Eq. (D-2) and Eq. (D-29). Nuts and washers must be appropriate for the rod.

[2] For use with the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 9.2, as set forth in ACI 318-14 17.3.3 or ACI 318-11 D.4.3. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. Values correspond to a brittle steel element.

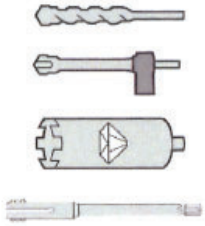
[3] For use with the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 9.2, as set forth in ACI 318-14 17.3.3 or ACI 318-11 D.4.3. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. Values correspond to a ductile steel element.

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 35 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

Fractional Threaded Rod and Reinforcing Bars



Concrete Breakout Strength



Carbide Bit or
Hilti Hollow Carbide Bit or
Diamond Core Bit + Roughening Tool

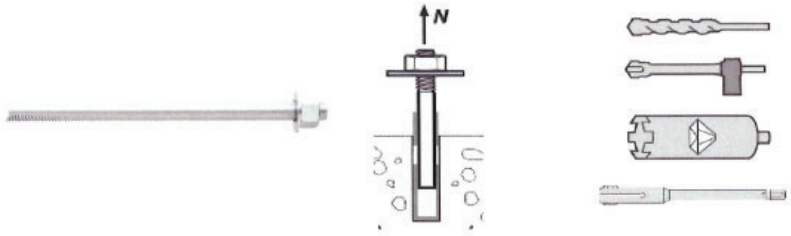
TABLE 12—CONCRETE BREAKOUT DESIGN INFORMATION FOR FRACTIONAL THREADED ROD AND REINFORCING BARS IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT (OR HILTI HOLLOW CARBIDE DRILL BIT) OR CORE DRILLED WITH A DIAMOND CORE BIT AND ROUGHENED WITH A HILTI ROUGHENING TOOL[1]

DESIGN INFORMATION	Symbol	Units	Nominal rod diameter (in.) / Reinforcing bar size							
			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1 1/4 or #10
Effectiveness factor for cracked concrete	$k_{c,cr}$	in-lb (SI)	17 (7.1)							
Effectiveness factor for uncracked concrete	$k_{c,uncr}$	in-lb (SI)	24 (10)							
Minimum Embedment	$h_{ef,min}$	in. (mm)	2 3/8 (60)	2 3/4 (70)	3 1/8 (79)	3 1/2 (89)	3 1/2 (89)	4 (102)	4 1/2 (114)	5 (127)
Maximum Embedment	$h_{ef,max}$	in. (mm)	7 1/2 (191)	10 (254)	12 1/2 (318)	15 (381)	17 1/2 (445)	20 (508)	22 1/2 (572)	25 (635)
Min. anchor spacing[3]	s_{min}	in. (mm)	1 7/8 (48)	2 1/2 (64)	3 1/8 (79)	3 3/4 (95)	4 3/8 (111)	5 (127)	5 5/8 (143)	6 1/4 (159)
Min. edge distance (Threaded rods)	c_{min}	in. (mm)	1¾ (45)	1¾ (45)	2 (3) (50) (3)	2 1/8 (3) (55) (3)	2¼ (3) (60) (3)	2¾ (3) (70) (3)	n/a	3 1/8 (3) (80) (3)
Min. edge distance (Reinforcing bars)[3]	c_{min}	-	5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances							
Minimum concrete thickness	h_{min}	in. (mm)	h_{ef} + 1 1/4 (h_{ef} + 30)		$h_{ef} + 2d_0$ (4)					
Critical edge distance – splitting (for uncracked concrete)	c_{ac}	-	See Section 4.1.10.2 of this report.							
Strength reduction factor for tension, concrete failure modes, Condition B[2]	ϕ	-	0.65							
Strength reduction factor for shear, concrete failure modes, Condition B[2]	ϕ	-	0.70							

For **SI**: 1 inch ≅ 25.4 mm, 1 lbf = 4.448 N, 1 psi = 0.006897 MPa.
For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf, 1 MPa = 145.0 psi

[1] Additional setting information is described in Figure 9, Manufacturers Printed Installation Instructions (MPII).
[2] Values provided for post-installed anchors under Condition B without supplementary reinforcement as defined in ACI 318-14 17.3.3 or ACI 318-11 D.4.3.
[3] For installations with 1 3/4-inch edge distance, refer to Section 4.1.9.2 for spacing and maximum torque requirements.
[4] d_0 = hole diameter.

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 36 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020



Fractional Threaded Rod | Bond Strength | Carbide Bit or Hilti Hollow Carbide Bit or Diamond Core Bit + Roughening Tool

TABLE 14—BOND STRENGTH DESIGN INFORMATION FOR FRACTIONAL THREADED ROD IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT (OR HILTI HOLLOW CARBIDE DRILL BIT) OR CORE DRILLED WITH A DIAMOND CORE BIT AND ROUGHENED WITH A HILTI ROUGHENING TOOL[1]

DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)						
				3/8	1/2	5/8	3/4	7/8	1	1 1/4
Minimum Embedment		$h_{ef,min}$	in. (mm)	2 3/8 (60)	2 3/4 (70)	3 1/8 (79)	3 1/2 (89)	3 1/2 (89)	4 (102)	5 (127)
Maximum Embedment		$h_{ef,max}$	in. (mm)	7 1/2 (191)	10 (254)	12 1/2 (318)	15 (381)	17 1/2 (445)	20 (508)	25 (635)
Temperature range A[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	1,045 (7.2)	1,135 (7.8)	1,170 (8.1)	1,260 (8.7)	1,290 (8.9)	1,325 (9.1)	1,380 (9.5)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)
Temperature range B[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	1,045 (7.2)	1,135 (7.8)	1,170 (8.1)	1,260 (8.7)	1,290 (8.9)	1,325 (9.1)	1,380 (9.5)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)
Temperature range C[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	855 (5.9)	930 (6.4)	960 (6.6)	1,035 (7.1)	1,055 (7.3)	1,085 (7.5)	1,130 (7.8)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)
Permissible installation conditions	Dry and water saturated concrete	Anchor Category	-	1						
		ϕ_d, ϕ_{ws}	-	0.65						
Reduction for seismic tension	Hammer drilled	$\alpha_{N,seis}$	-	0.88	0.99	0.99	1.0	1.0	0.95	0.99
	Core drilled + roughening	$\alpha_{N,seis}$	-	N/A		0.88	0.96	0.96	1.0	0.82

For **SI**: 1 inch ≡ 25.4 mm, 1 lbf = 4.448 N, 1 psi = 0.006897 MPa.
For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf, 1 MPa = 145.0 psi

[1] Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi (17.2 MPa). For concrete compressive strength, f'_c, between 2,500 psi (17.2 MPa) and 8,000 psi (55.2 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1], the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2{,}500)^{0.1}$ [For SI: $(f'_c / 17.2)^{0.1}$]. See Section 4.1.4 of this report for bond strength determination.
[2] Temperature range A: Maximum short term temperature = 130°F (55°C), Maximum long term temperature = 110°F (43°C).
Temperature range B: Maximum short term temperature = 176°F (80°C), Maximum long term temperature = 110°F (43°C).
Temperature range C: Maximum short term temperature = 248°F (120°C), Maximum long term temperature = 162°F (72°C).
Short term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.

ATTACHMENT 2

PIPE WALL THICKNESS DATA SHEET

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 38 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

"Annealed" Welded and Seamless Comparison of Wall Thicknesses

- Alloys Stocked Include Types 304-L and 316-L. Other corrosion resistant alloys are available.
- Specifications: ASTM A 312
- Stocked in 17 - 24 foot random mill lengths, plain ends.
- "Annealed" pipe is used when the specifications referenced are required and is available only in the NPS diameters and schedule wall thickness shown. Welded "annealed" pipe is available per ASTM A 312, ASI SA-312 and ASTM A 358, A 376, A 409 and MIL-P-24691 (corrosion tested) and is stocked in most sizes thr 24" diameter. Seamless "annealed" pipe is available per ASTM A 312 and MIL-P-24691 (corrosion tested) is stocked through 4" size.

Nominal Pipe Size	Outside Diameter	Sch 5s	Lbs/ft	Sch 10s	Lbs/Ft	Sch 40s	Lbs/Ft	Sch 80s	Lbs/Ft	Sch 160	Lbs/Ft	XX Strong	Lbs
1/8	.405			.049	.19	.068	.25	.095	.32				
1/4	.540			.065	.31	.088	.40	.119	.50				
3/8	.675			.065	.43	.091	.58	.126	.76				
1/2	.840	.065	.55	.083	.69	.109	.87	.147	1.1	.187	1.3	.294	1.8
3/4	1.050	.065	.70	.083	.88	.113	1.2	.154	1.5	.218	2.0	.308	2.5
1	1.315	.065	.88	.109	1.4	.133	1.7	.179	2.2	.250	2.9	.358	3.7
1 1/4	1.660	.065	1.1	.109	1.8	.140	2.3	.191	3.1	.250	3.9	.382	5.3
1 1/2	1.900	.065	1.3	.109	2.1	.145	2.8	.200	3.7	.281	5.0	.400	6.6
2	2 3/8	.065	1.6	.109	2.7	.154	3.7	.218	5.1	.343	7.6	.436	9.2
2 1/2	2 7/8	.083	2.5	.120	3.6	.203	5.9	.276	7.8	.375	10.2	.552	14.
3	3 1/2	.083	3.1	.120	4.4	.216	7.8	.300	10.5	.438	14.7	.600	19.
3 1/2	4	.083	3.6	.120	5.1	.226	9.3	.318	12.8			.636	23.
4	4 1/2	.083	4.0	.120	5.7	.237	11.0	.337	15.3	.531	23.0	.674	28.
5	5 9/16	.109	6.5	.134	8.0	.258	15.0	.375	21.3	.625	33.7	.750	39.
6	6 5/8	.109	7.8	.134	9.5	.280	19.4	.432	29.2	.719	46.4	.864	54.
8	8 5/8	.109	10.1	.148	13.7	.322	29.2	.500	44.4	.906	76.5	.875	74.
10	10 3/4	.134	15.6	.165	19.1	.365	41.4	.500	56.0	1.125	118	1.00	107
12	12 3/4	.156	21.5	.180	24.7	.375	50.7	.500	67.0	1.312	164	1.00	128
	14	.156	23.6	.188	28.4	.375	55.9	.500	73.8				
	16	.165	28.6	.188	32.5	.375	64.1	.500	84.7				
	18	.165	32.2	.188	36.6	.375	72.3	.500	95.7				
	20	.188	40.7	.218	47.1	.375	80.5	.500	107				
	22	.188	44.8	.218	51.9	.375	88.7	.500	118				
	24	.218	56.7	.250	64.9	.375	96.9	.500	128				
	26					.375	105	.500	139				
	28					.375	113	.500	150				
	30	.250	81.3	.312	101	.375	121	.500	161				
	32					.375	130	.500	172				
	34					.375	138	.500	183				
	36					.375	146	.500	194				
	40					.375	162	.500	216				
	42					.375	171	.500	227				
	48					.375	195	.500	260				

ATTACHMENT 3

HDPE PIPE DATA SHEET

Sargent & Lundy Engineering Services, Inc.	RPP-CALC-63664, Rev. 0 **CALCULATION SHEET**		
Project No. S54413.024	**Calculation No.** S54413.024-S-002	**Rev.** 1	**Page No.** 40 of 40
Title: LERF Basin 41 Catch Basin Design			
Prepared By: RW Davidson	**Date:** 4/27/2020	**Checked By:** PP Santos	**Date:** 4/27/2020

HDPE Water/Sewer | IPS

PRESSURE-RATED HDPE PIPE

JM Eagle

DELIVERING GOOD WATER TO YOU

SUBMITTAL AND DATA SHEET

HDPE IRON PIPE SIZE (IPS) PRESSURE PIPE

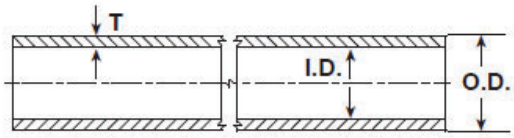
PIPE SIZE (IN)	AVG.O.D. (IN)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)
		DR 7 (335 psi)			DR 9 (250 psi)			DR 11 (200 psi)		
4	4.500	0.643	3.137	3.40	0.500	3.440	2.75	0.409	3.633	2.30
5	5.375	0.795	3.747	4.85	0.618	4.109	3.92	0.506	4.338	3.29
6	6.625	0.946	4.619	7.36	0.736	5.065	5.96	0.602	5.349	4.99
7	7.125	1.018	5.056	8.52	0.792	5.446	6.89	0.648	5.751	5.78
8	8.625	1.232	6.013	12.48	0.958	6.594	10.09	0.784	6.963	8.46
10	10.750	1.536	7.494	19.40	1.194	8.219	15.68	0.977	8.679	13.14
12	12.750	1.821	8.889	27.28	1.417	9.746	22.07	1.159	10.293	18.49
14	14.000	2.000	9.760	32.90	1.556	10.107	26.61	1.273	11.301	22.30
16	16.000	2.286	11.154	42.97	1.778	12.231	34.75	1.455	12.915	29.12
18	18.000	2.571	12.549	54.37	2.000	13.760	43.97	1.636	14.532	36.84
20	20.000	2.857	13.943	67.13	2.222	15.289	54.28	1.818	16.146	45.49
22	22.000	3.143	15.337	81.23	2.444	16.819	65.68	2.000	17.760	55.05
24	24.000	3.429	16.732	96.67	2.667	18.346	78.18	2.182	19.374	65.52
26	26.000	N/A	N/A	N/A	2.889	19.875	91.75	2.364	20.988	76.90
28	28.000	N/A	N/A	N/A	3.111	21.405	106.40	2.545	22.605	89.15
30	30.000	N/A	N/A	N/A	3.333	22.934	122.13	2.727	24.219	102.35
32	32.000	N/A	N/A	N/A	N/A	N/A	N/A	2.909	25.833	116.46
34	34.000	N/A	N/A	N/A	N/A	N/A	N/A	3.091	27.447	131.48
36	36.000	N/A	N/A	N/A	N/A	N/A	N/A	3.273	29.061	147.41

Product Standard:
ANSI/AWWA C906
ASTM F714
ASTM D3035
Pipe Compound:
PPI TR-4 PE 4710, ASTM D3350
Cell Class 445574 C/E
Certification: ANSI/NSF 61, ANSI/NSF 14*
Additional Option:
Perforated (4" - 8")*

Nominal Laying Length: 40/50 feet (Laying length tolerances are in accordance with AWWA and ASTM standards)
Coil option available upon request for size 6" and below.
Installation: JM Eagle™ HDPE Water/Sewer Installation Guide

Manning Coefficient (n) = 0.009
Hazen-Williams Coefficient (c) = 150

*Supply may vary based on plant location. Please call regarding availability.



T: (Wall Thickness) **I.D.:** (Inside Diameter) **O.D.:** (Outside Diameter)

PIPE SIZE (IN)	AVG.O.D. (IN)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)
		DR 13.5 (160 psi)			DR 17 (125 psi)			DR 19 (111 psi)		
4	4.500	0.333	3.794	1.91	0.265	3.938	1.55	0.237	3.998	1.39
5	5.375	0.412	4.531	2.73	0.327	4.705	2.21	0.283	4.775	1.99
6	6.625	0.491	5.584	4.15	0.390	5.798	3.35	0.349	5.885	3.02
7	7.125	0.528	6.006	4.80	0.420	6.237	3.88	0.375	6.330	3.49
8	8.625	0.639	7.270	7.03	0.507	7.550	5.68	0.454	7.663	5.12
10	10.750	0.796	9.062	10.92	0.632	9.410	8.82	0.566	9.550	7.95
12	12.750	0.944	10.749	15.36	0.750	11.160	12.41	0.671	11.327	11.19
14	14.000	1.037	11.802	18.52	0.824	12.253	14.98	0.737	12.438	13.49
16	16.000	1.185	13.488	24.19	0.941	14.005	19.55	0.842	14.215	17.61
18	18.000	1.333	15.174	30.61	1.059	15.755	24.75	0.947	15.992	22.29
20	20.000	1.481	16.860	37.79	1.176	17.507	30.53	1.053	17.768	27.52
22	22.000	1.630	18.544	45.75	1.294	19.257	36.86	1.158	19.545	33.30
24	24.000	1.778	20.231	54.44	1.412	21.007	43.99	1.263	21.322	39.63
26	26.000	1.926	21.917	63.89	1.529	22.759	51.61	1.368	23.100	46.51
28	28.000	2.074	23.603	74.09	1.647	24.508	59.87	1.474	24.875	53.94
30	30.000	2.222	25.289	85.04	1.765	26.258	68.74	1.579	26.653	61.92
32	32.000	2.370	26.967	96.76	1.882	28.010	78.18	1.684	28.430	70.45
34	34.000	2.519	28.660	109.26	2.000	29.760	88.28	1.790	30.205	79.54
36	36.000	2.667	30.346	122.49	2.118	31.510	98.98	1.895	31.983	89.17
42	42.000	3.111	35.404	166.70	2.471	36.761	134.72	2.211	37.314	121.37
48	48.000	3.556	40.462	217.76	2.824	42.013	175.97	2.526	42.644	158.52
54	54.000	N/A	N/A	N/A	3.177	47.265	222.67	2.842	47.975	200.63

PIPE SIZE (IN)	AVG.O.D. (IN)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)	MIN. T. (IN)	AVG I.D. (IN)	WGT (LBS/FT)
		DR 21 (100 psi)			DR 26 (80 psi)			DR 32.5 (63 psi)		
4	4.500	0.214	4.046	1.27	0.173	4.133	1.03	0.138	4.207	0.83
5	5.375	0.265	4.832	1.81	0.214	4.936	1.48	0.171	5.025	1.19
6	6.625	0.315	5.957	2.74	0.255	6.084	2.24	0.204	6.193	1.81
7	7.125	0.340	6.406	3.18	0.274	6.544	2.59	0.219	6.661	2.09
8	8.625	0.411	7.754	4.66	0.332	7.921	3.80	0.265	8.063	3.06
10	10.750	0.512	9.665	7.24	0.413	9.874	5.90	0.331	10.048	4.77
12	12.750	0.607	11.463	10.17	0.490	11.711	8.30	0.392	11.919	6.69
14	14.000	0.667	12.586	12.28	0.538	12.895	10.00	0.431	13.086	8.08
16	16.000	0.762	14.385	16.03	0.615	14.696	13.07	0.492	14.957	10.54
18	18.000	0.857	16.183	20.28	0.692	16.533	16.54	0.554	16.826	13.36
20	20.000	0.952	17.982	25.03	0.769	18.370	20.43	0.615	18.696	16.48
22	22.000	1.048	19.778	30.31	0.846	20.206	24.72	0.677	20.565	19.95
24	24.000	1.143	21.577	36.06	0.923	22.043	29.42	0.738	22.435	23.72
26	26.000	1.238	23.375	42.32	1.000	23.880	34.53	0.800	24.304	27.86
28	28.000	1.333	25.174	49.07	1.077	25.717	40.05	0.862	26.173	32.33
30	30.000	1.429	26.971	56.36	1.154	27.554	45.98	0.923	28.043	37.09
32	32.000	1.542	28.730	64.11	1.231	29.390	52.31	0.985	29.912	42.22
34	34.000	1.619	30.568	72.36	1.308	31.227	59.06	1.046	31.782	47.63
36	36.000	1.714	32.366	81.12	1.385	33.064	66.22	1.108	33.651	53.42
42	42.000	2.000	37.760	110.43	1.615	38.576	90.08	1.292	39.261	72.68
48	48.000	2.286	43.154	144.25	1.846	44.086	117.68	1.477	44.869	94.95
54	54.000	2.571	48.549	182.51	2.077	49.597	148.95	1.662	50.477	120.20
63	63.000	3.000	56.640	248.46	2.423	57.863	202.73	1.938	58.891	163.53

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE: May 19,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63745 **Rev.** 00

2. **Title:**
LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Ayers, Lynn M	*Ayers, Lynn M*	05/19/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/24/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/10/2020
Document Control Approval	Scales, Anthony	*Scales, Anthony*	05/19/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/29/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/10/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/07/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	04/29/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Becasue of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Taylor Grant and Jeremy Debban is signing as Checker for Darrel Packard. Taylor Grant and Darrel Packard are not currently in SPF.

The trademark attribution information below is applicable, and should be added to the next revision.

Bobcat is a registered trademark of Clark Equipment Company, West Fargo, North Dakota.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
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Rutherford, Wally	ETF ENGINEERING
Sackett, Tom E	TANK FARM PROJECTS
Samoska, Jerry A	INSTRUMENT & CNTRL ENGINEERING
Shultz, Milton V	NUCLEAR SAFETY
Smith, Gregory E	TANK FARM PROJECTS ENGINEERING
Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63745
Revision 0

LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection

Prepared by

G. T. Grant
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
April 2020

washington river protection solutions

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REGISTERED
PROFESSIONAL ENGINEER

5-18-2020

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

Approved for Public Release;
Further Dissemination Unlimited

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 51 **Date** 04/08/2020 **Rev. No.** 0 **Calculation No:** S54413.024-C-001

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions

Title:

LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection

Purpose and Objective:

The purpose of this calculation is to estimate the risk of damage to the secondary (bottom) HDPE-liner during construction. The greatest risk for damage is expected when the gravel drainage layer is spread using lightweight construction equipment. A geotextile will be installed over the HDPE liner prior to placing and spreading the gravel. The potential for damaging the geotextile will be evaluated first; the potential for damage to the liner will then be evaluated if necessary.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	51	Print Name/ Sign:	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	04/08/2020	4/9/2020	4/10/2020

Revision Description (Revision Description/Affected Pages):

		Print Name/ Sign:			
		Date:			

Revision Description (Revision Description/Affected Pages):

RPP-CALC-63745, Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev. No.	Page No.
S54413.024	S54413.024-C-001	0	2 of 51

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
G. Taylor Grant	4/8/2020
Checker (Print Name and Sign):	**Date:**
Darrel Packard	4/9/2020

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 3 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE OF CONTENTS

1.0 PURPOSE 5

2.0 METHODOLOGY 5

3.0 DESIGN INPUTS 5
- 3.1 Gravel Drainage Layer 5
- 3.2 Construction Equipment 6

4.0 ASSUMPTIONS 6

5.0 COMPUTER SOFTWARE 6

6.0 RESULTS 7

7.0 REFERENCES 7

8.0 CALCULATIONS 8
- 8.1 Burst Resistance (Ref. 1, Section 2.5.2): 8
- 8.2 Tensile Strength Requirements (Ref. 1, Section 2.5.3): 9
- 8.3 Puncture Strength Requirements (Ref. 1, Section 2.5.4): 10

Attachments

ATTACHMENT – 1 – DESIGNING WITH GEOSYNTHETICS, 6TH EDITION

ATTACHMENT – 2 – GEOTEXTILE CUT SHEETS

ATTACHMENT – 3 – BOBCAT T550 SKID-STEER SPECIFICATIONS

ATTACHMENT – 4 – GEOSYNTHTIC INSTITUTE GRI TEST METHOD GT12(a) – ASTM VERSION

ATTACHMENT – 5 – CORRELATION OF ASTM D4833 AND D6241 GEOTEXTILE PUNCTURE TEST METHODS AND RESULTS FOR USE ON WISDOT PROJECTS

ATTACHMENT – 6 – H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER

ATTACHMENT – 7 – WSDOT M41-10 9-03.12(5) GRAVEL BACKFILL FOR DRYWELLS GRADATION

ATTACHMENT – 8 – CAT D6 DOZER SPECIFICATIONS

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 4 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Acronyms

ASTM	ASTM International or American Society for Testing and Materials
DCR	Demand-to-Capacity Ratio
GCL	Geosynthetic Clay Liner
HDPE	High Density Polyethylene
LERF	Liquid Effluent Retention Facility

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 5 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

1.0 PURPOSE

The purpose of this calculation is to estimate the risk of damage to the secondary (bottom) HDPE-liner during construction. The greatest risk for damage is expected when the gravel drainage layer is spread using lightweight construction equipment. A geotextile will be installed over the HDPE liner prior to placing and spreading the gravel. The potential for damaging the geotextile will be evaluated first; the potential for damage to the liner will then be evaluated if necessary.

2.0 METHODOLOGY

The liner system along the basin floor is comprised of (from top to bottom):

- Primary HDPE liner
- GCL
- Geotextile
- Gravel Drainage Layer
- Geotextile
- Secondary HDPE liner
- Geotextile
- Soil/Bentonite mixture
- Geotextile

Beneath the gravel drainage layer is a geotextile with the secondary HDPE liner underneath the geotextile. The geotextile will be analyzed for its burst, tensile, and puncture strength, and compared to typical values to ensure sufficient strength to protect the secondary HDPE liner during construction. Typical geotextile strength values will come from Reference 2. The required burst, tensile, and puncture strengths will be calculated in accordance with Section 2.5.2 “Burst Resistance,” 2.5.3 “Tensile Strength,” and 2.5.4 “Puncture Resistance” in Reference 1. The results of the calculations will be used to specify the required geotextile strengths.

3.0 DESIGN INPUTS

3.1 Gravel Drainage Layer

The gravel drainage layer “shall conform to WSDOT M41-10 9-03.12(5) Gravel Backfill for Drywells gradation, or an approved equal” (Reference 7, Section 31-90-52 2.1.D.1.a.ii). The maximum sieve size for this gradation is 1.5” and requires 99-100% of material to pass. The maximum dimeter will be used in these calculations.

Gravel diameter = d_a = 1.5 in (Reference 7)

3.2 Construction Equipment

A Bobcat skid-steer (or similar) will be allowed above the liner. Its use will be limited to spreading gravel, and it will never drive on less than 0.5 feet of gravel. Information regarding the weight and balance of the assumed Bobcat model T550 skid-steer was obtained from Cat's website.

Bobcat ground pressure = p_{bobcat}` = 5.8 psi (Reference 3)

A dozer could potentially be used for spreading gravel. A Cat D6 dozer ground pressure is obtained from Cat's website.

Dozer ground pressure = p_{dozer}` = 7.9 psi (Reference 8)

The maximum ground pressure of the construction equipment will be used in the following calculations.

Equipment ground pressure = p` = MAX($p_{bobcat}$`, p_{dozer}`) = 7.9 psi

4.0 ASSUMPTIONS

No assumptions have been made in this calculation.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Calculations are checked using a handheld calculator.

6.0 RESULTS

A summary of results is shown below.

Item	Parameter	DCR	Remark
Geotextile	Burst	0.061	
	Tensile	0.008	
	Puncture	0.081	

A summary of material requirements is shown below.

Item	Parameter	Requirement
Geotextile	Burst	N/A
	Tensile	N/A - Tension will be controlled by liner stress in Calculation S54413.024-C-004 / RPP-CALC-63748 Rev. 0
	Puncture	700 lbs (ASTM D6241)

The burst and tensile forces acting on the geotextile are negligible compared to the capacities of the HDPE liner. The puncture force calculated in Section 8.3 (56.45 lbs, ASTM D4833) is less than the required HDPE material strength of 108 lbs given in the specifications. The required strengths of the HDPE liner will be controlled by Calculation S54413.024-C-004 / RPP-CALC-63748 Rev. 0, *Side Slope Liner Stresses*.

7.0 REFERENCES

1) Koerner, Robert M., *Designing with Geosynthetics*, 6th Edition

2) Tencate geotextile cut sheets.

3) Bobcat S740 Skid-steer Specifications

4) Geosynthetic Institute, GRI Test Method GT12(a) – ASTM Version, *Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials*

5) Elhajjar, Rani, Hani H. Titi, Stacy Van Dyke, and Hamid Erfanian, *Correlation of ASTM D4833 and D6241 Geotextile Puncture Test Methods and Results for Use on WisDOT Projects*, 2017

6) H-2-838749, Sheet 1, Rev. 0, LERF Basin 41 Civil Secondary Liner

7) RPP-SPEC-63632, Rev. 0, LERF Basin 41 Design Construction Specification

8) CAT D6 Dozer Specifications

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 8 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

8.0 CALCULATIONS

8.1 Burst Resistance (Ref. 1, Section 2.5.2):

Section 2.5.2 in Reference 1 discusses geotextiles to be used as a soil separator. The below calculation will be compared to ASTM D3786 (Mullen Burst Strength) because "the field situation is analogous to the ASTM D3786 (Mullen) burst test…" according to Reference 1, Page 178.

The below equation is from Reference 1, Attachment 1, Page 179.

$$FS = (p_{test} \times d_{test}) / (\Pi RF \times p` \times d_v)$$

Where the below values are defined on Reference 1, Attachment 1, Pages 178 and 179, unless noted:

FS = factor of safety for burst resistance

d_v = the maximum void diameter in between individual stones
$\approx 0.33 \times d_a = 0.33 \times 1.5$ in = 0.495 in

d_{test} = the diameter of the burst test device = 30 mm

ΠRF = cumulative reduction factors = 2.5 (Reference 1, Attachment 1, Table 2.8a, Page 175, max. value for Separation – Installation Damage)

p_{test} = burst pressure of the geotextile at failure

The above equation can be rewritten to solve for p_{test} which will result in the geotextiles burst strength:

$$p_{test} = (FS \times \Pi RF \times p` \times d_v) / (d_{test})$$

The factor of safety will be determined once the required and allowable strengths have been determined, therefore set FS = 1.

$$p_{test} = (FS \times \Pi RF \times p` \times d_v) / (d_{test}) = (1 \times 2.5 \times 7.9 \text{ psi} \times 0.495 \text{ in}) / (1.181 \text{ in}) = 8.28 \text{ psi}$$

Reference 2 provides several cut sheets of geotextiles. The Mullen Burst Strength of a typical geotextile subjected to the Mullen Burst Test has a strength of 135 psi – 740 psi (ASTM D3786). Conservatively use a strength of 135 psi.

$$DCR = p_{test} / 135 \text{ psi} = 8.28 \text{ psi} / 135 \text{ psi} = 0.061$$

Although the Mullen Burst Strength is not a common test method for geotextiles anymore, the resulting DCR demonstrates the geotextiles ability to resist bursting under the applied loads.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 9 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

8.2 Tensile Strength Requirements (Ref. 1, Section 2.5.3):

Section 2.5.3 in Reference 1 discusses the tensile stress in geotextile that can develop when voids are present in between stones on top of the geotextile. See Figure 2.23 below from Reference 1, Page 182.

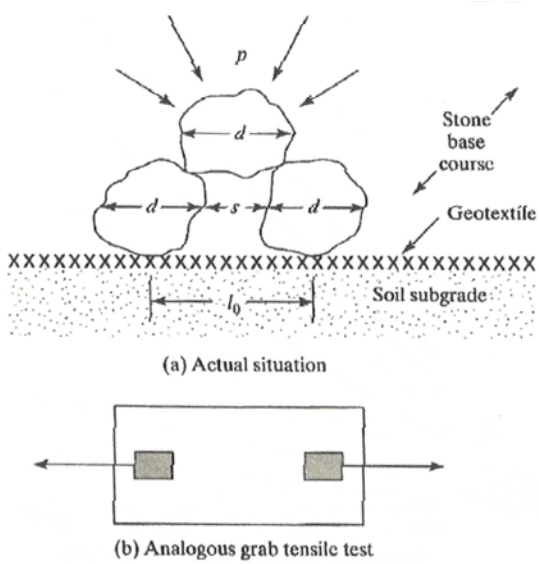

Figure 2.23 Geotextile being subjected to tensile stress as surface pressure is applied and stone base attempts to spread laterally.

The required strength of the geotextile will be based on Equation 2.29 from Reference 1, Page 182:

$T_{reqd} = p` \times d_v^2 \times f(\varepsilon)$

Where:

p` is defined in Section 3.2

d_v is defined in Section 8.1

f(ε) is the geotextiles strain function. A consistent minimum elongation is 0.50 (Reference 2). Example 2.9 in Reference 1, Page 183 used f(ε)=0.52. Set f(ε)=1.0 to be conservative.

$T_{reqd} = p` \times d_v^2 \times f(\varepsilon) = 7.9 \text{ psi} \times (0.495 \text{ in})^2 \times 1.0 = 1.94 \text{ lbs}$

The required grab tensile strength is 230 lbs (Reference 4, Table 1a) for a 10 oz/sy geotextile.

DCR = 1.94 lbs / 230 lbs = 0.008

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 10 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

8.3 Puncture Strength Requirements (Ref. 1, Section 2.5.4):

Section 2.5.4 in Reference 1 discusses the required puncture resistance of the geotextile. The puncture resistance of a geotextile is important to prevent damage to the geotextile from small object, stones, etc, that may be pressed against the geotextile. This is illustrated below in Figure 2.24 from Reference 1, Page 184.

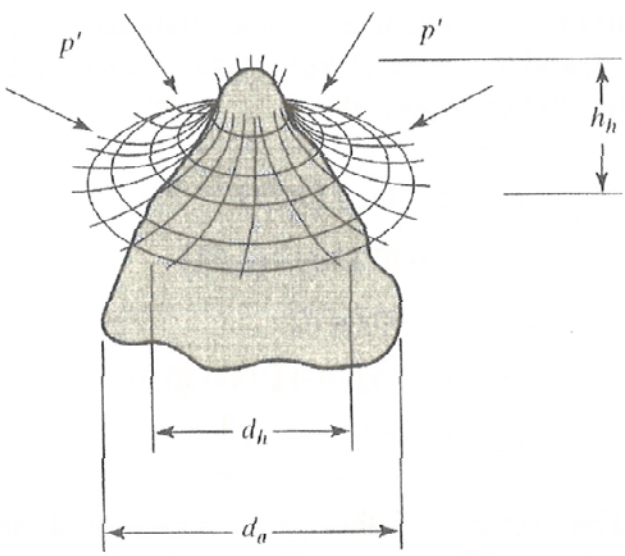

Figure 2.24 Visualization of a stone puncturing a geotextile as pressure is applied from above.

The required puncture strength of the geotextile is determined by Equation 2.30 from Reference 1, Page 184:

$F_{req} = p` \times d_a^2 \times S_1 \times S_2 \times S_3$

Where:

p` is defined in Section 3.2

d_a is defined in Section 3.1

S_1 is a "protrusion factor of the puncturing object," defined in Table 2.9 in Reference 1, Page 185.

S_2 is a "scale factor to adjust the ASTM D4833 puncture test value that uses an 8.0 mm diameter puncture probe to the actual puncturing object," defined in Table 2.9 in Reference 1, Page 185.

S_3 is a "shape factor to adjust the ASTM D4833 flat puncture probe to the actual shape of the puncturing object," defined in Table 2.9 in Reference 1, Page 185.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 11 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Table 2.9 from Reference 1, Page 185 is shown below:

TABLE 2.9 RECOMMENDED VALUES FOR INDEPENDENT FACTORS USED IN PUNCTURE ANALYSIS (DIMENSIONLESS)

Puncturing Object	S_1	S_2	S_3
angular & relatively large	0.9	0.8	0.9
angular & relatively small	0.6	0.6	0.7
subrounded & relatively large	0.7	0.6	0.6
subrounded & relatively small	0.4	0.4	0.5
rounded & relatively large	0.5	0.4	0.4
rounded & relatively small	0.2	0.2	0.3

S_1 = protrusion factor
S_2 = scale factor
S_3 = shape factor
} see Eq. 2.30

The values for S_1, S_2, and S_3 will conservatively be taken as the values for a puncturing object that is "angular & relatively large."

$S_1 = 0.9$

$S_2 = 0.8$

$S_3 = 0.9$

The required puncture strength is:

$F_{req} = p` \times d_a^2 \times S_1 \times S_2 \times S_3 = 7.9 \text{ psi} \times (1.5 \text{ in})^2 \times 0.9 \times 0.8 \times 0.9 = 11.52 \text{ lbs}$

The required puncture strength calculated above is for use with ASTM D4833. Current industry practice uses ASTM D6241 more commonly, however there is not a one-to-one correlation between the two ASTM methods. A correlation between the two ASTM methods is developed in Reference 5.

$F_{req_CBR} = 4.90 \times F_{req} = 4.90 \times 11.52 \text{ lbs} = 56.45 \text{ lbs}$

The required geotextile puncture strength in accordance with ASTM D6241 is 700 lbs.

DCR = 56.45 lbs / 700 lbs = 0.081

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 12 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 1 – DESIGN WITH GEOSYNTHETICS, 6TH EDITION

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.**	0	**Page No.**	13 of 51
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection						
Prepared By:	G. Taylor Grant	**Date:**	04/08/2020	**Checked By:**	Darrel J. Packard	**Date:**	04/09/2020

modified for the anticipated in-situ conditions. This could be done directly in the test procedure, for example by conducting a completely simulated performance test; but in most cases, this simply is not possible. Simulating installation damage, performing long-term creep testing, using site-specific liquids, reproducing in-situ pore water stresses, providing complete stress state modeling, and so on are generally not feasible. To account for such differences between the laboratory measured test value and the desired performance value, two approaches can be taken:

1. Require an extremely high factor of safety at the end of a problem.
2. Use reduction factors on the laboratory-generated test value to make it into a site-specific allowable value.

At the suggestion of Voskamp and Risseeuw [66], the latter alternative of *reduction factors* (RF values) will be used in this book. By doing this, the usual value of factor of safety can be assessed in the final analysis. Our approach will be to refer to the general laboratory-obtained value as an "ultimate" value and to modify it by reduction factors to obtain an "allowable" value. See [67] for additional rationale and numeric values.

2.4.1 Strength Related Problems

For problems dealing with geotextile strength, such as in separation and reinforcement applications, the formulation of the allowable values takes the form of equation 2.24a. Typical ranges of values for reduction factors for different applications are given in table 2.8a. These values must be tempered by the site-specific considerations. Also, note that if the laboratory test includes the mechanism listed, it would appear in the equation as a value of 1.0.

$$T_{allow} = T_{ult}\left(\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CBD}}\right) \tag{2.24a}$$

$$T_{allow} = T_{ult}\left(\frac{1}{\Pi RF}\right) \tag{2.24b}$$

TABLE 2.8a RECOMMENDED STRENGTH REDUCTION FACTOR VALUES FOR USE IN EQ. 2.24a

Area	Range of Reduction Factors		
	Installation Damage	Creep*	Chemical/Biological Degradation**
Separation	1.1 to 2.5	1.5 to 2.5	1.0 to 1.5
Cushioning	1.1 to 2.0	1.2 to 1.5	1.0 to 2.0
Unpaved roads	1.1 to 2.0	1.5 to 2.5	1.0 to 1.5
Walls	1.1 to 2.0	2.0 to 4.0	1.0 to 1.5
Embankments	1.1 to 2.0	2.0 to 3.5	1.0 to 1.5
Bearing and foundations	1.1 to 2.0	2.0 to 4.0	1.0 to 1.5
Slope stabilization	1.1 to 1.5	2.0 to 3.0	1.0 to 1.5
Pavement overlays	1.1 to 1.5	1.0 to 2.0	1.0 to 1.5
Railroads (filter/sep.)	1.5 to 3.0	1.0 to 1.5	1.5 to 2.0
Flexible forms	1.1 to 1.5	1.5 to 3.0	1.0 to 1.5
Silt fences	1.1 to 1.5	1.5 to 2.5	1.0 to 1.5

*The low end of the range refers to applications which have relatively short service lifetimes and/or situations where creep deformations are not critical to the overall system performance.
**Previous editions of this book have listed biological degradation as a separate reduction factor. As described in Section 2.3.6, however, there is no evidence of such degradation for the polymers used to manufacture geotextiles.

where
T_{allow} = allowable tensile strength,
T_{ult} = ultimate tensile strength,
RF_{ID} = reduction factor for installation damage (≥ 1.0),
RF_{CR} = reduction factor for creep (≥ 1.0),
RF_{CBD} = reduction factor for chemical and biological degradation (≥ 1.0), and
ΠRF = value of cumulative reduction factors (≥ 1.0).

Note that equation 2.24a could have included additional site-specific terms, such as reduction factors for seams and for intentionally made holes. It also could have been formulated with fractional multipliers (values ≤ 1.0) and placed in the numerator of the equation or on the opposite side of the equation as with the *load and reduction factor design method* (LRFD). While the equation indicates tensile strength, it can be applied to burst strength, tear strength, puncture strength, impact strength, and so on.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.**	0	**Page No.** 14 of 51	
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection						
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020

2.4.2 Flow Related Problems

For problems dealing with flow through or within a geotextile, such as filtration and drainage applications, the formulation of the allowable values takes the form of equation 2.25a. Typical values for reduction factors are given in table 2.8b. Note that these values must be tempered by the site-specific conditions as in section 2.4.1. If the laboratory test includes the mechanism listed, it would appear in the equation as a value of 1.0.

$$q_{allow} = q_{ult}\left(\frac{1}{RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}}\right) \quad (2.25a)$$

$$q_{allow} = q_{ult}\left(\frac{1}{\Pi RF}\right) \quad (2.25b)$$

where

q_{allow} = allowable flow rate,
q_{ult} = ultimate flow rate,
RF_{SCB} = reduction factor for soil clogging and blinding (≥ 1.0),
RF_{CR} = reduction factor for creep reduction of void space (≥ 1.0),
RF_{IN} = reduction factor for adjacent materials intruding into geotextile's void space (≥ 1.0),
RF_{CC} = reduction factor for chemical clogging (≥ 1.0),
RF_{BC} = reduction factor for biological clogging (≥ 1.0), and
ΠRF = value of cumulative reduction factors (≥ 1.0).

TABLE 2.8b RECOMMENDED FLOW REDUCTION FACTOR VALUES FOR USE IN EQUATION 2.25a

Application	Range of Reduction Factors				
	Soil Clogging and Blinding*	Creep Reduction of Voids	Intrusion into Voids	Chemical Clogging**	Biological Clogging***
Retaining wall filters	2.0 to 4.0	1.5 to 2.0	1.0 to 1.2	1.0 to 1.2	1.0 to 1.3
Underdrain filters	2.0 to 10	1.0 to 1.5	1.0 to 1.2	1.2 to 1.5	2.0 to 4.0***
Erosion control filters	2.0 to 10	1.0 to 1.5	1.0 to 1.2	1.0 to 1.2	2.0 to 4.0
Landfill filters	2.0 to 10	1.5 to 2.0	1.0 to 1.2	1.2 to 1.5	2.0 to 5.0***
Gravity drainage	2.0 to 4.0	2.0 to 3.0	1.0 to 1.2	1.2 to 1.5	1.2 to 1.5
Pressure drainage	2.0 to 3.0	2.0 to 3.0	1.0 to 1.2	1.1 to 1.3	1.1 to 1.3

*If stone rip-rap or concrete blocks cover the surface of the geotextile use either the upper values, orinclude an addition reduction factor.
**Values can be higher particularly for high alkalinity groundwater.
***Values can be higher for extremely high microorganism content and/or growth of organisms and plant/vegetation roots.

As with the equation 2.24 for strength reduction, this flow reduction equation could also have additional site-specific terms included, e.g., blocking of a portion of the geotextile's surface by rip-rap or concrete blocks.

2.5 DESIGNING FOR SEPARATION

Application areas for geotextiles used for the separation function were given in section 1.3.3. There are indeed many specific applications, and it could said, in a general sense, that geotextiles always serve a separation function. If they do not serve this function, any other function, including the primary function, will not be served properly. This should not give the impression that the geotextile function of separation always play a secondary role. Many situations call for separation only, and in such cases the geotextiles do serve a significant and worthwhile purpose.

2.5.1 Separation Applications

There are many geotextile applications where separation is the major function. Certainly, the use of thick and heavy geotextiles used to cushion geomembranes against stone puncture falls into this category. Since it is geomembrane-related it will be addressed in chapter 5. A much more common application that best illustrates the use of geotextiles as separators is its placement between a reasonably firm soil subgrade (beneath) and a stone base course, aggregate, or ballast (above). We say "reasonably firm" because it is assumed that the subgrade deformation is not sufficiently large to mobilize uniformly high-tensile stress in the geotextile. (The application of geotextiles in unpaved roads on soft soils with membrane-type reinforcement is treated later in section 2.6.1.) Thus, for a separation function to occur, the geotextile has only to be placed on the soil subgrade and then have stone placed, spread, and compacted on top of it. The subsequent deformations are very localized and occur around each individual stone particle. A number of design scenarios can be developed showing what geotextile properties are required for this type of situation.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.**	0	**Page No.** 15 of 51	
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection						
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020

2.5.2 Burst Resistance

Consider a geotextile on a soil subgrade with stone of average particle diameter (d_a) placed above it. If the stone is uniformly sized, there will be voids within it that will be available for the geotextile to enter. This entry is caused by the simultaneous action of the traffic loads being transmitted to the stone, through the geotextile, and into the underlying soil. The stressed soil then tries to push the geotextile up into the voids within the stone. The situation is shown schematically in figure 2.21. Giroud [68] provides a formulation for the required geotextile strength that can be adopted for this application.

$$T_{reqd} = \frac{1}{2} p' d_v [f(\varepsilon)] \tag{2.26}$$

where

T_{reqd} = required geotextile strength,
p' = stress on the geotextile that is slightly less than, p, the tire inflation pressure at the ground surface,
d_v = maximum void diameter of the stone $\cong 0.33 d_a$,
d_a = the average stone diameter,
$f(\varepsilon)$ = strain function of the deformed geotextile $= \frac{1}{4}\left(\frac{2y}{b} + \frac{b}{2y}\right)$, in which
b = width of opening (or void)
y = deformation into the opening (or void)

The field situation is analogous to the ASTM D3786 (Mullen) burst test, which has the geotextile being stressed into a gradually increasing hemispherical shape until it fails (recall section 2.3.3). Thus, the adapted form of equation 2.26 is as follows:

$$T_{ult} = \frac{1}{2} p_{test} d_{test} [f(\varepsilon)] \tag{2.27}$$

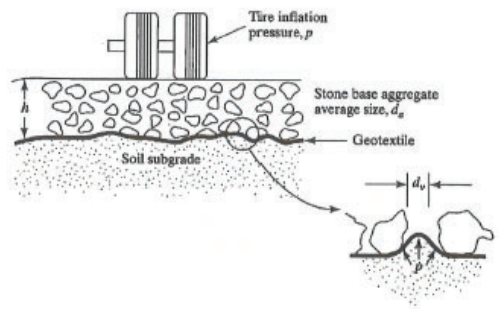

Figure 2.21 Geotextile being forced up into voids of stone base by traffic tire loads.

where

T_{ult} = ultimate geotextile strength,
p_{test} = burst pressure of the geotextile at failure (its strength), and
d_{test} = diameter of the burst test device (= 30 mm).

Knowing that $T_{allow} = T_{ult}/(\Pi RF)$, where ΠRF = cumulative reduction factors, we can formulate an expression for the factor-of-safety (FS) as follows:

$$FS = \frac{T_{allow}}{T_{reqd}} = \frac{(p_{test}\ d_{test})}{(\Pi RF) p' d_v}$$

For example, if d_{test} = 30 mm; $d_v = 0.33\ d_a$; and $\Pi RF = 1.5$ (which is reasonable since creep is not an issue with this application), then the FS value is the following, with d_a in units of mm.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.** 0	**Page No.** 16 of 51
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection				
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020	

$$FS = \frac{p_{test}(30)}{(1.5)p'(0.33d_a)}$$

$$FS = \frac{60.6p_{test}}{p'd_a} \qquad (2.28)$$

Example 2.8:

Given a truck with 700 kPa tire inflation pressure on a poorly graded aggregate layer consisting of 50 mm maximum-size stone. What is the factor of safety using a geotextile beneath the aggregate having an ultimate burst strength of 2000 kPa and cumulative reduction factors of 1.5.

Solution: Assuming that the tire inflation pressure is not significantly reduced through the thickness of the stone base, we can solve equation 2.28 as follows:

$$FS = \frac{60.6(2000)}{700(50)}$$

$$FS = 3.5$$

Note that with the reduction factors of 1.5 already included, the resulting factor of safety value is acceptable.

For a range of stone base particle diameters (d_a), values of tire inflation pressure (p'), and cumulative reduction factors of 1.5, along with a factor of safety of 2.0, we can generate the design guide in figure 2.22. Here it can be seen that stone size is quite significant insofar as the required burst pressure values are concerned. Note also that these are poorly graded aggregates and that the presence of fines will lessen the severity of the design; hence this approach should be considered to be a worst-case design.

2.5.3 Tensile Strength

Continuing the discussion of geotextile roadway separation, there are other processes acting on the geotextile simultaneous as its

tendency to burst in an out-of-plane mode. One of these is tensile stress being mobilized by in-plane deformation. This occurs as the geotextile is locked into position by stone-base aggregate above it and soil subgrade below it. A lateral, or in-plane, tensile stress in the geotextile is mobilized when an upper piece of aggregate is forced between two lower pieces that are in contact with the geotextile. The analogy to the grab tensile test can be readily visualized, as illustrated in figure 2.23. Here we can estimate the maximum strain that the geotextile will undergo as the upper stone wedges itself down to the level of the geotextile. Using the dimensions shown (where $S \simeq d/2$ and l_f = deformed geotextile length), the maximum strain with no slippage nor stone breakage can be calculated.

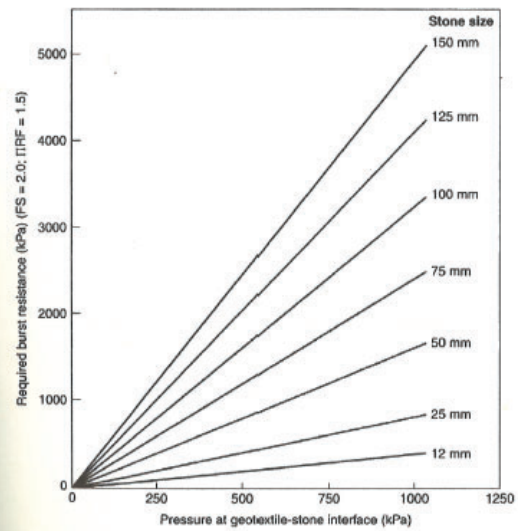

Figure 2.22 Design guide for burst analysis of geotextile used in a separation function based on cumulative reduction factors of 1.5 and a factor of safety of 2.0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.**	0	**Page No.** 17 of 51	
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection						
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020

$$\varepsilon = \frac{l_f - l_o}{l_o}(100)$$
$$= \frac{[d + 2(d/2)] - 3(d/2)}{3(d/2)}(100)$$
$$= \frac{4(d/2) - 3(d/2)}{3(d/2)}(100)$$
$$\varepsilon = 33\%$$

Note that the preceding assumptions result in a strain that is independent of particle size. Thus, the strain in the geotextile could be as high as 33% given the idealized (upper bound) assumptions stated above. Now the tensile force being mobilized is related to the pressure exerting on the stone as follows [68]:

$$T_{reqd} = p'(d_v)^2\,[f(\varepsilon)] \tag{2.29}$$

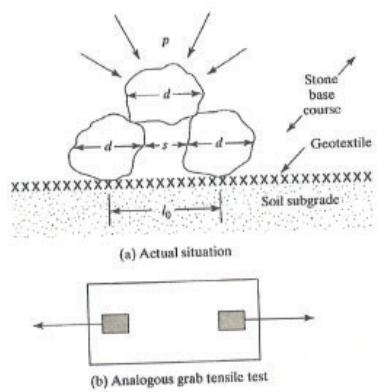

Figure 2.23 Geotextile being subjected to tensile stress as surface pressure is applied and stone base attempts to spread laterally.

where

T_{reqd} = required grab tensile force,
p' = applied pressure,
d_v = maximum void diameter $\simeq 0.33\,d_a$, where
d_a = average stone diameter, and
$f(\varepsilon)$ = strain function of the deformed geotextile
$= \frac{1}{4}\left(\frac{2y}{b} + \frac{b}{2y}\right)$, where
b = width of stone void, and
y = deformation into stone void.

