S&ME

JOB NO. 1356-06-825
SHEET NO. 1/6
DATE 2/12/08
COMPUTED BY WMH
CHECKED BY IKB/1/08

JOB NAME Duke Energy – Allen Steam Station Ash Landfill
SUBJECT Design Transmissivity

OBJECTIVE:

Evaluate the design transmissivity of the geocomposite drainage layer used for the leachate collection system (LCS) and leak detection system (LDS) of the liner system for the proposed retired ash basin (RAB) ash landfill.

METHOD:

Develop a geocomposite drainage layer design transmissivity as described by Giroud et al. (2000) to account for in service reductions in flow capacity. Design transmissivity values were calculated for three operational conditions: Case 1, liner system with 2' operational cover; Case 2, liner system with 2' operational cover, 10'-80' compacted waste and 6" daily cover; and Case 3, closed landfill.

CALCULATIONS:

Drainage Layer Transmissivity Design Values

Transmissivity is calculated using the following equation:

$$\theta = kt \qquad \text{(Equation 1)}$$

Where:

Θ=hydraulic transmissivity (cm^2/sec);

k=hydraulic conductivity (cm/sec); and

t=drainage layer thickness (0.69cm).

Use the following equations to estimate the appropriate geocomposite drainage layer design transmissivity value:

$$\theta_{LTIS} = \frac{\theta_{measured}}{\prod(RF)} = \frac{\theta_{measured}}{RF_{IMCO} * RF_{IMIN} * RF_{CR} * RF_{IN} * RF_{CD} * RF_{PC} * RF_{CC} * RF_{BC}} \qquad \text{(Equation 2)}$$

$$\theta_{Design} = \frac{\theta_{LTIS}}{FS} \qquad \text{(Equation 3)}$$

Where

Θ_{LTIS}=long term in-situ soil hydraulic transmissivity of the geocomposite;

$\Theta_{measured}$=value of hydraulic transmissivity obtained after laboratory testing;

Π (RF) = product of all reduction factors;

RF_{IMCO}=reduction factor for immediate compression;

RF_{IMIN}=reduction factor for immediate intrusion;

RF_{cr}=creep reduction factor;

RF_{in}=intrusion reduction factor;

RF_{cd}=chemical clogging/degradation reduction factor;

RF_{PC}= particulate clogging reduction factor;

RF_{cc}=chemical clogging reduction factor;

RF_{bc}=biological clogging reduction factor;

Θ_{design}=geocomposite transmissivity appropriate for use in design;

FS= factor of safety.

Evaluation of $\theta_{measured}$

- For Cases 1, 2 and 3 laboratory transmissivity tests were performed in accordance with ASTM D 4716. Test parameters replicating operational conditions of the LCS and LDS, including seating times of 100 hrs under normal stresses of 250 and 7,200 psf were used. Furthermore, sample profiles were arranged to replicate geocomposite contact conditions for LCS and LDS. These profiles consisted of a sand/geocomposite/HDPE geomembrane profile for the LCS and a HDPE geomembrane/geocomposite/ HDPE geomembrane profile for the LDS. Laboratory testing was performed by TRI/Environmental, Inc. of Austin, Texas. Lab test results are reported in Attachment 1.
- GSE Permanet TRx, a triaxial drainage net, was selected due to the products sustained flow capacity under high normal load.

LCS Reduction Factors

Reduction factors used to evaluate LCS geocomposite drainage layer design transmissivity values are presented in Table 1. As discussed in the preceding section, site specific operational conditions of the LCS geocomposite drainage layer were replicated during laboratory transmissivity testing. This allowed for minimization of several of the reduction factors.

Table 1: LCS Reduction Factors

		Range of Values		Operating Conditions			
		LINER	**COVER**	**Case 1 (No Waste)**	**Case 2 (10'-80' Waste)**	**Case 3 (Closed Landfill Liner)**	**Case 3 (Closed Landfill Cover)**
RF_{IMCO}	Reduction factor for immediate compression	1.0	1.0	1.0	1.0	1.0	1.0
RF_{IMIN}	Reduction factor for immediate intrusion	1.5	1.0	1.0	1.0	1.0	1.0
RF_{CR}	Reduction factor for creep	1.4-2.0[1]	1.1-1.4[1]	1.4	1.4	1.4	1.1
RF_{IN}	Reduction factor for delayed intrusion	1.0-1.2[1]	1.0-1.2[1]	1.1	1.0	1.0	1.0
RF_{CD}	Reduction factor for chemical degradation	1.5	1.2	1.0	1.0	1.0	1.0
RF_{PC}	Reduction factor for particulate clogging	1.2	1.2	1.0	1.2	1.2	1.2
RF_{CC}	Reduction factor for chemical clogging	1.5-2.0[1]	1.0-1.2[1]	1.0	1.0	1.0	1.0
RF_{BC}	Reduction factor for biological clogging	1.5-2.0[1]	1.2-1.5[1]	1.0	1.0	1.5	1.2
	Overrall Reduction Factors =	RF		**1.54**	**1.68**	**2.52**	**1.58**

[1] Published Values from Giroud et al. (2000) and Qian et al. (2002)

LDS Reduction Factors

Reduction factors used to evaluate the LDS geocomposite drainage layer design transmissivity values are presented in Table 2. Again, the replication of site specific operational conditions of the LDS geocomposite drainage layer during laboratory transmissivity testing allowed for minimization of several of the reduction factors.

