PROJECT-3 REPORT

ENGG*6610 Urban Stormwater Management

Submitted to

Dr. Narayan Shrestha

Submitted by

Pardeep Kaur
1076663
Gurkaranbir Singh
1074664

Introduction

This Project involves the location of Pine Ridge Subdivision of the City of Guelph, Ontario Canada. The project site was converted from agricultural area to residential area, where predevelopment site was used for crops such as soybean, corn and other beans in recent years. The soil type of the site is Burford Loam and site has flat topography. Site was assumed to have an no impact from outside the boundaries of the site.

Project Objectives:

- Change in hydrological response (pre-development vs post-development)
- Clearly stated design criteria for stormwater management system
- A concise description of modelling and design methodology
- Conveyance system design (including sizing)
- Wet pond design (including sizing and its outlets)
- Model results (including pre-, post-uncontrolled, and post-controlled outflow hydrographs for each of the events used to design the pond)
- Design drawings
- Discussion of the effectiveness of the design relative to the stated criteria
- Discussion of the limitations of simulation/evaluation

Methodology

- Develop SWMM model for predevelopment site for 100-year, 10 year and 5-year return period
- Develop a model for post-development- for 100-year, 10 year and 5-year return period
- Conveyance system designed to control runoff
- Wet pond designed to make flow similar to pre-development

Predevelopment Site

- In the SWMM model a backdrop image is used to draw one sub-catchment and the automated area is Area= 14 ha, Overland flow length is 400 ft from the city of Pickering SWMM guidelines) and then the width is calculated (W=1148.3m).
- The slope is calculated from contours by using equation.1 and table.1

$$\text{Slope (\%)} = \frac{High\ contour - Low\ contour}{Distance} * 100$$

- Percent of impervious area for the agricultural field (loam) is 2% from Table 3-1 Impervious area as a percentage of land use (Storm Water Management Model Reference Manual Volume I -Hydrology, 2015).
- (N-Improv) Manning's n Roughness coefficient is considered as 0.011 took from Table 13 from the City of Pickering SWMM guidelines.
- (N-Perv) Manning's n for the previous area (short grass pasture) = 0.213 used from Table 14- Intercept Coefficient for Shallow Concentrated Flow Equation, city of Pickering SWMM guidelines
- Curve number CN = 71 used from the City of Pickering SWMM guidelines.
- One outfall (OUT) is used having an invert elevation 320 m considered as more than 300 m.
- The city of Guelph doesn't have a design storm so design storm, so the City of Pickering design storm is used for this project as it is close to Guelph. (City of Pickering 1 hour-AES Storm Hyetograph for 100-year Return Period, for 10-year Return Period and 5-year Return Period Graph 1,2,3).

- Rain Gauge is added, and time series are prepared for 100, 10 and 5-year return period and a Time interval of 5 minutes is used.
- The model is run for 3 times for 3 different rainfall data.

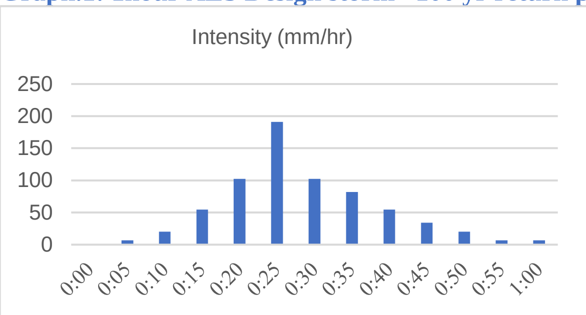
Table:1 Slope calculation

High Contour	Low Contour	Distance	Slope (%)
340	335	210	2.38
335	332	113	2.65
330	326	122	3.28
Average			2.77

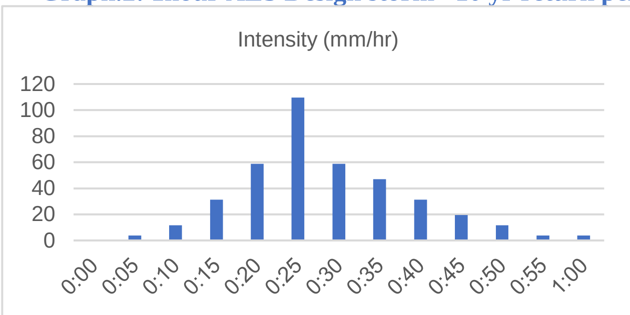
Table:2 Properties of Sub-catchment

Property	Value
Area	14 ha
Width	1148.3 m
% Slope	2.77
% Impervious area	2
N-Imperv	0.011
N-Perv	0.213
Curve Number	71

