A-3

Evaluation of Hydraulic Performance for SCA Final Cover Design

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CALCULATION PACKAGE COVER SHEET

Client: Honeywell **Project:** Onondaga Lake SCA Final Cover Design **Project/Proposal #:** GD5497

TITLE OF COMPUTATIONS **EVALUATION OF HYDRAULIC PERFORMANCE FOR SCA FINAL COVER DESIGN**

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Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

EVALUATION OF HYDRAULIC PERFORMANCE FOR SCA FINAL COVER DESIGN

INTRODUCTION

This package was prepared in support of the final cover design of the Sediment Consolidation Area (SCA) for the Onondaga Lake Bottom Site, located on Wastebed 13 (WB-13). This package presents an analysis of the hydraulic performance of the proposed SCA final cover system, which includes geosynthetics and soil components. The analysis presented in this package has three main objectives:

1. Evaluate the infiltration rate through the proposed SCA final cover system. The infiltration rate through the cover system is used to calculate the amount of liquid to be pumped through the base liner liquid management system (LMS) after placement of the final cover of the SCA in the calculation package titled “Sump and Riser Calculations for SCA Final Cover Design”.
2. Evaluate the impingement rate on the proposed SCA final cover system. The impingement rate on the SCA final cover system is used to calculate the thickness of the geocomposite drainage layer and spacing of 4-inch diameter drainage collection pipes required to maintain an acceptable liquid head above the final cover geomembrane liner as discussed later in this package.
3. Calculate the liquid head on the proposed SCA final cover system. The liquid head on the SCA final cover system is used to analyze the veneer stability of the final cover system in the calculation package titled “Veneer Stability Analyses for SCA Final Cover Design”.

METHODOLOGY

The water balance analysis of the SCA final cover system was performed using the “Hydraulic Evaluation of Landfill Performance” (HELP) software, Version 3.07 developed by the U.S. Environmental Protection Agency. HELP is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model accepts weather, soil, and design data and accounts for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, lateral drainage, and leakage through liners [Schroeder et al., 1994]. The outputs from HELP were used to calculate the liquid head above the geomembrane and infiltration rate through the geomembrane as discussed below. It is noted that the HELP software is limited in only being able to model one slope per simulation.

Due to the varying slopes comprising the SCA final cover system (i.e., the downstream slope is steeper than the upstream slope), the design method for liquid collection layers on two different slopes proposed by Giroud et al. [2000] was used to calculate the maximum liquid head above the geocomposite drainage layer on the slopes of the SCA final cover. The upstream slope is defined as the gently sloping areas of the top and main decks, including the side slopes along the top deck (referred to as "SCA top area"). The downstream slope is defined as the side slopes along the main deck (referred to as "main deck side slopes").

The maximum liquid head on the upstream slope ($t_{up\ max}$) was calculated using the following equation [Giroud et al., 2000]:

$$t_{up\,max} \approx \frac{q_h(L_{up})}{k_{up}(\sin\beta_{up})}$$

where,

q_h = liquid impingement rate (i.e., rate of liquid supply per unit horizontal area);
L_{up} = horizontal length of upstream slope;
k_{up} = hydraulic conductivity of liquid collection layer on upstream slope; and
β_{up} = slope angle of liquid collection layer on upstream slope.

The maximum liquid head on the downstream slope ($t_{down\ max}$) was calculated using the following equation [Giroud et al., 2000]:

$$t_{down\,max} \approx \frac{q_h(L_{up} + L_{down})}{k_{down}(\sin\beta_{down})}$$

where,

q_h = liquid impingement rate (i.e., rate of liquid supply per unit horizontal area);
L_{up} = horizontal length of upstream slope;
L_{down} = horizontal length of downstream slope;
k_{down} = hydraulic conductivity of liquid collection layer on downstream slope; and
β_{down} = slope angle of liquid collection layer on downstream slope.

The liquid impingement rate was determined using the HELP model outputs. The above equations from Giroud et al. [2000] are applicable when a geosynthetic liquid collection layer (i.e., geocomposite) is present on both the downstream and upstream slopes. An example calculation of the maximum liquid head is included in Attachment 1.

The infiltration rate through the SCA final cover system was calculated using the calculated liquid head and equation proposed by Giroud [1997]:

$$Q_{leakage\ per\ area} = \frac{n * 0.976 * C_{qo} * \left[1 + 0.1 * \left(\frac{h}{t_u}\right)^{0.95}\right] * d^{0.2} * h^{0.9} * k_u{}^{0.74}}{A}$$

where,

$Q_{leakage\ per\ area}$	=	leakage rate per geomembrane area;
A	=	geomembrane area;
n	=	number of defects per geomembrane area;
C_{qo}	=	contact quality factor;
h	=	hydraulic head on top of the geomembrane;
t_u	=	thickness of the underlying soil layer;
k_u	=	hydraulic conductivity of the underlying soil layer; and
d	=	diameter of circular defect.

The geomembrane was assumed to contain one hole per acre and have good contact with the soil layer below, both of which can typically be achieved during construction. The holes in the geomembrane were assumed to be 0.16 in^2, following the recommendations of Giroud and Bonaparte [1989]. An example calculation of the infiltration rate through the geomembrane is included in Attachment 2.

SCA FINAL COVER DESIGN

In general, the SCA final cover system consists of gently sloping (i.e., approximately 1% slopes) areas of the top and main decks with maximum side slopes of 4 horizontal to 1 vertical (4H:1V or 25%) and 3.33 horizontal to 1 vertical (3.33H:1V or 30%) along the top and main decks, respectively.

The SCA final cover system consists of the following layers, from top to bottom, as shown in Figures 1 and 2:

- Vegetative soil layer;
- Protective soil layer;
- Geocomposite drainage layer with drainage collection pipes;
- Geomembrane (GM) liner;
- Geotextile cushion layer; and
- Leveling layer.

The allowable maximum liquid head above the final cover geomembrane on the SCA top area was set to a target value of approximately 12 inches. An SCA final cover system without a geocomposite drainage layer was evaluated initially, which resulted in a saturated cover soil with a maximum peak daily liquid head greater than 24 inches. To reduce the maximum liquid head above the final cover geomembrane to the target value of approximately 12 inches, a geocomposite drainage layer and 4-inch diameter drainage collection pipes were added to the cover system. On the main deck side slopes, the allowable maximum liquid head must be contained within the geocomposite thickness.

CASES ANALYZED

Both the gently sloping areas of the SCA top area (i.e., upstream slope), and the main deck side slopes (i.e., downstream slope) have been considered as part of the analyses in this package. The target maximum peak daily liquid head above the GM cover is approximately 12 inches on the SCA top area and less than the thickness of the geocomposite drainage layer on the main deck side slopes.

For the SCA top area, the two following cases were evaluated:

- Case 1: SCA final cover system without a geocomposite drainage layer or 4-inch diameter drainage collection pipes; and
- Case 2: SCA final cover system with a geocomposite drainage layer and 4-inch diameter drainage collection pipes.

The geocomposite on the SCA top area is assumed to be single-sided with a nonwoven, needle-punched geotextile.

For the main deck side slopes, the two following cases were evaluated:

- Case 3: SCA final cover system with a geocomposite drainage layer with the same thickness on the SCA top area; and
- Case 4: SCA final cover system with a thicker geocomposite drainage layer on the main deck side slopes.

For both of these cases, the geocomposite used for the drainage layer on the main deck side slopes is assumed to be double-sided with nonwoven, needle-punched geotextiles.

INPUT PARAMETERS

The HELP software accepts parameters for layer type, hydraulic conductivity (*K*) for each layer, drainage path length, slope, moisture storage values, and climate. These parameters are further discussed below.

Material Layer Properties

The material layers in the SCA final cover system include the vegetative soil layer, protective soil layer, geocomposite drainage layer, drainage collection pipes, GM liner, geotextile cushion layer, and leveling layer, as discussed above and shown in Figures 1 and 2. Specific properties for the different layers of materials are included in Table 1 and are discussed below. It is noted that the HELP default parameters were used to select the total porosity, field capacity, and wilting point of each layer, however, the hydraulic conductivity was modified to better represent expected or potentially critical conditions.

The proposed vegetative soil layer has a thickness of 6 inches and is modeled as a sandy silt with a hydraulic conductivity of $1.0\text{x}10^{-4}$ cm/s (based on the default hydraulic conductivity value [$3.7\text{x}10^{-4}$ cm/s] for soils similar to sandy silts in HELP). The proposed protective soil layer has a thickness of 18 inches and is modeled as a sandy clay material with a hydraulic conductivity of $1.0\text{x}10^{-5}$ cm/s (based on the default hydraulic conductivity value [$3.3\text{x}10^{-5}$ cm/s] for soils similar to sandy clays in HELP).

