Redline / Strikeout Version

Part III, Appendix III-D.6-A

Contaminated Water / Leachate Collection System Design Analysis

Including References

ATTACHMENT D.6-A

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENTS

1. LOADS ON THE LEACHATE COLLECTION SYSTEM
2. RING DEFLECTION
3. STRUCTURAL CAPACITY OF THE LEACHATE COLLECTION SYSTEM
4. COMPRESSED THICKNESS AND HYDRAULIC CONDUCTIVITY OF THE GEONET
5. HELP MODEL ANALYSIS
6. LEACHATE COLLECTION SYSTEM FLOW RATES
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8. LEACHATE COLLECTION SYSTEM DESIGN
9. LEACHATE TANK SIZE

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ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 1: LOADS ON THE LEACHATE COLLECTION SYSTEM (III-D.6-A.1)

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Client: Rancho Viejo Waste Management, LLC

Project: Pescadito Environmental Resource Center

Project #: 148866

Calculated By: LJC **Date:** ~~1/26/15~~7/24/17

Checked By: ~~RDS~~MWO **Date:** ~~2/06/15~~7/25/2017

TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

Problem Statement

Determine the maximum loading (W) on the leachate conveyance pipes (leachate collection pipe, leachate riser pipe and leachate cleanout pipe). Two loading scenarios are considered:

- ❑ Full Loading: W_{FL} = Loading on pipe due to landfill at final grade.
- ❑ Point-Source Loading: W_{IL} = Loading on pipe due to 5 feet of waste (half of one 10-foot lift) and compactor concentrated load.

The greatest loading will be used in subsequent calculations to determine the pipes' ability to resist the load.

Given

- ❑ Joint Task Force on Sanitary Sewers of the American Society of Civil Engineers and Water Pollution Control Federation. (2007). *Gravity Sanitary Sewer Design and Construction*. American Society of Civil Engineers, Manuals and Reports on Engineering Practice, No. 60, Pages 166-191.
- ❑ Budhu, Muni (2000). *Soil Mechanics & Foundations,* John Wiley & Sons, Inc., New York.
- ❑ KWH Pipe. (2006). *Sclairpipe: Versatile High Density Polyethylene Pipe*.
- ❑ Caterpillar, Inc. (2014). *Caterpillar Performance Handbook*. Edition 44, Pages 25-13.
- ❑ Leachate design details, Appendix - III-D.3.
- ❑ Geotechnical Analysis Report, Appendix - III-D.5.

Assumptions

General Assumptions

- ❑ Three different leachate conveyance pipes are present in the landfill that must be analyzed:
    - Case 1: 6-inch SDR-7.3 Leachate Collection Pipe in Leachate Chimney
    - Case 2: 18-inch SDR-11 Leachate Riser Pipe On Side-Wall
    - Case 3: 6-inch SDR-11 Leachate Cleanout Pipe On Side-Wall
- ❑ Outer Pipe Diameters for Cases 1-3:

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TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

Case #	Outer Diameter (Bc)
Case 1: 6-inch SDR-7.3 Leachate Collection Pipe	6.517 in = 0.54 ft
Case 2: 18-inch SDR-11 Leachate Riser Pipe	17.803 in = 1.48 ft
Case 3: 6-inch SDR-11 Leachate Cleanout Pipe	6.552 in = 0.55 ft
Bc obtained from reference KWH Sclairpipe "General Information"	

Full Loading Assumptions (Final Landform Constructed)

- ❑ Marston's formula utilized to calculate the prism load (Equation 9.1 in reference ASCE No. 60):

$$W_c = C_c w B_c^2$$

Where,

W_c=Linear load on pipe (lb/ft)
C_c = Load coefficient, obtained from Table 9-4 of ASCE No. 60
w = Unit weight of overlying fill (pcf)
B_c = Outer diameter of pipe (ft)
H = Height of fill above the top of the pipe (ft)

- ❑ It is assumed that the soil conditions immediately under the pipe are the same as those surrounding the pipe trench, in which case the settlement ratio can be considered equal to zero, and thus the load coefficient (C_c) is equal to the height of fill (H) divided by the outer diameter on the pipe (B_c) (reference ASCE No. 60). The equation then simplifies to:

$$W_c = C_c w B_c^2 = \left(\frac{H}{B_c}\right) w B_c^2 = H w B_c$$

- ❑ Assumed embankment conditions over a positive projecting pipe since the pipe is located in a wide trench and the top of the pipe is near the surface of compacted soil.
- ❑ Maximum overlying waste thickness of 241~~380~~ feet for the leachate collection pipe in the chimney.
- ❑ Maximum overlying waste thickness of 206.4~~175~~ for the leachate riser pipe and the leachate cleanout pipe.

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TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

- ❑ Cohesive soil density is 129 lb/ft^3 based on the average moist density for onsite soils, as determined in the Geotechnical Analysis Report, Appendix III-D.5.
- ❑ Assume waste density is 65 pcf, from Geotechnical Analysis Report, Appendix III-D.5.
- ❑ Assume density of aggregate used in leachate collection trench is 135 pcf, see Soil Mechanics and Foundations.

Point-Source Loading Assumptions

- ❑ D.L. Holl's integration of Boussinesq's formula utilized to calculate the load on the pipe due to a superimposed concentrated load (corresponding to a landfill compactor, Equation 9.13 from reference ASCE No. 60):

$$W_{sc} = C_s \frac{PF}{L}$$

Where,

W_{sc} = Load on pipe (lb/ft)
P = Concentrated load (lb)
F = Impact Factor
C_s = Load Coefficient, a function of $B_c/2H$
H = Height of fill above top of pipe (ft)
B_c = Outer diameter of pipe (ft)
L = Effective length of pipe (ft)

- ❑ Five feet of waste is placed (minimum anticipated waste thickness prior to use of compactor)
- ❑ P = Total weight of compactor divided by 2 axles = 123,319 lb/2 = 61,660 lb (reference Caterpillar).
- ❑ F = 1.0 (recommend per ASCE No. 60 for H > 3 ft)
- ❑ L = 3 ft (recommended per ASCE No. 60 for pipe lengths > 3 ft)
- ❑ H for each case is shown in the following table:

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TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

Case	H
Case 1: 6-inch SDR-7.3 Leachate Collection Pipe	1.5 ft of drainage layer material + 5 ft of waste (1/2 lift) = 6.5 ft
Case 2: 18-inch SDR-11 Leachate Riser Pipe	4.5 ft of drainage layer material + 5 ft of waste (1/2 lift) = 9.5 ft
Case 3: 6-inch SDR-11 Leachate Cleanout Pipe	2 ft of drainage layer material + 5 ft of waste (1/2 lift) = 7 ft

- Load coefficient C_s obtained from ASCE No. 60, Table 9-4, based on the following ratios:

Case	B_c	H	L	$\frac{B_c}{2H}$	$\frac{L}{2H}$	C_s
1	0.54	6.5	3	0.042	0.21	0.037
2	1.48	9	3	0.082	0.21	0.037
3	0.55	7	3	0.039	0.21	0.037

Calculations

Case 1: Leachate Collection Pipe

Full Loading – Final Landform Constructed (W_{FL})

AVERAGE LOAD ON LEACHATE COLLECTION PIPE - FINAL GRADE			
Layer	**Thickness, t (ft)**	**Density, γ_{sat} (pcf)**	**t x γ_{sat} (psf)**
Final Cover	3.08	129	397
Waste	241380	65	24,70015,665
Granular Drainage Material	1.5	135	202.5
TOTAL THICKNESS, H:	**246385**	**SUM OF (t x γ):**	**25,30016,265**
(t x γ)/total thickness = AVERAGE DENSITY, w (pcf):			**66.2 65.7**

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TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

The total weight is divided by the pipe thickness to get a load per linear unit for comparison to the value that is reported for point-source loading:

W_{FL} = H*w*B_c = (241385 ft)(66.265.7 pcf)(0.54 ft) = 13,6598,615 lb/ft = 1,138718 lb/in

Point Source Loading - Concentrated Compactor Load (W_{IL})