Table 2: LDS Reduction Factors

		Operating Conditions			
		Range of Values	Case 1 (No Waste)	Case 2 (10'-80' Waste)	Case 3 (Closed Landfill Liner)
		LINER			
RF_{IMCO}	Reduction factor for immediate compression	1.0	1.0	1.0	1.0
RF_{IMIN}	Reduction factor for immediate intrusion	1.5	1.0	1.0	1.0
RF_{CR}	Reduction factor for creep	1.4-2.0[1]	1.4	1.4	1.4
RF_{IN}	Reduction factor for delayed intrusion	1.0-1.2[1]	1.0	1.0	1.0
RF_{CD}	Reduction factor for chemical degradation	1.5	1.0	1.0	1.0
RF_{PC}	Reduction factor for particulate clogging	1.2	1.0	1.0	1.0
RF_{CC}	Reduction factor for chemical clogging	1.5-2.0[1]	1.0	1.0	1.0
RF_{BC}	Reduction factor for biological clogging	1.5-2.0[1]	1.0	1.0	1.0
	Overall Reduction Factor =	RF	**1.4**	**1.4**	**1.4**

[1] Published Values from Giroud et al. (2000) and Qian et al. (2002)

RESULTS:

Design transmissivity values were calculated for three operational conditions: Case 1, liner system with 2' operational cover; Case 2, liner system with 2' operational cover, 10'-80' compacted waste and 6" daily cover; and Case 3, closed landfill.

LCS Design Transmissivity and Hydraulic Conductivity

The estimated LCS geocomposite drainage layer design transmissivity values for operational conditions are presented in Table 3.

Table 3: LCS Design Transmissivity and Hydraulic Conductivity

Operation Conditions	$\Theta_{measured}$ (m^2/s)	Θ_{LTIS}	k_{design} (cm/s)
Case 1	5.53E-03	3.59E-03	52
Case 2	3.36E-03	2.00E-03	29
Case 3	3.36E-03	1.33E-03	19

Please note that a hand calculation verifying the k_{design} is provided in Attachment 2.

LDS Design Transmissivity and Hydraulic Conductivity

The estimated LDS geocomposite drainage layer design transmissivity values for operational conditions are presented in Table 4. These values will be used to evaluate the LDS performance and action leakage rate (ALR).

Table 4: LDS Design Transmissivity and Hydraulic Conductivity

Operation Conditions	$\Theta_{measured}$ (m^2/s)	Θ_{LTIS}	k_{design} (cm/s)
Case 1	5.77E-03	4.12E-03	60
Case 2	4.45E-03	3.18E-03	46
Case 3	4.45E-03	3.18E-03	46

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REFERENCE:

1. J. P. Giroud, J. G. Zornberg and A. Zhao (2000) "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers". *Geosynthetics International*, Vol. 7, Nos 4-5.
2. X. Qian, R. M. Koerner and D. H. Gray (2002) "Geotechnical Aspects of Landfill Design and Construction" Prentice Hall, Inc. Upper Saddle River , New Jersey 07458
3. Geosynthetics Specifiers Guide 2008. Vol. 25, Number 6

February 11, 2008

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Bill To:

<= Same (Proj. Number: 1356-06-825)

Dear Mr. Harrison:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report for laboratory testing.

Project:	**Ash Landfill**
TRI Job Reference Number:	E2302-57-06
Material(s) Tested:	4 GSE Permanet TRx -2-8oz Double Sided Geocomposite(s)
Test(s) Requested:	Transmissivity (ASTM D 4716)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

Patel

Dr. Mansukh Patel
Sr. Laboratory Coordinator
Geosynthetic Services Division
www.GeosyntheticTesting.com

cc: Sam R. Allen, Vice President and Division Manager

GeosyntheticTesting.com
9063 Bee Caves Road / Austin, TX 78733 / 512 263 2101 / fax 512 263 2558

GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

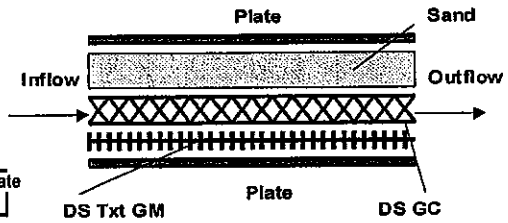
Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

