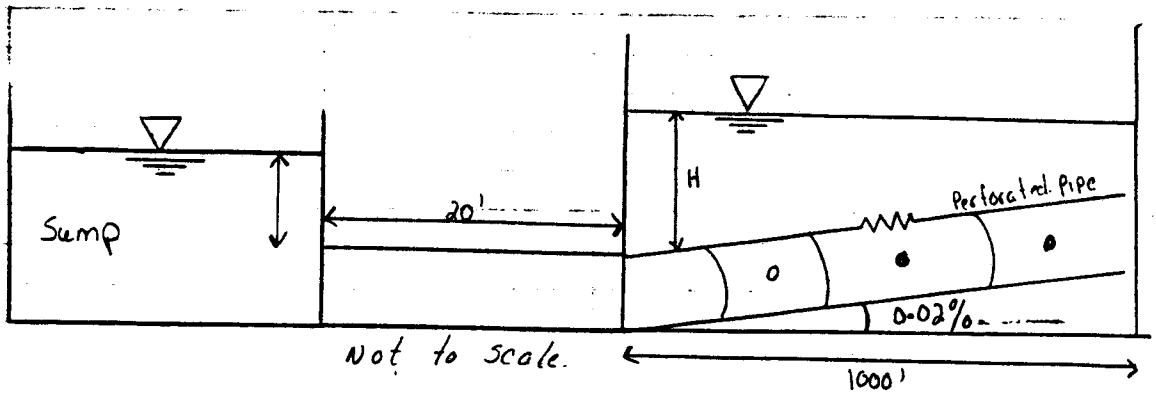
APPENDIX A

HEAD LOSS CALCULATIONS

The hydraulic analysis conducted for leachate head build up in a Landfill was done in two steps. The first analysis was concerned with head losses in the piping system. The second analysis concentrated on the head losses through the surrounding drainage material, natural and synthetic. For the later there were two different Case's of concern. Case One was a socked geotextile covered with sand. Case two was a burritio textile covered, first by a layer of gravel then by sand.

Pipe loss Analysis

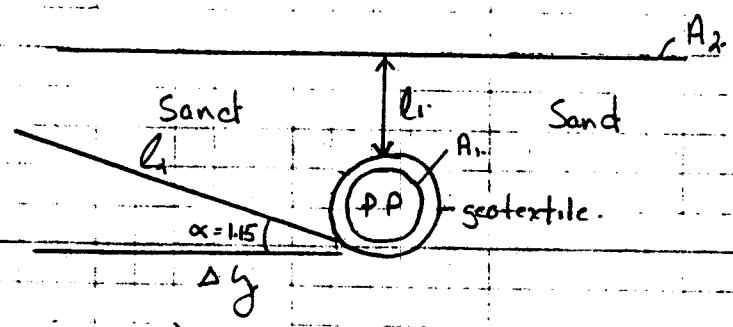


Assumptions

- The minor losses in the pipe that connects sump and Landfill are 20% of the total losses in that pipe.
- The perforated pipe is cut into ten, one hundred feet, sections.
- Each section has four orifices per foot of pipe.
- Total infiltration is 30% of total precipitation.
- Sump Pipe is Commercial steel.
- Based on Reynolds number flow is laminar

Sump pipe Length (L_s) = 20 ft
Sump pipe Diameter (D_s) = 8 in
Perforated pipe Length (L_p) = 1000 ft
Perforated pipe Diameter (D_p) = 8 in
PP slope = 0.02%
Precipitation Rate = 5×10^6 ft^3/yr
Approach Velocity = 2.27×10^{-5} ft/s
friction factor for PP = 0.0076
coefficent of velocity = 0.98
Runoff Coefficient = 0.7
Infiltration = 1.5×10^6 ft^3/yr
friction factor Sump Pipe = 0.0076
Velocity through office hole = .00218 ft/s

Case 1 | Socked pipe.



$h_{L\,pipe} = 3.0 \times 10^{-3}$ ft
$h_{L\,geotextile} = 1.94 \times 10^{-4}$ ft
$h_{L\,perforation} = 1.66 \times 10^{-7}$ ft
} Determined previously

Bernoulli from sump to LF

$\Delta h = -h_{L\,total}$

$\Delta h = -(h_{L\,pipe} + h_{L\,geo} + h_{L\,per} + h_{L\,sand})$

$V = K \frac{\Delta h}{L}$

$\Delta h = \frac{V}{K} L$

$h_{L\,sand\,total} = \frac{V_{avg} L}{K}$

where: $V_{avg} = Q_t / [(A_1 + A_2)\frac{1}{2}]$

$L = (l_1 + l_2)/2$

$V = \frac{Q}{\left(\frac{A_1 + A_2}{2}\right)}$

if Slope $= \frac{\Delta x}{\Delta y} = \frac{l_1}{\Delta y}$ Then $l_2 = l_1 \sqrt{1 + \left(\frac{1}{S}\right)^2}$

