Annexe QC-61

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Analyse de la couche drainante

1.1 Objectifs

La présente section vise à calculer le facteur de sécurité du réseau de collecte des eaux de lixiviation en fonction du débit généré par le LET. L'objectif consiste à vérifier le respect d'un facteur de sécurité acceptable avec l'utilisation d'une pierre nette possédant une perméabilité minimale de 1 cm/s en guise de couche de drainage, tout en s'assurant que la tête d'eau, sur le système d'imperméabilisation, n'excède pas 30 cm telle qu'elle est prescrite dans la réglementation québécoise.

1.2 Méthodologie

L'analyse consiste à calculer le facteur de sécurité. La formule utilisée se résume comme suit : (Giroud, Zornerg, and Zhao, 2000).

$$FS_h = k\left[\frac{\frac{t_{permis}\cdot \sin\beta}{L} + \left(\frac{t_{permis}\cdot \cos\beta}{L}\right)^2}{q_h}\right]$$

où :

FS_h = facteur de sécurité
k_{req} = perméabilité de la couche drainante (m/s)
q_h = taux d'infiltration (m/s)
β = pente de la couche drainante
t_{permis} = hauteur de liquide permise (m)
L = longueur de drainage (m)

1.3 Valeurs des paramètres

Les valeurs des paramètres utilisées pour la présente analyse sont résumées comme suit :

k = 3×10^{-2} m/s perméabilité minimale de la pierre nette (selon HELP). La perméabilité réelle sera plus élevée puisque de la pierre nette est utilisée (perméabilité initiale de l'ordre de 10 cm/s[1])

q_h = $2{,}54 \times 10^{-7}$ m/s (voir la section 1.4 ci-après)

β = $\tan^{-1}(0{,}02)$ = $1{,}1458^{o}$

t_{permis} = 0,3 m

L = 50 m

1.4 Calcul du débit unitaire

Le débit de lixiviat généré par le LET a été évalué avec le modèle HELP en supposant une cellule ouverte et une hauteur de 3 m de matières résiduelles saturées. Ce débit a été estimé à 25,36 mm/j.

1.5 Résultats

$$FS_h = k\left[\frac{\frac{t_{permis}\cdot\sin\beta}{L}+\left(\frac{t_{permis}\cdot\cos\beta}{L}\right)^2}{q_h}\right]$$

$$FS_h = 3\cdot10^{-2}\left[\frac{\frac{0{,}3\cdot\sin 1{,}1458}{50}+\left(\frac{0{,}3\cdot\cos 1{,}1458}{50}\right)^2}{2{,}54\cdot10^{-7}}\right]$$

$$FS_h = 3\cdot10^{-2}\left[\frac{1{,}2\cdot10^{-4}+3{,}6\cdot10^{-5}}{2{,}54\cdot10^{-7}}\right] = 18.42$$

Un facteur de sécurité de l'ordre de 18.42 est jugé amplement acceptable.

[1] Bell, Graem, Fell, Robin, MacGregor, Patrick & Stapledon, David (2005). *Geotechnical Engineering of Dams*. London, UK. : Taylor and Francis Group.

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**                                                                  **
**                                                                  **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE        **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)        **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY           **
**                    USAE WATERWAYS EXPERIMENT STATION             **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY       **
**                                                                  **
**                                                                  **
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PRECIPITATION DATA FILE:    C:\HELP\LSJ-PI.D4
TEMPERATURE DATA FILE:      C:\HELP\LSJ-TI.D7
SOLAR RADIATION DATA FILE:  C:\HELP\LSJ-TI.D13
EVAPOTRANSPIRATION DATA:    C:\HELP\LSJ-EI.D11
SOIL AND DESIGN DATA FILE:  c:\HELP\LSJ_3M4.D10
OUTPUT DATA FILE:           C:\HELP\LSJO3M5.OUT

TIME:  11:11     DATE:  12/14/2011

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     TITLE:  LET LSJ - CET avec 3 m de matieres residuelles

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                              LAYER  1
                              --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   5
          THICKNESS                    =     20.00   CM
          POROSITY                     =      0.4570 VOL/VOL
          FIELD CAPACITY               =      0.1310 VOL/VOL
          WILTING POINT                =      0.0580 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4078 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
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LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	300.00	CM
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2200	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	50.00	CM
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1325	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	50.0	METERS

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.15	CM
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/HECTARE
FML INSTALLATION DEFECTS	=	0.00	HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

THICKNESS	=	0.60	CM
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	33.0000000000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	50.0	METERS

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.15 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	0.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	0.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.60 CM
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 75. METERS.

