Technical Memorandum

330 Trillium Drive, Unit D ● Kitchener, ON N2E 3J2 ● 519.748.1440

Via Email:	Darren.mackenzie@notl.com
To:	Darren MacKenzie, C.Tech., rcsi, Town of Niagara-on-the-Lake
From:	Patricia Wiebe, P.Eng., GEI Consultants
cc:	Danielle Anders, M.A.Sc., P.Eng., GEI Consultants
	Sarah Primmer, P.Eng., GEI Consultants
Date:	April 3, 2025
Re:	Initial Analysis Tech Memo
	Vineyard Creek Estates Stormwater Management Pond Review
	Niagara-on-the-Lake, ON
Project No.	2408081

1. Introduction

GEI has been retained to review drainage and flooding issues within the Sandalwood Crescent area of Niagara-on-the-Lake. This project was initiated due to the following two events:

- Concern from a nearby resident [redacted] that the Vineyard Creek Estates Stormwater Management Pond (located on Sandalwood Crescent) is not operating as intended
- Concern from a nearby resident [redacted] that the two large rainfall events on June 18th, 2024, and July 10th, 2024 (noted as approximately 80-90mm per event over 12 hours) resulted in flooding of the adjacent right-of-way and driveways.

After an on-site meeting with one nearby resident [redacted] his concerns were summarized as follows:

- Concerns with flooding that mainly occurred during large storms in the summer of 2024.
- Flooding occurred at [redacted] Queenston Road, water entered through basement windows (house was built around 2021, lot was empty prior to that, there is a drainage ditch/swale that moves water from the adjacent business to the culvert across Queenston Road, which ultimately drains to the stormwater management pond).
- Previously blocked screen/outlet in the pond which has been subsequently cleaned and resident noted no extreme issues since.
- Concerns that the pond inlet is too low and in large storms the hydraulic gradeline will back up the system to [redacted] Queenston Road.
- Concerns that the pond may have been partially filled in by neighbouring properties during their construction.
- Concerns that the pond was not designed correctly to handle a large storm.

Another nearby resident [redacted] commented on the flooding that occurred during the June 18th, 2024, and July 10th, 2024 storms, was looking for any insights to improve drainage and reduce flooding, and provided the following photo from July 10th.

Figure 1. Photo of Flooding adjacent to stormwater management pond on July 10th, 2024.

1.1. Background Review

The following documents and drawings of Vineyard Creek Estates and its' stormwater management pond were available for review:

- Drawing No. 03-024-GSP - General Servicing Plan, Record of Construction (Kerry T. Howe Engineering Ltd., Revision No. 4, dated September 6, 2006)
- Drawing No. 03-024-P1 – Pond Detail & Section A, Record of Construction (Kerry T. Howe Engineering Ltd., Revision No. 5, dated September 6, 2006)
- Drawing No. 03-024-P2 - Pond & West Ditch Sections, Record of Construction (Kerry T. Howe Engineering Ltd., Revision No. 5, dated September 6, 2006)

- Drawing No. 03-024-P3 – Pond & STMH.15 Details (Kerry T. Howe Engineering Ltd., Revision No. 5, dated September 6, 2006)
- Stormwater Management Report – Vineyard Creek Estates (Kerry T. Howe Engineering Ltd., dated June 2005)
- Niagara-on-the-Lake GIS Data for storm sewers, catchbasins, and manholes (received February 20, 2025)
- Correspondence and photos of stormwater management pond in 2024 and 2025.

1.2. Scope of Works for Analysis

The following scope of work was undertaken:

- Review of Drainage Catchments (area, imperviousness, flow length, slope) based on Ontario's Digital Elevation Mapping (DEM) as compared to the Vineyard Creek Estates Design
- Re-run of Stormwater Management Facility modelling with the updated catchment parameters and comparison to the original modelling.
- Addition of upstream proposed development to the stormwater model and review of possible controls and impacts.

At the time of this technical memo, the analysis of the impact of the upstream proposed developments has not been completed. This will be summarized in a future Technical Memo.

2. Summary of 2005 Stormwater Management Pond Design

Based on the information provided, the pond was intended to collect runoff from the Vineyard Creek Estates subdivision (Sandalwood Crescent development) and upstream contributing areas before ultimately outletting to Four Mile Creek. The IDF curve information used was a four-hour Chicago rainfall distribution based on the St. Catharines Airport AES rainfall data and are as follows:

Table 1. IDF Curve Parameters from 2005 Stormwater Management Report

Design Storm Event	Depth (mm)	a	b	c
2	32.78	719.65	5.849	0.813
5	42.50	996.92	4.233	0.826
100	69.23	1815.30	3.090	0.847

This rainfall distribution from the 2005 Stormwater Management Report was used for all analysis instead of updating to the latest standards in keeping with the intent of the original design. The report also includes the Quality storm, the 10-year, 25-year, and 50-year design storm events but did not provide those results in every table.

Table 5.2 of the report notes the contributing area to the pond as 27.57 ha at a future imperviousness of 27.03%. The following are the results of the pond's function as per Table 5.2:

Table 2. Pond Function as per 2005 Stormwater Management Report

Stage	Design Storm Event	Inflow (m^3/s)	Hydrograph Volume (m^3)	Peak Outflow (m^3/s)	Active Storage Volume (m^3)	Water Elevation (m)
Bottom of Active Storage	--	--	--	--	0	116.59
--	2	0.793	2,170	0.157	1,236	117.38
--	5	1.288	3,191	0.245	1,824	117.71
--	100	3.051	6,622	1.262	2,887	118.22
Top of Pond	--	--	--	--	2,960	118.25

It should be noted that different ponding elevations are shown in the As Constructed drawings. We do not have a copy of the additional modelling that revised the ponding elevations.

Table 3. Pond Function as per 2006 Record of Construction Drawings

Design Storm Event	Water Elevation (m)
2	117.682
5	117.861
100	118.205

3. Findings of Additional Analysis

3.1. Recreating Original Design Results

The 2005 Stormwater Management Report provided the overall catchment area, future imperviousness, inflow and hydrograph volume at the pond inlet for the 2, 5, and 100-year design storm events. In this modelling, the flow length, slope, minimum and maximum infiltration rates, and initial abstractions we adjusted to match inflow rate and hydrograph volume from the 2005 report. This gave us a point of comparison to compare our recreation of the pond stage-storage-discharge table based on the drawings to the results in the 2005 report. The modelling parameters (flow length, slope, infiltration rate, abstractions) were not carried over to the revised modelling and were revised to parameters based on our own analysis.

Table 4. Pond Function in a recreation of 2005 Model

Stage	Design Storm Event	Inflow (m^3/s)	Hydrograph Volume (m^3)	Peak Outflow (m^3/s)	Storage Volume (m^3)	Water Elevation (m)
Bottom of Active Storage	--	--	--	--	0	116.40
--	2	0.725	1,692	0.051	1,264	117.34
--	5	1.302	2,416	0.125	1,609	117.53
--	100	3.014	6,625	0.732	2,821	118.10
Top of Pond	--	--	--	--	3,490	118.37

As can be seen when comparing Table 4 to Tables 2 and 3, we were not able to exactly match the results found in the historic documents. However, the results are within approximately 0.2m of the historic modelling and so are considered reasonable enough to represent the original intention of the design. A copy of the stage storage discharge table and the record of construction drawings can be found in Appendix A. A copy of the modelling based on the original stormwater management report parameters can be found in Appendix B.

A survey was conducted of the pond area on March 23rd, 2025, and the results were compared to the pond design. The active storage volume was within 10% of the design volume and is therefore constructed appropriately and does not change the results. The permanent pool volume was approximately 60% smaller than the design volume and is therefore not providing the water quality that was anticipated. GEI can provide recommendations for improved water quality measures in future analysis with the Town's support. The elevations of the outlet controls have not been confirmed at this time and could be confirmed in future analysis with the Town's support.

3.2. Revised Parameters for Analysis

Our analysis of the area resulted in the following parameters:

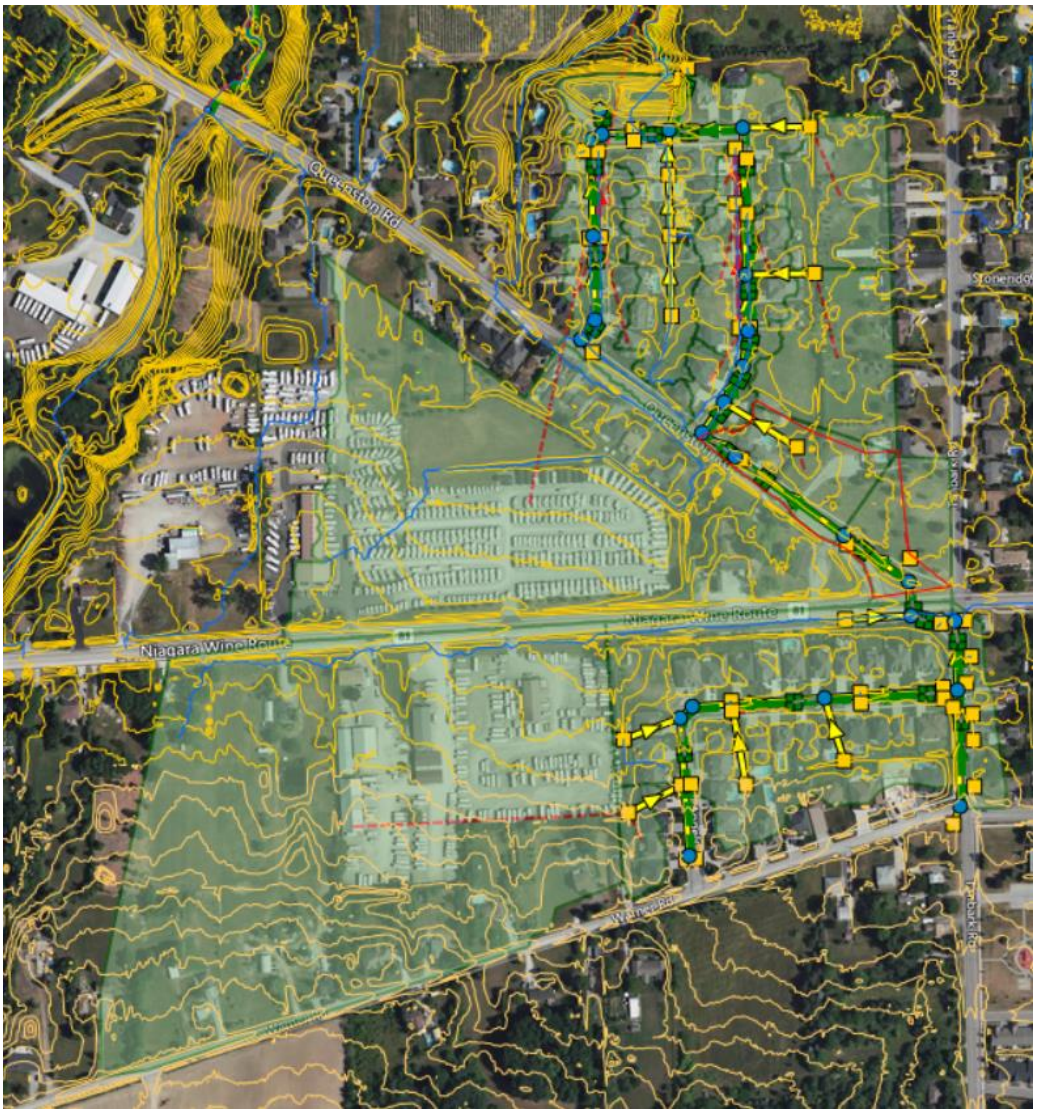
- Contributing Area – 28.58 ha
- Imperviousness – 55%
- Slope – 2.5%
- Flow Length of Overall Catchment – 450m
- Infiltration Rates – Hydrologic Soil Group 'C' (5-125mm/hr)
- Initial Abstraction – 5mm (Pervious) and 1.5mm (Impervious)

The contributing area, imperviousness, flow length and slope were taken based on the Ontario DEM mapping, GIS data of the Town's storm sewer system, and aerial imagery. The pond outlet controls were recreated based on the Record of Construction Drawings and details. The infiltration rates were assumed based on nearby Ontario Soils Mapping.

The imperviousness of 30% used for developed areas in the 2005 Stormwater Management Report aligns with the current design standards for single-detached houses. However, the houses that have been built on Sandalwood Crescent, Angels Drive, and Warner Road have been built to maximum zoning allowances with accessory buildings, large driveways, and pools.