The purpose of the geocomposite drainage layer is to reduce the liquid head on the GM and in turn, improve the final cover veneer stability. A 200-mil, single-sided geocomposite with a measured transmissivity of $1.0\text{x}10^{-3}$ m^2/s (i.e., design hydraulic conductivity of approximately 2.7 cm/s considering reduction factors) was used for the SCA top area. Both 200-mil and 250-mil, double-sided geocomposites with measured transmissivities of $1.0\text{x}10^{-4}$ m^2/s (i.e., design hydraulic conductivity of approximately 0.27 cm/s considering reduction factors) and 5.0×10^{-4} m^2/s (i.e., design hydraulic conductivity of approximately 1.1 cm/s considering reduction factors), respectively, were analyzed for the main deck side slopes. The design hydraulic conductivity of the geocomposites was calculated assuming the following reduction factors:

RF_{CR} = Reduction factor for creep = 1.20;
RF_{IN} = Reduction factor for delayed intrusion = 1.10;
RF_{CD} = Reduction factor for chemical degradation = 1.20;
RF_{PC} = Reduction factor for particulate clogging = 1.20;
RF_{CC} = Reduction factor for chemical clogging = 1.20;
RF_{BC} = Reduction factor for biological clogging = 1.30; and
FS = Overall factor of safety = 2.50.

An example calculation of the design hydraulic conductivity for the single-sided geocomposite on the SCA top area is shown in Attachment 3.

Drainage collection pipes with a 4-inch diameter were added beneath the geocomposite drainage layer to reduce the length of the longest possible drainage path on the SCA top area. The spacing of the drainage collection pipes was selected such that the calculated liquid head was less than the target liquid head (approximately 12 inches) on the SCA top area.

The cover GM was modeled using the HELP model parameters for a low-density polyethylene (LDPE) liner, available in the HELP database. As discussed previously, the GM was assumed to contain one hole per acre and have good contact with the soil layer below.

The leveling layer and geotextile cushion layer are not intended to serve as a low permeability barrier, and is not expected to have a significant impact on the infiltration through the GM cover or the liquid head build-up on top of the GM cover. Therefore, these layers were not modeled as part of these analyses.

Drainage Path Lengths and Slopes

As mentioned previously, the final cover slopes on the gently sloping areas of the top and main decks will be a minimum of 1.0% towards the side slopes. The transition between the top and main decks has maximum side slopes of 4H:1V. The longest possible drainage path along the SCA top area to the main deck side slopes is approximately 1,300 ft in length without drainage collection pipes, as shown in Figure 3. With 4-inch diameter drainage collection pipes spaced at approximately 100 ft, the longest possible drainage path along the SCA top area is reduced to 150 ft as shown in Figure 4. A slope of 1% has been conservatively assumed for the entire drainage path length along the SCA top area.

For the main deck side slopes, the drainage path length is approximately 100 ft. The minimum side slope is 4H:1V and the maximum side slope is 3.33H:1V based on final design grades.

Climate Data

The data for precipitation, temperature, humidity, and solar radiation were modeled using the HELP software synthetic data generation function for Syracuse, New York for a 100-year modeling period. This generation used recorded mean monthly data for Syracuse, shown in Table 2, to stochastically generate daily data with approximately the same statistical characteristics as the historic data. The precipitation data were manually adjusted to account for the design storm event of a 25-year, 24-hour rainfall. The rainfall corresponding to the design storm event was selected to be 4.4 inches based on recommendations from the Natural Resources Conservation Service [NRCS, 1986], as shown in Figure 5. The evaporative zone depth, which is the maximum depth from which water may be removed by evapotranspiration, was assumed to be 24 inches, corresponding to the total thickness of the vegetative soil layer and the protective soil layer in the final cover system. For this analysis, it was assumed that a good stand of grass will be established on the final cover system; therefore, the leaf area index (i.e., the dimensionless ratio of leaf area of active vegetation to the nominal surface area) of 3.5 was selected. Values of the climate parameters are shown in Table 3.

RESULTS OF ANALYSIS

The results of the HELP model analyses for Cases 1 through 4 are summarized in Table 4, and the HELP output files are included in Attachment 4. For the SCA top area, the initial calculation for a 1300 ft drainage length without a geocomposite drainage layer resulted in a calculated maximum liquid head of approximately 34 inches (see Case 1). To achieve the target maximum peak daily liquid head of approximately 12 inches, a 200-mil single-sided geocomposite drainage layer must be installed and a drainage length of approximately 150 ft must be achieved (see Case 2). A drainage length of 150 ft can be achieved by installing 4-inch diameter drainage collection pipes within the SCA final cover system.

For the main deck side slopes, the initial calculation for a 200-mil double-sided geocomposite and 100 ft drainage length resulted in a maximum peak daily liquid head of 0.53 inches, which is more than twice the thickness of the 200-mil (i.e., 0.2 inches) geocomposite drainage layer (see

Case 3). Using a 250-mil (i.e., 0.25 inches) thick double-sided geocomposite on the main deck side slopes results in a maximum peak daily liquid head of 0.14 inches, which can be contained within the geocomposites thickness (see Case 4).

SUMMARY AND CONCLUSIONS

This package presents the analyses of the hydraulic performance of the proposed SCA final cover system using the HELP model. The evaluation presented in this package has three main objectives: (i) evaluate the infiltration rate through the proposed SCA final cover system; (ii) evaluate the impingement rate on the SCA final cover; and (iii) evaluate the liquid head above the GM in the final cover system on the SCA. The analysis indicates a calculated average annual liquid infiltration rate through the SCA final cover system of approximately 0.1 gallons per minute. Additionally, the analysis indicates a calculated average annual liquid impingement rate on the SCA final cover system of approximately 0.02 inches per day.

To achieve the target liquid heads above the GM liner, a 250-mil double-sided geocomposite drainage layer is required on the main deck side slopes and a 200-mil single-sided geocomposite with 4-inch diameter drainage collection pipes spaced every 100 ft is required on the SCA top area. The drainage collection pipes should terminate where the geocomposite daylights in the SCA perimeter ditches at the base of the main deck side slopes. A cross section of the drainage collection pipes is shown in Figure 1, while a plan view of the layout of the drainage collection pipes is shown in Figure 4. When these components are included in the final cover system, the calculated peak daily liquid heads in the cover system are approximately 0.14 inches and 12 inches for the main deck side slopes and SCA top area, respectively.

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Giroud, J.P. "*Equations for Calculating the Rate of Liquid Migration Through Composite Liners Due to Geomembrane Defects*", Geosynthetics International, Vol.4, No.3-4, 1997.

Giroud, J.P. and Bonaparte, R. "*Leakage Through Liners Constructed with Geomembranes, Part I: Geomembrane Liners*", Geotextiles and Geomembranes, Vol.8, No.1, 1989.

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Natural Resources Conservation Service (NRCS), "*Urban Hydrology for Small Watersheds*", 210-VI-TR-55, Second Edition, June 1986.

Schroeder, P.R., et al. "*The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3*", EPA/600/9-94/xxx, U.S. EPA Risk Reduction Engineering Laboratory, Cincinnati, OH, 1994.

Tables

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
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Table 1: Material Properties of Layers within SCA Final Cover System

Layer	Description[1]	Layer Type[2]	HELP Default[3]	HELP USCS Name	Thickness (in)	k (cm/s)[4]
1	Vegetative Soil Layer	1	8	ML	6.00	1.00E-04
2	Protective Layer	2	13	SC	18.00	1.00E-05
3	Geocomposite Drainage Layer (200-mil Single-Sided)	2	20	Drainage Net (0.5 cm)	0.20	2.66E+00
	Geocomposite Drainage Layer (200-mil Double-Sided)				0.20	2.70E-01
	Geocomposite Drainage Layer (250-mil Double-Sided)				0.25	1.06E+00
4	Geomembrane[5]	4	36	LDPE	0.04	4.00E-13

Notes:
1. This is a general description of each layer.
2. The following layer types are available in the HELP model: 1 = Vertical Percolation, 2 = Lateral Drainage, 3 = Barrier Soil Liner, 4 = Geomembrane Liner (GM).
3. This is the HELP default soil texture number. It is noted that the hydraulic conductivity of each layer may be changed from the HELP default to better represent expected or potentially critical conditions. All input parameters can be found in the HELP output files provided in Attachment 2.
4. Geocomposite hydraulic conductivity values represent the design hydraulic conductivity considering reduction factors as discussed in Attachment 3.
5. This layer was modeled as low density polyethylene (LDPE) GM, using typical values from the HELP database. Selection of a different GM type will not affect the results significantly.