Example 2.9:

Given a truck with 700 kPa tire inflation pressure on a stone base course consisting of 50 mm maximum-size stone with a geotextile beneath it. Calculate (a) the required grab tensile stress on the geotextile, and (b) the factor of safety for a geotextile whose grab strength at 33% is 500 N with cumulative reduction factors of 2.5. Use a value of f(ε) = 0.52.

Solution: (a) Using an empirical relationship that $d_v = 0.33\,d_a$ and the value of $f(\varepsilon) = 0.52$, the required grab tensile strength is as follows:

$$T_{reqd} = p'(d_v)^2(0.52)$$
$$= p'(0.33d_a)^2(0.52)$$
$$= 0.057\,p'd_a^2$$
$$= 0.057(700)(1000)(0.050)^2$$
$$T_{reqd} = 100N$$

(b) The factor of safety on a 500 N grab tensile geotextile at 33% strain with reduction factors of 2.5 is as follows:

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.**	0	**Page No.** 18 of 51	
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection						
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020

$$FS = \frac{T_{allow}}{T_{reqd}}$$

$$= \frac{500/2.5}{100}$$

$FS = 2.0$, *which is acceptable.*

2.5.4 Puncture Resistance

The geotextile must always survive the installation process. This is not just related to the roadway separation function; indeed, fabric survivability is critical in all types of applications; without it the best of designs are futile (recall figure 2.18). In this regard, sharp stones, tree stumps, roots, miscellaneous debris, and other items, either on the ground surface beneath the geotextile or placed above it, could puncture through the geotextile during backfilling and when traffic loads are imposed. The design method suggested for this situation is shown schematically in figure 2.24. For these conditions, the vertical force exerted on the geotextile (which is gradually tightening around the protruding object) is as follows:

$$F_{reqd} = p' d_a^2 S_1 S_2 S_3 \tag{2.30}$$

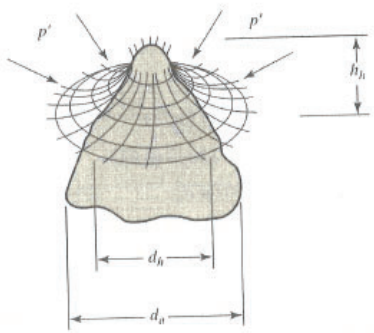

Figure 2.24 Visualization of a stone puncturing a geotextile as pressure is applied from above.

where

F_{reqd} = required vertical puncturing force to be resisted,
d_a = average diameter of the puncturing aggregate or sharp object,
p' = pressure exerted on the geotextile (approximately 100% of tire inflation pressure at the ground surface for thin covering thicknesses),
S_1 = protrusion factor of the puncturing object (see table 2.9),
S_2 = scale factor to adjust the ASTM D4833 puncture test value that uses a 8.0 mm diameter puncture probe to the actual puncturing object (see table 2.9),
S_3 = shape factor to adjust the ASTM D4833 flat puncture probe to the actual shape of the puncturing object (see table 2.9).

TABLE 2.9 RECOMMENDED VALUES FOR INDEPENDENT FACTORS USED IN PUNCTURE ANALYSIS (DIMENSIONLESS)

Puncturing Object	S_1	S_2	S_3
angular & relatively large	0.9	0.8	0.9
angular & relatively small	0.6	0.6	0.7
subrounded & relatively large	0.7	0.6	0.6
subrounded & relatively small	0.4	0.4	0.5
rounded & relatively large	0.5	0.4	0.4
rounded & relatively small	0.2	0.2	0.3

S_1 = protrusion factor
S_2 = scale factor
S_3 = shape factor
} see Eq. 2.30

Example 2.10:

What is the factor of safety against puncture of a geotextile from a subrounded 25 mm diameter stone on the ground surface mobilized by a loaded truck with tire inflation pressure of 550 kPa traveling on the surface of the base course? The geotextile has an ultimate puncture strength of 300 N according to ASTM D4833.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 19 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 2 – GEOTEXTILE CUT SHEETS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 20 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TENCATE Mirafi®

TENCATE GEOSYNTHETICS
Americas

Mirafi® S1000

Drainage Separation

Mirafi® S1000 is a needlepunched nonwoven geotextile composed of polypropylene fibers, which are formed into a stable network such that the fibers retain their relative position. Mirafi® S1000 is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids.

TenCate Geosynthetics Americas Laboratories are accredited by Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP).

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value
Weight	ASTM D5261	oz/yd² (g/m²)	10.0 (339)
Thickness	ASTM D5199	mils (mm)	115 (2.9)
Grab Tensile Strength	ASTM D4632	lbs (N)	270 (1202)
Grab Tensile Elongation	ASTM D4632	%	50
Trapezoid Tear Strength	ASTM D4533	lbs (N)	105 (467)
CBR Puncture Strength	ASTM D6241	lbs (N)	725 (3226)
			Minimum Roll Value
Permittivity	ASTM D4491	sec⁻¹	1.2
Permeability	ASTM D4491	cm/sec	0.32
Flow Rate	ASTM D4491	gal/min/ft² (l/min/m²)	85 (3463)
			Maximum Opening Size
Apparent Opening Size (AOS)	ASTM D4751	U.S. Sieve (mm)	100 (0.15)
			Minimum Test Value
UV Resistance (at 500 hours)	ASTM D4355	% strength retained	80

Physical Properties	Unit	Roll Size
Roll Dimensions (width x length)	ft (m)	15 x 300 (4.5 x 91)
Roll Area	yd² (m²)	500 (418)

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FGS000384
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Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 21 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TENCATE Mirafi

Mirafi® 180N

Mirafi® 180N is a nonwoven geotextile composed of polypropylene fibers, which are formed into a stable network such that the fibers retain their relative position. 180N is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids.

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Grab Tensile Strength	ASTM D 4632	kN (lbs)	0.9 (205)	0.9 (205)
Grab Tensile Elongation	ASTM D 4632	%	50	50
Trapezoid Tear Strength	ASTM D 4533	kN (lbs)	0.36 (80)	0.36 (80)
Mullen Burst Strength	ASTM D 3786	kPa (psi)	2618 (380)	
Puncture Strength[1]	ASTM D 4833	kN (lbs)	0.58 (130)	
CBR Puncture Strength	ASTM D 6241	kN (lbs)	2.22 (500)	
Apparent Opening Size (AOS)	ASTM D 4751	mm (U.S. Sieve)	0.180 (80)	
Permittivity	ASTM D 4491	sec^{-1}	1.2	
Permeability	ASTM D 4491	cm/sec	0.21	
Flow Rate	ASTM D 4491	$l/min/m^2$ ($gal/min/ft^2$)	3866 (95)	
UV Resistance (at 500 hours)	ASTM D 4355	% strength retained	70	

[1] ASTM D 4833 has been replaced with ASTM D 6241

Physical Properties	Test Method	Unit	Typical Value
Weight	ASTM D 5261	g/m^2 (oz/yd^2)	278 (8.2)
Thickness	ASTM D 5199	mm (mils)	2.1 (82.5)
Roll Dimensions (width x length)	--	m (ft)	4.5 x 91 (15 x 300)
Roll Area	--	m^2 (yd^2)	418 (500)
Estimated Roll Weight	--	kg (lb)	124 (273)

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TENCATE materials that make a difference

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 22 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TENCATE Mirafi®

FILTRATION PROTECTION

Mirafi® S-Series Nonwoven Polypropylene Geotextiles

for geomembrane liner protection, landfill gas collection, and landfill drainage systems

Mirafi® S-Series Nonwoven Geotextiles

TenCate® develops and produces materials that function to increase performance, reduce costs and deliver measurable results by working with our customers to provide advanced solutions.

The Difference Mirafi® S-Series Nonwoven Geotextiles Make:

- Construction. Mirafi® S-Series polypropylene nonwoven geotextiles easily conform to the ground or trench surface for trouble-free installation.
- Strength. Mirafi® S-Series geotextiles withstand installation stresses with high puncture and tear resistance.
- Drainage. High permittivity properties provide high water flow rates while providing excellent soil retention.
- Environmental. Mirafi® S-Series geotextiles are chemically stable in a wide range of aggressive environments.
- Cost Effective. Mirafi® S-Series geotextiles provide economical solutions to many civil engineering applications including a cost-effective alternative to graded-aggregate filters.

APPLICATIONS

Mirafi® S-Series nonwoven geotextiles are used in a wide variety of applications in the environmental market. These include separation, filtration, and protection applications.

Mirafi® S-Series nonwovens are used in critical subsurface drainage systems, soil separation, permanent erosion control, HDPE and other geomembranes in landfill construction. These geotextiles provide the required puncture strength and abrasion resistance to withstand installation and application stresses to create an effective long-term solution. Other applications for Mirafi® S-Series nonwovens in landfill applications include leachate collection/removal systems and for gas collection and venting systems.

Nonwoven geotextiles play a critical role in the collection of liquids in waste containment systems. The nonwoven geotextiles prevent clogging of the collection pipes and drainage aggregates. The successful removal of these liquids is critical to the performance of the landfill site. Mirafi® S-Series geotextiles assist in maintaining an outlet for gases to escape from below the liner systems. Gases may also travel within the nonwoven fabrics laterally until it reaches a vent. For these collection systems to be effective, they must have a properly designed protective filter. Mirafi® S-Series Nonwoven Geotextiles allow designers flexibility in finding an economic source of a specific aggregate gradation and assuring that the in-place aggregate provides effective filter performance.

INSTALLATION GUIDELINES*

Mirafi® S-Series should be handled and deployed in a way that prevents damage to the geotextile. The subgrade surface should be even and free of debris of any kind. Adjacent panels of Mirafi® S Series geotextile shall be overlapped, sewn or heat-seamed unless another method of seaming is specified by the engineer. It is important that overlapped panels of nonwoven geotextile be continuously joined to prevent any migration of soil through the overlaps. Overlap requirements for Mirafi® S-Series geotextiles should be specified by the project engineer or agency or follow the most current AASHTO M288 geotextile installation guidelines in absence of project specifications. In windy conditions, the outside edges of deployed panels of Mirafi® S-Series geotextile should be weighted down with sandbags or an equivalent manner as directed by the project engineer or agency. The sandbags should remain in place until the adjacent geotextile panel is fastened or until an overlying layer of material is placed.

* These guidelines serve as a general basis for installation. Detailed instructions are available from your TenCate® representative.

Protective & Outdoor Fabrics
Aerospace Composites
Armour Composites
Geosynthetics
Industrial Fabrics
Synthetic Grass

TENCATE materials that make a difference

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 23 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TENCATE Mirafi®

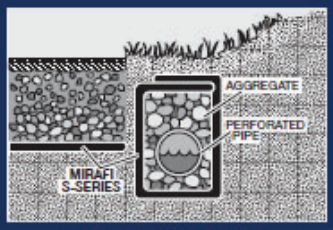
Mirafi® S-Series Nonwoven Polypropylene Geotextiles

for geomembrane liner protection, landfill gas collection, and landfill drainage systems

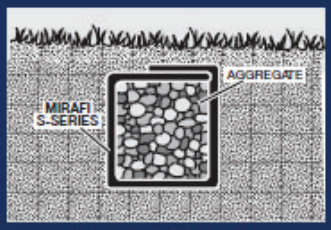
Property / Test Method	Units	S600	S800	S1000	S1200	S1600
MECHANICAL PROPERTIES						
Weight	oz/yd²	6	8	10	12	16
ASTM D5261	(g/m²)	(203)	(271)	(339)	(407)	(542)
Thickness	mils	80	90	115	130	175
ASTN D5199	(mm)	(2.0)	(2.3)	(2.9)	(3.3)	(4.4)
Grab Tensile Strength	lbs	170	230	270	320	425
ASTM D4632	(N)	(757)	(1024)	(1202)	(1424)	(1891)
Grab Tensile Elongation	%	50	50	50	50	50
ASTM D4632						
Trapezoid Tear Strength	lbs	70	95	105	125	155
ASTM D4533	(N)	(312)	(423)	(467)	(556)	(690)
CBR Puncture Strength	lbs	450	600	725	900	1200
ASTM D6241	(N)	(2003)	(2670)	(3226)	(4005)	(5340)
UV Resistance after 500 hrs.	% strength	80	80	80	80	80
ASTM D4355						
HYDRAULIC PROPERTIES						
Apparent Opening Size (AOS)	US Sieve	80	100	100	100	100
ASTM D4751	(mm)	(0.18)	(0.15)	(0.15)	(0.15)	(0.15)
Permittivity	sec⁻¹	1.5	1.4	1.2	0.9	0.7
ASTM D4491						
Flow Rate	gal/min/ft²	110	110	85	65	50
ASTM D4491	(l/min/m²)	(4481)	(4481)	(3463)	(2648)	(2037)
Packaging						
Roll Width	ft (m)	15 (4.5)	15 (4.5)	15 (4.5)	15 (4.5)	15 (4.5)
Roll Length	ft (m)	300 (91)	300 (91)	300 (91)	300 (91)	300 (91)
Area	yd² (m²)	500 (418)	500 (418)	500 (418)	500 (418)	500 (418)

Values and methods could change without notice

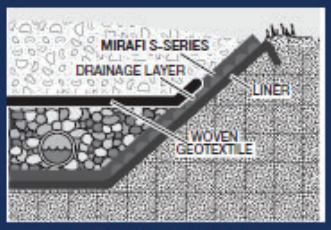
Mirafi® S-Series Nonwoven Geotextiles



Cut-off/Interceptor Drain



French Drain Without Pipe



Liner Protection Within a Landfill

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 24 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

GEOSYNTHETICS

Mirafi® N-Series Nonwoven Polypropylene Geotextiles

For Soil Separation, Filtration and Protection

Ten Cate Nicolon

DESCRIPTION
Drainfield 3' x 360' (1,080 sq-ft.)
Drainfield 4' x 360' (1,440 sq-ft.)
135N – 3' x 360' (1,080 sq-ft.) - 3 oz.
140NL – 12.5' x 360' (4,500 sq-ft.) - 3.8 oz. 157-140NL125
140NL – 15' x 360' (5,400 sq-ft.) - 3.8 oz. 157-140NL15
140NC – 12.5' x 360' (4,500 sq-ft.) - 4 oz. 157-140NC125
140NC – 15' x 360' (5,400 sq-ft.) - 4 oz. 157-140NC15
140N – 12.5' x 360' (4,500 sq-ft.) - 4.5 oz. 157-140N125
140N – 15' x 360' (5,400 sq-ft.) - 4.5 oz. 157-140N15
160N – 15' x 300' (4,500 sq-ft.) - 6 oz. 157-160N15
170N - 15' x 300' (4,500 sq-ft.) - 7 oz. 157-170N15
180N – 15' x 300' (4,500 sq-ft.) - 8 oz. 157-180N15
1100N – 15' x 300' (4,500 sq-ft.) - 10 oz. 157-1100N15
1120N – 15' x 300' (4,500 sq-ft.) - 12 oz. 157-1120N
1160N – 15' x 150' (2,250 sq-ft.) - 16 oz. 157-1160N

CUSTOM SIZES AVAILABLE BY SPECIAL ORDER

PRODUCT DESCRIPTION

Mirafi N-Series products are nonwoven geotextiles comprised of polypropylene staple fibers. Mirafi N-Series Nonwoven Polypropylene Geotextiles provide excellent physical and hydraulic properties in addition to high tensile strengths.

FEATURES AND BENEFITS

- **Construction.** Mirafi N-Series geotextiles easily conform to the ground or trench surface for trouble-free installation.
- **Strength.** Mirafi N-Series geotextiles withstand severe installation stresses with high puncture and burst resistance.
- **Filtration.** High permeability properties provide high water flow rates while providing excellent filtration properties.
- **Environmental.** Mirafi N-Series geotextiles are chemically stable in a wide range of aggressive environments.
- **Cost effective.** Mirafi N-Series geotextiles provide economical solutions to many civil engineering applications including a cost-effective alternative to graded-aggregate filters.

APPLICATIONS

Mirafi N-Series Nonwovens are used in a wide variety of applications including separation, filtration, and protection applications.

Lightweight nonwovens are predominantly used for subsurface drainage applications along highways, within embankments, under airfields, and athletic fields. For these drainage structures to be effective, they must have a properly designed protective filter. Mirafi N-Series Nonwoven Geotextiles eliminate the problems of determining the aggregate gradation required to match soil conditions, finding a convenient and economical source of a specific aggregate gradation, transporting and placing graded aggregate, and assuring that the in-place aggregate gradation provides effective filter performance.

Heavyweight nonwovens are used in critical subsurface drainage systems, soil separation, permanent erosion control, and geomembrane liner protection within landfills. These geotextiles provide the required strength and abrasion resistance to withstand installation and application stresses to create an effective, long-term solution.

PROPERTY / TEST METHOD	UNITS	140NL	CALTRANS 140NC	140N	160N	170N	CALTRANS 180N	1100N	1120N	1160N
MECHANICAL PROPERTIES										
Grab Tensile Strength ASTM D 4632										
–Strength @ Ultimate	kN (lbs)	0.40 (90)	0.45 (100)	0.53 (120)	0.71 (160)	0.80 (180)	0.9 (205)	1.11 (250)	1.34 (300)	1.69 (380)
–Elongation @ Ultimate	%	50	50	50	50	50	50	50	50	50
Mullen Burst Strength ASTM D 3786	kPa (p.s.i.)	1205 (175)	1447 (210)	1550 (225)	2100 (305)	2273 (330)	2618 (380)	3445 (500)	4030 (585)	5098 (740)
Trapezoidal Tear Strength ASTM D 4355	kN (lbs)	0.16 (35)	0.20 (45)	0.22 (50)	0.27 (60)	0.33 (75)	0.36 (80)	0.45 (100)	0.51 (115)	0.62 (140)
Puncture Strength ASTM D 4833	kN (lbs)	0.24 (55)	0.30 (65)	0.30 (65)	0.42 (95)	0.46 (105)	0.58 (130)	0.69 (155)	0.78 (175)	1.05 (235)
UV Resistance after 500 hrs. ASTM D 4355	% strength	70	70	70	70	70	70	70	70	70
HYDRAULIC PROPERTIES										
Apparent Opening Size (AOS) ASTM D 4751	US Sieve	60	70	70	70	80	80	100	100	100
	mm	0.25	0.212	0.212	0.212	0.180	0.180	0.150	0.150	0.150
Permittivity ASTM D 4491	sec-1	2.0	1.9	1.8	1.4	1.4	1.2	1.0	0.8	0.7
Flow Rate ASTM D 4491	l/min/m² (gal/min/ft²)	5907 (145)	5698 (140)	5500 (135)	4477 (110)	4278 (105)	3866 (95)	3056 (75)	2648 (65)	2037 (50)

NOTE: All Mechanical Properties and Hydraulic Properties shown are Minimum Average Roll Values (MARV).

88-8 White Cap CONSTRUCTION SUPPLY

Your Caltrans Product Specialist: Kathy Brooks 800.936.6626

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 25 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 3 – BOBCAT T550 SKID-STEER SPECIFICATIONS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 26 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

12/19/2019 Compare Bobcat Compact Track Loaders - Bobcat Company

SHARE

Loaders / Compact Track Loaders

Compare Models

To compare models, start by selecting products using the dropdown menus.

Standard Optional N/A Not Applicable Units US

Configuration	Bobcat T550 Standard	Bobcat T550 Roller Suspension Option	Select product...	Select product...
Emissions Tier (EPA)	Tier 4	Tier 4		
Engine Cooling	Liquid			
Engine Fuel	Diesel			
Horsepower	66 hp			
Turbocharged Engine	✓			

Performance

Rated Operating Capacity (ISO)	1,995 lb	1,895 lb		
Operating Capacity (50% of Tip)	2850 lb	2707 lb		
Tipping Load	5700 lb	5414 lb		
Operating Weight	7557 lb	7758 lb		
Travel Speed	7.1 mph	7.1 mph		
Travel Speed (2-speed option)	10.4 mph	n/a		
Ground Pressure (Rubber)	4.9 psi	5.8 psi		

https://www.bobcat.com/loaders/compact-track-loaders/compare-models 1/3

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 27 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
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12/19/2019 Compare Bobcat Compact Track Loaders - Bobcat Company

Capacities

Fuel Tank	36.5 gal	36.5 gal		

Hydraulic System

System Relief @ Quick Couplers	3,500 psi			
Auxiliary Std Flow	17.1 gal/min			
Auxiliary High Flow	26.7 gal/min			

Dimension

Length	133 in			
Length without Attachment	104.6 in			
Length with Standard Bucket	133 in			
Width	67 in	71.5 in		
Width (with bucket)	68 in	74 in		
Height	77.8 in			
Height with Operator Cab	77.8 in			
Height to Bucket Hinge Pin	114.5 in			
Reach @ Maximum Height	19.3 in			
Turning Radius	80 in	80 in		
Length of track on ground	54.1 in			
Track Width	12.6 in			
Track Width - Optional	15.8 in			

https://www.bobcat.com/loaders/compact-track-loaders/compare-models 2/3

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 28 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

12/19/2019 Compare Bobcat Compact Track Loaders - Bobcat Company

Features

Joystick Control	✓		
Air Conditioning	✓		
Backup Alarm	■		
BICS System (Interlock)	■		
Cab Heater	✓		
Operating Lights	■		
Suspension Seat	■		
Two Speed Travel	N/A		
Deluxe Instrumentation	✓		
Engine Shutdown	■		
Hydraulic Bucket Positioning	✓		
High Flow Option	✓		
Auxiliary Hydraulics	■		
Bob-Tach Attachment System	■		
Power Bob-Tach	✓		
ACS (Switchable Controls)	✓		
Ride Control	✓		
Horn	■		

Certain specification(s) are based on engineering calculations and are not actual measurements. Specification(s) are provided for comparison purposes only and are subject to change without notice. Specification(s) for your individual equipment will vary based on normal variations in design, manufacturing, operating conditions, and other factors.

https://www.bobcat.com/loaders/compact-track-loaders/compare-models 3/3

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 29 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 4 – GEOSYNTHTIC INSTITUTE GRI TEST METHOD GT12(A) – ASTM VERSION

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 30 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

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GRI GEI GII GSI GAI GCI

Rev. 2: March 3, 2016
Revision Schedule: pg. 7

GRI Test Method GT12(a)* - ASTM Version

Standard Specification for

"Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials"

This specification was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers nonwoven geotextile test properties for subsequent use as protection (or cushioning) materials.

Note 1: The typical use will be as a protective covering or underlayment of a geomembrane against puncture or tear due to rock, stones, concrete or other hard surfaces and/or objects.

1.2 This specification sets forth a set of physical, mechanical and endurance properties that must be met, or exceeded by the geotextile being manufactured.

1.3 In the context of quality systems and management, this specification represents a manufacturing quality control (MQC) document.

Note 2: Manufacturing quality control represents those actions taken by a manufacturer to assure that a product represents the stated objective and properties set forth in the specification.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

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Note 3: This particular specification for nonwoven protection geotextiles falls under the concept of MQC.

3.3 Minimum Average Roll Value (MARV) – For geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97.7% confidence that the property in question will meet published values. For normally distributed data, "MARV" is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

4. Material Classification and Formulation

4.1 This specification covers geotextiles used as protection (or cushioning) materials.

4.2 The type of resins are usually polypropylene, polyester or polyethylene, but other resins are also possible in this regard.

4.3 The type of geotextile style is designated as a nonwoven since research has shown these fabrics to be most effective in the typical applications toward which this specification is directed. While needle-punched nonwovens are usually used, heat bonded and resin dipped manufacturing styles (or others) can also be considered.

5. Specification Requirements

5.1 The geotextiles for use as protection (or cushioning) materials shall conform to Table 1. The table is given in English units and in SI (Metric) units. The conversion from English to SI units is "soft".

5.2 Since there are a number of geotextile puncture test methods available, Table 2 is provided. Either of these tests can be considered to be an alternative test replacing ASTM D4833 in Table 1. The decision to make such a replacement must be agreed upon by the parties involved. The table is given in English units and in SI (Metric) units. The conversion from English to SI units is "soft".

5.3 The required values for all properties in Tables 1 and 2 are to be minimum average roll values (MARV) except UV resistance which is a minimum value.

6. Workmanship and Appearance

6.1 The finished geotextile shall have good appearance qualities. It shall be free from such defects that would affect the specific properties of the geotextile, or its proper functioning.

6.2 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 32 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

USA Units

Table 1(a) – Required Properties, Test Methods and Values for Geotextiles Used as Geomembrane Protection (or Cushioning) Materials

Property(1)	Test Method ASTM	Unit	Mass/Unit Area (oz/yd^2)					
Mass per unit area	D5261	oz/yd^2	10	12	16	24	32	60
Grab tensile strength	D4632	lb	230	300	370	450	500	630
Grab tensile elongation	D4632	%	50	50	50	50	50	50
Trap. tear strength	D4533	lb	95	115	145	200	215	290
Puncture (CBR) strength	D6241	lb	700	800	900	1100	1700	2400
UV resistance(2)	D7238	%	70	70	70	70	70	70

Notes:
(1) All values are MARV except UV resistance; it is a minimum value.
(2) Evaluation to be on 2.0 inch strip tensile specimens per ASTM D 5035 after 500 lt. hrs. exposure.

S.I. (Metric) Units

Table 1(b) – Required Properties, Test Methods and Values for Geotextiles Used as Geomembrane Protection (or Cushioning) Materials

Property(1)	Test Method ASTM	Unit	Mass/Unit Area (g/m^2)					
Mass per unit area	D5261	g/m^2	340	406	542	812	1080	2000
Grab tensile strength	D4632	kN	1.02	1.33	1.64	2.00	2.25	2.80
Grab tensile elongation	D4632	%	50	50	50	50	50	50
Trap. tear strength	D4533	kN	0.42	0.51	0.64	0.89	0.96	1.27
Puncture (CBR) strength	D6241	kN	3.11	3.56	4.00	4.90	7.56	10.60
UV resistance(2)	D7238	%	70	70	70	70	70	70

Notes:
(1) All values are MARV except UV resistance; it is a minimum value.
(2) Evaluation to be on 50 mm strip tensile specimens per ASTM D5035 after 500 lt. hrs. exposure.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 33 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 5 – CORRELATION OF ASTM D4833 AND D6241 GEOTEXTILE PUNCTURE TEST METHODS AND RESULTS FOR USE ON WISDOT PROJECTS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 34 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Correlation of ASTM D4833 and D6241 Geotextile Puncture Test Methods and Results for Use on WisDOT Projects

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WisDOT ID no. 0092-15-07

May 2017

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Chapter 6

Proposed Geotextile Specification Limits

This chapter presents a summary of test results correlation and comparison from the geotextile industry data. In addition, a set of proposed specification limits are presented based on WisDOT geotextiles types.

6.1 Geotextile Industry Data

Minimum average roll values (MARV) for a subset of the geotextiles tested in this project were found through research and data collection of vendor specification sheets. Table 6.1 and 6.2 show the results in context of the vendor provided MARV numbers. The research team also obtained additional data and information from geotextile manufacturers that included both CBR and pin puncture strength test data as well as published values of CBR and pin puncture strength. These new data obtained are summarized in Tables B1 and B2 in Appendix B. In addition, the data values are used to provide a comparison to the models developed based on the experimental study conducted herein.

Table 6.1 Comparison of Phase 1 to Industry MARV

Geotextile Material Type	ASTM Test	No. of Tests	Average Puncture Load, lbs (N)	Standard Deviation in Puncture Load, lbs (N)	Coefficient of Variation in Puncture Load (%)	Average Elongation, in (mm)
A (nonwoven) 4 oz/yd^2	D4833	15	73 (324)	10 (43)	13.3	0.50 (12.7)
	D6241	10	362 (1611)	41 (184)	11.4	1.89 (48.0)
	D6241/D4833 Ratio: 4.9					
	MARV-D6241 Puncture load, lbs (N) : 250 (1113)					
B (woven) 4 oz/yd^2	D4833	15	100 (443)	7 (29)	6.6	0.35 (8.9)
	D6241	10	733 (3261)	20 (92)	2.8	1.40 (35.6)
	D6241/D4833 Ratio: 7.3					
	MARV-D6241 Puncture load, lbs (N) : 700 (3115)					
C	D4833	15	115 (510)	21 (93)	18.3	0.46 (11.7)

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 36 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

(nonwoven) 8 oz/yd^2	D6241	15	595 (2648)	57 (255)	9.6	1.88 (47.8)
	D6241/D4833 Ratio: 5.2					
	MARV-D6241 Puncture load, lbs (N) : 500 (2224)					
D (woven) 8 oz/yd^2	D4833	10	178 (790)	18 (81)	10.3	0.46 (11.7)
	D6241	15	1392 (6190)	151 (673)	10.9	1.44 (36.6)
	D6241/D4833 Ratio: 7.8					
	MARV-D6241 Puncture load, lbs (N) : 1250 (5563)					
E (nonwoven) 12 oz/yd^2	D4833	10	240 (1069)	16 (73)	6.8	0.59 (15.0)
	D6241	15	1268 (5642)	101 (451)	8.0	2.47 (62.7)
	D6241/D4833 Ratio: 5.3					
	MARV-D6241 Puncture load, lbs (N) : 900 (4005)					

Table 6.2: Comparison of Phase 2 test values to industry MARV

Fabric Type	Project Number and Date	Vendor/Type	MARV			Testing – Average Values			
			D4833 MARV	D6241 MARV	D6241/D4833 Ratio-MARV	D4833 (N) -WISDOT	D4833 (N) - UWM	D6241 (N) - UWM	D6241/D4833 Ratio-UWM
DF	1195-13-71	Propex Geotex 401 (non-woven)	289	1380	4.8	213	148	950	6.5
DF	1170-01-70	Willacochee Industrial Fabrics, Winfab 400N (non-woven)	289	1380	4.8	227	158	627	4.0
DF	9200-04-71	Hanes Geo Components Terra Tex N07 (non-woven)	467	2110	4.5	472	499	2759	5.5
DF	1030-11-70	Tencate – Mirafi 140N (non-woven)	300	1380	4.6	480	463	2600	5.6

DF	2753-06-71	Geosynthetics ST180N (non-woven)	467	-	-	452	295	1084	3.7
DF	1060-33-73	Propex Geotex 701 (non-woven)	445	2047	4.6	497	274	880	3.2
SAS	1133-03-71	Propex 701 (non-woven)	445	2113	4.7	509	342	1731	5.1
SAS	8160-14-71	Geosynthetics ST180N (non-woven)	467	-	-	465	300	1312	4.4
SAS	1060-33-75	Tencate Mirafi 170N (non-woven)	460	2003	4.4	540	391	1845	4.7

6.2 Experimental Data Based Models

The results of the experimental data obtained from Phase I and II for both woven and nonwoven geotextiles are summarized in Table 6.3 (see Figures 4.30 to 4.35 in Chapter 4).

Table 6.3: Correlations between CBR and pin puncture strength based on the experimental test results.

Geotextile Test Result		Correlation: PS(CBR) = α × PS(Pin)	R^2
Phase I	Woven	PS(CBR) = 7.46 × PS(Pin)	0.98
	Nonwoven	PS(CBR) = 5.19 × PS(Pin)	0.98
Phase II	Woven	PS(CBR) = 4.28 × PS(Pin)	0.85
	Nonwoven	PS(CBR) = 5.57 × PS(Pin)	0.85
Combined (Phase I and Phase II)	Woven	PS(CBR) = 6.36 × PS(Pin)	0.91
	Nonwoven	PS(CBR) = 4.90 × PS(Pin)	0.92

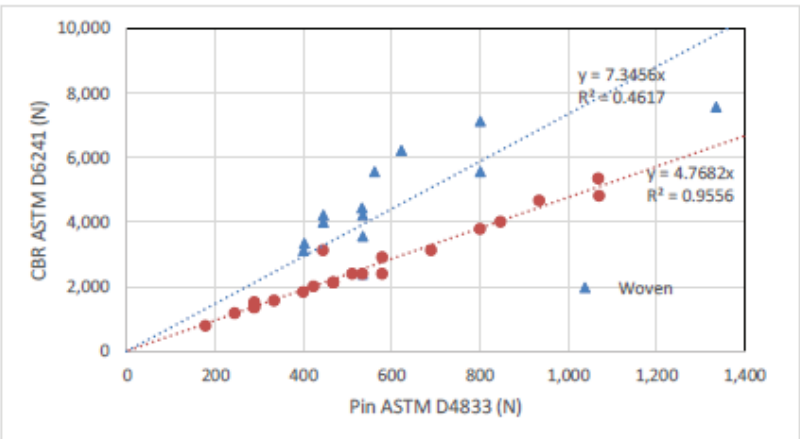
PS(CBR): CBR Puncture Strength (N, lbs) from ASTM D6241
PS(Pin): Pin Puncture Strength (N, lbs) from ASTM D4833
α: Correlation Constant

These models have a good coefficient of correlation values and will be used to propose the average minimum limits for geotextile CBR puncture strength for WisDOT. The current pin puncture strength based WisDOT specifications are summarized in Table 6.4.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 38 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

The results of the nonwoven geotextiles in Phase I & II (*PS(CBR) = 4.90 × PS(Pin)*) are selected to propose for the specifications. These results have a 0.92 coefficient of determination, which is a good correlation with the largest number of test points of 142. Further, using this set of data does not bias the factor to the woven specimens which achieve the highest benefit from moving to the CBR standard. The data obtained from the geotextile industry tests/specifications are compiled and presented in Figure 6.1. The results show that the data compiled from the industry is within a reasonable agreement of the models presented in this report. The analysis of geotextile industry data for the nonwoven geotextiles showed the following correlations: ~ *PS(CBR) = 4.75 × PS(Pin)*, which is a reasonable outcome compared with the model obtained from the experimental test results. Additionally as a result of the phase III additional tests conducted, we include a recommendation to include a minimum UV stability for the geotextiles based on possible exposure in the field.



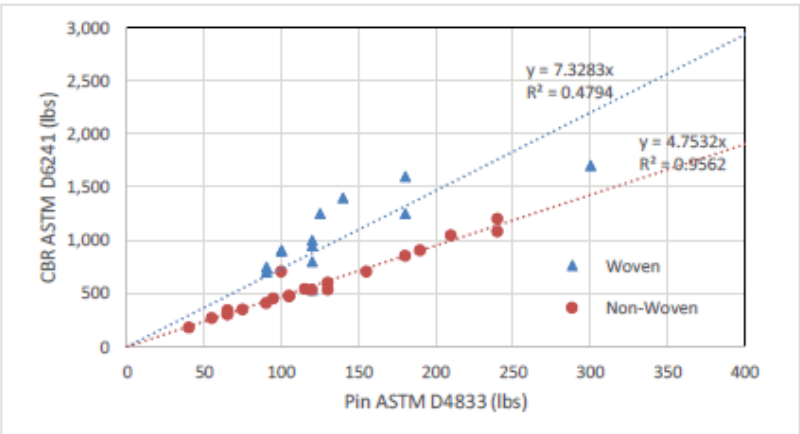


Figure 6.1 Industry data shown for comparative purposes (in SI and U.S. customary units)

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 39 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Table 6.4 Current and proposed WisDOT specification limits

Geotextile Type	Minimum Puncture Strength (Average)			
	Current WisDOT Specifications Based on ASTM D4833 (Pin)		Proposed WisDOT Specifications Based on ASTM D6241 (CBR)	
	lbs.	N	lbs.	N
Subgrade Aggregate Separation (SAS)	70	300	340	1500
Marsh Stabilization (MS)	NA	NA	NA	NA
Drainage Filtration (DF), Schedule A	40	175	190	840
Drainage Filtration (DF), Schedule B	70	300	340	1500
Drainage Filtration (DF), Schedule C	70	311	340	1500
Subgrade Reinforcement (SR)	NA (145)*	NA (650)*	NA (700)**	NA(3100)**
Riprap (R)	80	350	390	1700
Heavy Riprap (HR)	100	440	490	2100
Modified Subgrade Aggregate Separation Type C (SAS-C)	70	300	340	1500
Embankment Stabilization (ES)	NA	NA	NA	NA
UV Radiation Stabilization ASTM D4355 for 500 hours of exposure – 50% Retention of Strength				

* Specification values are obtained from WisDOT project documents.

** Based on same data from WisDOT project documents

106

Chapter 7

Summary

The results from Phase 1 and II show that the CBR puncture strength can possibly be predicted for woven and nonwoven PP materials. The Woven PP materials exhibit a CBR puncture strength approximately double that of nonwoven PP materials with the same mass per unit area. The CBR displacement/elongation at puncture failure is determined by weave type rather than mass per unit area for PP materials. D6241 appears to correlate more with the weight of the fabric. We also found that the CBR puncture strength failure of a woven material is likely a function of filament tensile strength and CBR failure of nonwoven materials is a function of fiber-fiber contact area. When the results from D4833 are compared with the obtained values from WisDOT using the same standard, we see similar results obtained. Industry obtained minimum average roll value (MARV) numbers for both methods show similar correlations to the results obtained. The results also show consistent higher values for D6241 compared to the values from D4833. The outliers with high strength from the D6241 approach sometimes correlate with the higher strength (e.g. Group5 SAS), however in other cases (e.g. in the DF) series we do not see this correlation. Finally, in the proposed specifications in Chapter 6 we recommend values based on the correlations obtained in this report to enable and justify transitions to the new ASTM D6241 standard.

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 41 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 6 – H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER

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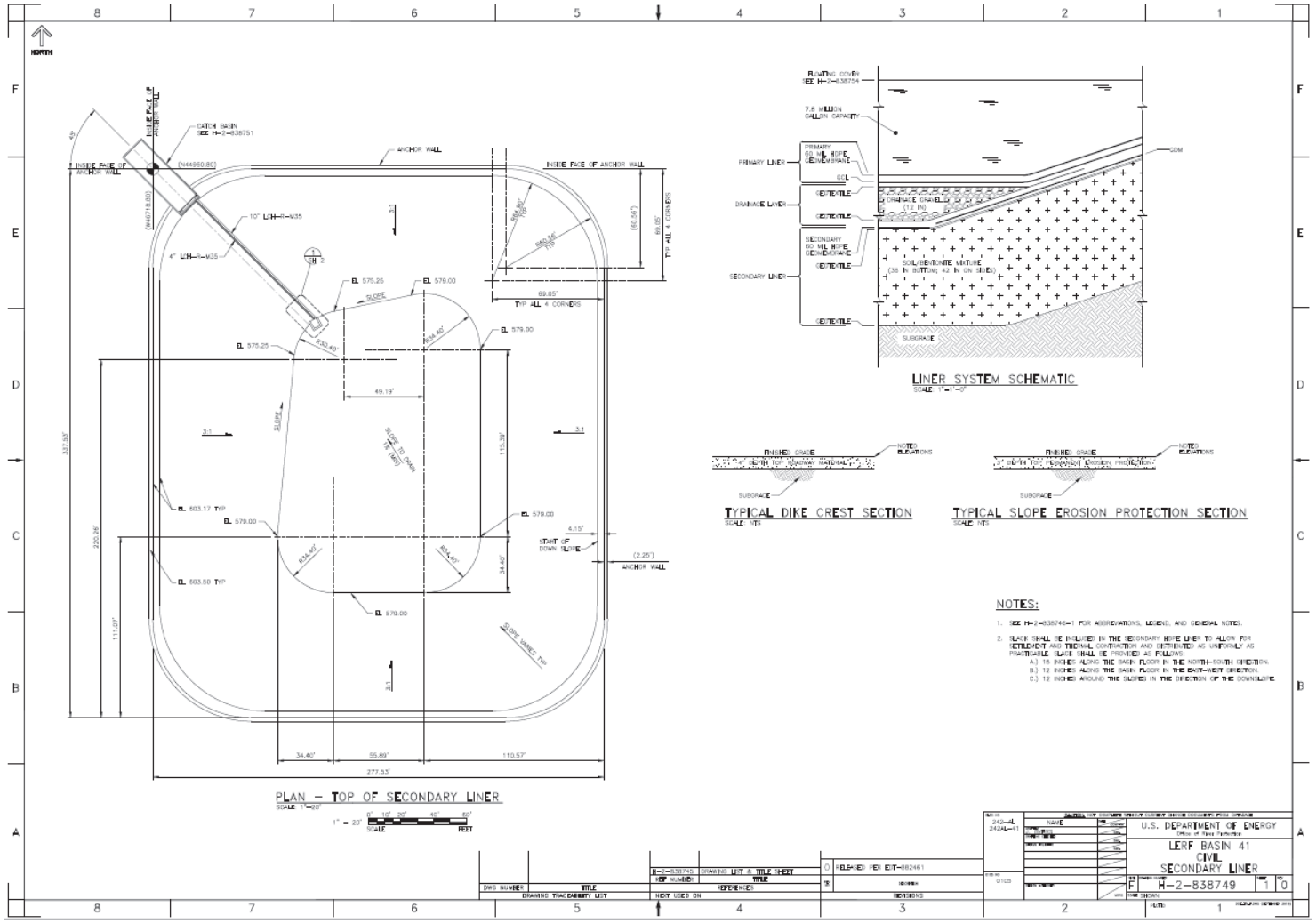
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-001	**Rev.**	0	**Page No.**	42 of 51
Title:	LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection						
Prepared By:	G. Taylor Grant	**Date:**	04/08/2020	**Checked By:**	Darrel J. Packard	**Date:**	04/09/2020



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 43 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 7 – WSDOT M41-10 9-03.12(5) GRAVEL BACKFILL FOR DRYWELLS GRADATION

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 44 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

9-03.12(5) Gravel Backfill for Drywells

Gravel backfill for drywells shall conform to the following gradings:

Sieve Size	Percent Passing
1½″	99-100
1″	50-100
¾″	0-20
⅜″	0-2
No. 200	0-1.5

As an alternative, AASHTO grading No. 4 may be used in accordance with Section 9-03.1(4)C. Alkali silica reactivity testing is not required.

9-03.13 Backfill for Sand Drains

Backfill for sand drains shall conform to the following grading:

Sieve Size	Percent Passing
½″	90-100
No. 4	57-100
No. 10	40-100
No. 50	3-30
No. 100	0-4
No. 200	0-3.0

All percentages are by weight.

That portion of backfill retained on a No. 4 sieve shall contain not more than 0.05 percent by weight of wood waste.

9-03.13(1) Sand Drainage Blanket

Aggregate for the sand drainage blanket shall consist of granular material, free from wood, bark, or other extraneous material and shall meet the following requirements for grading:

Sieve Size	Percent Passing
2½″	90-100
No. 4	24-100
No. 10	14-100
No. 50	0-30
No. 100	0-7.0
No. 200	0-3.0

All percentages are by weight.

That portion of backfill retained on a No. 4 sieve shall contain not more than 0.05 percent by weight of wood waste.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 45 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 8 – CAT D6 DOZER SPECIFICATIONS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 46 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

PRODUCT SPECIFICATIONS FOR D6

ENGINE

Engine Model	Cat C9.3B
Power - Net	215 HP
Emissions	U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final
Net Power - Rated - ISO 9249/SAE J1349	215 HP
Net Power - Rated - ISO 9249/SAE J1349 (DIN)	219 HP
Build Number	20A
Note (1)	Rated horsepower at 2,200 rpm
Note (2)	All non-road Tier 4 Interim and Final, Stage IIIB, IV and V and Korea Tier 4 Final diesel engines are required to use only ultra-low sulfur diesel (ULSD) fuels containing 15 ppm (mg/kg) sulfur or less. Biodiesel blends up to B20 (20% blend by volume) are acceptable when blended with 15 ppm (mg/kg) sulfur or less ULSD. B20 should meet ASTM D7467 specification (biodiesel blend stock should meet Cat biodiesel spec, ASTM D6751 or EN 14214). Cat DEO-ULS or oils that meet the Cat ECF-3, API CJ-4 and ACEA E9 specification are required. Consult your OMM for further machine specific fuel recommendations.
Note (3)	Diesel Exhaust Fluid (DEF) used in Cat Selective Catalytic Reduction (SCR) systems must meet the requirements outlined in the International Organization for Standardization (ISO) standard 22241.
Note (4)	Basic machine specs provided below. For complete specifications and dimensions by configuration, blade and track shoe offerings and more, please visit the product download section to view the full D6/D6 XE Technical Specifications.

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 47 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

DIMENSIONS – LGP VPAT (30-IN)

Operating Weight	50650 lb

TRANSMISSION

Power Train	Fully Automatic 4-Speed Powershift

SERVICE REFILL CAPACITIES

Fuel Tank	90 gal (US)
DEF Tank	7.4 gal (US)

AIR CONDITIONING SYSTEM

Air Conditioning	The air conditioning system on this machine contains the fluorinated greenhouse gas refrigerant R134a (Global Warming Potential = 1430). The system contains 1.36 kg of refrigerant which has a CO_2 equivalent of 1.946 metric tonnes.

D6 PUSH ARM

Operating Weight	48500 lb
Ground Pressure	7.9 psi
Width of Standard Shoe	24 in
Blade	Semi-Universal (SU)
Blade Capacity	7.5 yd^3

D6 LGP (30-IN) PUSH ARM

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 48 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Operating Weight	50130 lb
Ground Pressure	6.6 psi
Width of Standard Shoe	30 in
Blade	Semi-Universal (SU)
Blade Capacity	7.6 yd³

D6 LGP (36-IN) PUSH ARM

Operating Weight	52615 lb
Ground Pressure	5.1 psi
Width of Standard Shoe	36 in
Blade	Straight
Blade Capacity	5 yd³

D6 VPAT

Operating Weight	49030 lb
Ground Pressure	7.1 psi
Width of Standard Shoe	24 in
Blade	VPAT
Blade Capacity	5.4 yd³

D6 LGP (30-IN) VPAT

Operating Weight	50650 lb
Ground Pressure	5.8 psi
Width of Standard Shoe	30 in

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 49 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Width of Standard Shoe	30 in
Blade	VPAT
Blade Capacity	5.9 yd³

D6 LGP (36-IN) VPAT

Operating Weight	51875 lb
Ground Pressure	5 psi
Width of Standard Shoe	36 in
Blade	VPAT
Blade Capacity	6.5 yd³

D6 STANDARD EQUIPMENT

POWER TRAIN

- Hydraulic reversing fan
- Double reduction planetary final drives
- Cat C9.3B diesel engine
- Fully-automatic 4-speed transmission

OPERATOR ENVIRONMENT

- Cloth seat
- Added storage areas
- Electrohydraulic implement and steering controls
- Lights - 6 LED
- Communication radio ready
- Cab mounted modular Heating/Ventilation/Air Conditioning (HVAC) system
- Fully redesigned cab, sound suppressed, with Integrated Roll Over Protective Structure (ROPS)
- Integrated rearview camera
- Adjustable operator controls/armrests
- Full-color 10-inch (254 mm) liquid crystal touch screen display

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 50 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

CAT TECHNOLOGY

Slope Indicate

Product Link, Cellular PLE641

Attachment Ready Option (ARO) with Assist/Cat GRADE with Slope Assist

UNDERCARRIAGE

Redesigned track roller frame

SERVICE AND MAINTENANCE

Ecology drains

30-minute cab removal

Rear access ladder

Fire extinguisher mounting provision

Shovel holder

Underhood work light

Ground level service center

HYDRAULICS

Independent steering and implement pumps

Load sensing hydraulics

ATTACHMENTS

Ripper-ready rear hydraulics

D6 OPTIONAL EQUIPMENT

OPERATOR ENVIRONMENT

Premium lights - 12 LED

Integrated warning lights

Deluxe leather heated/ventilated seat

CAT TECHNOLOGY

Cat GRADE with 3D

Product Link Elite PLE631 - Dual Cellular/Satellite

BLADES

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-001	**Rev.** 0	**Page No.** 51 of 51
Title: LERF Basin 41 Construction Equipment Limitations for Liner and Geotextile Protection			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Semi-Universal

Straight blade

Angle blade

Foldable VPAT - under 3 m (9.9 ft) transport width (Not available in all regions)

Variable Pitch Angle Tilt (VPAT)

Waste/Landfill

INDERCARRIAGE

Moderate Service or Extreme Service track shoes

10-Roller Fine Grading undercarriage

Heavy Duty (HDXL with DuraLink) or SystemOne

ERVICE AND MAINTENANCE

Refilling fuel pump (EU only)

TTACHMENTS

High lift ripper with straight or curved shanks

Winch

Forestry and Waste Special Arrangements

Counterweights

Ripper and winch-ready rear hydraulics

Side screens

Rear screen - hinged or fixed

Sweeps

Drawbar

DOCUMENT RELEASE AND CHANGE FORM

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By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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DATE: May 27, 2020 HANFORD RELEASE

1. **Doc No:** RPP-CALC-63746 **Rev.** 00

2. **Title:**
LERF Basin 41 Static and Dynamic Loads on Leachate Pipe

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Ayers, Lynn M	*Ayers, Lynn M*	05/19/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/23/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/10/2020
Document Control Approval	Scales, Anthony	*Scales, Anthony*	05/19/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/29/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/10/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/07/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	05/12/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Becasue of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Taylor Grant and Jeremy Debban is signing as Checker for Darrel Packard. Taylor Grant and Darrel Packard are not currently in SPF.

The trademark attribution information below is applicable, and should be added to the next revision.

Bobcat is a registered trademark of Clark Equipment Company, West Fargo, North Dakota.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
McFerran, Brandon E	242-A/AW/ETF OPERATIONS
McShane, Michael P	ENGINEERING PROGRAMS
Omberg Carro, Susan K	NUCLEAR SAFETY

DOCUMENT RELEASE AND CHANGE FORM	**Doc No:** RPP-CALC-63746 **Rev.** 00

14. **Distribution**

Name	**Organization**
Powers, Daniel J	ETF ENGINEERING
Roosendaal, Gene D	TFP PROJECT MANAGEMENT
Rutherford, Wally	ETF ENGINEERING
Sackett, Tom E	TANK FARM PROJECTS
Samoska, Jerry A	INSTRUMENT & CNTRL ENGINEERING
Shultz, Milton V	NUCLEAR SAFETY
Smith, Gregory E	TANK FARM PROJECTS ENGINEERING
Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63746
Revision 0

LERF Basin 41 Static and Dynamic Loads on Leachate Pipe

Prepared by

G. T. Grant
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
April 2020

washington river protection solutions

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5-18-2020

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Approved for Public Release;
Further Dissemination Unlimited

RPP-CALC-63746 Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 52	
		Date 04/07/2020	**Rev. No.** 0
		Calculation No: S54413.024-C-002	

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions

Title:

LERF Basin 41 Static and Dynamic Loads on Leachate Pipe

Purpose and Objective:

The purpose of this calculation is to demonstrate the ability of the 4” and 10” diameter leachate pipes in the northwest corner of the basin to withstand both static and dynamic loads expected during construction and operation.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	52	Print Name/ Sign:	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	04/07/2020	4/9/2020	4/10/2020

Revision Description (Revision Description/Affected Pages):

		Print Name/ Sign:			
		Date:			

Revision Description (Revision Description/Affected Pages):

RPP-CALC-63746 Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev. No.	Page No.
S54413.024	S54413.024-C-002	0	2 of 52

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
G. Taylor Grant	4/7/2020
Checker (Print Name and Sign):	**Date:**
Darrel Packard	4/9/2020

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 3 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE OF CONTENTS

1.0 PURPOSE 5

2.0 METHODOLOGY 5
- 2.1 Pipes 5
- 2.2 Loads 5
- 2.3 Acceptance Criteria 5

3.0 DESIGN INPUTS 6
- 3.1 Basin Geometry 6
- 3.2 Gravel Drainage Layer 6
- 3.3 Pipes 6
- 3.4 Construction Equipment 6
- 3.5 Unit Weight of Leachate 7

4.0 ASSUMPTIONS 7

5.0 COMPUTER SOFTWARE 7

6.0 RESULTS 7

7.0 REFERENCES 8

8.0 CALCULATIONS 9
- 8.1 Loads on Pipe During Normal Operation 9
- 8.2 Pipe Deflection During Normal Operation 9
- 8.3 Pipe Buckling During Normal Operation 10
- 8.4 Gravel Drainage Layer Loads During Construction 11
- 8.5 Construction Equipment Loads During Construction 11

Attachments

ATTACHMENT – 1 – H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER
H-2-838749, SHEET 2, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER DETAILS

ATTACHMENT – 2 – DRISCOPLEX 9200 HDPE LINER PIPE CUT SHEETS

ATTACHMENT – 3 – EPA/600/2-88/052, LINING OF WASTE CONTAINMENT AND OTHER IMPOUNDMENT FACILITIES

ATTACHMENT – 4 – PLASIC PIPES INSTITUTE HANDBOOK OF PE PIPE

ATTACHMENT – 5 – SD-LEF-TI-005 REV 1 CALCULATION 3, STATIC AND DYNAMIC LOADS ON LEACHATE RISER

ATTACHMENT – 6 – BOBCAT S740 SKID-STEER SPECIFICATIONS

ATTACHMENT – 7 – CAT D6 DOZER SPECIFICATIONS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 4 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Acronyms

DCR	Demand-to-Capacity Ratio
DR	Dimension Ratio
LERF	Liquid Effluent Retention Facility

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 5 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

1.0 PURPOSE

The purpose of this calculation is to demonstrate the ability of the 4” and 10” diameter leachate pipes in the northwest corner of the basin to withstand both static and dynamic loads expected during construction and operation.