Hydraulic Transmissivity (ASTM D 4716)

Direction Tested: Machine Direction

Normal Load (psf):	250
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

Plate / Ottawa Sand / Sample / 60 mil Textured HDPE Geomembrane / Plate



PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		
Seat Time (hours)	Specimen		1									
	Volume (cc)		762	769	767							
	Time (s)		15.09	15.20	15.15							
	Flow Rate (GPM/ft width)		0.80	0.80	0.80						0.80	0.00
100	Transmissivity (m^2/s)		5.52E-03	5.53E-03	5.54E-03						5.53E-03	7.36E-06
	Test Temp (C)			20.0								
	Temp. Corr. Factor			1.000								

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GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
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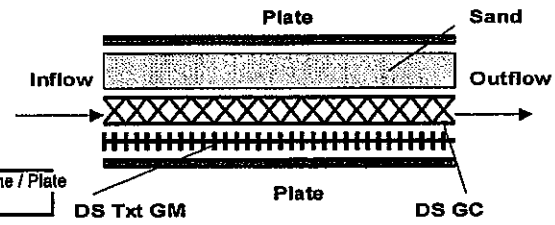
Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		
Hydraulic Transmissivity (ASTM D 4716)												
Direction Tested: Machine Direction												
Normal Load (psf):	7,200											
Hydraulic Gradient:	0.03											
Test Length (in)	12											
Test Width (in)	12											
Plate / Ottawa Sand / Sample / 60 mil Textured HDPE Geomembrane / Plate												
Seat Time (hours)	Specimen		1									
	Volume (cc)		623	621	628							
	Time (s)		20.27	20.26	20.44							
100	Flow Rate (GPM/ft width)		0.49	0.49	0.49						0.49	0.00
	Transmissivity (m^2/s)		3.36E-03	3.35E-03	3.38E-03						3.36E-03	4.96E-06
	Test Temp (C)			20.0								
	Temp. Corr. Factor			1.000								



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GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

Hydraulic Transmissivity (ASTM D 4716)

Direction Tested: Machine Direction

Normal Load (psf):	250
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

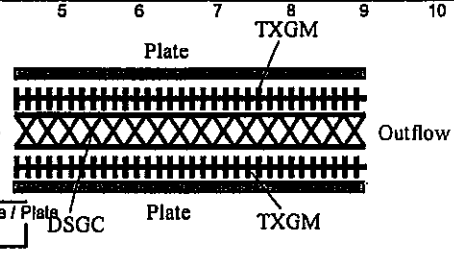

Plate / 60 mil TX HDPE Geomembrane / Sample / 6 mil TX HDPE Geomembrane / Plate

PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		
Seat Time (hours)	Specimen		1									
Volume (cc)		806	805	814								
Time (s)		15.29	15.27	15.41								
100 Flow Rate (GPM/ft width)		0.84	0.84	0.84							0.84	0.00
Transmissivity (m^2/s)		5.76E-03	5.77E-03	5.78E-03							5.77E-03	6.75E-06
Test Temp (C)			20.0									
Temp. Corr. Factor			1.000									

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GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-67-06

Hydraulic Transmissivity (ASTM D 4716)

Direction Tested: Machine Direction

Normal Load (psf):	7,200
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

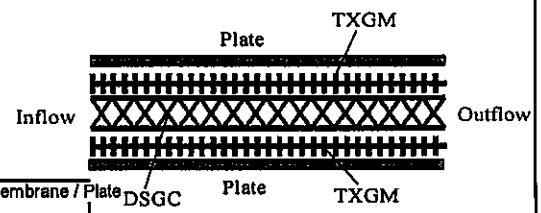

Plate / 60 mil TX HDPE Geomembrane / Sample / 6 mil TX HDPE Geomembrane / Plate

PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		
Seat Time (hours)	Specimen		1									
Volume (cc)		612	613	615								
Time (s)		15.07	15.09	15.10								
100 Flow Rate (GPM/ft width)		0.64	0.64	0.65							0.64	0.00
Transmissivity (m^2/s)		4.44E-03	4.44E-03	4.45E-03							4.45E-03	7.09E-06
Test Temp (C)			20.0									
Temp. Corr. Factor			1.000									

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Design Transmissivity: Attachment 2 1/1

LCS geocomposite drainage layer design transmissivity:

Case 1 (No Waste Present):

$\theta_{measured} = 5.53 \cdot 10^{-3}\ m^2/s$

$RF = 1.54$

$\theta_{LTIS} = \frac{5.53 \cdot 10^{-3}\ m^2/s}{1.54} = 3.59 \cdot 10^{-3}\ m^2/s$ ✓ mm

$K = \frac{\theta}{t} = \frac{3.59 \cdot 10^{-3}\ m^2/s}{(.0069\ m)} = 52\ cm/s$ ✓ mm