Table 2: Normal Mean Precipitation and Temperature Data for Syracuse, NY

Month	**Precipitation (in.)**	**Temperature (^{o}F)**
January	2.61	22.80
February	2.65	24.00
March	3.11	33.30
April	3.34	46.10
May	3.16	57.00
June	3.63	66.30
July	3.76	70.90
August	3.77	69.30
September	3.29	62.10
October	3.14	51.30
November	3.45	40.60
December	3.20	28.30

Note:

These are the default normal mean monthly values of precipitation and temperature for Syracuse, NY, available in the HELP software.

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Table 3: Climate Parameters for Syracuse, NY and Other Parameters for the SCA Final Cover System (HELP Default Values Unless Stated Otherwise)

Parameter	Value	Units
Fraction of Area allowing Runoff	100%	percent of total area
Evaporative Zone Depth	24	inches
Latitude	43.07	degrees
Maximum Leaf Area Index	3.5[3]	--
Start of Growing Season (date)	124[4]	--
End of Growing Season (date)	284[4]	--
Planar Area[1]	1	acre
Average Annual Wind Speed	9.7	miles/hr
Average 1st Quarter Relative Humidity	72%	--
Average 2nd Quarter Relative Humidity	68%	--
Average 3rd Quarter Relative Humidity	75%	--
Average 4th Quarter Relative Humidity	76%	--
Peak Daily Rainfall, 25-year, 24-hour storm event[2]	4.40	inches

Notes:
1. The area was modeled as one acre to produce values on a per-acre basis. This was multiplied by the total number of acres to calculate total flow rates over the entire area of the SCA. The total area of the SCA is approximately 50 acres.
2. Value from National Resources Conservation Service data shown in Figure 5.
3. This value corresponds to a good stand of grass on top of the final cover.
4. These dates correspond to May 4 through October 11.

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Table 4: Results of HELP Modeling, Giroud [1997], and Giroud et al. [2000] Calculations for the SCA Final Cover System

Location	Case	Geocomposite Thickness (mil)	Drainage Length (ft)	Curve Number [1]	Peak Daily Values				Average Annual Values				
					Infiltration Rate (ft^3/ac-day)	Infiltration Rate (gal/min)	Impingement Rate (in./day)	H_{MAX} (in) cover[2]	Infiltration Rate (ft^3/ac-yr)	Infiltration Rate (gal/min)	Impingement Rate (in./yr)	Impingement Rate (in./day)	H_{AVG} (in) cover
SCA Top Area	1	-	1300	69.1	1.1	0.3	0.00	34.1	140.6	0.1	0.1	< 0.01	8.9
	2	200	150	72.8	0.4	0.1	0.24	12.2	18.3	< 0.1	6.6	0.02	0.1
Main Deck Side Slopes	3	200	100	75.9	< 0.1	< 0.1	0.33	0.53[3]	0.2	< 0.1	6.5	0.02	< 0.1[3]
	4	250	100	75.9	< 0.1	< 0.1	0.35	0.14[3]	0.2	< 0.1	6.5	0.02	< 0.1[3]

Notes:

1. The curve number was calculated by HELP based on model inputs.
2. The target maximum peak daily liquid head (H_{MAX}) above the GM cover is 12 inches on the SCA top area and less than the thickness of the geocomposite on the main deck side slopes.
3. The equations of Giroud et al. [2000] were used to calculate the maximum peak daily liquid head (H_{MAX}) and average annual daily liquid head (H_{AVG}) for the main deck side slopes since the calculations involved a change in slope.
4. The SCA was assumed to have a total acreage of 50 acres.
5. The HELP Output files are included in Attachment 4.

Figures

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
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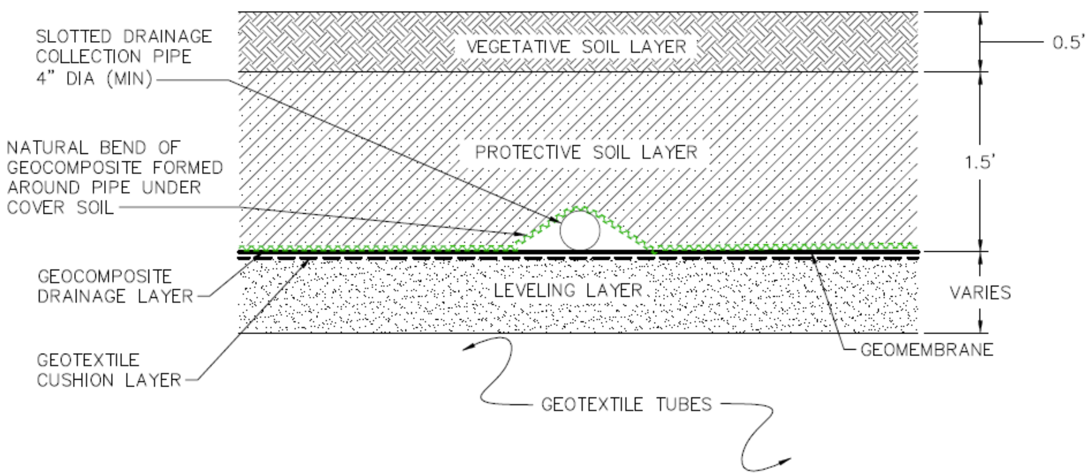

Figure 1: Cross Section of Final Cover System for SCA Top Area (i.e., Gently Sloping Areas of the Top and Main Decks and Top Deck Side Slopes)

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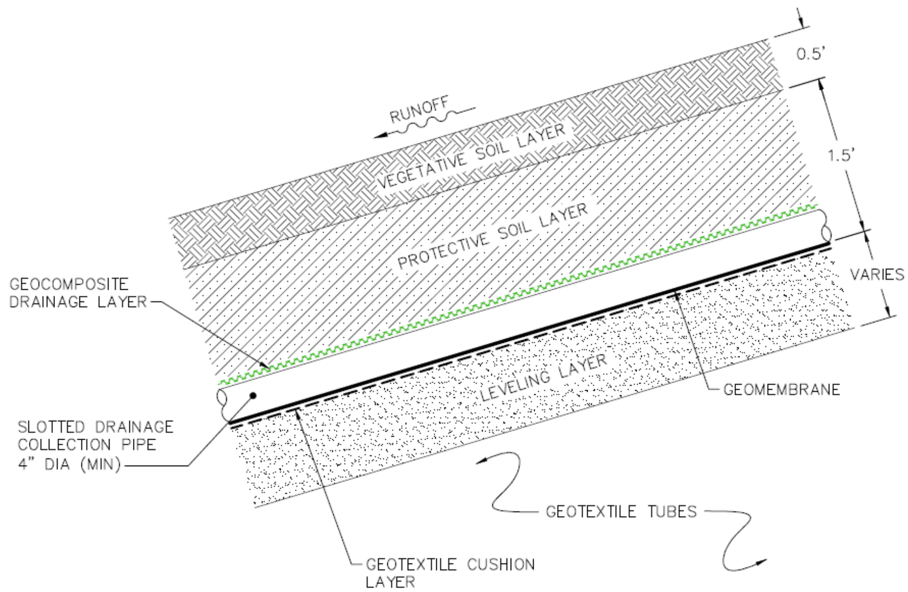