2.0 METHODOLOGY

2.1 Pipes

The pipes that will be analyzed are a 4” diameter perforated pipe and a 10” diameter perforated pipe as shown on drawing H-2-838749, Sheet 2, Rev. 0 (Attachment 1). In general, smaller diameter pipes can withstand loads better than larger diameter pipes, so the 10” diameter pipe will be analyzed.

2.2 Loads

The pipes and cover material are shown in Sections C and D on drawing H-2-838749, Sheet 2, Rev. 0 (Attachment 1). The pipes will be subjected to loads from the gravel drainage layer, effluent, placement of the gravel drainage layer, and construction equipment traveling over the pipes. Loads from other sources are possible, as mentioned in Section 3.5 Design Loads in Reference 6, however, loads from other sources are not expected to control.

During normal operation, the pipes will be subjected to the gravel drainage layer and the effluent loads concurrently. During construction, the pipe will be subjected to placement of the gravel drainage layer and construction equipment traveling over the pipes, which will be nonconcurrent. Placement of the gravel drainage layer will be analyzed by applying an impact factor to the unit weight of gravel, and then analyzing as a static system.

2.3 Acceptance Criteria

Pipe deflection and buckling capacity will be calculated for during normal operation, and buckling capacity will be calculated for during construction.

The deflection will be calculated using the Iowa Formula, given in Reference 1, Appendix I, Section I.2.3 “Deflection,” using normal operating loads. The allowable deflection is given in Reference 1, Appendix I, Section I.2.7 “Procedures for Calculating Required Pipe Strength.”

The buckling capacity of the pipe will be calculated using the Luscher Equation, given in Reference 3, Page 221 “Luscher Equation for Constrained Buckling Below Ground Water Level.” This equation will be used to calculate the allowable compressive pressure on the pipe. The allowable compressive pressure will be compared to the normal operating loads, placement of the gravel drainage layer loads, and the construction equipment loads to determine if the pipe is adequate for resisting buckling.

3.0 DESIGN INPUTS

3.1 Basin Geometry

The basin geometry is given in the below drawings. These drawings are included in Attachment 1.

H-2-838749, Sheet 1, Rev. 0

H-2-838749, Sheet 2, Rev. 0

D_e = The maximum possible depth of effluent in the basin. The lowest point of the basin that effluent could reach is the top of the primary liner (Attachment 1, Drawing H-2-838749, Sheet 1, Liner System Schematic) and is elevation 576.50' (Attachment 1, Drawing H-2-838749, Sheet 2, Detail 2). The highest elevation around the perimeter of the basin is the top of concrete of the anchor wall and is 603.50' (Attachment 1, Drawing H-2-838750, Sheet 1, Section C). Therefore, D_e = top elevation – bottom elevation = 603.50' – 576.50' = 27.00'.

The actual top of effluent elevation is less than the top of the concrete anchor wall, but this freeboard will conservatively be disregarded.

3.2 Gravel Drainage Layer

The height of the gravel drainage layer is 2 feet. (Drawing H-2-838749, Sheet 2, Rev. 0, Section C). The height of gravel on top of each pipe is therefore:

Height of gravel above 10" pipe = B_{p10} = 2 ft – 10 in = 14 in

Height of gravel above 4" pipe = B_{p4} = 2 ft – 4 in = 20 in

Unit weight of gravel = W_g = 135 pcf (Engineering Judgement)

3.3 Pipes

The leachate pipes are shown in Drawing H-2-838749, Sheet 2, Rev. 0, Detail 1.

Large pipe diameter = d_l = 10 in

Small pipe diameter = d_s = 4 in

3.4 Construction Equipment

The largest piece of construction equipment expected above the pipes will be a Bobcat S740 skid-steer (or similar). The below values are provided from Bobcat's website, see Reference 5.

The bobcat width of wheelbase = x_{bobcat} = 48.3 in

The bobcat operating weight = W_{bobcat} = 8794 lbs

Near the sump of the basin, a dozer could potentially be used for spreading gravel. The below values are from Cat's website, see Reference 9.

The dozer width of wheelbase = x_{dozer} = 76 in

The dozer operating weight = W_{dozer} = 52615 lbs

3.5 Unit Weight of Leachate

The unit weight of leachate is taken from Reference 4, Page 1.

Unit weight of leachate = W_e = 62.4 pcf

4.0 ASSUMPTIONS

There are no assumptions in this calculation. Engineering judgement, where used, is documented herein.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Calculations are checked using a handheld calculator.

6.0 RESULTS

A summary of results is below.

Load Case	Item	DCR	Remarks
Norm. Operating	Deflection	0.761	
Norm. Operating	Buckling	0.924	
Const. Gravel	Buckling	<0.924	Loads less than during normal operation
Const. Equipment	Buckling	>1	Add note to drawings: No construction equipment nor vehicle shall drive over the leachate pipes after installation.

Property	Required	Remarks
Pipe Dimension Ratio	DR ≤26	

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 8 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

7.0 REFERENCES

1) EPA/600/2-88/052, Lining of Waste Containment and Other Impoundment Facilities, 1988
2) Driscoplex 9200 HDPE Liner Pipe cut sheets
3) Handbook of PE Pipe, 2nd Edition, Chapter 6 - Design of PE Piping Systems, Plastic Pipes Institute
4) SD-LEF-TI-005 REV 1 Calculation 3, *Static and Dynamic Loads on Leachate Riser*, 1991
5) Bobcat S740 Skid-steer Specifications
6) TFC-ENG-STD-06, REV D-2, *DESIGN LOADS FOR TANK FARM FACILITIES*
7) H-2-838749, SHEET 1, REV. 0, Basin Bottom Liner Plan, Section and Details
8) H-2-838749, SHEET 2, REV. 0, Basin Bottom Liner Details
9) CAT D6 Dozer Specifications

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 9 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

8.0 CALCULATIONS

8.1 Loads on Pipe During Normal Operation

The sum of vertical pressures acting on the pipe are:

$\sigma_a = D_e \times W_e + W_g \times B_{p10} = 27 \text{ ft} \times 62.4 \text{ pcf} + 135 \text{ pcf} \times 14 \text{ in} = 12.79 \text{ psi}$

The stress on the pipe will need to be adjusted to account for the ½ inch perforations at 8 inch spacing.

The length of perforation per foot: (Reference 1, Page I-10)

$p = (½ \text{ in} / 8 \text{ in}) \times 12 \text{ in} = 0.75 \text{ ft}$

Adjusting for the ½ inch perforations @ 8inch spacing: (Reference 1, Page I-10)

$\sigma_d = [12 \text{ in} / (12 \text{ in} – p)] \times \sigma_a = [12 \text{ in} / (12 \text{ in} –0.75 \text{ ft})] \times 12.79 \text{ psi} = 13.64 \text{ psi}$

8.2 Pipe Deflection During Normal Operation

Pipe deflection will be calculated using the Iowa Formula given in Reference 1, Pages I-10, I-12, and I-13:

$\Delta_y = T_l \times (Bc \times \sigma_d \times K \times r^3) / (E \times I + 0.061 \times E` \times r^3)$

Time lagging factor: $T_l = 1.0$ (Reference 1, Page I-10, no time lag is expected)

Modulus of passive soil resistance:

$E` = 300$ psi (Reference 1, Page I-11, gravel will not be compacted – minimum value used)

Bedding factor: $K = 0.1$ (Reference 1 page I-11, conservative value)

Modulus of elasticity: $E = 120000$ psi (Reference 2)

Mean radius of pipe: $r = 5$ in

Pipe width: $B_c = 10.75$ in (Reference 2)

Pipe wall thickness: $t = 0.413$ in (Reference 2, DR 26.0)

Pipe moment of inertia: $I = t^3 / 12 = (0.413 \text{ in})^3 / 12 = 0.00587 \text{ in}^3$

Deflection: $\Delta_y = T_l \times (B_c \times \sigma_d \times K \times r^3) / (E \times I + 0.061 \times E` \times r^3)$

$= 1.0 \times [10.75 \text{ in} \times 13.64 \text{ psi} \times 0.1 \times (5 \text{ in})^3] / [120000 \text{ psi} \times 0.00587 \text{ in}^3 + 0.061 \times 300 \text{ psi} \times (5 \text{ in})^3]$

$= 0.613$ in

The allowable deflection is given in Reference 1, Page I-16 and is a range of 5%-10% of the pipe width. The average of the range of allowable deflection will be used as the acceptance criteria.

$\Delta_{yall} = ½(0.05 + 0.10) \times B_c = ½(0.05 + 0.1) \times 10.75 \text{ in} = 0.806 \text{ in}$

DCR: $DCR_{\Delta y} = \Delta_y / \Delta_{yall} = 0.613 \text{ in} / 0.806 \text{ in} = 0.761$

8.3 Pipe Buckling During Normal Operation

Reference 1, Page I-13 states that a pipe's buckling capacity should be provided by the pipe manufacturer. Performance Pipe's website refers to the Plastic Pipes Institute Handbook of PE Pipe (Reference 3) for design guidance, which will be used to calculate the pipe's buckling capacity.

Pipe buckling will not be a concern when the basin is empty. For buckling scenarios, it is assumed the basin will be full, therefore, the section "Luscher Equation for Constrained Buckling Below Ground Water Level" will be used (Reference 3, Page 221).

Allowable compressive stress: $P_{wc} = (5.65 / N) \times \{(R \times B` \times E` \times E) / [(12 \times (DR - 1)^3]\}^{0.5}$

Buoyancy reduction factor: $R = 1 - 0.33 \times H_{GW} / H$

Where:

H_{GW} = the height of water above the pipe

H = the height of cover above the pipe

The buoyancy factor reduces the allowable compressive stress in the pipe. The reduction factor is 1 when there is no groundwater acting on the pipe. When the groundwater is at the top of the soil layer, then the reduction factor is 1 – 0.33 = 0.67. This is assumed to be the greatest reduction factor, and will be used.

$R = 1 - 0.33 \times 1 = 0.67$

$B` = 1 / [1 + 4 \times e^{(-0.065 \times B_{p10})}] = 1 / [1 + 4 \times e^{(-0.065 \times 1.167)}]$

$B` = 0.212$

Dimension ratio: $DR = 26$

Safety Factor: N = 2. Reference 3, Page 222 states that "the designer should apply a safety factor commensurate with the application." It is recommended for thermoplastic pipes a safety factor of 2 should be applied. A factor of safety of 2 for this application is reasonable.

Allowable compressive stress: $P_{wc} = (5.65 / N) \times \{(R \times B` \times E` \times E) / [(12 \times (DR - 1)^3]\}^{0.5}$

$= (5.65 / 2) \times \{(0.67 \times 0.212 \times 300 \times 120000) / [(12 \times (26 - 1)^3]\}^{0.5}$

$= 14.76$ psi

DCR: $DCR_b = \sigma_d / P_{wc} = 13.64 \text{ psi} / 14.76 \text{ psi} = 0.924$

The applied loads are conservative since the leachate will not reach a depth of 27 feet during normal operation.

8.4 Gravel Drainage Layer Loads During Construction

The gravel drainage layer will be analyzed with an impact factor in order to determine the effects of placing the 2' thick gravel drainage layer.

Height of gravel to be placed around of pipe:

$B_g = 24$ in

Stress on pipe with a 1.5 impact factor:

$\sigma_{ac} = 1.5 \times (W_g \times B_g) = 1.5 \times (135 \text{ pcf} \times 24 \text{ in}) = 2.81$ psi

The stress of the gravel with an impact factor is less than that of the during operation stress determined in section 8.1, therefore, the stress in section 8.1 will govern.

8.5 Construction Equipment Loads During Construction

The weight of construction equipment traveling over the pipe after it has been installed has been analyzed for a similar scenario in Reference 4. The weight of the equipment in Reference 4, however, is less than the weight of the Bobcat model given in Reference 5 and the dozer model given in Reference 9. The calculations in Reference 4 concluded that small construction equipment could damage the pipe after it had been installed, and therefore should be avoided by small construction equipment.

Given the results in Reference 4 and that the Bobcat model in Reference 5 and dozer model in Reference 9 both weigh more than the equipment used in Reference 4, a note will be on the design drawings that deal with the leachate pipes that state "no construction equipment nor vehicle shall drive over the leachate pipes after installation."

CALCULATION SHEET

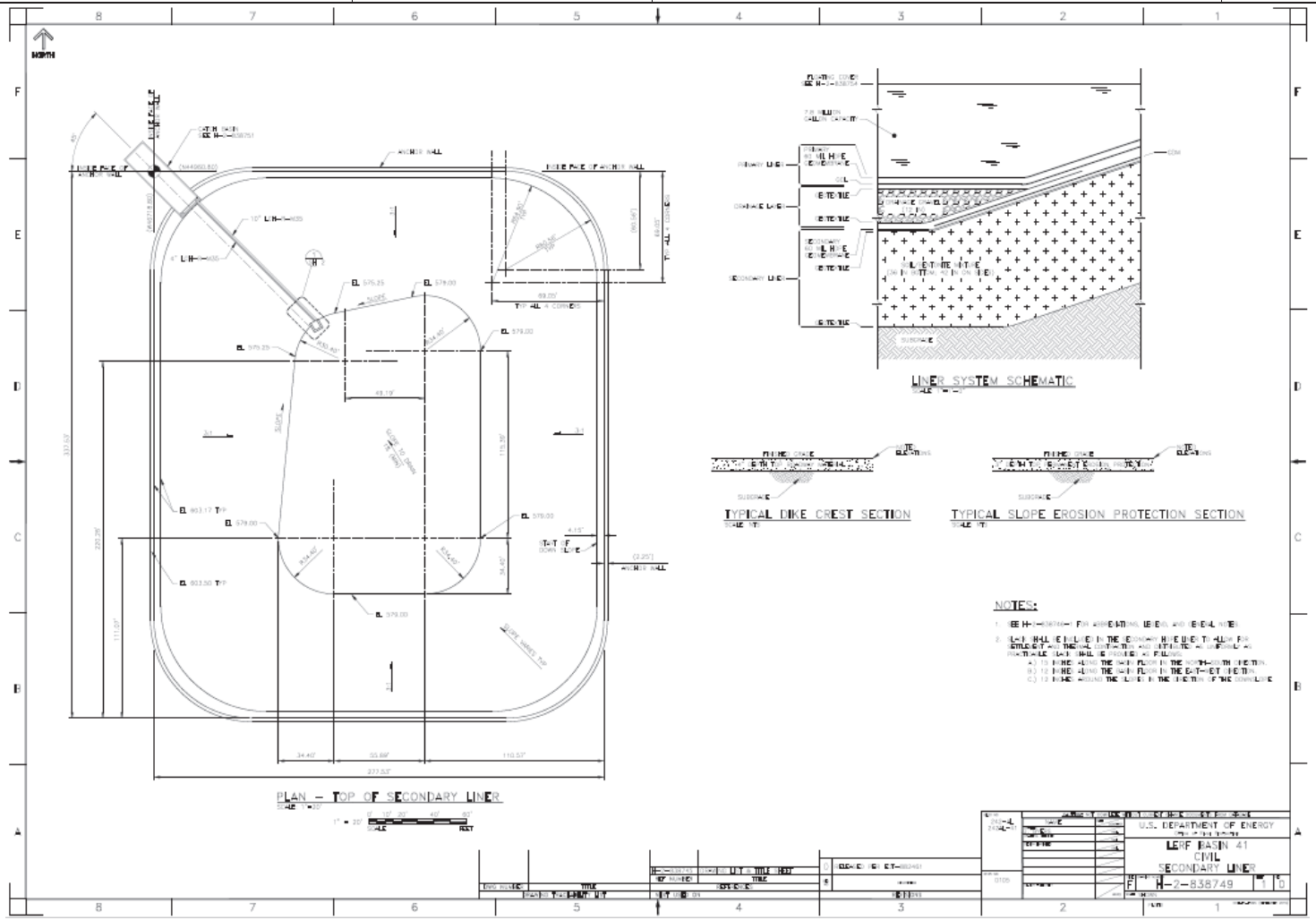
Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 12 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 1 - H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER
H-2-838749, SHEET 2, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER DETAILS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

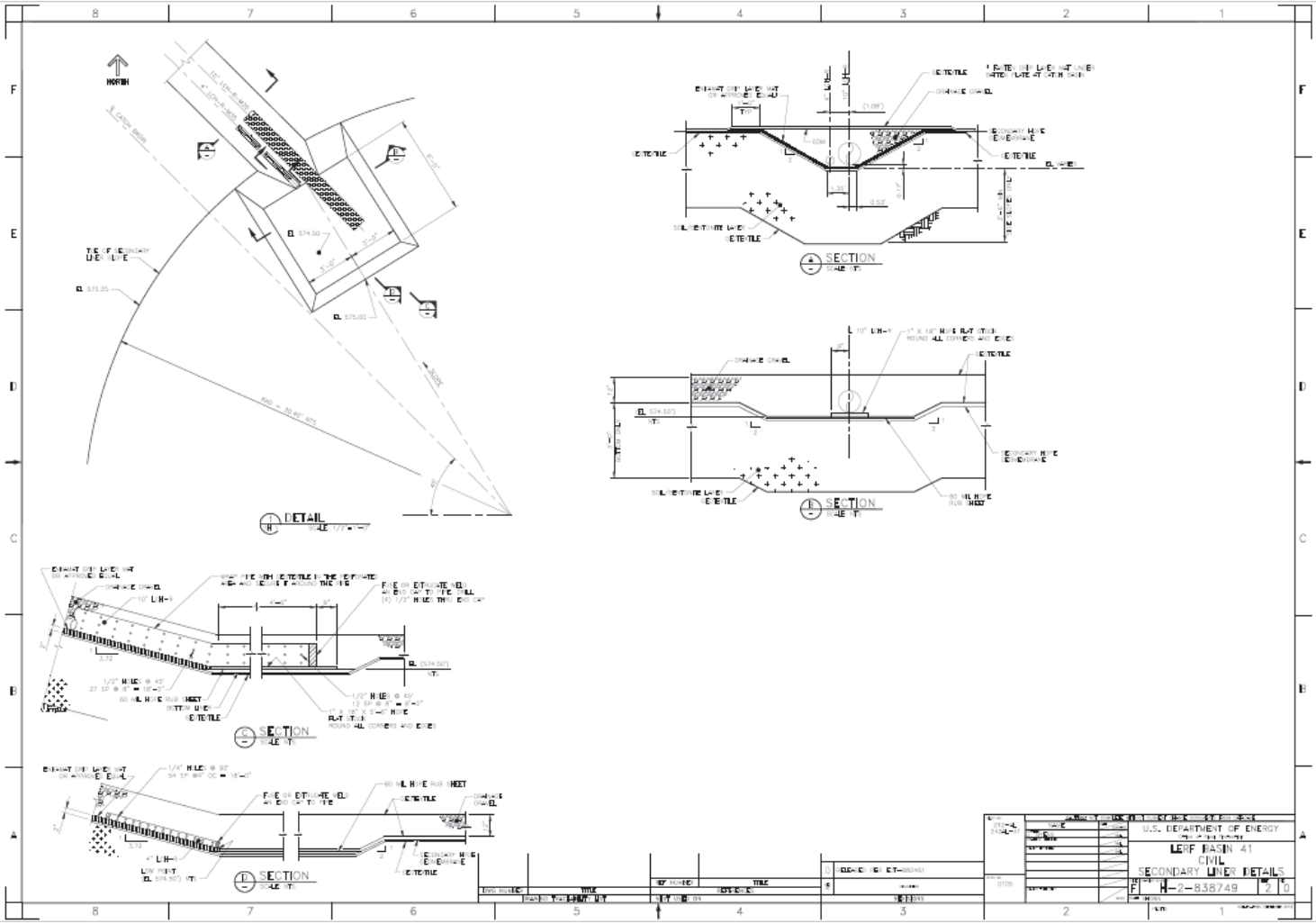
Project No.	S54413.024	**Calculation No.**	S54413.024-C-002	**Rev.**	0	**Page No.**	13 of 52
Title:	LERF Basin 41 Static and Dynamic Loads on Leachate Pipe						
Prepared By:	G. Taylor Grant	**Date:**	04/07/2020	**Checked By:**	Darrel J. Packard	**Date:**	04/09/2020



Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-002	**Rev.** 0	**Page No.** 14 of 52
Title:	LERF Basin 41 Static and Dynamic Loads on Leachate Pipe				
Prepared By:	G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard		**Date:** 04/09/2020



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 15 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 2 - DRISCOPLEX 9200 HDPE LINER PIPE CUT SHEETS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 16 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

PERFORMANCE PIPE
A Division of Chevron Phillips Chemical Company LP

Iron Pipe Size (IPS) and Dimension Data — PE4710 (PE3408)

DriscoPlex® Pipe for Municipal and Industrial Applications

Pressure Ratings are calculated using 0.63 design factor for HDS at 73°F as listed in PPI TR-4 for PE 4710 materials. HDPE can accomodate up to 1.5 times the pipe pressure rating for a recurring surge and up to 2.0 times the pipe pressure rating for an occasional surge. Temperature, Chemical, and Environmental use considerations may require use of additional design factors.

Pressure Rating		125 psi DR 17.0			100 psi DR 21.0			80 psi DR 26.0			63 psi DR 32.5			
Nominal Pipe Size	IPS OD (in)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Nominal Pipe Size
1 1/4"	1.660													1 1/4"
1 1/2"	1.900													1 1/2"
2"	2.375	0.140	2.078	0.43										2"
3"	3.500	0.206	3.063	0.94										3"
4"	4.500	0.265	3.938	1.55	0.214	4.046	1.27							4"
6"	6.625	0.390	5.798	3.36	0.315	5.957	2.75	0.255	6.084	2.24	0.204	6.193	1.81	6"
8"	8.625	0.507	7.550	5.69	0.411	7.754	4.66	0.332	7.921	3.80	0.265	8.063	3.07	8"
10"	10.750	0.632	9.410	8.83	0.512	9.665	7.24	0.413	9.874	5.91	0.331	10.048	4.77	10"
12"	12.750	0.750	11.160	12.43	0.607	11.463	10.19	0.490	11.711	8.31	0.392	11.919	6.71	12"
14"	14.000	0.824	12.253	14.98	0.667	12.586	12.28	0.538	12.859	10.02	0.431	13.086	8.09	14"
16"	16.000	0.941	14.005	19.57	0.762	14.385	16.04	0.615	14.696	13.09	0.492	14.957	10.56	16"
18"	18.000	1.059	15.755	24.77	0.857	16.183	20.30	0.692	16.533	16.57	0.554	16.826	13.37	18"
20"	20.000	1.176	17.507	30.58	0.952	17.982	25.07	0.769	18.370	20.45	0.615	18.696	16.50	20"
22"	22.000	1.294	19.257	37.00	1.048	19.778	30.33	0.846	20.206	24.75	0.677	20.565	19.97	22"
24"	24.000	1.412	21.007	44.03	1.143	21.577	36.10	0.923	22.043	29.45	0.738	22.435	23.76	24"
26"	26.000	1.529	22.759	51.67	1.238	23.375	42.36	1.000	23.880	34.57	0.800	24.304	27.89	26"
28"	28.000	1.647	24.508	59.93	1.333	25.174	49.13	1.077	25.717	40.09	0.862	26.173	32.34	28"
30"	30.000	1.765	26.258	68.80	1.429	26.971	56.40	1.154	27.554	46.02	0.923	28.043	37.13	30"
32"	32.000	1.882	28.010	78.28	1.524	28.769	64.17	1.231	29.390	52.36	0.985	29.912	42.24	32"
34"	34.000	2.000	29.760	88.37	1.619	30.568	72.44	1.308	31.227	59.11	1.046	31.782	47.69	34"
36"	36.000	2.118	31.510	99.07	1.714	32.366	81.21	1.385	33.064	66.27	1.108	33.651	53.46	36"
42"	42.000	2.471	36.761	134.84	2.000	37.760	110.54	1.615	38.576	90.20	1.292	39.261	72.77	42"
48"	48.000	2.824	42.013	176.12	2.286	43.154	144.38	1.846	44.086	117.81	1.477	44.869	95.05	48"
54"	54.000	3.176	47.266	222.90	2.571	48.549	182.73	2.077	49.597	149.10	1.662	50.477	120.29	54"

This size and dimension chart is intended for reference purposes. It should not be used in place of the advice from a licensed Professional Engineer. Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter is calculated using IPS OD and Minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimension and tolerances in the applicable pipe manufacturing specification.

Visit www.performancepipe.com for the most current literature.

Bulletin: PP 152-4710

February 2015 Supersedes all previous publications
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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 17 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

PERFORMANCE PIPE
A Division of Chevron Phillips Chemical Company LP

PerformancePipe.com

DRISCOPLEX® 9200
HDPE LINER DATA SHEET

DriscoPlex® 9200 Liner meets or exceeds:

ASTM D3350
cell classification PE445574C
PPI TR-4 designation PE4710
Produced to Customer Specific sizes

DriscoPlex® 9200 Liner for:

Lining existing pipelines for service in Oil & Gas Gathering, Coal Bed Methane, Raw Water, Brine Water, Landfill Methane, Landfill Leachate, etc.
Iron Pipe Size OD (IPS) ¾" to 54",
40' and 50' Joints / Solid Black

NOMINAL PIPE PROPERTIES [1]	UNIT	TEST METHOD	VALUE PE4710
Density	gms / cm^3	ASTM D1505	.960 (black)
Melt Index (MI) Condition 190°C / 2.16kg	gms / 10 minutes	ASTM D1238	0.08
Hydrostatic Design Basis 73° F (23° C)	psi	ASTM D2837	1600
Hydrostatic Design Basis 140° F (60° C)	psi	ASTM D2837	1000
Color: UV Stabilizer [C]	---	ASTM D3350	Min 2% Carbon Black
NOMINAL MATERIAL PROPERTIES [1] [2]	**UNIT**	**TEST METHOD**	**VALUE PE4710**
Flexural Modulus 2% Secant – 16:1 span: depth. 0.5 in / min.	psi	ASTM D790	>120,000
Tensile Strength at Yield	psi	ASTM D638 Type IV	>3500
Elongation at Break 2 in / min., Type IV Bar	%	ASTM D638	>800
Elastic Modulus	psi	ASTM D638	>175,000
Hardness	Shore D	ASTM D2240	62
PENT	hrs	ASTM F1473	>500
Vicat Softening Temperature	°F	ASTM D1525	256
Brittleness Temperature	°F	ASTM D746	< -103
Thermal Expansion	in / in / °F	ASTM D696	1.0 x 10^{-4}

1. This is not a product specification and does not guarantee or establish specific minimum or maximum values or manufacturing tolerance for material or piping products to be supplied.
2. Values obtained from tests of specimens taken from piping product may vary from these typical values.

When Performance Matters Rely on Performance Pipe

Bulletin: PP112 / October 2015

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Performance Pipe, a division of Chevron Phillips Chemical Company LP | 5085 W. Park Blvd | Suite 500 | Plano, TX 75093 | Phone: 800-527-0662 | Fax: 972-599-7348

This data sheet provides typical properties for Performance Pipe piping products. Before using this product, the user is advised and cautioned to make their own determination and assessment of the safety and suitability of the product for the specific use in question and is further advised against relying on the information contained herein as it may relate to any specific use or application. It is the ultimate responsibility of the user to ensure that the product is suited and the information is application to the user's specific application. Chevron Phillips Chemical Company LP does not make, and expressly disclaims, all warranties, including warranties of merchantability or fitness for a particular purpose, regardless of whether oral or written, express or implied, allegedly arising from any usage of any trade or from any course of dealing in connection with the use of information contained herein or the product itself. The user expressly assumes all risk and liability, whether based in contract, tort or otherwise, in connection with the use of the information contained herein or the product itself. Further, information contained herein is given without reference to any intellectual property issues, as well as federal, state or local laws which may be encountered in the use thereof. Such questions should be investigated by the user. The data sheet may change periodically. Visit www.Performance Pipe.com for the most current data sheet.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 18 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 3 – EPA/600/2-88/052, LINING OF WASTE CONTAINMENT AND OTHER IMPOUNDMENT FACILITIES

where

W = force per unit length of pipe, and

B_c = outside diameter of pipe.

I.2.2.2 Positive Projecting Condition (Figure I-4)--

This condition is assumed to exist whenever the top of the pipe is at or above the level of the bottom of the unit. In this case, the load on the pipe can be assumed to be equal to the weight of a prism of overlying waste fill with a width B_c and height H_f plus the weight of a similar prism of gravel backfill above the pipe; because the pressure due to the gravel backfill typically will be small compared to the pressure due to the waste fill, the vertical pressure on the top of the pipe can be assumed to be equal to the unit weight of the waste fill multiplied by the distance from top of the waste fill to top of pipe, thus:

$$\sigma_v = (\omega_f)(H_f).$$

I.2.2.3 Perforated Pipe--

Perforations will reduce the effective length of pipe available to carry loads and resist deflection. The effect of perforations can be taken into account by using an increased load per nominal unit length of the pipe. If l_p equals the cumulative length in inches of perforations per foot of pipe, the increased vertical stress to be used equals:

$$(\sigma_v)_{design} = \frac{12}{12-l_p} \times (\sigma_v)_{actual}.$$

I.2.3 Deflection

A well-accepted formula for calculating flexible pipe deflection under earth loading is that developed by Spangler. This equation, also known as the Iowa formula, is presented together with suggested values for its various constants in the 1970 edition of the American Society of Civil Engineers (ASCE) Manual of Practice, No. 37, Chapter 9, Section E, Subsection 1, and is as follows:

$$\Delta y = D_e \frac{KWr^3}{EI + 0.061\,E'r^3}$$

where,

Δy = horizontal and vertical deflection of the pipe (in.),

D_e = a factor, generally taken at a conservative value of 1.5, compensating for the lag or time dependent behavior of the soil/pipe systems (dimensionless),

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 20 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

W = vertical load acting on the pipe per unit of pipe length (lb/in.),

r = mean radius of the pipe (in.),

E = modulus of elasticity of the pipe materials (psi),

E' = modulus of passive soil resistance (psi) (normally estimated to be 300 psi for soils of Proctor density of 65%, and 700 psi for soils of Proctor density of at least 90%),

K = bedding constant, reflecting the support the pipe receives from the bottom of the trench (dimensionless) (a conservative value generally taken is 0.10), and

I = moment of inertia of pipe wall per unit of length (in.^{4}/in.); for any round pipe, $I = t^3/12$ where t is the average thickness (in).

The equation can be rewritten to express pipe deflection as a decimal fraction of the pipe diameter, B_c, and to relate it to the vertical stress on the pipe as follows:

$$\frac{W}{B_c} = \sigma_v = \frac{(\Delta y)}{(B_c)}\left(\frac{EI + 0.061E'r^3}{D_e K r^3}\right).$$

Solutions to this equation are shown graphically in Fig. J-7 where the quantity $\sigma_v/(\Delta y/B_c)$ has been plotted against the passive soil modulus E'. The relationship between $\sigma_v/(\Delta y/B_c)$ and E' has been shown for four plastic pipes: 4 and 6-in. Schedule 40 and 4 and 6-in. Schedule 80 PVC pipe. In computing the quantity EI for these pipes, a reduced modulus was used to account for creep of the plastic pipe. A value equal to 142,000 psi was used to correspond to the modulus at 50 years under sustained loading (see Janson, 1974). Also shown is the relationship for EI = 0. This would represent a relationship between $\sigma_v/(\Delta y/B_c)$ and E', if the stiffness of the pipe is neglected.

In addition to using the chart to check the adequacy of a given pipe, the chart can be used to determine the necessary value of EI/r^3 which the pipe must have for given values of $\sigma_{max}/(\Delta y/B_c)$ and E'. Although it is customary to use either 300 or 700 psi for the value of the modulus of passive soil resistance, it should be noted that the modulus of elasticity of a coarse grained soil (sand or gravel) increases with increasing pressure (or depth in the ground). Thus, it should be expected that the modulus of passive soil resistance also would increase with increasing pressure or depth of fill.

The term EI in Spangler's equation reflects the pipe's contribution to the total resistance to deflection under load offered by the pipe/soil system. This term, known as the pipe's Stiffness Factor, is related to the pipe's behavior under parallel plate loading as per ASTM D2412, "External Loading Properties of Plastic Pipe by Parallel Plate Loading," by the following expression:

$$EI = 0.149r^3(F/\Delta y),$$

where

E, I and r are as previously defined:

F = the recorded load (lb/linear in.) required to produce a pipe deflection Δy, and

Δy = the pipe's deflection (in.).

Minimum values of the term $F/\Delta y$, called Pipe Stiffness, are set according to Pipe DR (dimension ratio) by the ASTM PVC Sewer Pipe Specifications D3033 and D3034. The DR represents the ratio of the pipe's average outside diameter to its minimum wall thickness. Thus, for each DR there is a corresponding minimum specified value of $F/\Delta y$.

The above expression for EI can be substituted into the previous equation for deflection to obtain the following:

$$\frac{\sigma_v}{(\Delta y/B_c)} = \frac{(0.149F/Wy) + 0.061E'}{D_e K}.$$

Solutions to this equation can be made on a graph similar to Figure I-7 where the quantity $\sigma_v/(\Delta y/B_c)$ is plotted against the soil modulus E' for several values of $F/\Delta y$.

I.2.4 Buckling Capacity

The capacity of a buried plastic drain pipe to support vertical stresses may be limited by buckling. Estimates of the vertical stresses at which buckling of the 6-in. Schedule 40 PVC pipe (the most flexible of the four pipes shown) will occur are indicated by the curve in Figure I-7. For the four pipes shown, buckling would not be a controlling factor. However, it could be a controlling factor, depending on the flexibility of the pipe and the modulus of passive soil resistance. Specific information for other sizes and pipe materials proposed for use in the collection system should be secured from the pipe manufacturer.

I.2.5 Compressive Strength

The capacity of the pipe to support vertical stresses may be influenced by the circumferential compressive strength of the pipe. The designer or

reviewer should secure up-to-date information on circumferential compressive strength characteristics from the manufacturer of the type of pipe proposed for use.

1.2.6 Construction Loadings

A pipe correctly designed to withstand loading from a high fill can fail from loading received during construction. Although only a fraction of a stationary wheel or tracked vehicle load applied at the ground surface over a trench is transmitted to a pipe through the trench backfill, the percentage increases rapidly as the vertical distance between the loaded surface and the top of the pipe decreases. In addition, moving loads cause impact loading which is generally considered to have a 1.5 to 2.0 multiplier effect over stationary loading.

In general, equipment should not cross leachate collection drains installed in trenches with shallow cover or in projecting installations. When equipment must be routed across a drain, impact loading can be minimized by mounding material over the pipe to provide a vertical separation of 4 ft between the loaded surface and the top of the pipe.

1.2.7 Procedures for Calculating Required Pipe Strength

The procedures used to select the proper strength pipe are illustrated in the following examples:

Trench Installation (Figures I-5 and I-8)

Given: z = 1 ft - 8 in. H_f = 100 ft waste fill

B_d = 1 ft - 6 in. ω_f = 50 pcf

$K\mu'$ = 0.19 γ = 110 pcf

pipe diameter = 4 in.

Determine: Required pipe strength/schedule.

Step 1 - Determine the maximum vertical pressure σ_v (psi) acting on the top of the pipe:

$$\frac{z}{B_d} = \frac{1.67}{1.5} = 1.11, \text{ and}$$

$$q_f = (\omega_f)\, H_f = 100\ (50)$$

$$= 5000 \text{ psf.}$$

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 23 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 4 – PLASIC PIPES INSTITUTE HANDBOOK OF PE PIPE

raised to a power. Therefore the lower the DR, the higher the resistance. Buried pipe has an added resistance due to support (or constraint) from the surrounding soil.

Non-pressurized pipes or gravity flow pipes are most likely to have a net compressive stress in the pipe wall and, therefore, the allowable buckling pressure should be calculated and compared to the total (soil and ground water) pressure. For most pressure pipe applications, the fluid pressure in the pipe exceeds the external pressure, and the net stress in the pipe wall is tensile. Buckling needs only be considered for that time the pipe is not under pressure, such as during and immediately after construction and during system shut-downs and, in cases in which a surge pressure event can produce a temporary negative internal pressure. Under these circumstances the pipe will react much stiffer to buckling as its modulus is higher under short term loading. When designing, select a modulus appropriate for the duration of the negative external pressure. For pipe that are subjected to negative pressure due to surge, consideration should be given to selecting a DR that gives the pipe sufficient unconstrained collapse strength to resist the full applied negative pressure without support for the soil. This is to insure against construction affects that result in the embedment material not developing its full design strength.

This chapter gives two equations for calculating buckling. The modified Luscher Equation is for buried pipes that are beneath the ground water level, subject to vacuum pressure, or under live load with a shallow cover. These forces act to increase even the slightest eccentricity in the pipe wall by following deformation inward. While soil pressure alone can create instability, soil is less likely to follow deformation inward, particularly if it is granular. So, dry ground buckling is only considered for deep applications and is given by the Moore-Selig Equation found in the section, "Buckling of Pipes in Deep, Dry Fills".

Luscher Equation for Constrained Buckling Below Ground Water Level

For pipes below the ground water level, operating under a full or partial vacuum, or subject to live load, Luscher's equation may be used to determine the allowable constrained buckling pressure. Equation 3-15 and 3-16 are for DR and profile pipe respectively.

(3-15)
$$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$$

(3-16)
$$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{EI}{D_M{}^3}}$$

WHERE
P_{WC} = allowable constrained buckling pressure, lb/in²
N = safety factor

(3-17) $$R = 1 - 0.33\frac{H_{GW}}{H}$$

WHERE
R = buoyancy reduction factor
H_{GW} = height of ground water above pipe, ft
H = depth of cover, ft

(3-18) $$B' = \frac{1}{1 + 4e^{(-0.065H)}}$$

WHERE
e = natural log base number, 2.71828
E' = soil reaction modulus, psi
E = apparent modulus of elasticity, psi
DR = Dimension Ratio
I = pipe wall moment of inertia, in⁴/in ($t^3/12$, if solid wall construction)
D_M = Mean diameter ($D_I + 2z$ or $D_O - t$), in

Although buckling occurs rapidly, long-term external pressure can gradually deform the pipe to the point of instability. This behavior is considered viscoelastic and can be accounted for in Equations 3-15 and 3-16 by using the apparent modulus of elasticity value for the appropriate time and temperature of the loading. For instance, a vacuum event is resisted by the short-term value of the modulus whereas continuous ground water pressure would be resisted by the 50 year value. For modulus values see Appendix, Chapter 3.

For pipes buried with less than 4 ft or a full diameter of cover, Equations 3-15 and 3-16 may have limited applicability. In this case the designer may want to use Equations 3-39 and 3-40.

The designer should apply a safety factor commensurate with the application. A safety factor of 2.0 has been used for thermoplastic pipe.

The allowable constrained buckling pressure should be compared to the total vertical stress acting on the pipe crown from the combined load of soil, and ground water or floodwater. It is prudent to check buckling resistance against a ground water level for a 100-year-flood. In this calculation the total vertical stress is typically taken as the prism load pressure for saturated soil, plus the fluid pressure of any floodwater above the ground surface.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 26 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 5 – SD-LEF-TI-005 REV 1 CALCULATION 3, STATIC AND DYNAMIC LOADS ON LEACHATE RISER

RPP-CALC-63746 Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 27 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

HANFORD HNF-SD-LEF-TI-005 Rev. 1 Page No. 1 of 1

DESIGN ANALYSIS Revision 0

Client WHC WO/Job No. W-105/ER1162

Subject Static & Dynamic Loads on Leachate Pipe Date 3/28/91 By 3/28/91 Checked 3/28/91 By S D Conwell

Location Revised By

These calculations demonstrate the ability of the secondary leachate pipe to withstand both normally expected and construction-impact loadings.

References: 1. Lining of Waste Containment and Other Impoundment Facilities, EPA/600/2-88/052.
2. Driscopipe Catalogue, 'Driscopipe Systems Design,' and 'Driscopipe 8600 Dimensions and Pressure Ratings.'
3. ECOS Part B Appl., Sweet-Edward/EMCON, Prj. 8401.08

DIMENSIONS:

$in \equiv 1L$ $ft \equiv 12 \cdot in$ $cm \equiv 2.54 \cdot in$ $lb \equiv 1M$ $s \equiv 1T$

$si \equiv in^2$ $sf \equiv ft^2$ $ci \equiv in^3$ $cf \equiv ft^3$

VARIABLES:

From drawing H-2-79591: Elevation of effluent surface = 598.6 feet
Elevation of bottom of sump = 576.6 feet

Depth of Effluent: $D_e := 22 \cdot ft$

From drawing H-2-79790: Large LCH-R: $D_1 := 10 \cdot in$

Small LCH-R: $d_s := 4 \cdot in$

Backfill on Pipe: $B_p := 1.1 \cdot 12 \cdot in - 10 \cdot in$ $B_p = 3.2 \cdot inches$

Normal working values:

Weight of Effluent: $W_e := 62.4 \frac{lb}{cf}$ Weight of Gravel: $W_g := 145 \frac{lb}{cf}$

CALCULATIONS:

VERTICAL PRESSURE (From EPA, page I-16):

$\sigma_a := D_e \cdot W_e + W_g \cdot B_p$ $\sigma_a = 9.802 \cdot pounds \cdot inches^{-2}$

Attachment 2-3

884 Revision 1

18

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 28 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD — HNF-SD-LEF-TI-005 Rev. 1 — Page No. 2 of — Revision 0

DESIGN ANALYSIS

Client: WHC — WO/Job No. W405/ER1162

Subject: Loads on LCH.P — Date: 3/29/91 — By: [illegible]

Checked: 3/28/91 — By: [illegible]

Location — Revised — By

Adjusting for perforations (from EPA, page I-10):

A half-inch hole every eight inches is equivalent to a 3/4 inch hole each foot:

$$\sigma_d := \frac{12}{12 - .75} \cdot \sigma_a \qquad \sigma_d = 10.455 \cdot \text{pounds} \cdot \text{inches}^{-2}$$

DEFLECTION ('Iowa' formula, EPA page I-10):

Time Lagging Factor: $T_1 := 1.0$ (Due to a liquid rather than a soil overburden, and the small abount of gravel backfill, no time lag is expected or used.)

Modulus of Passive Soil Resistance: $R_s := 300 \cdot \frac{lb}{si}$

(This is a minimum, as gravel will not be compacted during construction.)

Bedding Factor: $K := 0.1$

Pipe characteristic values are those for Driscopipe 8600, as found in 'Driscopipe Engineering Characteristics' and 'Dimensions and Pressure Ratings.' This brand of pipe conforms to the M-35 Pipe Code.

Modulus of Elasticity: $E := 110000 \cdot \frac{lb}{si}$ (Driscopipe 8600)

Mean Radius of Pipe: $r := 10 \cdot in$ — Pipe Width: $B_c := 10.75 \cdot in$

Pipe MOI (as per EPA page I-11): SDR := 25.3

Wall thickness: $t := .425 \cdot in$

$$I := \frac{t^3}{12}$$

Attachment 2-1

19

RPP-CALC-63746 Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 29 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

RAISER ENGINEERS HANFORD — HNF-SD-LEF-TI-005 Rev. 1 — Page No. 3 of — Revision 0

DESIGN ANALYSIS

Client WHC — WO/Job No. W-105/EB1163

Subject Loads on LCH-2 — Date 3/28/91 By [illegible]

Checked 3/28/91 By [illegible]

Location — Revised — By

IOWA FORMULA:

$$def := \frac{\sigma_d \cdot T_1 \cdot K \cdot r^3 \cdot B_c}{E \cdot I + 0.061 \cdot R_s \cdot r^3} \qquad def = 0.591 \cdot inches$$

Allowable pipe deflection ratio: EPA gives a range of .05 to 0.1 (page I-16).

$$dr := \frac{def}{r} \qquad dr = 0.059 \qquad 0.05 < 0.059 < 0.1$$

Safety Factor:

$$\frac{0.1}{dr} = 1.691$$

BUCKLING FAILURE (checked as per "Driscopipe Systems Design", page 54):

Stress in pipe wall:

$$S_a := (SDR - 1) \cdot \frac{\sigma_d}{2} \qquad S_a = 127.032 \cdot pounds \cdot inches^{-2}$$

From Chart 25, page 53 of "Systems Design" $E_t = 97500 \cdot psi^{-1}$

Critical Collapse Differential Pressure:

$$P_c := 2.32 \cdot \frac{E_t}{SDR^3} \qquad P_c = 13.968 \cdot pounds \cdot inches^{-2}$$

Attachment 2-5

20

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 30 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD HNF-SD-LEF-TI-005 REV 1 Page No. 4 of Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. W-105/ER1162

Subject Loads on LCH-R Date 3/22/91 By [illegible]

Checked 3/28/91 By [illegible]

Location Revised By

Chart 26, page 53 of "Systems Design" gives values of soil resistivity. Gravel values are not listed, so the previous assumed value of 300 psi will be used.

Critical Buckling Pressure:

$$P_{cb} := .8 \cdot \left[R_s \cdot P_c\right]^{.5} \qquad P_{cb} = 51.786 \cdot pounds \cdot inches^{-2}$$

Safety Factor:

$$\frac{P_{cb}}{\sigma_d} = 4.953$$

The values for deflection failure and buckling failure determined above indicate that the selected pipe is acceptable under normal basin conditions.

CONSTRUCTION LOADING
(As per Ref. 3)

Variables:

P = static load imposed by construction equipment
Pd = dynamic load imposed by construction equipment
Tw = total weight of construction equipment
W = weight per axle of construction equipment
da = distance between axles
R = hypotenuse distance to off-pipe axle

Values:

$T_w := 2000 \cdot lb \qquad W := T_w \cdot .5 \qquad d_a := 60 \cdot in$

$$R := \left[B_p^2 + d_a^2\right]^{.5}$$

Attachment 2-6

21

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 31 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD

HNF-SD-LEF-TI-005 Rev1

DESIGN ANALYSIS

Page No. 3 of

Revision 0

Client WHC

WO/Job No. W-105 / ER1162

Subject Loads on LCH-R

Date 3/28/91 By

Checked 3/28/91 By

Location

Revised By

$$P := \frac{3 \cdot W \cdot B_p^3}{2 \cdot \pi \cdot R_p^5} + \frac{3 \cdot W}{2 \cdot \pi \cdot B_p^2} \qquad P = 46.627 \cdot \text{pounds} \cdot \text{inches}^{-2}$$

Add 50% for dynamic loading:

$$P_d := P \cdot 1.5 \qquad P_d = 69.941 \cdot \text{pounds} \cdot \text{inches}^{-2}$$

Deflection due to dynamic loading by equipment:

$$def_d := \frac{P_d \cdot T_1 \cdot K \cdot r_c^3 \cdot B}{E \cdot I + 0.061 \cdot R_s \cdot r^3} \qquad def_d = 3.956 \cdot \text{inches}$$

Buckling due to dynamic loading:

Critical buckling stress was determined above. The safety factor under dynamic conditions is:

Critical Stress: $P_{cb} = 51.786 \cdot \text{pounds} \cdot \text{inches}^{-2}$

Dynamic Load Stress: $P_d = 69.941 \cdot \text{pounds} \cdot \text{inches}^{-2}$

Safety Factor: $\frac{P_{cb}}{P_d} = 0.74$

Attachment 2-7

22

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 32 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD HNF-SD-LEF-TI-005 Rev1 Page No. 6 of Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. W-705/ER1162

Subject Loads on LCH-R Date 3/28/91 By [illegible]

Checked 3/28/91 By [illegible]

Location Revised By

The above analyses demonstrate that while the leachate riser pipe has adequate strength to withstand the static load imposed by a filled basin, it is too weak to support a dynamic load imposed by small construction equipment. The riser, however, extends only four feet into the Northwest corner of the basin, and can easily be avoided during placement of the gravel leachate collection system.

Attachment 2-8

23

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 33 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 6 – BOBCAT S740 SKID-STEER SPECIFICATIONS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 34 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

SHARE

Skid-Steer Loaders / S740 Skid-Steer Loader

Specifications & Options

Standard Optional N/A Not Applicable

Units US

	Bobcat S740
Emissions Tier (EPA)	Tier 4
Engine Cooling	Liquid
Engine Fuel	Diesel
Horsepower	74 hp
Turbocharged Engine	✓

Performance

Rated Operating Capacity (ISO)	3,100 lb
Tipping Load	6200 lb
Operating Weight	8794 lb
Travel Speed	7.1 mph
Travel Speed (2-speed option)	12.3 mph

Capacities

Fuel Tank	23.9 gal

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 35 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

12/23/2019 S740 Skid-Steer Loader Specs & Options - Bobcat Company

Hydraulic System

System Relief @ Quick Couplers	3,500 psi
Auxiliary Std Flow	23 gal/min
Auxiliary High Flow	30.5 gal/min

Dimension

Length	141.6 in
Length without Attachment	114.3 in
Length with Standard Bucket	141.6 in
Width	72.1 in
Width (with bucket)	74 in
Height	81.3 in
Height with Operator Cab	81.3 in
Height to Bucket Hinge Pin	132 in
Reach @ Maximum Height	31.5 in
Turning Radius	85.8 in
Wheelbase	48.3 in

https://www.bobcat.com/loaders/skid-steer-loaders/models/s740/specs-options 2/4

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 36 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 7 - CAT D6 DOZER SPECIFICATIONS

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 37 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

PRODUCT SPECIFICATIONS FOR D6

ENGINE

Engine Model	Cat C9.3B
Power - Net	215 HP
Emissions	U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final
Net Power - Rated - ISO 9249/SAE J1349	215 HP
Net Power - Rated - ISO 9249/SAE J1349 (DIN)	219 HP
Build Number	20A
Note (1)	Rated horsepower at 2,200 rpm
Note (2)	All non-road Tier 4 Interim and Final, Stage IIIB, IV and V and Korea Tier 4 Final diesel engines are required to use only ultra-low sulfur diesel (ULSD) fuels containing 15 ppm (mg/kg) sulfur or less. Biodiesel blends up to B20 (20% blend by volume) are acceptable when blended with 15 ppm (mg/kg) sulfur or less ULSD. B20 should meet ASTM D7467 specification (biodiesel blend stock should meet Cat biodiesel spec, ASTM D6751 or EN 14214). Cat DEO-ULS or oils that meet the Cat ECF-3, API CJ-4 and ACEA E9 specification are required. Consult your OMM for further machine specific fuel recommendations.
Note (3)	Diesel Exhaust Fluid (DEF) used in Cat Selective Catalytic Reduction (SCR) systems must meet the requirements outlined in the International Organization for Standardization (ISO) standard 22241.
Note (4)	Basic machine specs provided below. For complete specifications and dimensions by configuration, blade and track shoe offerings and more, please visit the product download section to view the full D6/D6 XE Technical Specifications.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 38 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

DIMENSIONS – LGP VPAT (30-IN)

Operating Weight	50650 lb

TRANSMISSION

Power Train	Fully Automatic 4-Speed Powershift

SERVICE REFILL CAPACITIES

Fuel Tank	90 gal (US)
DEF Tank	7.4 gal (US)

AIR CONDITIONING SYSTEM

Air Conditioning	The air conditioning system on this machine contains the fluorinated greenhouse gas refrigerant R134a (Global Warming Potential = 1430). The system contains 1.36 kg of refrigerant which has a CO2 equivalent of 1.946 metric tonnes.