AVERAGE LOAD ON LEACHATE COLLECTION PIPE – HALF OF INITIAL LIFT OF WASTE			
Layer	**Thickness, t (ft)**	**Density, γ_{sat} (pcf)**	**t x γ_{sat} (psf)**
Waste	5	65	325
Granular Drainage Material	1.5	135	202.5
TOTAL THICKNESS:	**6.5**	**SUM OF (t x γ):**	**527.5**
(t x γ)/total thickness = AVERAGE DENSITY, w (pcf):			81.2

$$W_c = H \times w \times B_c = (6.5)(81.2)(0.54) = 285.01\,\frac{\text{lb}}{\text{ft}} = 23.75\,\frac{\text{lb}}{\text{in}}\ \text{(half initial lift of waste)}$$

$$W_{sc} = C_s\frac{PF}{L} = (0.037)\frac{(61{,}660\ \text{lb})(1.0\ \text{lb})}{3\ \text{ft}} = 760.47\,\frac{\text{lb}}{\text{ft}} = 63.37\,\frac{\text{lb}}{\text{in}}\ \text{(compactor load)}$$

$$W_{IL} = W_c + W_{sc} = 23.75 + 63.37 = 87.12\,\frac{\text{lb}}{\text{in}}$$

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TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

Case 2: Leachate Riser Pipe

Full Loading – Final Landform Constructed (W_{FL})

AVERAGE LOAD ON LEACHATE RISER PIPE - FINAL GRADE			
Layer	**Thickness, t (ft)**	**Density, γ_{sat} (pcf)**	**t x γ_{sat} (psf)**
Final Cover	3.08	129	397
Waste	206.4~~175~~	65	13,416 ~~11,375~~
Granular Drainage Material	4.5	135	608~~540~~
TOTAL THICKNESS, H:	**214~~182~~**	**SUM OF (t x γ):**	**14,421~~12,312~~**
		(t x γ)/total thickness = AVERAGE DENSITY, w (pcf):	**67.4~~67.6~~**

The total weight is divided by the pipe thickness to get a load per linear unit for comparison to the value that is reported for point-source loading:

W_{FL} = H*w*B_c = (214~~182~~ ft)(67.~~6~~4 pcf)(1.48 ft) = ~~18,208~~21,347 lb/ft = 1,779~~517~~ lb/in

Point Source Loading - Concentrated Compactor Load (W_{IL})

AVERAGE LOAD ON LEACHATE RISER PIPE - INITIAL LIFT OF WASTE			
Layer	**Thickness, t (ft)**	**Density, γ_{sat} (pcf)**	**t x γ_{sat} (psf)**
Waste	5	65	325
Granular Drainage Layer	4.5	135	~~540~~608
TOTAL THICKNESS:	**9.5**	**SUM OF (t x γ):**	**~~865~~933**
		(t x γ)/total thickness = AVERAGE DENSITY, w (pcf):	**~~96.1~~98.2**

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TITLE: **LOADS ON THE LEACHATE COLLECTION SYSTEM**

$$W_c = H \times w \times B_c = (9.5)(9\cancel{6.1}8.2)(1.48) = \cancel{1,280}1,381\ \frac{lb}{ft} = \cancel{106.7}115.1\ \frac{lb}{in}\ \text{(initial lift of waste)}$$

$$W_{sc} = C_s\frac{PF}{L} = (0.037)\frac{(61,660\ lb)(1.0\ lb)}{3\ ft} = 760.5\ \frac{lb}{ft} = 63.4\frac{lb}{in}\ \text{(compactor load)}$$

$$W_{IL} = W_c + W_{sc} = 1\cancel{06.7}15.1 + 63.4 = \cancel{170.}178.5\cancel{1}\ \frac{lb}{in}$$

<u>Case 3: Leachate Cleanout Pipe</u>

Full Loading – Final Landform Constructed (W_{FL})

AVERAGE LOAD ON LEACHATE CLEANOUT PIPE - FINAL GRADE			
Layer	**Thickness, t (ft)**	**Density, γ_{sat} (pcf)**	**t x γ_{sat} (psf)**
Final Cover	3.08	129	397
Waste	206.4~~175~~	65	~~11,375~~13,416
Granular Drainage Layer	2	135	270
TOTAL THICKNESS, H:	**211.5~~180~~**	**SUM OF (t x γ):**	**14,083~~12,042~~**
(t x γ)/total thickness = AVERAGE DENSITY, w (pcf):			**66.6~~66.9~~**

The total weight is divided by the pipe thickness to get a load per linear unit for comparison to the value that is reported for point-source loading:

W_{FL} = H*w*B_c = (~~180~~ 211.5 ft)(66.~~9~~6 pcf)(0.55 ft) = ~~6,623~~7,747 lb/ft = ~~551.9~~646 lb/in

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TITLE: **LOADS ON THE LEACHATE COLLECTION SYSTEM**

Point Source Loading - Concentrated Compactor Load (W_{IL})

AVERAGE LOAD ON LEACHATE CLEANOUT PIPE - INITIAL LIFT OF WASTE			
Layer	**Thickness, t (ft)**	**Density, γ_{sat} (pcf)**	**t x γ_{sat} (psf)**
Waste	5	65	325
Granular Drainage Layer	2	135	270
TOTAL THICKNESS:	**7**	**SUM OF (t x γ):**	**595**
(t x γ)/total thickness = AVERAGE DENSITY, w (pcf):			**85**

$$W_c = H \times w \times B_c = (7)(85)(0.55) = 327.25\frac{\text{lb}}{\text{ft}} = 27.27\frac{\text{lb}}{\text{in}} \text{ (initial lift of waste)}$$

$$W_{sc} = C_s\frac{PF}{L} = (0.037)\frac{(61{,}660\text{ lb})(1.0\text{ lb})}{3\text{ ft}} = 760.47\frac{\text{lb}}{\text{ft}} = 63.37\frac{\text{lb}}{\text{in}} \text{ (compactor load)}$$

$$W_{IL} = W_c + W_{sc} = 27.27 + 63.37 = 90.64\frac{\text{lb}}{\text{in}}$$

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TITLE: LOADS ON THE LEACHATE COLLECTION SYSTEM

Results

The maximum loads per unit length on the leachate pipes are summarized in the table below.

Case #	Load From Final Grade (W_{FL}) (lb/in)	Load From Initial Lift (W_{IL}) (lb/in)
Case 1: Leachate Collection Pipe	718~~1,138~~	87.12
Case 2: Leachate Riser Pipe	1,7791,517	~~170.1~~178.5
Case 3: Leachate Cleanout Pipe	646~~551.9~~	90.64

The full-loading scenario has been determined to provide a greater loading on the pipe than point-source loading. Therefore, all calculations will use the full loading values to analyze the pipe strength.

Case #	Load From Final Grade (psf)
Case 1: Leachate Collection Pipe	16,265~~25,300~~
Case 2: Leachate Riser Pipe	14,421~~12,312~~
Case 3: Leachate Cleanout Pipe	14,083~~12,042~~

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 2: RING DEFLECTION OF LEACHATE PIPE (III-D.6-A.2)

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TITLE: RING DEFLECTION OF LEACHATE PIPES

Problem Statement

Determine the ring deflection of the leachate collection pipe, leachate riser pipe, and leachate cleanout pipe.

Given

- WL Plastics Corp. (2005). *WLPipeCalc V2.0 Supplement*.
- Loads on the Leachate Collection System calculation (III-D.6-A.1).
- Leachate design details, Appendix III-D.3.
- Geotechnical Analysis Report, Appendix III-D.5.