Figure 2: Cross Section of Final Cover System for Main Deck Side Slopes

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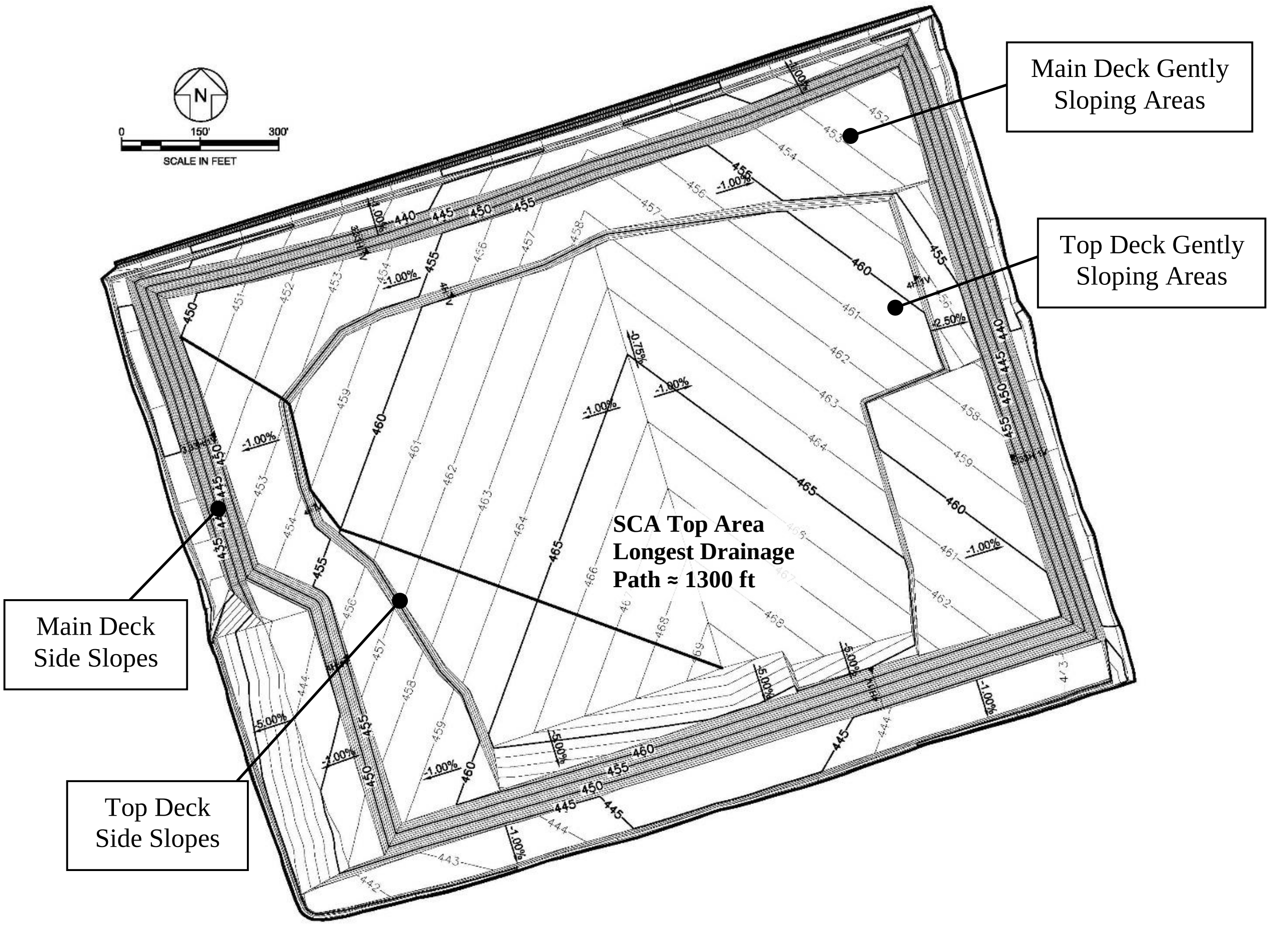

Figure 3: Design Top of Final Cover Grading Plan

Note:

The grading plan shown here is based on a topographic survey of the SCA conducted December 7, 2014. It is noted that minor revisions to the grading plan are not expected to significantly impact the HELP calculation results.

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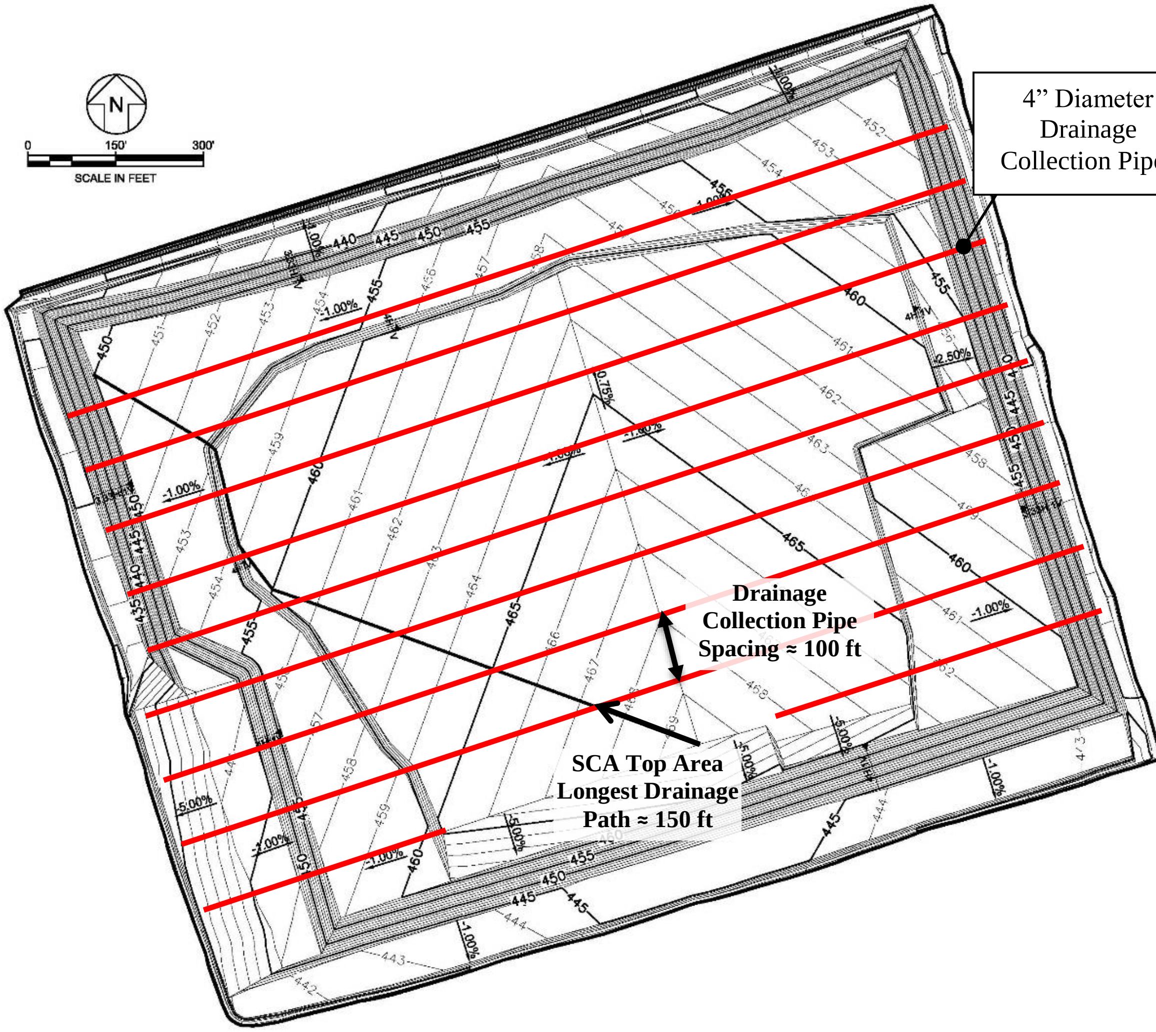

Figure 4: Plan View of Drainage Collection Pipe Layout (100 ft distance between pipes reduces drainage length to approximately 150 ft).

Note:

The grading plan shown here is based on a topographic survey of the SCA conducted December 7, 2014. Drainage collection pipes terminate where the geocomposite drainage layer daylights in SCA perimeter ditches at the base of the main deck side slopes.