D6 PUSH ARM

Operating Weight	48500 lb
Ground Pressure	7.9 psi
Width of Standard Shoe	24 in
Blade	Semi-Universal (SU)
Blade Capacity	7.5 yd^3

D6 LGP (30-IN) PUSH ARM

Operating Weight	50130 lb
Ground Pressure	6.6 psi
Width of Standard Shoe	30 in
Blade	Semi-Universal (SU)
Blade Capacity	7.6 yd³

D6 LGP (36-IN) PUSH ARM

Operating Weight	52615 lb
Ground Pressure	5.1 psi
Width of Standard Shoe	36 in
Blade	Straight
Blade Capacity	5 yd³

D6 VPAT

Operating Weight	49030 lb
Ground Pressure	7.1 psi
Width of Standard Shoe	24 in
Blade	VPAT
Blade Capacity	5.4 yd³

D6 LGP (30-IN) VPAT

Operating Weight	50650 lb
Ground Pressure	5.8 psi
Width of Standard Shoe	30 in

Width of Standard Shoe	30 in
Blade	VPAT
Blade Capacity	5.9 yd³

D6 LGP (36-IN) VPAT

Operating Weight	51875 lb
Ground Pressure	5 psi
Width of Standard Shoe	36 in
Blade	VPAT
Blade Capacity	6.5 yd³

D6 STANDARD EQUIPMENT

POWER TRAIN

- Hydraulic reversing fan
- Double reduction planetary final drives
- Cat C9.3B diesel engine
- Fully-automatic 4-speed transmission

OPERATOR ENVIRONMENT

- Cloth seat
- Added storage areas
- Electrohydraulic implement and steering controls
- Lights - 6 LED
- Communication radio ready
- Cab mounted modular Heating/Ventilation/Air Conditioning (HVAC) system
- Fully redesigned cab, sound suppressed, with Integrated Roll Over Protective Structure (ROPS)
- Integrated rearview camera
- Adjustable operator controls/armrests
- Full-color 10-inch (254 mm) liquid crystal touch screen display

CAT TECHNOLOGY

Slope Indicate

Product Link, Cellular PLE641

Attachment Ready Option (ARO) with Assist/Cat GRADE with Slope Assist

UNDERCARRIAGE

Redesigned track roller frame

SERVICE AND MAINTENANCE

Ecology drains

30-minute cab removal

Rear access ladder

Fire extinguisher mounting provision

Shovel holder

Underhood work light

Ground level service center

HYDRAULICS

Independent steering and implement pumps

Load sensing hydraulics

ATTACHMENTS

Ripper-ready rear hydraulics

D6 OPTIONAL EQUIPMENT

OPERATOR ENVIRONMENT

Premium lights - 12 LED

Integrated warning lights

Deluxe leather heated/ventilated seat

CAT TECHNOLOGY

Cat GRADE with 3D

Product Link Elite PLE631 - Dual Cellular/Satellite

BLADES

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 42 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Semi-Universal

Straight blade

Angle blade

Foldable VPAT - under 3 m (9.9 ft) transport width (Not available in all regions)

Variable Pitch Angle Tilt (VPAT)

Waste/Landfill

NDERCARRIAGE

Moderate Service or Extreme Service track shoes

10-Roller Fine Grading undercarriage

Heavy Duty (HDXL with DuraLink) or SystemOne

ERVICE AND MAINTENANCE

Refilling fuel pump (EU only)

TTACHMENTS

High lift ripper with straight or curved shanks

Winch

Forestry and Waste Special Arrangements

Counterweights

Ripper and winch-ready rear hydraulics

Side screens

Rear screen - hinged or fixed

Sweeps

Drawbar

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 43 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
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D6/D6 XE

Track-Type Tractors

Technical Specifications

Engine

Engine Model	Cat® C9.3B	
Emissions	U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final	
Build Number	20A	
Net Power (Rated) – D6 2,200 rpm/D6 XE 1,700 rpm		
ISO 9249/SAE J1349	161 kW	215 hp
ISO 9249/SAE J1349 (DIN)		219 hp
D6 Engine Power (Maximum) – 1,200 rpm		
ISO 14396	187 kW	251 hp
ISO 14396 (DIN)		254 hp
D6 XE Engine Power (Maximum) – 1,400 rpm		
ISO 14396	177 kW	237 hp
ISO 14396 (DIN)		241 hp
Bore	115 mm	4.5 in
Stroke	149 mm	5.9 in
Displacement	9.3 L	567 in³

- The new Cat C9.3B engine features a new high pressure common rail fuel system, simplified engine system electronics, and simplified air system through the removal of the previously used exhaust gas recirculation (EGR) system.
- The XE drive train allows the engine to operate in a tighter rpm range, 1,400-1,700 rpm, which helps extend engine life and provide improved fuel economy. The increased drive train efficiency also allows the machine to provide more engine power to the ground, resulting in greater machine performance.
- Net power advertised is the power available at the engine flywheel when the engine is equipped with a fan, air cleaner, clean emissions module and alternator.
- No derating required up to 2286 m (7,500 ft). Above this, automatic derating occurs.
- All non-road Tier 4 Interim and Final, Stage IIIB, IV and V and Korea Tier 4 Final diesel engines are required to use only ultra-low sulfur diesel (ULSD) fuels containing 15 ppm (mg/kg) sulfur or less. Biodiesel blends up to B20 (20% blend by volume) are acceptable when blended with 15 ppm (mg/kg) sulfur or less ULSD. B20 should meet ASTM D7467 specification (biodiesel blend stock should meet Cat biodiesel spec, ASTM D6751 or EN 14214). Cat DEO-ULS™ or oils that meet the Cat ECF-3, API CJ-4, and ACEA E9 specification are required. Consult your OMM for further machine specific fuel recommendations.
- Diesel Exhaust Fluid (DEF) used in Cat Selective Catalytic Reduction (SCR) systems must meet the requirements outlined in the International Organization for Standardization (ISO) standard 22241.

D6 XE Drive Train

Type	Electric Drive
Electric Drive System Nominal Voltage	715 Volts

CAT®

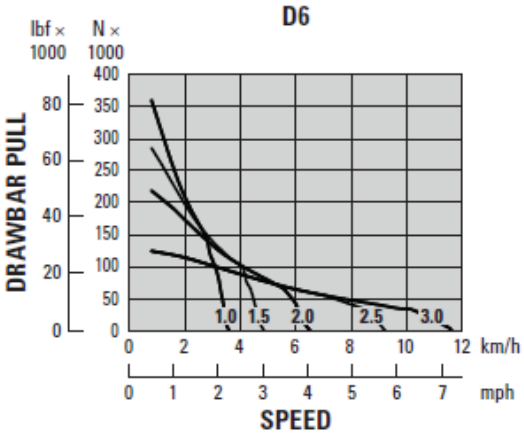
CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 44 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

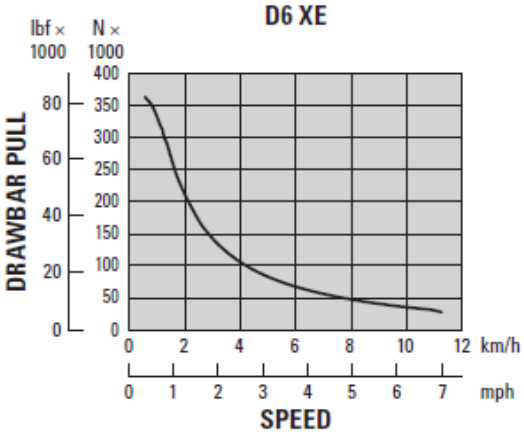
Maximum Drawbar Power		
D6	114 kW	153 hp
D6 XE	119 kW	160 hp

D6 Travel Speed		
1.0 Forward	3.6 km/h	2.2 mph
1.5 Forward	4.9 km/h	3.0 mph
2.0 Forward	6.5 km/h	4.0 mph
2.5 Forward	9.2 km/h	5.7 mph
3.0 Forward	11.7 km/h	7.2 mph
1.0 Reverse	3.6 km/h	2.2 mph
1.5 Reverse	4.9 km/h	3.0 mph
2.0 Reverse	6.5 km/h	4.0 mph
2.5 Reverse	8.7 km/h	5.4 mph
3.0 Reverse	11.7 km/h	7.2 mph



NOTE: Usable pull will depend on traction and weight of machine.

D6 XE Travel Speed		
1.0 Forward	3.6 km/h	2.2 mph
1.5 Forward	4.9 km/h	3.0 mph
2.0 Forward	6.5 km/h	4.0 mph
2.5 Forward	9.2 km/h	5.7 mph
3.0 Forward	11.7 km/h	7.2 mph
1.0 Reverse	3.6 km/h	2.2 mph
1.5 Reverse	4.9 km/h	3.0 mph
2.0 Reverse	6.5 km/h	4.0 mph
2.5 Reverse	9.2 km/h	5.7 mph
3.0 Reverse	11.7 km/h	7.2 mph



NOTE: Usable pull will depend on traction and weight of machine.

- The fully automatic D6 4-speed transmission, with lock-up clutch torque divider, continuously optimizes gear and engine speed for the application.
- The D6 XE Electric Drive power train has no gears to shift. The dozer automatically optimizes power and efficiency for the application and provides constant power to the ground.
- Thirty ground speed selections are available for both power trains, from 0.0 to 3.0 in 0.1 increments.

2

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 45 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Hydraulic Controls – Maximum Operating Flows

	D6 (1,900 rpm engine speed*)		D6 XE (1,700 rpm engine speed*)	
Implement Pump Maximum Flow	212 L/min	56 gal/min	212 L/min	56 gal/min
Steering Pump Maximum Flow	198 L/min	52 gal/min	240 L/min	63 gal/min
Fan Pump Flow at Maximum Fan (1,550 rpm)	42 L/min	11 gal/min	—	—
Fan Pump Flow at Maximum Fan (1,625 rpm)	—	—	44 L/min	12 gal/min

*Engine speed varies with load and travel speed. A high idle/low working load speed shown.

Hydraulic Controls – Maximum Operating Pressures

Implement Relief*	27 600 ± 500 kPa	4,000 ± 73 psi
Steering – D6 (89 cc pump)**		
Electronic Relief	42 500 ± 1000 kPa	6,168 ± 145 psi
System Maximum Relief	47 800 ± 1000 kPa	6,938 ± 145 psi
Steering – D6 XE (100 cc pump)***		
Electronic Relief	44 500 ± 1000 kPa	6,459 ± 145 psi
System Maximum Relief	47 800 ± 1000 kPa	6,938 ± 145 psi

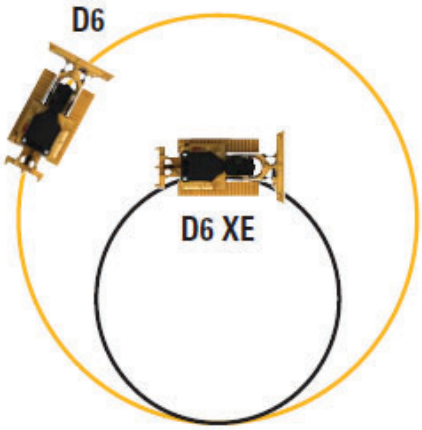
*Implement relief pressure increased over prior model D6 tractors. Consult with your dealer prior to using older vintage or third party implements.

**The same differential steering system is used for both power trains. This system maintains full power to both tracks to provide best-in-class turning with a loaded blade.

***The D6 XE power train utilizes a larger steering pump and enhanced steering controls to provide more steering power, compared to the D6 power train, to turn larger loads and to improve maneuverability. This includes the ability to counter-rotate in gear.

Steering

The D6 XE power train provides up to a 45 percent steering radius reduction compared to the D6. The D6 XE offers in-gear counter rotation for increased maneuverability.



3

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 46 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE

	Configuration	D6/D6 XE*	
	Operating Weight**	22 000 kg	48,500 lb
	Shipping Weight***	19 060 kg	42,020 lb
	Ground Pressure (ISO 16754)	54 kPa	7.9 psi
	Undercarriage (Standard)	42 Section with 7 Bottom Rollers	
1	Track Gauge	1.930 m	76 in
2	Width of Maximum Track Shoe	0.610 m	24 in
3	Width over Tracks	2.540 m	100 in
	Width over Trunnions	2.692 m	106 in
4	Length of Track on Ground	2.964 m	116.7 in
	Ground Contact Area (ISO 16754)	3.992 m²	6188 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.361 m	14.2 in
	Oscillation at Front Idler	0.103 m	4.0 in
5	Machine Height****	3.172 m	124.9 in
6	Length of Machine without Blade	4.730 m	186.2 in

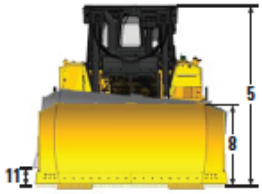
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, 6 SU blade, and calculated per ISO 16754 unless otherwise specified.

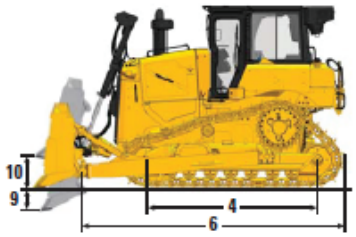
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

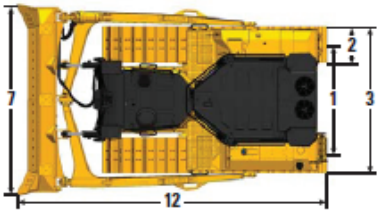
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link™ Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 SU		6 SU Landfill		6A	
	Capacity (ISO 9246)	5.7 m³	7.5 yd³	11.2 m³	14.6 yd³	4.2 m³	5.5 yd³
7	Width across End Bits	3.312 m	10 ft 10.4 in	3.312 m	10 ft 10.4 in	4.389 m	14 ft 4.8 in
	Width without End Bits	3.246 m	10 ft 7.8 in	3.246 m	10 ft 7.8 in	4.250 m	13 ft 11.3 in
	Width across End Bits (Blade Angled)	N/A		N/A		3.982 m	13 ft 0.8 in
	Width without End Bits (Blade Angled)	N/A		N/A		3.858 m	12 ft 7.9 in
	Maximum Blade Angle	N/A		N/A		25 degrees	
8	Height	1.408 m	4 ft 7.4 in	2.027 m	6 ft 7.8 in	1.150 m	3 ft 9.3 in
9	Dig Depth	0.502 m	19.8 in	0.502 m	19.8 in	0.595 m	23.4 in
10	Lift Height	1.180 m	46.5 in	1.180 m	46.5 in	1.084 m	42.7 in
11	Maximum Tilt at Blade Corner	0.564 m	22.2 in	0.564 m	22.2 in	0.599 m	23.6 in
	Maximum Tilt Angle	9.8 degrees		9.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.436 m	17 ft 10.0 in	5.436 m	17 ft 10.0 in	5.377 m	17 ft 7.7 in
	Length of Machine (Blade Angled)	N/A		N/A		6.418 m	21 ft 0.7 in
	Weight (Blade)	1373 kg	3,027 lb	1592 kg	3,510 lb	1253 kg	2,762 lb
	Weight (Blade and Push Arms)	2608 kg	5,750 lb	2827 kg	6,232 lb	3394 kg	7,842 lb

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 47 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP (30 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	22 740 kg	50,130 lb
	Shipping Weight***	19 580 kg	43,165 lb
	Ground Pressure (ISO 16754)	46 kPA	6.6 psi
	Undercarriage (Standard)	42 Section with 7 Bottom Rollers	
1	Track Gauge	2.080 m	82 in
2	Width of Maximum Track Shoe	0.760 m	30 in
3	Width over Tracks	2.840 m	111.8 in
	Width over Trunnions	2.994 m	117.9 in
4	Length of Track on Ground	2.964 m	116.7 in
	Ground Contact Area (ISO 16754)	4.990 m²	7,735 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.361 m	14.2 in
	Oscillation at Front Idler	0.100 m	3.9 in
5	Machine Height****	3.172 m	124.9 in
6	Length of Machine without Blade	4.730 m	186.2 in

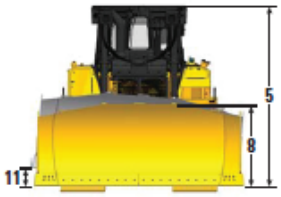
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, 6 SU blade, and calculated per ISO 16754 unless otherwise specified.

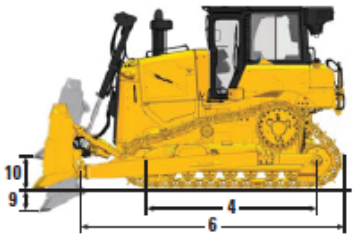
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

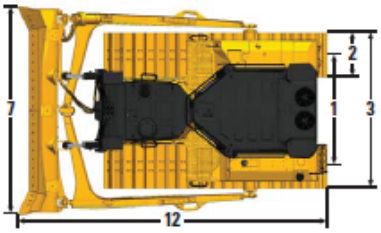
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 SU LGP (30 in)		6 SU LGP (30 in) Landfill		6A LGP (30 in)	
	Capacity (ISO 9246)	5.8 m³	7.6 yd³	12.3 m³	16.1 yd³	4.6 m³	6.0 yd³
7	Width across End Bits	3.613 m	11 ft 10.2 in	3.613 m	11 ft 10.2 in	4.735 m	15 ft 6.4 in
	Width without End Bits	3.551 m	11 ft 7.8 in	3.551 m	11 ft 7.8 in	4.596 m	15 ft 1.0 in
	Width across End Bits (Blade Angled)	N/A		N/A		4.295 m	14 ft 1.1 in
	Width without End Bits (Blade Angled)	N/A		N/A		4.172 m	13 ft 8.3 in
	Maximum Blade Angle	N/A		N/A		25 degrees	
8	Height	1.408 m	4 ft 7.4 in	2.027 m	6 ft 7.8 in	1.150 m	3 ft 9.3 in
9	Dig Depth	0.502 m	19.8 in	0.502 m	19.8 in	0.568 m	22.3 in
10	Lift Height	1.180 m	46.5 in	1.180 m	46.5 in	1.125 m	44.3 in
11	Maximum Tilt at Blade Corner	0.551 m	21.7 in	0.551 m	21.7 in	0.640 m	25.2 in
	Maximum Tilt Angle	8.8 degrees		8.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.436 m	17 ft 10.0 in	5.436 m	17 ft 10.0 in	5.448 m	17 ft 10.5 in
	Length of Machine (Blade Angled)	N/A		N/A		6.561 m	21 ft 6.3 in
	Weight (Blade)	1446 kg	3,188 lb	1700 kg	3,748 lb	1350 kg	2,976 lb
	Weight (Blade and Push Arms)	2827 kg	6,232 lb	2973 kg	6,554 lb	3414 kg	7,527 lb

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 48 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP (36 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	23 866 kg	52,615 lb
	Shipping Weight***	21 165 kg	46,660 lb
	Ground Pressure (ISO 16754)	35 kPa	5.1 psi
	Undercarriage (Standard)	45 Section with 8 Bottom Rollers	
1	Track Gauge	2.286 m	90 in
2	Width of Maximum Track Shoe	0.915 m	36 in
3	Width over Tracks	3.200 m	126.0 in
	Width over Trunnions	3.491 m	137.4 in
4	Length of Track on Ground	3.247 m	127.8 in
	Ground Contact Area (ISO 16754)	6.505 m²	10,083 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.411 m	16.2 in
	Oscillation at Front Idler	0.116 m	4.6 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.040 m	198.4 in

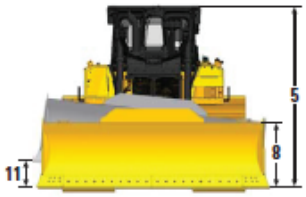
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, 6 S blade, and calculated per ISO 16754 unless otherwise specified.

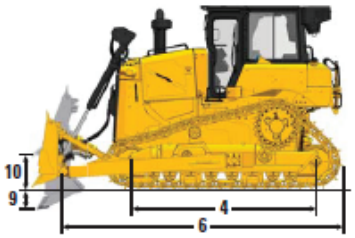
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

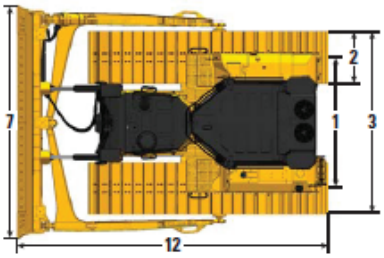
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 S LGP (36 in)		6 S LGP (36 in) Landfill		6A LGP (36 in)	
	Capacity (ISO 9246)	3.8 m³	5.0 yd³	9.40 m³	12.3 yd³	5.0 m³	6.5 yd³
7	Width across End Bits	4.063 m	13 ft 4 in	4.063 m	13 ft 4 in	5.100 m	16 ft 8.8 in
	Width without End Bits	3.917 m	12 ft 10.2 in	3.917 m	12 ft 10.2 in	4.961 m	16 ft 3.3 in
	Width across End Bits (Blade Angled)	N/A		N/A		4.626 m	15 ft 2.1 in
	Width without End Bits (Blade Angled)	N/A		N/A		4.502 m	14 ft 9.2 in
	Maximum Blade Angle	N/A		N/A		25 degrees	
8	Height	1.108 m	3 ft 7.6 in	1.767 m	3 ft 7.6 in	1.150 m	3 ft 9.3 in
9	Dig Depth	0.600 m	1 ft 11.6 in	0.600 m	1 ft 11.6 in	0.719 m	28.3 in
10	Lift Height	1.080 m	3 ft 6.5 in	1.080 m	3 ft 6.5 in	1.173 m	46.2 in
11	Maximum Tilt at Blade Corner	0.500 m	1 ft 7.7 in	0.500 m	1 ft 7.7 in	0.689 m	27.1 in
	Maximum Tilt Angle	8.8 degrees		8.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.483 m	17 ft 11.9 in	5.483 m	17 ft 11.9 in	5.960 m	19 ft 6.6 in
	Length of Machine (Blade Angled)	N/A		N/A		6.996 m	22 ft 10.3 in
	Weight (Blade)	1220 kg	2,690 lb	1432 kg	3,157 lb	1453 kg	3,203 lb
	Weight (Blade and Push Arms)	2370 kg	5,225 lb	2582 kg	5,692 lb	3618 kg	7,976 lb

6

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 49 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE VPAT

	Configuration	D6/D6 XE*	
	Operating Weight**	22 240 kg	49,030 lb
	Shipping Weight***	20 500 kg	45,195 lb
	Ground Pressure (ISO 16754)	49 kPa	7.1 psi
	Undercarriage (Standard)	45 Section with 8 Bottom Rollers	
1	Track Gauge	2.080 m	82 in
2	Width of Maximum Track Shoe	0.610 m	24 in
3	Width over Tracks	2.690 m	105.9 in
4	Length of Track on Ground	3.247 m	127.8 in
	Ground Contact Area (ISO 16754)	4.473 m²	6,933 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.422 m	16.6 in
	Oscillation at Front Idler	0.112 m	4.4 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.134 m	202.1 in

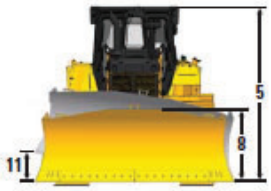
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, VPAT blade, and calculated per ISO 16754 unless otherwise specified.

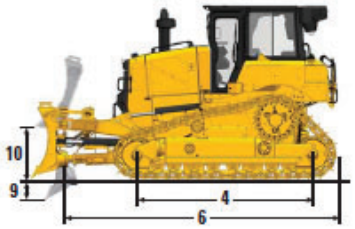
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

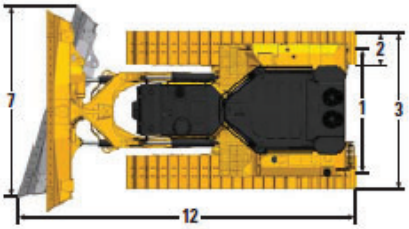
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT	
	Capacity (ISO 9246)	4.1 m³	5.4 yd³
7	Width across End Bits	3.680 m	12 ft 0.9 in
	Width without End Bits	3.570 m	11 ft 8.6 in
	Width across End Bits (Blade Angled)	3.363 m	11 ft 0.4 in
	Width without End Bits (Blade Angled)	3.266 m	10 ft 8.6 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.576 m	22.7 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.365 m	20 ft 10.6 in
	Weight (Blade)	1414 kg	3,117 lb

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 50 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP VPAT (30 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	22 975 kg	50,650 lb
	Shipping Weight***	21 125 kg	46,575 lb
	Ground Pressure (ISO 16754)	40 kPa	5.8 psi
	Undercarriage (Standard)	46 Section with 8 Bottom Rollers	
	Undercarriage (Optional)	46 Section with 10 Bottom Rollers	
1	Track Gauge	2.286 m	90 in
2	Width of Maximum Track Shoe	0.760 m	30 in
3	Width over Tracks	3.046 m	119.9 in
4	Length of Track on Ground	3.355 m	132.1 in
	Ground Contact Area (ISO 16754)	5.591 m²	8,666 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.390 m	15.4 in
	Oscillation at Front Idler	0.121 m	4.8 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.134 m	202.1 in

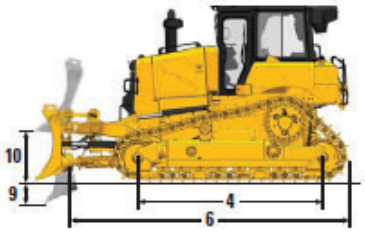
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, VPAT blade, and calculated per ISO 16754 unless otherwise specified.

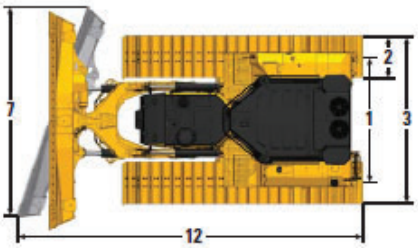
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.





Blade

	Configuration	6 VPAT LGP (30 in)	
	Capacity (ISO 9246)	4.5 m³	5.9 yd³
7	Width across End Bits	4.000 m	13 ft 1.5 in
	Width without End Bits	3.890 m	12 ft 9.1 in
	Width across End Bits (Blade Angled)	3.655 m	11 ft 11.9 in
	Width without End Bits (Blade Angled)	3.554 m	11 ft 7.9 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.625 m	24.6 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.430 m	21 ft 1.1 in
	Weight (Blade)	1516 kg	3,342 lb

8

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 51 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP VPAT (36 in)

	Configuration	D6/D6 XE*	
	Operating Weight**	23 530 kg	51,875 lb
	Shipping Weight***	21 580 kg	47,575 lb
	Ground Pressure (ISO 16754)	35 kPa	5.0 psi
	Undercarriage (Standard)	46 Section with 8 Bottom Rollers	
	Undercarriage (Optional)	46 Section with 10 Bottom Rollers	
1	Track Gauge	2.39 m	94 in
2	Width of Maximum Track Shoe	0.915 m	36 in
3	Width over Tracks	3.305 m	130.1 in
4	Length of Track on Ground	3.355 m	132.1 in
	Ground Contact Area (ISO 16754)	6.709 m²	9,510 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.383 m	15.1 in
	Oscillation at Front Idler	0.121 m	4.8 in
5	Machine Height****	3.222 m	126.9 in
6	Length of Machine without Blade	5.134 m	202.1 in

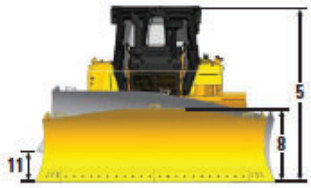
All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of maximum width for configuration, VPAT blade, and calculated per ISO 16754 unless otherwise specified.

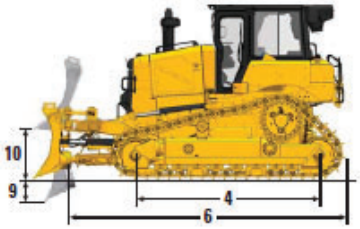
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

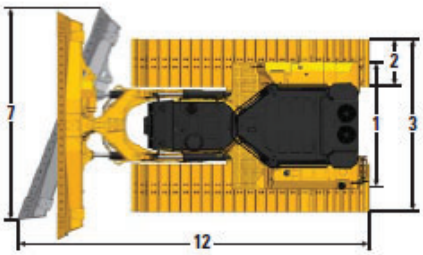
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, tow point, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and tow point.

****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT LGP (36 in)	
	Capacity (ISO 9246)	4.86 m³	6.5 yd³
7	Width across End Bits	4.340 m	14 ft 2.9 in
	Width without End Bits	4.230 m	13 ft 10.5 in
	Width across End Bits (Blade Angled)	3.966 m	13 ft 0.1 in
	Width without End Bits (Blade Angled)	3.868 m	12 ft 8.3 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.684 m	26.9 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.500 m	21 ft 3.9 in
	Weight (Blade)	1617 kg	3,565 lb

9

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-002	**Rev.** 0	**Page No.** 52 of 52
Title: LERF Basin 41 Static and Dynamic Loads on Leachate Pipe			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

D6/D6 XE Track-Type Tractors Specifications

Configuration Tables – D6/D6 XE LGP Folding VPAT (30 in) – *EU only*

	Configuration	D6/D6 XE*	
	Operating Weight**	22 360 kg	49,295 lb
	Shipping Weight***	19 775 kg	43,595 lb
	Ground Pressure (ISO 16754)	45 kPa	6.5 psi
	Undercarriage (Standard)	46 Section with 8 Bottom Rollers	
	Undercarriage (Optional)	46 Section with 10 Bottom Rollers	
1	Track Gauge	2.286 m	90 in
2	Width of Standard Track Shoe****	0.660 m	26 in
	Optional Maximum Track Shoe****	0.760 m	30 in
3	Width over Tracks	2.946 m	116.0 in
4	Length of Track on Ground	3.355 m	132.1 in
	Ground Contact Area (ISO 16754)	4.845 m²	7,510 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.390 m	15.4 in
	Oscillation at Front Idler	0.121 m	4.8 in
5	Machine Height*****	3.222 m	126.9 in
6	Length of Machine without Blade	5 134 m	202.1 in

All dimensions above with Heavy Duty undercarriage with Moderate Service shoes of standard width for configuration, Foldable VPAT blade, and calculated per ISO 16754 unless otherwise specified.

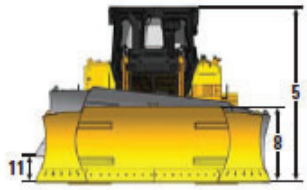
*XE power train adds 0.7 kPA (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

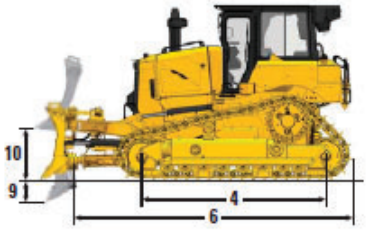
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

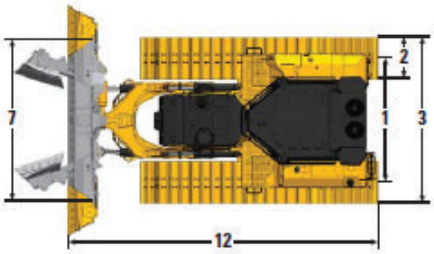
***Shipping weight includes blade lift cylinders, C-frame, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Standard track shoe width ensures 3.0 m shipping width with blade folded. Optional 30 inch track shoes provide lower ground pressure of 42 kPa (6.1 psi). Increases shipping width to 3.046 m (120.0 in).

*****Machine height from tip of grouser to top of Product Link Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.4 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat GRADE with 3D antennas are installed there is no addition to machine height.







Blade

	Configuration	6 VPAT LGP Folding (30 in)	
	Capacity (ISO 9246)	5.2 m³	6.8 yd³
7	Width across End Bits	4.229 m	13 ft 10.5 in
	Width without End Bits	4.115 m	13 ft 6.0 in
	Width of Folded Blade	2.960 m	9 ft 8.5 in
	Maximum Blade Angle	24.1 degrees	
8	Height	1.312 m	4 ft 3.7 in
9	Dig Depth	0.698 m	27.5 in
10	Lift Height	1.131 m	44.5 in
11	Maximum Tilt at Blade Corner	0.659 m	26.0 in
	Maximum Tilt Angle	9 degrees	
	Pitch Adjustment	+3.1/–2.9 degrees	
12	Length of Machine (Blade Straight)	5.662 m	18 ft 6.9 in
	Length of Machine (Blade Angled)	6.643 m	21 ft 9.5 in
	Weight (Blade)	2254 kg	4,969 lb

10

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE: May 20,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63747 **Rev.** 00

2. **Title:**
LERF Basin 41 Wind Uplift Forces and Required Ballast

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Harrison, Sarah E	*Harrison, Sarah E*	05/20/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/23/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/10/2020
Document Control Approval	Hood, Evan	*Hood, Evan*	05/19/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/30/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/10/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/18/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	05/19/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Becasue of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Taylor Grant and Jeremy Debban is signing as Checker for Darrel Packard. Taylor Grant and Darrel Packard are not currently in SPF.

The following trademark statement applies to this calculation and will be added to the document at the next revision:

Excel is a registered trademark of the Microsoft Corporation, Redmond, Washington.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
McFerran, Brandon E	242-A/AW/ETF OPERATIONS
McShane, Michael P	ENGINEERING PROGRAMS
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Name	**Organization**
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Rutherford, Wally	ETF ENGINEERING
Sackett, Tom E	TANK FARM PROJECTS
Samoska, Jerry A	INSTRUMENT & CNTRL ENGINEERING
Shultz, Milton V	NUCLEAR SAFETY
Smith, Gregory E	TANK FARM PROJECTS ENGINEERING
Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63747
Revision 0

LERF Basin 41 Wind Uplift Forces and Required Ballast

Prepared by

G. T. Grant
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
May 2020

washington river protection solutions

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PROFESSIONAL ENGINEER

5-18-2020

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

A-6007-231 (REV 0)

Approved for Public Release;
Further Dissemination Unlimited

RPP-CALC-63747 Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 17	
		Date 05/14/2020	**Rev. No.** 1
		Calculation No: S54413.024-C-003	

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions

Title:

LERF Basin 41 Wind Uplift Forces and Required Ballast

Purpose and Objective:

The purpose of this calculation is to determine the required ballast to counteract wind uplift forces on the HDPE liner system. Ballast will be determined in the form of sandbags for during construction and water for post construction.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	16	**Print Name/ Sign:**	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	04/07/2020	4/9/2020	4/9/2020
Revision Description (Revision Description/Affected Pages):					
1	17	**Print Name/ Sign:**	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	05/14/2020	05/15/2020	05/15/2020

Revision Description (Revision Description/Affected Pages):

Revised the design wind speed for during construction from 64 mph to 82 mph. Expanded Section 8.2 to calculate the wind uplift force due to an 80 mph wind speed and a 90 mph wind speed, then used linear interpolation to calculate the wind uplift force due to an 82 mph wind speed. (Affected Sections 3.1, 6.0, and 8.2)

Added 2 acronyms. (Affected Page 3)

Updated Attachment 4. (Affected Attachment 4)

RPP-CALC-63747 Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Page No.
S54413.024	S54413.024-C-003 Rev. 1	2 of 17

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
G. Taylor Grant	5/14/2020
Checker (Print Name and Sign):	**Date:**
Darrel Packard	5/15/2020

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1		**Page No.** 3 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast			
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

TABLE OF CONTENTS

1.0 PURPOSE 4
2.0 METHODOLOGY 4
3.0 DESIGN INPUTS 4
3.1 Wind Speed 4
3.2 Water Weight 4
3.3 Liner Weight 4
3.4 Sandbag Weight 4
4.0 ASSUMPTIONS 5
5.0 COMPUTER SOFTWARE 5
6.0 RESULTS 5
7.0 REFERENCES 5
8.0 CALCULATIONS 5
8.1 Operation 5
8.2 Construction 6

Attachments

ATTACHMENT – 1 – GEOSYTHETIC DESIGN GUIDANCE FOR HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS

ATTACHMENT – 2 – ARGU AMERICA HDPE SMOOTH LINER CUT SHEET

ATTACHMENT – 3 – TFC-ENG-STD-06, REV D-2, DESIGN LOADS FOR TANK FARM FACILITIES

ATTACHMENT – 4 – H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER

Acronyms

DCR	Demand-to-Capacity Ratio
HDPE	High Density Polyethylene
LERF	Liquid Effluent Retention Facility
mph	mile per hour
psf	pound per square foot

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1	**Page No.** 4 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast		

Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

1.0 PURPOSE

The purpose of this calculation is to determine the required ballast to counteract wind uplift forces on the HDPE liner system. Ballast will be determined in the form of sandbags for during construction and water for post construction.

2.0 METHODOLOGY

Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments (Reference 1) has a procedure on Pages VI-14 and VI-34 to calculate the wind uplift forces on a basin liner system. This method will be used to calculate the maximum wind uplift forces on the liner system. The required water level to counteract the wind uplift will then be determined.

This calculation provides a recommended sandbag spacing for securing the HDPE liner during construction, however, the Contractor is ultimately responsible for securing the HDPE liner during construction.

3.0 DESIGN INPUTS

3.1 Wind Speed

Design Loads for Tank Farm Facilities, TFC-ENG-STD-06, REV D-2, Table 3 (Reference 3, Page 30) provides the design wind speed of 110 mph. This will be the design wind speed for anchorage calculations during operation. During construction, a reduced wind load may be used since it will be temporary. The reduced wind load for during construction is from Table 3, Note e, and is 82 mph (Reference 3, Page 30)

V_{op} = 110 mph

V_{con} = 82 mph

3.2 Water Weight

Weight of water =W_w = 62.4 pcf

3.3 Liner Weight

The weight of the HDPE liner is taken as 4200 lbs per 13800 sf (Reference 2).

Weight of the HDPE liner = W_L = 4200 lbs / 13800 sf = 0.304 psf

3.4 Sandbag Weight

The weight of a sandbag is taken as 50 lbs. The Contractor may need to adjust the recommended spacing determined in this calculation based on actual sandbag weight, or other ballast used.

Weight of sandbag = W_S = 50 lbs

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1	**Page No.** 5 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast		

Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

4.0 ASSUMPTIONS

No assumptions have been made in this calculation.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Calculations are checked using a handheld calculator. Microsoft Excel was used to generate graphs. The Microsoft Excel generated graphs were checked using a handheld calculator.

6.0 RESULTS

During operation and while the basin is empty, a water depth of 6 inches will counteract the wind uplift forces. During construction, it is recommended to provide one 50 lb sandbag per 3.11 sf.

7.0 REFERENCES

1) Richardson, Gregory N., and Robert M. Koerner, *Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments*, Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency
2) ARGU America HDPE Smooth Liner Cut Sheet
3) TFC-ENG-STD-06 REV D-2, Design Loads for Tank Farm Facilities
4) H-2-838750, Sheet 1, Rev. 0, LERF Basin 41 Civil Primary Liner

8.0 CALCULATIONS

8.1 Operation

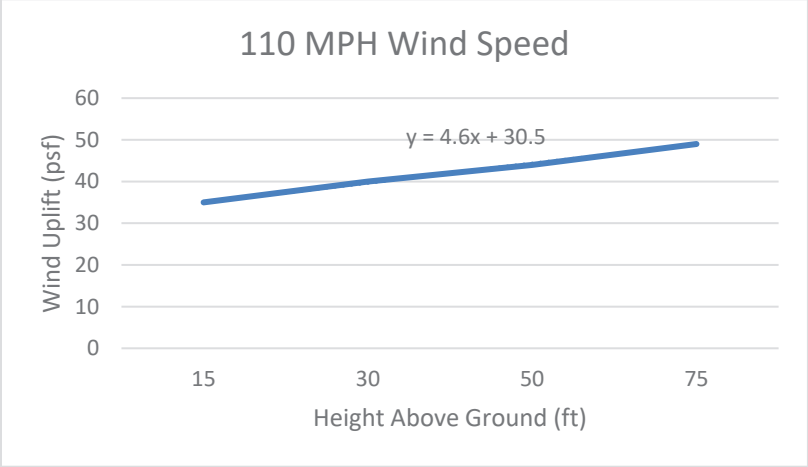
Table 6.2 from Reference 1, Page VI-14, is below and provides wind uplift forces based on design wind speeds and the height above ground. For basins located below grade it is permitted to graph the wind uplift force versus height above ground for a given wind speed, and then use extrapolation to determine the wind uplift force (Reference 1, Page VI-13).

Table 6.2 Wind Uplift Forces, PSF (Factory Mutual System)

Height Above Ground, (ft)	Wind Isotach, mph (Figure 6.2): City, Suburban Areas, Towns and Wooded Areas					Flat, Open Country, or Open Coastal Belt>1500ft from Coast					
	70	80	90	100	110	70	80	90	100	110	120
0-15	10*	11	14	17	20	14	18	23	29	35	41
30	10	13	17	21	25	16	21	27	33	40	48
50	12	15	19	24	29	18	24	30	37	44	53
75	14	18	22	27	33	20	26	33	40	49	58

* Uplift Pressures in PSF

The below graph provides the wind uplift for a 110 mph wind speed. The maximum uplift force occurs at the top of the basin.



At height above ground = 0 ft, the uplift force U_{op} = 30.5 psf.

When the basin is complete but empty, uplift forces may be resisted by water.

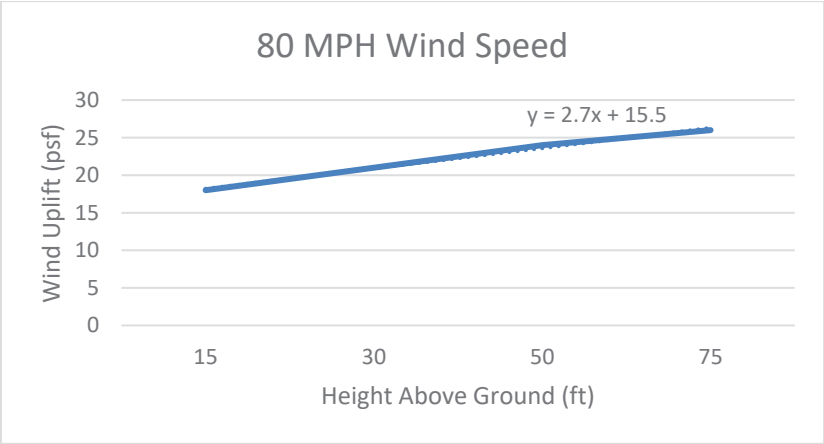
Height of water = $(U_{op} - W_L) / W_w$ = (30.5 psf – 0.304 psf) / 62.4 pcf = 0.48 ft = 5.8 inch

Maintaining a water depth of 6 inches will result in a DCR = 5.8/6 = 0.967 < 1 okay

8.2 Construction

Table 6.2 from Reference 1, Page VI-14, provides wind uplift forces based on design wind speeds at 10 mph intervals. The uplift force will be determined for an 80 mph wind speed and a 90 mph wind speed. Linear interpolation will be used to determine the uplift force for V_{con} = 82 mph.

The below graph provides the wind uplift for V_{con_80} = 80 mph wind speed. The maximum uplift force occurs at the top of the basin.

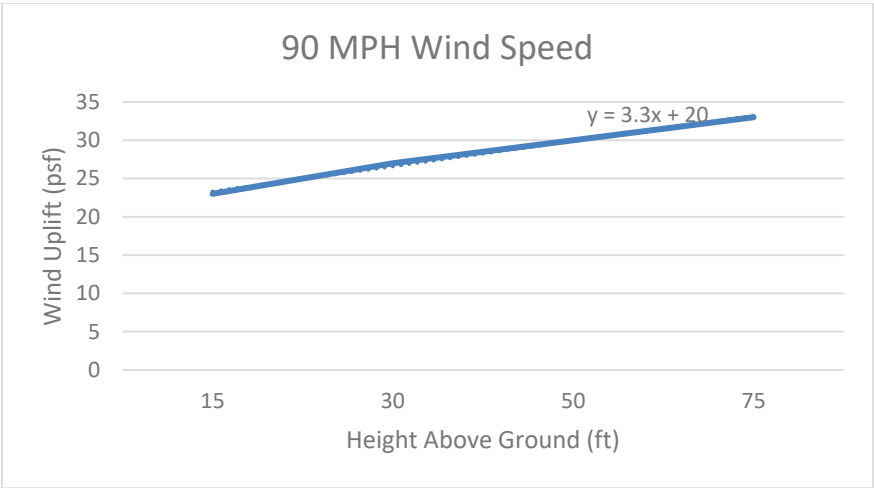


CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1		**Page No.** 7 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast			
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

At height above ground = 0 ft, the uplift force U_{con_80} = 15.5 psf.

The below graph provides the wind uplift for V_{con_90} = 90 mph wind speed. The maximum uplift force occurs at the top of the basin.



At height above ground = 0 ft, the uplift force U_{con_90} = 20 psf.

Uplift force at 82 mph = $U_{con} = U_{con_80} + [(U_{con_90} - U_{con_80}) / (V_{con_90} - V_{con_80})] \times (V_{con} - V_{con_80})$

$= 15.5 \text{ psf} + [(20 \text{ psf} - 15.5 \text{ psf}) / (90 \text{ mph} - 80 \text{ mph})] \times (82 \text{ mph} - 80 \text{ mph})$

$= 16.4$ mph

Sandbag spacing = $S_{con} = W_S / (U_{con} - W_L)$ = 50 lbs / (16.4 psf – 0.304 psf) = 3.11 sf

It is recommended to place sandbags at least one 50 lb bag per 3.11 sf.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1		**Page No.** 8 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast			
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

ATTACHMENT – 1 - GEOSYTHETIC DESIGN GUIDANCE FOR HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS

temperature limitations. This is particularly true with the thermoplastic materials, since their properties change with temperature. Temperature also affects the rate that solvents will evaporate and the rate that seams become strong. Most manufacturers suggest that their adhesive systems work best when the temperature of the liner material itself is above 60° F. When ambient temperatures are below 60° F and a solvent adhesive system is being used, heat guns can provide an effective means to help bring the temperature of the liner material up to ideal conditions. Extreme caution must be exercised when using heat guns around flammable solvents, which may ignite, and cholorinated solvents which may generate toxic gas.

Cold weather seaming requires that the field crew exercise caution when making seams to assure that the temperature of the liner material reaches minimum acceptable conditions. A cold weather contact adhesive is sometimes used. Field seaming during precipitation must be avoided. Depending upon the location and the weather conditions, the number of panels placed in one day should not exceed the number which can be seamed in one day. This assures that, should bad weather conditions occur overnight, unseamed panels will not be left on the subgrade, subject to damage, especially from wind.

Wind Uplift Forces--

Wind blowing over a geomembrane exerts varying amounts of uplift force depending on the velocity of the wind and the roughness of the surrounding land. When not adequately resisted by sandbags, the membrane will lift off the ground and exert tear stresses on the sheet and seams. Such wind induced stresses have been responsible for numerous failures. Using methods developed by the flat roof industry, some insight into the problem can be gained.

In the absence of site specific data, design wind speeds for the USA are given in Figure 6.2. These values are annual extremes based on a 100-year mean recurrence intervals and represent worst case situations. These contour values are used directly with Table 6.2 to determine the wind uplift value based on elevation above ground and surface roughness. Thus the method is applicable for FMLs placed at the ground level and on elevated caps. For FMLs below grade we recommend a linear extrapolation as demonstrated in Design Example 6.1. It should be noted that the roofing industry recognizes that the perimeter and corners of sheets are the initiating points for uplift and compensate accordingly. For example, they multiply the perimeter uplift forces by 2 and the corner values by 3 for added safety. The temporary nature of a liner installation may not justify such conservatism.

Anchoring--

Proper anchoring of the liner around the facility perimeter, as well as conscientious tailoring and sealing of the liner around penetrating structures, are essential to satisfactory liner performance. Generally, in cut-and-fill type facilities, it is recommended that the liner material be anchored at the top of the dike or berm one of two ways: (1) using the trench-and-backfill method, or (2) anchoring to a concrete structure. The trench-and-backfill method seems to be recommended most often by liner manufacturers, probably due to its simplicity and economy. Excavation of the anchor trench in preparation for laying the liner is usually accomplished with a trenching machine or by using the blade of a motor

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1	**Page No.** 10 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast		
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

Table 6.2 Wind Uplift Forces, PSF (Factory Mutual System)

Height Above Ground, (ft)	Wind Isotach, mph (Figure 6.2): City, Suburban Areas, Towns and Wooded Areas					Flat, Open Country, or Open Coastal Belt>1500ft from Coast					
	70	80	90	100	110	70	80	90	100	110	120
0-15	10*	11	14	17	20	14	18	23	29	35	41
30	10	13	17	21	25	16	21	27	33	40	48
50	12	15	19	24	29	18	24	30	37	44	53
75	14	18	22	27	33	20	26	33	40	49	58

* Uplift Pressures in PSF

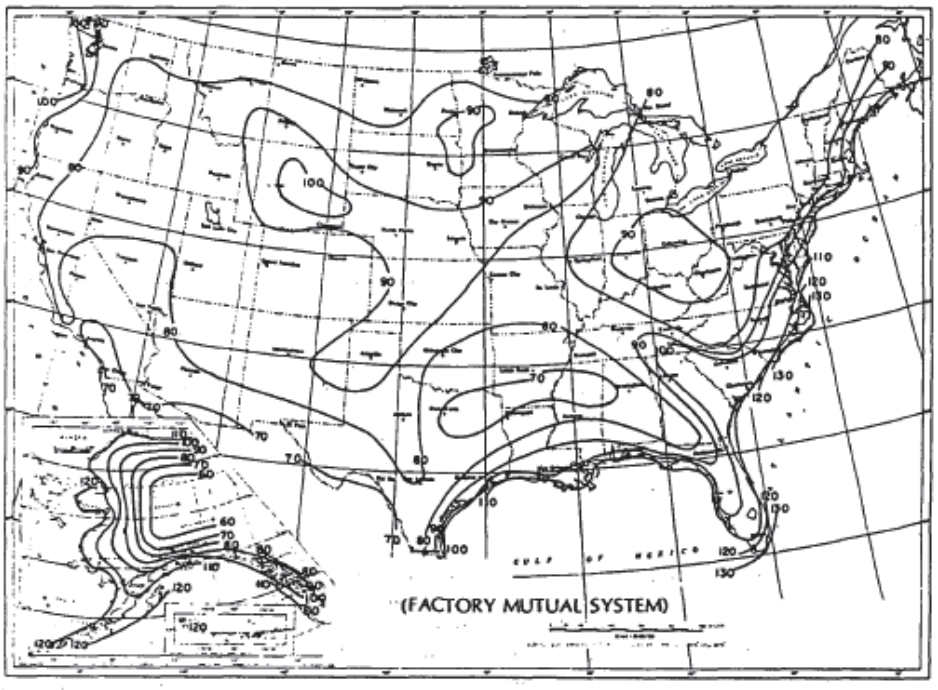


Figure 6.2 Design Maximum Wind Speeds

EPA VI - 14

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1	**Page No.** 11 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast		
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

Cell Component: FLEXIBLE MEMBRANE

Consideration: WIND LIFT: CALCULATE THE REQUIRED SANDBAG SPACING FOR FML/FMC PANELS DURING PLACEMENT.