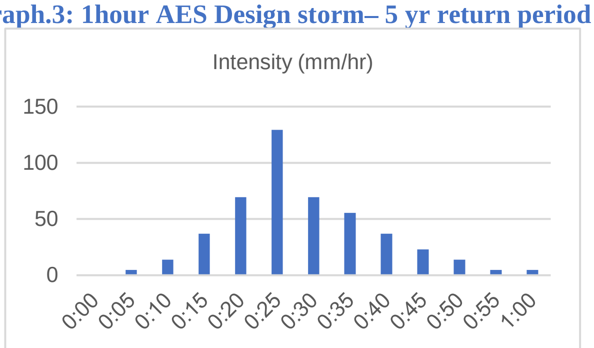
Graph.1: 1hour AES Design storm– 100 yr return period



Graph.2: 1hour AES Design storm– 10 yr return period



Graph.3: 1hour AES Design storm– 5 yr return period



Simulation Results

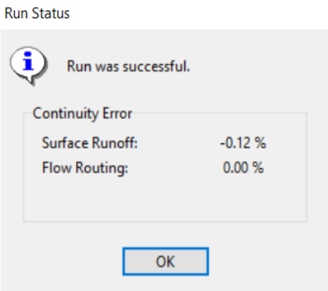


Fig:1. 100-yr Return Period

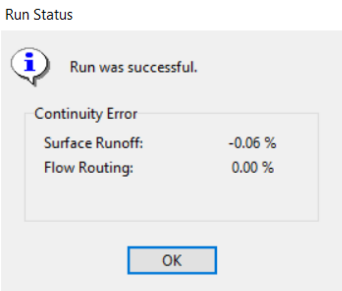


Fig:2. 10-yr Return Period

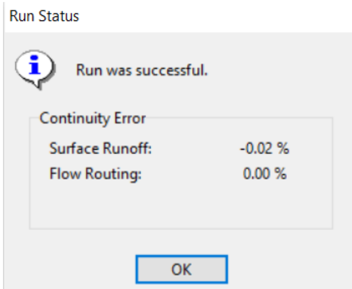
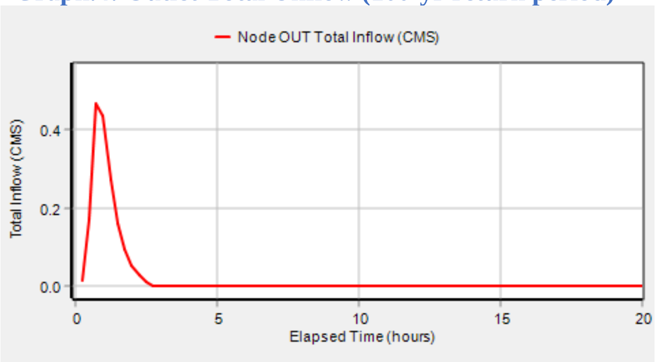
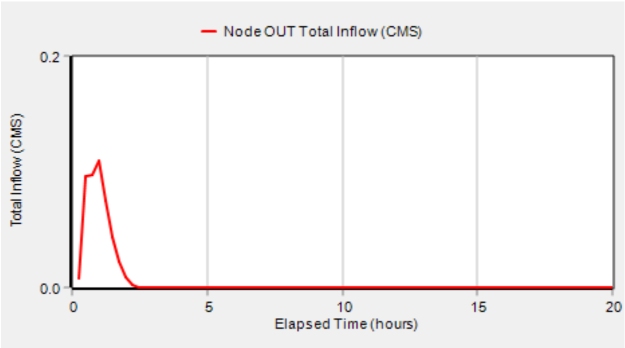


Fig:3. 5-yr Return Period

Graph.4: Outlet Total Unflow (100-yr return period)



Graph.5: Outlet Total Unflow (10-yr return period)