This analysis assumes that there is no stormwater management controls on the commercial properties contributing to the stormwater management pond. Any controls would reduce the peak flow rate and volume contributing to the pond.

Figure 2. Screenshot of Ontario DEM, aerial imaging, and Town GIS data used to assess contributing area and imperviousness.



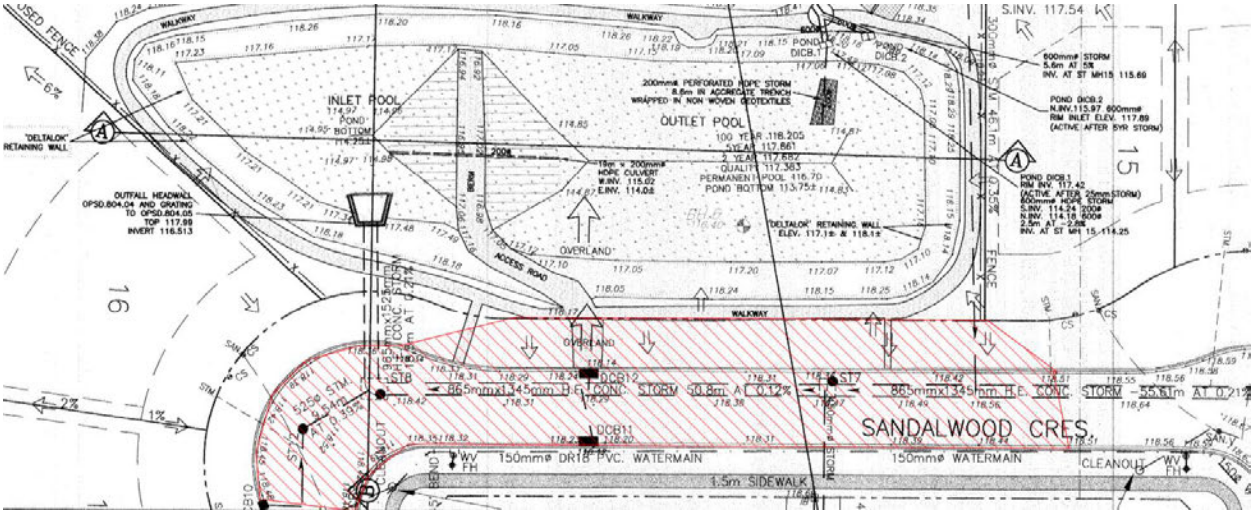
The revised contributing area and imperviousness provided the following results for the pond's function:

Table 5. Pond Function with Revised Parameters

Stage	Design Storm Event	Inflow (m^3/s)	Hydrograph Volume (m^3)	Peak Outflow (m^3/s)	Storage Volume (m^3)	Water Elevation (m)
Bottom of Active Storage	--	--	--	--	0	116.40
--	2	2.693	4,902	0.733	2,824	118.10
--	5	4.268	6,736	1.485	3,472	118.36
Top of Pond	--	--	--	--	3,490	118.37
--	100	9.447	13,417	6.467	3,718	118.46

The approximate extents of flooding to an elevation of 118.50 in this area based on the Record of Construction drawings would be as shown in the figure below. This approximately aligns with the extent of ponding seen on July 10th, 2024.

Figure 3. 118.50m Ponding in Right-of-Way from Record of Construction Drawings



A copy of the modelling based on the revised parameters can be found in Appendix C.

3.3. Hydraulic Grade Line Analysis

A water elevation of 118.46m in the stormwater management pond would not back up to 1225 Queenston Road given that the adjacent storm manhole (ID No. 0796) is noted to have an invert elevation of 119.31m in the Town's GIS data. There could be blockages or capacity constraints with the culvert, ditch, or pipes between the pond and culvert, but is not directly caused by the pond's design.

4. Initial Conclusions

Based on the available information, the stormwater management pond appears to have been designed in a way that meets the standards of the time at which it was built. However, the increased imperviousness of the catchment area has changed the way the pond is functioning. The ponding witnessed by the residents last summer does not appear to be related to a blockage or misfunction but rather aligns with what we can expect out of an intense storm event at this pond.

Based on our experience, other municipalities have similarly noticed differences between their design guidelines and the actual imperviousness of lots with accessory buildings and hardscaping. Some municipalities have begun to require stormwater management ponds to accommodate a higher level of imperviousness on single detached lots and to provide an emergency overland flow route with sufficient freeboard to adjacent buildings to accommodate some inlet/outlet blockages. Any future improvements to this existing stormwater management pond are recommended to consider these aspects of the design.

To assist in the continued evaluation and development of recommended solutions, the following next steps will be undertaken.

5. Next Steps

5.1. Confirming Pond is as per Design

A survey of the pond outlet controls will assist in confirming that the pond's function aligns with the 2005 design. Any additional information the Town can provide regarding the stormwater management design of the existing commercial properties and the designs of proposed upstream development will provide details that can be considered in the analysis.

5.2. Confirming Allowable Release Rate

Potential next steps include more analysis about the allowable release rates to the downstream Four Mile Creek. There appeared to have been tables discussing the existing flow rates from the site that were not included in the Stormwater Management Report document provided. If a greater flow rate is acceptable, we could look at adjusting the pond's outlet controls to reduce ponding levels and flooding. We can also look at how redesigning the pond in the existing site limits could improve water quantity and quality controls.

5.3. Closing

This memo has been prepared to provide an update to the Town of the status of the current analysis. If you have any questions, please feel free to contact me [redacted].

Sincerely,

GEI CONSULTANTS CANADA LTD.

Patricia Wiebe, P.Eng.
Project Engineer

Sarah Primmer, P.Eng.
Senior Project Manager

Appendices

Appendix A	Pond Function
Appendix B	Modelling Based on 2005 Stormwater Management Report
Appendix C	Modelling Results based on Revised Parameters

PW/SP
B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\2408081 Stormwater Catchment and Pond Review\Work in Progress\GEI-Technical Memo 1_2025-04-03.docx

Appendix A Pond Function

A.1. Record of Construction Drawings

A.2. Stage-Storage-Discharge Table

A.3. Surveyed Pond Extents and Stage-Storage-Discharge Table

A.1. Record of Construction Drawings

SANDALWOOD CRESCENT

SANDALWOOD CRESCENT

QUEENSTON ROAD

BLOCK 38

INLET POOL

OUTLET POOL

TYPICAL LOT

LOT SERVICING DETAIL
N.T.S.

TYPICAL ROAD CROSS-SECTION
SCALE 1:100

NO.	REVISION	DATE	INIT.
4	RECORD OF CONSTRUCTION	SEPT. 2006	JH
3	ISSUED FOR CONSTRUCTION	FEB. 20/06	R.B.
2	ISSUED FOR TENDER	AUG. 19/05	R.B.
1	ISSUED FOR REVIEW	JUNE 13/05	R.B.

NOTES
1) THE POSITION OF POLE LINES, CONDUITS, WATERMAINS, SEWERS AND OTHER UNDERGROUND AND OVERGROUND UTILITIES AND STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONSTRUCTION DRAWINGS AND WHERE SHOWN THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.
2) BEFORE STARTING THE WORK, THE CONTRACTOR SHALL INFORM HIMSELF OF THE EXACT LOCATION OF SUCH UTILITIES AND STRUCTURES AND SHALL ASSUME ALL LIABILITY FOR DAMAGE TO THEM.
3) HYDRO AND BELL POLES ARE TO BE ANCHORED TO THE GROUND WHERE REQUIRED SO AS TO ENSURE THE STABILITY OF THE POLE LINES.
4) THE CONTRACTOR IS TO CHECK WITH ALL THE UTILITIES INVOLVED.
5) ALL MANHOLE FRAMES, CATCH BASIN FRAMES, WATER VALVES AND GAS VALVES TO BE ADJUSTED TO FINISH GRADE.
6) EXISTING TREES AND VEGETATION OUTSIDE OF CONSTRUCTION AREAS TO REMAIN UNDISTURBED.

LEGEND

EXISTING SYMBOLS
- STANDARD IRON BAR
- IRON BAR
- ROUND IRON BAR
- MANHOLE
- WATER VALVE
- CATCHBASIN
- FIRE HYDRANT
- UTILITY POLE
- SANITARY
- WATERMAIN
- GASMAIN
- BURIED HYDRO

AS-BUILT SYMBOLS
- SANITARY VALVE
- STORM MANHOLE
- WATER VALVE
- FIRE HYDRANT
- CATCHBASIN
- DOUBLE CATCHBASIN
- DITCH INLET CB
- SANITARY
- STORM
- WATERMAIN

DRAFTING J.H./R.B.
DESIGN R.B.
CHECKED BY D.Ingram P.Eng.
PROJ. SUPVR. W.A.G.Mackay

REGISTERED PROFESSIONAL ENGINEER — W. A. G. MACKAY — KERRY T. HOWE ENGINEERING LTD.

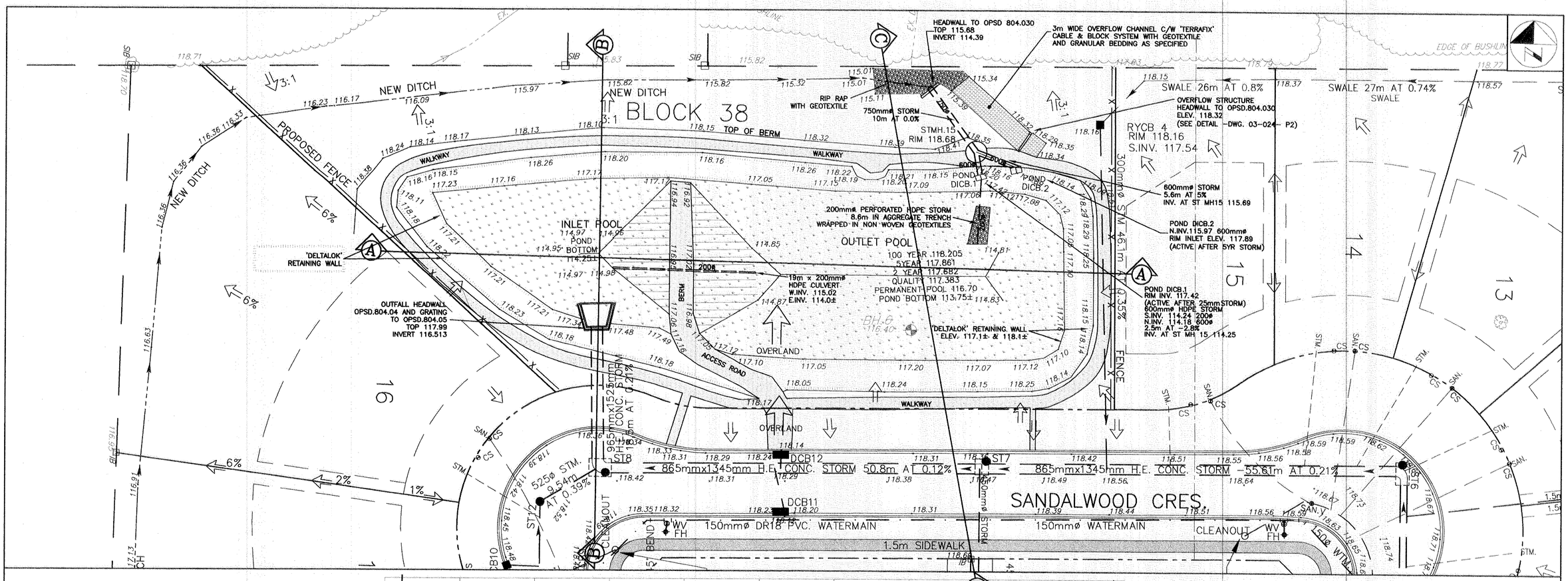
KERRY T. HOWE ENGINEERING LTD.
CONSULTING ENGINEERS
98 Church Street
St. Catharines, Ontario
(905) 688-6550