Assumptions

- Pipe deflection may be determined with a variation of the Modified Iowa formula shown below (reference Equation 30 from WL Plastics WL PipeCalc™ Supplement):

$$\text{Percent Deflection} = \frac{PT}{144}\left(\frac{K \times D_L}{\frac{2E}{3}\left(\frac{1}{DR-1}\right)^3 + 0.061E'}\right) \times 100\%$$

Where:
P_T = total load pressure at pipe crown (lb/ft^2)
K = bedding factor
D_L = deflection lag factor
E' = modulus of soil reaction (psi)
E = modulus of elasticity for the pipe (psi)
DR = SDR = standard dimension ratio

- The following pipes to be analyzed:
  - Case 1: 6-inch SDR-7.3 Leachate Collection Pipe
  - Case 2: 18-inch SDR-11 Leachate Riser Pipe On Side-Wall
  - Case 3: 6-inch SDR-11 Leachate Cleanout Pipe On Side-Wall

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TITLE: RING DEFLECTION OF LEACHATE PIPES

- It is noted that deflection is a function of standard dimensional ratio (SDR) and is independent of pipe diameter.
- D_L = 1.0 (see WL Plastics WL PipeCalc™ Supplement)
- P_T varies depending on the pipe being considered:
  - P_T = ~~25,300~~16,265 psf for final conditions overlying the leachate collection pipe (see Loads on the Leachate Collection System calculation)
  - P_T = 12~~4,312~~421 psf for final conditions overlying the leachate riser pipe (see Loads on the Leachate Collection System calculation)
  - P_T = 14,083~~2,042~~ psf for final conditions overlying the leachate cleanout pipe (see Loads on the Leachate Collection System calculation)
- K = 0.1 (reference WL Plastics WL PipeCalc™ Supplement)
- E' = 3,000 psi for leachate chimney, riser pipe, and leachate cleanout pipe (reference WL Plastics WL PipeCalc™ Supplement)
- E = 15,000 psi (reference WL Plastics WL PipeCalc™ Supplement)
- The WL Plastics WL PipeCalc™ Supplement, which states that long-term deflection is typically limited to 8% for non-pressure PE3408 pipes.

Calculation

The maximum pipe deflection is incurred with the maximum loading on the pipe. Maximum loading occurs when the landfill is fully constructed and final grades are achieved.

Calculations were conducted for all cases using the following formula:

$$\text{Percent Deflection} = \frac{P_T}{144}\left(\frac{K \times D_L}{\frac{2E}{3}\left(\frac{1}{DR\text{-}1}\right)^3 + 0.061E'}\right) \times 100\%$$

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TITLE: RING DEFLECTION OF LEACHATE PIPES

Case 1: Leachate Collection Pipe

6-inch, SDR-7.3 Pipe:

$$\text{Percent Deflection} = \frac{16{,}265\ \text{~~}25{,}300\text{~~}}{144}\left(\frac{(0.1)(1.0)}{\frac{(2)(15{,}000)}{3}\left(\frac{1}{7.3\text{-}1}\right)^{3}+(0.061)(3{,}000)}\right)\times 100\% = 7.88\ 5.07\%$$

Case 2: Leachate Riser Pipe

18-inch, SDR-11 Pipe:

$$\text{Percent Deflection} = \frac{12{,}312\ 14{,}421}{144}\left(\frac{(0.1)(1.0)}{\frac{(2)(15{,}000)}{3}\left(\frac{1}{11\text{-}1}\right)^{3}+(0.061)(3{,}000)}\right)\times 100\% = 4.43\ 5.19\%$$

Case 3: Leachate Cleanout Pipe

6-inch, SDR-11 Pipe:

$$\text{Percent Deflection} = \frac{12{,}042\ 14{,}083}{144}\left(\frac{(0.1)(1.0)}{\frac{(2)(15{,}000)}{3}\left(\frac{1}{11\text{-}1}\right)^{3}+(0.061)(3{,}000)}\right)\times 100\% = 4.33\ 5.07\%$$

Results

The calculated ring deflections represent the worst-case loading conditions at the landfill. The calculated maximum percent ring deflection is 5.07~~7.88~~% for the SDR-7.3 pipe in the leachate chimney, 5.19~~4.43~~% for the leachate riser pipe, and 5.07~~4.33~~% for the leachate cleanout pipe. The ring deflections for each of the cases are less than 8.0%. Therefore, the maximum deflection of the pipes is acceptable.

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 3: STRUCTURAL CAPACITY OF THE LEACHATE COLLECTION SYSTEM (III-D.6-A.3)

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TITLE: STRUCTURAL CAPACITY OF THE LEACHATE PIPES

Problem Statement

Determine if the proposed leachate pipes (leachate collection pipe, leachate riser pipe, leachate cleanout pipe) possess sufficient strength to support the overlying landfill materials due to:

1. Wall crushing
2. Wall buckling

Given

- ❑ Loads on the Leachate Collection System calculation (III-D.6-A.1).
- ❑ The safety factor against wall crushing is determined by the following formula (see Equation 25 from WL Plastics WL PipeCalc™ Supplement in III-D.6-A.2).

$$N_c = \frac{460{,}800}{P_T \times DR}$$

Where:

N_c = safety factor against wall crushing
P_T = total load pressure at pipe crown (psf)
$P_T = P_E + P_L$
P_E = overburden pressure at pipe crown (lb/ft^2)
$P_E = wH$
w = material density (pcf)
H = height of material above the pipe crown (ft)
P_L = live load pressure at pipe crown = 0
(S)DR = pipe dimension ratio
= (pipe outer diameter)/(pipe wall thickness)

- ❑ The safety factor against wall buckling is determined by the following formula (see Equation 26 from WL Plastics WL PipeCalc™ Supplement from III-D.6-A.2)

$$N_B = \frac{144 P_{WC}}{P_T}$$

Where:

N_B = safety factor against wall buckling
P_T = total load pressure at pipe crown (psf)
P_{WC} = constrained bulking pressure (psi) (Equation 27 from WL Plastics)

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TITLE: STRUCTURAL CAPACITY OF THE LEACHATE PIPES

$$P_{WC}=5.65\sqrt{\frac{RB'E'E}{12(DR-1)^3}}$$

R = reduction factor for buoyancy (Equation 28 from WL Plastics)

$$R=1-0.33\frac{H'}{H}$$

H' = height of leachate above pipe (ft)
H = material cover above pipe (ft)
B' = elastic support factor (Equation 29 from WL Plastics)

$$B'=\frac{1}{1+10.87312^{(-0.065H)}}$$

E' = modulus of soil reaction (psi)
E = modulus of elasticity for the pipe (psi)
= 15,000 psi for long term conditions at 120°F
(S)DR = pipe dimension ratio
= (pipe outer diameter)/(pipe wall thickness)

Assumptions

- The following pipes to be analyzed:
  - Case 1: 6-inch SDR-7.3 Leachate Collection Pipe in Leachate Chimney
  - Case 2: 18-inch SDR-11 Leachate Riser Pipe On Side-Wall
  - Case 3: 6-inch SDR-11 Leachate Cleanout Pipe On Side-Wall

- H' = 1.0 ft in the proposed landfill (based on the TCEQ requirement for a maximum leachate head of 30 cm which is approximately 1 ft, should H' be equal to 0, R will still be equal to 1, which will produce the same results.

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TITLE: STRUCTURAL CAPACITY OF THE LEACHATE PIPES

- H = The aggregate thickness, total waste thickness and final cover:

Case	Aggregate Thickness (ft)	Waste Thickness (ft)	Final Cover Thickness (ft)	H (ft)
Case 1: Leachate Collection Pipe	2	241~~380~~	3.08	246~~385~~
Case 2: Leachate Riser Pipe	4.5	206.4~~175~~	3.08	214~~182~~
Case 3: Leachate Cleanout Pipe	2	206.4~~175~~	3.08	211~~180~~

- The values for P_E, taken from the Loads on the Leachate Collection System calculation are shown in the table below

Case #	Load From Final Grade (psf)
Case 1: Leachate Collection Pipe	~~25,300~~16,265
Case 2: Leachate Riser Pipe	~~12,312~~14,421
Case 3: Leachate Cleanout Pipe	~~12,042~~14,083

- E = 15,000 psi (see WL Plastics WL PipeCalc™ Supplement – Table 17)
- E' = 3,000 psi (see WL Plastics WL PipeCalc™ Supplement – Table 10)

Calculations

Wall Crushing

Case 1: Leachate Collection Pipe (6")

Calculate the safety factor against wall crushing for the 6-inch SDR-7.3 HDPE pipe:

$$P_T = P_E + P_L = \sout{25{,}300}16{,}265 \text{ psf} + 0 = \sout{25{,}300}16{,}265 \text{ psf}$$

$$N_c = \frac{460{,}800}{P_T \times DR} = \frac{460{,}800}{(\sout{25{,}300}16{,}265)(7.3)} = \sout{2.49}3.88$$