Required Material Properties	Range	Test	Standard
FLEXIBLE MEMBRANE • UNIT WEIGHT	3-20 OSY	DENSITY	ASTM D792

Draft NTG Minimum

Analysis Procedure:

(1) DETERMINE DESIGN MAXIMUM WIND SPEED, V_{WIND}

• USE SITE SPECIFIC DATA OR REFERENCE FIG 6.2

(2) DETERMINE WIND-UPLIFT PRESSURE, P_{WIND}

• REFERENCE TABLE 6.2 w/ $V_{WIND} \rightarrow P_{WIND}$

NOTE: PERFORM LINEAR INTERPOLATION FOR DEPTHS < 0 FT

(3) CALCULATE SAND BAG SPACING

• W_S = WEIGHT OF SANDBAG

• TRIBUTARY AREA = P_{WIND}/W_S = TA

(4) CALCULATE DESIGN RATIO

DR = TA/[ACTUAL FIELD TRIBUTARY AREA]

Design Ratio:

DR_{MIN} = 1.1 (SHORT-TERM ONLY)

References:

FACTORY MUTUAL SYSTEM

Example:

GIVEN:

• PHILADELPHIA, PA
- ANNUAL EXTREME WIND SPEED (FIG 6.2)
V_{WIND} = 80 MPH

• WIND = 100 YR EXTREME, OPEN COUNTRY

• FML DEPTH = -20 to +20 FT

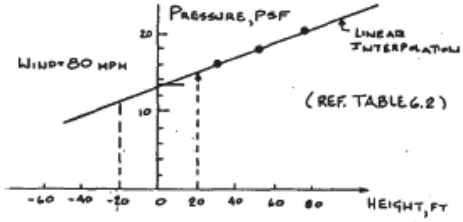
• SANDBAG = 80 lb. @ 1 PER 10 SQ. FT.

• HEIGHT TO FM = -20 FT, 0 FT, +20 FT

(1) DETERMINE DESIGN MAXIMUM WIND SPEED, V_{WIND}

V_{WIND} = 80 MPH (REF FIG 6.2)

(2) DETERMINE WIND UP-LIFT PRESSURE, P_{WIND}



DEPTH -20 FT → 11 PSF
0 FT → 14 PSF
20 FT → 15 PSF

(3) CALCULATE SAND BAG SPACING

-20 FT → 80 lb / 11 PSF = 7.3 SQ. FT.
0 FT → 80 lb / 14 PSF = 5.7 SQ. FT.
+20 FT → 80 lb / 15 PSF = 5.3 SQ. FT.

(4) CALCULATE DESIGN RATIOS

-20 FT. ⇒ 7.3/10.0 = 0.73 NG
0 FT ⇒ 5.7/10.0 = 0.57 NG
+20 FT ⇒ 5.3/10.0 = 0.53 NG

Example No. 6.1

EPA VI-34

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1		**Page No.** 12 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast			
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

ATTACHMENT – 2 – ARGU AMERICA HDPE SMOOTH LINER CUT SHEET

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1	**Page No.** 13 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast		

Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

GEOSYNTHETICS

agru The Plastics Experts.

Smooth Liner®

HIGH DENSITY POLYETHYLENE

PRODUCT DATA

Property	Test Method	Frequency	Minimum Average Values				
Thickness (minimum avg), mil (mm)	ASTM D5199	Per Roll	30 (0.75)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness (minimum), mil (mm)			27 (0.68)	36 (0.9)	54 (1.35)	72 (1.8)	90 (2.25)
Density, g/cc, minimum	ASTM D792, Method B	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (both directions)	ASTM D6693, Type IV						
Strength @ Yield, lb/in width (N/mm)	2in/minute	20,000 lb	66 (11.6)	88 (15.4)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Yield, % (GL=1.3 in)			12	12	12	12	12
Strength @ Break, lb/in width (N/mm)			120 (21)	160 (28)	240 (42)	320 (56)	400 (70)
Elongation @ Break, % (GL=2.0 in)			700	700	700	700	700
Tear Resistance, lbs (N)	ASTM D1004	45,000 lb	22 (98)	30 (133)	45 (200)	60 (267)	72 (320)
Puncture Resistance, lbs (N)	ASTM D4833	45,000 lb	60 (267)	80 (356)	120 (534)	160 (712)	190 (845)
Carbon Black Content, % (range)	ASTM D4218	20,000 lb	2 - 3	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion (Category)	ASTM D5596	45,000 lb	Only near spherical agglomerates: 10 views Cat. 1 or 2				
Stress Crack Resistance (SP NCTL), hrs.	ASTM D5397 Appendix	200,000 lb	500	500	500	500	500
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	200,000 lb	≥140	≥140	≥140	≥140	≥140

AGRU America's geomembranes are certified to pass Low Temp. Brittleness via ASTM D746 (-80°C), Dimensional Stability via ASTM D1204 (±2% @ 100°C). Oven Aging and UV Resistance are tested per GRI GM 13. These product specifications meet or exceed GRI's GM13.

SUPPLY INFORMATION (STANDARD ROLL DIMENSIONS)

THICKNESS		WIDTH		LENGTH		AREA (APPROX.)	
mil	mm	ft	m	ft	m	ft^2	m^2
30	0.75	23	7	1,175	358	27,025	2,511
40	1.0	23	7	900	274	20,700	1,923
60	1.5	23	7	600	183	13,800	1,282
80	2.0	23	7	455	139	10,465	972
100	2.5	23	7	365	111	8,395	780

Note:

Average roll weight is 4,200 lbs (1,905 kg). All rolls are supplied with two slings. Rolls are wound on 6" core. Special length available upon request. Roll length and width have a tolerance of ±1%. The weight values may change due to project specifications (i.e. absolute minimum thickness or special roll length) or shipping requirments (i.e. international containerized shipments).

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Revision Date: December 3, 2018 12:42 PM

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1		**Page No.** 14 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast			
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

ATTACHMENT – 3 – TFC-ENG-STD-06, REV D-2, DESIGN LOADS FOR TANK FARM FACILITIES

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1	**Page No.** 15 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast		

Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

Design Loads for Tank Farm Facilities	Manual	Engineering
	Document	TFC-ENG-STD-06, REV D-2
	Page	30 of 34
	Issue Date	July 31, 2019

Table 3. Wind Load.

		WDC-3	WDC-2	WDC-1/ NDC-0[e]
Basic Straight Wind Design Speed (3-Second Gust), V	Nominal[a] [c]	95 mi/h	91 mi/h	85 mi/h
	Ultimate[b] [c]	122 mi/h[f]	115 mi/h	110 mi/h
Exposure Category		C[d]	C[d]	C[d]

NOTES:

(a) For use with IBC 2009, ASCE 7-05, and other compatible codes and standards, including the exceptions of IBC 2015, Section 1609.1.1.

(b) For use with IBC 2015, ASCE 7-10, and other compatible codes and standards.

(c) Conversion of Nominal Wind speed to Ultimate Wind Speed (Basic Wind Speed ASCE 7-10 corresponds to the rounded value from the following relationship: $V_{asd} = V_{ult} \sqrt{0.6}$ (IBC 2015 Equation 16-33).

(d) Exposure "C," flat and generally open terrain, should be used for all construction unless it can be shown that the necessary permanent shielding will be provided by natural terrain (not including shielding from trees or adjacent buildings).

(e) NDC-0 SSCs shall be designed for WDC-1 wind loading. Wind loads on temporary SSCs erected for a period of less than 180 days, and Construction Project SSCs may be designed to a reduced basic straight wind design speed, provided wind damage to the structure:

1. Will not result in injury to personnel.
2. Will not result in damage to permanent SSCs.
3. Will not result in significant cost to repair or replace the temporary structure.

The reduced basic straight wind design speed shall be based on ASCE 37, but should not be less than 82 mi/h (ultimate)/64 mi/h (nominal) for a 3-Second Gust.

(f) The WDC-3 wind loading of 122 mph is determined from ANSI/ANS-2.3 Figure 4 for Region III wind hazard Site at return period of 2500 years. There are no requirements for extreme wind missile design at the Hanford Site. This is based on the PWHA site specific wind speed for WDC-3 of 96 mph, which is less than the 110 mph missile criteria of DOE-STD-1020-2016.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-003 Rev. 1		**Page No.** 16 of 17
Title: LERF Basin 41 Wind Uplift Forces and Required Ballast			
Prepared By: G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020

ATTACHMENT – 4 – H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER

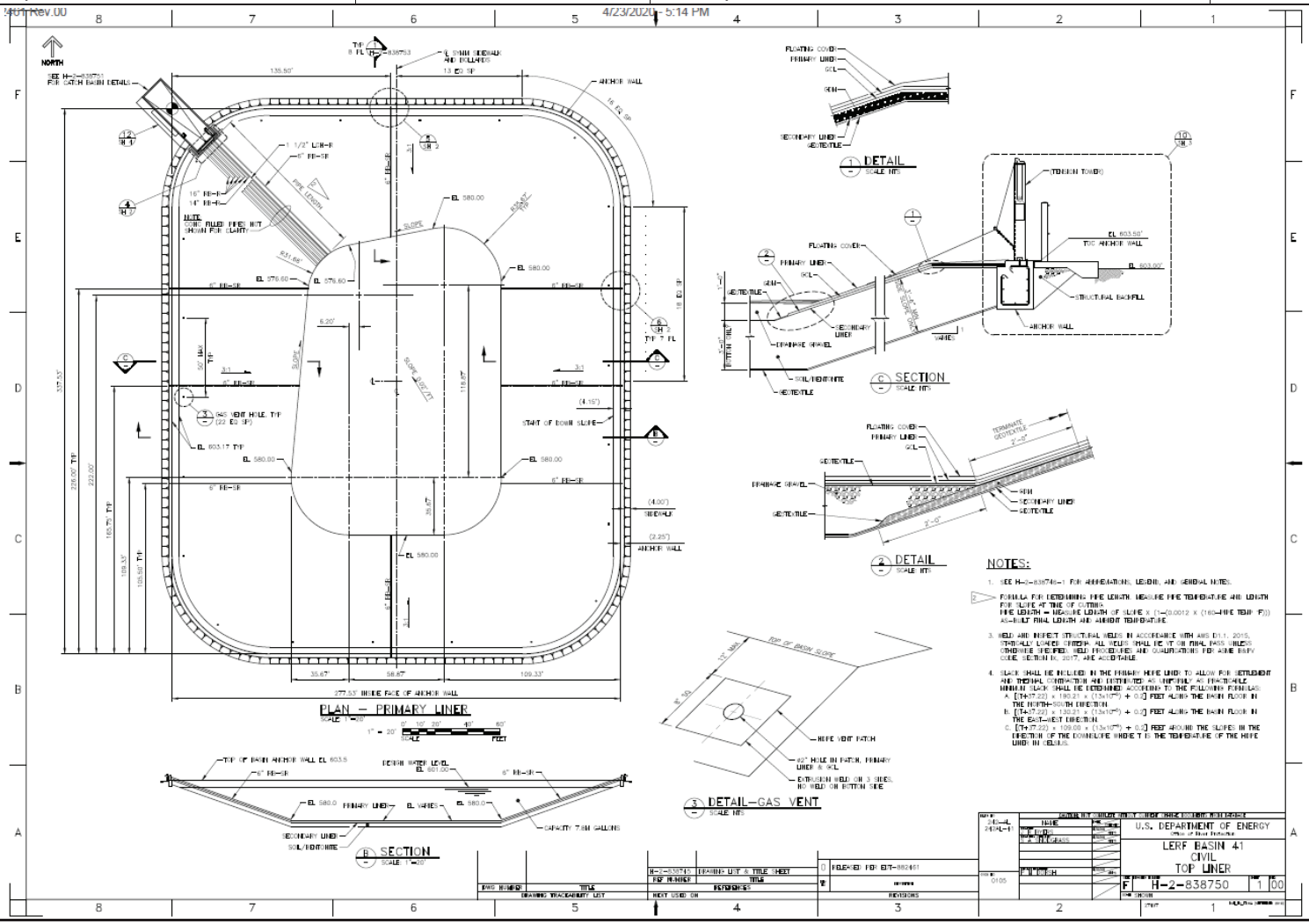
RPP-CALC-63747, Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-003 Rev. 1	**Page No.** 17 of 17	
Title:	LERF Basin 41 Wind Uplift Forces and Required Ballast				
Prepared By:	G. Taylor Grant	**Date:** 05/14/2020	**Checked By:** Darrel J. Packard	**Date:** 05/15/2020	

M01 Rev.00 4/23/2020 - 5:14 PM



DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE:
May 20, 2020
HANFORD RELEASE

1. **Doc No:** RPP-CALC-63748 **Rev.** 00

2. **Title:**
LERF Basin 41 Side Slope Liner Stresses

3. **Project Number:** ☐N/A
T1P226

4. **Design Verification Required:**
☐Yes ☒No

5. **USQ Number:** ☒ N/A
RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type:
public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Aardal, Janis D	*Aardal, Janis D*	05/19/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/23/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/10/2020
Document Control Approval	Hood, Evan	*Hood, Evan*	05/19/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/29/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/10/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/13/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	05/14/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Becasue of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Taylor Grant and Jeremy Debban is signing as Checker for Darrel Packard. Taylor Grant and Darrel Packard are not currently in SPF.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
McFerran, Brandon E	242-A/AW/ETF OPERATIONS
McShane, Michael P	ENGINEERING PROGRAMS
Omberg Carro, Susan K	NUCLEAR SAFETY
Powers, Daniel J	ETF ENGINEERING
Roosendaal, Gene D	TFP PROJECT MANAGEMENT
Rutherford, Wally	ETF ENGINEERING
Sackett, Tom E	TANK FARM PROJECTS

DOCUMENT RELEASE AND CHANGE FORM	**Doc No:** RPP-CALC-63748 **Rev.** 00

14. **Distribution**

Name	**Organization**
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Shultz, Milton V	NUCLEAR SAFETY
Smith, Gregory E	TANK FARM PROJECTS ENGINEERING
Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63748
Revision 0

LERF Basin 41 Side Slope Liner Stresses

Prepared by

G. T. Grant
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
April 2020

washington river protection solutions

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5-18-2020

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

A-6007-231 (REV 0)

Approved for Public Release;
Further Dissemination Unlimited

RPP-CALC-63748 Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 32	
		Date 04/08/2020	**Rev. No.** 0
		Calculation No: S54413.024-C-004	

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions

Title:

LERF Basin 41 Side Slope Liner Stresses

Purpose and Objective:

The purpose of this calculation is to determine the stresses in the liner system for LERF Basin 41, except for the northwest corner of the basin which contains the effluent collection and removal piping system. That corner contains gravel and is in calculation S54413.024-C-005 / RPP-CALC-63749.

The calculated liner stresses will be used to determine the required material strengths to ensure that no liner material will be stressed beyond its capacity.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	32	Print Name/ Sign:	G. Taylor Grant	Darrell Packard	Paul M. Dorsh, P.E.
		Date:	04/08/2020	4/9/2020	4/9/2020

Revision Description (Revision Description/Affected Pages):

		Print Name/ Sign:			
		Date:			

Revision Description (Revision Description/Affected Pages):

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev. No.	Page No.
S54413.024	S54413.024-C-004	0	2 of 32

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
G. Taylor Grant	4/8/2020
Checker (Print Name and Sign):	**Date:**
Darrel Packard	4/9/2020

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 3 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE OF CONTENTS

1.0 PURPOSE 5

2.0 METHODOLOGY 5

3.0 DESIGN INPUTS 5
- 3.1 Friction Angles 5
- 3.2 Basin Geometry 6
- 3.3 Effluent Weight 7
- 3.4 Gravel 7

4.0 ASSUMPTIONS 7

5.0 COMPUTER SOFTWARE 7

6.0 RESULTS 7

7.0 REFERENCES 8

8.0 CALCULATIONS 8
- 8.1 Primary Liner 8
- 8.2 GCL 9
- 8.3 Geotextile 9
- 8.4 GDM 10
- 8.5 Secondary Liner 11

Attachments

ATTACHMENT – 1 – H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER
H-2-838749, SHEET 2, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER DETAILS
H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER

ATTACHMENT – 2 –DESIGNING WITH GEOSYNTHETICS, 6TH EDITION

ATTACHMENT – 3 – GEOSYNTHETIC INSTITUTE GRI-GN4 STANDARD

ATTACHMENT – 4 – FREE BODY DIAGRAM OF LINER FORCES

ATTACHMENT – 5 – HNF-SD-LEF-TI-005 REV 1 CALCULATION 5 SIDE SLOPE LINER STRESSES

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 4 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Acronyms

cf	cubic foot (ft^3)
DCR	Demand-to-Capacity Ratio
deg	degree (angle)
ft	foot (length)
GCL	Geosynthetic Clay Liner
GDM	Geosynthetic Drainage Material
HDPE	High Density Polyethylene
lb	pound force
LERF	Liquid Effluent Retention Facility
psf	pound per square foot (lb/ft^2)
psi	pound per square inch (lb/in^2)
pcf	pound per cubic foot (lb/ft^3)
plf	pound per lineal foot (lb/ft)
sf	square feet

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 5 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

1.0 PURPOSE

The purpose of this calculation is to determine the stresses in the liner system for LERF Basin 41, except for the northwest corner of the basin which contains the effluent collection and removal piping system. This corner contains gravel and is a separate calculation. The liner stresses will be used to specify minimum required material strengths.

2.0 METHODOLOGY

The forces on each layer of the liner system will be analyzed, beginning at the top layer. Although the liquid waste (essentially water) in the basins is a shearless fluid, the approach taken in the calculation will be to assume shear forces are transmitted at the waste-primary liner interface. This will result in a conservative approach. The stresses in the liner layers will be analyzed at the toe of the slope around the basin floor. This will be the location of the greatest liquid depth which will cause the greatest stresses.

The liner system along the slopes in the basin is comprised of (from top to bottom):

- Primary HDPE liner
- GCL
- Geotextile
- GDM
- Secondary HDPE liner
- Geotextile
- Soil/Bentonite mixture
- Geotextile

The Primary HDPE liner and the Secondary HDPE liner are also referred to as the “top” and “bottom” liners, respectively, in the drawings. This calculation deals with the interface between two layers, so often there will be phrases such as “top of X layer to bottom of Y layer.” For this reason, the top HDPE liner will herein be referred to as the primary and the bottom HDPE liner will herein be referred to as the secondary.

3.0 DESIGN INPUTS

3.1 Friction Angles

The friction angles between two materials are taken from Reference 1. Where similar surface-to-surface interfaces are not provided in Reference 1, similar surface-to-similar surface angles are used. The friction angles are presented below, along with remarks.

Friction Angle	Remarks
d_2 = 10 deg	Bottom of primary liner to top of GCL. This is the angle of smooth HDPE to slit film geotextile (Reference 1, Page 540)

d_i = 15 deg	The internal friction angle of the GCL. This is the friction angle at internal interfaces of the material (Reference 1, Table 6.1, Page 770). The average internal friction value of the four GCL samples was taken for the Hydration With Mild Leachate – Free Swell case.
d_4 = 24 deg	Bottom of GCL to top of geotextile. This is the angle of geomembrane to geotextile (woven slit film) combinations, and interface assumed to be similar to GCL-geotextile (Reference 1, Page 540).

The below friction angles between two materials are taken from Reference 2. These friction angles are for similar materials that will be installed. The friction angles are presented below, along with remarks.

Friction Angle	Remarks
d_6 = 15 deg	Bottom of geotextile to top of GDM. Value is based on geonet to smooth HDPE, which is expected to be similar to geonet to geotextile.
d_8 = 12 deg	Bottom of GDM to top of secondary liner. Value is based on geonet to smooth HDPE.
d_{10} = 7.6 deg	Bottom of secondary liner to top of soil/bentonite layer. Reference 2 derived a range of friction angles between smooth HDPE and clay soils, and range from 7.6 to 18.3 degrees. The lowest value will be used.

3.2 Basin Geometry

The basin geometry is given in the below drawings. These drawings are included in Attachment 1.

H-2-838749, Sheet 1, Rev. 0

H-2-838750, Sheet 1, Rev. 0

H_e = The maximum possible depth of effluent around the toe of the basin. The lowest point of the basin that effluent could reach is the top of the primary liner (Attachment 1, Drawing H-2-838749, Sheet 1, Liner System Schematic) and is elevation 576.50’ (Attachment 1, Drawing H-2-838749, Sheet 1). The highest elevation around the perimeter of the basin is the top of concrete of the anchor wall and is 603.50’ (Attachment 1, Drawing H-2-838750, Sheet 1, Section C). Therefore, H_e = top elevation – bottom elevation = 603.50’ – 576.50’ = 27.00’.

Slope = the greatest slope (in degrees) around the basin. The slopes along the north, south, east, and west sides are all 3:1 (Attachment 1, Drawing H-2-838749, Sheet 1, and Attachment 1, Drawing H-2-838750, Sheet 1). Around the radii the slope will be slightly shallower than the 3:1 along the sides. Therefore, the Slope = 1/3 = 0.33 = 18.43 degrees.

3.3 Effluent Weight

The unit weight of effluent = S_l = 62.4 pcf (Reference 2)

3.4 Gravel

Unit weight of gravel = S_{gravel} = 135 pcf (Engineering Judgement)

4.0 ASSUMPTIONS

There are no assumptions in this calculation. Engineering judgement, where used, is documented herein.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Calculations are checked using a handheld calculator.

6.0 RESULTS

A summary of the calculated DCRs is presented below.

Layer	Tension, Shear, or Normal Stress	DCR
Primary Liner	Tension	$DCR_{\sigma p}$ = 0.164
GCL	Internal Shear	DCR_{tibc} = 0.658
Geotextile	Tension	$DCR_{\sigma geo}$ = 0.262
GDM	Tension	$DCR_{\sigma net}$ = 0.173
	Normal	DCR_{Nnet} = 0.096
Secondary Liner	Tension	$DCR_{\sigma s}$ = 0.093

The required material properties are presented below. (Reference 7)

Layer	Property	Required Value
Primary Liner	Tension Yield Strength	≥2000 psi
	Thickness	≥60 mils
GCL	Internal Friction Angle	≥15 deg
Geotextile	Thickness	≥70 mils
	Tear Strength	≥95 lb
GDM	Tension Yield Strength	≥540 plf
	Compressive Strength	≥120 psi
Secondary Liner	Tension Yield Strength	≥2000 psi
	Thickness	≥60 mils

7.0 REFERENCES

1) Koerner, Robert M., *Designing with Geosynthetics*, 6th Edition

2) HNF-SD-LEF-TI-005 R1, Calculation 5, Side Slope Liner Stresses, 1990

3) Geosynthetic Institute, GRI-GN4 Standard, *Test Methods, Required Properties and Testing Frequency* for Biplanar Geonets and Biplanar Geonet Composites

4) H-2-838749, Sheet 1, Rev. 0, LERF Basin 41 Civil Secondary Liner

5) H-2-838749, Sheet 2, Rev. 0, LERF Basin 41 Civil Secondary Liner Details

6) H-2-838750, Sheet 1, Rev. 0, LERF Basin 41 Civil Primary Liner

7) RPP-SPEC-63632, Rev. 0, LERF Basin 41 Design Construction Specification

8.0 CALCULATIONS

8.1 Primary Liner

Weight of liquid acting on a one-foot wide strip of liner:

$W_1 = S_1 \times H_e \times 1\text{ ft} = 62.4\text{ pcf} \times 27\text{ ft} \times 1\text{ ft} = 1684.80\text{ plf}$

Force acting down the slope of the primary liner due to the weight of the liquid:

$F_1 = W_1 \times \sin(\text{slope}) = 1684.80\text{ plf} \times \sin(18.43\text{ deg}) = 532.64\text{ plf}$

Normal force resisting the liquid weight:

$N = W_1 = 1684.80\text{ plf}$

Shear force below the primary liner:

$F_2 = N \times \tan(d_2) = 1684.80\text{ plf} \times \tan(10\text{ deg}) = 297.08\text{ plf}$

$F_1 - F_2 = 532.64\text{ plf} - 297.08\text{ plf} = 235.56\text{ plf}$

Since $F_1 > F_2$ the primary liner is in tension.

Thickness of primary liner:

$t_p = 60\text{ mil} = 0.06\text{ in}$

Required tensile yield stress of HDPE:

σ_{py} = 2000 psi

Actual tensile stress in primary liner:

$\sigma_{pact} = (F_1 - F_2) / t_p$ = (532.64 plf – 297.08 plf) / 0.06 in = 327.17 psi

DCR for tensile stresses in the primary liner:

$DCR_{\sigma p} = \sigma_{pact} / \sigma_{py}$ = 327.17 psi / 2000 psi = 0.164 < 1.0 okay

8.2 GCL

Shear force acting on the GCL:

$F_3 = F_2$ = 297.08 plf (equal and opposite force to F_2)

Shear force below the GCL:

F_4 = N x tan(d_4) = 1684.80 plf x tan(24 deg) = 750.12 plf

$F_3 - F_4$ = 297.08 plf – 750.12 plf = -453.04 plf

Since $F_3 < F_4$ the GCL layer is not in tension.

Check the internal stresses at the internal interfaces in the GCL:

Internal force resulting from the normal force:

F_i = N x tan(d_i) = 1684.80 plf x tan(15 deg) = 451.44 plf

DCR at internal interface of GCL:

$DCR_{tibc} = F_3 / F_i$ = 297.08 plf / 451.44 plf = 0.658 < 1.0 okay

8.3 Geotextile

Shear force acting on the geotextile:

$F_5 = F_4$ = 750.12 plf (conservative because the shear force acting on the geotextile is limited by the shear force that the primary liner can transfer to the GCL, i.e. F_4 cannot exceed F_3)

Shear force below the geotextile:

F_6 = N x tan(d_6) = 1684.80 plf x tan(15 deg) = 451.44 plf

$F_5 - F_6 = 750.12 \text{ plf} - 451.44 \text{ plf} = 298.68 \text{ plf}$

Since $F_5 > F_6$ the geotextile is in tension.

Calculate the tensile stresses:

Required thickness of geotextile:

$t_{geo} = 0.070 \text{ in}$

Actual tensile stress in geotextile:

$\sigma_{geoact} = (F_5 - F_6) / t_{geo} = (750.12 \text{ plf} - 451.44 \text{ plf}) / 0.07 \text{ in} = 355.57 \text{ psi}$

Required strength of geotextile:

$\sigma_{geoall} = 95 \text{ lb} / (t_{geo} \times 1 \text{ in}) = 95 \text{ lb} / (0.070 \text{ in} \times 1 \text{ in}) = 1357.14 \text{ psi}$

DCR for tensile stresses in geotextile:

$DCR_{\sigma geo} = \sigma_{geoact} / \sigma_{geoall} = 355.57 \text{ psi} / 1357.14 \text{ psi} = 0.262 < 1.0$ okay

8.4 GDM

Shear force acting on the GDM:

$F_7 = F_6 = 451.44 \text{ plf}$

Shear force below the GDM:

$F_8 = N \times \tan(d_8) = 1684.80 \text{ plf} \times \tan(12 \text{ deg}) = 358.12 \text{ plf}$

$F_7 - F_8 = 451.44 \text{ plf} - 358.12 \text{ plf} = 93.32 \text{ plf}$

Since $F_7 > F_8$ the GDM is in tension.

Calculate the tensile stresses:

Required GDM yield stress in roll direction:

$\sigma_{nety} = 540 \text{ plf}$

$\sigma_{netact} = F_7 - F_8 = 451.44 \text{ plf} - 358.12 \text{ plf} = 93.32 \text{ plf}$

DCR for tensile stresses in GDM:

$DCR_{\sigma net} = \sigma_{netact} / \sigma_{nety} = 93.32$ plf / 540 plf = 0.173 < 1.0 okay

Now calculate the normal stresses on the GDM. This is important because if the GDM is compressed then it may not be able to adequately transmit effluent.

$\sigma_{Nnetact} = S_1 \times H_b = 62.4$ pcf x 27 ft = 1684.80 psf

Required allowable compressive stress:

$\sigma_{Nnetall} = 120$ psi = 17280 psf (Reference 3)

DCR for normal stresses in GDM:

$DCR_{Nnet} = \sigma_{Nnetact} / \sigma_{Nnetall} = 1684.80$ psf / 17280 psf = 0.096 < 1.0 okay

8.5 Secondary Liner

Shear force acting on the secondary liner:

$F_9 = F_8 = 358.12$ plf

Shear force below the secondary liner:

$F_{10} = N \times \sin(d_{10}) = 1684.80$ plf x tan(7.6 deg) = 224.80 plf

$F_9 - F_{10} = 358.12$ plf – 224.80 plf = 133.32 plf

Since $F_9 > F_{10}$ the secondary liner is in tension.

Thickness of the secondary liner:

$t_s = t_p = 60$ mil = 0.060 inch

Required tensile yield stress of HDPE:

$\sigma_{sy} = \sigma_{py} = 2000$ psi

Actual tensile stress in secondary liner:

$\sigma_{sact} = (F_9 - F_{10}) / t_s = (358.12$ plf – 224.80 plf) / 0.06 in = 185.17 psi

DCR for tensile stresses in the secondary liner:

$DCR_{\sigma s} = \sigma_{sact} / \sigma_{sy} = 185.17$ psi / 2000 psi = 0.093 < 1.0 okay

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 12 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 1 - H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER
H-2-838749, SHEET 2, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER DETAILS
H-2-838750, SHEET 1, REV. 0, CIVIL PRIMARY LINER

RPP-CALC-63748, Rev. 0

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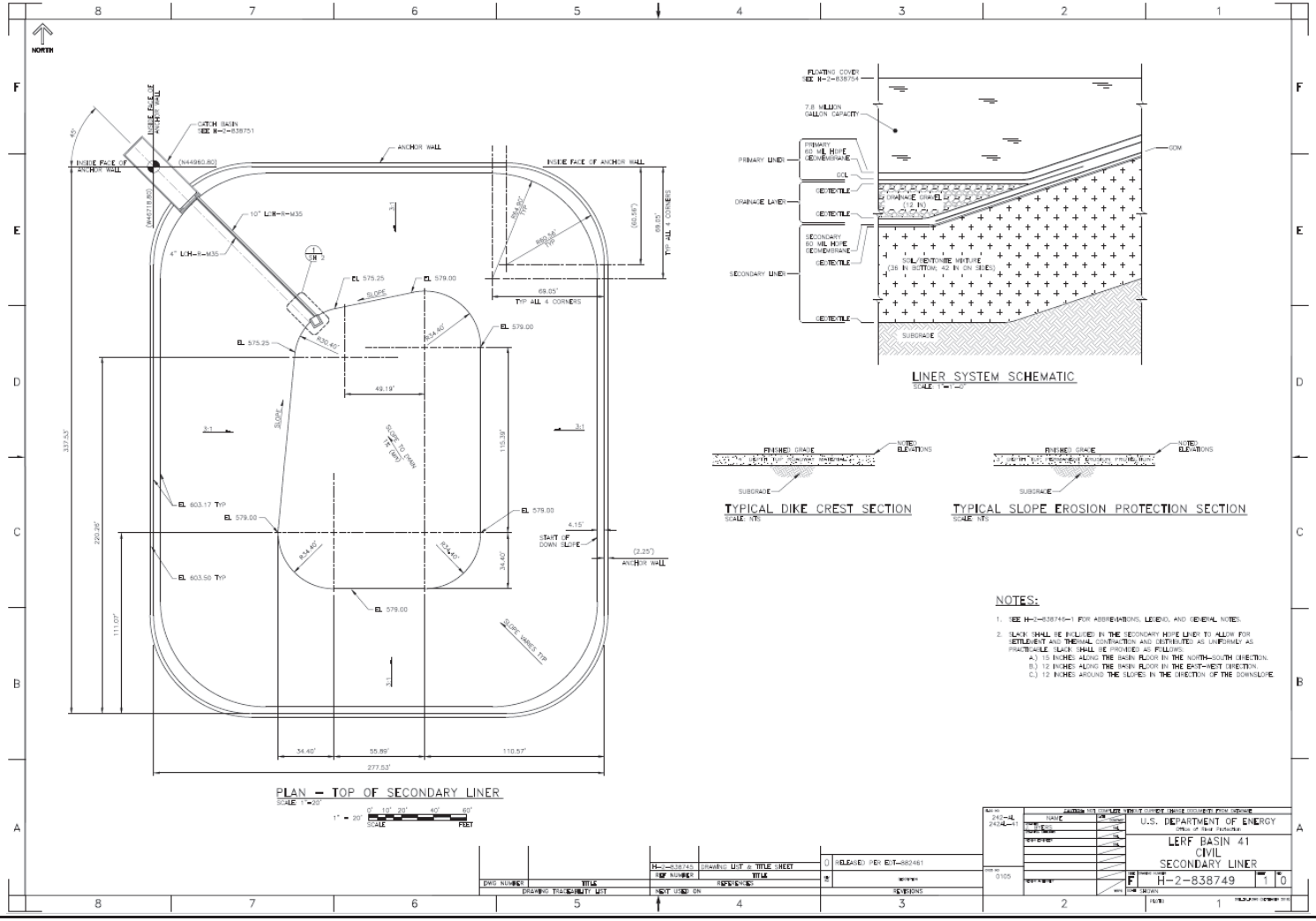
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-004	**Rev.**	0	**Page No.** 13 of 32	
Title:	LERF Basin 41 Side Slope Liner Stresses						
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020



RPP-CALC-63748, Rev. 0

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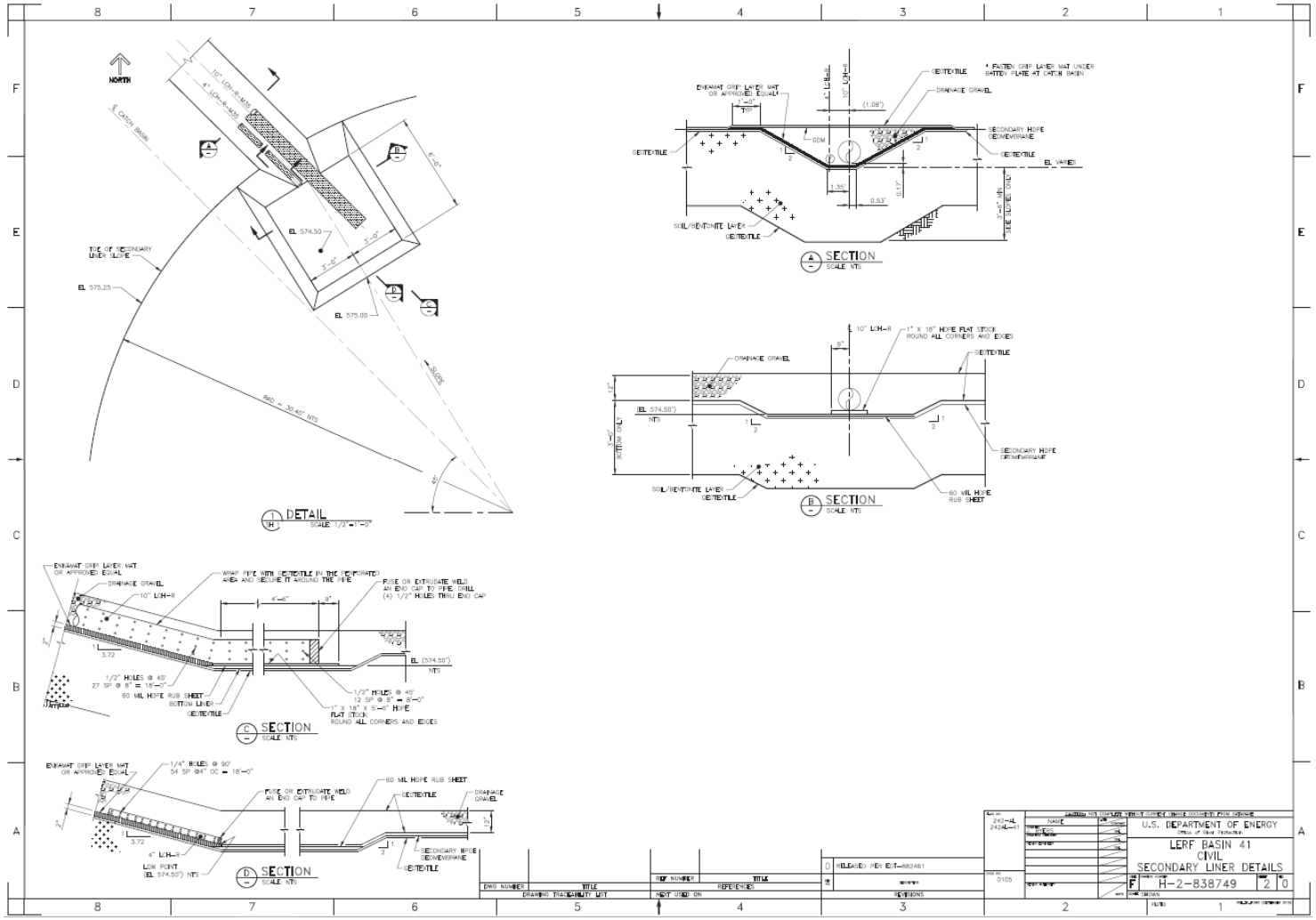
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-004	**Rev.**	0	**Page No.** 14 of 32	
Title:	LERF Basin 41 Side Slope Liner Stresses						
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020



RPP-CALC-63748, Rev. 0

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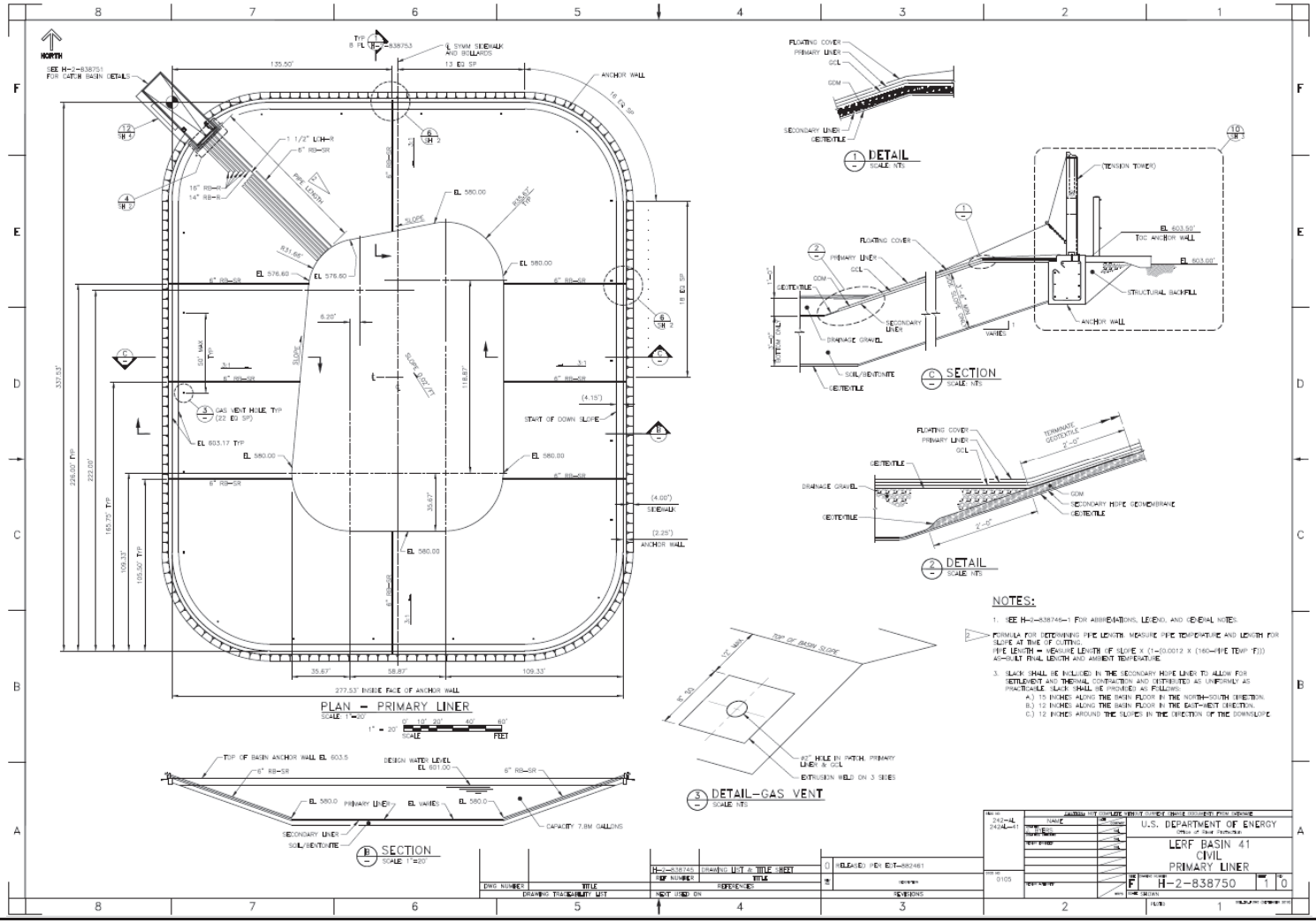
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-004	**Rev.**	0	**Page No.**	15 of 32
Title:	LERF Basin 41 Side Slope Liner Stresses						
Prepared By:	G. Taylor Grant	**Date:**	04/08/2020	**Checked By:**	Darrel J. Packard	**Date:**	04/09/2020



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 16 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 2 - DESIGNING WITH GEOSYNTHETICS, 6TH EDITION

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 17 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE 2.4 PEAK SOIL-TO-GEOTEXTILE FRICTION ANGLES AND EFFICIENCIES (IN PARENTHESES) FOR SELECTED COHESIONLESS SOILS

Geotextile type	Concrete sand $\varphi = 30$ deg.	Rounded sand $\varphi = 28$ deg.	Silty sand $\varphi = 26$ deg.
Woven, monofilament	26 deg. (84%)	–	–
Woven, slit film	24 deg. (77%)	24 deg. (84%)	23 deg. (87%)
Nonwoven, heat bonded	26 deg. (84%)	–	–
Nonwoven, needle punched	30 deg. (100%)	26 deg. (92%)	25 deg. (96%)

Source: After Martin, et al. [35]

Note: Literature values such as the above should *not* be used in critical designs. Site specific geotextiles and soils must be individually tested and evaluated in accordance with the particular project conditions, e.g., saturation, type of liquid, normal stress, consolidation time, shear rate, displacement amount, etc.

dependent on the normal force applied to the soil, which mobilizes shearing resistances on both surfaces of the geotextile.

Since the test greatly resembles a direct shear test, albeit with stationary soil on both sides of the tensioned geotextile, a possible design strategy is to take direct shear test results (for both sides of the geotextile) and use these values for pullout design purposes. However, this may not be a conservative practice.

Test results by Collios et al. [36] show a relationship of pullout test results to shear test results with some notable exceptions. For pullout testing, if the soil particles are smaller than the geotextile openings, efficiencies are high; if not, they can be low. In all cases, however, pullout test resistances are less than the sum of the direct shear test resistances. This is due to the fact that the geotextile is taut in the pullout test and exhibits large deformations. This, in turn, causes the soil particles to reorient themselves into a reduced shear strength mode at the soil-to-geotextile interfaces, resulting in lower pullout resistance. The stress state mobilized in this test is both interesting and complex as evidenced by the approximate one-hundred technical references on this topic.

2.3.4 Hydraulic Properties

Unlike the physical and mechanical properties just discussed, traditional tests on textile materials rarely have hydraulic applications;

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 18 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE 5.6 PEAK FRICTION VALUES AND EFFICIENCIES OF VARIOUS GEOSYNTEHTIC INTERFACES*

(a) Soil-to-Geomembrane Friction Angles

Geomembrane	Soil type: Concrete sand ($\phi = 30°$)		Ottawa sand ($\phi = 28°$)		Mica schist sand ($\phi = 26°$)	
HDPE						
textured	30°	(1.00)	26°	(0.92)	22°	(0.83)
smooth	18°	(0.56)	18°	(0.61)	17°	(0.63)
PVC						
rough	27°	(0.88)	—	—	25°	(0.96)
smooth	25°	(0.81)	—	—	21°	(0.79)
fPP-R	25°	(0.81)	21°	(0.72)	23°	(0.87)

(b) Geomembrane-to-Geotextile Friction Angles

Geotextile	Geomembrane: HDPE Textured	HDPE Smooth	PVC Rough	PVC Smooth	fPP-R
Nonwoven, needle punched	32°	8°	23°	21°	15°
Nonwoven heat bonded	28°	11°	20°	18°	21°
Woven, monofilament	19°	6°	11°	10°	9°
Woven, slit film	32°	10°	28°	24°	13°

(c) Soil-to-Geotextile Friction Angles

Geotextile	Soil type: Concrete sand ($\phi = 30°$)		Concrete sand ($\phi = 30°$)		Mica schist sand ($\phi = 26°$)	
Nonwoven, needle punched	30°	(1.00)	26°	(0.92)	25°	(0.96)
Nonwoven heat bonded	26°	(0.84)	—	—	—	—
Woven, monofilament	26°	(0.84)	—	—	—	—
Woven, slit film	24°	(0.77)	24°	(0.84)	23°	(0.87)

*Efficiency values (in parentheses) are based on the relationship E = (tan

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 19 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE 6.1 SUMMARY OF GCL INTERNAL DIRECT SHEAR TEST RESULTS

Designation		Hydration with Distilled Water			Hydration with Tap Water		
		Dry*	Constrained Swell	Free Swell	Dry*	Contrained Swell	Free Swell
GCL-1	ϕ (degrees)	37°	16°	0°	37°	18°	0°
	c (kPa)	6.9	2.8	4.1	6.9	2.8	3.4
GCL-2	ϕ (degrees)	36°	31°	10°	36°	34°	15°
	c (kPa)	68	6.9	9.0	68	6.9	6.9
GCL-3	ϕ (degrees)	42°	37°	23°	42°	43°	26°
	c (kPa)	14	8.5	4.8	14	5.5	10
GCL-4	ϕ (degrees)	26°	19°	0°	26°	18°	0°
	c (kPa)	50	4.8	2.8	50	4.8	3.4

Designation		Hydration with Mild Leachate			Hydration with Harsh Leachate		
		Dry	Constrained Swell	Free Swell	Dry	Contrained Swell	Free Swell
GCL-1	ϕ (degrees)	37°	24°	4°	37°	19°	0°
	c (kPa)	6.9	6.2	3.4	6.9	5.5	2.8
GCL-2	ϕ (degrees)	36°	43°	20°	36°	39°	30°
	c (kPa)	68	4.8	12	68	4.1	8.3
GCL-3	ϕ (degrees)	42°	39°	25°	42°	45°	32°
	c (kPa)	14	8.3	14	14	4.8	12
GCL-4	ϕ (degrees)	26°	18°	13°	26°	13°	0°
	c (kPa)	50	4.8	3.4	50	7.6	3.4

Designation		Hydration with Diesel Fuel		
		Dry	Constrained Swell	Free Swell
GCL-1	ϕ (degrees)	37°	37°	38°
	c (kPa)	6.9	6.9	6.2
GCL-2	ϕ (degrees)	36°	36°	46°
	c (kPa)	68	68	4.8
GCL-3	ϕ (degrees)	42°	42°	40°
	c (kPa)	14	6.2	4.8
GCL-4	ϕ (degrees)	26°	24°	29°
	c (kPa)	50	4.1	6.2

**Dry* refers to the GCL as received, placed under desired normal stress, then sheared at midplane.

Constrained swell refers to GCL hydrated under the desired normal stress, then sheared at the midplane.

Free swell refers to GCL hydrated under zero normal stress, then placed under the desired normal stress, and immediately sheared at midplane.

Source: After Leisher [4].

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 20 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 3 - GEOSYNTHETIC INSTITUTE GRI-GN4 STANDARD

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 21 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

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Final: October 3, 2018
Revision Schedule on Page 10

GRI-GN4 Standard*

Standard Specification for

"Test Methods, Required Properties and Testing Frequency for Biplanar Geonets and Biplanar Geonet Composites"

This specification was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This generic specification covers biplanar geonets and biplanar geonet composites (sometimes called geocomposites) for subsequent use in transmitting liquids within the manufactured plane of the materials.

Note 1: This specification does not cover triplanar geonets or drainage composites made therefrom. It also does not cover the category of geosynthetic drainage materials called "geospacers".

1.2 This specification sets forth a set of physical, mechanical, hydraulic, and endurance properties that must be met, or exceeded by the product being manufactured.

Note 2: The specification is based on tap water being the transmitted liquid. It can be modified to accommodate other liquids as agreed upon by the parties involved.

*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute's Website <<geosynthetic.institute.org>>.

Note 5: In a drainage geocomposite, the geonet serves the primary function of drainage, whereas the geotextile(s) serves the dual functions of separation and filtration.

4.2 The geonets covered in this specification are made from a formulation consisting of high density polyethylene (density ≥ 0.950 g/cc), in a weight percentage of approximately 97%, with about 2% carbon black, and the remainder being antioxidants for protection during extrusion and long-term service performance.

Note 6: The density of the base resin will be slightly lower, e.g., ≥ 0.940 g/cc, however, this is still in the category of high density polyethylene (HDPE).

4.3 The resin shall be virgin material with no more than 25% rework. If rework is used, it must be a similar formulation as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

4.5 The type of geotextile is commonly a needle punched nonwoven polypropylene thermally bonded to the geonet core in the manufacturing facility.

4.6 In this specification, the geotextile properties follow the AASHTO M288-16 specification since it is used on a widespread basis in providing for separation and filtration functions. If the site-specific design calls for a different geotextile, or one with different properties, it must be communicated between the parties involved.

Note 7: Alternative geotextiles are burnished needle punched nonwovens (one or both sides), heat-bonded nonwovens, slit-film wovens or monofilament wovens.

5. Specification Requirements

5.1 The geonets, before lamination with geotextiles, shall conform to Table 1 which is given in three nominal thicknesses. Other thicknesses up to 400 mils (10.2 mm) are possible and information is available from the respective manufacturers. Table 1a is given in English units and Table 1b in S.I. units. The conversion from English to S.I. units is "soft". The values listed are "minimum average" values except for carbon black which is a range.

Note 8: To obtain the minimum average value, the number of test values required by the respective standard is numerically averaged and the value must equal or exceed the listed specification value.

5.2 The geotextiles, before lamination to the geonet, shall conform to Table 1 which is given in two mass per unit area values. Other mass per unit areas are possible and information is available from the respective manufacturers.

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CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-004	**Rev.** 0	**Page No.** 23 of 32
Title:	LERF Basin 41 Side Slope Liner Stresses				
Prepared By:	G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard		**Date:** 04/09/2020

U.S. English Units

Table 1(a) – MQC Specification for Biplanar Geonets and Geonet Composites

Property	Test Method	Test Value Based on Geonet Thickness						Test Frequency
(a) Geonet (before lamination)		**200 mil**		**250 mil**		**300 mil**		
Thickness(1), mils (min. ave.)	D5199	200		250		300		per 50,000 lb.
Density(2), g/cc (min. ave.)	D1505/D792	0.95		0.95		0.95		per 50,000 lb.
Carbon Black Content, % (range)	D1603/D4218	1.5 to 3.0		1.5 to 3.0		1.5 to 3.0		per 100,000 lb.
Tensile Strength(3), lb. (min. ave.)	D7179	180		240		300		per 50,000 lb.
Compressive Strength(4), lb/in.^{2} (min. ave.)	D6364	120		120		120		per 100,000 lb.
Flow Rate/Width(5), gal/min-ft (min. ave.)	D4716	5.0		7.2		9.0		per 200,000 lb.
(b) Geotextile (before lamination)(6)								
Mass/Unit Area, oz/sy (MARV)	D5261	6	8	6	8	6	8	Note (7)
Grab Strength, lb. (MARV)	D4632	157	200	157	200	157	200	
Grab Elongation, % (MARV)	D4632	50	50	50	50	50	50	
Tear Strength, lb. (MARV)	D4533	55	80	55	80	55	80	
Puncture Strength, lb. (MARV)	D6241	310	430	310	430	310	430	
Permittivity, sec^{-1} (MARV)	D4491	0.2	0.2	0.2	0.2	0.2	0.2	
AOS, mm (MaxARV)	D4751	0.25	0.25	0.25	0.25	0.25	0.25	
UV Stability, % ret. (500 hr.)	D4355	50	50	50	50	50	50	
(c) Single-Sided Laminated Composite								
Flow Rate/Width(5), gal/min-ft (min. ave.)	D4716	2.7	2.2	3.9	3.2	4.9	4.0	per 200,000 lb.
Ply Adhesion(8), lb./in. (min. ave.)	D7005	1.0	1.0	1.0	1.0	1.0	1.0	per 100,000 lb.
(d) Double-Sided Laminated Composite								
Flow Rate/Width(5), gal/min-ft (min.-ave.)	D4716	2.0	1.5	2.9	2.2	3.6	2.7	per 200,000 lb.
Ply Adhesion(8), lb./in. (min. ave.)	D7005	1.0	1.0	1.0	1.0	1.0	1.0	per 100,000 lb.