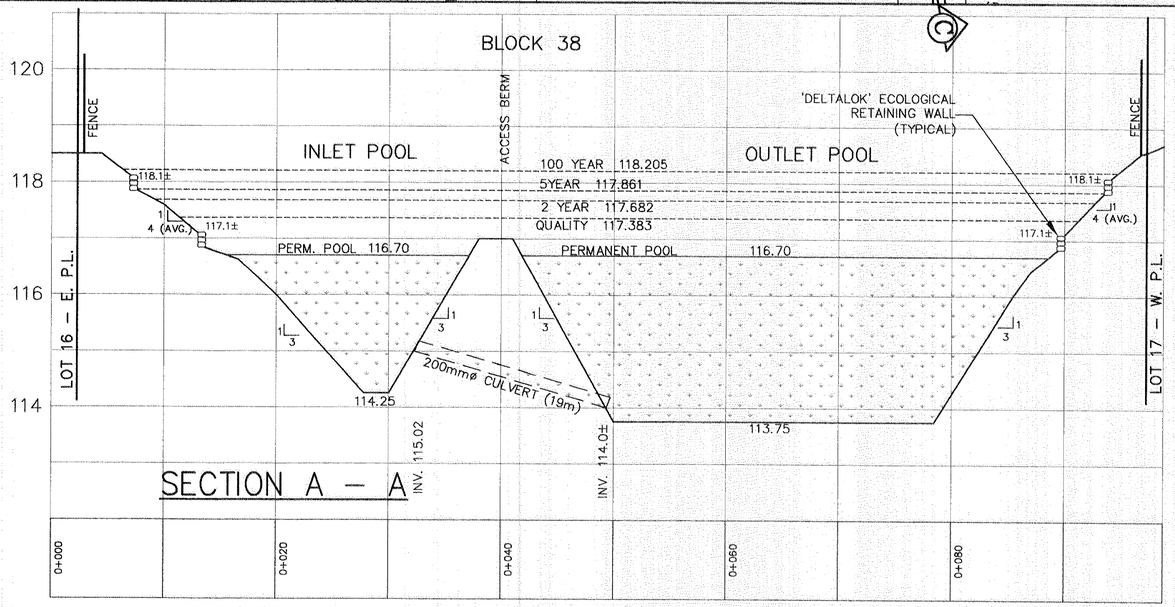
BENCH MARK DATUM
Control benchmark – Top of the north bore of the hydrant located on the S.E. corner of Tanbark & Regional Road 81 – York Road – Ele. 123.852.
Alternate Benchmark – Very top of the hydrant opposite House # 281 Tanbark. Ele. – 121.188

VINEYARD CREEK ESTATES IN THE TOWN OF NIAGARA-ON-THE-LAKE

GENERAL SERVICING PLAN
Record of Construction

FIELD NOTES Book No. 802
PLOT DATE SEPTEMBER 6, 2006
SCALE 1:500
DWG. No. 03-024-GSP REV. 4
CAD FILE: 03-024-ROC.dwg





NO.	REVISION	DATE	INIT.
5	RECORD OF CONSTRUCTION	SEPT. 2006	JH
4	ISSUED FOR CONSTRUCTION	FEB. 20/06	R.B.
3	REVISED FOR M.O.E.	SEPT.14/05	R.B.
2	ISSUED FOR TENDER	AUG.19/05	R.B.
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DRAFTING R.B.
DESIGN D.I.
CHECKED BY D.I.
PROJ. SUPVR. W.A.G. MACKAY

PROFESSIONAL ENGINEERS ONTARIO — W. A. G. MACKAY — KERRY T. HOWE ENGINEERING LTD.

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BENCH MARK DATUM
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VINEYARD CREEK ESTATES IN THE TOWN OF NIAGARA-ON-THE-LAKE

POND DETAIL & SECTION A
Record of Construction

FIELD NOTES: Book No, 802
PLOT DATE: SEPTEMBER 06, 2006
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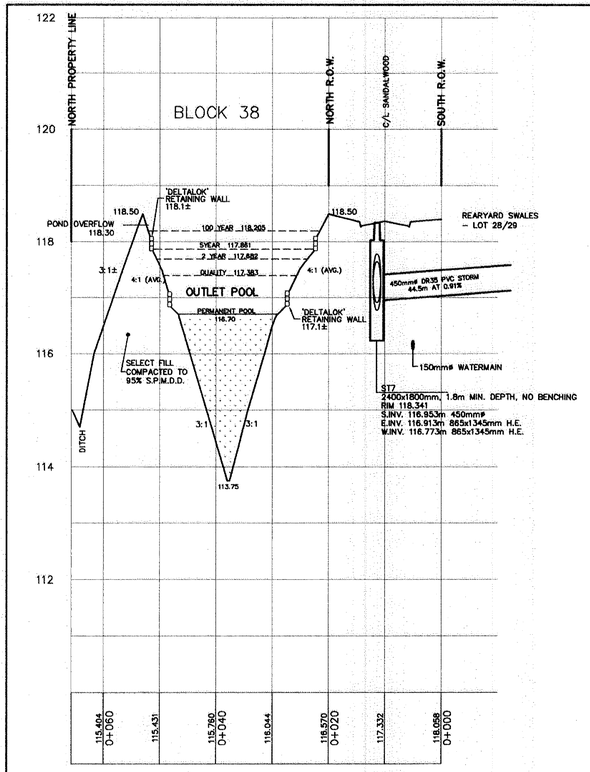
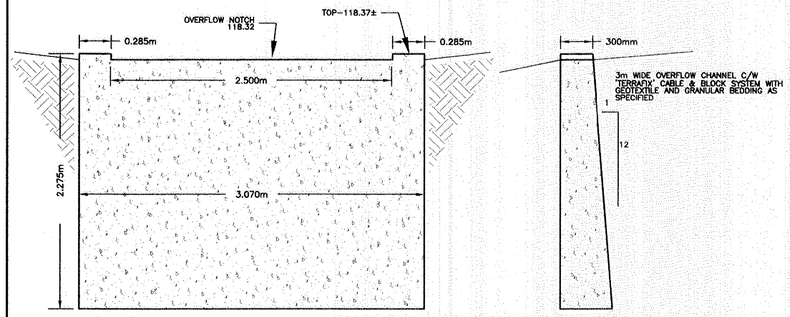
DWG. No. 03-024-P1 REV. 5
CAD FILE: 03-024-ROC.dwg



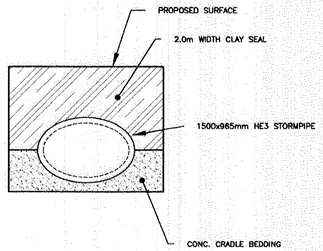
POND SECTION C – C

HORZ. 1:500
VET. 1:50



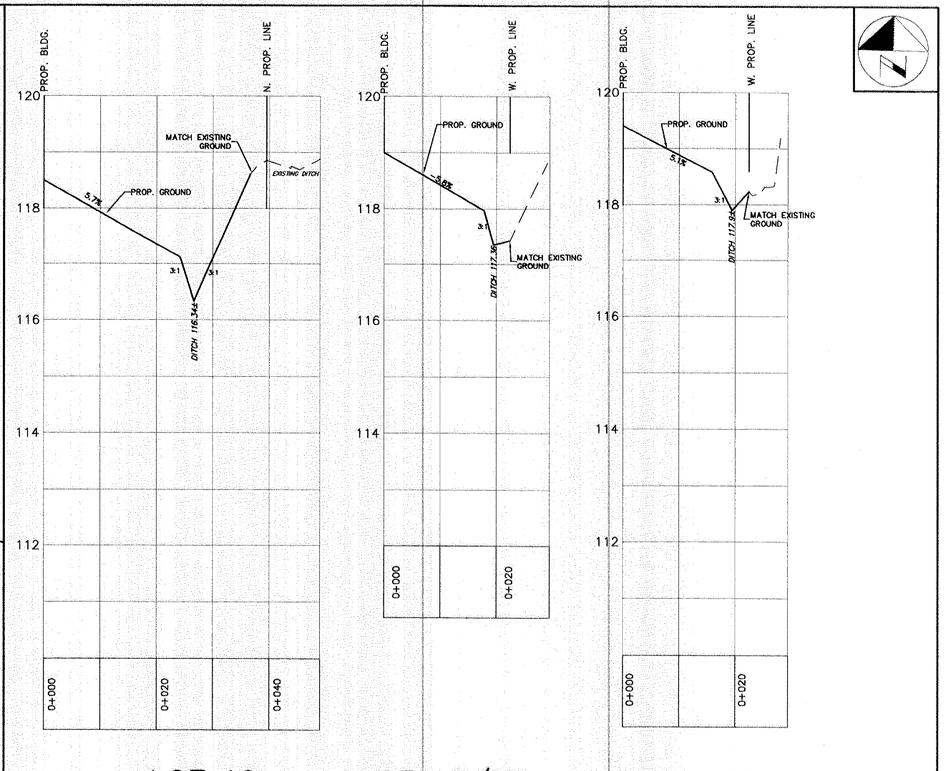
OVERFLOW STRUTURE

(OPSD.804.03 – NO PIPE OPENING)
SCALE 1:25



CLAY SEAL DETAIL

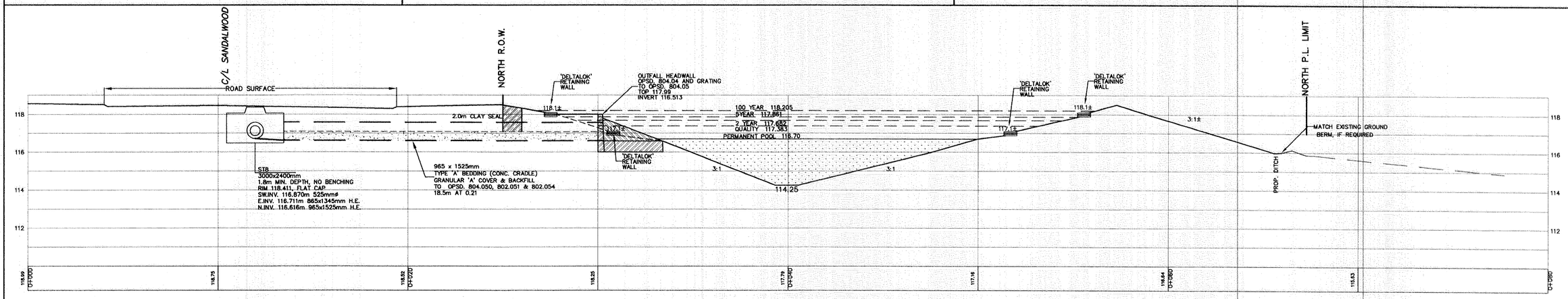
SCALE 1:50



LOT 16 LOT 17/18 LOT 18/19

WEST DITCH CROSS-SECTIONS

HORZ. 1:500
VET. 1:50



POND SECTION B – B

SACLE 1:100

NO.	REVISION	DATE	INIT.
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3	REVISED FOR MOE.	SEPT.14/05	R.B.
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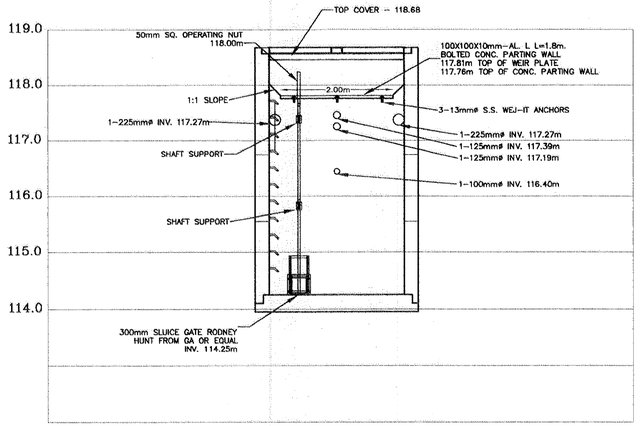
VINEYARD CREEK ESTATES IN THE TOWN OF NIAGARA-ON-THE-LAKE

POND & WEST DITCH SECTIONS

Record of Construction

FIELD NOTES: Book No, 802
PLOT DATE: SEPTEMBER 06, 2006
SCALE: AS NOTED
DWG. No. 03-024-P2 REV. 5
CAD FILE: 03-024-ROC.dwg