Calculate the safety factor against wall buckling for the 6-inch SDR-7.3 HDPE pipe in landfill:

$$R = 1-0.33\left(\frac{H'}{H}\right) = 1-0.33\left(\frac{1.0 \text{ ft}}{246\sout{385} \text{ ft}}\right) = 1.00$$

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TITLE: STRUCTURAL CAPACITY OF THE LEACHATE PIPES

$$B' = \frac{1}{1+10.87312^{-0.065H}} = \frac{1}{1+10.87312^{-(0.065 \times 246\,\text{~~385~~})}} = 1.00$$

$$P_{WC} = 5.65\sqrt{\frac{RB'E'E}{12(DR-1)^3}} = 5.65\sqrt{\frac{(1.00)(1.00)(15{,}000)(3{,}000)}{12(7.3-1)^3}} = 692$$

$$N_B = \frac{144P_{WC}}{P_T} = \frac{(144)(692)}{\text{~~25,300~~}\,16{,}265} = \text{~~3.9~~}\,6.13\text{~~4~~}$$

<u>Case 2: Leachate Riser Pipe (18")</u>

Calculate the safety factor against wall crushing for the 18-inch SDR-11 HDPE pipe:

$P_T = P_E + P_L =$ ~~12,312~~14,421 psf + 0 = ~~12,312~~14,421 psf

$$N_c = \frac{460{,}800}{P_T \times DR} = \frac{460{,}800}{(\text{~~12,312~~}\,14{,}421)(11)} = \text{~~3.4~~}\,2.90\text{~~0~~}$$

Calculate the safety factor against wall buckling for the 18-inch SDR-11 HDPE pipe in landfill:

$$R = 1-0.33\left(\frac{H'}{H}\right) = 1-0.33\left(\frac{1.0\ \text{ft}}{\text{~~182~~}\,214\ \text{ft}}\right) = 1.00$$

$$B' = \frac{1}{1+10.87312^{-0.065H}} = \frac{1}{1+10.87312^{-(0.065 \times 214\,\text{~~182~~})}} = 1.00$$

$$P_{WC} = 5.65\sqrt{\frac{RB'E'E}{12(DR-1)^3}} = 5.65\sqrt{\frac{(1.00)(1.00)(15{,}000)(3{,}000)}{12(11-1)^3}} = 346$$

$$N_B = \frac{144P_{WC}}{P_T} = \frac{(144)(346)}{\text{~~12,312~~}\,14{,}421} = \text{~~4.04~~}\,3.45$$

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TITLE: STRUCTURAL CAPACITY OF THE LEACHATE PIPES

Case 3: Leachate Cleanout Pipe (6")

Calculate the safety factor against wall crushing for the 6-inch SDR-11 HDPE pipe:

$$P_T = P_E + P_L = 14{,}083\ \text{12,042}\ psf + 0 = \text{12,042}\ psf$$

$$N_c = \frac{460{,}800}{P_T \times DR} = \frac{460{,}800}{(14{,}083\ \text{12,042})(11)} = 2.97\ \text{3.48}$$

Calculate the safety factor against wall buckling for the 6-inch SDR-11 HDPE pipe in landfill:

$$R = 1 - 0.33\left(\frac{H'}{H}\right) = 1 - 0.33\left(\frac{1.0\ ft}{\text{180}\ 211\ ft}\right) = 1.00$$

$$B' = \frac{1}{1 + 10.87312^{-0.065H}} = \frac{1}{1 + 10.87312^{-(0.065 \times 211\ \text{180})}} = 1.00$$

$$P_{WC} = 5.65\sqrt{\frac{RB'E'E}{12(DR-1)^3}} = 5.65\sqrt{\frac{(1.00)(1.00)(15{,}000)(3{,}000)}{12(11-1)^3}} = 346$$

$$N_B = \frac{144 P_{WC}}{P_T} = \frac{(144)(346)}{\text{12,042}\ 14{,}083} = \text{4.14}\ 3.54$$

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TITLE: STRUCTURAL CAPACITY OF THE LEACHATE PIPES

Results

The proposed leachate collection pipes will possess sufficient strength to support the overlying landfill, as shown by the calculated factors of safety against pipe wall buckling and pipe wall crushing for each of the leachate pipes.

Leachate Pipe Factors of Safety			
Pipe Failure Mode	**Factor of Safety**		
	Leachate Collection Pipe (6-inch, SDR-7.3)	**Leachate Riser Pipe (18-inch, SDR-11)**	**Leachate Cleanout Pipe (6-inch, SDR-11)**
Wall Crushing	3.88~~2.49~~	2.90~~3.40~~	2.97~~3.48~~
Wall Buckling	6.13~~3.94~~	3.45~~4.05~~	3.54~~4.14~~

The leachate pipes will be surrounded by a granular envelope that serves as an additional level of protection if the leachate collection pipe would be crushed.

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 4: COMPRESSED THICKNESS AND HYDRAULIC CONDUCTIVITY OF THE GEONET (III-D.6-A.4)

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TITLE Compressed Thickness and Hydraulic Conductivity of the Geonet

Problem Statement

Determine the hydraulic conductivity of the geonet component of the geocomposite for open conditions, intermediate conditions, and closed conditions.

Given

- GSE Lining Technology, LLC. (2010). *Performance & Properties - GSE PermaNet Geonets & Geocomposites.*
- Koerner, Robert M. (2005). *Designing with Geosynthetics.* Fifth Edition, Prentice Hall, New Jersey.
- Appendix III-D.5 Geotechnical Analysis Report

Assumptions

- The waste thickness for open conditions is assumed to be 10 feet, which is equal to one lift of waste.
- The assumed waste thickness for intermediate conditions is ~~190~~ 120.5 feet (half of the waste thickness for closed conditions).
- The waste thickness for closed conditions is assumed to be ~~380~~ 241 feet, based on peak waste thickness determination AutoCAD Civil 3D 2014.
- The final cover thickness is 3.08 feet of soil cover for an alternative water balance cover.
- Maximum average unit weight of cover soils is 129 pcf, see Geotechnical Analysis – Appendix III-D.5
- Unit weight of waste is 65 pcf, see Geotechnical Analysis – Appendix III-D.5.
- Properties for a typical geocomposite that may be used at this landfill are taken from page 2 of the GSE PermaNet reference:
  - The thickness of unloaded geonet is 0.27 inches (270 mil)
  - Compression strength is 40,000 psf
  - Transmissivity is 19 gal/min/ft (4 x 10^{-3} m^2/sec)

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TITLE **Compressed Thickness and Hydraulic Conductivity of the Geonet**

Calculations

Calculate the compressed geonet thickness for the different scenarios:

Layer	Thickness (ft)	Unit Weight (pcf)	Load on Geonet (psf)	Total Load on Geonet (psi)	Geonet Compression (in)[1]	Resultant Geonet Thickness (in)
Open Conditions						
Daily Cover	0.5	129	64.5	7	0.005	0.265
Waste	10	65	650			
Protective Cover	2	129	258			
		Total	972.5			
Intermediate Conditions						
Intermediate Cover	1	129	129	~~88~~57	0.013~~5~~	0.25~~5~~7
Waste	~~190~~120.5	65	~~12,350~~7,833			
Protective Cover	2	129	258			
		Total	~~12,737~~8,220			
Closed Conditions						
Final Cover	3.08	129	~~397.32~~397.3~~.~~3	~~176~~113	0.020~~3~~	0.25~~4~~0
Waste	~~380~~241	65	~~24700~~15,665			
Protective Cover	2	129	258			
		Total	~~25,355~~16,320			

1. Geocomposite compression is determined from the figure on page 2 of the GSE PermaNet reference.

Use Equation 4.5 from *Designing with Geosynthetics* to determine the allowable transmissivity of the geonet for each scenario:

$$T_{allow} = T_{ult}\left(\frac{1}{RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{bc}}\right)$$

Where:
T_{allow} = Allowable Transmissivity of the geonet;
T_{ult} = 4 x 10^{-3} m^2/sec from GSE reference;
RF_{CR} = Creep reduction factor;
RF_{IN} = Intrusion reduction factor;
RF_{CC} = Chemical clogging reduction factor; and
RF_{BC} = Biological Clogging reduction factor.