Thus, $L = \frac{1}{2}\left(l_1 + l_1 \sqrt{1 + \left(\frac{1}{S}\right)^2}\right) = \frac{1}{2}(l_1 + l_1 50\,ft)$ where $S = .02$

For V_{avg}, need to determine A_2, A_1

$A_2 = 2\,\Delta y \times L_{pipe}$ but $\Delta y = l_2 \cos(1.15°) = l_1 50\,ft \cos 1.15$

Thus $\Delta y = l_1 50\,ft$

$A_2 = 2\, l_1 50\,ft \times 1000\,ft = l_1 \times 10^5\,ft^2$

$A_1 = (\frac{\pi}{4})(\frac{8}{12}) \times 1000\,ft = 349\,ft^2$

Thus, $V_{avg} = \frac{(.0475\,ft^3/s)}{\frac{1}{2}(349\,ft^2 + l_1 1 \times 10^5\,ft^2)}$ where $Q = 4.75 \times 10^{-2}$

head loss through Sump pipe

$$h_L = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \quad \text{where} \quad V = Q/A$$

$$V = \frac{(1.5\times10^6\ ft^3/yr)}{\left(\frac{\pi}{4}\right)\left(\frac{8}{12}\right)^2(86400s \times 365 days)}$$

$$V = 0.136\ ft/s$$

$$h_L = (.0076)\left(\frac{20ft}{(8/12)}\right)\left(\frac{(0.136\ ft/s)^2}{2\times 32.2\ ft/s^2}\right)$$

$$h_L = 4.81\times10^{-4}\ ft$$

Minor losses = 20% of h_L. Thus

$$h_{L total} = 4.81\times10^{-4}ft + (.2)(4.81\times10^{-4})$$

$$h_{L total} = 5.77\times10^{-4}\ ft$$

head loss through Perforated Pipe

$h_{L total}$ = head loss through orifice + head loss through Pipe

$$h_{L orifice} = \left(\frac{1}{C_v^2} - 1\right)\frac{V_o^2}{2g} \quad \text{where} \quad C_v = \text{Coefficent of Velocity}, \; V_o = \text{Orifice hole Velocity}$$

$$h_{Lo} = \left(\frac{1}{(.98)^2} - 1\right)\frac{(0.00218\ ft/s)^2}{(2\times 32.2\ ft/s^2)}$$

$h_{Lo} = 3.04\times10^{-9}\ ft$ There are a total of 400 orifice per section

Thus, $h_{Lo_{total}} = (3.04\times10^{-9}\ ft)(4000) = 1.22\times10^{-5}\ ft$

There are ten sections of pipe each having a different flow rate.

example:

6Q'	5Q'	4Q'	3Q'	2Q'	Q'

← Flow direction

Thus h_L for each sections changes

$h_{L\,pipe} = h_{L_1} + h_{L_2} + h_{L_3} + h_{L_4} \ldots\ldots h_{L_{10}}$

Section Flow rates

$Q_n = [(N_s + 1) - S_\#] \times Q_s$ where N_s = # of sections
S = Section #
Q_s = Total Loading divided by # of sections

Thus

$h_L = f\left(\frac{L}{D}\right)\frac{V_d^2}{2g}$ where V = velocity for each section. Q_n = Flow rate for each section.

$h_{L\,total} = 1.3 \times 10^{-3} + 1.2 \times 10^{-5} ft = 1.31 \times 10^{-3}$

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42-392 100 RECYCLED WHITE 5 SQUARE
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head loss through Sump pipe

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example:

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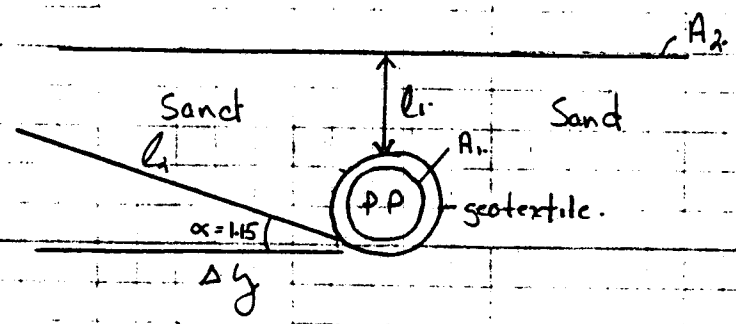
Case I | Socked Pipe.