SCS RUNOFF CURVE NUMBER	=	83.70	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	20.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	8.156	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	9.140	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.160	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	81.237	CM
TOTAL INITIAL WATER	=	81.237	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CARIBOU MAINE

STATION LATITUDE	= 46.52	DEGREES
MAXIMUM LEAF AREA INDEX	= 0.00	
START OF GROWING SEASON (JULIAN DATE)	= 144	
END OF GROWING SEASON (JULIAN DATE)	= 260	
EVAPORATIVE ZONE DEPTH	= 20.0	CM
AVERAGE ANNUAL WIND SPEED	= 14.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	= 70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	= 69.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	= 76.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	= 78.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CARIBOU MAINE

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
68.8	53.8	64.6	67.0	84.8	88.7
130.3	102.1	110.2	79.5	76.8	74.1

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CARIBOU MAINE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-16.8	-14.6	-7.5	1.6	9.9	15.5
18.1	16.8	11.5	5.3	-2.3	-12.0

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CARIBOU MAINE
AND STATION LATITUDE = 48.25 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	74.22	77.40	72.02	54.68	49.70	94.20
	135.76	109.32	127.20	75.72	76.86	76.76
STD. DEVIATIONS	25.11	16.76	37.54	22.06	11.57	23.21
	26.85	42.79	69.41	30.22	20.80	24.59
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	7.341	7.175	11.121	9.869	51.549	71.464
	101.218	67.720	62.748	32.654	14.448	6.588
STD. DEVIATIONS	0.394	0.606	1.128	4.443	14.140	12.864
	17.493	30.761	6.223	6.205	5.237	0.983
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	11.0609	0.9632	1.4002	40.1149	187.7688	62.8888
	23.2224	31.0349	45.9710	48.6587	39.4126	45.1128
STD. DEVIATIONS	18.9442	0.1946	1.7107	51.8081	124.5759	30.9709
	13.7976	21.9484	14.1282	38.5659	7.3228	27.7170
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.1721	0.0165	0.0218	0.6452	2.9224	1.0114
	0.3614	0.4830	0.7393	0.7573	0.6339	0.7021
STD. DEVIATIONS	0.2948	0.0035	0.0266	0.8332	1.9389	0.4981
	0.2147	0.3416	0.2272	0.6002	0.1178	0.4314

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	MM		CU. METERS	PERCENT
PRECIPITATION	1023.84	(80.560)	10238.4	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	443.895	(23.0812)	4438.95	43.356
LATERAL DRAINAGE COLLECTED FROM LAYER 3	537.60907	(157.34502)	5376.091	52.50909
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00032	(0.00009)	0.003	0.00003
AVERAGE HEAD ON TOP OF LAYER 4	7.055	(2.071)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.00031	(0.00009)	0.003	0.00003
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00001	(0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 6	0.000	(0.000)		
CHANGE IN WATER STORAGE	42.335	(3.7557)	423.35	4.135

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(MM)	(CU. METERS)
PRECIPITATION	49.70	497.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	25.35736	253.57362
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000014	0.00014
AVERAGE HEAD ON TOP OF LAYER 4	122.343	
MAXIMUM HEAD ON TOP OF LAYER 4	180.684	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	13.1 METERS	
DRAINAGE COLLECTED FROM LAYER 5	0.00001	0.00014
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00000
AVERAGE HEAD ON TOP OF LAYER 6	0.000	
MAXIMUM HEAD ON TOP OF LAYER 6	0.246	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	0.0 METERS	
SNOW WATER	398.71	3987.1365

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4570
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0582

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(CM)	(VOL/VOL)
1	7.3740	0.3687
2	87.5999	0.2920
3	2.0953	0.0419
4	0.0000	0.0000
5	0.0060	0.0100
6	0.0000	0.0000
7	0.4500	0.7500
SNOW WATER	4.879	

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