APPENDIX A

Action Leakage Rate (ALR) Calculation

Golder Associates

CALCULATIONS

Date:	**April 16, 2013** **Revised November 4, 2013**	**Made by:** **Checked by:**	**JPG** **BJG**
Project No.:	**123-89494**	**Revised by:** **Checked by:**	**MTW** **JB**
Subject:	**Action Leakage Rate Calculation**	**Reviewed by:**	(PAM) 11/4/13
Project Short Title:	**FACULTATIVE POND RESPONSE ACTION PLAN FOR RMU-2 EXPANSION**		

In accordance with 6 NYCRR Part 373.2-11 regulations, the action leakage rate (ALR) must be calculated for Facultative (Fac) Pond 5 as part of the RMU-2 expansion. *This revision of the ALR calculation includes only Fac Pond 5.*

1.0 OBJECTIVE

Determine the ALR for the Facultative Pond 5 leak detection system (LDS). The ALR is defined as the maximum design flow rate that the LDS can remove without the fluid head on the bottom liner exceeding one (1) foot.

2.0 METHOD

The ALR is the maximum design flow rate that the LDS can remove without the fluid head on the bottom liner exceeding 1 foot. In order for liquid to flow through the LDS, it must be collected and conveyed to the sump and then flow into the perforated section of the side slope riser pipe and be pumped out. This calculation will determine the limiting flow rate, ie. the ALR.

3.0 REFERENCES

1. "Response Action Plan Residuals Management Unit 1 Model City TSDR Facility" prepared by Rust Environment and Infrastructure, February 1993.
2. "Response Action Plan Residuals Management Unit 2" prepared by Arcadis, April 2003. Revised August 2013.
3. RMU-2 Technical Specifications, Section 02210, Earthworks, Article 2.09.
4. Fac Pond Permit Drawing No. 3 "Fac Pond Grading Plans" prepared by Arcadis of New York, Inc., August 2009. Revised November 2013.
5. Fac Pond Permit Drawing No. 4 "Fac Pond Sections and Details" prepared by Arcadis of New York, Inc., August 2009. Revised November 2013.
6. 6 NYCRR Subpart 373.2-11 Surface Impoundments, effective September 6, 2006.

Golder Associates Inc.
10 Canal Street, Suite 217
Bristol, PA 19007 USA
Tel: (215) 826-1560 Fax: (215) 826-9458 www.golder.com

4.0 ASSUMPTIONS

1. The liner system has been designed to meet the minimum requirements outlined in Reference 5.
2. The LDS has been designed to meet the minimum requirements outlined in Reference 5 for permeability/transmissivity, bottom slope, clogging, and sump size.
3. Liquids collected in the LDS sump will be pumped to minimize head on the bottom liner.

5.0 CALCULATION

Three potentially limiting flow rates will be evaluated to determine the ALR. These flow rates are:

- Flow rate from the geocomposite that drains directly into the sump.
- Flow rate through the stone in the vicinity of the perforated section of the side slope riser pipe.
- Flow rate through the perforations in the horizontal portion of the side slope riser.

5.1 Flow Rate Through Geocomposite

The daily flow rate from the geocomposite draining directly into the sump can be calculated as:

$$Q_{GEO} = L\Phi i$$

Where,

Φ	=	Geocomposite transmissivity (per Reference 5) Minimum design value = 3.0 x 10^{-4} m^2/sec = 0.003 ft^2/sec
L	=	Length of geocomposite draining directly into the sump
i	=	Hydraulic gradient perpendicular to the rim of the sump From Figure 34 (Reference 3), both Fac ponds have floor slopes of 1.4% and side slopes of 33%.

Sumps are square in plan view with a trapezoidal cross-section. The bottom dimensions are 10 feet by 10 feet, the side slopes are 3H:1V, and the sump is two (2) feet deep. The rim dimensions at the top of the sump are each 22 feet in length.

Sides parallel to the centerline of the pond are assumed to have hydraulic gradient of 0.014. Sides perpendicular to the center line of the pond have hydraulic gradients as follows:

i = 0.33 (pond side slope) and i = 0.016 (along pond centerline)

$$Q_{GEO} = L\Phi i$$

$$Q_{GEO} = 22\ (0.003)\ (0.33) + 22(0.003)(0.014) + 22(0.003)(0.014) + 22(0.003)(0.016)$$

$$Q_{GEO} = 0.0218\ cfs + 0.000924\ cfs + 0.000924\ cfs + 0.00106\ cfs$$

$$Q_{GEO} = 0.0247\ cfs = 15{,}964\ gpd$$

5.2 Flow Rate Through Sump Drainage Stone

Since sump design is the same for both basins, this calculation is applicable to both basins.