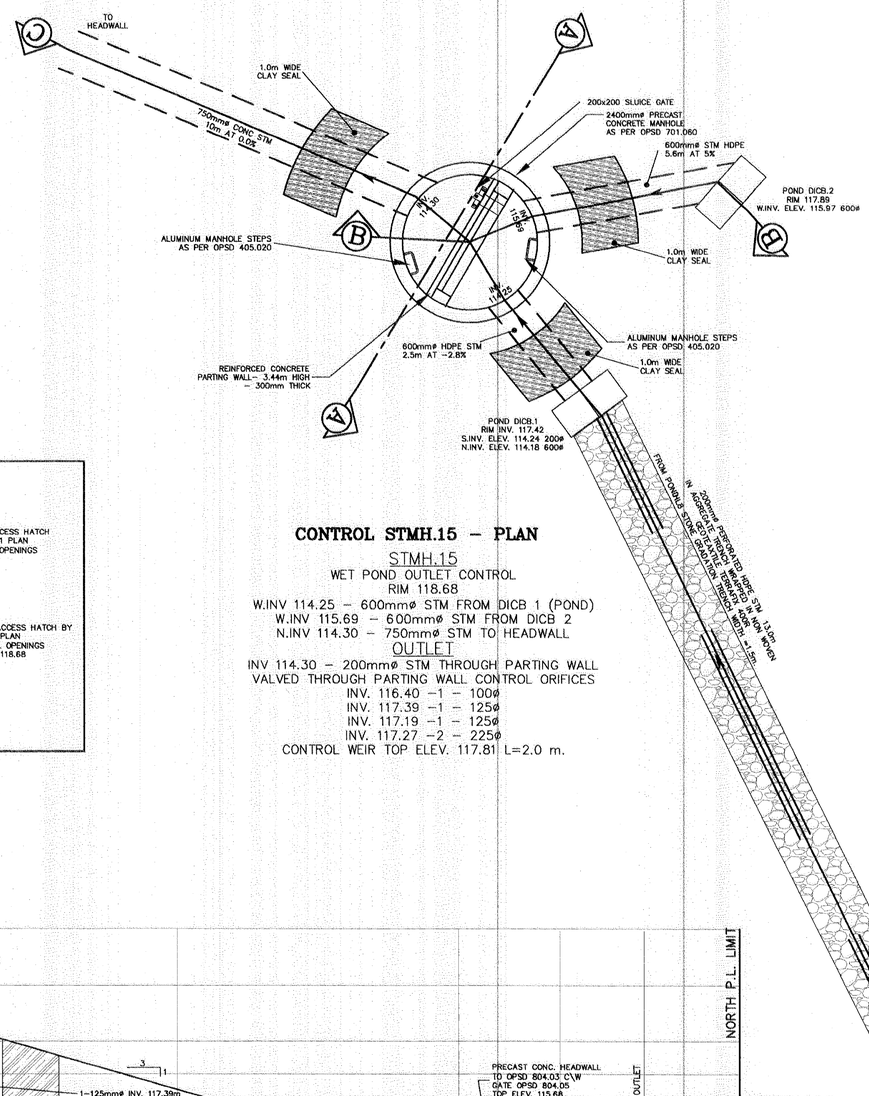
SECTION A–A
CONTROL STMH.15
PARTING WALL – ORIFICE DETAIL

CONTROL STMH.15
PARTING WALL NOTES:

1. WALL TO BE 2400x3440x300mm WITH ONE MAT OF 15M REINFORCING STEEL SPACED AT 300mm o/c.
2. REINFORCING STEEL SHALL BE GRADE 400 AND TENSION LAPS SHALL BE OF CLASS B.
3. CONCRETE SPECIFICATION

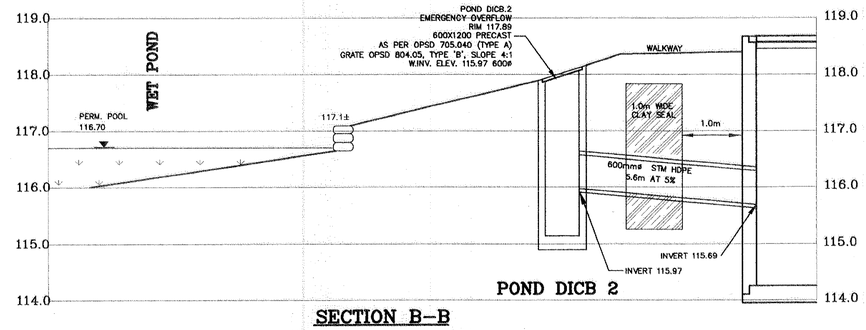
CLASS OF CONCRETE	30MPa (355kg)
NOM. COARSE AGGREGATE SIZE	19mm
AIR CONTENT	7.0%±1.5
SLUMP	70mm±20
CONCRETE COVER AT INLET	70mm±20

4. PRECAST MANUFACTURER TO PROVIDE 15M THREADED COUPLERS IN THE BASE AND VERTICAL SECTIONS AT 300 o/c TO A HEIGHT OF THE PARTING WALL.

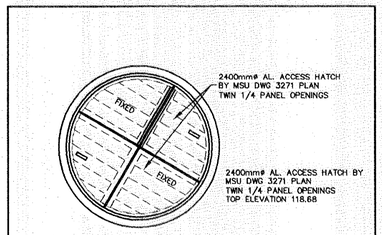


CONTROL STMH.15 – PLAN

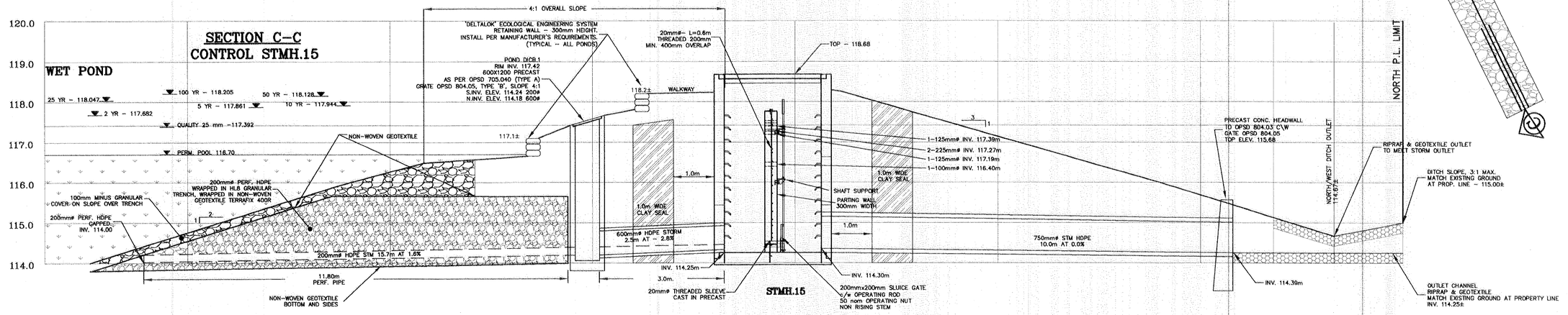
STMH.15
WET POND OUTLET CONTROL
RIM 118.68
W.INV 114.25 – 600mmø STM FROM DICB 1 (POND)
W.INV 115.69 – 600mmø STM FROM DICB 2
N.INV 114.30 – 750mmø STM TO HEADWALL
OUTLET
INV 114.30 – 200mmø STM THROUGH PARTING WALL
VALVED THROUGH PARTING WALL CONTROL ORIFICES
INV. 116.40 –1 – 100ø
INV. 117.39 –1 – 125ø
INV. 117.19 –1 – 125ø
INV. 117.27 –2 – 225ø
CONTROL WEIR TOP ELEV. 117.81 L=2.0 m.



SECTION B–B
CONTROL STMH.15



CONTROL STMH.15
TOP PLAN



NO.	REVISION	DATE	INIT.
5	RECORD OF CONSTRUCTION	SEPT. 2006	J.H.
4	ISSUED FOR CONSTRUCTION	FEB. 20/06	R.B.
3	REVISED FOR M.O.E.	SEPT.14/05	R.B.
2	ISSUED FOR TENDER	AUG. 19/05	R.B.
1	ISSUED FOR REVIEW	JUNE 10/05	R.B.

NOTES
1) THE POSITION OF POLE LINES, CONDUITS, WATERMAINS, SEWERS AND OTHER UNDERGROUND AND OVERGROUND UTILITIES AND STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONSTRUCTION DRAWINGS AND WHERE SHOWN THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.
2) BEFORE STARTING THE WORK, THE CONTRACTOR SHALL INFORM HIMSELF OF THE EXACT LOCATION OF SUCH UTILITIES AND STRUCTURES AND SHALL ASSUME ALL LIABILITY FOR DAMAGE TO THEM.
3) HYDRO AND BELL POLES ARE TO BE ANCHORED TO THE GROUND WHERE REQUIRED SO AS TO ENSURE THE STABILITY OF THE POLE LINES.
4) THE CONTRACTOR IS TO CHECK WITH ALL THE UTILITIES INVOLVED.
5) ALL MANHOLE FRAMES, CATCH BASIN FRAMES, WATER VALVES AND GAS VALVES TO BE ADJUSTED TO FINISH GRADE.
6) EXISTING TREES AND VEGETATION OUTSIDE OF CONSTRUCTION AREAS TO REMAIN UNDISTURBED.

LEGEND

EXISTING SYMBOLS		PROPOSED SYMBOLS	
SIB	STANDARD IRON BAR	MH	SANITARY MANHOLE
IB	IRON BAR	MH	STORM MANHOLE
RIB	ROUND IRON BAR	WV	WATER VALVE
MH	MANHOLE	HYD	FIRE HYDRANT
WV	WATER VALVE	CB	CATCHBASIN
CB	CATCHBASIN	DCB	DOUBLE CATCHBASIN
HYD	FIRE HYDRANT	CB	DITCH INLET CB
UP	UTILITY POLE	PROP. SAN.	SANITARY
SAN	SANITARY	PROP. STM.	STORM
WTR	WATERMAIN	PROP. WTM.	WATERMAIN
GAS	GASMAIN		
HYDRO	BURIED HYDRO		

DRAFTING: J.H./R.B.
DESIGN: D.I.
CHECKED BY: D.I.
PROJ. SUPVR.: W.A.G.Mackay

REGISTERED PROFESSIONAL ENGINEER W. A. G. MACKAY PROFESSIONAL ENGINEER
KERRY T. HOWE ENGINEERING LTD.

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98 Church Street
St. Catharines ,Ontario
(905) 688–6550

BENCH MARK DATUM
Control benchmark – Top of the north bore of the hydrant located on the S.E. corner of Tanbark & Regional Road 81 – York Road – Ele. 123.852.
Alternate Benchmark – Very top of the hydrant opposite House # 281 Tanbark. Ele. – 121.188

VINEYARD CREEK ESTATES IN THE TOWN OF NIAGARA–ON–THE–LAKE

POND & STMH.15 DETAILS

FIELD NOTES: Book No. 802
PLOT DATE: SEPTEMBER 06, 2006
SCALE: 1:50
DWG. No. 03–024–P3 REV. 5
CAD FILE: 03–024–ROC.dwg

A.2. Stage-Storage-Discharge Table

Vineyard Creek Estates SWM Facility
Town of Niagara-on-the-Lake
Our File: 2408081
April 3, 2025

SWM Facility - per 2005 Design Report - Stage/Storage Volume Calculations

Forebay/Permanent Pool Storage Volume Calculations

Elevation (masl)	Depth (m)	Forebay Surface Area (m^2)	Forebay Incremental Storage Volume (m^3)	Accumulative Volume (m^3)	
113.50	0.00	0			Bottom of Forebay
113.75	0.25	3			
114.00	0.50	38.3	5.2	5.2	Pond Bottom / Bottom of Permanent Pool
114.25	0.75	111.4	18.7	23.9	
114.50	1.00	196.4	38.5	62.4	
114.75	1.25	287.1	60.4	122.8	
115.00	1.50	383.1	83.8	206.6	
115.25	1.75	484.6	108.5	315.0	
115.50	2.00	591.5	134.5	449.5	
115.75	2.25	703.9	161.9	611.5	
116.00	2.50	821.3	190.7	802.1	
116.25	2.75	944.3	220.7	1022.8	
116.40	2.90	1021.3	147.4	1170.2	Top of Permanent Pool

Active Storage Volume Calculations

Elevation (m)	Depth (m)	Active Surface Area (m^2)	Active Incremental Volume (m^3)	Accumulative Active Volume (m^3)	
116.40	0.00	1,021.3	0.00	0.00	Bottom of Active Storage
116.59	0.19	1,143.0	205.61	205.61	
116.75	0.35	1,252.0	191.60	397.21	
117.00	0.60	1,441.0	336.63	733.83	
117.25	0.85	1,639.6	385.08	1,118.91	
117.42	1.02	1,781.1	290.76	1,409.67	DICB.1 T/G
117.50	1.10	1,847.7	145.15	1,554.82	
117.75	1.35	2,064.0	488.96	2,043.78	
117.81	1.41	2,117.4	125.44	2,169.22	STMH.15 Control Weir
117.89	1.49	2,188.5	172.23	2,341.46	DICB.2 T/G
118.00	1.60	2,286.3	246.11	2,587.57	
118.25	1.85	2,515.0	600.16	**3,187.73**	Top of Pond
118.32	1.92	2,515.0	176.05	3,363.78	Overflow Notch
118.37	1.97	2,515.0	125.75	3,489.53	Overflow Top
118.57	2.17	2,515.0	503.00	3,992.53	Flow across Top of Pond

Outlet Structures

Perforated 200mm Dia.

