Highland Park Stormwater Management Report

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Sign-off Sheet

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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

CORPORATE AUTHORIZATION

PROFESSIONAL ENGINEER
CLAYTON B. GAMSON
ALBERTA
April 17/2014

RESPONSIBLE ENGINEER

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1.0 Introduction

This stormwater management report (SWMR) report was prepared on behalf of 1127864 Alberta Ltd. in accordance with the requirements of the County of Lacombe Design Guidelines. It will serve as a supplement to the engineering design drawings prepared by Stantec Consulting Ltd. for Highland Park subdivision. Highland Park is located in the County of Lacombe in the NE$^1/_4$ Sec. 17- Twp. 39- Rge. 01-W5M, as shown on **Figure 1.1, Site Location**.

The objective of this study is to demonstrate that the proposed stormwater management facility will meet Alberta Environment (AENV) criteria for permissible release rate and water quality improvement. It will also outline the proposed configuration for the drainage systems within the residential development.

2.0 Site Description

Figure 2.1, Study Area shows the site location and study catchment area, which will comprise of 27.45 ha of country residential low density along with 59.69ha of offsite lands. The site is located in Lacombe county 9.5 km north of the Town of Sylvan Lake and 0.5 km north east of the Summer Village of Birchcliff. In addition to Highland Park, the study area includes off-site area that naturally flows through the Highland Park existing land. The majority of the area proposed for development is currently undeveloped farm land with neighboring farmlands to the south, west and north. The land generally slopes from the east to the west with gentle grades for the majority of the land and steeper slopes towards the southern and western boundaries of the study area.

All drainage from Highland Park goes to Sylvan Lake. The majority of the site drains to a natural drainage ditch which naturally drains overland down to Sylvan Lake with a small portion of the site draining to the south through adjacent lands and eventually makes its way into Sylvan Lake as well. The post-development scenario will match both of these flows as they exist today in order to not create a negative effect on the downstream hydrology.

3.0 Methodology and Input Data

3.1 SINGLE EVENT ANALYSIS

The most common method of analysis used for stormwater management is based on a single storm event; either a real historic storm or a theoretical design storm. A one in two (1:2) and a one in one-hundred (1:100) year return period design storms were used, with the Chicago distribution. This distribution does not necessarily reflect the shape that such a rare storm event would exhibit in the County of Lacombe, but it represents two important characteristics for design purposes:

- The total precipitation of the Chicago storms, for any duration, is the same as the total precipitation defined statistically for the 1:2 and the 1:100 year events.

- The peak intensity of the Chicago Storms, for any time increment, is the same as the peak intensity defined statistically for the 1:2 and the 1:100 year events.

The storm duration was 24 hour and the rainfall time increments were 1 minute for the 1:2 and 5 minutes for the 1:100 year storm events.

Rainfall intensities for the Chicago distribution are determined from an *intensity-duration-frequency* (IDF) relationship that is described as

$$i = \frac{a}{(t+b)^c} \qquad [1]$$

where i is intensity (mm/hr), a, b and c are IDF parameters and t is the time duration (minutes). The time to storm peak is determined by

$$\frac{t_p}{t_d} = r \quad \text{or} \quad t_p = r(t_d) \qquad [2]$$

where t_p is the time to peak and r is the ratio of time to peak versus storm duration, t_d.

The following parameters were used to derive the rainfall intensities for these design storms as provided AES for the City of Lacombe:

1:2 year:	a = 380.7	b = 6.66	c = 0.736	r = 0.3
1:100 year:	a = 1201.1	b = 5.55	c = 0.777	r = 0.3

Table 3.1 lists the rainfall intensities for the design storm.

3.2 COMPUTER MODEL

PCSWMM Professional 2013 with full support for US EPA SWMM5, was used to compute the runoff and route the resulting flows through the major drainage system. This is a *discrete* model that was specifically developed for analysis of drainage systems.

The user's manual (CHI, 2010) provides a detailed description of the US EPA SWMM5 model.

A new PCSWMM model was used for Highland Park to simulate the single event scenario

The PCSWMM input and output data for the single event and the continuous simulation are included in Appendix A and Appendix B respectfully.

3.3 SURFACE RUNOFF

Impervious areas were determined based on approximate average values of physical imperviousness for the study area.

Abstraction losses are accounted for in PCSWMM as soil infiltration and depression storage. This is discussed further in the technical manual (IMC, September, 1996). For this study the following parameters were used:

- Maximum infiltration rate, F_0 = 75.0 mm/hr
- Minimum infiltration rate, F_C = 7.5 mm/hr
- rate of decay, k = 4.14 hr^{-1}
- depression storage, impervious areas = 1.6 mm
- depression storage, pervious areas = 3.2 mm

Other model parameters required for the PCSWMM model are representative of the physical characteristics of each subcatchment.