Using the flownet created for the sump, the flow through the stone is calculated:

$$Q_{FLOWNET} = k\,H\,\frac{N_f}{N_D}L$$

Where,

k	=	Hydraulic conductivity of drainage stone; 0.4 cm/s = 1,134 ft/day (Reference 3).
H	=	Head difference between free surface at top of drainage stone (equal to 1 foot above the top of the secondary liner at the sump fringe) and average centroid of perforations (ie. center of pipe).
	=	2.25 ft.
N_f	=	Number of flow paths from flow net = 8
N_d	=	Number of equipotential drops from flow net = 3
L	=	Length of perforated pipe = 10 ft.

$$Q_{FLOWNET} = (1{,}134\,ft/day)\,(2.25\,ft)\,\frac{8}{3}(10\,ft)$$

$$Q_{FLOWNET} = 68{,}040\,\frac{ft^3}{day} = 508{,}939\,gpd$$

5.3 Flow Rate Through Perforation in Side Slope Pipe

For an 18-inch diameter perforated pipe in the sump, using an orifice equation, the flow through the perforations calculated:

$$Q_{ORIFICE} = CA\sqrt{2gh}$$

Where,

C	=	Orifice coefficient (assume 0.61 for sharp edged orifice).
A	=	Area of orifice (ft^2)
g	=	Acceleration due to gravity (32.2 ft/sec^2)
h	=	Head above side slope riser pipe (ft) (assume middle of pipe)

From Advanced Drainage Systems, Inc. manufacturer data for perforated high density polyethylene pipe (HDPE), standard AASHTO class II perforated 18-inch dia. pipe has minimum water inlet area of 1.42 in^2/ft = 0.00986 ft^2/ft.

$$Q_{ORIFICE} = 0.61(0.00986)\sqrt{2 * 32.2 * 2.25}$$

$$Q_{ORIFICE} = 0.072\,\frac{cfs}{linear\ foot}$$

$$Q_{PERF} = (Length\ of\ perforated\ pipe)(Q_{ORIFICE})$$

$$Q_{PERF} = 10ft\ \times 0.072\,\frac{cfs}{linear\ foot}$$

$$Q_{PERF} = 0.72\,cfs = 465{,}348\,gpd$$

6.0 CONCLUSIONS

The daily flow rate from the drainage geocomposite at the edge of the sump is the limiting factor.

A factor of safety of 2.0 is applied to the limit flow rate for the pond to determine the pond-specific ALRs.