INV	114.30	m
Q =	0.166	m^3/s
Cd =	0.600	
H =	3.970	m
2g =	19.620	
A =	0.031	m^2
D =	0.200	m

Length of Flow Over Grate

Head over Grate (m)	Length (m)
0	1.200
0.1	2
0.15	2.4

DICB.1 - Flow Over Grate
modelled with no blockage

d1 =	1.78	m
h =	0.83	
H =	0.95	m
2g =	19.62	
L =	2.4	m
Q =	3.520	m^3/s

DICB.1 600mm Dia. Pipe

INV	114.25	m
Q =	1.469	m^3/s
Cd =	0.600	
H =	3.820	m
2g =	19.620	
A =	0.283	m^2
D =	0.600	m

DICB.2 - Flow Over Grate
modelled with no blockage

d1 =	1.78	m
h =	1.30	
H =	0.48	m
2g =	19.62	
L =	2.4	m
Q =	1.164	m^3/s

DICB.2 600mm Dia. Pipe

INV	115.97	m
Q =	1.089	m^3/s
Cd =	0.600	
H =	2.100	m
2g =	19.620	
A =	0.283	m^2
D =	0.600	m

STMH.15 - 100mm dia.

INV	116.40	m
Q =	0.030	m^3/s
Cd =	0.600	
H =	2.120	m
2g =	19.620	
A =	0.008	m^2
D =	0.100	m

STMH.15 - 125mm dia.

INV	117.19	m
Q =	0.037	m^3/s
Cd =	0.600	
H =	1.318	m
2g =	19.620	
A =	0.012	m^2
D =	0.125	m

STMH.15 - 2 - 225mm dia.

INV	117.27	m
Q =	0.230	m^3/s
Cd =	0.600	
H =	1.188	m
2g =	19.620	
A =	0.080	m^2
D (2) =	0.225	m

STMH.15 - 125mm dia.

INV	117.39	m
Q =	0.034	m^3/s
Cd =	0.600	
H =	1.117	m
2g =	19.620	
A =	0.012	m^2
D =	0.125	m

STMH.15 Control Weir

d1 =	2.170	m
h =	1.410	
H =	0.760	m
2g =	19.620	
L =	2.0	m
Q =	1.979	m^3/s

Overflow Weir

d1 =	1.780	m
h =	1.730	
H =	0.050	m
2g =	19.620	
L =	2.5	m
Q =	0.038	m^3/s

Orifice Flow = Cd A $\sqrt{2gH}$

Weir Flow = 0.433 $\sqrt{2g(\frac{d}{d+h})}LH^{3/2}$

Cd = Discharge Coefficient
A = Area of Orifice
2g = 19.62
H = Depth of Water above orifice - half of orifice diameter

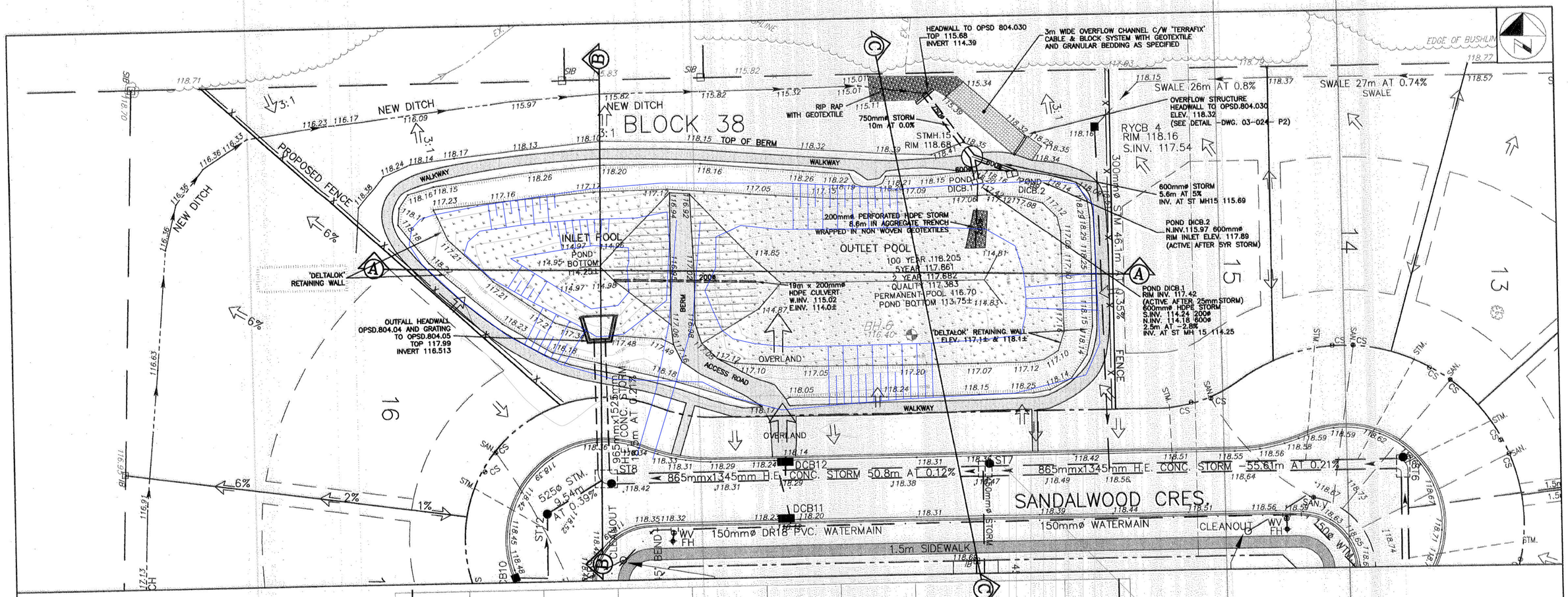
L = Length of Weir
2g = 19.62
d = total depth of water
h = depth of water below weir
H = depth of water above weir

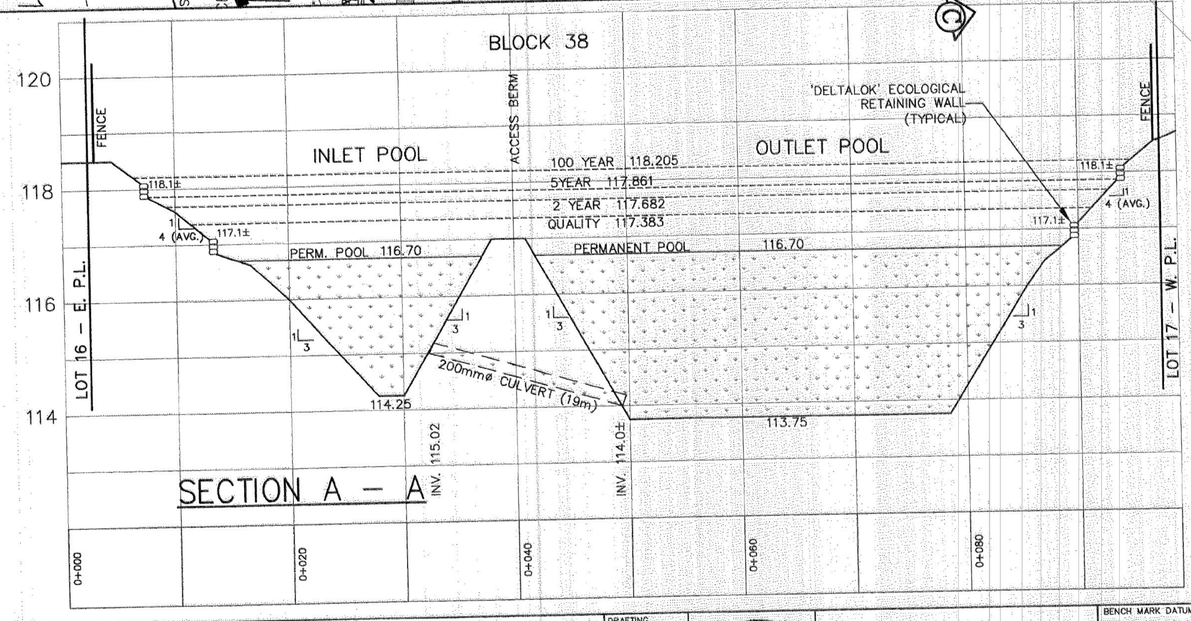
Stage-Storage-Discharge Table

			DICB.1			DICB.2		DICB.1 + DICB.2	STM.15					STM.15			
Elevation (m)	Stage (m)	Storage (m^3)	200mm dia. Perf. Pipe (m^3/s)	Major Control Grate (m^3/s)	600mm dia. Pipe to MH (m^3/s)	Major Control Grate (m^3/s)	600mm dia. Pipe to MH (m^3/s)	Total Flow (m^3/s)	100mm dia. (m^3/s)	125mm dia. (m^3/s)	2 - 225mm dia. (m^3/s)	125mm dia. (m^3/s)	Control Weir (m^3/s)	Total Flow (m^3/s)	Weir Overflow (m^3/s)	Actual Discharge (m^3/s)	
116.40	0.00	0.0	0.000						0.000	0.000	0.000	0.000	0.000	0.000		0.000	Bottom of Active Storage
116.59	0.19	205.6	0.034					0.034	0.008	0.000	0.000	0.000	0.000	0.008		0.008	
116.75	0.35	397.2	0.067					0.067	0.011	0.000	0.000	0.000	0.000	0.011		0.011	
117.00	0.60	733.8	0.135					0.135	0.015	0.000	0.000	0.000	0.000	0.015		0.015	
117.25	0.85	1,118.9	0.141					0.141	0.019	0.007	0.000	0.000	0.000	0.025		0.025	
117.42	1.02	1,409.7	0.145	0.000				0.145	0.021	0.013	0.041	0.004	0.000	0.078		0.078	DICB.1 T/G
117.50	1.10	1,554.8	0.147	0.063	1.291			0.210	0.021	0.016	0.072	0.007	0.000	0.117		0.117	
117.75	1.35	2,043.8	0.153	0.666	1.344			0.819	0.024	0.023	0.128	0.018	0.000	0.193		0.193	
117.81	1.41	2,169.2	0.154	0.865	1.357			1.019	0.024	0.024	0.138	0.020	0.000	0.206		0.206	STMH.15 Control Weir
117.89	1.49	2,341.5	0.156	1.159	1.373	0.000		1.315	0.025	0.026	0.151	0.022	0.062	0.286		0.286	DICB.2 T/G
118.00	1.60	2,587.6	0.158	1.613	1.396	0.101	0.988	1.497	0.026	0.028	0.166	0.024	0.233	0.477		0.477	
118.25	1.85	3,187.7	0.164	2.842	1.445	0.745	1.057	2.190	0.028	0.033	0.197	0.029	0.850	1.137		1.137	Top of Pond
118.32	1.92	3,363.8	0.165		1.459	0.981	1.076	2.440	0.029	0.034	0.205	0.030	1.070	1.367	0.000	1.367	Overflow Notch
118.37	1.97	3,489.5	0.166		1.469	1.164	1.089	2.558	0.029	0.034	0.210	0.031	1.238	1.543	0.038	1.581	Overflow Top
118.57	2.17	3,992.5	0.170		1.507	2.005	1.140	2.646	0.030	0.037	0.230	0.034	1.999	2.332	15.763	18.095	Flow across Top of Pond

Flows limited to constraining factor for each elevation

A.3. Surveyed Pond Extents and Stage-Storage-Discharge Table





NO.	REVISION	DATE	INIT.
5	RECORD OF CONSTRUCTION	SEPT. 2006	JH
4	ISSUED FOR CONSTRUCTION	FEB. 20/06	R.B.
3	REVISED FOR M.O.E.	SEPT.14/05	R.B.
2	ISSUED FOR TENDER	AUG.19/05	R.B.
1	ISSUED FOR REVIEW	JUNE 13/05	R.B.