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} Determined previously

Bernoulli from sump to LF $\qquad V = k\dfrac{\Delta h}{L}$

$\Delta h = -h_{L\,total}$ $\qquad \Delta h = \dfrac{V}{k} L$

$\Delta h = -(h_{L\,pipe} + h_{geo} + h_{per} + h_{sand})$

$h_{sand_{Total}} = \dfrac{V_{avg} L}{k}$ $\qquad$ where: $V_{avg} = Q_t / [(A_1 + A_2)\frac{1}{2}]$ $\qquad V = \dfrac{Q}{\left(\frac{A_1 + A_2}{2}\right)}$

$L = (l_1 + l_2)/2$

if Slope $= \dfrac{\Delta x}{\Delta y} = \dfrac{l_1}{\Delta y}$ Then $l_2 = l_1\sqrt{1 + \left(\frac{1}{S}\right)^2}$

Thus, $L = \frac{1}{2}\left(l_1 + l_1\sqrt{1 + \left(\frac{1}{S}\right)^2}\right) = \frac{1}{2}(l_1 + l_1 50\text{ft})$ where $S = .02$

For V_{avg}, need to determine A_2, A_1

$A_2 = 2\,\Delta y \times L_{pipe}$ but $\Delta y = l_2 \cos(1.15°) = l_1 50\text{ft} \cos 1.15$

Thus $\qquad \Delta y = l_1 50\text{ft}$

$A_2 = 2\, l_1 50\text{ft} \times 1000\text{ft} = l_1 \times 10^5 \text{ft}^2$

$A_1 = (\frac{\pi}{4})(\frac{8}{12}) \times 1000\text{ ft} = 34.9\text{ ft}^2$

Thus, $V_{avg} = \dfrac{(.0475\text{ ft}^3/s)}{\frac{1}{2}(34\text{ ft}^2 + l_1 1 \times 10^5 \text{ft}^2)}$ $\qquad$ where $Q = 4.75 \times 10^{-2}$

Case 1 con't

$$h_{sand_{total}} = \frac{\left[\left(\frac{4.25\times10^{-2}}{\frac{1}{2}(349\,ft^2 + l_1\,1\times10^{-5}\,ft^2)}\right)\times\left(\frac{1}{2}(l_1 + l_1\,50\,ft)\right)\right]}{3.28\times10^{-4}\,ft/s}$$

where $K = 3.28\times10^{-4}\,ft/s$

Assuming $l_1 = 1\,ft$

$h_{sand_{total}} = 0.074\,ft$

but, we only want vertical head loss across the sand.

So, setting $L = h_{sand_{total}}$ and $l_1 = h_1$,

$.070\,ft = \frac{1}{2}(h_1 + h_1\,50\,ft)$

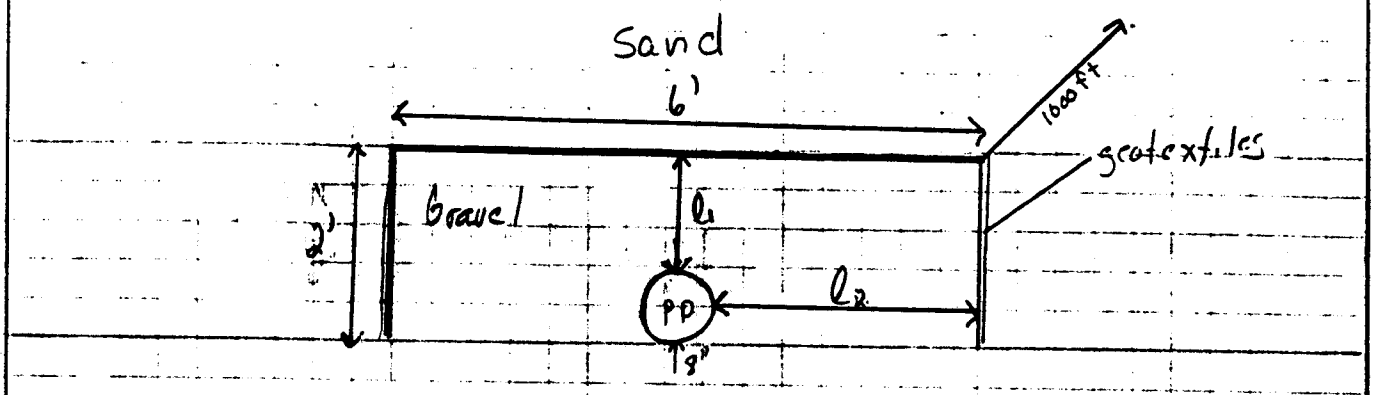
$h_1 = 2.74\times10^{-3}\,ft$ = head loss across sand in vertical direction