Fac Pond 5
ALR = 0.5 x 15,964 gpd
ALR = 7,982 gpd

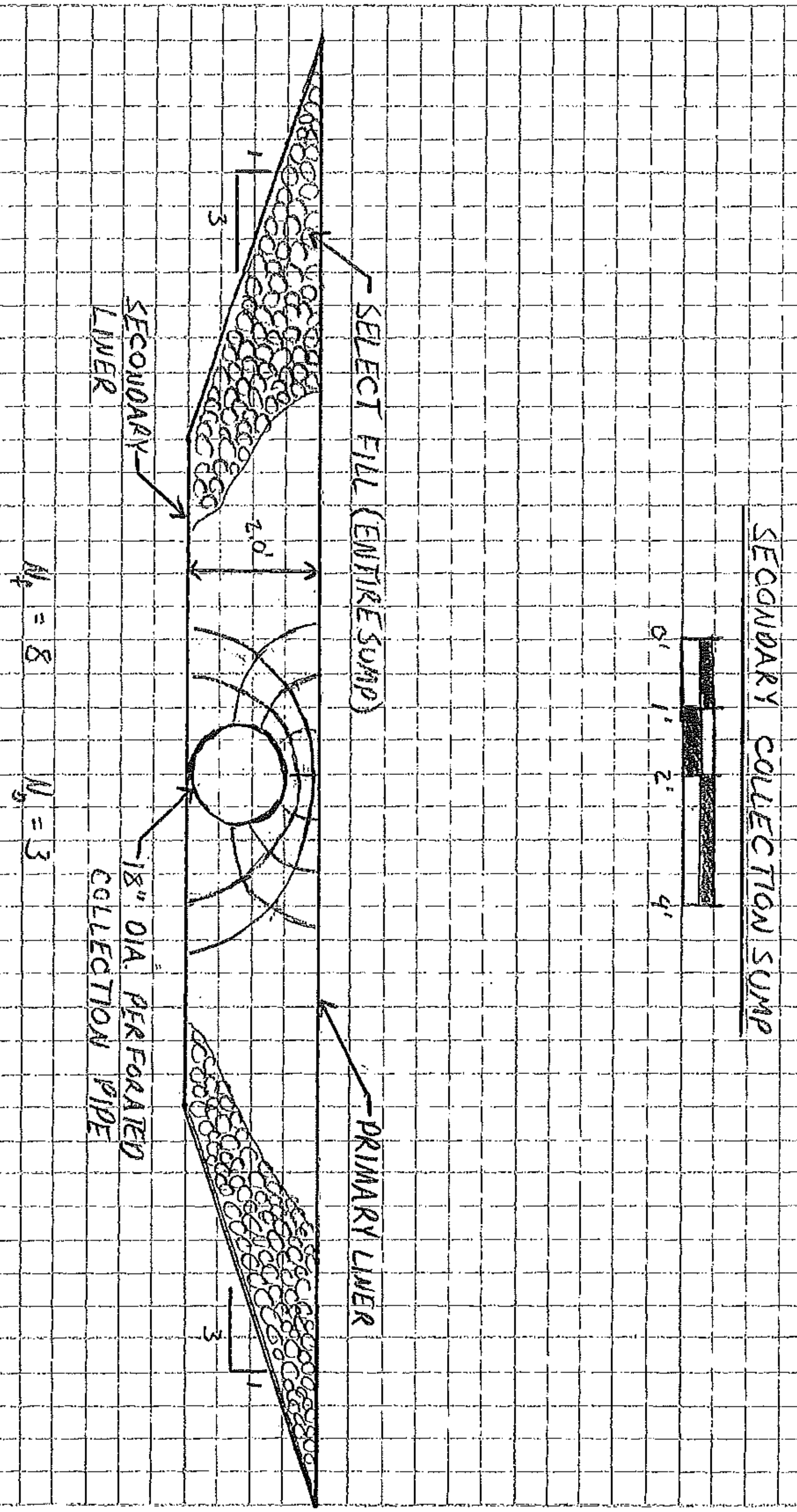
Table 1: Calculated ALR Values

Fac Pond	Pond-Specific ALR [gpd]	Pond Area[1] [acres]	Unit-Specific ALR [gpad]
5	7,982	4.7	1,698

Notes:
1. Pond area is the planimetric area as measured along the centerline of the top of slope for the side slope liner system.

Golder Associates

SUBJECT Model City Fac Ponds ALR		
Job No. 123-89494	Made by JPG	Date 2/13/13
Ref.	Checked	Sheet 5 of 5
	Reviewed	



APPENDIX B

Response Rate (RR) Calculation

Golder Associates

CALCULATIONS

Date:	April 16, 2013 Revised November 4, 2013	**Made by:**	BJG
		Checked by:	JPG
Project No.:	123-89494	**Revised by:**	MTW
		Checked by:	JB
Subject:	Response Rate Calculation	**Reviewed by:**	PAW 11/4/13
Project Short Title:	**FACULTATIVE POND RESPONSE ACTION PLAN FOR RMU-2 EXPANSION**		

In accordance with 6 NYCRR Part 373.2-11 regulations, the computed action leakage rate (ALR) must include a Response Rate (RR) calculation. The RR calculation includes the likelihood and amounts of other sources of liquids in the leak detection system (LDS) calculated for Facultative (FAC) Pond 5 as part of the RMU-2 expansion. *This revision of the calculation includes only Fac Pond 5.*

1.0 OBJECTIVE

Quantify the leakage Response Rate in FAC Pond 5 at the Model City Landfill.

2.0 METHOD

The Response Rate is equal to the maximum anticipated inflow to the LDS from all likely sources. Permeation through the primary and secondary geomembrane layers and leakage through the secondary geomembrane will be combined to calculate the maximum anticipated inflow.

3.0 REFERENCES

1. "Soil Mechanics and Foundations," 2nd Edition, Budhu, 2007.
2. "Response Action Plan Residuals Management Unit 2," prepared by Arcadis, April 2003. Revised August 2013.
3. "Response Action Plan Residuals Management Unit 1 Model City TSDR Facility," prepared by RUST Environment and Infrastructure, February 1993.
4. "Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation: Version 3," U.S. Environmental Protection Agency, August 1994.
5. "Hydrologic Evaluation of Landfill Performance (HELP) Model User's Guide: Version 3," U.S. Environmental Protection Agency, September 1994.
6. Fac Pond Permit Drawing No. 3 "Fac Pond Grading Plans" prepared by Arcadis of New York, Inc., August 2009. Revised November 2013.
7. Fac Pond Permit Drawing No. 4 "Fac Pond Sections and Details" prepared by Arcadis of New York, Inc., August 2009. Revised November 2013.
8. 6 NYCRR Subpart 373.2-11 Surface Impoundments, effective September 6, 2006.
9. "Upper Tills Unit Potentiometric Surface Contours October 2011" drawing prepared by Golder Associates Inc. dated January 2012.

Golder Associates Inc.
10 Canal Street, Suite 217
Bristol, PA 19007 USA
Tel: (215) 826-1560 Fax: (215) 826-9458 www.golder.com

4.0 ASSUMPTIONS

1) Manufacturing defects in the primary geomembrane occur at a rate of 1 per acre and are approximately 1 mm in diameter (Reference 4).

2) Installation defects in the primary geomembrane occur at a rate of 5 per acre and are assumed to be 1 cm^2 in area (Reference 4).