(1) The diameter of the presser foot shall be 2.22 in. and the pressure shall be 2.9 lb./in^2.
(2) Density is of the formulated material; the base resin will be slightly lower.
(3) This is the average peak value for five equally spaced machine direction tests across the roll width.
(4) Test to be conducted using Section 6.3, the movable plate method.
(5) Geonets shall be tested between rigid end platens at a hydraulic gradient of 1.0 (hence, this is also the "transmissivity"); a pressure of 10,000 lb./ft^2, and a seating dwell time of 15 min. If specimen is a geocomposite the geotextile side(s) should be tested using flexible boundaries. Test values are for machine direction only.
(6) These values are Class 1 and Class 2 of the AASHTO M288-00 specification for drainage (filtration) requirements of 15 to 50% fines passing #200 sieve. Generally, one or the other will be used.
(7) Since these geotextile values are MARV, the statistics needed to obtain such values dictate the frequency of testing.
(8) This is the average of five equally spaced machine direction tests across the roll width of the single-sided geocomposite. Both sides should be tested for the double-sided geocomposite.

GRI-GN4 - 8 of 10

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 24 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 4 – FREE BODY DIAGRAM OF LINER FORCES

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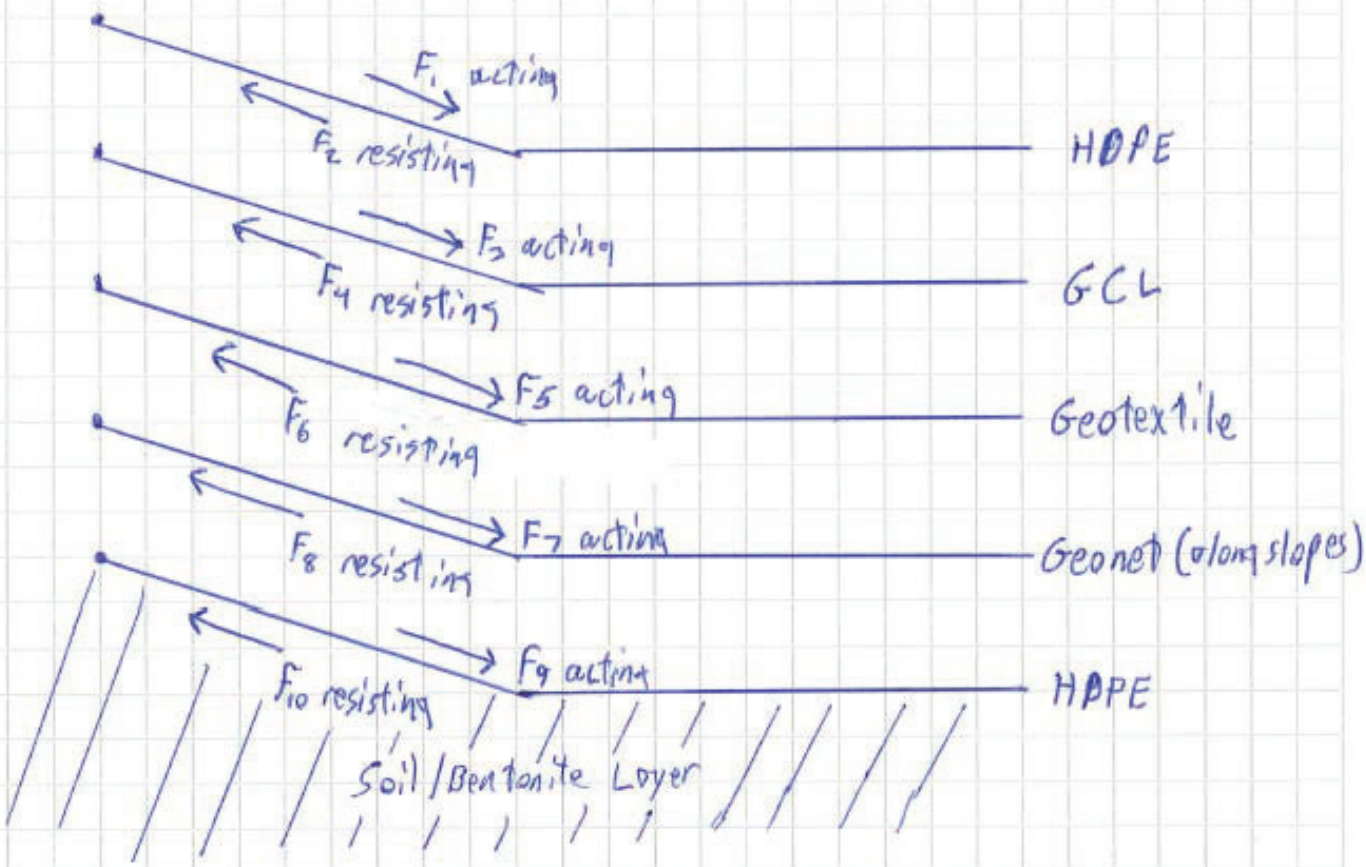
CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 25 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Free body diagram of forces on the Liner System around the basin perimeter (excluding the northwest corner).



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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 26 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 5 – HNF-SD-LEF-TI-005 REV 1 CALCULATION 5 SIDE SLOPE LINER STRESSES

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 27 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD HNF-SD-LEF-TI-005 Rev 1 Page No. 1 of 18

DESIGN ANALYSIS Revision 0

Client WHC WO/Job No. ER-0156

Subject Interim Retention Storage Basins (IRSB) Date 9/19/90 By DKB

Checked 9/25/90 By R Hillebrand

Location 242 A-L, 200 East Revised By

SIDE SLOPE LINER STRESSES

1.0 OBJECTIVE

This calculation addresses the stresses in the liner system for the W-105 Retention Basins, except for the one corner of each basin containing the piping systems. This corner contains gravel and separate calculation. A separate calculation, "Side Slope Liner Stability - Pipe Trench" addresses stresses and stability at the pipe trench.

2.0 DESIGN INPUTS

2.1 References

2.1.1 Koerner, R.M., "Designing with Geosynthetics," 2nd Edition, Prentice Hall, Sections 5.6.8, 5,3, 5.1.3.8, and as referenced below, 1990.

2.1.2 Industrial Fabric Association International, "The Use of Geosynthetics in Waste Containment," Presentation Handout, Page 7, undated.

2.1.3 Letter to W. Simpson, James Clem Corporation, from Geoservices, Inc., "Report on the Direct Shear Testing of Selected CLAYMAX CL," Table 1 and Attachment 1, dated 10 March 1989.

2.1.4 Technical Report to Acme Concrete Company from Chen-Northern, Inc., "Tests of Drainage Gravel for the Grout Vault Storage Facility, Kaiser B714 Project," dated 26 February 1990.

2.1.5 Akzo Industrial Systems Company, "ENKAMAT "S" Reinforced Grip Layer Matting [RGLM], Specifications," Asheville, NC 28802, undated.

2.1.6 Mathsoft, Inc., "Mathcad Version 2.5 User's Guide," Cambridge, Ma 02139, June 1989.

2.1.7 Lettter to W. Simpson, James Clem Corporation from R. H. Swan, Jr., GeoServices, Inc, Consulting Engineers, "Report on the Direct Shear Testing of Selected CLAYMAX CL Interfaces, GeoServices Project Number: P1157, GeoServices Document Number: NL89038," Norcross, Georgia, dated March 10, 1989.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 28 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

HANFORD HNF-SD-LEF-TI-005 Rev1: DESIGN ANALYSIS Revision 0

Client WHC WO/Job No. ER-0156

Subject Interim Retention Storage Basins (IRSB) Date 9/19/90 By DKO

Checked 9/25/90 By RHollenbach

Location 242 AL, 200 East Revised By

Other references are listed below when applied to a specific area of the calculation.

2.2 Units Required for Calculation (This Information Required for MATHCAD)

ft ≡ 1L lb ≡ 1M sec ≡ 1T

(In this calculation "lb" represents "pounds-mass", the base unit of mass. "lbf is used for force, see below.)

II. Angular measure

rad ≡ 1

$$deg \equiv \frac{\pi}{180} \cdot rad$$

III. Derived units: Length

$$in \equiv \frac{ft}{12} \qquad m \equiv \frac{ft}{.3048} \qquad mil \equiv 0.001 \cdot in$$

$$cm \equiv 0.01 \cdot m$$

IV. Derived units: Mass

$$slug \equiv 32.174 \cdot lb$$

V. Derived units: Time

$$min \equiv 60 \cdot sec \qquad hr \equiv 3600 \cdot sec \qquad day \equiv 24 \cdot hr$$

$$yr \equiv 365.2422 \cdot day$$ (tropical year)

VI. Derived units: Area, Volume

$$gal \equiv 0.1337 \cdot ft^3$$

36

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 29 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD HNF-SD-LEF-TI-005 Rev 1 Page No. 3 of 10

DESIGN ANALYSIS Revision 0

Client WHC WO/Job No. ER-0156

Subject Interim Retention Storage Basins (IRSB) Date 9/19/90 By DKB

Checked SEP 25 1990 By R. Hollebach

Location 242 AL, 200 East Revised By

VII. Derived units: Acceleration

$$g = 32.174 \cdot \frac{ft}{sec^2} \quad \text{(acceleration of gravity)}$$

VIII. Derived units: Force, Pressure

$$lbf = g \cdot lb \quad \text{(pound force)} \qquad psi = \frac{lbf}{in^2}$$

2.3 Given or Known Data

$$\rho_1 := 1.94 \cdot \frac{slug}{ft^3} \quad \text{Density of liquid waste}$$

$$S_1 := \rho_1 \cdot g$$

$$S_1 = 62.4 \cdot \frac{lbf}{ft^3} \quad \text{Specific weight of liquid waste}$$

$$S_{gravel} := 122.1 \cdot \frac{lbf}{ft^3}$$

Maximum specific weight of gravel layer, per Reference 2.1.4

$$H_b := 603.5 \cdot ft - 576.60 \cdot ft$$

37

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 30 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

HANFORD HNF-SD-LEF-TI-005 Rev1 Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. ER-0156

Subject Interim Retention Storage Basins (IRSB) Date 9/19/90 By DKB

Checked SEP 25 1990 By R Hellen Lech

Location 242 AL, 200 East Revised By

$H_b = 26.9 \cdot ft$ Maximum internal height of basin. The highest liquid level will be several feet below the maximum basin height. Using 0the maximum basin height as the liquid height is a conservative assumption.

Determine maximum slope angle: The nominal slope angle is 18.4 degress, corresponding to a slope of 3:1. However, some areas may have a slightly steeper slope.

Reference: Drawing No. H-2-79590, Sheet 1 of 1, Rev. 1, Zone E-6, E-8.

$T_{elev} := 603.5 \cdot ft$ Top elevation of dike

$B_{elev} := 576.6 \cdot ft$ Bottom elevation at vicinity of sump

$\delta_{elev} := T_{elev} - B_{elev}$ Vertical distance for calculating slope angle.

$\delta_{length} := 73.0 \cdot ft$ Horizontal distance (minimum identified) for calculating slope angle.

$$slope := \frac{\delta_{elev}}{\delta_{length}}$$

$slope = 0.4$

$\beta := atan(slope)$

$\beta = 20.2 \cdot deg$ Maximum slope angle. The maximum angle will be used during the calculation, as a conservative assumption.

38

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 31 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD HNF-SD-LEF-TI-005 Rev1. Page No. 5 of 18 Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. ER-0156
Subject Interim Retention Storage Basins (IRSB) Date 9/19/90 By DKB
Checked By RHallock
Location 242 AL, 200 East Revised By

2.4 Friction Angles

Figure 1 presents the layers of the basin liner systems, while Figure 2 offers an expanded view of the layers. The top liner is referred to as the primary liner in this calculation, while the bottom liner is referred to as the secondary liner.
The expressions "primary" and "secondary" are used in the referenced documentation. "Top" and "bottom" are used on project drawings.

Friction angles represent the coeficient of friction at the layer boundaries. They are presented below, along with remarks.

ANGLE	REMARKS
$\delta_2 := 10 \cdot deg$	Bottom of primary liner to top of bentonite carpet liner. This is the value of smooth HDPE to slit film geotextile (Reference 2.1.1, Page 382)--probably conservative.
$\delta_4 := 24 \cdot deg$	Bottom of bentonite carpet liner to top of geotextile. This angle is based on Reference 2.1.1, Page 382, for geomembrane-to-geotextile (woven slit film) combinations, an interface assumed to be similar to bentonite carpet liner-geotextile.
$\delta_i := 12 \cdot deg$	The "internal" friction angle for the bentonite carpet liner. This is the friction angle at internal interfaces of the material, from Reference 2.1.7.
$\delta_6 := 15 \cdot deg$	Bottom of geotextile to top of geonet. Per Reference 2.1.1, Page 468, the angle for geonet to smooth HDPE is 12 (see $\delta(8)$ below), so 15 degrees is taken to be a valid conservative value for geotextile to geonet.

39

DOE Richland, WA

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-004	**Rev.** 0	**Page No.** 32 of 32
Title: LERF Basin 41 Side Slope Liner Stresses			
Prepared By: G. Taylor Grant	**Date:** 04/08/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

KAISER ENGINEERS HANFORD

HNF-SD-LEF-TI-005 Rev1

Page No. 6 of 18

Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. ER-0156

Subject Interim Retention Storage Basins (IRSB) Date 9/19/90 By DKB

Check SEP 25 1990 By

Location 242 AL, 200 East Revised By

$\delta_8 := 12 \cdot deg$ Bottom of geonet to top of secondary liner.

Value is based on Reference 2.1.1, Page 468 for geonet to smooth HDPE .

$\delta_{10} := 7.6 \cdot deg$ Bottom of secondary liner to top of soil/bentonite layer.

Reference 2.1.1, Page 382-384, including Table 5.6, provides friction values and efficiencies for soil-to-geomembrane interfaces. From these data, friction angles for smooth HDPE to clay soils were derived, and range from 7.6 to 18.3 degrees.

The data provided in the reference are for various types of undrained clays. Project W-105 uses a soil/bentonite mix, and a friction angle of 7.6 degrees is expected to be technically conservative.

2.5 Calculation

The approach will be to analyze forces on each layer of the system, beginning at the top. It is based on Reference 2.1.1, "Designing with Geosynthetics," Section 5.6.8.

Assumption:

Although the liquid waste (essentially water) in the basins is a shearless fluid, the approach taken in the calculation will be to assume shear forces are transmitted at the waste-primary liner interface. This will result in a technically conservative approach.

Calculation for Primary Liner

$W_1 := S_1 \cdot H_b \cdot 1 \cdot ft$ weight of liquid acting on one foot strip of liner.

40

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE: May 26,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63749 **Rev.** 00

2. **Title:**
LERF Basin 41 Side Slope Liner Stability and Stress - Pipe Trench

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Raymer, Julia R	*Raymer, Julia R*	05/26/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/24/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/10/2020
Document Control Approval	Hood, Evan	*Hood, Evan*	05/19/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/29/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/10/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/13/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	04/29/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Because of the General Service statusof the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Taylor Grant and Jeremy Debban is signing as Checker for Darrel Packard. Taylor Grant and Darrel Packard are not currently in SPF.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
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Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
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McShane, Michael P	ENGINEERING PROGRAMS
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Powers, Daniel J	ETF ENGINEERING
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Rutherford, Wally	ETF ENGINEERING
Sackett, Tom E	TANK FARM PROJECTS
Samoska, Jerry A	INSTRUMENT & CNTRL ENGINEERING

DOCUMENT RELEASE AND CHANGE FORM	**Doc No:** RPP-CALC-63749 **Rev.** 00

14. **Distribution**

Name	**Organization**
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Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63749
Revision 0

LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench

Prepared by

G. T. Grant
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
May 2020

5-21-2020

washington river protection solutions

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

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Approved for Public Release;
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RPP-CALC-63749 Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 30 **Date** 05/21/2020 **Rev. No.** 1 **Calculation No:** S54413.024-C-005

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions

Title:

LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench

Purpose and Objective:

The purpose of this calculation is to determine the stresses in the liner system adjacent to the effluent piping system in the northwest corner of LERF Basin 41. The liner system beyond the northwest corner is in calculation S54413.024-C-004 / RPP-CALC-63748.

The calculated liner stresses will be used to determine the required material strengths to ensure that no liner material will be stressed beyond its capacity.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	30	**Print Name/ Sign:**	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	04/08/2020	4/09/2020	4/09/2020

Revision Description (Revision Description/Affected Pages):

1	30	**Print Name/ Sign:**	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	05/21/2020	05/21/2020	05/21/2020

Revision Description (Revision Description/Affected Pages):

Removed Attachment 4 and renumbered Attachment 5 to Attachment 4.

Formatted Section 8 so that each Subsection is on its own page.

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Page No.
S54413.024	S54413.024-C-005 Rev. 1	2 of 30

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	✓			
2. Calculation sheet headers complete with calculation number, revision number, etc.	✓			
3. Calculation sheet contents are legible, accurate, and complete per format.	✓			
4. Listed attachments included.	✓			
5. Calculation objective clearly described.	✓			
6. Criteria are suitable and properly referenced to task specific documents.	✓			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	✓			
8. Calculation method identified and appropriate for the design activity.	✓			
9. Calculation results reasonable and correctly described in results and conclusions.	✓			
10. Physical property calculations generated by CAD software verified via hand calculations.			✓	
11. Computer program identified with version and revision.			✓	
12. Computer input/output provided or referenced and reasonable.			✓	
13. Computer run traceable to calculation (file #, etc.).			✓	
14. Computer input/output data and problem type within validation/verification range of use.			✓	
15. Computer program validation/verification addressed.			✓	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			✓	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	✓	
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
G. Taylor Grant	05/21/2020
Checker (Print Name and Sign):	**Date:**
Darrel Packard	05/21/2020

Signatures obtained only after discrepancies are corrected and comments are resolved.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 3 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

TABLE OF CONTENTS

1.0 PURPOSE 5

2.0 METHODOLOGY 5

3.0 DESIGN INPUTS 5
- 3.1 Friction Angles 5
- 3.2 Basin Geometry 6
- 3.3 Primary and Secondary Liner Thickness 6
- 3.4 Geotextile Thickness 6
- 3.5 Effluent Weight 7
- 3.6 Gravel 7

4.0 ASSUMPTIONS 7

5.0 COMPUTER SOFTWARE 7

6.0 RESULTS 7

7.0 REFERENCES 8

8.0 CALCULATIONS 9
- 8.1 Primary Liner 9
- 8.2 GCL 10
- 8.3 Geotextile 11
- 8.4 Gravel 12
- 8.5 Grip Layer Mat 13
- 8.6 Secondary Liner 14

Attachments

ATTACHMENT – 1 – H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER
H-2-838749, SHEET 2, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER DETAILS
H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER

ATTACHMENT – 2 –DESIGNING WITH GEOSYNTHETICS, 6TH EDITION

ATTACHMENT – 3 – FREE BODY DIAGRAM OF LINER FORCES

ATTACHMENT – 4 – HNF-SD-LEF-TI-005 REV 1 CALCULATION 6 SIDE SLOPE LINER STABILITY AND STRESS – PIPE TRENCH

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 4 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

Acronyms

cf	cubic foot (ft^3)
DCR	Demand-to-Capacity Ratio
deg	degree (angle)
ft	foot (length)
GCL	Geosynthetic Clay Liner
GDM	Geosynthetic Drainage Material
HDPE	High Density Polyethylene
lb	pound force
LERF	Liquid Effluent Retention Facility
psf	pound per square foot (lb/ft^2)
psi	pound per square inch (lb/in^2)
pcf	pound per cubic foot (lb/ft^3)
plf	pound per lineal foot (lb/ft)
sf	square feet

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 5 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

1.0 PURPOSE

The purpose of this calculation is to determine the stability of the liner system at the northwest corner of the basin containing the pipe trench. The pipe trench is lined with gravel and a grip layer mat. Attachments 1 and 3 show the liner layers and free body diagram of the liner forces.

A separate calculation addresses the stresses along the side slopes for the balance of the basin containing geonet. Since the composite liner systems are identical down to either the GDM or gravel, the results of the companion calculation are quite similar, and will serve as one basis for this calculation, down to the point where gravel replaces the GDM.

2.0 METHODOLOGY

The forces on each layer of the liner system will be analyzed, beginning at the top layer. Although the liquid waste (essentially water) in the basin is a shearless fluid, the approach taken in the calculation will be to assume shear forces are transmitted at the waste-primary liner interface. This will result in a conservative approach. The stresses in the liner layers will be analyzed at the toe of the slope around the basin floor. This will be the location of the greatest liquid depth which will cause the greatest stresses.

3.0 DESIGN INPUTS

3.1 Friction Angles

The friction angles between two materials are taken from Reference 1. Where similar surface-to-surface interfaces are not provided in Reference 1, similar surface-to-similar surface angles are used. The friction angles are presented below, along with remarks.

Friction Angle	Remarks
d_2 = 10 deg	Bottom of primary liner to top of GCL. This is the angle of smooth HDPE to slit film geotextile (Reference 1, Page 540)
d_i = 15 deg	The internal friction angle of the GCL. This is the friction angle at internal interfaces of the material (Reference 1, Table 6.1, Page 770). The average internal friction value of the four GCL samples was taken for the Hydration With Mild Leachate – Free Swell case.
d_4 = 24 deg	Bottom of GCL to top of geotextile. This is the friction angle of geomembrane to geotextile (woven slit film) combinations, and interface assumed to be similar to GCL-geotextile (Reference 1, Page 540).
d_6 = 26 deg	Bottom of geotextile to top of gravel. This is the friction angle of nonwoven, needle punched geotextile to rounded sand (Reference 1, Page 140).

d_{10} = 15 deg	Bottom of grip layer mat to top of secondary liner. This is the friction angle of Enkamat to smooth geomembrane (Reference 6, Page 490).

The below friction angles between two materials are taken from Reference 2. These friction angles are for similar materials that will be installed. The friction angles are presented below, along with remarks.

Friction Angle	Remarks
d_8 = 25 deg	Bottom of gravel to top of grip layer mat. Based on an example referenced in Reference 2.
d_{12} = 7.6 deg	Bottom of secondary liner to top of soil/bentonite layer. Reference 2 derived a range of friction angles between smooth HDPE and clay soils, and range from 7.6 to 18.3 degrees. The lowest value will be used.

3.2 Basin Geometry

The basin geometry is given in the below drawings. These drawings are included in Attachment 1.

H-2-838749, Sheet 1, Rev. 0

H-2-838749, Sheet 2, Rev. 0

H-2-838750, Sheet 1, Rev. 0

H_e = The maximum possible depth of effluent around the toe of the basin. The lowest point of the basin that effluent could reach is the top of the primary liner (Attachment 1, Drawing H-2-838749, Sheet 1, Liner System Schematic) and is elevation 576.50’ (Attachment 1, Drawing H-2-838750, Sheet 1). The highest elevation around the perimeter of the basin is the top of concrete of the anchor wall and is 603.50’ (Attachment 1, Drawing H-2-838750, Sheet 1, Section C). Therefore, H_e = top elevation – bottom elevation = 603.50’ – 576.50’ = 27.00’.

Slope = the greatest slope (in degrees) around the radius of the northwest corner. The slope is a 3.72:1 (Attachment 1, Drawing H-2-838749, Sheet 2), therefore the Slope = 1/3.72 = 0.27 = 15.05 degrees.

3.3 Primary and Secondary Liner Thickness

The specified thickness of the HDPE Liner = t_p = 60 mil = 0.06 in (Reference 7)

3.4 Geotextile Thickness

The specified thickness of the geotextile = t_{geo} = 70 mil = 0.07 in (Reference 7)

3.5 Effluent Weight

The unit weight of effluent = S_l = 62.4 pcf (Reference 2)

3.6 Gravel

The unit weight of gravel = S_{gravel} = 135 pcf (Engineering Judgement)

4.0 ASSUMPTIONS

There are no assumptions in this calculation. Engineering judgement, where used, is documented herein.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Calculations are checked using a handheld calculator.

6.0 RESULTS

A summary of the calculated DCRs is presented below.

Layer	Tension, Shear, or Normal Stress	DCR
Primary Liner	Tension	$DCR_{\sigma p}$ = 0.098
GCL	Internal Shear	DCR_{tibc} = 0.658
Geotextile	Shear	$DCR\tau_{geo}$ = 0.658
Grip Layer Mat	Tension	$DCR_{\sigma g}$ = 0.193
Secondary Liner	Tension	$DCR_{\sigma s}$ = 0.182

The required material properties are presented below. (Reference 7 unless noted)

Layer	Type	Required Value
Primary Liner	Tension Yield Strength	≥2000 psi
	Thickness	≥60 mils
GCL	Internal Friction Angle	≥15 deg
Geotextile	Thickness	≥70 mils
	Tear Strength	≥95 lb
Grip Layer Mat	Tension Yield Strength (Reference 4)	≥2000 plf

Secondary Liner	Tension Yield Strength	≥2000 psi
	Thickness	≥60 mils

7.0 REFERENCES

1) Koerner, Robert M., *Designing with Geosynthetics*, 6th Edition

2) HNF-SD-LEF-TI-005 R1, Calculation 6, Side Slope Liner Stability and Stress – Pipe Trench, 1990

3) H-2-838749, Sheet 1, Rev. 0, LERF Basin 41 Civil Secondary Liner

4) H-2-838749, Sheet 2, Rev. 0, LERF Basin 41 Civil Secondary Liner Details

5) H-2-838750, Sheet 1, Rev. 0, LERF Basin 41 Civil Primary Liner

6) 4th International Conference on Geotextiles Geomembranes and Related Products Volume 2, *Geosynthetics for Safe Waste Disposal*, Hoekstra, S. E. and H.C. Berkhout

7) RPP-SPEC-63632, Rev. 0, LERF Basin 41 Design Construction Specification

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 9 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

8.0 CALCULATIONS

8.1 Primary Liner

Weight of liquid acting on a one-foot wide strip of liner:

$W_1 = S_1 \times H_b \times 1\text{ ft} = 62.4\text{ pcf} \times 27\text{ ft} \times 1\text{ ft} = 1684.80\text{ plf}$

Force acting down the slope of the primary liner due to the weight of the liquid:

$F_1 = W_1 \times \sin(\text{slope}) = 1684.80\text{ plf} \times \sin(15.05\text{ deg}) = 437.48\text{ plf}$

Normal force resisting the liquid weight:

$N = W_1 = 1684.80\text{ plf}$

Shear force below the primary liner:

$F_2 = N \times \tan(d_2) = 1684.80\text{ plf} \times \tan(10\text{ deg}) = 297.08\text{ plf}$

$F_1 - F_2 = 437.48\text{ plf} - 297.08\text{ plf} = 140.40\text{ plf}$

Since $F_1 > F_2$ the primary liner is in tension.

Thickness of primary liner:

$t_p = 60\text{ mil} = 0.06\text{ in}$

Required tensile yield stress of HDPE:

$\sigma_{py} = 2000\text{ psi}$

Actual tensile stress in primary liner:

$\sigma_{pact} = (F_1 - F_2) / t_p = (437.48\text{ plf} - 297.08\text{ plf}) / 0.06\text{ in} = 195.00\text{ psi}$

DCR for tensile stresses in the primary liner:

$DCR_{\sigma p} = \sigma_{pact} / \sigma_{pacy} = 195.00\text{ psi} / 2000\text{ psi} = 0.098 < 1.0$ okay

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1	**Page No.** 10 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench		
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

8.2 GCL

Shear force acting on the GCL:

$F_3 = F_2 = 297.08$ plf (equal and opposite force to F_2)

Shear force below the GCL:

$F_4 = N \times \tan(d_4) = 1684.80 \text{ plf} \times \tan(24 \text{ deg}) = 750.12 \text{ plf}$

$F_3 - F_4 = 297.08 \text{ plf} - 750.12 \text{ plf} = -453.04 \text{ plf}$

Since $F_3 < F_4$ the GCL is not in tension.

Check the internal stresses at the internal interfaces in the GCL:

Internal force resulting from the normal force:

$F_i = N \times \tan(d_i) = 1684.80 \text{ plf} \times \tan(15 \text{ deg}) = 451.44 \text{ plf}$

DCR at internal interface of GCL:

$DCR_{tibc} = F_3 / F_i = 297.08 \text{ plf} / 451.44 \text{ plf} = 0.658 < 1.0$ okay

8.3 Geotextile

Shear force acting on the geotextile:

$F_5 = F_4 = 750.12$ plf (conservative because the shear force acting on the geotextile is limited by the shear force that the primary liner can transfer to the GCL, i.e. F_4 cannot exceed F_3)

Shear force below the geotextile:

$F_6 = N \times \tan(d_6) = 1684.80 \text{ plf} \times \tan(26 \text{ deg}) = 821.73 \text{ plf}$

$F_5 - F_6 = 750.12 \text{ plf} - 821.73 \text{ plf} = -71.61 \text{ plf}$

Since $F_5 < F_6$ the geotextile is in shear.

Calculate the shear stress:

Required thickness of geotextile:

$t_{geo} = 0.070$ in

Actual shear stress in geotextile:

$\tau_{geoact} = F_5 / t_{geo} = 750.12 \text{ plf} / 0.07 \text{ in} = 893.00$ psi

Required strength of geotextile:

$\tau_{geoall} = 95 \text{ lb} / (t_{geo} \times 1 \text{ in}) = 95 \text{ lb} / (0.070 \text{ in} \times 1 \text{ in}) = 1357.14$ psi

DCR for tensile stresses in geotextile:

$DCR\tau_{geo} = \tau_{geoact} / \tau_{geoall} = 893.00 \text{ psi} / 1357.14 \text{ psi} = 0.658 < 1.0$ okay

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1	**Page No.** 12 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench		

Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

8.4 Gravel

The weight of the gravel layer will be addressed:

The thickness of the gravel layer is 2 feet.

$h_{gravel} = 2$ ft

The weight of gravel is:

$W_{gravel} = S_{gravel} \times h_{gravel} \times 1 \text{ ft} \times \cos(\text{slope}) = 135 \text{ pcf} \times 2 \text{ ft} \times 1 \text{ ft} \times \cos(15.05) = 260.74 \text{ plf}$

Normal force at the bottom of the gravel layer:

$G_n = N + W_{gravel} = 1684.80 \text{ plf} + 260.74 \text{ plf} = 1945.54 \text{ plf}$

Set F_7 equal and opposite to F_6 (shear force beneath the geotextile)

$F_7 = F_6 = 821.73$ plf

Shear force below the gravel:

$F_8 = G_n \times \sin(d_8) = 1945.54 \text{ plf} \times \tan(25 \text{ deg}) = 907.22 \text{ plf}$

$F_7 - F_8 = 821.73 \text{ plf} - 907.22 \text{ plf} = -85.49 \text{ plf}$

Since $F_7 > F_8$ the gravel is in compression.

8.5 Grip Layer Mat

Shear force acting on the grip layer mat:

$F_9 = F_8 = 907.22$ plf

Shear force below the grip layer mat:

$F_{10} = G_n \times \tan(d_{10}) = 1945.54$ plf x tan(15 deg) = 521.31 plf

$F_9 - F_{10} = 907.22$ plf – 521.31 plf = 385.91 plf

Since $F_9 > F_{10}$ the grip layer mat is in tension.

Required tensile strength of grip layer mat:

$\sigma_{gy} = 2000$ plf

Actual tensile stress in primary liner:

$\sigma_{gact} = F_9 - F_{10} = 907.22$ plf – 521.31 plf = 385.91 plf

DCR for tensile stresses in the grip layer mat:

$DCR_{\sigma g} = \sigma_{gact} / \sigma_{gy} = 385.91$ plf / 2000 plf = 0.193 < 1.0 okay

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 14 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

8.6 Secondary Liner

Shear force acting on the secondary liner:

$F_{11} = F_{10} = 521.31$ plf

Shear force below the secondary liner:

$F_{12} = G_n \times \tan(d_{12}) = 1945.54$ plf x tan(7.6 deg) = 259.59 plf

$F_{11} - F_{12} = 521.31$ plf – 259.59 plf = 261.72 plf

Since $F_{11} > F_{12}$ the secondary liner is in tension.

Thickness of the secondary liner:

$t_s = t_p = 60$ mil = 0.060 inch

Required tensile yield stress of HDPE:

$\sigma_{sy} = \sigma_{py} = 2000$ psi

Actual tensile stress in secondary liner:

$\sigma_{secact} = (F_{11} - F_{12}) / t_s = (521.31$ plf – 259.59 plf) / 0.06 in = 363.50 psi

DCR for tensile stresses in the secondary liner:

$DCR_{\sigma s} = \sigma_{secant} / \sigma_{sy} = 363.50$ psi / 2000 psi = 0.182 < 1.0 okay

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 15 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

ATTACHMENT – 1 – H-2-838749, SHEET 1, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER
H-2-838749, SHEET 2, REV. 0, LERF BASIN 41 CIVIL SECONDARY LINER DETAILS
H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER

RPP-CALC-63749, Rev. 0

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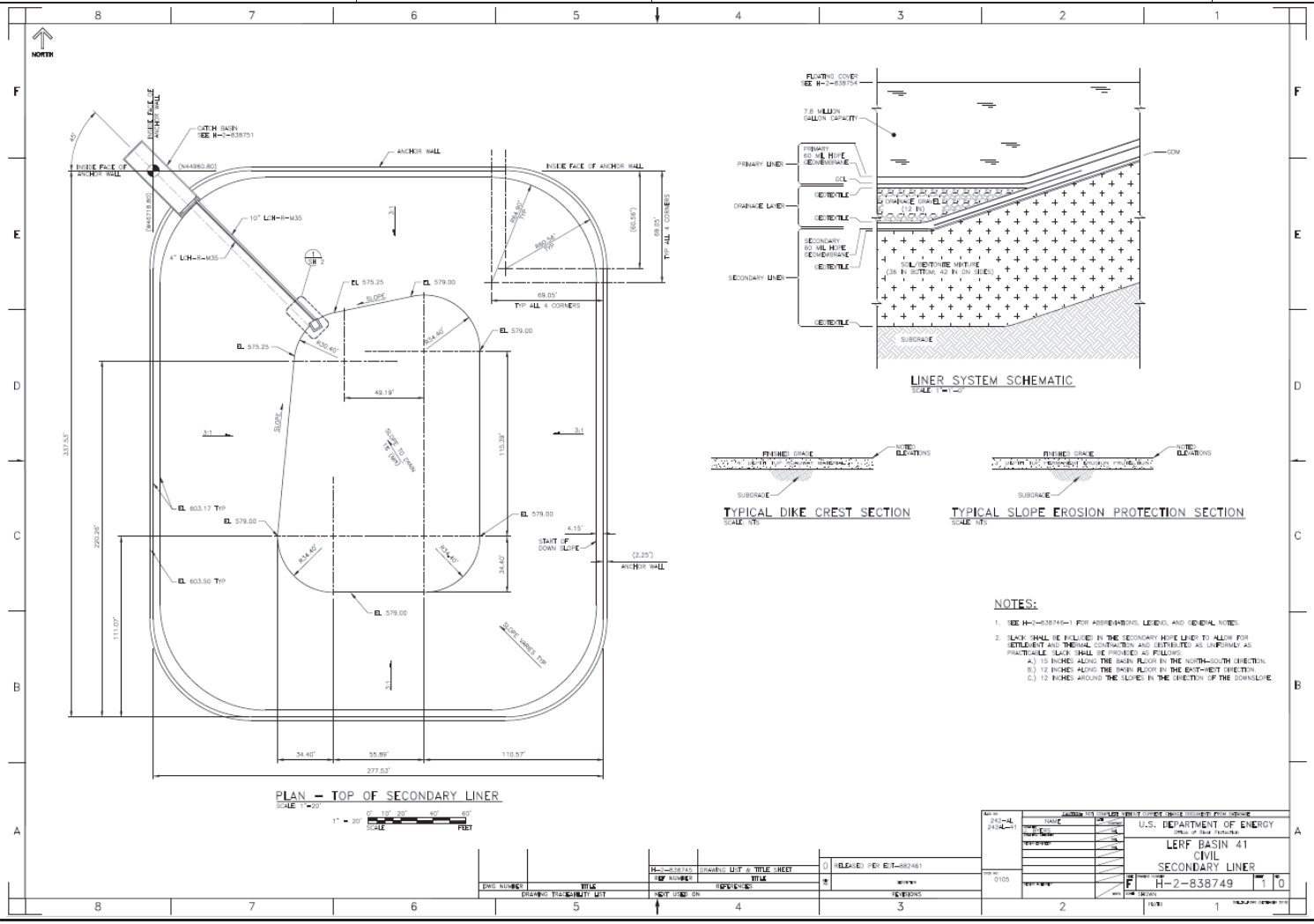
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-005 Rev. 1		**Page No.** 16 of 30
Title:	LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench				
Prepared By:	G. Taylor Grant	**Date:** 05/21/2020	**Checked By:**	Darrel J. Packard	**Date:** 05/21/2020



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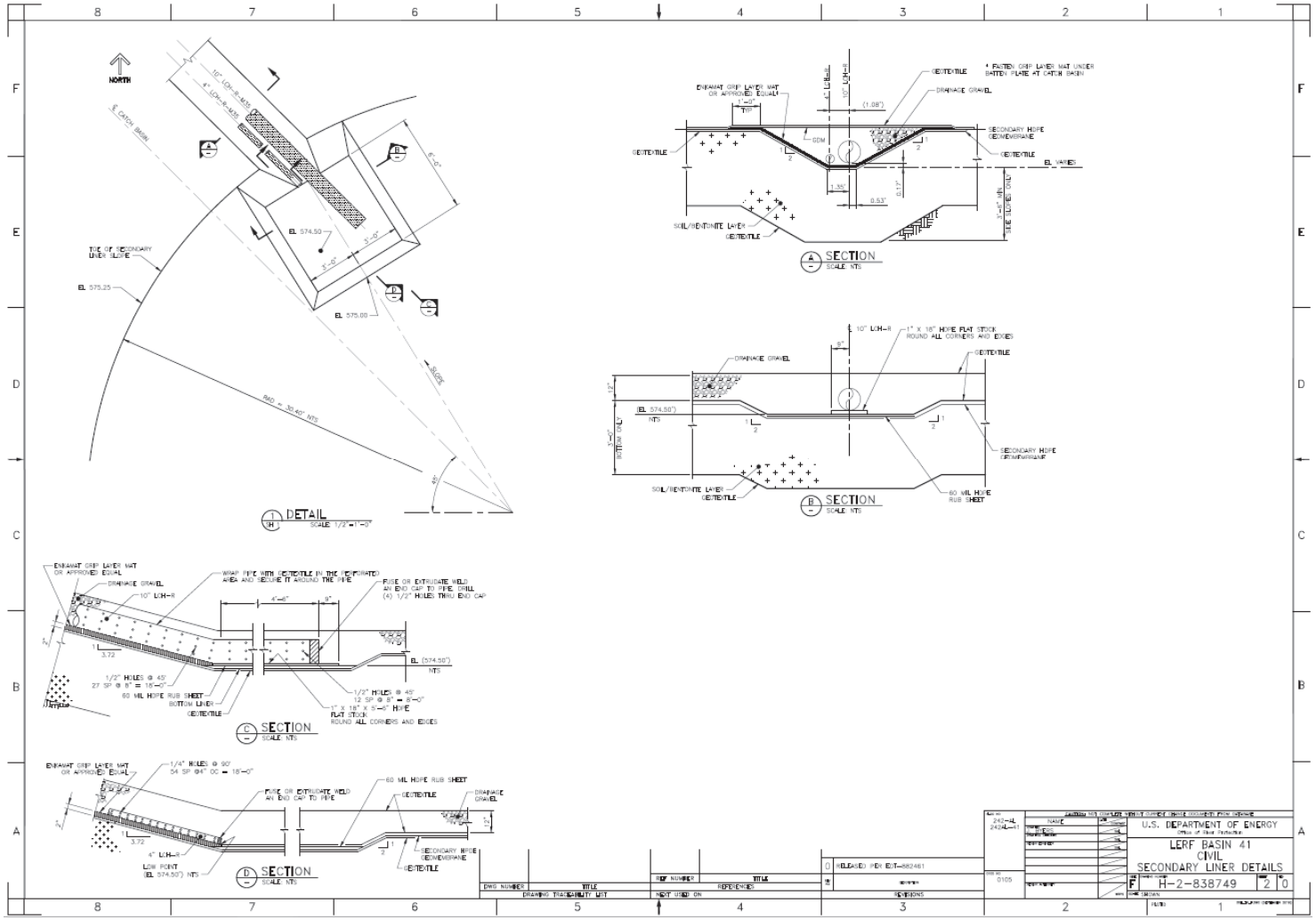
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-005 Rev. 1		**Page No.** 17 of 30
Title:	LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench				
Prepared By:	G. Taylor Grant	**Date:** 05/21/2020	**Checked By:**	Darrel J. Packard	**Date:** 05/21/2020



RPP-CALC-63749, Rev. 0

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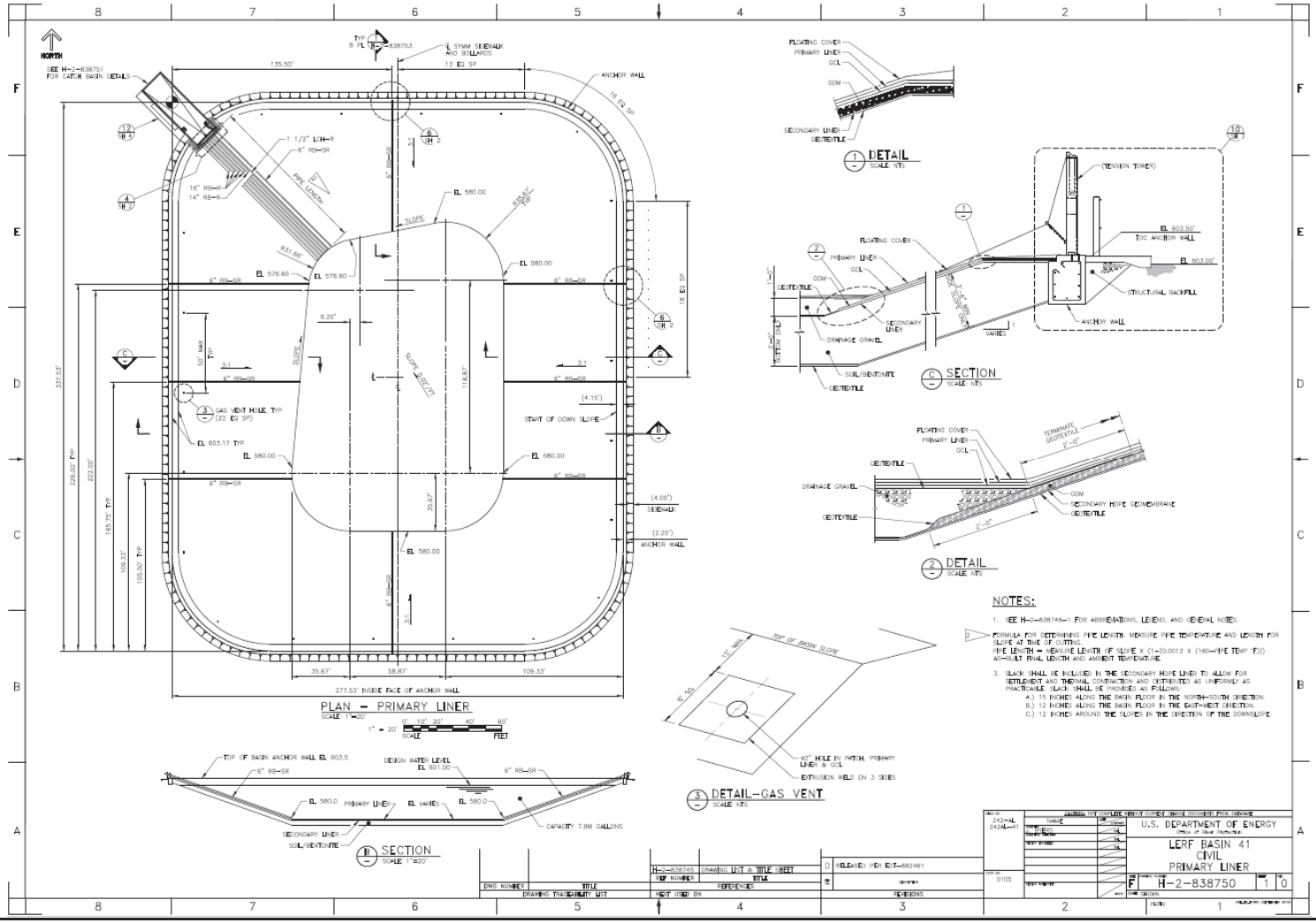
CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-005 Rev. 1	**Page No.** 18 of 30	
Title:	LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench				
Prepared By:	G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020	



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 19 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

ATTACHMENT – 2 – DESIGNING WITH GEOSYNTHETICS, 6TH EDITION

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 20 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

TABLE 2.4 PEAK SOIL-TO-GEOTEXTILE FRICTION ANGLES AND EFFICIENCIES (IN PARENTHESES) FOR SELECTED COHESIONLESS SOILS

Geotextile type	Concrete sand $\varphi = 30$ deg.	Rounded sand $\varphi = 28$ deg.	Silty sand $\varphi = 26$ deg.
Woven, monofilament	26 deg. (84%)	–	–
Woven, slit film	24 deg. (77%)	24 deg. (84%)	23 deg. (87%)
Nonwoven, heat bonded	26 deg. (84%)	–	–
Nonwoven, needle punched	30 deg. (100%)	26 deg. (92%)	25 deg. (96%)

Source: After Martin, et al. [35]

Note: *Literature values such as the above should not be used in critical designs. Site specific geotextiles and soils must be individually tested and evaluated in accordance with the particular project conditions, e.g., saturation, type of liquid, normal stress, consolidation time, shear rate, displacement amount, etc.*

dependent on the normal force applied to the soil, which mobilizes shearing resistances on both surfaces of the geotextile.

Since the test greatly resembles a direct shear test, albeit with stationary soil on both sides of the tensioned geotextile, a possible design strategy is to take direct shear test results (for both sides of the geotextile) and use these values for pullout design purposes. However, this may not be a conservative practice.

Test results by Collios et al. [36] show a relationship of pullout test results to shear test results with some notable exceptions. For pullout testing, if the soil particles are smaller than the geotextile openings, efficiencies are high; if not, they can be low. In all cases, however, pullout test resistances are less than the sum of the direct shear test resistances. This is due to the fact that the geotextile is taut in the pullout test and exhibits large deformations. This, in turn, causes the soil particles to reorient themselves into a reduced shear strength mode at the soil-to-geotextile interfaces, resulting in lower pullout resistance. The stress state mobilized in this test is both interesting and complex as evidenced by the approximate one-hundred technical references on this topic.

2.3.4 Hydraulic Properties

Unlike the physical and mechanical properties just discussed, traditional tests on textile materials rarely have hydraulic applications;

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 21 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

TABLE 5.6 PEAK FRICTION VALUES AND EFFICIENCIES OF VARIOUS GEOSYNTEHTIC INTERFACES*

(a) Soil-to-Geomembrane Friction Angles

Geomembrane	Soil type: Concrete sand ($\phi = 30°$)		Ottawa sand ($\phi = 28°$)		Mica schist sand ($\phi = 26°$)	
HDPE						
textured	30°	(1.00)	26°	(0.92)	22°	(0.83)
smooth	18°	(0.56)	18°	(0.61)	17°	(0.63)
PVC						
rough	27°	(0.88)	—	—	25°	(0.96)
smooth	25°	(0.81)	—	—	21°	(0.79)
fPP-R	25°	(0.81)	21°	(0.72)	23°	(0.87)

(b) Geomembrane-to-Geotextile Friction Angles

Geotextile	Geomembrane: HDPE Textured	HDPE Smooth	PVC Rough	PVC Smooth	fPP-R
Nonwoven, needle punched	32°	8°	23°	21°	15°
Nonwoven heat bonded	28°	11°	20°	18°	21°
Woven, monofilament	19°	6°	11°	10°	9°
Woven, slit film	32°	10°	28°	24°	13°

(c) Soil-to-Geotextile Friction Angles

Geotextile	Soil type: Concrete sand ($\phi = 30°$)		Concrete sand ($\phi = 30°$)		Mica schist sand ($\phi = 26°$)	
Nonwoven, needle punched	30°	(1.00)	26°	(0.92)	25°	(0.96)
Nonwoven heat bonded	26°	(0.84)	—	—	—	—
Woven, monofilament	26°	(0.84)	—	—	—	—
Woven, slit film	24°	(0.77)	24°	(0.84)	23°	(0.87)

*Efficiency values (in parentheses) are based on the relationship E = (tan

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 22 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

TABLE 6.1 SUMMARY OF GCL INTERNAL DIRECT SHEAR TEST RESULTS

Designation		Hydration with Distilled Water			Hydration with Tap Water		
		Dry*	Constrained Swell	Free Swell	Dry*	Contrained Swell	Free Swell
GCL-1	ϕ (degrees)	37°	16°	0°	37°	18°	0°
	c (kPa)	6.9	2.8	4.1	6.9	2.8	3.4
GCL-2	ϕ (degrees)	36°	31°	10°	36°	34°	15°
	c (kPa)	68	6.9	9.0	68	6.9	6.9
GCL-3	ϕ (degrees)	42°	37°	23°	42°	43°	26°
	c (kPa)	14	8.5	4.8	14	5.5	10
GCL-4	ϕ (degrees)	26°	19°	0°	26°	18°	0°
	c (kPa)	50	4.8	2.8	50	4.8	3.4

Designation		Hydration with Mild Leachate			Hydration with Harsh Leachate		
		Dry	Constrained Swell	Free Swell	Dry	Contrained Swell	Free Swell
GCL-1	ϕ (degrees)	37°	24°	4°	37°	19°	0°
	c (kPa)	6.9	6.2	3.4	6.9	5.5	2.8
GCL-2	ϕ (degrees)	36°	43°	20°	36°	39°	30°
	c (kPa)	68	4.8	12	68	4.1	8.3
GCL-3	ϕ (degrees)	42°	39°	25°	42°	45°	32°
	c (kPa)	14	8.3	14	14	4.8	12
GCL-4	ϕ (degrees)	26°	18°	13°	26°	13°	0°
	c (kPa)	50	4.8	3.4	50	7.6	3.4

Designation		Hydration with Diesel Fuel		
		Dry	Constrained Swell	Free Swell
GCL-1	ϕ (degrees)	37°	37°	38°
	c (kPa)	6.9	6.9	6.2
GCL-2	ϕ (degrees)	36°	36°	46°
	c (kPa)	68	68	4.8
GCL-3	ϕ (degrees)	42°	42°	40°
	c (kPa)	14	6.2	4.8
GCL-4	ϕ (degrees)	26°	24°	29°
	c (kPa)	50	4.1	6.2

**Dry* refers to the GCL as received, placed under desired normal stress, then sheared at midplane.

Constrained swell refers to GCL hydrated under the desired normal stress, then sheared at the midplane.

Free swell refers to GCL hydrated under zero normal stress, then placed under the desired normal stress, and immediately sheared at midplane.

Source: After Leisher [4].