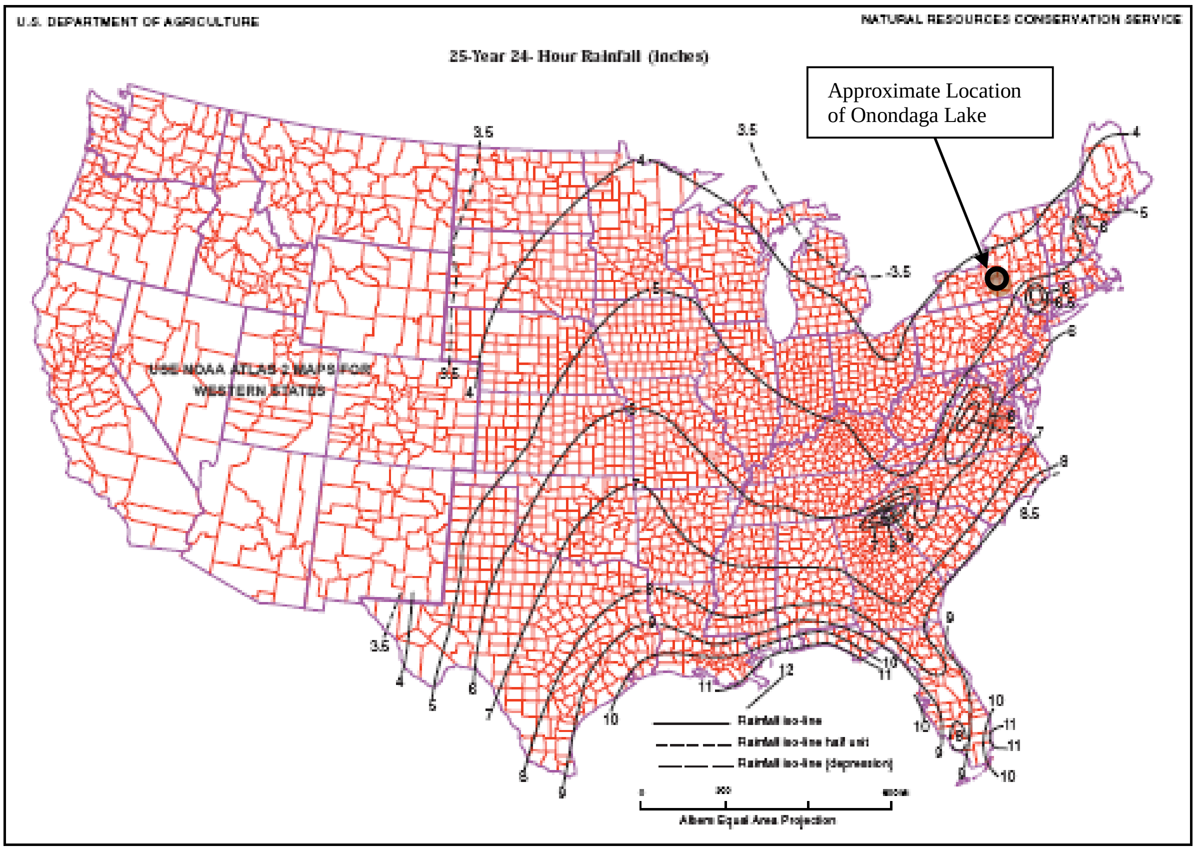

Figure 5: NRCS Map for Calculation of 25-year, 24-hour Storm Event [NRCS, 1986]

Note:

The value selected for the model is 4.40 inches, based on the approximate location of Onondaga Lake.

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Attachment 1: Example Calculation of Liquid Head on Two Different Slopes [Giroud et al., 2000]

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Impingement Rate, q_h 0.4 in./day 1.18E-07 m/s <-- Peak Daily Impingement Rate Calculated in HELP

Slope Geometry

Upstream Slope (i.e., SCA Top Area)					Downstream Slope (i.e., Main Deck Side Slopes)				
Drainage Length, D_{up}	150	ft	45.72	m	Drainage Length, D_{down}	100	ft	30.48	m
Inclination, β_{up}	0.57	°	0.01	rad	Inclination, β_{down}	14.03	°	0.24	rad
Horizontal Length, L_{up}	150	ft	45.72	m	Horizontal Length, L_{down}	97	ft	29.57	m
$L_{up} = D_{up} * \beta_{up}$					$L_{down} = D_{down} * \beta_{down}$				

Hydraulic Conductivities of Geocomposite Drainage Layer

Geocomposite Used	Biplanar, single-sided, 200-mil				Geocomposite Used	Biplanar, double-sided, 250-mil			
Geocomposite, k_{up}	-	-	0.027	m/s	Geocomposite, k_{down}	-	-	0.011	m/s

Calculated Liquid Head on Upstream and Downstream Slopes

$t_{up,max}$	0.02	m	$t_{down,max}$	3.45E-03	m
	0.80	in		0.14	in

$$t_{up\ max} \approx \frac{q_h L_{up}}{k_{up} \sin \beta_{up}}$$

$$t_{down\ max} = \frac{q_h \left(L_{up} + L_{down}\right)}{k_{down} \sin \beta_{down}}$$

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

Attachment 2: Example Calculation of Infiltration Rate through Geomembrane [Giroud, 1997]

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

Input Parameters	English Units		SI Units	
Geomembrane (GM) area, A	1	acre	4047	m^2
Liquid Head on top of GM, h	12.2	in	0.31	m
Thickness of underlying layer, t_u	2	ft	0.61	m
Permeability of underlying layer, k_u	1.85E-07	ft/s	5.65E-08	m/s
Contact quality factor, C_{qo}	0.21	-	0.21	-
Number of defects, n	1	-	1	-
Diameter of circular defect, d	0.45	in.	0.01	m

Calculated Leakage Rate Per GM Area	English Units		SI Units	
$Q_{leakage\ per\ area}$	3.00	gal/acre/day	3.29E-11	$m^3/s/m^2$

$$Q_{leakage\ per\ area} = \frac{n * 0.976 * C_{qo} * \left[1 + 0.1 * \left(\frac{h}{t_u}\right)^{0.95}\right] * d^{0.2} * h^{0.9} * {k_u}^{0.74}}{A}$$

Attachment 3: Example Calculation of Geocomposite Transmissivity

The specified value of transmissivity measured in a laboratory can be converted to a design hydraulic transmissivity by accounting for several reduction factors and an overall factor of safety, with the following equation:

$$\theta_{des} = \frac{\theta_{lab}}{RF_{CR} * RF_{IN} * RF_{CD} * RF_{PC} * RF_{CC} * RF_{BC} * FS}$$

Where:

- θ_{des} = Transmissivity for Design;
- θ_{lab} = Laboratory Measured Transmissivity = 1.0x10^{-3} m^2/s (i.e., 200-mil, single-sided geocomposite on SCA top areas);
- RF_{CR} = Reduction factor for creep = 1.20;
- RF_{IN} = Reduction factor for delayed intrusion = 1.10;
- RF_{CD} = Reduction factor for chemical degradation = 1.20;
- RF_{PC} = Reduction factor for particulate clogging = 1.20;
- RF_{CC} = Reduction factor for chemical clogging = 1.20;
- RF_{BC} = Reduction factor for biological clogging = 1.30; and
- FS = Overall factor of safety = 2.50.

Based on the above equation, the calculated design transmissivity for the geocomposite on the SCA top areas is 1.35x10^{-4} m^2/s. This can be converted to hydraulic conductivity using the following equation:

$$k = \frac{\theta}{t}$$

Where:

- k = Hydraulic conductivity;
- θ = Geocomposite transmissivity = 1.35x10^{-4} m^2/s (as calculated above); and
- t = Geocomposite thickness = 5.08x10^{-3} m (i.e., 200 mil or 0.2 in.).

Therefore, the calculated hydraulic conductivity for design is 2.66 cm/s.

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

Attachment 4: HELP Output Files

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

CASE 1: SCA TOP AREA WITHOUT A GEOCOMPOSITE DRAINAGE LAYER OR DRAINAGE COLLECTION PIPE

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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            **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    \OLPRECIP.D4
TEMPERATURE DATA FILE:      \OLTEMP.D7
SOLAR RADIATION DATA FILE:  \OLSOLAR.D13
EVAPOTRANSPIRATION DATA:    \OL_LAI35.D11
SOIL AND DESIGN DATA FILE:  \1-NO_GC.D10
OUTPUT DATA FILE:           \1-NO_GC.OUT

TIME:  12: 1     DATE:   6/30/2015

******************************************************************************

     TITLE:  Onondaga Lake SCA Closure

******************************************************************************
     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER 108
           THICKNESS                  =      6.00   INCHES
           POROSITY                   =      0.4630 VOL/VOL
           FIELD CAPACITY             =      0.2320 VOL/VOL
           WILTING POINT              =      0.1160 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4575 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC


                                 LAYER  2
                                 --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER 113
           THICKNESS                  =     18.00   INCHES
           POROSITY                   =      0.4300 VOL/VOL
           FIELD CAPACITY             =      0.3210 VOL/VOL
           WILTING POINT              =      0.2210 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4317 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-05 CM/SEC
           SLOPE                      =      1.00   PERCENT
           DRAINAGE LENGTH            =   1300.0    FEET
```

```
                         LAYER  3
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  36
THICKNESS                    =      0.04   INCHES
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.    =  0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD



           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  1.%
          AND A SLOPE LENGTH OF 1300. FEET.