3) Manufacturing defects in the secondary geomembrane occur at a rate of 1 per acre and are approximately 1 mm in diameter (Reference 4).

4) Installation defects in the secondary geomembrane occur at a rate of 5 per acre and are assumed to be 1 cm^2 in area (Reference 4).

5) The liner system cross section is composed (working from top to bottom) of a primary 30-mil Ethylene Interpolymer Alloy (EIA) geomembrane, a 200-mil Geosynthetic Clay Liner (GCL), a geocomposite drainage layer, a secondary 30-mil EIA geomembrane, and a 3-foot thick layer of compacted clay. The hydraulic conductivity of the EIA liner is assumed to be $2x10^{-11}$ cm/s, which is one of the highest hydraulic conductivities for geomembrane materials listed in the HELP Engineering Document (Reference 4). The hydraulic conductivity of the GCL is assumed to be $5x10^{-9}$ cm/s (Reference 2), and the hydraulic conductivity of the compacted clay is assumed to be $1x10^{-7}$ cm/s (Reference 2).

6) The combined effective hydraulic conductivity through two or more layers is calculated using the procedure described in Reference 5.

5.0 CALCULATION

5.1 Leakage Through the Primary Liner System

The leakage of liquid stored in the pond through the primary liner system is influenced by the number and size of small defects in the geomembrane and the transmissivity of the GCL layer directly below. Assumptions 1 and 2 outline the estimated defects due to manufacturing and installation per the EPA's HELP Model Engineering Documents (Reference 4). Leakage through these geomembrane defects is estimated using equation 149 from Reference 4 outlined below:

$$q_h = k_s i_{ave} n \pi R^2 (0.87719)$$

Where,

q_h	=	flow per unit area of geomembrane (m/s)
k_s	=	hydraulic conductivity of controlling soil layer = $1x10^{-9}$ m/s
i_{ave}	=	average hydraulic gradient from HELP equ. 150
n	=	number of defects per unit area (#/m^2)
R	=	radius of wetted area around flaw from HELP equ. 162 (m)

The average hydraulic gradient is calculated using equation 150 from Reference 4 outlined below:

$$i_{ave} = 1 + [h_g \div (2T_s * \ln(R \div r_o)]$$

Where,

h_g = hydraulic head on secondary layer (m)
T_s = thickness of controlling soil layer (m)
r_o = radius of defect (m)

The radius of wetted area around each defect is calculated using equation 162 from Reference 4 outlined below:

$$R = 0.26a_o^{0.05}h_g^{0.45}k_s^{-0.13}$$

Where,

a_o = area of defect (m^2)

<u>Leakage Through Manufacturing Defects in Primary Geomembrane for FAC Pond 5</u>

$$R = 0.26a_o^{0.05}h_g^{0.45}k_s^{-0.13}$$

Where,

a_o = area of defect (m^2) = $7.85x10^{-7}$ m^2
h_g = hydraulic head on secondary layer (m) = 16.2 ft = 4.94 m
k_s = hydraulic conductivity of controlling layer = $5x10^{-9}$ m/s

$$R = 0.26(7.85x10^{-7})^{0.05}(4.94)^{0.45}(5.00x10^{-9})^{-0.13}$$

$$\boldsymbol{R = 5.77\ m;}$$

$$i_{ave} = 1 + [h_g \div (2T_s * \ln(R/r_o)]$$

Where,

h_g = hydraulic head on secondary layer (m) = 16.2 ft = 4.94 m
T_s = thickness of controlling soil layer (m) = .0167 ft = 0.0051 m
r_o = radius of defect (m) = $5.0x10^{-4}$ m

$$i_{ave} = 1 + [4.94 \div (2(0.005) * \ln(5.77/5.0x10^{-4})]$$

$$\boldsymbol{i_{ave} = 52.86;}$$

$$q_h = k_s i_{ave} n \pi R^2 (0.87719)$$

$$q_h = (5x10^{-9} cm/s)(52.86)(1 flaw \div 4046 m^2)\pi(5.77m)^2(0.87719)$$

$$\boldsymbol{q_h = ((5.99 \times 10^{-11}\ m/s)(86,400\ s/day)(1.0\ acres)) \div (9.35 \times 10^{-7}\ gallons/[meter \cdot acres])}$$
$$\boldsymbol{q_h = 5.53\ gallons/acre/day}$$

This calculated flow rate is 5.53 gallons/acre/day of liquid from the pond leaking through manufacturing defects in the primary geomembrane of FAC Pond 5. A summary of leakage through the primary liner for the pond can be found in Table 1.