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TITLE Compressed Thickness and Hydraulic Conductivity of the Geonet

Conservatively assume from Table 4.2 in *Designing with Geosynthetics* that all reduction factors are 2 for geonet used for primary leachate collection for all scenarios.

$$T_{allow} = 4 \times 10^{-3} \frac{m^2}{sec}\left(\frac{1}{2 \times 2 \times 2 \times 2}\right) = 2.5 \times 10^{-4} \frac{m^2}{sec}$$

Calculate the allowable hydraulic conductivity of the compressed geonet for each scenario:

$$k_{allow} = \frac{T_{allow}}{t}$$

Scenario	Compacted Geonet Thickness (in)	Compacted Geonet Thickness (m)	T_{allow} (m²/sec)	k_{allow} (cm/sec)
Open Conditions	0.265	0.006731	2.5x10^{-4}	3.714
Intermediate Conditions	0.2575	0.0064770006528	2.5x10^{-4}	3.833060
Closed Conditions	0.255040	0.0060960006350	2.5x10^{-4}	3.9374.101

Results

The calculated thickness and hydraulic conductivities for the geonet for each scenario are listed above. The thicknesses and hydraulic conductivities are used in the HELP model scenarios to calculate leachate head on the liner.

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 5: HELP MODEL ANALYSIS (III-D.6-A.5)

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TITLE: HELP MODEL ANALYSIS

Overview

The USEPA Hydrologic Evaluation of Landfill Performance (HELP) Model was used to predict the leachate generation rates, leachate head on the bottom liner system and percolation through the bottom liner for the proposed landfill design. The HELP model is an unsaturated flow, water balance model that uses site-specific climate, soil and design data to simulate landfill conditions over a specified time period.

The following scenarios were modeled for the proposed conditions:

- Open (Daily Cover) Conditions
- Intermediate Conditions
- Closed Conditions

Input Parameters

The HELP model input parameters for the modeled scenarios are described in the following sections. The input parameters were determined based on the proposed landfill design details, 30 TAC Chapter 330 requirements, site-specific data collected during geotechnical site investigations, and local weather data.

Groundwater Inflow

It was assumed that there will be no groundwater inflow into the landfill.

Evapotranspiration Data

Evapotranspiration data was generated by HELP from Brownsville, Texas data within the HELP model. Brownsville was selected as the nearest and most representative location of the site from the available locations within the HELP model. The evaporative zone depth was set to 60 inches based on the HELP model User's Manual for a clay material.

A leaf area index of 0 (bare ground) was used for the open conditions model, a leaf area index of 1 (poor stand of grass) was used for intermediate conditions, and a leaf area index of 2 (fair stand of grass) was used for closed conditions.

Climate Data

The climate data was synthetically generated using coefficients for Brownsville, Texas. The default temperature and precipitation coefficients were modified by using data obtained from the NOAA Climate Online Database for the last 45 years (1968-2013) at the weather station located in Laredo, Texas, **Refer to Table D.6-A.5-1.**

Table D.6-A.5-1 HELP Model Weather Input Parameters		
Month	**Avg. Precip. (in)**	**Avg. Temp (°F)**
January	0.82	56.54
February	0.86	61.01
March	0.88	68.83
April	1.37	76.04
May	2.65	82.01
June	2.68	86.48
July	1.93	87.88
August	2.29	87.94
September	3.09	82.92
October	2.41	75.4
November	1.07	65.5
December	0.91	57.73

Runoff Potential

Runoff potential for the open conditions was conservatively assumed to be zero, although operational daily cover will allow runoff on graded portions of the operational areas. Runoff potential for intermediate conditions was assumed to be 75%, as areas with intermediate cover will be rough graded to drain. The closed conditions model assumes a runoff potential for 100% of the surface area, since the vegetative cover and grading of the final landform will be constructed and maintained to effectively control stormwater runoff and minimize ponding on top of the final cover.

Runoff Curve Number

A runoff curve number of 85 was conservatively chosen based on the site-specific soil properties and the final cover design.

Daily and Intermediate Cover Soil Layers

The open conditions model assumes that 6 inches of daily cover soil is in place and the intermediate conditions model assumes that twelve inches of intermediate soil cover is in place. The hydraulic conductivity was modified from the HELP default value to be 1×10^{-5} cm/sec; which is higher than the actual hydraulic conductivities of on-site soils as detailed in Appendix III-D.5 – Geotechnical Analysis Report.

Final Cover Soil Layers

The closed conditions were modeled with a seven inch erosion layer (six inches required by regulations plus one inch to account for calculated erosion) and a 30 inch infiltration layer. The hydraulic conductivity was conservatively modified from the HELP default hydraulic conductivity to be 1×10^{-5} cm/sec; the geotechnical report indicates that existing on-site soils exhibit a much lower hydraulic conductivity.

Waste Layer

The waste layers were modeled at the following thicknesses for the three scenarios:

- Open Conditions – 10 feet
- Intermediate Conditions – ~~190~~120.5 feet
- Closed Conditions – ~~380~~ 241 feet

The HELP default soil texture 18 was used to represent the waste layers.

Protective Cover Soil Layer

The protective cover soil layer will consist of a 24 inch layer of on-site soils. The HELP default soil texture ~~28~~ 0 was used for the protective cover soils based on the classification of on-site soils in the geology report.

Leachate Collection Layer

The leachate collection layer will consist of a double sided drainage geocomposite. The layer properties were modified to reflect the hydraulic conductivity values calculated in III-D.6-A.4 for the overlying loads in each model scenario. The geonet thickness was set to 0.265 inches for open conditions, 0.257~~5~~ inches for intermediate conditions, and 0.2540 inches for closed conditions, which are the minimum thicknesses calculated in Appendix III-D.6-A.4. The slope and drainage length for the geocomposite drainage layer were determined from the proposed drainage grades shown on drawings in Appendix III-D.3. The slopes of the leachate collection layer for the 500 ft drainage lengths are either 2.0% or 2.5% and the ~~the drainage lengths ranged from 461 ft to 614 ft~~slope of the leachate collection layer for the 450 ft drainage length is 2.0%. Analyses were run for all the combinations of the slopes and lengths for Open Conditions, results showed that a slope of 2.5%

and a drainage length of 461 500 ft resulted in the highest peak daily and average annual leachate generation rates, therefore the models for intermediate and closed conditions were run with the same parameters.

Composite Liner System

The composite liner will consist of two components per TCEQ 330.331(b). The upper layer will consist of a 60-mil thick High Density Polyethylene (HDPE) and the bottom layer will consist of a 24 inch thick re-compacted soil with a maximum hydraulic conductivity of 1 x10^{-7} cm/sec.

- Geomembrane Layer

  The geomembrane liner will consist of a 60-mil HDPE geomembrane; HELP default soil texture 35 was used to model the geomembrane. It was conservatively assumed that the liner will have a "good" installation quality, with 3 pinholes per acre and 3 installation defects per acre. However, adherence to the CQA Plan (Appendix III-D.7) will greatly minimize the likelihood of holes and installation defects in the geomembrane liner.

- Compacted Soil Liner Layer

  The compacted soil layer (CSL) will consist of a 24 inch thick layer of compacted soil, with a recompacted hydraulic conductivity of at least 1x10^{-7} cm/sec, per 30 TAC Chapter 330. It should be noted that cells to contain Class I non-hazardous waste will have 36 inch layer of compacted soil. The 24-inch CSL was used to be conservative.

Moisture Content of Soil Layers

The initial moisture content for each soil layer above the composite liner was conservatively set equal to the field capacity of each soil layer for the open conditions model. The compacted soil layer component of the composite liner was specified as a barrier soil layer and HELP assigns a saturation moisture content equal to the porosity. The exception to this is the waste layer, where an initial moisture content of 20%0.2 vol/vol was used for open conditions: scenarios A through C. This value was all scenarios based on the upper end of published data.average moisture content of waste from the *HELP Model User's Guide for Version 3.* For the remainder of the scenarios (all intermediate scenarios and closed conditions), the waste layer was given the final moisture content from the previous scenario. The moisture content of the other soil layers were generated by the HELP model.

Leachate Recirculation

Leachate recirculation is assumed to take place during all conditions; 100% of the leachate collected from the leachate collection layer is recirculated into the waste mass.