The following Manning roughness values were used for all subcatchments (IMC, September, 1996):

- n = 0.015 for impervious areas
- n = 0.25 for pervious areas

3.4 DESIGN OBJECTIVES

The following specific design criteria were used for this study:

- Determine existing drainage patterns.
- Develop a post-development plan that will meet pre-development peak flow rates.
- Demonstrate that the proposed stormwater management facility can meet Alberta Environment (AENV) criteria for permissible release rates and water quality.

4.0 Pre-Development Drainage

4.1 PRE-DEVELOPOMENT

The Town of Sylvan Lake did an infrastructure study to identify a growth strategy for the development that was going to happen in and around the Town. Even though this Highland Park development is located outside of the specified drainage basin boundary for that study, it was still looked at for general concepts and strategies. This study determined a pre-development unit area release rate of 2.10 L/s/ha that all new developments would have to control post-development release rates to. Since the parameters used for this study vary drastically compared to the Highland Park study area, and this study area is not actually in the Sylvan Lake Servicing study, it can easily be argued that a higher release rate is suitable for this development. The Chicago based 1:2 year 24 hour storm event was used to estimate the pre-development flows for these urban type subcatchments. This was done as a measure to not overestimate the undeveloped lands drainage patterns. This is a common engineering practice to use this storm event in determining pre-development flows in order to set a target rate for the post-development 1:100 year storm event.

Figure 4.1, Pre-Development Subcatchments illustrates the predevelopment subcatchments and major drainage directions. Table 4.1 shows the parameters used in the analysis for each pre-development subcatchment. Subcatchment 1 (38.17 ha) flows overland to a low point where two 600mm culverts are located. There is a natural traplow that is created where runoff will pond at the inlet of the culverts. Table 4.2 summarizes the culverts and Table 4.3 summarizes the storage rating curve. These culverts convey the runoff under the road and into the study area. Subcatchment 2 (20.70 ha) represents the off-site drainage to the north of Highland Park. These subcatchments contain some minor traplows that were not taken into account during the analysis. Subcatchment 3 (19.10 ha) receives the flow from the previously mentioned culverts and the offsite lands to the north as well as overland flows from within the north portion of the Highland Park subdivision which are then directed to a natural drainage ditch (Birchcliff Creek) that drains offsite towards Sylvan Lake. Subcatchment 4 (9.17 ha) sheet flows overland to the southwest corner of the site onto the adjacent land to the south which is currently routed through ditches and culverts and eventually discharges into Sylvan Lake.

Figure 4.2, Pre-Development Schematic illustrates the segments used in the PCSWMM model for the pre-development and the order of routing for each segment.

According to the Sylvan Lake Water Quality Assessment and Watershed Management Considerations (AXYS Environmental Consulting Ltd., 2005) the Birchcliff Creek is a tributary stream that flows into Sylvan Lake. It was recommended that a 30m leave strip be accommodated for a development guideline in order to protect the watercourse.

As shown on Figure 4.1, the top end of the Birchcliff Creek is just to the north of the Highland Park development with the creek running into the site and then out the west side of the site. The 30m buffer strip is also shown here.

As shown in table 4.1, the unit area release rate for the natural drainage channel is 3.9 L/s/ha which will be the target for the release rate out of the proposed storm pond. The unit area release rate out of subcatchment 4 is 5.1 L/s/ha which is higher due to a much smaller subcatchment and a steeper topography. This peak runoff rate will be used for post development flows draining off site to the south.

5.0 Proposed Stormwater Management

5.1 POST DEVELOPMENT

The Highland Park development will consist of an overland drainage network. The proposed development shall be graded such that the majority of the development can have the overland flows drain\spill to the proposed stormwater management facility by roadway ditches and culverts. Please see **Figure 5.1, Post-Development Subcatchments** Stormwater Management Plan. Table 5.1 shows the parameters used in the analysis for each post-development subcatchment. It is not possible to have the back of lots from the southwest lots drain to the pond due to topography. Previsions will be made to have this flow match the pre-development flows.

Previsions will be made and detailed design will be done in order to route all of the off-site drainage (from the east and north) around the proposed lots within Highland Park through grass swales. These flows will be routed to the natural existing ravine (Birchcliff Creek) and continue downstream, by-passing the proposed pond, and eventually discharging into Sylvan Lake. As mentioned before a 30m buffer was suggested for this receiving stream. There is a small portion of the creek that will be rerouted around the proposed lots. Since this is near the top end of the Birchcliff creek and it is at the back of the proposed lots, there will be no negative effect on the drainage course, and the re-routing will look just as good as the natural drainage course does now. Since no urban development will be done on these off-site flows, there is no need to pre-treat the drainage as the flows are just getting re-routed from what Is currently happening. All of the offsite lands will be modeled at the pre-development rates.