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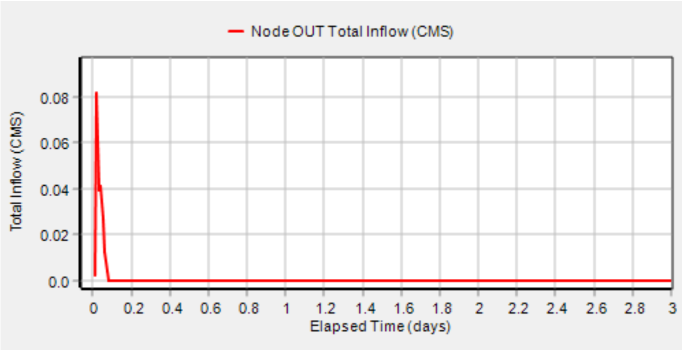


Peak Flor for 3 different Simulations

Return Period	Peak Flow
100-yr return period	0.47 m
10-yr return period	0.11
5-yr return period	0.08

Post-development Site

The post-development site consists of a residential area and other areas and the site has been discretized into 6 sub-catchments as shown in figure.4. and Percentage impervious area is used as 25% and Curve Number is used as 81.

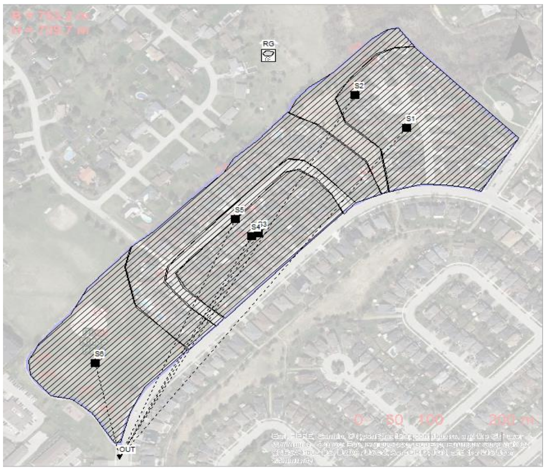


Fig.4: Post-development site

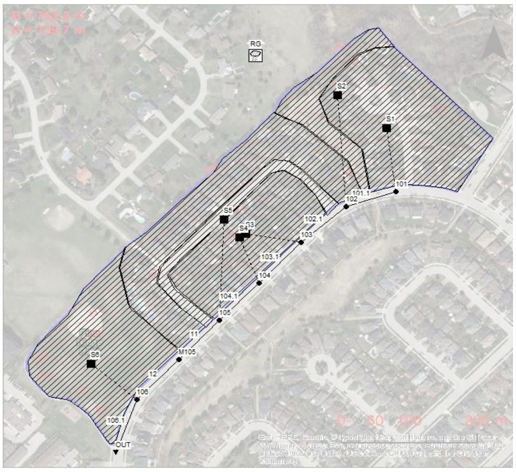


Fig.5: Sewer design

Table.3:Sub-catchment Properties

Subcatchment	Raingauge	Outlet	Area (ha)	Imperviousness (%)	Width (m)	Calculating Weightage Imperviousness for Wetpond
S101	RG	OUT1	3.56	60	291.9947507	213.6
S102	RG	OUT1	1	2	82.02099738	2
S103	RG	OUT1	2.45	60	200.9514436	147
S104	RG	OUT1	0.72	100	59.05511811	72
S105	RG	OUT1	3.04	60	249.343832	182.4
S106	RG	OUT1	3.05	2	250.164042	6.1
			13.82			45.09

Table.4: Sub-catchment Properties

Subcatchment	High Contour	Low Contour	Distance	Slope (%)
S101	340	335	213.8	2.34
S102	338	336	90.8	2.20
S103	335	333	200	1.00
S104	335	331	200	2.00
S105	336	331	240	2.08
S106	332	326	196	3.06