5.2 Permeation Through the Primary Liner System

Permeation through the primary geomembrane occurs regardless of the presence of material or installation defects. The flow rate through the primary liner is estimated using Darcy's Law (Reference 1):

$$Q = k_e iA$$

Where,

k_e = effective hydraulic conductivity (ft/day)
i = hydraulic gradient across the geomembrane = H/t
H = hydraulic head (ft) = Max. Operating Level of Pond
t = geomembrane thickness (ft)
A = Area of Liner (ft^2)

The effective hydraulic conductivity combines the hydraulic conductivities of the geomembrane and the GCL layer directly below it. The effective hydraulic conductivity is calculated using the following equation (Reference 5):

$$k_e = (t_1+t_2)\div[(t_1\div k_1)+(t_2\div k_2)]$$

Where,

k_e = Effective hydraulic conductivity (ft/day)
k_1 = Hydraulic conductivity of layer 1 (ft/day)
t_2 = Thickness of layer 1 (ft)
k_1 = Hydraulic conductivity of layer 2 (ft/day)
t_2 = Thickness of layer 2 (ft)

Permeation Through Primary Geomembrane for FAC Pond 5

$$k_e = (t_1+t_2)\div[(t_1\div k_1)+(t_2\div k_2)]$$

Where,

k_e = Effective hydraulic conductivity (ft/day)
k_1 = Hydraulic conductivity of geomembrane (ft/day) = $5.67\text{x}10^{-8}$ ft/day
t_2 = Thickness of layer 1 (ft) = 0.0025 ft
k_1 = Hydraulic conductivity of layer 2 (ft/day) = $1.42\text{x}10^{-5}$ ft/day
t_2 = Thickness of layer 2 (ft) = 0.0167 ft

$$k_e = (.0025+.0167)\div[(.0025\div5.67\text{x}10^{-8})+(.0167\div1.42\text{x}10^{-5})]$$

$$\mathbf{k_e = 4.24\text{x}10^{-7}\ ft/day;}$$

$$Q = k_e iA$$

Where,

k_e = effective hydraulic conductivity (ft/day)
i = hydraulic gradient across the geomembrane = H/t = 16.2/0.0192 = 843.8
H = hydraulic head (ft) = Max. Operating Level of Pond = 16.2 ft
t = layer thickness (ft) = 0.0025 ft + 0.0167 = 0.0192
A = Area of Liner (ft^2) = 1.0 acres = 43,560 ft^2

$$Q = (4.24x10^{-7}\ ft/day)(843.8)(\ 43{,}560\ ft^2)$$

$$Q = 15.58\,ft^3(7.48\,gal/ft^3) = \mathbf{116.57\ gallons/acre/day}$$

The calculations for the permeation rates through the primary liner are presented in Scenario 3 of the attachments to this calculation. The calculated permeation rate through the primary geomembrane for the pond is summarized in Table 2.

5.3 Permeation Through the Secondary Liner System

Permeation through the secondary geomembrane occurs due to pressure exerted by a groundwater table that is higher than the bottom of the secondary liner system and excess pore water pressure in the compacted clay layer below the geomembrane. Permeation of groundwater and clay consolidation water through the secondary geomembrane is calculated using the same method used to find the volumes permeated through the primary geomembrane. For groundwater permeation, the hydraulic head (h) used will be equal to the difference between the elevations of the bottom of the compacted clay layer at the lowest point, 301 feet for Fac Pond 5, compared to the highest piezometric head from the confined aquifer in the Upper Tills Unit below the footprint of 308 feet for Fac Pond 5, and the effective hydraulic conductivity (k) through the secondary geomembrane will be a combination of the 30-mil EIA geomembrane and the 3-foot layer of compacted clay.

Initially, the compacted clay layer below the secondary geomembrane will have excess pore pressure due to the initial loading of the pond. As the layer settles due to the extra loading from the full pond, water will be expelled from the clay. To be conservative, these calculations will be done assuming the clay layer is saturated and the pond is full (at maximum operating level). Under these conditions, the initial pore pressure will equal the initial load applied by the pond being filled to the maximum operating level. Assuming that the water can be forced either up through the geomembrane or down into the native soil, the hydraulic head (h) acting on the geomembrane used will be one-half of the pore pressure. The layer thickness (t) used in this calculation to find the permeability of the compacted clay will also be equal to one-half of the actual layer thickness in order to model the two drainage paths. The consolidation water has been included in this analysis, however it is recognized that over time the liquid contributed by this mechanism will become negligible.

The permeation through the secondary liner system was calculated using the same methodology presented in Section 5.2. The calculations for the permeation rates through the secondary liner in the pond are presented in Scenario 3 of the attachments to this calculation. The permeation rates through the secondary geomembrane for the pond are summarized in Table 2.