NOTES
1) THE POSITION OF POLE LINES, CONDUITS, WATERMAINS, SEWERS AND OTHER UNDERGROUND AND OVERGROUND UTILITIES AND STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONSTRUCTION DRAWINGS AND WHERE SHOWN THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.
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4) THE CONTRACTOR IS TO CHECK WITH ALL THE UTILITIES INVOLVED.
5) ALL MANHOLE FRAMES, CATCH BASIN FRAMES, WATER VALVES AND GAS VALVES TO BE ADJUSTED TO FINISH GRADE.
6) EXISTING TREES AND VEGETATION OUTSIDE OF CONSTRUCTION AREAS TO REMAIN UNDISTURBED.

DRAFTING R.B.
DESIGN D.I.
CHECKED BY D.I.
PROJ. SUPVR. W.A.G. MACKAY

KERRY T. HOWE ENGINEERING LTD.
CONSULTING ENGINEERS
98 Church Street
St. Catharines, Ontario
(905) 688-6550

BENCH MARK DATUM
Control benchmark - Top of the north bore of the hydrant located on the S.E. corner of Tanbark & Regional Road 81 - York Road - Ele. 123.852.
Alternate Benchmark - Very top of the hydrant opposite House # 281 Tanbark. Ele. - 121.188

VINEYARD CREEK ESTATES IN THE TOWN OF NIAGARA-ON-THE-LAKE

POND DETAIL & SECTION A

Record of Construction

FIELD NOTES Book No. 802
PLOT DATE SEPTEMBER 06, 2006
SCALE HORZ. 1:250 VERT. 1:50
DWG. No. 03-024-P1 REV. 5
CAD FILE: 03-024-ROC.dwg

Vineyard Creek Estates SWM Facility
Town of Niagara-on-the-Lake
Our File: 2408081
April 3, 2025

SWM Facility - per March 2025 Survey - Stage/Storage Volume Calculations

Forebay/Permanent Pool Storage Volume Calculations

Elevation (masl)	Depth (m)	Surface Area (m^2)	Incremental Volume (m^3)	Accumulative Volume (m^3)	
115.10	0.00	10.5	0.0	0.0	Pond Bottom / Bottom of Permanent Pool
115.20	0.10	22.3	1.6	1.6	
115.30	0.20	40.4	3.1	4.8	
115.40	0.30	66.4	5.3	10.1	
115.50	0.40	98.4	8.2	18.4	
115.60	0.50	139.5	11.9	30.3	
115.70	0.60	194.0	16.7	46.9	
115.80	0.70	247.7	22.1	69.0	
115.90	0.80	315.0	28.1	97.1	
116.00	0.90	369.6	34.2	131.4	
116.10	1.00	817.3	59.3	190.7	
116.20	1.10	908.3	86.3	277.0	
116.30	1.20	976.1	94.2	371.2	
116.40	1.30	1045.1	101.1	472.3	

Active Storage Volume Calculations

Elevation (m)	Depth (m)	Active Surface Area (m^2)	Active Incremental Volume (m^3)	Accumulative Active Volume (m^3)	
116.40	0.00	1,045.1	0.00	0.00	STMH.15 100mm dia. Orifice Invert
116.50	0.10	1,117.2	108.11	108.11	
116.60	0.20	1,197.0	115.71	223.82	
116.70	0.30	1,286.4	124.17	347.99	
116.80	0.40	1,397.4	134.19	482.18	
116.90	0.50	1,501.8	144.96	627.14	
117.00	0.60	1,590.6	154.62	781.76	
117.10	0.70	1,671.3	163.09	944.86	
117.20	0.80	1,754.8	171.30	1,116.16	
117.30	0.90	1,840.8	179.78	1,295.94	
117.42	1.02	1,943.5	227.06	1,523.00	DICB.1 T/G
117.50	1.10	2,011.3	158.19	1,681.20	
117.60	1.20	2,096.0	205.36	1,886.56	
117.70	1.30	2,178.0	213.70	2,100.26	
117.81	1.41	2,257.3	243.94	2,344.20	STMH.15 Control Weir
117.89	1.49	2,257.3	180.58	2,524.79	DICB.2 T/G
118.32	1.92	2,257.3	970.64	3,495.42	Overflow Notch
118.37	1.97	2,257.3	112.87	3,608.29	Overflow Top
118.47	2.07	2,257.3	225.73	3,834.02	Flow across Top of Pond

Outlet Structures

Perforated 200mm Dia.

INV	114.30	m
Q =	0.165	m^3/s
Cd =	0.600	
H =	3.920	m
2g =	19.620	
A =	0.031	m^2
D =	0.200	m

DICB.1 - Flow Over Grate
modelled with no blockage

d1 =	1.20	m
h =	0.40	
H =	1.42	m
2g =	19.62	
L =	2.4	m
Q =	6.745	m^3/s

DICB.2 - Flow Over Grate
modelled with no blockage

d1 =	1.20	m
h =	0.80	
H =	1.02	m
2g =	19.62	
L =	2.4	m
Q =	3.673	m^3/s

Length of Flow Over Grate

Head over Grate (m)	Length (m)
0	1.200
0.1	2
0.15	2.4

DICB.1 600mm Dia. Pipe

INV	114.25	m
Q =	1.334	m^3/s
Cd =	0.600	
H =	3.150	m
2g =	19.620	
A =	0.283	m^2
D =	0.600	m

DICB.2 600mm Dia. Pipe

INV	115.97	m
Q =	0.899	m^3/s
Cd =	0.600	
H =	1.430	m
2g =	19.620	
A =	0.283	m^2
D =	0.600	m

STMH.15 - 100mm dia.

INV	116.40	m
Q =	0.029	m^3/s
Cd =	0.600	
H =	1.870	m
2g =	19.620	
A =	0.008	m^2
D =	0.100	m

STMH.15 - 125mm dia.

INV	117.19	m
Q =	0.034	m^3/s
Cd =	0.600	
H =	1.068	m
2g =	19.620	
A =	0.012	m^2
D =	0.125	m

STMH.15 - 2 - 225mm dia.

INV	117.27	m
Q =	0.205	m^3/s
Cd =	0.600	
H =	0.938	m
2g =	19.620	
A =	0.080	m^2
D (2) =	0.225	m

STMH.15 - 125mm dia.

INV	117.39	m
Q =	0.030	m^3/s
Cd =	0.600	
H =	0.867	m
2g =	19.620	
A =	0.012	m^2
D =	0.125	m

STMH.15 Control Weir

INV	117.81	m
d1 =	1.410	m
h =	1.410	
H =	0.000	m
2g =	19.620	
L =	2.0	m
Q =	0.000	m^3/s

Overflow Weir

d1 =	1.200	m
h =	1.100	
H =	0.100	m
2g =	19.620	
L =	2.5	m
Q =	0.110	m^3/s

Orifice Flow = Cd A $\sqrt{2gH}$ *Weir Flow = 0.433* $\sqrt{2g(\frac{d}{d+h})}LH^{3/2}$

Cd = Discharge Coefficient
A = Area of Orifice
2g = 19.62
H = Depth of Water above orifice - half of orifice diameter

L = Length of Weir
2g = 19.62
d = total depth of water
h = depth of water below weir
H = depth of water above weir

Stage-Storage-Discharge Table

			DICB.1			DICB.2		DICB.1 + DICB.2	STM.15					STM.15			
Elevation (m)	Stage (m)	Storage (m^3)	200mm dia. Perf. Pipe (m^3/s)	Major Control Grate (m^3/s)	600mm dia. Pipe to MH (m^3/s)	Major Control Grate (m^3/s)	600mm dia. Pipe to MH (m^3/s)	Total Flow (m^3/s)	100mm dia. (m^3/s)	125mm dia. (m^3/s)	2 - 225mm dia. (m^3/s)	125mm dia. (m^3/s)	Control Weir (m^3/s)	Total Flow (m^3/s)	Weir Overflow (m^3/s)	Actual Discharge (m^3/s)	
116.40	0.00	0.0	0.000					0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	STMH.15 100mm dia. Orifice Invert
116.50	0.10	108.1	0.032					0.032	0.005	0.000	0.000	0.000	0.000	0.005		0.005	
116.60	0.20	223.8	0.063					0.063	0.008	0.000	0.000	0.000	0.000	0.008		0.008	
116.70	0.30	348.0	0.127					0.127	0.010	0.000	0.000	0.000	0.000	0.010		0.010	
116.80	0.40	482.2	0.129					0.129	0.012	0.000	0.000	0.000	0.000	0.012		0.012	
116.90	0.50	627.1	0.132					0.132	0.014	0.000	0.000	0.000	0.000	0.014		0.014	
117.00	0.60	781.8	0.135					0.135	0.015	0.000	0.000	0.000	0.000	0.015		0.015	
117.10	0.70	944.9	0.137					0.137	0.017	0.000	0.000	0.000	0.000	0.017		0.017	
117.20	0.80	1,116.2	0.140					0.140	0.018	0.000	0.000	0.000	0.000	0.018		0.018	
117.30	0.90	1,295.9	0.142					0.142	0.019	0.007	0.000	0.000	0.000	0.026		0.026	
117.42	1.02	1,523.0	0.145	0.000				0.145	0.021	0.013	0.041	0.000	0.000	0.075		0.075	DICB.1 T/G
117.50	1.10	1,681.2	0.147	0.075	1.291			0.222	0.021	0.016	0.072	0.007	0.000	0.117		0.117	
117.60	1.20	1,886.6	0.149	0.258	1.312			0.408	0.022	0.019	0.099	0.013	0.000	0.153		0.153	
117.70	1.30	2,100.3	0.152	0.511	1.334			0.662	0.023	0.022	0.119	0.016	0.000	0.180		0.180	
117.81	1.41	2,344.2	0.154	0.854	1.357			1.008	0.024	0.024	0.138	0.020	0.000	0.206		0.206	STMH.15 Control Weir
117.89	1.49	2,524.8	0.156	1.143	1.373	0.000		1.299	0.025	0.026	0.151	0.022	0.062	0.285		0.285	DICB.2 T/G
118.32	1.92	3,495.4	0.165	3.176	1.459	0.487	1.076	1.946	0.029	0.034	0.205	0.030	1.061	1.358	0.000	1.358	Overflow Notch
118.37	1.97	3,608.3	0.166		1.469	0.578	1.089	2.046	0.029	0.034	0.210	0.031	1.227	1.532	0.110	1.641	Overflow Top
118.47	2.07	3,834.0	0.168		1.488	0.775	1.115	2.263	0.030	0.036	0.220	0.033	1.586	1.905	12.247	14.152	Flow across Top of Pond

Flows limited to constraining factor for each elevation

Appendix B Modelling Based on 2005 Stormwater Management Report

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                            Version 2.25  rev. 473"
"                MIDUSS created                          Sunday, February 7, 2010"
"           10   Units used:                                          ie METRIC"
"                Job folder:          B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\"
"                2408081 Stormwater Catchment and Pond Review\Work in
Progress\Calculations"
"                Output filename:                  BasedonSWMReport__2yr-v5.out"
"                Licensee name:                                                "
"                Company                                                       "
"                Date & Time last used:                 3/21/2025 at 3:06:32 PM"
" 31          TIME PARAMETERS"
"        5.000   Time Step"
"      240.000   Max. Storm length"
"     1500.000   Max. Hydrograph"
" 32          STORM Chicago storm"
"            1   Chicago storm"
"      719.650   Coefficient A"
"        5.849   Constant B"
"        0.813   Exponent C"
"        0.400   Fraction R"
"      240.000   Duration"
"        1.000   Time step multiplier"
"             Maximum intensity            99.424    mm/hr"
"             Total depth                  32.777    mm"
"            6   002hyd   Hydrograph extension used in this file"
" 33          CATCHMENT 100"
"            1   Triangular SCS"
"            3   Specify values"
"            2   Horton equation"
"          100   Catchment 100"
"       27.030   % Impervious"
"       27.570   Total Area"
"     1100.000   Flow length"
"        3.500   Overland Slope"
"       20.118   Pervious Area"
"     1100.000   Pervious length"
"        3.500   Pervious slope"
"        7.452   Impervious Area"
"     1100.000   Impervious length"
"        3.500   Impervious slope"
"        0.250   Pervious Manning 'n'"
"      150.000   Pervious Max.infiltration"
"       12.500   Pervious Min.infiltration"
"        0.250   Pervious Lag constant (hours)"
"       10.000   Pervious Depression storage"
"        0.015   Impervious Manning 'n'"
"        0.000   Impervious Max.infiltration"
"        0.000   Impervious Min.infiltration"
"        0.050   Impervious Lag constant (hours)"
```