Additional analyses were ran which modeled introducing leachate into the waste layer. Leachate from the evaporation ponds or storage tanks may be introduced into the landfill, instead of being trucked offsite. Three scenarios were considered for introducing leachate into the landfill, the first was open conditions with 20 feet of waste, the second was intermediate conditions with 50 feet of waste and the third scenario was intermediate conditions with 100 feet of waste. All three scenarios were modeled for 1 year with 10 in/year of subsurface inflow to simulate the introduction of contaminated water other than what is being collected from the landfill. This is the equivalent of 744 gal/acre/day. All three of the scenarios showed that the landfill can handle the additional 744 gal/acre/day without the leachate head being greater than the thickness of the geocomposite.

HELP Model Results

The peak leachate generation rate of all modeled operating conditions (including open, intermediate, closed, open with introduced leachate, and intermediate with introduced leachate) is 8.68.9 cf/acre-day. This peak daily leachate generation rate is based on open conditions, and is the same whether or not leachate is introduced. The maximum leachate head on the liner is 0.0090.018 inches, which is less than the maximum 30 cm required under 30 TAC Chapter 330 and the minimum compressed thickness of the geonet, which is 0.2504 inches under closed conditions.

The HELP model soil layer inputs and results are summarized on **Table D.6-A.5-2**. The HELP model output files for all runs are provided in **Attachment III-D.6-B**.

See Revised Version in Replacement Pages Section

Table III-D.6-A.5-2
Leachate Generation Modeling Summary

	No Leachate Introduced					Additional Leachate or Gas Condensate Introduced to Waste at 744 gal/ac-day		
	Open Conditions			Intermediate Conditions	Closed Conditions	Open Conditions	Intermediate Conditions	
	Scenario A	Scenario B	Scenario C	Scenario A	Scenario A		50-ft Waste Layer	100-ft Waste Layer
General Design and Evapotranspiration Data								
Number of Years Modeled	1	1	1	5	30	1	1	1
Runoff Curve Number	85	85	85	85	85	85	85	85
Area Allowing Runoff (%)	0	0	0	75	100	0	75	75
Evaporative Zone Depth (in)	60	60	60	60	60	60	60	60
Maximum Leaf Area Index	0	0	0	1	2	0	1	1
Average Annual Wind Speed (mph)	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
Erosion Layer								
Layer No.	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A
Layer Type (HELP Model Layer Type Value)					Vertical Percolation (1)			
HELP Soil Texture					0			
Thickness (in)					7			
Hydraulic Conductivity (cm/sec)					$1x10^{-5}$			
Infiltration Layer								
Layer No.	N/A	N/A	N/A	N/A	2	N/A	N/A	N/A
Layer Type (HELP Model Layer Type Value)					Vertical Percolation (1)			
HELP Soil Texture					0			
Thickness (in)					30			
Hydraulic Conductivity (cm/sec)					$1x10^{-5}$			
Intermediate/Daily Cover								
Layer No.	1	1	1	1	N/A	1	1	1
Layer Type	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)		Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)
Layer Type (HELP Model Layer Type Value)	0	0	0	0		0	0	0
Thickness (in)	6	6	6	12		6	12	12
Hydraulic Conductivity (cm/sec)	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$		$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$
Solid Waste								
Layer No.	2	2	2	2	3	2	2	2
Layer Type (HELP Model Layer Type Value)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)
Initial Water Content (vol/vol)	0.2000	0.2000	0.2000	0.1928	0.1914	0.2000	0.2381	0.2508
HELP Soil Texture	18	18	18	18	18	18	18	18
Thickness (in)	120	120	120	1446	2892	240	600	1200
Hydraulic Conductivity (cm/sec)	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$
Protective Soil Cover								
Layer No.	3	3	3	3	4	3	3	3
Layer Type (HELP Model Layer Type Value)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)	Vertical Percolation (1)
HELP Soil Texture	0	0	0	0	0	0	0	0
Thickness (in)	24	24	24	24	24	24	24	24
Hydraulic Conductivity (cm/sec)	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$
Geocomposite (Geonet)								
Layer No.	4	4	4	4	5	4	4	4
Layer Type (HELP Model Layer Type Value)	Lateral Drainage (2)	Lateral Drainage (2)	Lateral Drainage (2)	Lateral Drainage (2)	Lateral Drainage (2)	Lateral Drainage (2)	Lateral Drainage (2)	Lateral Drainage (2)
HELP Soil Texture	0	0	0	0	0	0	0	0
Thickness (in)	0.265	0.265	0.265	0.257	0.250	0.264	0.262	0.258
Slope (%)	2.5	2.0	2.0	2.5	2.5	2.5	2.5	2.5
Drainage Length (ft)	500	500	450	500	500	500	500	500
Leachate Recirculation (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y
Hydraulic Conductivity (cm/sec)	3.714	3.714	3.714	3.83	3.937	3.714	3.714	3.83
Geomembrane								
Layer No.	5	5	5	5	6	5	5	5
Layer Type (HELP Model Layer Type Value)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)	Flexible Membrane Liner (4)
HELP Soil Texture	35	35	35	35	35	35	35	35
Thickness (in)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Installation Quality	Good (3)	Good (3)	Good (3)	Good	Good	Good (3)	Good (3)	Good (3)
Defects per Acre	3	3	3	3	3	3	3	3
Pinholes per Acre	3	3	3	3	3	3	3	3
Hydraulic Conductivity (cm/sec)	$2x10^{-13}$	$2x10^{-13}$	$2x10^{-13}$	$2x10^{-13}$	$2x10^{-13}$	$2x10^{-13}$	$2x10^{-13}$	$2x10^{-13}$
Compacted Soil Liner								
Layer No.	6	6	6	6	7	6	6	6
Layer Type (HELP Model Layer Type Value)	Barrier Soil Liner (3)	Barrier Soil Liner (3)	Barrier Soil Liner (3)	Barrier Soil Liner (3)	Barrier Soil Liner (3)	Barrier Soil Liner (3)	Barrier Soil Liner (3)	Barrier Soil Liner (3)
HELP Soil Texture	0	0	0	0	0	0	0	0
Thickness (in)	24	24	24	24	24	24	24	24
Hydraulic Conductivity (cm/sec)	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$
Results								
Avg. Annual Leachate Production (cf/yr/ac)	24.915	24.914	24.914	4.983	0.00	24.915	24.915	24.915
Peak Daily Leachate Production (cf/day/ac)	8.422	7.215	7.778	8.592	0.00	8.422	8.422	8.592
Leachate Recirculated from Geonet (cf/day/ac)	8.422	7.215	7.778	8.592	0.00	8.422	8.422	8.592
Leachate Introduced (in/year/ac)	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0
Max. Leachate Head on Liner (in)	0.018	0.005	0.005	0.004	0.0000	0.018	0.018	0.004
Final Water Content of Waste (vol/vol)	0.1928	0.1928	0.1928	0.1914	0.1907	0.2381	0.2508	0.2572

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 6: LEACHATE COLLECTION SYSTEM FLOW RATES (III-D.6-A.6)

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Client: Rancho Viejo Waste Management, LLC
Project: Pescadito Environmental Resource Center
Project #: 148866
Calculated By: LJC ORC Date: 1/25/158/4/17
Checked By: RDSMWO Date: 2/6/158/4/2017

TITLE: LEACHATE COLLECTION SYSTEM FLOW RATES

Problem Statement

Determine the daily generation rate into leachate collection system components to ensure that they are adequately sized.

Given

- The HELP model results included in Attachment B to Appendix III-D.6.
- Leachate liner grades and cell configuration shown in Appendix III-D.3.

Assumptions

- The maximum leachate generation rate occurs during operational (open) conditions, as determined from multiple HELP Model Runs. See "HELP Model Analysis". The peak daily leachate generation rate associated with this run is 8.8718.592 cf/acre-day
- All leachate collection system components will be uniformly sized. All will be sized to handle leachate conveyance volumes associated with the largest cell.
- The largest cell size is approximately 2646 acres.

Results

The maximum peak daily leachate generation rate calculated by the HELP model is for the open conditions scenario:

Peak Daily Rate (from the HELP model) = 8.5928.8 71(cf/acre-day)

(8.8718.592 cf/acre-day) x (2646 acres) x (1 day/ 86,400 sec) = 0.0047 0.0026 cfs

Therefore, the peak leachate generation rate is 0.00470.0026 cfs.