SCS RUNOFF CURVE NUMBER              =     69.10
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =     10.516  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     10.518  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      4.674  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     10.516  INCHES
TOTAL INITIAL WATER                  =     10.516  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR



            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          SYRACUSE              NEW YORK

     STATION LATITUDE                    =  43.07 DEGREES
     MAXIMUM LEAF AREA INDEX             =   3.50
     START OF GROWING SEASON (JULIAN DATE)  =    124
     END OF GROWING SEASON (JULIAN DATE)    =    284
     EVAPORATIVE ZONE DEPTH              =  24.0  INCHES
     AVERAGE ANNUAL WIND SPEED           =   9.70 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  72.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  68.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  76.00 %
```

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR SYRACUSE NEW YORK

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.61	2.65	3.11	3.34	3.16	3.63
3.76	3.77	3.29	3.14	3.45	3.20

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR SYRACUSE NEW YORK

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
22.80	24.00	33.30	46.10	57.00	66.30
70.90	69.30	62.10	51.30	40.60	28.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR SYRACUSE NEW YORK AND STATION LATITUDE = 43.07 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.59	2.72	3.16	3.27	3.09	3.71
	3.87	3.95	3.27	2.95	3.40	3.22
STD. DEVIATIONS	0.70	0.96	1.19	1.19	1.31	1.57
	1.67	1.76	1.60	1.16	1.19	0.76
RUNOFF						
TOTALS	0.889	1.771	5.193	2.052	0.492	0.308
	0.055	0.023	0.039	0.252	1.048	1.446
STD. DEVIATIONS	0.970	1.706	2.501	1.404	0.701	0.666
	0.413	0.165	0.182	0.561	1.232	1.062
EVAPOTRANSPIRATION						
TOTALS	0.491	0.405	0.470	1.837	2.914	5.448
	5.583	3.820	2.212	1.093	0.761	0.507

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015

Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
  STD. DEVIATIONS        0.080    0.076    0.172    0.717    0.835    0.656
                         1.135    1.332    0.695    0.183    0.146    0.120

LATERAL DRAINAGE COLLECTED FROM LAYER  2
----------------------------------------
  TOTALS                 0.0001   0.0000   0.0001   0.0005   0.0006   0.0003
                         0.0001   0.0000   0.0001   0.0002   0.0005   0.0006

  STD. DEVIATIONS        0.0001   0.0000   0.0001   0.0002   0.0001   0.0001
                         0.0001   0.0001   0.0001   0.0003   0.0004   0.0003

PERCOLATION/LEAKAGE THROUGH LAYER  3
------------------------------------
  TOTALS                 0.0045   0.0038   0.0045   0.0106   0.0155   0.0118
                         0.0041   0.0013   0.0016   0.0049   0.0103   0.0117

  STD. DEVIATIONS        0.0013   0.0004   0.0011   0.0036   0.0005   0.0013
                         0.0032   0.0028   0.0038   0.0065   0.0067   0.0046


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  3
-------------------------------------
  AVERAGES               4.4064   3.8803   4.3791  13.9741  20.8395  16.2045
                         4.7325   1.4559   2.1355   6.3271  14.0326  14.9159

  STD. DEVIATIONS        1.8106   0.4340   1.5550   5.4595   0.6349   1.8954
                         4.2548   3.6065   5.2027   8.7343   9.3103   6.4841

*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                     INCHES           CU. FEET       PERCENT
                               -------------------  -------------  ---------
 PRECIPITATION                  39.20    (   4.823)    142279.7     100.00

 RUNOFF                         13.569   (  3.4003)     49254.68     34.618

 EVAPOTRANSPIRATION             25.541   (  2.5085)     92712.91     65.162

 LATERAL DRAINAGE COLLECTED      0.00309 (  0.00107)       11.233    0.00790
   FROM LAYER  2

 PERCOLATION/LEAKAGE THROUGH     0.08474 (  0.02064)      307.617     0.21621
   LAYER  3

 AVERAGE HEAD ON TOP             8.940 (    2.345)
   OF LAYER  3
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

```
 CHANGE IN WATER STORAGE         -0.002   (  1.3963)         -6.77     -0.005

*******************************************************************************
******************************************************************************

               PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                 (INCHES)      (CU. FT.)
                                                ----------   -------------
      PRECIPITATION                               4.40         15972.000

      RUNOFF                                      4.342        15759.7324

      DRAINAGE COLLECTED FROM LAYER  2            0.00003          0.12346

      PERCOLATION/LEAKAGE THROUGH LAYER  3        0.000582         2.11189

      AVERAGE HEAD ON TOP OF LAYER  3            24.000

      MAXIMUM HEAD ON TOP OF LAYER  3            34.066

      LOCATION OF MAXIMUM HEAD IN LAYER  2
            (DISTANCE FROM DRAIN)               377.3 FEET

      SNOW WATER                                  9.62         34911.7891


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.4383

      MINIMUM VEG. SOIL WATER (VOL/VOL)                   0.1948


       ***  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.

******************************************************************************

******************************************************************************

                  FINAL WATER STORAGE AT END OF YEAR  100
    ----------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            2.7450         0.4575

                     2            7.5390         0.4188

                     3            0.0000         0.0000

                 SNOW WATER       0.046

******************************************************************************
******************************************************************************
```

CASE 2: SCA TOP AREA WITH A 200-MIL GEOCOMPOSITE DRAINAGE LAYER AND 4-INCH DIAMETER DRAINAGE COLLECTION PIPE

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\OLPRECIP.D4
TEMPERATURE DATA FILE:      C:\OLTEMP.D7
SOLAR RADIATION DATA FILE:  C:\OLSOLAR.D13
EVAPOTRANSPIRATION DATA:    C:\OL_LAI35.D11
SOIL AND DESIGN DATA FILE:  C:\1-FN200D.D10
OUTPUT DATA FILE:           C:\1-FN200D.OUT

TIME:  33:50     DATE:   4/ 7/2015


******************************************************************************

     TITLE:  Onondaga Lake SCA Closure

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER 108
           THICKNESS                 =      6.00   INCHES
           POROSITY                  =      0.4630 VOL/VOL
           FIELD CAPACITY            =      0.2320 VOL/VOL
           WILTING POINT             =      0.1160 VOL/VOL
           INITIAL SOIL WATER CONTENT  =    0.4565 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC


                                   LAYER  2
                                   --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER 113
           THICKNESS                 =     18.00   INCHES
           POROSITY                  =      0.4300 VOL/VOL
           FIELD CAPACITY            =      0.3210 VOL/VOL
           WILTING POINT             =      0.2210 VOL/VOL
           INITIAL SOIL WATER CONTENT  =    0.4109 VOL/VOL
```

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
          EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-05 CM/SEC

                                  LAYER  3
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER 220
          THICKNESS                  =      0.20   INCHES
          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.  =   2.66000009000     CM/SEC
          SLOPE                      =      1.00   PERCENT
          DRAINAGE LENGTH            =    150.0    FEET


                                  LAYER  4
                                  --------

                      TYPE 4 - FLEXIBLE MEMBRANE LINER
                        MATERIAL TEXTURE NUMBER  36
          THICKNESS                  =      0.04   INCHES
          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.  =  0.399999993000E-12 CM/SEC
          FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
          FML PLACEMENT QUALITY      =  3 - GOOD


                  GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                  ----------------------------------------

        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
               SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
               GOOD STAND OF GRASS, A SURFACE SLOPE OF  1.%
               AND A SLOPE LENGTH OF  150. FEET.

       SCS RUNOFF CURVE NUMBER            =     72.80
       FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
       AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
       EVAPORATIVE ZONE DEPTH             =     24.0    INCHES
       INITIAL WATER IN EVAPORATIVE ZONE  =     10.136  INCHES
       UPPER LIMIT OF EVAPORATIVE STORAGE =     10.518  INCHES
       LOWER LIMIT OF EVAPORATIVE STORAGE =      4.674  INCHES
       INITIAL SNOW WATER                 =      0.000  INCHES
       INITIAL WATER IN LAYER MATERIALS   =     10.138  INCHES
       TOTAL INITIAL WATER                =     10.138  INCHES
       TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

```
                  EVAPOTRANSPIRATION AND WEATHER DATA
                  -----------------------------------

       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                SYRACUSE              NEW YORK

           STATION LATITUDE                        =  43.07 DEGREES
           MAXIMUM LEAF AREA INDEX                 =   3.50
           START OF GROWING SEASON (JULIAN DATE)   =    124
           END OF GROWING SEASON (JULIAN DATE)     =    284
           EVAPORATIVE ZONE DEPTH                  =  24.0  INCHES
           AVERAGE ANNUAL WIND SPEED               =   9.70 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  72.00 %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  68.00 %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  75.00 %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  76.00 %


       NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK

                NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
     2.61        2.65        3.11        3.34        3.16        3.63
     3.76        3.77        3.29        3.14        3.45        3.20


       NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK

           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    22.80       24.00       33.30       46.10       57.00       66.30
    70.90       69.30       62.10       51.30       40.60       28.30


       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK
                  AND STATION LATITUDE  =  43.07 DEGREES

*******************************************************************************

       AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
 ------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                2.59     2.72     3.16     3.27     3.09     3.71
                          3.87     3.95     3.27     2.95     3.40     3.22
```

```
  STD. DEVIATIONS        0.70     0.96     1.19     1.19     1.31     1.57
                         1.67     1.76     1.60     1.16     1.19     0.76

RUNOFF
------
  TOTALS                 0.506    1.384    4.816    1.516    0.049    0.080
                         0.031    0.035    0.062    0.039    0.067    0.256

  STD. DEVIATIONS        0.713    1.475    2.374    1.470    0.193    0.292
                         0.211    0.150    0.204    0.163    0.217    0.496

EVAPOTRANSPIRATION
------------------
  TOTALS                 0.490    0.404    0.468    1.855    2.949    5.254
                         4.158    3.533    2.211    1.141    0.788    0.510

  STD. DEVIATIONS        0.081    0.077    0.174    0.734    0.830    0.736
                         1.412    1.227    0.713    0.197    0.149    0.122

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 0.0484   0.0000   0.1201   1.3789   0.6625   0.2505
                         0.0417   0.0418   0.0842   0.4415   1.1764   1.1200

  STD. DEVIATIONS        0.1498   0.0000   0.3439   0.5820   0.5506   0.3269
                         0.1538   0.2041   0.2653   0.6919   0.8863   0.8028

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                 0.0084   0.0000   0.0355   0.3590   0.1667   0.0747
                         0.0119   0.0076   0.0187   0.0902   0.2373   0.2163

  STD. DEVIATIONS        0.0264   0.0000   0.1000   0.1499   0.1341   0.0653
                         0.0371   0.0362   0.0565   0.1488   0.2086   0.1744


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  4
-------------------------------------
  AVERAGES               0.0049   0.0000   0.0776   0.6678   0.1156   0.0216
                         0.0047   0.0046   0.0167   0.0892   0.2918   0.2201

  STD. DEVIATIONS        0.0351   0.0000   0.2186   0.3307   0.2758   0.0771
                         0.0383   0.0301   0.0668   0.2297   0.4472   0.3309

*******************************************************************************

*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                     INCHES           CU. FEET       PERCENT
                               -------------------  -------------   ---------
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