```
"       10.000   Impervious Depression storage"
"                     0.725     0.000     0.000     0.000 c.m/sec"
"             Catchment 100          Pervious   Impervious Total Area "
"             Surface Area           20.118     7.452      27.570     hectare"
"             Time of concentration      ---    16.319     16.319     minutes"
"             Time to Centroid       0.000      148.734    148.734    minutes"
"             Rainfall depth         32.777     32.777     32.777     mm"
"             Rainfall volume        6594.00    2442.59    9036.59    c.m"
"             Rainfall losses        32.777     10.068     26.639     mm"
"             Runoff depth           0.000      22.709     6.138      mm"
"             Runoff volume          0.00       1692.29    1692.29    c.m"
"             Runoff coefficient     0.000      0.693      0.187      "
"             Maximum flow           0.000      0.725      0.725      c.m/sec"
" 40          HYDROGRAPH Add Runoff "
"            4   Add Runoff "
"                     0.725     0.725     0.000     0.000"
" 54          POND DESIGN"
"        0.725   Current peak flow    c.m/sec"
"        0.419   Target outflow    c.m/sec"
"       1692.3   Hydrograph volume    c.m"
"          15.   Number of stages"
"      116.400   Minimum water level    metre"
"      118.570   Maximum water level    metre"
"      116.400   Starting water level    metre"
"            0   Keep Design Data: 1 = True; 0 = False"
"                  Level Discharge    Volume"
"                116.400     0.000     0.000"
"                116.590   0.00800   205.600"
"                116.750   0.01100   397.200"
"                117.000   0.01500   733.800"
"                117.250   0.02500  1118.900"
"                117.420   0.07800  1409.700"
"                117.500    0.1170  1554.800"
"                117.750    0.1930  2043.800"
"                117.810    0.2060  2169.200"
"                117.890    0.2860  2341.500"
"                118.000    0.4770  2587.600"
"                118.250     1.137  3187.700"
"                118.320     1.367  3363.800"
"                118.370     1.581  3489.500"
"                118.570    18.095  3992.500"
"             Peak outflow                  0.051    c.m/sec"
"             Maximum level               117.335    metre"
"             Maximum storage            1264.271    c.m"
"             Centroidal lag               12.202   hours"
"                  0.725     0.725     0.051     0.000 c.m/sec"
" 38          START/RE-START TOTALS 100"
"            3   Runoff Totals on EXIT"
"             Total Catchment area                    27.570    hectare"
"             Total Impervious area                    7.452    hectare"
```

```
"             Total % impervious                        27.030"
" 19          EXIT"
```

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                            Version 2.25  rev. 473"
"                MIDUSS created                          Sunday, February 7, 2010"
"           10   Units used:                                          ie METRIC"
"                Job folder:          B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\"
"                2408081 Stormwater Catchment and Pond Review\Work in
Progress\Calculations"
"                Output filename:                  BasedonSWMReport__5yr-v5.out"
"                Licensee name:                                                "
"                Company                                                       "
"                Date & Time last used:                 3/21/2025 at 3:03:10 PM"
" 31          TIME PARAMETERS"
"        5.000   Time Step"
"      240.000   Max. Storm length"
"     1500.000   Max. Hydrograph"
" 32          STORM Chicago storm"
"            1   Chicago storm"
"      996.920   Coefficient A"
"        4.233   Constant B"
"        0.826   Exponent C"
"        0.400   Fraction R"
"      240.000   Duration"
"        1.000   Time step multiplier"
"             Maximum intensity           152.144    mm/hr"
"             Total depth                  42.500    mm"
"            6   005hyd   Hydrograph extension used in this file"
" 33          CATCHMENT 100"
"            1   Triangular SCS"
"            3   Specify values"
"            2   Horton equation"
"          100   Catchment 100"
"       27.030   % Impervious"
"       27.570   Total Area"
"     1100.000   Flow length"
"        3.500   Overland Slope"
"       20.118   Pervious Area"
"     1100.000   Pervious length"
"        3.500   Pervious slope"
"        7.452   Impervious Area"
"     1100.000   Impervious length"
"        3.500   Impervious slope"
"        0.250   Pervious Manning 'n'"
"      150.000   Pervious Max.infiltration"
"       12.500   Pervious Min.infiltration"
"        0.250   Pervious Lag constant (hours)"
"       10.000   Pervious Depression storage"
"        0.015   Impervious Manning 'n'"
"        0.000   Impervious Max.infiltration"
"        0.000   Impervious Min.infiltration"
"        0.050   Impervious Lag constant (hours)"
```

```
"       10.000   Impervious Depression storage"
"                     1.302     0.000     0.000     0.000 c.m/sec"
"             Catchment 100          Pervious   Impervious Total Area "
"             Surface Area           20.118     7.452      27.570     hectare"
"             Time of concentration      ---    13.765     13.765     minutes"
"             Time to Centroid       0.000      140.298    140.298    minutes"
"             Rainfall depth         42.500     42.500     42.500     mm"
"             Rainfall volume        0.8550     0.3167     1.1717     ha-m"
"             Rainfall losses        42.500     10.083     33.738     mm"
"             Runoff depth           0.000      32.417     8.762      mm"
"             Runoff volume          0.00       2415.79    2415.79    c.m"
"             Runoff coefficient     0.000      0.763      0.206      "
"             Maximum flow           0.000      1.302      1.302      c.m/sec"
" 40          HYDROGRAPH Add Runoff "
"            4   Add Runoff "
"                     1.302     1.302     0.000     0.000"
" 54          POND DESIGN"
"         1.302   Current peak flow    c.m/sec"
"         0.419   Target outflow    c.m/sec"
"        2415.8   Hydrograph volume    c.m"
"           15.   Number of stages"
"       116.400   Minimum water level    metre"
"       118.570   Maximum water level    metre"
"       116.400   Starting water level    metre"
"             0   Keep Design Data: 1 = True; 0 = False"
"                   Level Discharge    Volume"
"                 116.400     0.000     0.000"
"                 116.590   0.00800   205.600"
"                 116.750   0.01100   397.200"
"                 117.000   0.01500   733.800"
"                 117.250   0.02500  1118.900"
"                 117.420   0.07800  1409.700"
"                 117.500    0.1170  1554.800"
"                 117.750    0.1930  2043.800"
"                 117.810    0.2060  2169.200"
"                 117.890    0.2860  2341.500"
"                 118.000    0.4770  2587.600"
"                 118.250     1.137  3187.700"
"                 118.320     1.367  3363.800"
"                 118.370     1.581  3489.500"
"                 118.570    18.095  3992.500"
"             Peak outflow                  0.125    c.m/sec"
"             Maximum level               117.528    metre"
"             Maximum storage            1608.978    c.m"
"             Centroidal lag                9.829   hours"
"                  1.302     1.302     0.125     0.000 c.m/sec"
" 38          START/RE-START TOTALS 100"
"            3   Runoff Totals on EXIT"
"             Total Catchment area                     27.570    hectare"
"             Total Impervious area                     7.452    hectare"
```

```
"             Total % impervious                        27.030"
" 19          EXIT"
```

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                            Version 2.25  rev. 473"
"                MIDUSS created                          Sunday, February 7, 2010"
"           10   Units used:                                          ie METRIC"
"                Job folder:          B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\"
"                2408081 Stormwater Catchment and Pond Review\Work in
Progress\Calculations"
"                Output filename:                BasedonSWMReport__100yr-v5.out"
"                Licensee name:                                                "
"                Company                                                       "
"                Date & Time last used:                 3/21/2025 at 3:01:20 PM"
" 31          TIME PARAMETERS"
"        5.000   Time Step"
"      240.000   Max. Storm length"
"     1500.000   Max. Hydrograph"
" 32          STORM Chicago storm"
"            1   Chicago storm"
"     1815.300   Coefficient A"
"        3.090   Constant B"
"        0.847   Exponent C"
"        0.400   Fraction R"
"      240.000   Duration"
"        1.000   Time step multiplier"
"             Maximum intensity           295.424    mm/hr"
"             Total depth                  69.225    mm"
"            6   100hyd   Hydrograph extension used in this file"
" 33          CATCHMENT 100"
"            1   Triangular SCS"
"            3   Specify values"
"            2   Horton equation"
"          100   Catchment 100"
"       27.030   % Impervious"
"       27.570   Total Area"
"     1100.000   Flow length"
"        3.500   Overland Slope"
"       20.118   Pervious Area"
"     1100.000   Pervious length"
"        3.500   Pervious slope"
"        7.452   Impervious Area"
"     1100.000   Impervious length"
"        3.500   Impervious slope"
"        0.250   Pervious Manning 'n'"
"      150.000   Pervious Max.infiltration"
"       12.500   Pervious Min.infiltration"
"        0.250   Pervious Lag constant (hours)"
"       10.000   Pervious Depression storage"
"        0.015   Impervious Manning 'n'"
"        0.000   Impervious Max.infiltration"
"        0.000   Impervious Min.infiltration"
"        0.050   Impervious Lag constant (hours)"
```

```
"       10.000   Impervious Depression storage"
"                     3.014     0.000     0.000     0.000 c.m/sec"
"             Catchment 100          Pervious   Impervious Total Area "
"             Surface Area           20.118     7.452      27.570     hectare"
"             Time of concentration  82.924     10.556     34.926     minutes"
"             Time to Centroid       170.973    130.788    144.320    minutes"
"             Rainfall depth         69.225     69.225     69.225     mm"
"             Rainfall volume        1.3927     0.5159     1.9085     ha-m"
"             Rainfall losses        58.137     10.266     45.197     mm"
"             Runoff depth           11.088     58.959     24.028     mm"
"             Runoff volume          2230.74    4393.75    6624.49    c.m"
"             Runoff coefficient     0.160      0.852      0.347      "
"             Maximum flow           0.479      2.947      3.014      c.m/sec"
" 40          HYDROGRAPH Add Runoff "
"            4   Add Runoff "
"                     3.014     3.014     0.000     0.000"
" 54          POND DESIGN"
"         3.014   Current peak flow    c.m/sec"
"         0.419   Target outflow    c.m/sec"
"        6624.5   Hydrograph volume    c.m"
"          15.   Number of stages"
"       116.400   Minimum water level    metre"
"       118.570   Maximum water level    metre"
"       116.400   Starting water level    metre"
"             0   Keep Design Data: 1 = True; 0 = False"
"                   Level Discharge    Volume"
"                 116.400     0.000     0.000"
"                 116.590   0.00800   205.600"
"                 116.750   0.01100   397.200"
"                 117.000   0.01500   733.800"
"                 117.250   0.02500  1118.900"
"                 117.420   0.07800  1409.700"
"                 117.500    0.1170  1554.800"
"                 117.750    0.1930  2043.800"
"                 117.810    0.2060  2169.200"
"                 117.890    0.2860  2341.500"
"                 118.000    0.4770  2587.600"
"                 118.250     1.137  3187.700"
"                 118.320     1.367  3363.800"
"                 118.370     1.581  3489.500"
"                 118.570    18.095  3992.500"
"             Peak outflow                  0.732    c.m/sec"
"             Maximum level               118.097    metre"
"             Maximum storage            2820.547    c.m"
"             Centroidal lag                5.913   hours"
"                  3.014     3.014     0.732     0.000 c.m/sec"
" 38          START/RE-START TOTALS 100"
"            3   Runoff Totals on EXIT"
"             Total Catchment area                     27.570    hectare"
"             Total Impervious area                     7.452    hectare"
```