5.4 Leakage of Groundwater Through the Secondary Liner System

The leakage of groundwater through the secondary geomembrane is influenced by the number and size of small defects in the geomembrane and the transmissivity of the compacted clay layer directly below. The hydraulic head on secondary layer was determined as described above in Section 5.3. Assumptions 3 and 4 outline the estimated defects due to manufacturing and installation per the EPA's HELP Model Engineering Documents (Reference 4). Leakage through these geomembrane defects is estimated using equation 149 from Reference 4 outlined below:

$$q_h = k_s i_{ave} n \pi R^2 (0.87719)$$

Where,

q_h	=	flow per unit area of geomembrane (m/s)
k_s	=	hydraulic conductivity of controlling soil layer = $1x10^{-9}$ m/s
i_{ave}	=	average hydraulic gradient from HELP equ. 150
n	=	number of defects per unit area (#/m^2)
R	=	radius of wetted area around flaw from HELP equ. 162 (m)

The average hydraulic gradient is calculated using equation 150 from Reference 4 outlined below:

$$i_{ave} = 1 + [h_g \div (2T_s * \ln(R \div r_o)]$$

Where,

h_g	=	hydraulic head on secondary layer (m)
T_s	=	thickness of controlling soil layer (m)
r_o	=	radius of defect (m)

The radius of wetted area around each defect is calculated using equation 162 from Reference 4 outlined below:

$$R = 0.26 a_o^{0.05} h_g^{0.45} k_s^{-0.13}$$

Where,

a_o	=	area of defect (m^2)

<u>Groundwater Leakage Through Manufacturing Defects in Secondary Geomembrane for FAC Pond 5</u>

$$R = 0.26 a_o^{0.05} h_g^{0.45} k_s^{-0.13}$$

Where,

a_o	=	area of defect (m^2) = $7.85x10^{-7}$ m^2
h_g	=	hydraulic head on secondary layer (m) = 8.2 ft = 2.5 m
k_s	=	hydraulic conductivity of controlling soil layer = $1x10^{-9}$ m/s

$$R = 0.26(7.85x10^{-7})^{0.05}(2.5)^{0.45}(1.00x10^{-9})^{-0.13}$$

$$\boldsymbol{R = 2.88\ m;}$$

$$i_{ave} = 1 + [h_g \div (2T_s * \ln(R/r_o)]$$

Where,

h_g = hydraulic head on secondary layer (m) = 8.2 ft = 2.5 m
T_s = thickness of controlling soil layer (m) = 3 ft = 0.9144 m
r_o = radius of defect (m) = 5.0x10^{-4} m

$$i_{ave} = 1 + [2.5 \div (2(0.9144) * \ln(2.88/5.0x10^{-4})]$$

$$i_{ave} = 1.16;$$

$$q_h = k_s i_{ave} n \pi R^2 (0.87719)$$

$$q_h = (1x10^{-9})(1.16)(1 \div 4046)\pi(2.88)^2(0.87719)$$

$$q_h = ((6.52x10^{-12}\, m/s)(86{,}400\, s/day)(1.0\, acres)) \div (9.35x10^{-7}\, gallons/[meter \cdot acres])$$
$$q_h = 0.60 gallons/acre/day$$

This flow rate equates to 0.60 gallons/acre/day of groundwater leaking through manufacturing defects in the secondary geomembrane of FAC Pond 5. The same methodology presented above for leakage through manufacturing defects was used in determining the leakage rate due to installation defects. Installation defects are assumed to be 1 cm^2 and occur at a frequency of five (5) per acre. The groundwater leakage in the pond due to manufacturing defects and installation damage are presented in Scenarios 4 and 5 of the attachments to this calculation. A summary of calculated groundwater leakage rates through defects for the pond can be found in Table 3.

5.5 Compacted Clay Layer Consolidation Water Leakage Through the Secondary Geomembrane

The leakage volume of clay consolidation water through the secondary geomembrane is calculated using the same method used to find the groundwater leakage volume through the secondary geomembrane. In calculating the leakage of clay consolidation water, it is assumed that the clay layer is doubled drained. Therefore, the clay layer thickness (t) will be cut in half to model the two drainage paths. The head (h) is assumed to be the average depth of liquid in the pond. This value relates to the increase in pore pressure generated from the liquid within the pond. This increased pressure is the driving force of the clay consolidation. The consolidation water has been included in this analysis, however it is recognized that over time the liquid contributed by this mechanism will become negligible.

The calculated leakage rate for the compacted clay consolidation water was determined by the same methodology used for the leakage of groundwater through the secondary liner system and can be found in Scenarios 6 and 7 of the attachments to this calculation. A summary of calculated compacted clay layer consolidation water leakage rate through defects in the secondary geomembrane for the pond can be found in Table 3.

6.0 CONCLUSIONS

Combining all sources of liquids entering the leak detection system will yield the Response Rate for the FAC Pond. Tables 1 to 4 below summarize liquid quantities per day from each source. Table 5 summarizes the Response Rates for the pond.