Simulation Results

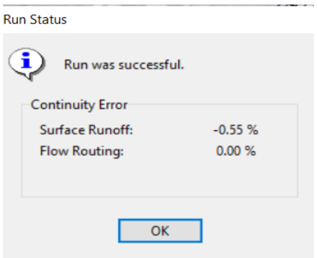


Fig:6. 100-yr Return Period

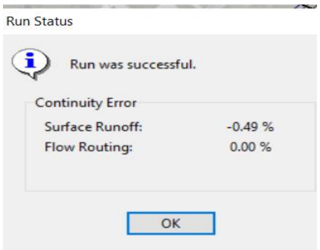


Fig:7. 10-yr Return Period

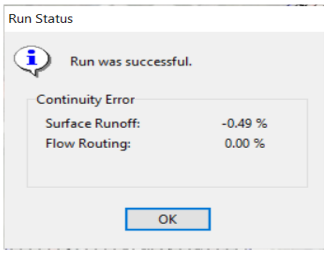
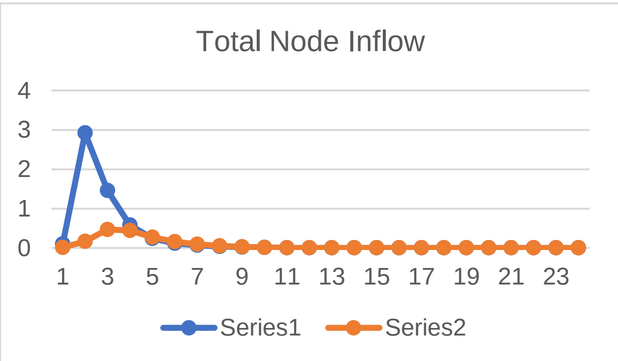


Fig:8. 5-yr Return Period

Graph.6:Node inflow comparison 100-yr return period



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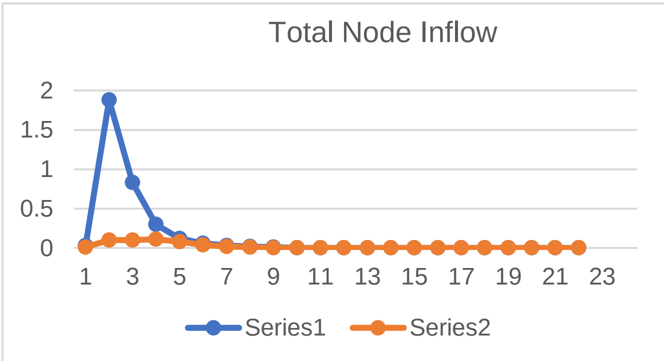
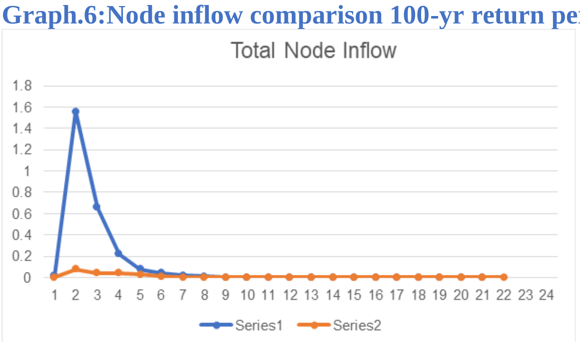


Graph.6:Node inflow comparison 100-yr return period



Design of Conveyance System

There are two types of flows minor and major flows in this project design of conveyance system will focus on controlling minor flow (5-year return period), to control major flow road designs and permeable pavements are involved. To control minor flow there will be conveyance control, and end-of-pipe control. Storm sewer manholes:

- Section 5.4.2 of City of Guelph Design Engineering Manual is used to consider design criteria for manholes.
- Manholes should be used at all junctions, changes in horizontal alignment, changes in grade and changes in pipe size
- Desirable manhole spacing is 90 m
  Storm Sewer Design Criteria
- Pipe diameter and minimum slope: Refer City of Guelph DEM (Page 33)
- For all the pipes (except for large ones: > 900mm in diameter), the minimum velocity is 0.6 m/s
- Maximum acceptable velocity = 3 m/s
- If velocity is sub-critical, then there is no limit on maximum velocity
- A minimum cover of 2.7 m from future road grade is required to the top outside edge of the pipe barrel
- No increase in pipe size from larger size upstream to a smaller size downstream will not be allowed regardless of the increase in grade
- Refer section 5.5 of City of Guelph DEM (Page 35)
- Should be designed based on the Rational Method • All storm sewers (minor system) are to be designed using the 5-year design storm (refer section 5.5 of City of Guelph DEM, page 35)
- Storm Sewer Flows Should be designed based on the Rational Method (refer the City of Guelph DEM, page 35)
- Use City of Guelph IDF curve, Refer the City of Guelph DEM, Table 1, Page 36
- Time of concentration, The initial time of concentration (inlet) shall be 5 minutes in all cases, except single-family residential unit and park areas, where td shall be 10 minutes (refer City of Guelph DEM, Page 36), Sum of inlet and travel time in the conduits: $tc = tinlet + ttravel$
- Below tables 5,6,7,8 gives complete information for sewer design.