```
"             Total % impervious                        27.030"
" 19          EXIT"
```

Appendix C Modelling Results based on Revised Parameters

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                            Version 2.25  rev. 473"
"                MIDUSS created                          Sunday, February 7, 2010"
"           10   Units used:                                            ie METRIC"
"                Job folder:          B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\"
"                2408081 Stormwater Catchment and Pond Review\Work in
Progress\Calculations"
"                Output filename:                     RevisedParameters-2yr.out"
"                Licensee name:                                                "
"                Company                                                       "
"                Date & Time last used:                 3/21/2025 at 3:12:09 PM"
" 31          TIME PARAMETERS"
"        5.000   Time Step"
"      240.000   Max. Storm length"
"     1500.000   Max. Hydrograph"
" 32          STORM Chicago storm"
"            1   Chicago storm"
"      719.650   Coefficient A"
"        5.849   Constant B"
"        0.813   Exponent C"
"        0.400   Fraction R"
"      240.000   Duration"
"        1.000   Time step multiplier"
"             Maximum intensity            99.424    mm/hr"
"             Total depth                  32.777    mm"
"            6   002hyd   Hydrograph extension used in this file"
" 33          CATCHMENT 100"
"            1   Triangular SCS"
"            3   Specify values"
"            2   Horton equation"
"          100   Catchment 100"
"       55.000   % Impervious"
"       28.580   Total Area"
"      450.000   Flow length"
"        2.500   Overland Slope"
"       12.861   Pervious Area"
"      450.000   Pervious length"
"        2.500   Pervious slope"
"       15.719   Impervious Area"
"      450.000   Impervious length"
"        2.500   Impervious slope"
"        0.250   Pervious Manning 'n'"
"      125.000   Pervious Max.infiltration"
"        5.000   Pervious Min.infiltration"
"        0.250   Pervious Lag constant (hours)"
"        5.000   Pervious Depression storage"
"        0.015   Impervious Manning 'n'"
"        0.000   Impervious Max.infiltration"
"        0.000   Impervious Min.infiltration"
"        0.050   Impervious Lag constant (hours)"
```

```
"        1.500   Impervious Depression storage"
"                     2.693     0.000     0.000     0.000 c.m/sec"
"             Catchment 100          Pervious   Impervious Total Area "
"             Surface Area           12.861     15.719     28.580     hectare"
"             Time of concentration      ---    10.559     10.559     minutes"
"             Time to Centroid       0.000      128.979    128.979    minutes"
"             Rainfall depth         32.777     32.777     32.777     mm"
"             Rainfall volume        4215.44    5152.20    9367.64    c.m"
"             Rainfall losses        32.777     1.591      15.625     mm"
"             Runoff depth           0.000      31.186     17.152     mm"
"             Runoff volume          0.00       4902.07    4902.07    c.m"
"             Runoff coefficient     0.000      0.951      0.523      "
"             Maximum flow           0.000      2.693      2.693      c.m/sec"
" 40          HYDROGRAPH Add Runoff "
"            4   Add Runoff "
"                     2.693     2.693     0.000     0.000"
" 54          POND DESIGN"
"         2.693   Current peak flow    c.m/sec"
"         0.419   Target outflow    c.m/sec"
"        4902.1   Hydrograph volume    c.m"
"           15.   Number of stages"
"       116.400   Minimum water level    metre"
"       118.570   Maximum water level    metre"
"       116.400   Starting water level    metre"
"             0   Keep Design Data: 1 = True; 0 = False"
"                   Level Discharge    Volume"
"                 116.400     0.000     0.000"
"                 116.590   0.00800   205.600"
"                 116.750   0.01100   397.200"
"                 117.000   0.01500   733.800"
"                 117.250   0.02500  1118.900"
"                 117.420   0.07800  1409.700"
"                 117.500    0.1170  1554.800"
"                 117.750    0.1930  2043.800"
"                 117.810    0.2060  2169.200"
"                 117.890    0.2860  2341.500"
"                 118.000    0.4770  2587.600"
"                 118.250     1.137  3187.700"
"                 118.320     1.367  3363.800"
"                 118.370     1.581  3489.500"
"                 118.570    18.095  3992.500"
"             Peak outflow                  0.733    c.m/sec"
"             Maximum level               118.098    metre"
"             Maximum storage            2823.760    c.m"
"             Centroidal lag                6.590   hours"
"                  2.693     2.693     0.733     0.000 c.m/sec"
" 38          START/RE-START TOTALS 100"
"            3   Runoff Totals on EXIT"
"             Total Catchment area                    28.580    hectare"
"             Total Impervious area                   15.719    hectare"
```

```
"             Total % impervious                        55.000"
" 19          EXIT"
```

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                            Version 2.25  rev. 473"
"                MIDUSS created                          Sunday, February 7, 2010"
"           10   Units used:                                            ie METRIC"
"                Job folder:          B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\"
"                2408081 Stormwater Catchment and Pond Review\Work in
Progress\Calculations"
"                Output filename:                     RevisedParameters-5yr.out"
"                Licensee name:                                                "
"                Company                                                       "
"                Date & Time last used:                 3/21/2025 at 3:16:00 PM"
" 31          TIME PARAMETERS"
"        5.000   Time Step"
"      240.000   Max. Storm length"
"     1500.000   Max. Hydrograph"
" 32          STORM Chicago storm"
"            1   Chicago storm"
"      996.920   Coefficient A"
"        4.233   Constant B"
"        0.826   Exponent C"
"        0.400   Fraction R"
"      240.000   Duration"
"        1.000   Time step multiplier"
"             Maximum intensity           152.144    mm/hr"
"             Total depth                  42.500    mm"
"            6   005hyd   Hydrograph extension used in this file"
" 33          CATCHMENT 100"
"            1   Triangular SCS"
"            3   Specify values"
"            2   Horton equation"
"          100   Catchment 100"
"       55.000   % Impervious"
"       28.580   Total Area"
"      450.000   Flow length"
"        2.500   Overland Slope"
"       12.861   Pervious Area"
"      450.000   Pervious length"
"        2.500   Pervious slope"
"       15.719   Impervious Area"
"      450.000   Impervious length"
"        2.500   Impervious slope"
"        0.250   Pervious Manning 'n'"
"      125.000   Pervious Max.infiltration"
"        5.000   Pervious Min.infiltration"
"        0.250   Pervious Lag constant (hours)"
"        5.000   Pervious Depression storage"
"        0.015   Impervious Manning 'n'"
"        0.000   Impervious Max.infiltration"
"        0.000   Impervious Min.infiltration"
"        0.050   Impervious Lag constant (hours)"
```

```
"        1.500   Impervious Depression storage"
"                     4.268     0.000     0.000     0.000 c.m/sec"
"             Catchment 100          Pervious   Impervious Total Area "
"             Surface Area           12.861     15.719     28.580     hectare"
"             Time of concentration  93.692     8.907      12.797     minutes"
"             Time to Centroid       169.249    125.411    127.423    minutes"
"             Rainfall depth         42.500     42.500     42.500     mm"
"             Rainfall volume        0.5466     0.6681     1.2147     ha-m"
"             Rainfall losses        40.097     1.614      18.932     mm"
"             Runoff depth           2.403      40.886     23.569     mm"
"             Runoff volume          309.08     6426.90    6735.99    c.m"
"             Runoff coefficient     0.057      0.962      0.555      "
"             Maximum flow           0.064      4.259      4.268      c.m/sec"
" 40          HYDROGRAPH Add Runoff "
"            4   Add Runoff "
"                     4.268     4.268     0.000     0.000"
" 54          POND DESIGN"
"        4.268   Current peak flow    c.m/sec"
"        0.419   Target outflow    c.m/sec"
"       6736.0   Hydrograph volume    c.m"
"          15.   Number of stages"
"      116.400   Minimum water level    metre"
"      118.570   Maximum water level    metre"
"      116.400   Starting water level    metre"
"             0   Keep Design Data: 1 = True; 0 = False"
"                   Level Discharge    Volume"
"                 116.400     0.000     0.000"
"                 116.590   0.00800   205.600"
"                 116.750   0.01100   397.200"
"                 117.000   0.01500   733.800"
"                 117.250   0.02500  1118.900"
"                 117.420   0.07800  1409.700"
"                 117.500    0.1170  1554.800"
"                 117.750    0.1930  2043.800"
"                 117.810    0.2060  2169.200"
"                 117.890    0.2860  2341.500"
"                 118.000    0.4770  2587.600"
"                 118.250     1.137  3187.700"
"                 118.320     1.367  3363.800"
"                 118.370     1.581  3489.500"
"                 118.570    18.095  3992.500"
"             Peak outflow                  1.485    c.m/sec"
"             Maximum level               118.363    metre"
"             Maximum storage            3471.608    c.m"
"             Centroidal lag                5.466   hours"
"                  4.268     4.268     1.485     0.000 c.m/sec"
" 38          START/RE-START TOTALS 100"
"            3   Runoff Totals on EXIT"
"             Total Catchment area                    28.580    hectare"
"             Total Impervious area                   15.719    hectare"
```

```
"             Total % impervious                        55.000"
" 19          EXIT"
```

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                            Version 2.25  rev. 473"
"                MIDUSS created                          Sunday, February 7, 2010"
"           10   Units used:                                          ie METRIC"
"                Job folder:          B:\Working\NIAGARA-ON-THE-LAKE, TOWN OF\"
"                2408081 Stormwater Catchment and Pond Review\Work in
Progress\Calculations"
"                Output filename:                   RevisedParameters-100yr.out"
"                Licensee name:                                               "
"                Company                                                      "
"                Date & Time last used:                 3/21/2025 at 3:19:11 PM"
" 31          TIME PARAMETERS"
"        5.000   Time Step"
"      240.000   Max. Storm length"
"     1500.000   Max. Hydrograph"
" 32          STORM Chicago storm"
"            1   Chicago storm"
"     1815.300   Coefficient A"
"        3.090   Constant B"
"        0.847   Exponent C"
"        0.400   Fraction R"
"      240.000   Duration"
"        1.000   Time step multiplier"
"             Maximum intensity           295.424    mm/hr"
"             Total depth                  69.225    mm"
"            6   100hyd   Hydrograph extension used in this file"
" 33          CATCHMENT 100"
"            1   Triangular SCS"
"            3   Specify values"
"            2   Horton equation"
"          100   Catchment 100"
"       55.000   % Impervious"
"       28.580   Total Area"
"      450.000   Flow length"
"        2.500   Overland Slope"
"       12.861   Pervious Area"
"      450.000   Pervious length"
"        2.500   Pervious slope"
"       15.719   Impervious Area"
"      450.000   Impervious length"
"        2.500   Impervious slope"
"        0.250   Pervious Manning 'n'"
"      125.000   Pervious Max.infiltration"
"        5.000   Pervious Min.infiltration"
"        0.250   Pervious Lag constant (hours)"
"        5.000   Pervious Depression storage"
"        0.015   Impervious Manning 'n'"
"        0.000   Impervious Max.infiltration"
"        0.000   Impervious Min.infiltration"
"        0.050   Impervious Lag constant (hours)"
```

```
"        1.500   Impervious Depression storage"
"                     9.447     0.000     0.000     0.000 c.m/sec"
"             Catchment 100          Pervious   Impervious Total Area "
"             Surface Area           12.861     15.719     28.580     hectare"
"             Time of concentration  41.553     6.830      14.362     minutes"
"             Time to Centroid       148.745    120.576    126.686    minutes"
"             Rainfall depth         69.225     69.225     69.225     mm"
"             Rainfall volume        0.8903     1.0881     1.9785     ha-m"
"             Rainfall losses        46.597     2.385      22.280     mm"
"             Runoff depth           22.628     66.840     46.945     mm"
"             Runoff volume          0.2910     1.0507     1.3417     ha-m"
"             Runoff coefficient     0.327      0.966      0.678      "
"             Maximum flow           1.108      9.150      9.447      c.m/sec"
" 40          HYDROGRAPH Add Runoff "
"            4   Add Runoff "
"                     9.447     9.447     0.000     0.000"
" 54          POND DESIGN"
"        9.447   Current peak flow    c.m/sec"
"        0.419   Target outflow    c.m/sec"
"      13416.8   Hydrograph volume    c.m"
"         15.   Number of stages"
"      116.400   Minimum water level    metre"
"      118.570   Maximum water level    metre"
"      116.400   Starting water level    metre"
"            0   Keep Design Data: 1 = True; 0 = False"
"                  Level Discharge    Volume"
"                116.400     0.000     0.000"
"                116.590   0.00800   205.600"
"                116.750   0.01100   397.200"
"                117.000   0.01500   733.800"
"                117.250   0.02500  1118.900"
"                117.420   0.07800  1409.700"
"                117.500    0.1170  1554.800"
"                117.750    0.1930  2043.800"
"                117.810    0.2060  2169.200"
"                117.890    0.2860  2341.500"
"                118.000    0.4770  2587.600"
"                118.250     1.137  3187.700"
"                118.320     1.367  3363.800"
"                118.370     1.581  3489.500"
"                118.570    18.095  3992.500"
"             Peak outflow                  6.467    c.m/sec"
"             Maximum level               118.461    metre"
"             Maximum storage            3718.319    c.m"
"             Centroidal lag                3.452   hours"
"                  9.447     9.447     6.467     0.000 c.m/sec"
" 38          START/RE-START TOTALS 100"
"            3   Runoff Totals on EXIT"
"             Total Catchment area                    28.580    hectare"
"             Total Impervious area                   15.719    hectare"
```

```
"             Total % impervious                        55.000"
" 19          EXIT"
```