Table 1: Leakage Through Defects in Primary Geomembrane in FAC Pond 5

	Pond 5
Manufacturing Defects (gallons/acre/day)	13.2
Installation Defects (gallons/acre/day)	138.4
Total (gallons/acre/day)	**151.6**

Table 2: Permeation Through Geomembranes in FAC Pond 5

	Pond 5
Leachate Liquid through Primary Liner System (gallons/acre/day)	187.1
Groundwater through Secondary Liner System (gallons/acre/day)	41.7
Clay Consolidation Water through Secondary Geomembrane (gallons/acre/day)	154.8
Total (gallons/acre/day)	**383.6**

Table 3: Leakage Through Defects in Secondary Geomembrane in FAC Pond 5

		Pond 5
Manufacturing Defects (gallons/acre/day)	Groundwater	0.5
	Clay Consolidation	1.0
Installation Defects (gallons/acre/day)	Groundwater	4.3
	Clay Consolidation	10.5
Total (gallons/acre/day)		**16.3**

Table 4: Response Rates for FAC Pond 5

	Pond 5
Total Permeation (gallons/acre/day)	383.6
Total Leakage (gallons/acre/day)	167.9
Total (gallons/acre/day)	**551.5**

Table 5: Final Response Rate Values

Fac Pond	Unit-Specific RR[2] [gpad]	Pond Area[1] [acres]	Pond-Specific RR [gpd]
5	552	4.7	2,595

Notes:
1. Pond area is the planimetric area as measured along the centerline of the top of slope for the side slope liner system.
2. Unit-specific RR values have been rounded up for conservatism

Scenario 1: Leakage Through Primary Liner Due to Manufacturing Defects

Assumption 1: One (1) defect per acre, with an approximate diameter of 1 mm

Pond 5		SI Units (m, s)
h_g = Hydraulic Head on Liner (ft)	26	7.9248
k_s = Permeability of Controlling Soil Layer (cm/s)	5.00E-09	5.00E-11
T_s = Thickness of Controlling Soil Layer (ft)	1.67E-02	5.09E-03
r_0 = Radius of Flaw (mm)	0.5	5.00E-04
a_0 = Flaw Area (m^2)		7.8540E-07
R = Radius of Wetted Area Around Flaw[1] (m)		7.1352
n = Density of Flaws (number per acre)	1	2.47E-04
Area of Pond (acres)	1	4047

Average Hydraulic Gradient, i_{avg} [2]	82.38
Leakage Rate Through Flaws, q_h (m/s) [3]	1.43E-10
Daily Leakage Volume (gallons/acre/day)	13.19

Notes:

(1) From HELP Model Engineering Documentation Equ. 162

(2) From HELP Model Engineering Documentation Equ. 150

(3) From HELP Model Engineering Documentation Equ. 149

Scenario 2: Leakage Through Primary Liner Due to Installation Defects
Assumption 1: Five (5) defects per acre, with an approximate diameter of 5.65 mm

Pond 5		SI Units (m, s)
h_g = Hydraulic Head on Liner (ft)	26	7.9248
k_s = Permeability of Controlling Soil Layer (cm/s)	5.00E-09	5.00E-11
T_s = Thickness of Controlling Soil Layer (ft)	1.67E-02	5.09E-03
r_0 = Radius of Flaw (mm)	5.65	5.65E-03
a_0 = Flaw Area (m^2)		1.0029E-04
R = Radius of Wetted Area Around Flaw(1) (m)		9.0931
n = Density of Flaws (number per acre)	5	1.24E-03
Area of Pond (acres)	1	4047

Average Hydraulic Gradient, i_{avg} (2)	106.43
Leakage Rate Through Flaws, q_h (m/s) (3)	1.50E-09
Daily Leakage Volume (gallons/acre/day)	138.38

Notes:
(1) From HELP Model Engineering Documentation Equ. 162
(2) From HELP Model Engineering Documentation Equ. 150
(3) From HELP Model Engineering Documentation Equ. 149

Scenario 3: Permeation through the primary and secondary layers

Assumed hydraulic conductivity of 30-mil liner, k= 2x10^{-11} cm/s

Q=kiA

Pond 5

For primary layer (permeation from pond through liner)

k = Effective Hydraulic Conductivity	4.24E-07
i = Hydraulic Gradient = H/t	1354.2
H = Hydraulic Head (ft)	26
t = layer thickness (ft)	0.019
A = Area (acres)	1
Daily Leakage Volume (gallons/acre/day)	187.08

For secondary layer (groundwater permeation)

k = Effective Hydraulic Conductivity	5.49E-05
i = Hydraulic Gradient = H/t	2.3314
H = Hydraulic Head (ft)	7
t = layer thickness (ft)	3.0025
A = Area (acres)	1
Daily Leakage Volume (gallons/acre/day)	41.70

For secondary layer (clay consolidation water permeation)

k = Effective Hydraulic Conductivity	5.49E-05
i = Hydraulic Gradient = H/t	8.6522
H = Hydraulic Head (ft)	13
t = layer thickness (ft)	1.5025
A = Area (acres)	1
Daily Leakage Volume (gallons/acre/day)	154.77