Table.5: Sewer Design

Conduit	U/S Node	U/S GL	D/S Node	D/s GL	Elevaltion Diff	L (m)	Area (ha)
101.1	101	334.8	102	334.5	0.3	74.8	3.56
102.1	102	334.5	103	332.9	1.6	87.1	1
103.1	103	332.9	104	331.7	1.2	87.8	2.45
104.1	104	331.7	105	330.8	0.9	82.5	0.72
105.1	105	330.8	M105	329.9	0.9	87.3	3.04
105.2	M105	329.9	106	328	1.9	87.8	
106.1	106	328	OUT	324	4	88.3	3.05

Table.6 Sewer Design

Conduit	Ground Slope (m/m)	Adjusted Pipe Slope (m/m)	t(inlet)	t(travel)	tc(sum)	Rainfall Intensity (mm/hr)	C(runoff coeff)	Q = KCIA (m3/s)
101.1	0.401%	0.500%	5	0.66	5	139.3	0.6	0.83
102.1	1.837%	1.400%	5	0.49	5.66	134.4	0.25	0.09
103.1	1.367%	1.000%	5	0.50	6.15	131.1	0.6	0.54
104.1	1.091%	0.900%	5	0.47	6.65	127.8	0.7	0.18
105.1	1.031%	0.750%	5	0.49	7.11	124.9	0.6	0.63
105.2	2.164%	0.930%	5	0.49	7.61	122.0	0.6	0.00
106.1	4.530%	1.000%	5	0.51	8.10	119.2	0.25	0.25

Table.7 Sewer Design

Conduit	Cum Q (m3/s)	Diameter (m)	Velocity (m/s)	Adj Velocity (m/s)
101.1	0.83	0.75	1.88	2.10
102.1	0.92	0.6	2.99	2.99
103.1	1.46	0.73	2.94	2.94
104.1	1.64	0.80	2.95	2.95
105.1	2.27	0.91	2.94	2.94
105.2	2.27	0.80	2.99	2.99
106.1	2.52	0.72	2.90	2.90

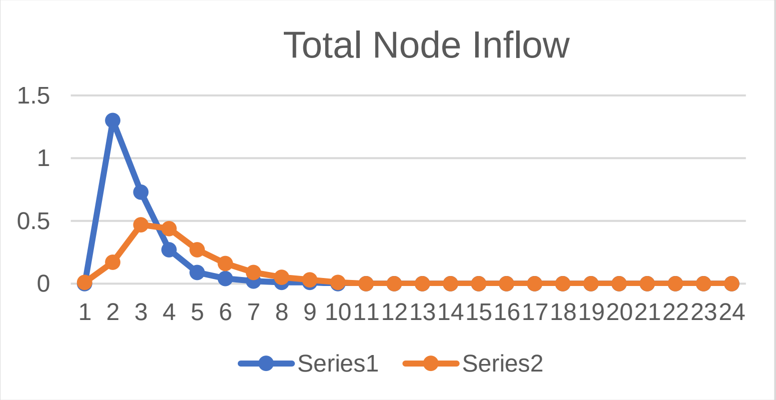
Table.8 Sewer Design

U/S level to the top of the sewer	The diameter of pipe (designed)	U/S level to the invert sewer	Maximum depth	Length (m)	Adjusted Slope (m/m)	D/S invert level required for the slope	D/S level to the top of the sewer
332.1	0.75	331.4	3.448	74.8	0.0040	331.1	331.8
331.8	0.59	331.2	3.285	87.1	0.0140	329.995	330.6
330.2	0.73	329.5	3.435	87.8	0.0100	328.587	329.3
329	0.80	328.2	3.501	82.5	0.0090	327.457	328.3
328.1	0.91	327.2	3.615	87.3	0.0075	326.530	327.4
327.2	0.80	326.4	3.496	87.8	0.0093	325.587	326.4
325.3	0.72	324.6	3.421	88.3	0.0100	323.696	324.4