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 23 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

ATTACHMENT – 3 – FREE BODY DIAGRAM OF LINER FORCES

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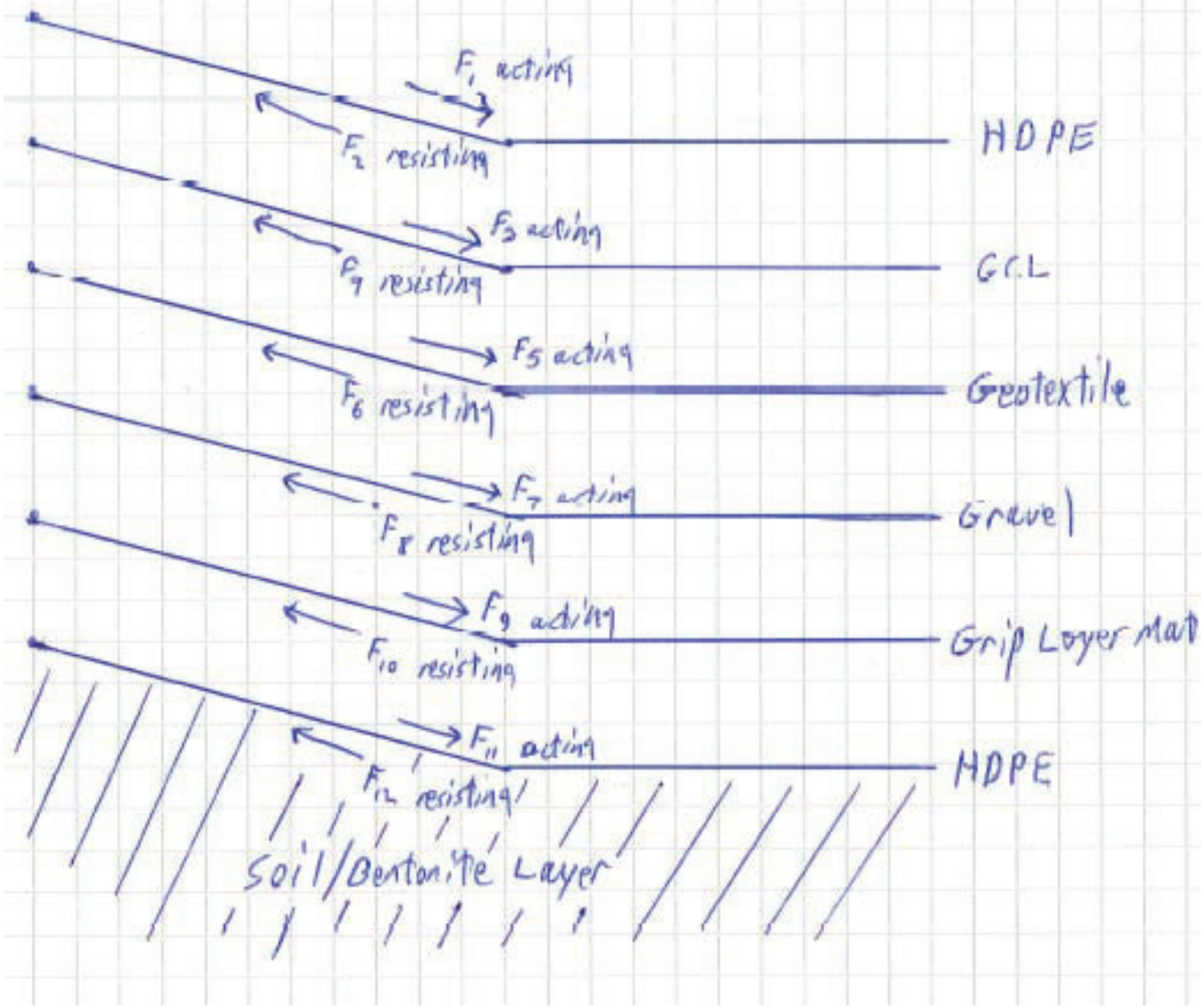
CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 24 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

Free body diagram of forces on the Liner System around the piping system in the northwest corner of the basin.



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 25 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

ATTACHMENT – 4 – HNF-SD-LEF-TI-005 REV 1 CALCULATION 6 SIDE SLOPE LINER STABILITY AND STRESS – PIPE TRENCH

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 26 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

HNF-SD-LEF-TI-005 Rev 1

KAISER ENGINEERS HANFORD

Page No. 1 of 19

Revision 0

DESIGN ANALYSIS

Client W HC WO/Job No. ER-0156/W-105

Subject Side-Slope Liner Stability + Stresses: Pipe Trench Date 9/20/90 By DKD

Checked SEP 25 1990 By RHL

Location 242 A L, 200 East Revised By

SIDE SLOPE LINER STABILITY - PIPE TRENCH

1.0 OBJECTIVE

This calculation addresses the stability of the liner system at the corner containing the pipe trench, for the W-105 Retention basins. The pipe trench is lined with gravel and a grip layer mat, refer to Project Drawing No. H-2-79590. The remainder of the 3-to-1 side sloped areas of the basins use a geonet in lieu of the gravel and grip layer mat.

A separate calculation addresses stresses along the side slopes containing geonet. Since the composite liner systems are identical down to either the geonet or gravel/grip layer mat, the results of the companion calculation are quite similar, and will serve as one basis for this calculation, down to the point where gravel replaces the geonet.

2.0 DESIGN INPUTS

2.1 References

2.1.1 Koerner, R.M., "Designing with Geosynthetics," 2nd Edition, Prentice Hall, Sections 5.6.8, 5,3, 5.1.3.8, and as referenced below, 1990.

2.1.2 Industrial Fabric Association International, "The Use of Geosynthetics in Waste Containment," Presentation Handout, Page 7, undated.

2.1.3 Letter to W. Simpson, James Clem Corporation, from Geoservices, Inc., "Report on the Direct Shear Testing of Selected CLAYMAX CL," Table 1 and Attachment 1, dated 10 March 1989.

2.1.4 Technical Report to Acme Concrete Company from Chen-Northern, Inc., "Tests of Drainage Gravel for the Grout Vault Storage Facility, Kaiser B714 Project," dated 26 February 1990.

2.1.5 Akzo Industrial Systems Company, "ENKAMAT "S" Reinforced Grip Layer Matting [RGLM], Specifications," Asheville, NC 28802, undated.

2.1.6 Mathsoft, Inc., "Mathcad Version 2.5 User's Guide," Cambridge, Ma 02139, June 1989.

2.1.7 Letter to W. Simpson, James Clem Corporation from R. H.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 27 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

HNF-SD-LEF-TI-005 Rev 1

KAISER ENGINEERS HANFORD

Page No. 2 of 19

Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. ER-0156/W-105

Subject Side-Slope Liner Stability + Stresses: Pipe Trench Date 9/20/90 By DKD

Checked SEP 25 1990 By

Location 242 A L, 200 East Revised By

Swan, Jr., GeoServices, Inc, Consulting Engineers, "Report on the Direct Shear Testing of Selected CLAYMAX CL Interfaces, GeoServices Project Number: P1157, GeoServices Document Number: NL89038," Norcross, Georgia, Dated March 10, 1989.

Other references are listed below when applied to a specific area of the calculation.

2.2 Units for Required for Calculation (This Information
I. Base unitsATHCAD)

ft ≡ 1L lb ≡ 1M sec ≡ 1T

(In this document "lb" represents "pounds-mass", the base unit of mass. "lbf is used for force, see below.)

II. Angular measure

rad ≡ 1

$$deg \equiv \frac{\pi}{180} \cdot rad$$

III. Derived units: Length

$$in \equiv \frac{ft}{12} \qquad m \equiv \frac{ft}{.3048} \qquad mil \equiv 0.001 \cdot in$$

$$cm \equiv 0.01 \cdot m$$

IV. Derived units: Mass

$$slug \equiv 32.174 \cdot lb$$

V. Derived units: Time

$$min \equiv 60 \cdot sec \qquad hr \equiv 3600 \cdot sec \qquad day \equiv 24 \cdot hr$$

$$yr \equiv 365.2422 \cdot day$$ (tropical year)

VI. Derived units: Area, Volume

$$gal \equiv 0.1337 \cdot ft^3$$

58

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 28 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

KAISER ENGINEERS HANFORD

HNF-SD-LEF-TI-005 Rev 1.

Page No. 3 of 19

Revision 0

DESIGN ANALYSIS

Client WHC WO/Job No. ER-0156/W-105

Subject Side-Slope Liner Stability + Stresses: Pipe Trench Date 9/20/90 By DKD

Checked SEP 25 1990 By

Location 242 A L, 200 East Revised By

VII. Derived units: Acceleration

$$g = 32.174 \cdot \frac{ft}{sec^2}$$ (acceleration of gravity)

VIII. Derived units: Force, Pressure

$lbf = g \cdot lb$ (pound force)

$$psi = \frac{lbf}{in^2}$$

2.3 Given or Known Data

$$\rho_1 := 1.94 \cdot \frac{slug}{ft^3}$$ Density of liquid waste

$$S_1 := \rho_1 \cdot g$$

$$S_1 = 62.4 \cdot \frac{lbf}{ft^3}$$ Specific weight of liquid waste

$$S_{gravel} := 122.1 \cdot \frac{lbf}{ft^3}$$ Maximum specific weight of gravel layer, per Reference 2.1.4

$$H_b := 603.5 \cdot ft - 576.60 \cdot ft$$

$$H_b = 26.9 \cdot ft$$ Maximum internal height of basin. The highest liquid level will be several feet below the maximum basin height. Using the maximum internal height of the basin is a conservative assumption.

59

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 29 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

HNF-SD-LEF-TI-005 Rev1.

KAISER ENGINEERS HANFORD

Page No. 4 of 19
Revision 0

DESIGN ANALYSIS

Client WHC
WO/Job No. ER-0156/W-105
Subject Side-Slope Liner Stability + Stresses: Pipe Trench
Date 9/20/90 By DKD
Checked SEP 25 1990 By DHallenbeck
Location 242 A2, 200 East
Revised By

$\beta := 18.4 \cdot deg$ — Slope angle corresponding to a slope of 3:1. Actually, the slope in the corner is somewhat less that 3:1 so this is a conservative assumption.

2.4 Friction Angles

Figure 1 presents the layers of the basin liner systems, while Figure 2 offers an expanded view of the layers. The top liner is referred to as the primary liner in this calculation, and the bottom liner is referred to as the secondary liner. The expressions "primary" and "secondary" are used in the referenced documentation.

Friction angles represent the coeficient of friction at the layer boundaries. They are presented below, along with remarks.

ANGLE	REMARKS
$\delta_2 := 10 \cdot deg$	Bottom of primary liner to top of bentonite carpet liner. This is the value of smooth HDPE to slit film geotextile (Reference 2.1.1, Page 382)--probably conservative.
$\delta_4 := 24 \cdot deg$	Bottom of bentonite carpet liner to top of geotextile. This angle is based on Reference 2.1.1, Page 382, for geomembrane-to-geotextile (woven slit film) combinations, an interface assumed to be similar to bentonite carpet liner-geotextile.
$\delta_i := 12 \cdot deg$	The "internal" friction angle for the bentonite carpet liner. This is the friction angle at internal interfaces of the material, from Reference 2.1.7.
$\delta_6 := 30 \cdot deg$	Bottom of geotextile to top of gravel.

60

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-005 Rev. 1		**Page No.** 30 of 30
Title: LERF Basin 41 Side Slope Liner Stability and Stress – Pipe Trench			
Prepared By: G. Taylor Grant	**Date:** 05/21/2020	**Checked By:** Darrel J. Packard	**Date:** 05/21/2020

HNF-SD-LEF-TI-005 Rev1.

KAISER ENGINEERS HANFORD

Page No. 5 of 19
Revision 0

DESIGN ANALYSIS

Client WHC
WO/Job No. ER-0156/W-105
Subject Side-Slope Liner Stability + Stresses: Pipe Trench
Date 9/20/90 By DKD
Checked SEP 25 1990 By
Revised By
Location 242 A L, 200 East

Per Reference 2.1.1, Page 382, this angle is for nonwoven, needle-punched geotextile to concrete sand. The friction angle for gravel is expected to be slightly higher.

$\delta_8 := 25 \cdot deg$ Bottom of gravel to top of Enkamat S grid.

Value based on example for the South Hampton Landfill, Reference 2.1.5.

$\delta_{10} := 12 \cdot deg$ Bottom of Enkamat S, or similar, grid to to of secondary liner.

Value based on example for the South Hampton Landfill,Reference 2.1.5.

$\delta_{12} := 7.6 \cdot deg$ Bottom of secondary liner to top of soil/bentonite layer.

"Reference 2.1.1, Page 382-384, including Table 5.6, provides friction values and efficiencies for soil-to-geomembrane interfaces. From these data, friction angles for smooth HDPE to clay soils were derived, and range from 7.6 to 18.3 degrees.

The data provided in the reference are for various types of undrained clays. Project W-105 uses a soil/bentonite mix, and a friction angle of 7.6 degrees is expected to be technically conservative.

2.5 Calculation

The approach will be to analyze forces on each layer of the system, beginning at the top. It is based on Reference 2.1.1, "Designing with Geosynthetics," Section 5.6.8.

Assumption:

Although the liquid waste (essentially water) in the basins is a shearless fluid, the approach taken in the this calculation will be to assume shear forces are transmitted at the waste-primary liner interface. This will result in a technically conservative approach.

61

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE: May 26,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63750 **Rev.** 00

2. **Title:**
LERF Basin 41 Settlement of Foundation Soils

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Raymer, Julia R	*Raymer, Julia R*	05/26/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/24/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/08/2020
Document Control Approval	Meinecke, Kathryn R	*Meinecke, Kathryn R*	05/26/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/30/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/08/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/13/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	05/14/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Because of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Joshua Bickett and Jeremy Debban is signing as Checker for David Nielson. Joshua Bickett and David Nielson are not currently in SPF.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
Angevine, Brennan T	MISSION ANALYSIS ENGINEERING
Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
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Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
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Harris, John W	SAFETY PROGRAM SERVICES RC/P
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DOCUMENT RELEASE AND CHANGE FORM	**Doc No:** RPP-CALC-63750 **Rev.** 00

14. **Distribution**

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Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63750
Revision 0

LERF Basin 41 Settlement of Foundation Soils

Prepared by

Joshua M. Bickett
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
April 2020

washington river protection solutions

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5-18-2020

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Approved for Public Release;
Further Dissemination Unlimited

RPP-CALC-63750, Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 13	
		Date 4/8/2020	**Rev. No.** 0
		Calculation No: S54413.024-C-006	

Project No.	**Project Title:**	**Client:**
54413.024	LERF Basin 41	WRPS

Title:
LERF Basin 41 Settlement of Foundation Soils

Purpose and Objective:

The purpose of this calculation is to evaluate the LERF Basin 41 for the following items:

- Settlement of foundation soils
- Settlement of soil-bentonite layer

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	13	Print Name/ Sign:	Joshua M. Bickett	David E. Nielson, P.E.	Paul M. Dorsh, P.E.
		Date:	4/8/2020	4/8/2020	4/8/2020

Revision Description (Revision Description/Affected Pages):
Initial Release

		Print Name/ Sign:			
		Date:			

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RPP-CALC-63750, Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev. No.	Page No.
54413.024	S54413.024-C-006	0	2 of 13

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.			√	
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	ALL
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
Joshua M. Bickett	4/8/2020
Checker (Print Name and Sign):	**Date:**
David E. Nielson, P.E.	4/8/2020

Signatures obtained only after discrepancies are corrected and comments are resolved.

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-006	**Rev.** 0	**Page No.** 3 of 13
Title: LERF Basin 41 Evaluation of Dike Settlement Analysis			
Prepared By: Joshua M. Bickett	**Date:** 4/8/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/8/2020

TABLE OF CONTENTS

1.0 PURPOSE 5

2.0 METHODOLOGY 5
- 2.1 Design Basis Soil Properties 5
- 2.2 Design Requirements 5
- 2.3 Seismic Accelerations 6
- 2.4 Flood and Hydrodynamic Loading 7
- 2.5 Wind Loading 7
- 2.6 Surcharge Loading 7
- 2.7 Precipitation 7
- 2.8 Volcanic 7
- 2.9 Settlement Analysis 8
- 2.10 Acceptance Criteria 8

3.0 DESIGN INPUT 8

4.0 ASSUMPTIONS 9

5.0 CALCULATIONS 9
- 5.1 Design Basis Soil Parameters 9
- 5.2 Settlement of Foundation Soils 10
- 5.3 Settlement of Soil-Bentonite Layer 12
- 5.4 Settlement Summary 12

6.0 CONCLUSIONS 12

7.0 REFERENCES 13

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-006	**Rev.** 0	**Page No.** 4 of 13
Title: LERF Basin 41 Evaluation of Dike Settlement Analysis			
Prepared By: Joshua M. Bickett	**Date:** 4/8/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/8/2020

Acronyms

DOE	Department of Energy
FDC	Flood Design Category
LERF	Liquid Effluent Retention Facility
MCE	Maximum Considered Earthquake
NAD	North American Datum
NDC	Natural Phenomena Design Category
NPH	Natural Phenomena Hazard
PDC	Precipitation Design Category
SCRD	Supplemented Contractor Requirements Document
SDC	Seismic Design Category
SSC	Structures, Systems and Components
TOC	Tank Operations Contractor
VDC	Volcanic Design Category
WDC	Wind Design Category

Sargent & Lundy Engineering Services, Inc.	CALCULATION SHEET		
Project No. 54413.024	**Calculation No.** S54413.024-C-006	**Rev.** 0	**Page No.** 5 of 13
Title: LERF Basin 41 Evaluation of Dike Settlement Analysis			
Prepared By: Joshua M. Bickett	**Date:** 4/8/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/8/2020

1.0 PURPOSE

The purpose of this calculation is to evaluate the Liquid Effluent Retention Facility (LERF) Basin 41 for the following items:

- Settlement of foundation soils
- Settlement of soil-bentonite layer

The analyses performed herein are for the LERF Basin 41 Project adjacent to Area 200 East (and immediately adjacent to existing LERF Basins 42, 43 and 44) at the U.S. Department of Energy (DOE) Hanford Site in the State of Washington.

2.0 METHODOLOGY

2.1 Design Basis Soil Properties

Geotechnical and Seismic Design Input identified in Section 3.0 of this analysis is reviewed to establish the design basis soil profile and soil properties. The parameters and profile documented in the Existing Design Analysis identified in Section 3.0 of this analysis for LERF Basins 42, 43, 44 are utilized for this analysis after verifying consistency with the Geotechnical and Seismic Design Input. The elastic modulus and Poisson's Ratio are required parameters to be established. The basis for the compressibility of the soil bentonite layer is established by reference to the data reported in HNF-SD-LEF-TI-005.

The groundwater level observations provided in the Geotechnical and Seismic Design Input are utilized as the design groundwater for analysis.

2.2 Design Requirements

Current DOE requirements for both general design criteria and natural phenomena hazard (NPH) mitigation for the Hanford site are in Supplemented Contractor Requirements Document (SCRD) DOE O 420.1C and DOE STD-1020-2016.

DOE-STD-1020-2016 provides NPH design and evaluation criteria for seismic, wind, flood, precipitation, lightning, and volcanic hazards based on natural phenomena design categories (NDCs). The LERF Basin 41 Project is NDC-1. The design requirements are summarized in TFC-ENG-STD-06.

TFC-ENG-STD-06 establishes structural design loads and acceptance criteria for use in designing new Structures, Systems, and Components (SSCs), evaluating existing SSCs, evaluating anchorage effects of new and modified systems on existing SSCs, and designing additions and modifications to existing SSCs.

TFC-ENG-STD-06 fulfills three objectives:

- NPH requirements with DOE and other requirements governing design and evaluation of SSCs,

- Limit requirements and NPH criteria to those applicable to the DOE Hanford Site Tank Operations Contractor (TOC), which are applied to LERF Basin 41, and
- Stipulate the appropriate levels of depth, rigor, and thoroughness in complying with the requirements.

SSCs are designed and evaluated to withstand loads associated with the operation of the facility and the effects of NPHs. DOE O 420.1C, IBC 2015 and ASCE 7-10 are used as the minimum basic design requirements for DOE facilities.

The SSCs need not be subjected simultaneously to any combination of extreme wind, seismic ground motions, volcanic ashfall, and flood. However, common cause events are to be evaluated as single events.

SSCs are categorized into the following individual NDCs (recall LERF Basin 41 is NDC-1):

- For seismic hazards, Seismic Design Categories: SDC-1
- For extreme wind hazards, including straight-line wind, tornado, and hurricane hazards, Wind Design Categories: WDC-1
- For flood hazards, including seiche, tsunami, and other flood hazards, Flood Design Categories: FDC-1
- For precipitation hazards, Precipitation Design Categories: PDC-1
- For volcanic eruption hazards, Volcanic Design Categories: VDC-1.

2.3 Seismic Accelerations

Per TFC-ENG-STD-06 the return period for seismic design is not specifically defined for SDC-1 but is the same as that achieved for IBC-2015 for Risk Category II, $I_P = 1.0$ (ASCE 7-10), for Limit States A, B, C, or D.

Seismic analyses include horizontal and vertical components of motion expressed as a percentage of gravity. A site-specific maximum considered earthquake (MCE) spectra and design spectra (2/3MCE) are developed in Figure 50 of RPP-RPT-27570 for the site, which are based on a 2,500-year return period.

Given that is not appropriate to couple the seismic acceleration with static loads in a long term settlement analysis, the seismic design criteria is not applicable herein. Also, given the deep groundwater table, liquefaction induced ground surface settlement is not required. Ground surface settlement of unsaturated granular material is negligible and does not require analysis.

2.4 Flood and Hydrodynamic Loading

Per TFC-ENG-STD-06 the return period for flood analysis of structures not exposed to submersion for FDC-1 is 100 years. Flood and hydrodynamic loading are not input for a settlement analysis given the temporary nature of the loading condition.

2.5 Wind Loading

Per TFC-ENG-STD-06 the return period for extreme straight line wind loading analysis for WDC-1. The wind loads are defined as Exposure Category C with nominal 3-second gusts at 85 miles per hour and ultimate 3-second gusts at 110 miles per hour.

Wind loading is neglected as a design load for these analyses based the temporary nature of the loading condition and standard geotechnical engineering practice for settlement analysis.

2.6 Surcharge Loading

Surcharge for temporary loads (operating equipment or traffic) are considered as 500 psf. These traffic loads are not considered appropriate to include in the settlement analysis given the short duration of application and the location (dike crest, not on the liner) area. Sustained surcharge loads (generically includes ash, snow, etc) possibly contributing to the settlement magnitude of the overall basin system are anticipated to be small and can be represented by a 50 psf uniform load.

2.7 Precipitation

Per TFC-ENG-STD-06 the return period for precipitation structural loading analysis for PDC-1 is 100 years. The design basis precipitation load is 1.8 inch per TFC-ENG-STD-06 and intensity of 1 inch per hour per DOC 1961.

Loading due to PDC-1 rainfall is considered as temporary and analysis is not required to be specifically evaluated herein.

Per TFC-ENG-STD-06 the design snow load is 15 psf, which is bounded by the uniform 50 psf pressure established in the surcharge loading section above.

2.8 Volcanic

Per TFC-ENG-STD-06 the return period for volcanic ashfall structural load analysis for VDC-1 is 100 years. Ash loading considerations are considered bounded by the surcharge load analysis and are not required to be specifically evaluated herein.

2.9 Settlement Analysis

The profile analyzed herein is determined based on the maximum dike heights, topographic considerations, nearby structures (including existing basins), the soil conditions, and maximum retained effluent height. The location of maximum settlement is within the basin under the maximum retained effluent load and sustained surcharge.

At low stresses and strains, settlement of granular soils can be modelled using an elastic response. The settlement of the basin with base dimensions B (width) and L (length) on granular soil can be calculated using an elastic analysis defined in Bowles (1997):

$$\Delta H = q_0 * B * \Delta H = q_0 * B * \left(\frac{(1-\mu^2)}{E_s}\right) * I_s * I_f$$

Where;

ΔH = settlement (ft)
q_o = intensity of contact pressure (psf)
B = least lateral dimension of contact pressure (ft)
μ = Poisson's Ratio from Table 2-7 Bowles (1997)
E_s = Elastic (Young's) Modulus of the soil (psf) from Table 2-8 Bowles (1997)
I_s = Shape Factor $= I_1 + [(1-2\mu)/(1-\mu)]*I_2$
I_1 = Table 5-2 Bowles (1997)
I_2 = Table 5-2 Bowles (1997)
I_f = Depth Factor (conservatively neglected)

2.10 Acceptance Criteria

There are no acceptance criteria for these settlement analyses. The magnitude of settlement determined herein is input for evaluation of liner stress.

3.0 DESIGN INPUT

Topographic Data:

Existing site topographic survey is provided on the Project Design Drawings.

Horizontal Datum: NAD83

Vertical Datum: 200E (based on PT 29 Reference Drawing No. H-2-2310, Rev. 9)

Project Design Drawings:

H-2-838747, Sheet 1

H-2-838748, Sheet 1

H-2-838749, Sheet 1

H-2-838749, Sheet 2

H-2-838750, Sheet 1

Geotechnical and Seismic Data:

Shannon & Wilson, Inc. (1994a)

Shannon & Wilson, Inc. (1994b)

Shannon & Wilson, Inc. (1994c)

RPP-RPT-27570

Existing Design Analysis:

HNF-SD-LEF-TI-005

Design Standards:

TFC-ENG-STD-06

DOE-STD-1020-2016

DOE O 420.1C

4.0 ASSUMPTIONS

There are no assumptions that require further verification in these analyses. Engineering judgement, where used, is documented herein.

5.0 CALCULATIONS

5.1 Design Basis Soil Parameters

Based on the review of the geotechnical and seismic design input it is determined the design soil profile, soil parameters and groundwater level used in the existing analysis (HNF-SD-LEF-TI-005) can be used for this analysis of LERF Basin 41. The in situ subsurface material is subdivided into stratigraphic units based on constituents, structure, geotechnical engineering properties, stress history and geologic deposition.

Design Soil Profile

Natural Site Soil: Sand and Gravel
μ = 0.4 from Table 2-7 Bowles (1997)
E_s = 1,440,000 psf from Table 2-8 Bowles (1997) and HNF-SD-LEF-TI-005.

Soil-Bentonite: Sand and Bentonite
2.5 percent compression at 1300 psf, 19.6 percent moisture content and dry density of 104.2 pcf.

Groundwater is deep at the site, well below the bottom of the basin. Thus, it does not affect the settlement analyses. Groundwater is considered to be encountered at depths greater than 200 feet below the ground surface.

5.2 Settlement of Foundation Soils

Per Bowles (1997). the settlement of a rectangular base with dimensions B and L on an elastic half-space can be computed using an equation satisfying the Theory of Elasticity.

$$\Delta H = q_0 * B * \Delta H = q_0 * B * \left(\frac{(1-\mu^2)}{E_s}\right) * I_s * I_f$$

ΔH = settlement, in units of feet

q_0 = Intensity of contact pressure; since the impounded fluid is essentially water, the unit weight of the impounded fluid is approximately 62.4 pcf, conservatively use 65.0 pcf. Contact pressure on the liner then equals fluid unit weight multiplied by the depth of fluid. At the toe of the interior dike slope the fluid depth is 21 ft (max. fluid level – Top of liner Elevation = El. 601 − El. 580 = 21 ft). To conservatively represent the average fluid depth in the balance of the basin a depth of 23 ft is used (max. fluid level – average top of liner Elevation = El. 601 − El. 578 = 23 ft).

Interior Dike Slope Toe = 65 pounds per cubic foot * 21 feet = 1,365 pounds per square foot (psf)
Average Balance of Basin = 65 pounds per cubic foot * 23 feet = 1,495 pounds per square foot (psf)

To account for miscellaneous "sustained" environmental loads (surcharge loads) add 50 psf per the Design Requirements section of this analysis.

Thereby

$q_{0\ toe}$ = 1,365 psf + 50 psf = 1,415 psf
$q_{0\ ave}$ = 1,495 psf + 50 psf = 1,545 psf

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-006	**Rev.** 0	**Page No.** 11 of 13
Title: LERF Basin 41 Evaluation of Dike Settlement Analysis			
Prepared By: Joshua M. Bickett	**Date:** 4/8/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/8/2020

B = Least lateral dimension of contact area. Per the Project Design Drawings, the minimum planned width of the basin bottoms is approximately 120 feet and the approximately length, L = 180 feet.

μ = 0.4

E_s = 1,440,000 psf

Settlement of the natural soil at the toe of the interior dike slope (a basin corner) is calculated as follows:

I_s = Shape Factor; settlement was calculated to a depth of 120 feet below the basin bottom (H in ft). N = H/B = 120'/120' = 1.0 and M = L/B = 180/120 = 1.5. Referring to Table 5-2 in Bowles (1997), I_1= 0.132, and I_2=0.100.

$$I_s = I_1 + \left(\frac{1-2\mu}{1-\mu}\right) * I_2 = = 0.132 + \left(\frac{1-2(0.4)}{1-0.4}\right) * 0.100 = 0.165$$

I_f = Depth Ratio Factor (conservatively) taken as 1.0.

Inserting the above figures into the original equation gives:

$$\Delta H = 1{,}415 \text{ psf} * 120\ ft * \left(\frac{(1-(0.4)\text{^}2}{1{,}440{,}000}\right) * \ 0.165 * 1.0 = 0.016 \text{ feet} = 0.19 \text{ inch, use 0.25 inch.}$$

Settlement of the natural soil for the balance of the basin is calculated as follows:

I_s = Shape Factor; settlement was calculated to a depth of 120 feet below the basin bottom (H in ft). N = H/B' = 120'/60' = 2.0 and M = L'/B' = 90/60 = 1.5. Referring to Table 5-2 in Bowles (1997), I_1= 0.292, and I_2=0.086.

$$I_s = I_1 + \left(\frac{1-2\mu}{1-\mu}\right) * I_2 = 0.292 + \left(\frac{1-2(0.4)}{1-0.4}\right) * 0.086 = 0.321$$

I_f = Depth Ratio Factor (conservatively) taken as 1.0.

Inserting the above figures into the original equation gives:

$$\Delta H = 4 * \ 1{,}545 \text{ psf} * 60\ ft * \left(\frac{(1-(0.4)\text{^}2}{1{,}440{,}000}\right) * \ 0.321 * 1.0 = 0.069 \text{ feet} = 0.83 \text{ inches, use 1.0 inch.}$$

5.3 Settlement of Soil-Bentonite Layer

As documented in HNF-SD-LEF-TI-005, consolidation testing was performed on borrow sand and bentonite mix, at 8 percent mix ratio, determined the consolidation at approximately 1300 psf was about 2.5 percent. Use 3.0 percent to represent the slightly higher pressures in this analysis. The moisture content of the as-tested material was 19.6 percent. Higher mix ratios (on the order of 10 to 15 percent bentonite) are not expected to significantly impact the compressibility of the soil-bentonite mix. Therefore, compression of the 36-inch (bottom) and 42-inch (side/corner) thick soil-bentonite liner can be calculated as:

$\Delta H = \left(\frac{3.0}{100}\right) * 36 \text{ inches} = 1.08 \text{ inches}$, say 1.10 inches at bottom of basin.

$\Delta H = \left(\frac{3.0}{100}\right) * 42 \text{ inches} = 1.26 \text{ inches}$, say 1.25 inches at side/corner of basin.

5.4 Settlement Summary

Combining the settlement magnitudes of the soil-bentonite and foundation soil at the corner of the basin results in a total settlement of 1.50 inches (0.25 inch + 1.25 inch = 1.50 inch).

Combining the settlement magnitudes of the soil-bentonite and foundation soil at the center of the basin results in a total settlement of 2.25 inches (1.00 inch + 1.10 inch = 2.10 inch, use 2.25 inches).

6.0 CONCLUSIONS

The basin liner can be designed to accommodate settlement of 2.25 inches at the center of the basin and 1.50 inches of settlement at the corner of the basin under full depth of retained effluent and miscellaneous surcharge loads (NDCs).

The settlement around the perimeter of the basin where the liner is anchored can be considered as 0 inches.

The differential settlement between the dike crest and the basin corner is 1.50 inches. The differential settlement between the center of the basin and the corners of the basin is 0.75 inch (2.25 inches – 1.50 inch = 0.75 inch).

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-006	**Rev.** 0	**Page No.** 13 of 13
Title: LERF Basin 41 Evaluation of Dike Settlement Analysis			
Prepared By: Joshua M. Bickett	**Date:** 4/8/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/8/2020

7.0 REFERENCES

ASCE 7-10, "Minimum Design Loads for Buildings and Other Structures".

Bowles, Joseph E. (1997), *Foundation Analysis and Design*, 5th Ed., McGraw-Hill Companies, Inc.

DOE O 420.1C, "Facility Safety."

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Shannon & Wilson, Inc. (1994c), Final Report of Geotechnical Studies; ICF KH Project W 320, Tank 241-C-106 Waste Retrieval and Sluicing System; 200 East Area, Hanford Site, April 14, 1994.

TFC-ENG-STD-06, Rev D-2, Design Load for Tank Farm Facilities, July 31, 2019.

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

DATE: May 26,2020

HANFORD RELEASE

1. **Doc No:** RPP-CALC-63751 **Rev.** 00

2. **Title:**
LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner

3. **Project Number:** T1P226 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Ayers, Lynn M	*Ayers, Lynn M*	05/26/2020
Design Authority	Wilson, Nathaniel W	*Wilson, Nathaniel W*	04/24/2020
Checker	Debban, Jeremy A	*Debban, Jeremy A*	04/10/2020
Document Control Approval	Meinecke, Kathryn R	*Meinecke, Kathryn R*	05/26/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/30/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/10/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/12/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	05/14/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Because of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Taylor Grant and Jeremy Debban is signing as Checker for Darrel Packard. Taylor Grant and Darrel Packard are not currently in SPF.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☐N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
LERF FACILITIES	LERF	

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
MT-50497	00	Liquid Effluent Retention Facility (LERF) Basin 41

14. **Distribution**

Name	Organization
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Blaak, Whitney S	COGNIZANT SYSTEM ENGINEERING
Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
Joslyn, Cameron C	ETF ENGINEERING
McFerran, Brandon E	242-A/AW/ETF OPERATIONS
McShane, Michael P	ENGINEERING PROGRAMS
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Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

RPP-CALC-63751
Revision 0

LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner

Prepared by

G. T. Grant
Sargent & Lundy for Washington River Protection Solutions, LLC

Date Published
April 2020

washington river protection solutions

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5-18-2020

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

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Further Dissemination Unlimited

RPP-CALC-63751 Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 14	
		Date 04/07/2020	**Rev. No.** 0
		Calculation No: S54413.024-C-007	

Project No.	**Project Title:**	**Client:**
S54413.024	LERF Basin 41 Design	Washington River Protection Solutions

Title:

LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner

Purpose and Objective:

The purpose of this calculation is to determine the amount of slack necessary in the HDPE liner system to allow for thermal contraction and expansion due to environmental temperature changes. The amount of slack necessary to prevent tension in the HDPE liner due to thermal contraction will be specified on the design drawings.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	14	Print Name/ Sign:	G. Taylor Grant	Darrel J. Packard	Paul M. Dorsh, P.E.
		Date:	04/07/2020	4/9/2020	4/9/2020

Revision Description (Revision Description/Affected Pages):

		Print Name/ Sign:			
		Date:			

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RPP-CALC-63751 Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev. No.	Page No.
S54413.024	S54413.024-C-007	0	2 of 14

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.			√	
12. Computer input/output provided or referenced and reasonable.			√	
13. Computer run traceable to calculation (file #, etc.).			√	
14. Computer input/output data and problem type within validation/verification range of use.			√	
15. Computer program validation/verification addressed.			√	
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.			√	

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
G. Taylor Grant	4/7/2020
Checker (Print Name and Sign):	**Date:**
Darrel Packard	4/9/2020

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 3 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

TABLE OF CONTENTS

1.0 PURPOSE 4
2.0 METHODOLOGY 4
3.0 DESIGN INPUTS 4
4.0 ASSUMPTIONS 4
5.0 COMPUTER SOFTWARE 4
6.0 RESULTS 5
7.0 REFERENCES 5
8.0 CALCULATIONS 6

Attachments

ATTACHMENT – 1 – H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER (REFERENCE 1)

ATTACHMENT – 2 – DESIGNING WITH GEOSYNTHETICS, TABLE 5.10 (REFERENCE 2)

ATTACHMENT – 3 – TFC-ENG-STD-06, REV D-2, DESIGN LOADS FOR TANK FARM FACILITIES, PAGE 12 of 34 (REFERENCE 3)

ATTACHMENT – 4 – GEOSYTHETIC DESIGN GUIDANCE FOR HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS, PAGE VII-6 (REFERENCE 4)

Acronyms

HDPE	High Density Polyethylene
LERF	Liquid Effluent Retention Facility

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CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 4 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

1.0 PURPOSE

The purpose of this calculation is to determine the amount of slack necessary in the HDPE liners to allow for thermal contraction and expansion due to environmental temperature changes. The amount of slack necessary to prevent tension in the HDPE liner due to thermal contraction will be specified on the design drawings.

2.0 METHODOLOGY

The HDPE liners will be analyzed to determine the maximum expansion and contraction along the width and length of the basin. The greatest length and width of the HDPE liner across the basin, thermal coefficient of linear expansion, and the maximum temperature changes will be used to calculate the maximum expansion and contraction of the HDPE liner.

There is no acceptance criteria for the expansion and contraction. The result of this calculation will be used to specify the required slack of the HDPE liner on the design drawings.

3.0 DESIGN INPUTS

The thermal coefficient of linear expansion will come from Reference 2, Attachment 2, Table 5.10, Page 552. The table provides a range of coefficient of linear expansion for HDPE liners, therefore the greatest value is conservatively chosen. Coefficient of linear expansion = $C_{le} = 13x10^{-5}$ /ºC

The design drawing (Reference 1, Attachment 1) will be used to determine the greatest length and greatest width of the HDPE liner.

The minimum temperature to be designed for is from Reference 3, Attachment 3, Section 3.5.9 *Thermal Forces*. This section states "structures shall be designed for movements resulting from the maximum seasonal temperature change (-25ºF to +115ºF)." The minimum temperature of -25ºF will be used in the analysis. Low temperature = t_l = -25ºF = -31.67ºC.

The maximum temperature to be designed for is from Reference 4, Attachment 4, Page VII-6. This reference states that "the actual temperatures reached at the bottom and sides of a solid waste landfill have been measured and values as high as 160ºF." The maximum temperature of 160ºF will be used in the analysis. High temperature = t_h = 160ºF = 71.11ºC.

4.0 ASSUMPTIONS

No assumptions have been made in this calculation.

5.0 COMPUTER SOFTWARE

No unverified computer software was used in this analysis. Calculations are checked using a handheld calculator.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 5 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

6.0 RESULTS

The below values represent the maximum potential contraction of the HDPE liners due to environmental temperature changes.

Location	Maximum Contraction	Remarks
Bottom Length	2.54 ft	
Bottom Width	1.74 ft	
Side Slopes	1.46 ft	

The maximum contraction shown in the table above represents the expected contraction of the HDPE liner when the temperature is -25ºF and the temperature during installation was 160ºF. Since the required slack is dependent upon the temperature at the time of installation, the equation to calculate the required slack based on installation temperature will be provided on the design drawings for the Installer to calculate.

7.0 REFERENCES

1) H-2-838750, Sheet 1, Rev. 0, LERF Basin 41 Civil Primary Liner

2) Koerner, Robert M., *Designing with Geosynthetics*, 6th Edition

3) TFC-ENG-STD-06 REV D-2, Design Loads for Tank Farm Facilities

4) Richardson, Gregory N., and Robert M. Koerner, *Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments*, Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 6 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

8.0 CALCULATIONS

Maximum length of basin floor = l_{bf} = 35.67 ft + 118.87 ft + 35.67 ft = 190.21 ft (Reference 1, Attachment 1)

Maximum width of basin floor = w_{bf} = 35.67 ft + 58.87 ft + 35.67 ft = 130.21 ft (Reference 1, Attachment 1)

Maximum side slope length = d_s = 109.00 ft (Reference 1, Attachment 1)

Maximum thermal contraction:

Side slopes:

$ss_e = (t_l - t_h) \times d_s \times C_{le} = (-31.67^oC - 71.11^oC) \times 109.00\ ft \times 13x10^{-5}\ /C^o = -1.46\ ft$

Bottom width:

$bw_e = (t_l - t_h) \times w_{bf} \times C_{le} = (-31.67^oC - 71.11^oC) \times 130.21\ ft \times 13x10^{-5}\ /C^o = -1.74\ ft$

Bottom length:

$bl_e = (t_l - t_h) \times l_{bf} \times C_{le} = (-31.67^oC - 71.11^oC) \times 190.21ft \times 13x10^{-5}\ /C^o = -2.54\ ft$

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 7 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

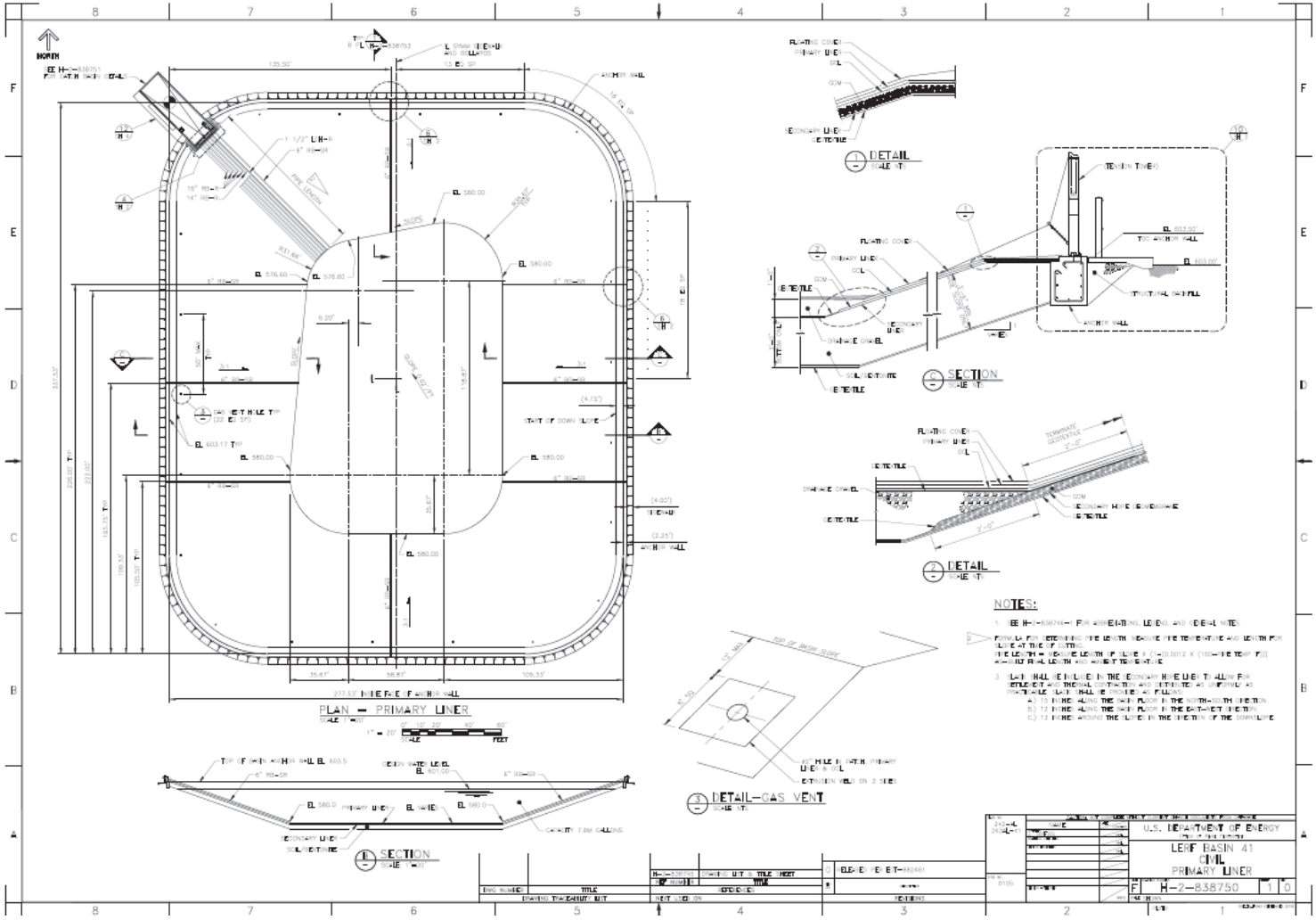
ATTACHMENT – 1 - H-2-838750, SHEET 1, REV. 0, LERF BASIN 41 CIVIL PRIMARY LINER

RPP-CALC-63751, Rev. 0

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-007	**Rev.**	0	**Page No.** 8 of 14	
Title:	LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner						
Prepared By:	G. Taylor Grant	**Date:** 04/07/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020



CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 9 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 2 – DESIGNING WITH GEOSYNTHETICS, TABLE 5.10

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CALCULATION SHEET

Project No.	S54413.024	**Calculation No.**	S54413.024-C-007	**Rev.**	0	**Page No.** 10 of 14	
Title:	LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner						
Prepared By:	G. Taylor Grant	**Date:** 04/07/2020	**Checked By:**	Darrel J. Packard		**Date:**	04/09/2020

cold has on the constructability of the system is that flexibility is decreased and seams are more difficult to make. The latter point is perhaps the most significant aspect of extremely cold conditions. The proposed seaming method should be attempted at site-installation temperatures on test specimens on simulated subgrades and evaluated to see that a satisfactory seam strength will indeed result.

Thermal Contraction and Expansion. There are a number of procedures that can be used to determine the coefficient of thermal contraction or expansion of a material—for example, ASTM D2102 and D2259 for contraction, and D1042, and D1204 for expansion and dimensional changes. All of them subject the test specimen to a constant source of cold (or heat) and carefully measure the separation distance between two given initial locations. Some typical data are presented in table 5.10. Example 5.3 uses this data to illustrate the effect during the installation of a geomembrane.

TABLE 5.10 COEFFICIENTS OF THERMAL LINEAR EXPANSIVITY

Polymer Type	Thermal Linear Expansivity ($\times 10^{-5}$/°C)
Polyethylene	
high-density	11 - 13
medium-density	14 - 16
low-density	10 - 12
linear-low-density	15 - 25
Polypropylene	5 - 9
Polyvinyl chloride	
unplasticized (e.g., pipe)	5 - 10
plasticized (e.g., geomembrane)	7 - 25
Polyamide	
nylon 6	7 - 9
nylon 66	7 - 9
Polystyrene	3 - 7
Polyester	5 - 9

Example 5.3

Calculate the amount of expansion that is generated during the installation of a HDPE liner for a surface impoundment anticipating a 40°C temperature increase from the coldest to warmest part of the day. Base the calculations on a 30 m distance and the range of thermal expansion values of table 5.10.

Solution: Minimum slack: 11×10^{-5} (40)(30)(1000) = 132 mm

Maximum slack: 13×10^{-5} (40)(30)(1000) = 156 mm

It is easily seen that the calculated amounts in example 5.3 are quite significant and that considerations for temperature expansion (or contraction) are important field-placement issues.

Oxidation. Whenever a free radical is created (e.g., on a carbon atom in the polyethylene chain), oxygen can create progressive long-term degradation. Oxygen combines with the free radical to form a hydroperoxy radical, which is passed around within the molecular structure. It eventually reacts with another polymer chain, creating a new free radical and causing chain scission. The reaction generally accelerates once it is triggered, as shown in the following equations:

$$R^{\cdot} + O_2 \rightarrow ROO^{\cdot} \quad (5.11)$$
$$ROO^{\cdot} + RH \rightarrow ROOH + R^{\cdot} \quad (5.12)$$

where

$R^{\cdot}$ = free radical
$ROO^{\cdot}$ = hydroperoxy-free radical
RH = polymer chain
$ROOH$ = oxidized polymer chain

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 11 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 3 – TFC-ENG-STD-06, REV D-2, DESIGN LOADS FOR TANK FARM FACILITIES, PAGE 12 OF 34

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 12 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

Basement or other rigid walls exposed to ordinary compacted backfill shall be designed for a static equivalent fluid pressure of 55 lb/ft^2, based on an at-rest earth pressure coefficient, K_o, of 0.50 and a soil density of 110 lb/ft^3.

Rigid walls exposed to backfill compacted to at least 75% of relative density shall be designed for 77 lb/ft^2, based on a K_o of 0.70 and a soil density of 110 lb/ft^3.

Superimposed lateral pressures resulting from uniform surcharge loadings shall be calculated by using appropriate earth pressure coefficients as shown above. Resultant forces from point and line loads shall be added.

3.5.9 Thermal Forces
(5.1.7)

The design of structures shall include the effects of stresses and movements resulting from variations in temperature. Structures shall be designed for movements resulting from the maximum seasonal temperature change (-25°F to +115°F). The design shall provide for the lags between air temperatures and the interior temperatures of massive concrete members or structures. Consideration shall be given to passive soil loading resulting from thermal growth of sub grade structures. See TFC-ENG-STD-02 for additional environmental/seasonal conditions.

3.5.10 Creep and Shrinkage Forces
(5.1.7)

Concrete and masonry structures shall be investigated for stresses and deformations induced by creep and shrinkage. For concrete and masonry structures, the minimum linear coefficient of shrinkage shall be 0.005 in/in., unless a detailed analysis is undertaken. The theoretical shrinkage displacement shall be computed as the product of the linear coefficient and the length of the member.

3.5.11 Ice Loads
(5.1.4, 5.1.6)

Ice loading shall be evaluated for ice-sensitive structures such as those with lattice type framing in accordance with the requirements of ASCE 7 Chapter 10. The equivalent radial ice thickness due to freezing rain is 0.25 inch, with a concurrent wind speed (3-second gust) of 40 mph.

For hoarfrost effects on ventilation systems refer to TFC-ENG-STD-07.

3.5.12 Load Combinations
(5.1.4, 5.1.6)

Load combinations, allowable stresses, deformation and strength requirements for load conditions for NDC-1 and NDC-2 SSCs, shall comply with IBC Section 1605 for Risk Category II and Risk Category IV SSCs. Load combinations, allowable stresses, deformation and strength requirements for NDC-3 SDCs shall comply with ACI 349 and AISC N690. The exception to this is that for seismic hazards the failure of an SSC shall be defined in terms of its limit state. Additional load combination requirements may apply based on industry standards identified in Section 3.6 below.

CALCULATION SHEET

Project No. S54413.024	**Calculation No.** S54413.024-C-007	**Rev.** 0	**Page No.** 13 of 14
Title: LERF Basin 41 Thermal Expansion/Contraction Potential, HDPE Liner			
Prepared By: G. Taylor Grant	**Date:** 04/07/2020	**Checked By:** Darrel J. Packard	**Date:** 04/09/2020

ATTACHMENT – 4 – GEOSYNTHETIC DESIGN GUIDANCE FOR HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS, PAGE VII-6

These temperatures cannot be reached unless some unnatural event occurs. Unfortunately, landfill fires are not at all uncommon and in such cases these high temperatures can be reached. They would be disastrous to the integrity of the FML.

The actual temperatures reached at the bottom and sides of a solid waste landfill have been measured and values as high as 160 °F have been reached. As shown in Table 7.3, Wolfgang (1959) gives a very comprehensive list of the burning characteristics of fibers. While not of direct concern to the FML itself, such elevated temperatures will actively promote biological growth which was discussed previously.