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 7: GEOTEXTILE PERMITTIVITY (III-D.6-A.7)

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Client:	Rancho Viejo Waste Management, LLC
Project:	Pescadito Environmental Resource Center
Project #:	148866
Calculated By:	ORCLJC — Date: 1/23/158/4/17
Checked By:	RDSMWO — Date: 2/6/158/4/2017

TITLE: GEOTEXTILE PERMITTIVITY

Problem Statement

Determine the necessary permittivity for the geotextile at installation to ensure continued performance after reduction factors are considered. Geotextile will be placed around the leachate drainage aggregate and is also a component of the geocomposite.

Given

- HELP Model results included in Appendix III-D.6-A5.
- Leachate flow rates calculated in Appendix III-D.6-A6.
  - Peak inflow rate = 0.00470.0026 cfs
- Leachate design details shown in Drawings located in Appendix III-D.3.
  - The leachate chimney will extended the entire length of the leachate collection trench, from the high point in the middle of each cell to the toes on either end of each cell. The maximum length for a leachate chimney is approximately 1,680502 ft.
  - The width of leachate chimney = 2 ft
- Koerner, Robert M. (2005). *Designing with Geosynthetics.* Fifth Edition, Prentice Hall, New Jersey (see III-D.6-A.4).

Assumptions

- The maximum head will be equal to the allowable head on the geotextile which is 30 cm or approximately 1.0 ft, in accordance with TCEQ 330.331(a)(2).
- Geotextile performance reduction factors, typical for landfilling operations (see Table 2.12 from Koerner in III-D.6-A.4).

  RF_{SCB} = Soil clogging/binding reduction factor = Range, 2.0-10.0;
  RF_{CR} = Creep reduction factor = Range, 1.5-2.0;
  RF_{IN} = Intrusion reduction factor = Range, 1.0-1.2;
  RF_{CC} = Chemical clogging reduction factor = Range, 1.2-1.5; and
  RF_{BC} = Biological Clogging reduction factor = Range, 2.0-5.0.

TITLE: GEOTEXTILE PERMITTIVITY

Calculations

1. Leachate Collection Trench Geotextile

First, calculate the needed permittivity for the geotextile to pass the flow rates calculated in "LCS Flow Rates" using Equation 2.16 from Koerner:

$$\Psi = \frac{q}{\Delta h A}$$

Where: Ψ = Permittivity
q = Peak inflow rate = 0.00470.0026 cfs
Δh = maximum allowable head on geotextile = 1.0 ft
L = Total chimney length = 5021,680 ft
W = Design width of leachate chimney = 2 ft
A = inflow area into trench = L x W = 1,680502 ft x2 ft= 1,0043,360 ft^2

$$\Psi_{reduced} = \frac{q}{\Delta h A} = \frac{0.00470.0026 cfs}{1 ft \times 3{,}3601{,}004 ft^2} = 1.3992.59 \times 10^{-6} \frac{1}{sec}$$

Next, determine the amount that the specified permittivity must be increased to account for performance reduction factors that will be encountered during landfill operations. Reduction factors are taken from Table 2.12 from Koerner and calculated using Equation 2.25a from the same refrerence. Due to the wide range of values for the reduction factors, the low, median, and high values are selected to determine a range of anticipated effective permittivities:

$$\Psi_{reduced} = \Psi_{installed}\left(\frac{1}{RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}}\right)$$

Therefore:

$$\Psi_{installed} = (\Psi_{reduced})\, x\, RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}$$

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Project: Pescadito Environmental Resource Center

Project #: 148866

Calculated By: ORC~~LJC~~ **Date:** ~~1/23/15~~8/4/17

Checked By: ~~RDS~~MWO **Date:** ~~2/6/15~~8/4/2017

TITLE: GEOTEXTILE PERMITTIVITY

Table D.6-A.7-1 – Required Installed Permittivity for Leachate Collection Trench

Run	RF_{SCB}	RF_{CR}	RF_{IN}	RF_{CC}	RF_{BC}	$\Psi_{reduced}$	$\Psi_{installed}$
Low Reduction	2.0	1.5	1.0	1.2	2.0	~~1.399~~2.59 $\times 10^{-6} \frac{1}{sec}$	1.9~~1.0~~ $\times 10^{-5} \frac{1}{sec}$
Average Reduction	6.0	1.75	1.1	1.35	3.5	~~1.399~~2.59 $\times 10^{-6} \frac{1}{sec}$	~~7.6~~1.4 $\times 10^{-}$~~5~~4 $\frac{1}{sec}$
High Reduction	10.0	2.0	1.2	1.5	5.0	~~1.399~~2.59 $\times 10^{-6} \frac{1}{sec}$	~~2.5~~4.7 $\times 10^{-4} \frac{1}{sec}$

2. Geocomposite Geotextile

First, calculate the needed permittivity for the geotextile using Equation 2.16 from Koerner, assuming no performance reduction:

$$\Psi = \frac{q}{\Delta h A}$$

Where: Ψ = Permittivity
q = Peak inflow rate = ~~0.0047~~ 0.0026 cfs
Δh = maximum allowable head on geotextile = 1.0 ft
A = maximum cell area = ~~46acres~~ 26 acres = ~~2,003,760~~1,133,000 ft²

$$q_{reduced} = \frac{q}{\Delta h A} = \frac{\sout{0.0047}0.0026\ cfs}{1ft \times \sout{2,003,760}1,133,000 ft^2} = \frac{\sout{2.35}2.30 \times 10^{-9}}{sec}$$

Next, determine the amount that the specified permittivity must be increased to account for performance reduction factors that will be encountered during landfill operations. Reduction factors are taken from Table 2.12 from Koerner and calculated using Equation 2.25a from the same ~~refrerence~~reference. Due to the wide range of values for the reduction factors, the low, median, and high values are selected to determine a range of anticipated effective permittivities:

$$\Psi_{installed} = (\Psi_{reduced})\ x\ RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}$$

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TITLE: GEOTEXTILE PERMITTIVITY

Table D.6-A.7-2 – Required Installed Permittivity for Geocomposite							
Run	RF_{SCB}	RF_{CR}	RF_{IN}	RF_{CC}	RF_{BC}	$\Psi_{reduced}$	$\Psi_{installed}$
Low Reduction	2.0	1.5	1.0	1.2	2.0	2.352.30 $\times 10^{-9} \frac{1}{sec}$	1.691.7 $\times 10^{-8} \frac{1}{sec}$
Average Reduction	6.0	1.75	1.1	1.35	3.5	2.352.30 $\times 10^{-9} \frac{1}{sec}$	1.281.3 $\times 10^{-7} \frac{1}{sec}$
High Reduction	10.0	2.0	1.2	1.5	5.0	2.352.30 $\times 10^{-9} \frac{1}{sec}$	4.234.1 $\times 10^{-7} \frac{1}{sec}$

Results

The initial permittivity of an installed geotextile will be reduced based on multiple performance factors. This calculation has identified the minimum acceptable initial permittivity at the time of installation in order to pass the leachate flow rates at the Pescadito Landfill once performance factors are considered. The most conservative reduction factors identify a minimum acceptable permittivity for the leachate collection trench to be 2.54.7x10^{-4}/s and 4.234.1x10^{-7}/s for the geocomposite, respectively. Engineer discretion may be used to refine performance factor assumptions based on site specific or other appropriate data.

Attachment A

to Appendix III-D.6

Contaminated Water/Leachate Collection System Design Analysis

PROBLEM STATEMENT 8: LEACHATE COLLECTION SYSTEM DESIGN (III-D.6-A.8)

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Calculated By:	~~LJC~~ORC	Date:	~~1/29/15~~8/4/17
Checked By:	~~RDS~~MWO	Date:	~~2/6/15~~8/4/2017

TITLE: LEACHATE COLLECTION SYSTEM DESIGN

Problem Statement

Determine whether the following components of the leachate collection system for the Pescadito Environmental Resource Center landfill are appropriately sized.