Simulation Results

Comparison of Outfall Inflow blue line represents the post-development inflow with sewer design which is 0.73m^3/s and the orange line represents pre-development outlet inflow which is 0.47m^3/s. There is still a difference between peak flow and the next wet pond need to be designed.

Graph.7: Comparison of pre-development and post-development outlet inflow



Design of End-of-pipe System (Wet Pond Design)

Three objectives of this design are taken from the City of Guelph Design Engineering Manual.

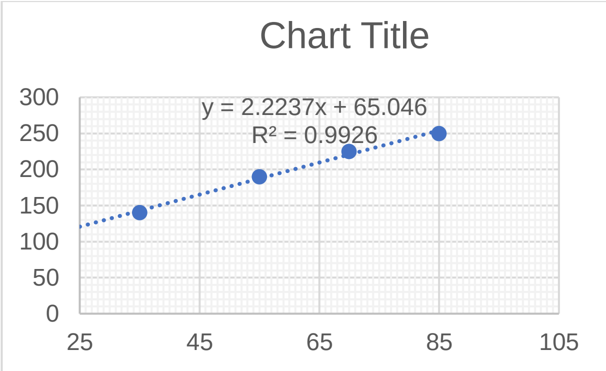
- Water Quantity Control Criteria
  To consider water Quantity criteria in a watershed and where there is no watershed study quantity control criterion available, post-development peak flows should be controlled to pre-development flows for the 2year through 100-year storm events.
- Water Quality Control Criteria
  “All developments shall provide as a minimum the Enhanced level of protection (i.e. 80% TSS removal)”.

- Erosion Control Criteria
  "For all development sites, the minimum erosion control requirement is extended detention of the 4 hours, 25mm Chicago distribution rainfall event for 24 hours" (City of Guelph, 2016).

Water Quality Storage Requirement

For water Quality sizing criteria, MOE (2003) stormwater management and planning design manual (SWPDM) and 40 m^3/ha is extended detention and the remainder is a permanent pool in the following values.

Protection Level	Storage volume (m^3/ha) for impervious level. Source: MOE (2003)			
	35%	55%	70%	85%
Enhanced (80% TSS removal)	**140**	**190**	**225**	**250**
Normal (70% TSS removal)	90	110	130	150
Basic (60% TSS removal)	60	75	85	95



Wet pond design:

For 80% TSS removal, volume for 45.09% imperviousness is extrapolated as shown in (chart) and got 165.3126 m^3/hr.

45.09% weightage imperviousness is calculated from the table.3

The total area for all sub-watersheds is 13.82 m^2.

Total Size = 165.3126*13.82 = 2285 m^3

Total Size for extended detention = Total area * extended detention

= 553 m^3

Total Size for permanent pool = 1732 m^3

Permanent Pool

Wet ponds have permanent pool of water , storm water flowing into a wet pond is diluted by permanent pool. Maximum depth = 3 m, Preferred depth = 2.5 m, Side slope = should not exceed 3:1; preferred 4: 1, L:B ratio: minimum 3:1; preferred 4:1 to 5:1 (Table 4.6 from MoE (2003) stormwater planning and design manual (SWPDM) can be followed for summary guidance)

Side slope (4:1) = 4m

Take Depth (preferred 1-2m) = 1m

B is assumed = 18.27 m (optimized value)

L:B = 4 , So, L = 73.06

Calculated volume for permanent pool is = 1731.821 m^3

Permanent Pool Dimension			
A1	=	1334.511	m2
A2	=	2129.13	m2
Side Slope	=	4:1 (H:V)	
Depth	=	1	m

Extended Detention

In addition to the permanent pool, wet ponds have an active storage volume called extended detention which is used during and after a storm. This active storage is multifunctional and is needed to store the runoff from other storms which otherwise could contribute to erosion and flooding of the receiving stream. Preferred Depth (water quality – extended detention + erosion control) = 1 m; maximum = 1.5 m • Side slope: 5:1; preferred 7.1 (30 on either side of the permanent pool); take 6:1