Thus

$\Delta h = -[(3.0\times10^{-3}\,ft) + (1.94\times10^{-4}\,ft) + (1.66\times10^{-7}\,ft) + (2.74\times10^{-3}\,ft)]$

$\Delta h_{total} = 5.9\times10^{-3}\,ft$

Case 2. | Burrito



$$h_{gravel} = \frac{V_a L_a}{K}$$

$$V_a = \frac{Q}{\frac{1}{2}(A_1 + A_2)}$$

$$L_a = \frac{l_1 + 2l_2}{2}$$

$$l_1 = \left(2ft - \frac{8}{12}ft\right) = 1.3ft$$

$$l_2 = \left(6ft - \frac{8}{12}ft\right)\frac{1}{2} = 2.67\ ft$$

$$A_1 = \frac{\pi}{4}\left(\frac{8}{12}\right)^2 \times 1000\ ft\ \ 349\ ft^2$$

$$A_2 = (2 \times 2ft + 6ft)(1000\ ft) = 10{,}000\ ft^2$$

Thus $V_a = \dfrac{(5 \times 10^{-5})}{\frac{1}{2}(349ft^2 + 10{,}000\ ft^2)} = 2.13$

$$L_a = \frac{1.3ft + 2(2.67ft)}{2} = 3.32\ ft$$

Thus

$$h_{gravel} = \frac{(2.13 \times 10^{-5}\ ft/s)(3.32ft)}{3.28 \times 10^{-3}\ ft/s}$$

$$h_{gravel} = 2.16 \times 10^{-2}\ ft$$

3.28×10^{-1} ft

$h_{gravel} = 2.16 \times 10^{-2}$ ft

Case 2 | Con't

head losses through geotextiles

$$h_L = \frac{VL}{k} \quad \text{where} \quad V = \frac{Q}{A} = \frac{(15 \times 10^6 \, ft^3/yr)}{(2+6+2)(1000)(86400 \times 365)}$$

$$V = 4.75 \times 10^{-6} \, ft/s$$

Thus

$$h_L = \frac{(4.75 \times 10^{-6})(4.17 \times 10^{-3} \, ft)}{(.0115 \, ft)} = 1.72 \times 10^{-6}$$

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Varibles

Precipitation Rate	56	in/yr
LCS Bay Width	400	ft
LCS Bay Length	1000	ft
Pipe Slope (s)	0.0002	ft/ft
Drainage Perm	0.01	cm/s
Precipitation Rate	1866666.67	ft^3/yr
Runoff Coefficient	0.7	
Leachate Loading Rate	560000	ft^3/yr

Pipe Diameter	8	in
Friction Factr (f)	0.02034	
# of sections	10.00000	
coeifficent of vel	0.98000	
App Vel Sock	0.00001	ft/sec
App Vel Burrito	0.00000	ft/sec
Hole Vel	0.00081	ft/sec
Re(max)	3146	
Pipe Area	0.35	ft^2

Geotextile

trans	0.01148	ft/s
thick	4.17E-03	ft

Perforated

Hole diam	1	in
Hole Area	0.005451	ft^2
# holes	4	
hole spcng	1	ft

Case 1 (socked)

Area1	349.062222	ft^2
Area2	99999.9947	ft^2
Length 1	1	ft
Length 2	50.009999	ft
Slope	0.02	%
Change in y	49.9999973	ft
Avg vel	3.5391E-07	ft/s
Avg Length	25.5049995	ft
K sand	0.000328	ft/s

Case 2 (burrito)

Area1	349.062222	ft^2
Area2	10000	ft^3
Length 1	1.33333333	ft
Length 2	2.66666667	ft
Slope	0.02	
Avg vel	3.4317E-06	ft/s
Avg Length	3.33333333	ft
K gravel	0.0032	ft/s

Pipe Section	Pipe Centroid ft	Centroid Elevation ft	Section Flow Rate ft^3/sec	Section Flow Rate ft/sec
1	50	0.01	2.E-02	0.0509

10	950	0.19	2.E-03	0.0051

HEAD LOSSES

Pipe ft	Perforation ft	Geotextile Socked (ft (ft)	Geotextile Burrito (ft)	head loss Sand (ft)	head loss Gravel (ft)
1.2E-04	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
9.9E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
7.9E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
6.0E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
4.4E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
3.1E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
2.0E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
1.1E-05	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
4.9E-06	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035
1.2E-06	4.2E-10	3.1E-06	6.5E-07	0.028	0.0035