```
PRECIPITATION                39.20    (   4.823)     142279.7     100.00

RUNOFF                        8.841   (  2.4182)      32094.07     22.557

EVAPOTRANSPIRATION           23.762   (  2.7230)      86255.23     60.624

LATERAL DRAINAGE COLLECTED    5.36610 (  1.92120)     19478.934   13.69060
  FROM LAYER  3

PERCOLATION/LEAKAGE THROUGH   1.22639 (  0.42197)      4451.789    3.12890
  LAYER  4

AVERAGE HEAD ON TOP           0.126 (    0.060)
  OF LAYER  4

CHANGE IN WATER STORAGE       0.000   (  1.2771)         -0.39      0.000
*******************************************************************************

*******************************************************************************

               PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------    -------------
       PRECIPITATION                            4.40        15972.000

       RUNOFF                                   4.213       15292.6318

       DRAINAGE COLLECTED FROM LAYER  3         0.24285       881.55237

       PERCOLATION/LEAKAGE THROUGH LAYER  4     0.107264      389.36798

       AVERAGE HEAD ON TOP OF LAYER  4         10.022

       MAXIMUM HEAD ON TOP OF LAYER  4         12.203

       LOCATION OF MAXIMUM HEAD IN LAYER  3
             (DISTANCE FROM DRAIN)             74.5 FEET

       SNOW WATER                               9.62        34911.7891


       MAXIMUM VEG. SOIL WATER (VOL/VOL)                0.4379

       MINIMUM VEG. SOIL WATER (VOL/VOL)                0.1948


        ***  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.


*******************************************************************************
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

```
******************************************************************************

                  FINAL WATER STORAGE AT END OF YEAR  100
    ----------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            2.7450         0.4575

                     2            7.3342         0.4075

                     3            0.0020         0.0100

                     4            0.0000         0.0000

                  SNOW WATER      0.046

******************************************************************************
******************************************************************************
```

CASE 3: SCA MAIN DECK SIDE SLOPES WITH A 200-MIL GEOCOMPOSITE DRAINAGE LAYER

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    \OLPRECIP.D4
TEMPERATURE DATA FILE:      \OLTEMP.D7
SOLAR RADIATION DATA FILE:  \OLSOLAR.D13
EVAPOTRANSPIRATION DATA:    \OL_LAI35.D11
SOIL AND DESIGN DATA FILE:  \S-FN200A.D10
OUTPUT DATA FILE:           \S-FN200A.OUT

TIME:  18:45     DATE:   4/14/2015

******************************************************************************

     TITLE:  Onondaga Lake SCA Closure

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER 108
           THICKNESS                    =      6.00   INCHES
           POROSITY                     =      0.4630 VOL/VOL
           FIELD CAPACITY               =      0.2320 VOL/VOL
           WILTING POINT                =      0.1160 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.4560 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC


                                  LAYER  2
                                  --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER 113
           THICKNESS                    =     18.00   INCHES
           POROSITY                     =      0.4300 VOL/VOL
           FIELD CAPACITY               =      0.3210 VOL/VOL
           WILTING POINT                =      0.2210 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.4115 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC
```

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
                         LAYER  3
                         --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER 220
   THICKNESS                    =      0.20   INCHES
   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.    =  0.270000011000     CM/SEC
   SLOPE                        =     25.00   PERCENT
   DRAINAGE LENGTH              =    100.0    FEET


                         LAYER  4
                         --------

               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  36
   THICKNESS                    =      0.04   INCHES
   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.    =  0.399999993000E-12 CM/SEC
   FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
   FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
   FML PLACEMENT QUALITY        =  3 - GOOD


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
           GOOD STAND OF GRASS, A SURFACE SLOPE OF 25.%
           AND A SLOPE LENGTH OF  100. FEET.

SCS RUNOFF CURVE NUMBER            =     75.90
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
EVAPORATIVE ZONE DEPTH             =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     10.143  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     10.518  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      4.674  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     10.145  INCHES
TOTAL INITIAL WATER                =     10.145  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
                  EVAPOTRANSPIRATION AND WEATHER DATA
                  -----------------------------------

       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                SYRACUSE              NEW YORK

           STATION LATITUDE                      =  43.07 DEGREES
           MAXIMUM LEAF AREA INDEX               =   3.50
           START OF GROWING SEASON (JULIAN DATE)  =    124
           END OF GROWING SEASON (JULIAN DATE)    =    284
           EVAPORATIVE ZONE DEPTH                =  24.0  INCHES
           AVERAGE ANNUAL WIND SPEED             =   9.70 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  72.00 %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  68.00 %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  75.00 %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  76.00 %


       NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK

                NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
      2.61        2.65        3.11        3.34        3.16        3.63
      3.76        3.77        3.29        3.14        3.45        3.20


       NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK

           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
     22.80       24.00       33.30       46.10       57.00       66.30
     70.90       69.30       62.10       51.30       40.60       28.30


       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK
                  AND STATION LATITUDE  =  43.07 DEGREES

*******************************************************************************

       AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------

                             JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                             -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                     2.59     2.72     3.16     3.27     3.09     3.71
                               3.87     3.95     3.27     2.95     3.40     3.22
```

```
  STD. DEVIATIONS        0.70     0.96     1.19     1.19     1.31     1.57
                         1.67     1.76     1.60     1.16     1.19     0.76
RUNOFF
------
  TOTALS                 0.510    1.388    4.823    1.526    0.058    0.088
                         0.035    0.040    0.070    0.051    0.080    0.262

  STD. DEVIATIONS        0.716    1.478    2.376    1.470    0.204    0.304
                         0.213    0.151    0.217    0.173    0.224    0.499

EVAPOTRANSPIRATION
------------------
  TOTALS                 0.490    0.404    0.468    1.854    2.949    5.252
                         4.163    3.531    2.208    1.139    0.787    0.510

  STD. DEVIATIONS        0.080    0.077    0.174    0.733    0.831    0.738
                         1.409    1.225    0.712    0.197    0.148    0.122

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 0.0466   0.0000   0.1571   1.6530   0.7225   0.2818
                         0.0473   0.0447   0.0897   0.4903   1.3411   1.2196

  STD. DEVIATIONS        0.1503   0.0000   0.4386   0.6618   0.6178   0.3567
                         0.1722   0.2194   0.2881   0.7815   1.0325   0.9122

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                 0.0034   0.0000   0.0063   0.0843   0.0715   0.0374
                         0.0053   0.0032   0.0067   0.0338   0.0830   0.0788

  STD. DEVIATIONS        0.0109   0.0000   0.0179   0.0348   0.0270   0.0232
                         0.0136   0.0141   0.0198   0.0480   0.0532   0.0453


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  4
-------------------------------------
  AVERAGES               0.0004   0.0000   0.0014   0.0153   0.0065   0.0026
                         0.0004   0.0004   0.0008   0.0044   0.0124   0.0109

  STD. DEVIATIONS        0.0013   0.0000   0.0039   0.0061   0.0055   0.0033
                         0.0015   0.0020   0.0027   0.0070   0.0096   0.0082

*******************************************************************************

*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                 INCHES             CU. FEET       PERCENT
                           -------------------   -------------   ---------
 PRECIPITATION               39.20     (   4.823)     142279.7     100.00
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

RUNOFF	8.932	(2.4161)	32422.89	22.788
EVAPOTRANSPIRATION	23.756	(2.7218)	86235.50	60.610
LATERAL DRAINAGE COLLECTED FROM LAYER 3	6.09367	(2.15624)	22120.031	15.54687
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.41371	(0.13082)	1501.749	1.05549
AVERAGE HEAD ON TOP OF LAYER 4	0.005	(0.002)		
CHANGE IN WATER STORAGE	0.000	(1.2799)	-0.49	0.000

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.40	15972.000
RUNOFF	4.215	15300.2031
DRAINAGE COLLECTED FROM LAYER 3	0.32939	1195.67102
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.010766	39.08068
AVERAGE HEAD ON TOP OF LAYER 4	0.091	
MAXIMUM HEAD ON TOP OF LAYER 4	0.185	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	9.62	34911.7891

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4371
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1948

*** 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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Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
******************************************************************************

                   FINAL WATER STORAGE AT END OF YEAR  100
    ----------------------------------------------------------------------
                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1            2.7450         0.4575

                      2            7.3386         0.4077

                      3            0.0020         0.0100

                      4            0.0000         0.0000

                   SNOW WATER      0.046

******************************************************************************
******************************************************************************
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

CASE 4: SCA MAIN DECK SIDE SLOPES WITH A 250-MIL GEOCOMPOSITE DRAINAGE LAYER

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

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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                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    \OLPRECIP.D4
TEMPERATURE DATA FILE:      \OLTEMP.D7
SOLAR RADIATION DATA FILE:  \OLSOLAR.D13
EVAPOTRANSPIRATION DATA:    \OL_LAI35.D11
SOIL AND DESIGN DATA FILE:  \S-FN250.D10
OUTPUT DATA FILE:           \S-FN250A.OUT

TIME:  20: 8     DATE:   4/15/2015

******************************************************************************

     TITLE:  Onondaga Lake SCA Closure

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER 108
           THICKNESS                   =      6.00   INCHES
           POROSITY                    =      0.4630 VOL/VOL
           FIELD CAPACITY              =      0.2320 VOL/VOL
           WILTING POINT               =      0.1160 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.4555 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC


                                   LAYER  2
                                   --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER 113
           THICKNESS                   =     18.00   INCHES
           POROSITY                    =      0.4300 VOL/VOL
           FIELD CAPACITY              =      0.3210 VOL/VOL
           WILTING POINT               =      0.2210 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.4120 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-05 CM/SEC
```