Table 7.3 Burning Characteristics of FML Polymeric Materials, after Wolfgang (1959)

Fiber	Polyethylene	Polypropylene	Polystyrene
Before touching flame	Melts, shrinks and curls from flame	Shrinks rapidly from flame, curls and melts	Melts, shrinks, and curls from flame
In flame	Melts and burns	Melts, ignites with difficulty	Melts and burns
After leaving	Burns rapidly	Burns slowly	Burns rapidly with production of great deal of soot
Odor	Burning paraffin	Faintly like burning asphalt	Benzene hyacinth
Ash	Soft, round same color as fiber	Hard, round light tan	Soft, round, same color as fiber

Environmental Stress Cracking

Stress cracking of polyethylene has been reported as early as 1950 by Carey (ASTM Bull, ASTBA, No. 167, July 1950), and its significance has been recognized via ASTM Standard D1693 entitled "Environmental Stress-Cracking of Ethylene Plastics". Under certain conditions of stress and in the presence of environments such as soaps, wetting agents, oils, detergents, or organic substances, ethylene plastics may exhibit mechanical failure by cracking. Figure 7.1a shows the existence of such cracking which occurred on laboratory test specimens but has also been similarly seen in field applications.

By definition, stress-crack is an external or internal rupture in a plastic caused by a tensile stress lower than the short term mechanical strength of the material. Failure is usually interpreted by visable

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Release Stamp

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Document Control Approval	Meinecke, Kathryn R	*Meinecke, Kathryn R*	05/26/2020
Environmental Protection	Wall, Jeremy M	*Wall, Jeremy M*	04/30/2020
Originator	Dorsh, Paul M	*Dorsh, Paul M*	04/09/2020
Other Approver	McShane, Michael P	*McShane, Michael P*	05/13/2020
Responsible Engineering Manager	Huntington, Matthew R	*Huntington, Matthew R*	05/14/2020

8. **Description of Change and Justification**

Initial Release.

Design checks were performed in accordance with Sargent & Lundy ESD Quality Assurance Procedure (QAP). Because of the General Service status of the equipment, a graded approach was applied and design verification was not performed as allowed by QAP 3.5, Design Verification.

Note that Paul Dorsh is signing as Originator for Joshua Bickett and Jeremy Debban is signing as Checker for David Nielson. Joshua Bickett and David Nielson are not currently in SPF.

Note: Section 5.0, Geo-Studio is a registered trademark of GEO-SLOPE International Ltd., Calgary, Alberta, Canada.

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Demiter, Scott M	ETF OPERATIONS
Foster, Jim	242-A/AW/ETF OPERATIONS
Goessmann, Glen E	ENGINEERING PROGRAMS
Greenhalgh, Aaron M	TANK FARM PROJECTS ENGINEERING
Halgren, Dale L	ETF ENGINEERING
Harris, John W	SAFETY PROGRAM SERVICES RC/P
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Smoot, Bill R	TFP RADCON
Swanson, Brad L	242-A/AW/ETF OPERATIONS
Wall, Jeremy M	RETRVL & CLOSURE/PROJ ENV CMPL
Wilson, Nathaniel W	ETF PROJECTS ENGINEERING

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LERF Basin 41 Evaluation of Dike Stability and Erosion

Prepared by

Joshua M. Bickett
Sargent & Lundy for Washington River Protection Solutions, LLC

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RPP-CALC-63752, Rev. 0

Sargent & Lundy Engineering Services, Inc.	**CALCULATION COVER SHEET**	**Page No.** 1 of 28	
		Date 4/29/2020	**Rev. No.** 1
		Calculation No: S54413.024-C-008	

Project No.	**Project Title:**	**Client:**
54413.024	LERF Basin 41	WRPS

Title:
LERF Basin 41 Evaluation of Dike Stability and Erosion

Purpose and Objective:

The purpose of this calculation is to evaluate the Liquid Effluent Retention Facility (LERF) Basin 41 for the following items:

- Global slope stability,
- Internal slope stability
- Structural stability,
- Erosion stability, and
- Piping.

Rev. No.	Total Pages		Prepared By	Checked By	PM/TL
0	28	**Print Name/ Sign:**	Joshua M. Bickett *signature on file*	David E. Nielson, P.E. *signature on file*	Paul M. Dorsh, P.E. *signature on file*
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CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev. No.	Page No.
54413.024	S54413.024-C-008	1	2 of 28

Items Checked	Accept Y	Accept N	Accept N/A	Description of Resolution for Unacceptable Items
1. Cover sheets properly completed.	√			
2. Calculation sheet headers complete with calculation number, revision number, etc.	√			
3. Calculation sheet contents are legible, accurate, and complete per format.	√			
4. Listed attachments included.	√			
5. Calculation objective clearly described.	√			
6. Criteria are suitable and properly referenced to task specific documents.	√			
7. Assumptions and input data selected, described, reasonable, and attached or referenced to task documents.	√			
8. Calculation method identified and appropriate for the design activity.	√			
9. Calculation results reasonable and correctly described in results and conclusions.	√			
10. Physical property calculations generated by CAD software verified via hand calculations.			√	
11. Computer program identified with version and revision.	√			
12. Computer input/output provided or referenced and reasonable.	√			
13. Computer run traceable to calculation (file #, etc.).	√			
14. Computer input/output data and problem type within validation/verification range of use.	√			
15. Computer program validation/verification addressed.	√			
16. Computer operating system in use for calculation preparation is the same as when the software was verified on machine.	√			

Calculation Checking Method	√	Applicable Pages
1. Direct Step-by-Step Check	√	ALL
2. Reference Chart(s) or Book(s) Comparison (Append Documentation)		
3. Alternate Calculation (Append Documentation)		

Comments:

Preparer (Print Name and Sign):	Date:
Joshua M. Bickett	4/29/2020
Checker (Print Name and Sign):	**Date:**
David E. Nielson, P.E.	4/29/2020

Signatures obtained only after discrepancies are corrected and comments are resolved.

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 3 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

TABLE OF CONTENTS

1.0 PURPOSE 6

2.0 METHODOLOGY 6
- 2.1 Critical Sections 6
- 2.2 Design Basis Soil Properties 6
- 2.3 Design Requirements 7
- 2.4 Site Classification for Seismic Design 8
- 2.5 Seismic Accelerations 8
- 2.6 Flood and Hydrodynamic Loading 8
- 2.7 Wind Loading 9
- 2.8 Surcharge Loading 9
- 2.9 Precipitation 10
- 2.10 Volcanic 10
- 2.11 Global Slope Stability Analysis 10
- 2.12 Internal Slope Stability Analysis 11
- 2.13 Structural Stability 12
- 2.14 Erosion Stability 12
- 2.15 Piping 12
- 2.16 Acceptance Criteria 13

3.0 DESIGN INPUTS 13

4.0 ASSUMPTIONS 14

5.0 COMPUTER SOFTWARE 14

6.0 CALCULATIONS 14
- 6.1 Critical Sections 14
- 6.2 Design Basis Soil Parameters 16
- 6.3 Site Class 17
- 6.4 Seismic Accelerations 17
- 6.5 Surcharge Loading 17
- 6.6 Global Slope Stability Analysis 17
- 6.7 Internal Slope Stability Analysis 19
- 6.8 Structural Stability 19
- 6.9 Erosion Stability 20
- 6.10 Piping 20

7.0 CONCLUSIONS 21

8.0 REFERENCES 22

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 4 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

Attachments

Attachment 1
Slope/W Input/Output Results 23

Attachment 2
Slope/W Audit Trail 27

Figures

Figure 6-1. Critical Global Stability Analysis Section Location 15

Tables

Table 6-1. Global Slope Stability Analysis Results 18

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 5 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

Acronyms

DOE	Department of Energy
FDC	Flood Design Category
FS	Factor of Safety or Safety Factor
LERF	Liquid Effluent Retention Facility
MCE	Maximum Considered Earthquake
NAD	North American Datum
NDC	Natural Phenomena Design Category
NPH	Natural Phenomena Hazard
PDC	Precipitation Design Category
PGA	Peak Ground Acceleration
SCRD	Supplemented Contractor Requirements Document
SDC	Seismic Design Category
SSC	Structures, Systems and Components
TOC	Tank Operations Contractor
VDC	Volcanic Design Category
WDC	Wind Design Category

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CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 6 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

1.0 PURPOSE

The purpose of this calculation is to evaluate the Liquid Effluent Retention Facility (LERF) Basin 41 for the following items:

- Global slope stability,
- Internal slope stability
- Structural stability,
- Erosion stability, and
- Piping.

The analyses performed herein are for the LERF Basin 41 Project adjacent to Area 200 East (and immediately adjacent to existing LERF Basins 42, 43 and 44) at the DOE Hanford Site in the State of Washington.

2.0 METHODOLOGY

2.1 Critical Sections

The critical section(s) for these analyses are determined based on the steepest terrain conditions adjacent to the development area, maximum dike heights, topographic considerations, property limitations, nearby structures (including existing basins), the soil conditions, and location of surcharge loading.

2.2 Design Basis Soil Properties

Geotechnical and Seismic Design Input identified in Section 3.0 of this analysis is reviewed to establish the design basis soil profile and soil properties. The parameters and profile documented in the Existing Design Analysis identified in Section 3.0 of this analysis for LERF Basins 42, 43, 44 are utilized for this analysis after verifying consistency with the Geotechnical and Seismic Design Input. The existing geotechnical data is supplemented with published literature values through correlation of material type or engineering judgment, where required.

The groundwater level observations provided in the Geotechnical and Seismic Design Input are utilized as the design groundwater for analysis.

2.3 Design Requirements

Current DOE requirements for both general design criteria and natural phenomena hazard (NPH) mitigation for the Hanford site are in Supplemented Contractor Requirements Document (SCRD) DOE O 420.1C and DOE STD-1020-2016.

DOE-STD-1020-2016 provides NPH design and evaluation criteria for seismic, wind, flood, precipitation, lightning, and volcanic hazards based on natural phenomena design categories (NDCs). The LERF Basin 41 Project is NDC-1. The design requirements are summarized in TFC-ENG-STD-06.

TFC-ENG-STD-06 establishes structural design loads and acceptance criteria for use in designing new Structures, Systems, and Components (SSCs), evaluating existing SSCs, evaluating anchorage effects of new and modified systems on existing SSCs, and designing additions and modifications to existing SSCs.

TFC-ENG-STD-06 fulfills three objectives:

- Integration of the Natural Phenomena Hazards (NPH) requirements with U.S. Department of Energy (DOE) and other requirements governing design and evaluation of SSCs,
- Limit requirements and NPH criteria to those applicable to the DOE Hanford Site Tank Operations Contractor (TOC), which are applied to LERF Basin 41, and
- Stipulate the appropriate levels of depth, rigor, and thoroughness in complying with the requirements.

SSCs are designed and evaluated to withstand loads associated with the operation of the facility and the effects of NPHs. DOE O 420.1C, IBC 2015 and ASCE 7-10 are used as the minimum basic design requirements for DOE facilities.

The SSCs need not be subjected simultaneously to any combination of extreme wind, seismic ground motions, volcanic ashfall, and flood. However, common cause events are to be evaluated as single events.

SSCs are categorized into the following individual NDCs (recall LERF Basin 41 is NDC-1):

- For seismic hazards, Seismic Design Categories: SDC-1
- For extreme wind hazards, including straight-line wind, tornado, and hurricane hazards, Wind Design Categories: WDC-1

- For flood hazards, including seiche, tsunami, and other flood hazards, Flood Design Categories: FDC-1
- For precipitation hazards, Precipitation Design Categories: PDC-1
- For volcanic eruption hazards, Volcanic Design Categories: VDC-1.

2.4 Site Classification for Seismic Design

In accordance with IBC 2015, the definitions provided in Table 20.3-1 of Chapter 20 in ASCE 7-10 are utilized to establish the seismic site classification for seismic design. Per Section 2.3.2 on page 2.46 of RPP-RPT-27570, the site is considered to meet the definition of Class C. This conclusion in RPP-RPT-27570 is compared to IBC 2015 requirements to verify Class C remains valid for design on this project.

2.5 Seismic Accelerations

Per TFC-ENG-STD-06 the return period for seismic design is not specifically defined for SDC-1 but is the same as that achieved for IBC 2015 for Risk Category II, $I_P = 1.0$ (ASCE 7-10), for Limit States A, B, C, or D.

Seismic analyses include horizontal and vertical components of motion expressed as a percentage of gravity. A site-specific maximum considered earthquake (MCE) spectra and design spectra (2/3MCE) are developed in Figure 50 of RPP-RPT-27570 for the site, which are based on a 2,500-year return period. The peak ground surface acceleration (PGA) for horizontal and vertical directions are of interest in this geotechnical analysis for slope stability. The design PGA is taken as the spectral acceleration at a 100 Hz frequency from the Figure 50 in RPP-RPT-27570.

Horizontal seismic PGA can be verified from Figure 22-7 in ASCE 7-10, which is based on a similar return period as the site-specific analysis. To scale the horizontal acceleration from Class B site to Class C site, a value of 1.2 is used per Table 11.8-1 in ASCE 7-10.

After obtaining the PGA values for the site, the values are correlated appropriately for the seismic global slope stability analysis using a coefficient per Melo and Sharma (2004). A typical and industry accepted horizontal coefficient for analysis is 1/2 of the PGA. Typically, literature references recommend values between 1/4 and 3/4 of the PGA. This analysis utilizes 0.5 as the coefficient factor consistent with the industry standard.

2.6 Flood and Hydrodynamic Loading

Per TFC-ENG-STD-06 the return period for flood analysis of structures not exposed to submersion for FDC-1 is 100 years. Given that any flooding on the exterior of the LERF Basin 41 would act as a buttressing (resisting) force, flood and hydrodynamic loading are not applicable for analysis of the exterior slope. Any flood or hydrodynamic loading conditions on the exterior slope are bounded by the analysis performed for the seismic and surcharge analyses.

Hydrodynamic load due to the seismic event for the retained fluid is calculated in accordance with Eq. 4 on page 8 of USBR 2011 for use in the Structural Stability analysis check of sliding. The pressure distribution is parabolic in shape. However, the maximum calculated pressure and the base of the fluid is applied uniformly throughout the full depth of the fluid as a conservative approximation. The pressure at the bottom of the retained effluent is calculated as follows:

$p = C_p \gamma_{effluent} a h$ Equation 4, page 8, USBR 2011

Where;

p = seismic induced pressure (psf)
C_p = pressure coefficient (0.3 based on basin geometry) determined from Figure 4b in USBR 2011
$\gamma_{effluent}$ = density of retained fluid (pcf)
a = seismic acceleration as percent of gravity
h = depth of fluid retained (ft)

The seismic force P_s is conservatively approximately as the pressure, p, times the depth of the fluid, h.

2.7 Wind Loading

Per TFC-ENG-STD-06 the return period for extreme straight line wind loading analysis for WDC-1. The wind loads are defined as Exposure Category C with nominal 3-second gusts at 85 miles per hour and ultimate 3-second gusts at 110 miles per hour.

Wind loading is neglected as a design load for these analyses based on the limited projection of the LERF Basin 41 dike above grade and standard geotechnical engineering practice for embankment analysis. Any wind loads are negligible and a specific analysis is bounded by the seismic and surcharge loading analyses.

2.8 Surcharge Loading

The static loading information for temporary loads (operating equipment or traffic) are considered as 500 psf. Typical traffic surcharge loading is taken as 250 psf, thus using 500 psf is considered conservative for typical applications. The traffic loading surcharge bounds analysis for other structural environmental loading surcharge conditions such as snow, rainfall, ash, etc. In the analysis model, the surcharge loading represents an infinitely long surcharge since the model is only two-dimensional. This is conservative relative to the actual area loading condition of these items.

Surcharge loading is not combined with other intermittent loading conditions, such as seismic loading. Sustained surcharge loads contributing to the stability of the slopes are conservatively neglected for the analyses. Sustained surcharge loads contributing to the driving forces in the slope stability are not present per the design drawings; therefore, these are not required in the analysis.

2.9 Precipitation

Per TFC-ENG-STD-06 the return period for precipitation structural loading analysis for PDC-1 is 100 years. The design basis precipitation load is 1.8 inch per TFC-ENG-STD-06 and intensity of 1 inch per hour per DOC 1961.

Rainfall intensity is considered for erosion stability evaluation of the dike side slopes. Structural loading on the dike for global stability analysis is considered bounded by the surcharge load analysis and is not required to be specifically evaluated herein.

2.10 Volcanic

Per TFC-ENG-STD-06 the return period for volcanic ashfall structural load analysis for VDC-1 is 100 years. Ash loading considerations are considered bounded by the surcharge load analysis and are not required to be specifically evaluated herein.

2.11 Global Slope Stability Analysis

Interior Dike Slope

The analysis is performed utilizing the GeoStudio SLOPE/W software. Three (3) general loading cases are analyzed: (1) normal static, (2) static with surcharge loading, and (3) seismic.

The slope stability analysis methodology used in the evaluation is based on the limit equilibrium concept. The limit equilibrium concept involves calculating a factor of safety against a failure by comparing the resisting (stabilizing) forces and/or moments within the mass of the structure to driving (destabilizing) forces and/or moments. The main destabilizing factor is the self-weight of the slope mass under normal loading conditions. A number of limit equilibrium methods have been developed over the last several decades to analyze the stability of slopes. The Morgenstern-Price method is used in this calculation since it is the most numerically robust analytical tool available in the computer software.

In a global slope stability analysis, the factor of safety is evaluated along a series of surfaces located through the slope mass. These surfaces are a series of small straight lines at the bases of slices, which are each analyzed for forces to establish the overall factor of safety. The software determines the location of the critical slip surface, which has the lowest factor of safety by analyzing a large number of potential failure surfaces, typically on the order of 10,000 to 20,000, that are systematically generated. The method used to locate the critical slip surface for the basin dike wall is the entry and exit approach.

Global stability analysis verifies deep seated potential failure surfaces exist with a minimum safety factor documented in the acceptance criteria. Near surface stability (shallow failure surfaces or erosion) of the dike slopes is evaluated as part of the erosion stability analysis. The internal structural stability analyses for the interfaces between materials is evaluated as part of the internal slope stability analysis.

Rapid drawdown analysis for the interior slopes of this structure is not required given that the liner system prevents saturation of the dike from the retained effluent. Rapid drawdown analysis due to site flooding for the exterior slopes is not required given the free draining nature of the dike materials.

Exterior Dike Slope

The global stability of the exterior dike slope is evaluated using a conservative simplified approach considering the slope as an infinite slope using the same methodology discussed in Section 2.14 below. This simplified approach is appropriate given that the external dike slope is separated from the interior dike slope by a large dike crest (approximately 38 ft) and since the existing dike slope will not undergo significant modification which has proven to be stable since its construction as part of Basin 42, Basin 43 and Basin 44 work. Per the discussion in USACE 2003, page C-27, Section C-7, the infinite slope analysis method is appropriate for cohesionless soil slopes and accurately represents other analysis methods, such as circular potential failure surfaces with multiple slices (the approach used to analyze the interior dike slope).

The seismic accelerations are accounted for in the analysis by considering the pseudostatic coefficients documented in Section 2.5 of this analysis as a reduction in normal force and additional driving force. It is conservative to consider the horizontal and vertical seismic components acting simultaneously in directions parallel and normal to the slope, respectively. Thereby; the normal (resisting) force is reduced to 92 percent of normal condition ($1g - 0.08g = 0.92g$) and the driving force is increased by 11 percent from normal condition ($1g + 0.11g = 1.11g$).

Surcharge loading case is not required to be specifically analyzed since it is bounded by the normal and seismic loading casing considered.

2.12 Internal Slope Stability Analysis

Internal slope stability is evaluated to verify sloughing does not occur on the interior side slopes due to the sliding resistance of dissimilar materials. The evaluation is performed by comparing the frictional resistance between the lower most layer of geotextile and the controlling material immediately adjacent to the geotextile in the profile (soil-bentonite mix). The evaluation is used to establish the critical side slope angle (maximum steepness a slide slope can be while maintaining the minimum safety factor). The ultimate frictional resistance between a non-woven needle punched geotextile and the soil-bentonite mix layer is taken as 100 percent of the soil-bentonite friction angle (φ) per Table 2.4 on page 140 of Koerner 2012 and evaluated using the following relationship:

FS = tan(1.0φ)/tan(s) USACE 2003, page C-29, equation C-27

Where;
FS = Safety factor
s = Dike Slope

2.13 Structural Stability

Sliding stability of the basin dike is analyzed by comparison of the resisting forces to the driving forces to confirm an adequate safety factor is available in the design.

Overturning of the exterior dike is not a possible failure mechanism since the earthen dike cannot exhibit sufficient tension to act as a rigid body to overturn. The earthen dike can only exhibit compression resistance.

2.14 Erosion Stability

Erosion stability of a 3” layer thickness of 1/2” minimum particle size crushed stone (if a thicker layer is used or currently present it is more conservative – note the thickness analyzed does not enter into the numerical evaluation and the thickness is only mentioned since it is mentioned in the existing basin analyses) is evaluated in HNF-SD-LEF-TI-005, Rev 1. The analysis was performed for the existing LERF basins and determined to be stable for the applicable rainfall conditions. Utilizing a similar surfacing material for the slope surface it is considered stable based on the previous analysis and engineering judgement.

Shallow surface failures (sloughing) are evaluated by comparing the frictional resistance of the surface material (friction angle, φ) to side slope angles to establish the critical slide slope angle (maximum steepness a slide slope can be while maintaining the minimum safety factor) using the following relationship:

FS = tan(φ)/tan(s) USACE 2003, page C-29, equation C-27

Terms in the above equation are defined above.

2.15 Piping

The potential for piping of material is evaluated in accordance with USACE 1993 by comparing the potential exit gradient to the critical gradient for the dike material. A conservative seepage path is considered as only the width of the dike crest (38 ft), to demonstrate the high safety factor for this potential failure mechanism. A more detailed analysis is not required since this approach conservatively neglects the contributions of all liner systems and conservatively represents the seepage path length.

2.16 Acceptance Criteria

Acceptable global slope stability safety factors are 1.5 for normal long term static loading (USACE 2003) and 1.3 for surcharge with static loading (also temporary, construction, or infrequent conditions) (USACE 2003). For seismic loading conditions, the standard minimum safety factor typically ranges from 1.0 to 1.15 (Melo and Sharma 2004) depending on the compatibility with the horizontal seismic coefficient. For this analysis, a value of 1.1 is used for the minimum acceptable safety factor with the horizontal coefficient of 0.5.

The acceptable safety factor for structural stability, internal slope stability, and erosion stability is 1.5.

The minimum safety factor for piping is 5 (USACE 1993).

3.0 DESIGN INPUTS

Topographic Data:

Existing site topographic survey and design elevations are provided on the Project Design Drawings.

Horizontal Datum: WCS South Zone NAD83

Vertical Datum: 200E

Project Design Drawings:

H-2-838747, Sheet 1

H-2-838748, Sheet 1

H-2-838749, Sheet 1

H-2-838749, Sheet 2

H-2-838750, Sheet 1

Geotechnical and Seismic Data:

Shannon & Wilson, Inc. (1994a)

Shannon & Wilson, Inc. (1994b)

Shannon & Wilson, Inc. (1994c)

RPP-RPT-27570

Existing Design Analysis:

HNF-SD-LEF-TI-005

Design Standards:

TFC-ENG-STD-06

DOE-STD-1020-2016

DOE O 420.1C

4.0 ASSUMPTIONS

There are no assumptions that require further verification in this analysis. Engineering judgement, where used, is documented herein.

5.0 COMPUTER SOFTWARE

The slope stability analyses are performed using GeoStudio 2012 SLOPE/W program Version 8.0 (Geo-Slope International Ltd. 2014). This program has been verified and validated in accordance with Sargent & Lundy (S&L) Standard Operating Procedure (SOP 0204). The S&L program number is 03.7.747-8.0. The computer runs are performed on S&L Computer No. ZL11226. The list of controlled files for this software is included in Attachment 2 as the long form audit trail.

6.0 CALCULATIONS

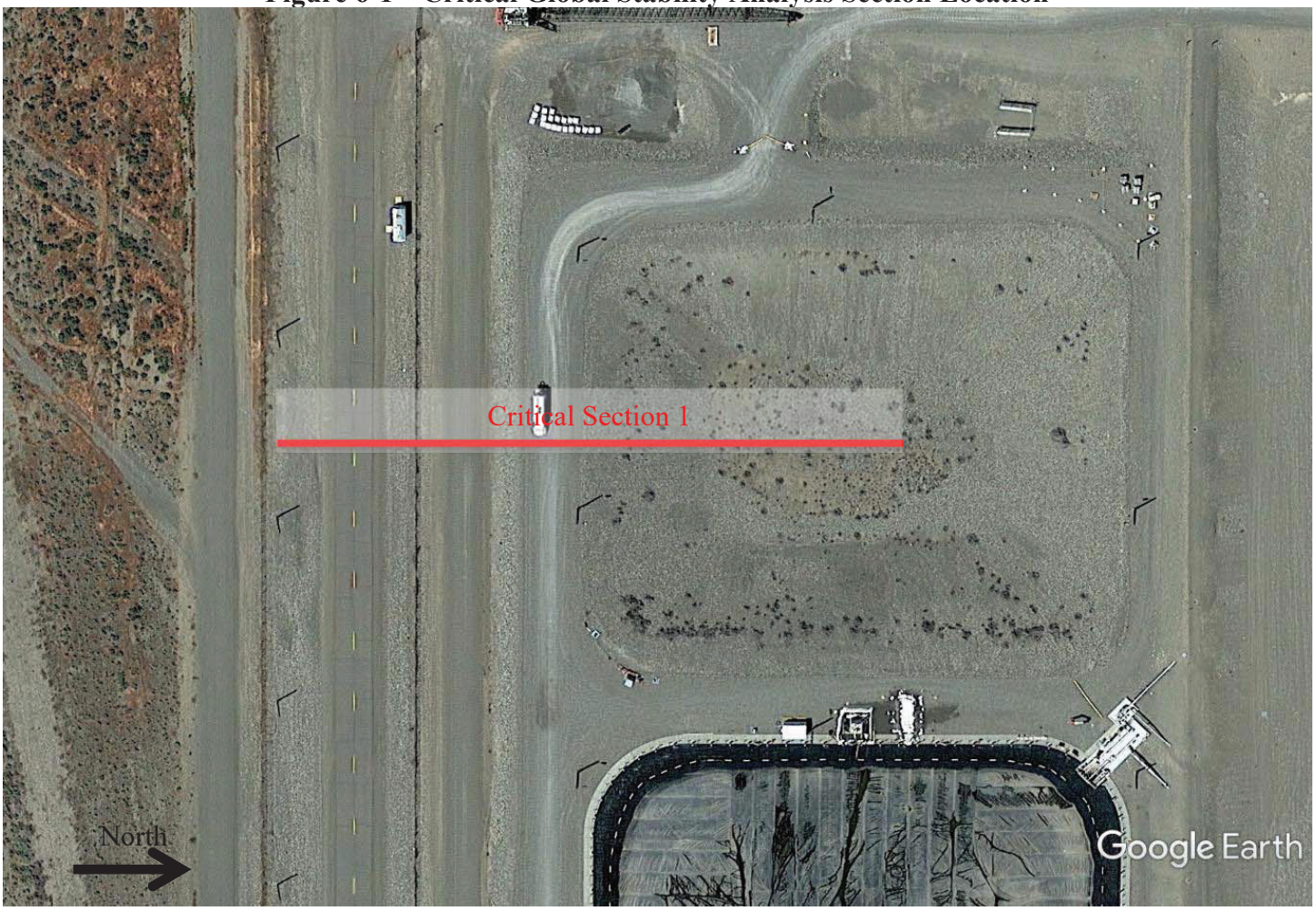
6.1 Critical Sections

The approximate location of the critical section for global stability analysis is identified is shown in red on the following figure:

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 15 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

Figure 6-1 – Critical Global Stability Analysis Section Location



The typical bottom (toe) of the slope on the interior of the basin is near elevation 580 ft, which is the top of the gravel drainage layer. On the interior of the basin bottom the elevation varies because it slopes to drain to the sump. Near the sump pit in the northwest corner of the basin, the top of the gravel drainage layer at the toe of the slope is approximately elevation 575.5 ft. The top of the soil bentonite layer is nominally 1 ft below the liner elevation. The slope stability analysis models the bottom of the basin (top of the soil bentonite layer) at elevation 575 ft to conservatively represent the overall site condition (given the cohesionless nature of the profile the bottom of elevation of the basin does not play a significant role in the analysis because the slope approaches an infinite slope when considering the depth of failure surface to the height of the slope). The gravel drainage layer is not included in the analysis since it is only installed in the bottom of the basin. The top of the anchor wall is elevation 603.5 ft, and the dike crest is modeled as elevation 603 ft in the slope stability analysis. Prevailing grade at the critical section location on the exterior of the basin is elevation 595 ft. The interior dike slope is 3H:1V and the exterior slope is 2.25H:1V.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 16 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

6.2 Design Basis Soil Parameters

Based on the review of the geotechnical and seismic design input, it is determined that the design soil profile, soil parameters and groundwater level used in the existing analysis (HNF-SD-LEF-TI-005) can be used for this analysis of LERF Basin 41. The geotechnical and seismic design input indicates that higher strength parameters are justifiable for the site; however, it is conservative to utilize the existing analysis parameters for design. The in situ subsurface material is subdivided into stratigraphic units based on constituents, structure, geotechnical engineering properties, stress history and geologic deposition.

Design Soil Profile

Dike Materials: Sand and Gravel
Moist Unit Wt. γ_{moist} = 135 pcf (HNF-SD-LEF-TI-005),
Friction Angle, φ' = 33 degrees (HNF-SD-LEF-TI-005)

Natural Site Soil: Sand and Gravel
Moist Unit Wt. γ_{moist} = 135 pcf, (Engineering Judgment)
Friction Angle, φ' = 37 degrees (Use 33 degrees) (Shannon & Wilson 1994a)

Soil-Bentonite: Sand (soil) and Bentonite
Moist Unit Wt. γ_{moist} = 100 pcf (HNF-SD-LEF-TI-005),
Friction Angle, φ' = 30 degrees (HNF-SD-LEF-TI-005)

Gravel Drainage Layer: Gravel
Moist Unit Wt. γ_{moist} = 135 pcf,(Engineering Judgment)
Friction Angle, φ' = 40 degrees (Sturm 2001, page 131, Figure 4.13)

Gravel Surface Cover: Gravel
Moist Unit Wt. γ_{moist} = 135 pcf (Engineering Judgement),
Friction Angle, φ' = 40 degrees (Sturm 2001, page 131, Figure 4.13)

Groundwater is deep at the site (approximately elevation 400 ft per Shannon & Wilson 1994a), well below the bottom of the basin. Thus, it does not affect the stability analyses. Groundwater is considered to be encountered at depths greater than 200 feet below the ground surface (included in the slope stability analyses at elevation 550 ft for modeling purposes only).

6.3 Site Class

Per RPP-RPT-27570, the harmonic average of the shear wave velocity in the upper 100 feet of the soil profile is approximately 1400 feet per second. This considers approximately 14 feet of fill with a shear wave velocity of 1000 feet per second. The natural site soil exhibits shear wave velocities higher than 1000 feet per second.

In accordance with IBC 2015, the definitions provided in Table 20.3-1 of Chapter 20 in ASCE 7-10 are utilized to establish the seismic site classification for seismic design. It is confirmed that the site meets the definition of Class C per ASCE 7-10, which is defined as a site with an average shear wave velocity between 1,200 and 2,500 feet per second.

6.4 Seismic Accelerations

Per Figure 50 of RPP-RPT-27570 at 100 Hz, the design horizontal PGA is 0.2148g (use 0.22g) and the design vertical PGA is 0.1566g (use 0.16g).

The horizontal PGA for the site in Figure 22-7 in ASCE 7-10 is approximately 0.18g, which is applicable for a site Class B. To scale the horizontal acceleration from a Class B site to a Class C site, a value of 1.2 is used per Table 11.8-1 in ASCE 7-10. Thereby, the horizontal PGA is 0.216g (0.18g*1.2 = 0.216g). This comparison shows good agreement and the use of 0.22g horizontal PGA is validated.

Using the pseudostatic slope stability analysis slope stability coefficient per Melo and Sharma (2004) of 0.5, the global slope stability analyses utilize a horizontal acceleration of 0.11g (0.22g * 0.5 = 0.11g) and a vertical acceleration of 0.08g (0.16g * 0.5 = 0.08g).

6.5 Surcharge Loading

An infinite strip (10 ft wide) with a pressure of 500 psf is applied to the crest of the dike for slope stability analyses.

6.6 Global Slope Stability Analysis

Internal Dike Slope

The detailed input/output sheets of the analysis are included Attachment 1 of this calculation. The sheets include a depiction of the critical slip surface and safety factor for each case analyzed. The input/output also include the subsurface profile parameters, stratigraphy, surcharge loading, and seismic loading where applicable. The following tables summarize the results of the computer analyses.

Table 6-1 – Global Slope Stability Analysis Results

Model Analysis No.	Analysis Case	Calculated Safety Factor	Result	Page No.
---	**Section 1**	---	---	---
01	Normal Case Interior Slope (long term condition)	1.97	OK	22
02	Normal Case + Surcharge Interior Slope (intermittent condition)	1.97	OK	23
03	Seismic Case Interior Slope (intermittent condition)	1.40	OK	24

The acceptance criteria are provided in Section 2.15 of this analysis.

Exterior Dike Slope

The static, long term condition analysis for the exterior dike slope is documented as follows (recall the minimum safety factor is 1.5):

$FS = \tan(\varphi)/\tan(s)$

Rearranging the equation to solve for s results in the following:

$s = \tan^{-1}[\tan(1.0\ \varphi)/FS]$

$s = \tan^{-1}[\tan(1.0 * 33 \text{ degrees})/1.5] = 23.41$ degrees = 2.3H:1V (use 2.25H:1V for design, given the conservative method of analysis and since overburden of surface erosion protection material is neglected).

The seismic, intermittent condition analysis for the exterior dike slope is documented as follows (recall the minimum safety factor is 1.1):

$s = \tan^{-1}[(0.92)*\tan(1.0\ \varphi)/FS/(1.11)]$

$s = \tan^{-1}[[(0.92)*\tan(1.0 * 33 \text{ degrees})/1.1/(1.11)] = 26.07$ degrees = 2.0H:1V (use 2.25H:1V for design).

Thereby, the exterior dike slope is validated for a slope of 2.25H:1V.

6.7 Internal Slope Stability Analysis

Comparing the frictional resistance between the soil bentonite mix and the lower most geotextile layer to side slope angles establishes the critical slide slope angle (maximum steepness a slide slope can be while maintaining the minimum safety factor). Recall the minimum safety factor is 1.5.
Thereby;

$FS = \tan(1.0\varphi)/\tan(s)$

Rearranging the equation to solve for s results in the following:

$s = \tan^{-1}[\tan(1.0\ \varphi)/FS]$

$s = \tan^{-1}[\tan(1.0 * 30 \text{ degrees})/1.5] = 21.1 \text{ degrees} = 2.6H{:}1V$ (use 3H:1V for design)

Thus, the slopes on the interior of the basin cannot exceed 2.6H:1V to maintain the minimum safety factor, which is not a limitation applicable to slopes within/immediately around the sump pit since these are confined with drainage gravel. Localized steeper slopes in sump area are considered stable due to the confinement.

6.8 Structural Stability

Sliding stability of the basin dike is analyzed by comparison of the resisting forces to the driving forces to confirm an adequate safety factor is available in the design.

The weight of the embankment is calculated using 125 pcf unit weight. The sliding evaluation is performed as follows:

Top (crest) width:	38 ft
Height:	8 ft = 603 ft – 595 ft)
Interior Slope:	3H:1V (design)
Exterior Slope:	2.25H:1V (conservative, actual is 3H:1V)
Base Width:	80 ft (at elevation 595 ft)
Cross Section Area:	472 sf = 0.5*8 ft * 24 ft + 38 ft *8 ft + 0.5 * 8 ft * 18 ft
Static Dike Weight:	59,000 lbs/ft = 472 sf * 125 pcf
Seismic Weight:	49,560 lbs/ft (49.5 kips) = 59,000 lbs/ft * (1g-0.16g)
Horz. Seismic Load:	12,980 lbs/ft (13.0 kips) = 59,000 lbs/ft * 0.22g
Max. Fluid Height:	6 ft = 601 ft – 595 ft
Fluid Weight:	62.4 pcf, use 65 pcf
Static Fluid Load:	1,170 lbs/ft (1.2 kips) = 0.5 * 6 ft * 6 ft * 65 pcf
Fluid Uplift Load:	0 lbs/ft (no groundwater, no saturated dike due to liner)
Seismic Fluid Load:	154.4 lbs/ft (0.2 kips) = $[C_p*\gamma_{effluent}*a*h]*h$ = 0.3 * 65pcf * 0.22g * 6ft * 6ft
Ice Load:	3,000 lbs/ft (3 kips) (HNF-SD-LEF-TI-005)

Driving Force: 17.4 k/ft = 13 k + 1.2 k + 0.2 k + 3 k
Resisting Force: 32.1 k/ft = 49.5 k * tan(33 degrees)
Safety Factor: 1.84 = 32.1 k / 17.4 k ….OK

6.9 Erosion Stability

Based on the previous analysis completed in HNF-SD-LEF-TI-005 and engineering judgment, erosion of the gravel surface material on the exterior slope of the dike during the design rainfall event of 1 inch per hour does not require numerical evaluation. A 0.5 inch minimum crushed stone size is adequate for use.

Shallow slope surface failures (sloughing erosion) of the Gravel Surface Cover material is evaluated by comparing the frictional resistance internally (or between it and the dike material) to the critical slope angle for stability while maintaining the minimum safety factor. Recall the minimum safety factor is 1.5.

Thereby;

$FS = \tan(\varphi)/\tan(s)$

Rearranging the equation to solve for s results in the following:

$s = \tan^{-1}[\tan(\varphi)/FS]$

$s = \tan^{-1}[\tan(40 \text{ degrees})/1.5] = 29.2$ degrees = 1.79H:1V (use 2.25H:1V for design with FS>1.5) …OK

Thus, the slopes on the exterior of the basin at 2.25H:1V maintain the minimum safety factor.

6.10 Piping

Per Page 4-22 of USACE 1993, the critical gradient, i_c, for sand is 1 (sand is a conservative representation of the material used for dike construction, which is sand and gravel). Considering a conservative seepage path length of 38 ft (dike crest width) and head pressure differential of 6 ft (fluid level at elevation 601 ft and prevailing grade at elevation 595 ft), the exit gradient, i_e, is 0.16 (head loss / length = 6 ft /38 ft = 0.16).

Thereby, the safety factor, FS, for piping is 6.25 ($FS = i_c / i_e = 1 / 0.16 = 6.25$), which exceeds the minimum for acceptance criterion of 5. Therefore, the dike is stable for piping considerations.

Sargent & Lundy Engineering Services, Inc.

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 21 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

7.0 CONCLUSIONS

Refer to the Design Input section of this analysis for the design drawings validated herein.

Interior side slopes (including the soil-bentonite mix) of the basin are stable for the NDCs at 3H:1V.

Exterior side slopes of the basin are stable for the NDCs at 2.25H:1V.

Global slope stability analysis determined that the interior dike slope maintains a safety factor 1.97 for normal static condition, 1.97 for static condition with surcharge, and 1.40 for the design seismic event.

Global slope stability analysis determined that the exterior dike slope maintains a safety factor of approximately 1.5 for normal static condition and exceeding 1.1 for the design seismic event. The surcharge load case maintains an adequate safety factor by inspection and numerical analysis is not required.

Structural stability is validated by sliding check and demonstrating a safety factor of 1.84. Overturning is not a plausible mechanism of failure and does not require a numerical evaluation.

Crushed stone surfacing material with minimum particle size of 0.5 inch is stable for use on the exterior slope for erosion protection.

The dike is stable for piping considerations by exhibiting a safety factor of at least 6.25.

Per the analysis contained herein, the dike will withstand the stress of the pressure exerted by the types and amounts of wastes to be placed in the impoundment; and will not fail due to scouring or piping, without dependence on any liner system included in the surface impoundment construction.

8.0 REFERENCES

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Sargent & Lundy Engineering Services, Inc.

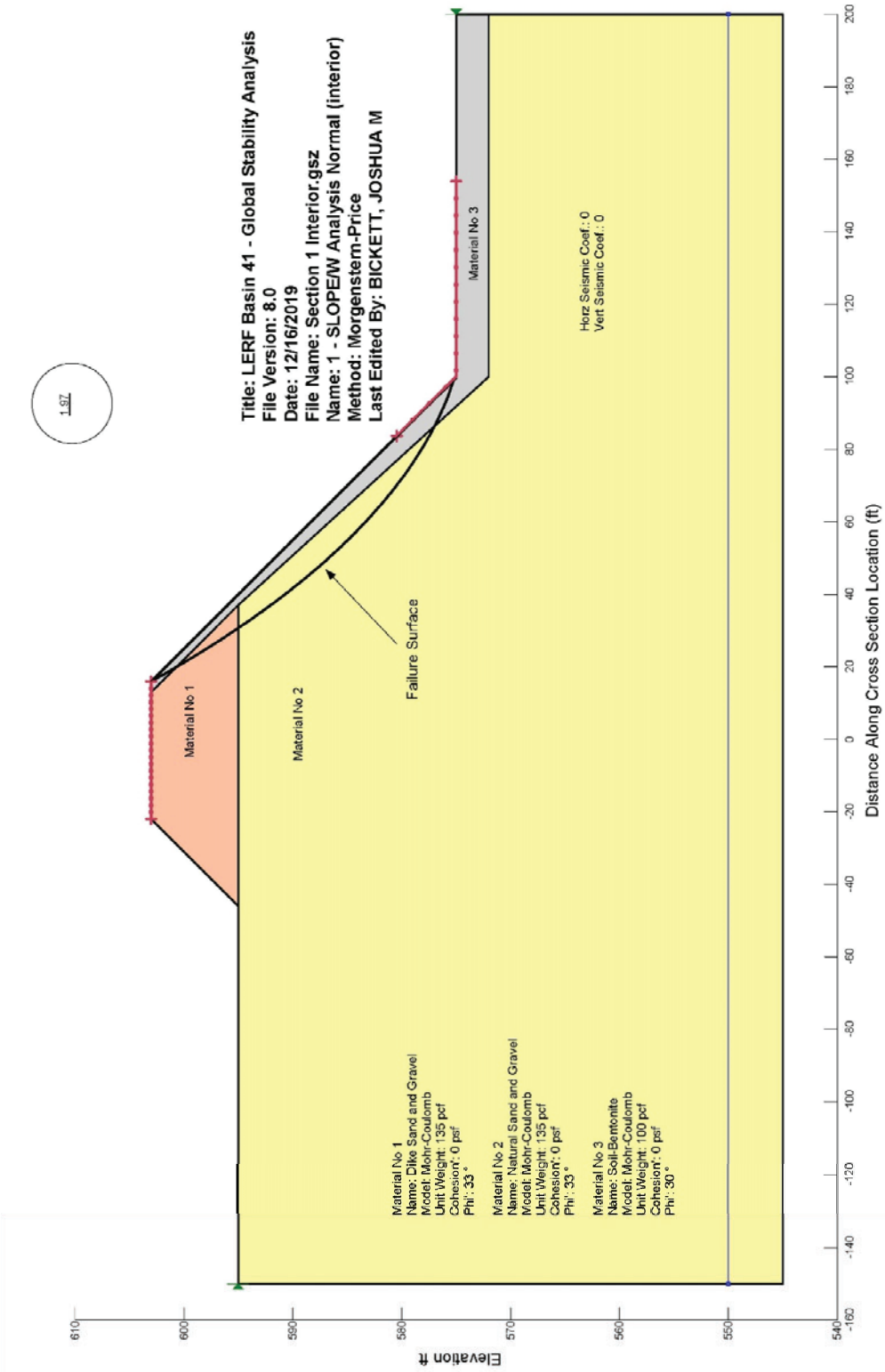
CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 23 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

ATTACHMENT 1
SLOPE/W INPUT/OUTPUT RESULTS

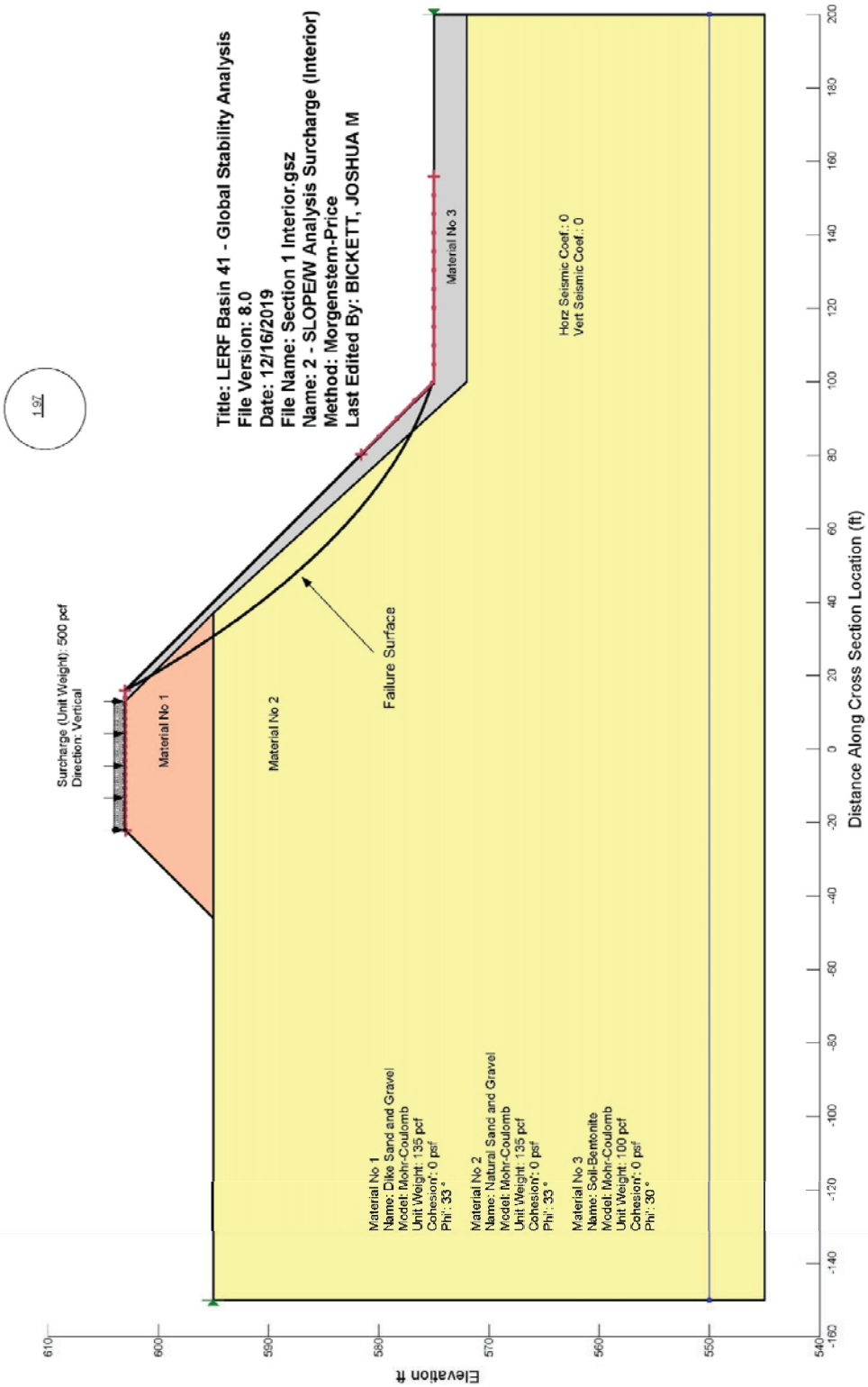
CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 24 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020



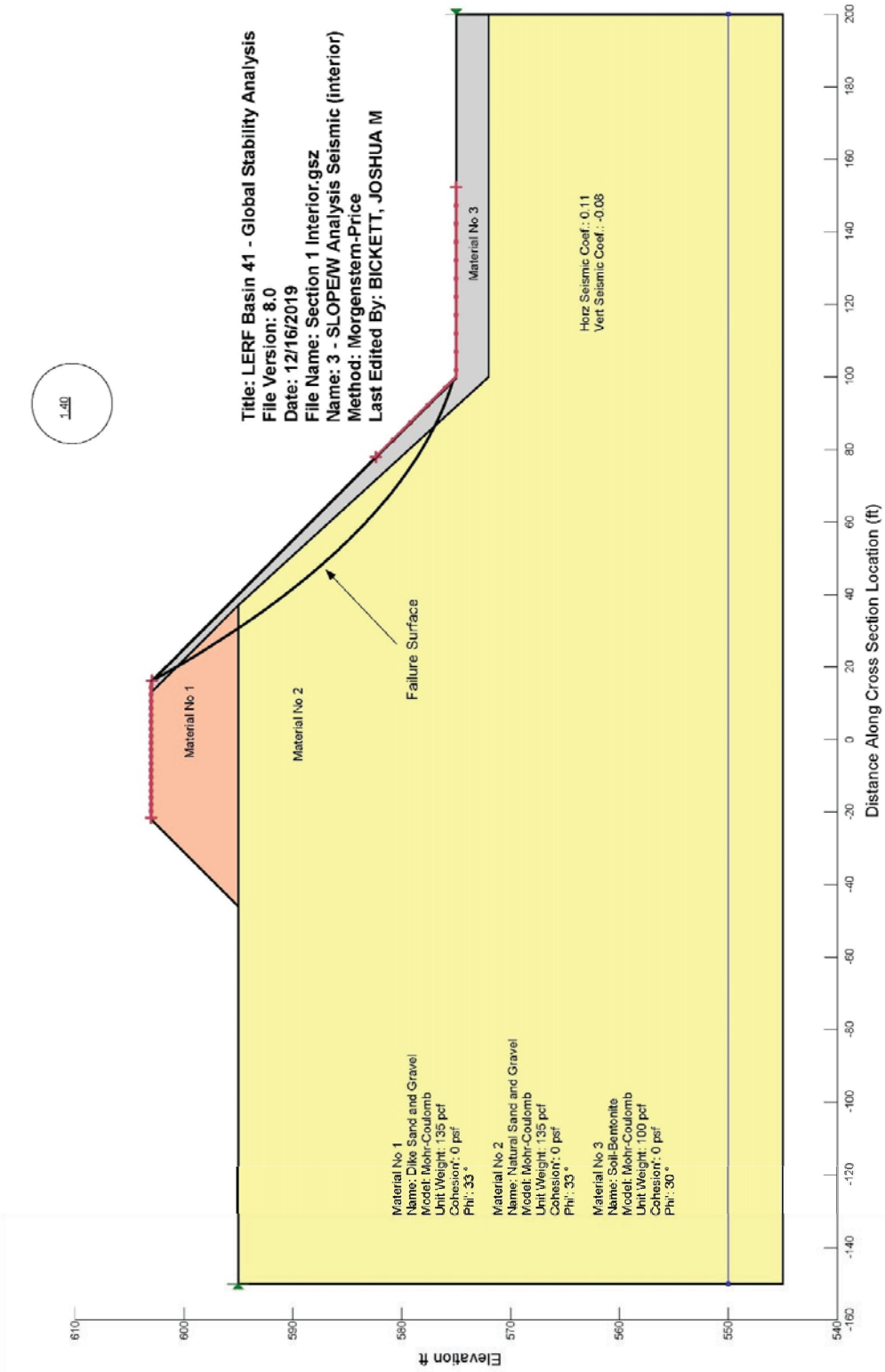
CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 25 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020



CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 26 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020



CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 27 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

ATTACHMENT 2
SLOPE/W AUDIT TRAIL

RPP-CALC-63752, Rev. 0

CALCULATION SHEET

Project No. 54413.024	**Calculation No.** S54413.024-C-008	**Rev.** 1	**Page No.** 28 of 28
Title: LERF Basin 41 Evaluation of Dike Stability and Erosion			
Prepared By: Joshua M. Bickett	**Date:** 4/29/2020	**Checked By:** David E. Nielson, P.E.	**Date:** 4/29/2020

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Executed 12-16-2019 10:45

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