Side slope = 7

At 1.0 m depth, the dimension of the permanent pool was:

B = 26.27 m

L = 81.06 m

Assume Depth = 0.24 (optimized value)

Calculated volume for extended detention = 552.8 m^3

Extended detention Dimension			
A1	=	2129.13	m2
A2	=	2499.243	m2
Side Slope	=	7:1 (H:V)	
Depth	=	0.24	m

Erosion Control

For Erosion control criteria MoE (2003) stormwater planning and design manual (SWPDM) are followed for design guidance.

- A separate volume for erosion control is needed at the top of the extended detention and following are design requirements:
  Preferred Depth (extended detention + erosion control) = 1 m; maximum = 1.5 m.
- Side slope: 5:1; preferred 7.1 (30 on either side of the permanent pool); take 6:1
- Minimum detention of the 4 hour, 25mm Chicago distribution rainfall event for 24 hours
- Preferred minimum of 100 mm orifice; if orifice control is being used: minimum = 75 mm (Table 4.6 of MoE, Page 4-54)

Side slope (6:1) = 6

B = 29.61 m

L = 84.41 m

Orifice height = 100 mm

Orifice width = 100 mm (circular)

Maximum depth = 1.53 m

Total depth required for erosion control = 0.29 m (Maximum 1.5 m, preferred of q m including extended detention)

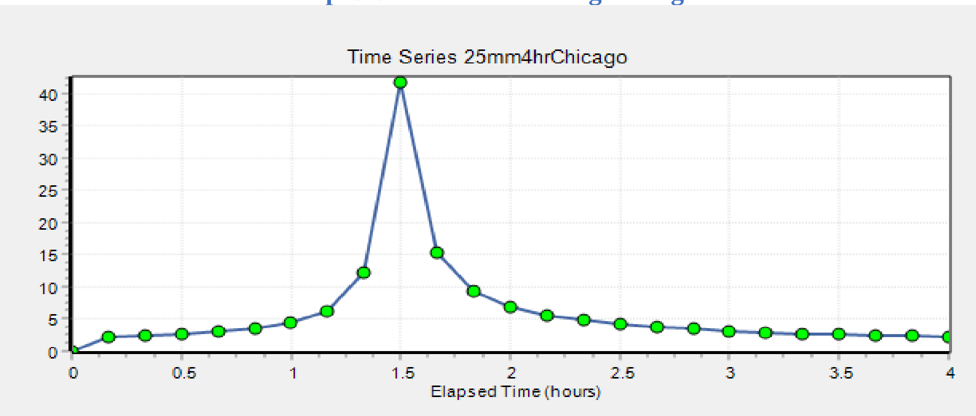
Dimensions at the top of the erosion depth

B = 33.10 m, L = 87.90 m

Erosion Control Dimension			
A1	=	2499.243	m2
A2	=	2909.763	m2
Side Slope	=	6:1 (H:V)	
Orifice Size (HxW)	=	0.1x0.25	m
Depth	=	1.53	m

For minimum detention 4-hour, 25 mm Chicago Distribution rainfall event for 24 hours is used from the Appendix of City of Pickering SWM Guideline. Rain gauge used time series of 4-hour, 25 mm Chicago Distribution rainfall event for 24 hours. 2

Graph.8: 25 mm 4hr Chicago Design



Flood Control

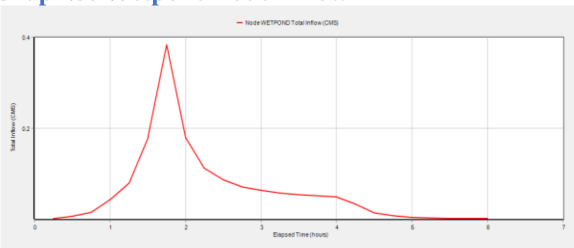
For 100-year, 1-hr flood

All of the areas calculated from the above calculations assigned to storage curve in the SWMM model

Table.9: Storage Unit (WET POND) Properties

Property	Value
Invert Elevation	320 m
Max. depth	6 m
Initial depth	1.25 m
Storage Curve	Tabular
Curve Name	WP-Curve