1. Leachate Collection Pipe
2. Leachate Sump

Given

- HELP Model results included in III-D.6-A.5.
- Leachate flow rates calculated in III-D.6-A.6.
- Leachate design grades shown in drawings in Appendix III-D.3

Assumptions

- The largest cell is approximately ~~46~~ 26 acres and produces a peak flow rate of ~~0.0047~~ 0.0026 cfs (see Leachate Flow Rate calculation).
- Each leachate collection trench is comprised of a pipe placed in aggregate and wrapped with geotextile, as detailed in the drawings provided in Appendix III-D.3.
- The leachate collection pipes must be sized to collect and convey all leachate from its contributing cell area without backing up.
- The leachate collection pipe within the trench is 6-inch SDR-7.3. This pipe has an inner diameter of 4.7 inches or 0.4 feet and an outer diameter of 0.54 feet.
- The typical Manning's roughness coefficient for HDPE pipe is 0.009.
- The leachate collection pipe has a 0.5 percent slope.
- The minimum permeability of the aggregate used in the sumps shall be 0.01 cm/sec and the porosity shall be 0.3.
- The leachate sump will be sized to store the volume from the peak leachate flow rate for the largest cell over 3 days. The peak flow rate occurs during open conditions, therefore the

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TITLE: LEACHATE COLLECTION SYSTEM DESIGN

sump will provide sufficient storage during open conditions and will have more than sufficient storage during subsequent conditions.

Calculations

1. Leachate Collection Pipe

Determine the full flow capacity of the 0.4-ft inner diameter pipe using Manning's equation:

$$Q = \left(\frac{1.486}{n}\right) AR^{\frac{2}{3}}S^{\frac{1}{2}}$$

Where: Q = Peak flow rate during open conditions = 0.00470.0026 cfs;
n = Manning's number = 0.009
A = cross-sectional area of pipe = $\pi d^2/4$ ft^2 = (π(0.4ft)^2/4) = 0.125 ft^2
R = hydraulic radius of pipe = d/4 ft = 0.4/4 = 0.10
S = slope of pipe = 0.005

$$Q = \left(\frac{1.486}{n}\right) AR^{\frac{2}{3}}S^{\left(\frac{1}{2}\right)}$$

$$Q = \left(\frac{1.486}{0.009}\right)(0.125)(0.1)^{\frac{2}{3}}(0.005)^{\left(\frac{1}{2}\right)}$$

$$Q = 0.314\ cfs$$

It is noted that the capacity of the pipe to convey 0.314 cfs significantly exceeds the peak flow rate that will develop for a 46 26 acre cell (0.00470.0026 cfs). Therefore, it is appropriately sized to handle peak flow rates.

2. Leachate Sump

Determine the required dimensions for a 4-foot deep sump to accommodate the maximum volume of leachate produced over 3 days during the open conditions.

Calculate the volume of 3 days of leachate.

$$V = Q \times 3\ days$$

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TITLE: LEACHATE COLLECTION SYSTEM DESIGN

Where: Q = Peak flow rate during open conditions for the largest cell = 0.0026~~.0047~~ cfs;

$$V = \sout{.0047}\,0.0026\ cfs \times 3\ days \times (\frac{24hrs}{1day}) \times (\frac{60min}{1hr}) \times (\frac{60sec}{1min}) = \sout{1218.24}\,673.92\ cf$$

Calculate the volume of a sump (truncated pyramid) that is 45 feet wide by 45 feet long at the top with a depth of 4 feet and sidelsopes of 3H:1V.

$$V = \frac{1}{3}(a^2 + ab + b^2)h$$

Where: a = 45 ft
b = 45 ft-(2*(slope*height)) = (45 ft-(2*(3 ft*4 ft)) = 21'
h = 4 ft

$$V_{sump} = \frac{1}{3}(45^2 + 45 * 21 + 21^2)4 = 4{,}548\ ft^3$$

Calculate the available volume in the sump.

$$V_{avail} = V_{sump} \times P$$

Where: V_{sump} =4,548 ft^3
P = Porosity of gravel fill in sump = 0.3

$$V_{avail} = 4{,}548\ ft^3 \times 0.3 = 1364.4\ ft^3$$

The available volume of the leachate sump is 1364.4 ft^3, which is greater than the required ~~1218.2~~673.92 ft^3.

Results

The leachate collection pipe and leachate sump are both designed to adequately handle the maximum leachate production of the largest cell during operational conditions.

ATTACHMENT A

TO APPENDIX III-D.6

CONTAMINATED WATER/LEACHATE COLLECTION SYSTEM DESIGN ANALYSIS

PROBLEM STATEMENT 9: LEACHATE TANK SIZE (III-D.6-A.9)

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Client:	Rancho Viejo Waste Management, LLC		
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Project #:	148866		
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Checked By:	~~RDS~~ MWO	Date:	~~2/6/15~~ 8/4/2017

TITLE: LEACHATE TANK SIZE

Problem Statement

Determine size of the leachate storage tanks and the volume of the secondary containment area.

Given

- The peak daily leachate generation rate is ~~8.871~~ 8.592 cf/day/ac from III–D.6-A.6 – Leachate Collection System Flow Rates.
- Design Drawings provided in Appendix III-D.3
- The depth of the 100-year, 24-hour rainfall event is 9.8 in.
- Secondary containment will be provided to accommodate 110% of one tanks volume or the volume of 1 tank plus the rainfall for the 100-year, 24-hour event

Assumptions

- There will be ~~2 equally sized~~ one leachate storage tan~~ks~~k
- The rational method will be used to determine the amount of rainfall generated from a 100-year, 24-hour storm event
- The tanks will provide enough storage to accommodate the leachate generated for 7 days during open conditions
- The area where tanks and spill containment will be placed is 1,482 sf, determined from Drawings in Appendix III-D.3.

Calculations

1. Tank Volume

$$V_{tank} = Q_{leach} \times A_{LF} \times 1\, week$$

Where:
V_{tank} = Volume of the leachate storage tanks
Q_{leach} = Peak daily leachate generation rate (cf/day/ac)
A_{LF} = Area of the largest cell (~~46~~ 26 acres)

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Project: Pescadito Environmental Resource Center

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TITLE: LEACHATE TANK SIZE

$$V_{tank} = \sout{8.871}8.592\ \frac{cf}{day \cdot ac} \times \sout{46}26\ ac\ \times 1\ week\ \times \frac{7\ days}{1\ week} = \sout{2,856}1,564\ ft^3 = \sout{21,367}11,700\ gal$$

~~Two~~ One 15,000 gallon storage tan~~ks~~ will adequately store one week's worth of leachate generated at the landfill at the peak generation rate for one week.

2. Secondary Containment Size

Method A

Secondary containment shall be large enough to hold 110% of one tank:

One tank is 15,000 gallons, therefore the secondary containment required will be 16,500 gallons or 2,206 ft^3.

Method B

Secondary containment will be large enough to hold the volume of one 15,000 gallon (2,005 ft^3) tank plus the runoff from the 100-year, 24-hour storm event.

The formula for the rational method is:

$$Q = CiA$$

Where:
Q = total volume of runoff
C = runoff coefficient, 1.0 (no runoff)
i = depth of water for the 100-year, 24-hour storm event, 9.8 in
A = area the rainfall is landing on (sf)

$$Q = 1.0\ \times 9.8\ in \times 1,482\ sf\ = 1,210\ ft^3$$

The total volume required is 2,005 ft^3 + 1,210 ft^3 = 3,215 ft^3

3. Secondary Containment Determination

The height of the wall for secondary containment will be determined by the largest volume of storage required (Method B) divided by the total area available for storage.

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TITLE: LEACHATE TANK SIZE

The area available for storage is the total area minus the footprint of one of the 16 ft diameter tanks.

$$A_{avail} = 1{,}482\ ft^2 - (\pi r^2) = 1{,}482\ ft^2 - \pi(8\ ft)^2 = 1{,}281\ ft^2$$
$$h_{req} = 3{,}215\ ft^3/1{,}281\ ft^2 = 2.44\ ft \sim 2.5ft$$

Results

TwoOne 16-ft diameter, 15,000 gallon tanks isare appropriately sized to contain one week's worth of leachate. Secondary containment is appropriately sized when placed in the location shown on the Design Drawings to a height of three feet. Tanks of different size and quantity may be used as long as the required secondary containment is provided.