Written by:	**Ray Wu / Clinton Carlson**	Date:	**08/20/2015**	Reviewed by:	**Sowmya Bulusu / Jay Beech**	Date:	**08/20/2015**
Client:	**Honeywell**	Project:	**Onondaga Lake SCA Final Cover Design**	Project/ Proposal No.:	**GD5497**	Task No.:	**03**

```
                         LAYER  3
                         --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER 220
 THICKNESS                  =      0.25   INCHES
 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.  =   1.05999994000     CM/SEC
 SLOPE                      =     25.00   PERCENT
 DRAINAGE LENGTH            =    100.0    FEET


                         LAYER  4
                         --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  36
 THICKNESS                  =      0.04   INCHES
 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.  =  0.399999993000E-12 CM/SEC
 FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
 FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
 FML PLACEMENT QUALITY      =  3 - GOOD


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF 25.%
          AND A SLOPE LENGTH OF  100. FEET.

 SCS RUNOFF CURVE NUMBER            =     75.90
 FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
 EVAPORATIVE ZONE DEPTH             =     24.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =     10.148  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =     10.518  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      4.674  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     10.151  INCHES
 TOTAL INITIAL WATER                =     10.151  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

```
                EVAPOTRANSPIRATION AND WEATHER DATA
                -----------------------------------

       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                SYRACUSE              NEW YORK

           STATION LATITUDE                        =  43.07 DEGREES
           MAXIMUM LEAF AREA INDEX                 =   3.50
           START OF GROWING SEASON (JULIAN DATE)   =    124
           END OF GROWING SEASON (JULIAN DATE)     =    284
           EVAPORATIVE ZONE DEPTH                  =  24.0  INCHES
           AVERAGE ANNUAL WIND SPEED               =   9.70 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  72.00 %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  68.00 %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  75.00 %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  76.00 %

       NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK

                NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
     2.61        2.65        3.11        3.34        3.16        3.63
     3.76        3.77        3.29        3.14        3.45        3.20

       NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK

           NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    22.80       24.00       33.30       46.10       57.00       66.30
    70.90       69.30       62.10       51.30       40.60       28.30


       NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                COEFFICIENTS FOR    SYRACUSE            NEW YORK
                  AND STATION LATITUDE  =  43.07 DEGREES


*******************************************************************************

       AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
 ------------------------------------------------------------------------------

                          JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                          -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                  2.59     2.72     3.16     3.27     3.09     3.71
                            3.87     3.95     3.27     2.95     3.40     3.22
```

```
    STD. DEVIATIONS        0.70     0.96     1.19     1.19     1.31     1.57
                           1.67     1.76     1.60     1.16     1.19     0.76

  RUNOFF
  ------
    TOTALS                 0.512    1.391    4.826    1.528    0.059    0.093
                           0.037    0.044    0.073    0.053    0.082    0.264

    STD. DEVIATIONS        0.717    1.479    2.377    1.469    0.207    0.315
                           0.221    0.160    0.222    0.178    0.228    0.501

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.490    0.404    0.468    1.854    2.949    5.256
                           4.168    3.530    2.205    1.139    0.786    0.510

    STD. DEVIATIONS        0.080    0.077    0.174    0.732    0.831    0.736
                           1.408    1.223    0.708    0.197    0.148    0.122

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  ----------------------------------------
    TOTALS                 0.0467   0.0000   0.1626   1.7011   0.7606   0.2958
                           0.0495   0.0453   0.0916   0.5080   1.3934   1.2583

    STD. DEVIATIONS        0.1533   0.0000   0.4515   0.6685   0.6241   0.3591
                           0.1786   0.2222   0.2922   0.8053   1.0617   0.9364

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  ------------------------------------
    TOTALS                 0.0012   0.0000   0.0026   0.0341   0.0271   0.0140
                           0.0019   0.0012   0.0026   0.0133   0.0329   0.0307

    STD. DEVIATIONS        0.0041   0.0000   0.0074   0.0136   0.0108   0.0093
                           0.0054   0.0055   0.0077   0.0189   0.0212   0.0185

-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES               0.0001   0.0000   0.0004   0.0042   0.0019   0.0008
                           0.0001   0.0001   0.0002   0.0012   0.0035   0.0031

    STD. DEVIATIONS        0.0004   0.0000   0.0011   0.0017   0.0015   0.0009
                           0.0004   0.0005   0.0007   0.0019   0.0027   0.0023

*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                  INCHES            CU. FEET       PERCENT
                            -------------------   -------------   ---------
 PRECIPITATION                39.20    (   4.823)     142279.7     100.00
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Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015

Client:	Honeywell	Project:	Onondaga Lake SCA Final Cover Design	Project/ Proposal No.:	GD5497	Task No.:	03

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RUNOFF                            8.962   (  2.4162)      32533.42     22.866

EVAPOTRANSPIRATION               23.759   (  2.7202)      86244.54     60.616

LATERAL DRAINAGE COLLECTED        6.31278 (  2.22009)     22915.404   16.10589
  FROM LAYER  3

PERCOLATION/LEAKAGE THROUGH       0.16169 (  0.05215)       586.931     0.41252
  LAYER  4

AVERAGE HEAD ON TOP               0.001 (    0.000)
  OF LAYER  4

CHANGE IN WATER STORAGE           0.000   (  1.2801)         -0.64      0.000

*******************************************************************************

*******************************************************************************

               PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------    -------------
     PRECIPITATION                               4.40         15972.000

     RUNOFF                                      4.216        15303.1348

     DRAINAGE COLLECTED FROM LAYER  3            0.34649       1257.74072

     PERCOLATION/LEAKAGE THROUGH LAYER  4        0.005485        19.91227

     AVERAGE HEAD ON TOP OF LAYER  4             0.025

     MAXIMUM HEAD ON TOP OF LAYER  4             0.034

     LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)                25.9 FEET

     SNOW WATER                                  9.62         34911.7891


     MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.4372

     MINIMUM VEG. SOIL WATER (VOL/VOL)                   0.1948


      ***  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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Written by:	Ray Wu / Clinton Carlson	Date:	08/20/2015	Reviewed by:	Sowmya Bulusu / Jay Beech	Date:	08/20/2015
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                 FINAL WATER STORAGE AT END OF YEAR  100
      ----------------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1           2.7450          0.4575

                    2           7.3398          0.4078

                    3           0.0025          0.0100

                    4           0.0000          0.0000

                 SNOW WATER     0.046

******************************************************************************
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