Graph.9: Wetpond node inflow



Graph.10: Wetpond node depth

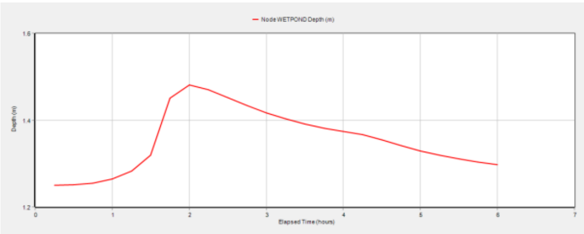


Table.10: Wet Pond Storage Curve

Depth (m)	Area (m)
0	1334.511
1	2129.13
1.25	2499.243
1.53	2909.7628
2.15	6302.7503

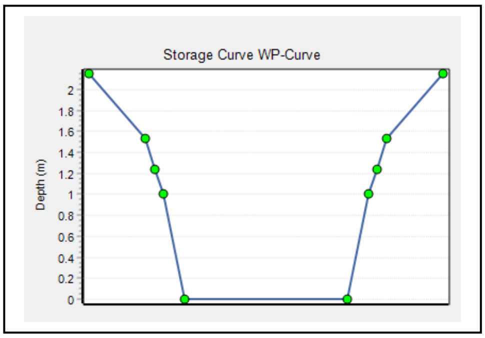


Table.11: Orifice Properties

Property	Value
Type	Side

Shape	Circular
Height	0.45m
Width	1m
Inlet offset	1.25 m
Discharge coefficient	0.65

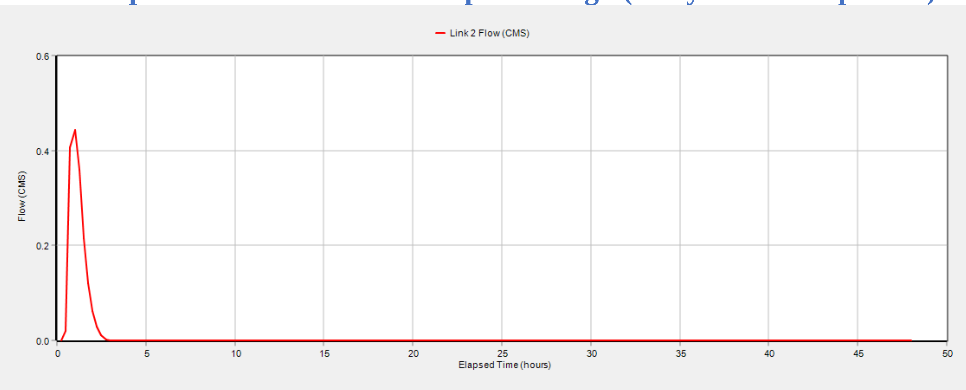
Orifice inlet offset = 1.25 m (Depth of bottom of orifice opening from inlet node invert)
Orifice height is adjusted to get at least a 24-hour gap to get depth 1.25 m.
Weir is added between the storage unit and outlet with properties shown in the table below and then flow was compared with the pre-development site.

Table.12: Weir Properties

Property	Value
Height	0.52 m
Length	0.52 m
Type	SIDE FLOW
Inlet offset	1.53 m
Discharge Coefficient	1.92

Predevelopment peak flow = 0.47
Post development peak flow = 0.44

Graph.11: Peak flow after wet pond design (100-year return period)



After wet pond design Peak flow is successfully reduced to the pre-development site for a 100-year return period and similarly for a 5 year and 10-year return period is successfully designed. Wet pond design can be seen in figure.9

Fig.9 Wet pond design

References

City of Guelph. (2016). *DEVELOPMENT ENGINEERING MANUAL.* City of Guelph: City of Guelph Engineering and Capital Infrastructure Services.

City of Pickering . (2019). *Stormwater Management Design Guidelines.* City of Pickering.

Environment, M. o. (2003). *Stormwater Management Planning and Design Manual.* Ontario: Ministry of the Environment.

Rossman, L. (2015). *Storm Water Management Model Reference Manual Volume I - Hydrology.* U.S: United States Enviromental Protection Agency.