Total Permeation (gallons/day):	**383.56**

Scenario 4: Groundwater Leakage Due to Manufacturing Defects

Assumption 1: One (1) defect per acre, with an approximate diameter of 1 mm

Assumption 2: Hydraulic head is acting on the bottom of the clay layer

Pond 5		SI Units (m, s)
h_g = Hydraulic Head on Secondary Layer (ft)	7	2.1336
k_s = Permeability of Controlling Soil Layer (cm/s)	1.00E-07	1.00E-09
T_s = Thickness of Controlling Soil Layer (ft)	3	0.9144
r_0 = Radius of Flaw (mm)	0.5	5.00E-04
a_0 = Flaw Area (m^2)		7.8540E-07
R = Radius of Wetted Area Around Flaw[1] (m)		2.6781
n = Density of Flaws (number per acre)	1	2.47E-04
Area of Pond (acres)	1	4047

Average Hydraulic Gradient, i_{avg} [2]	1.14
Leakage Rate Through Flaws, q_h (m/s) [3]	5.55E-12
Daily Leakage Volume (gallons/acre/day)	0.51

Notes:

(1) From HELP Model Engineering Documentation Equ. 162

(2) From HELP Model Engineering Documentation Equ. 150

(3) From HELP Model Engineering Documentation Equ. 149

Scenario 5: Groundwater Leakage Due to Installation Defects

Assumption 1: Five (5) defects per acre, with an approximate diameter of 5.65 mm

Assumption 2: Hydraulic head is acting on the bottom of the clay layer

Pond 5		SI Units (m, s)
h_g = Hydraulic Head on Secondary Layer (ft)	7	2.1336
k_s = Permeability of Controlling Soil Layer (cm/s)	1.00E-07	1.00E-09
T_s = Thickness of Controlling Soil Layer (ft)	3	0.9144
r_0 = Radius of Flaw (mm)	5.65	5.65E-03
a_0 = Flaw Area (m^2)		1.0029E-04
R = Radius of Wetted Area Around Flaw[1] (m)		3.4130
n = Density of Flaws (number per acre)	5	1.24E-03
Area of Pond (acres)	1	4047

Average Hydraulic Gradient, i_{avg} [2]	1.18
Leakage Rate Through Flaws, q_h (m/s) [3]	4.69E-11
Daily Leakage Volume (gallons/acre/day)	4.33

Notes:

(1) From HELP Model Engineering Documentation Equ. 162

(2) From HELP Model Engineering Documentation Equ. 150

(3) From HELP Model Engineering Documentation Equ. 149

Scenario 6: Secondary Clay Layer Consolidation Water Leakage Due to Manufacturing De
Assumption 1: One (1) defect per acre, with an approximate diameter of 1 mm

Pond 5		SI Units (m, s)
h_g = Hydraulic Head on Liner (ft)	13	3.9624
k_s = Permeability of Controlling Soil Layer (cm/s)	1.00E-07	1.00E-09
T_s = Thickness of Controlling Soil Layer (ft)	3	0.9144
r_0 = Radius of Flaw (mm)	0.5	5.00E-04
a_0 = Flaw Area (m^2)		7.8540E-07
R = Radius of Wetted Area Around Flaw[1] (cm^2/s)		3.5384
n = Density of Flaws (number per acre)	1	2.47E-04
Area of Pond (acres)	1	4047

Average Hydraulic Gradient, i_{avg} [2]	1.24
Leakage Rate Through Flaws, q_h (m/s) [3]	1.06E-11
Daily Leakage Volume (gallons/acre/day)	0.98

Notes:
(1) From HELP Model Engineering Documentation Equ. 162
(2) From HELP Model Engineering Documentation Equ. 150
(3) From HELP Model Engineering Documentation Equ. 149

Scenario 7: Secondary Clay Layer Consolidation Water Leakage Due to Installation Defect

Assumption 1: Five (5) defects per acre, with an approximate diameter of 5.65 mm

Pond 5		SI Units (m, s)
h_g = Hydraulic Head on Liner (ft)	13	3.9624
k_s = Permeability of Controlling Soil Layer (cm/s)	1.00E-07	1.00E-09
T_s = Thickness of Controlling Soil Layer (ft)	1.5	0.4572
r_0 = Radius of Flaw (mm)	5.65	5.65E-03
a_0 = Flaw Area (m^2)		1.0029E-04
R = Radius of Wetted Area Around Flaw[1] (cm^2/s)		4.5094
n = Density of Flaws (number per acre)	5	1.24E-03
Area of Pond (acres)	1	4047

Average Hydraulic Gradient, i_{avg} [2]	1.65
Leakage Rate Through Flaws, q_h (m/s) [3]	1.14E-10
Daily Leakage Volume (gallons/acre/day)	10.54

Notes:

(1) From HELP Model Engineering Documentation Equ. 162

(2) From HELP Model Engineering Documentation Equ. 150

(3) From HELP Model Engineering Documentation Equ. 149