All runoff inside the site location will flow overland via roadways, swales, ditches and culverts. It is important that developments have a properly designed overland drainage system because poorly designed developments will still experience overland drainage, but often with consequences. In Alberta, overland drainage systems are typically designed such that property will not experience flood damage for storms up to and including the 1:100 year return period, and this is the standard that the Highland Park development will be designed to.

Overland drainage shall conform to the County of Lacombe Design Guidelines, and also the water velocity and depth relations as outlined in the Alberta Environment (AENV) Stormwater Management Guidelines.

Figure 5.2, Post-Development Schematic illustrates the segments used in the PCSWMM model for the post-development and the order of routing for each segment.

5.2 STORMWATER MANAGEMENT FACILITY CONFIGURATION

A wet pond is proposed to provide stormwater management for the Highland Park development. The facility will have an active (fluctuating) depth of 1.5 m. The wet pond will have a permanent depth of approximately 2.5 m that will permit the outlet pipe to be submerged below the winter ice level and a forebay where water will flow overland into the pond will be appropriately sized to meet the AENV dimensioning criteria for proper settling and jet dispersion. Since this rural subdivision does not have a pipe system and is all overland flows, sediments will be removed prior to reaching the pond.

The proposed stormwater management facility will discharge to the existing west central ravine (Birchcliff Creek) that subsequently drains southwest to Sylvan Lake. The proposed stormwater management facility will attenuate flows down to pre-development levels; therefore, erosion of the existing ravine is not expected to be an issue; never-the-less, it will initially be monitored for erosion.

A shallow bench that supports the growth of wetland vegetation will be constructed around the edge of the wet pond. The wetland vegetation will promote the uptake and neutralization of pollutants found in stormwater runoff. The proposed configuration will result in a substantial band of wetland vegetation around the water's edge, and once established the facility will look very much like a naturally occurring wetland with open water in the middle.

A Pond is proposed to be constructed as a wet pond. A conceptual layout is shown on **Figure 5.3, Conceptual Pond**. This pond is designed based on the minimum criteria specified in Section 3.4 for water quality improvement. The High Water Level (HWL) is the design maximum operating level, which contains (at least) the 1:100 year event storage volume. Based on the 22.67 ha of contributing area, the discharge rate at the HWL is 70 L/s (0.070 m^3/s). This translates to a unit rate of about 3.1 L/s/ha which is lower than what the pre-development flow rate was modeled at.

Table 5.2 summarizes the preliminary design data for the Pond based on the concept shown in Figure 5.3. The storage volume below the NWL is not available for discharge rate (quantity) control. This storage is significant only in terms of water quality with respect to turnover rate and the pond's ability to improve the quality of the receiving stormwater. The storage volume above the NWL is the available capacity for control of discharges to the receiving outlet. This storage is referred to as *active* storage.

Discharges from the Pond will be made by storm sewer to the natural drainage channel. They will be controlled by an outlet control structure that incorporates two levels of operation:

- An ICD will provide normal unregulated control based on orifice flow principles. The ICD will be sized to pass the design flow of 70 L/s based on water levels in the storage facility at a depth of 1.5 m above normal water level.

- An overflow weir will accommodate increased flows for runoff volumes in excess of 1:100 year storm event.

Figure 5.4, Control Structure provides conceptual details for the control structure that will be used for this Pond.

5.3 STORM POND SEDIMENT REMOVAL

As previously mentioned, the proposed facility is proposed to have an adequately sized sediment forebay in the location where the storm trunk enters the facility. Appendix B contains spreadsheet output that demonstrates the proposed forebay is adequately sized to meet the dimensioning criteria provided in Alberta Environment's Stormwater Management Guidelines. The dimensioning criteria are based on formulas that utilize settling velocity and dispersion velocity concepts. The sediment forebay inflow and outflow parameters were taken as that which will ultimately be experienced under full build out conditions.

Given the proposed configuration that incorporates wetland vegetation and an adequately sized sediment forebay, we are confident that the proposed stormwater management facility will meet Alberta Environment's requirement for removing 85% of Total Suspended Solids for particles greater than or equal to 75 microns in diameter.

5.4 DETENTION TIME

As per Alberta Environment's Stormwater Management Guidelines, stormwater management facilities must provide a minimum 24 hour (1 day) detention time to promote stormwater quality enhancement. This is generally defined as the theoretical time required to displace the contents of a stormwater pond at a given rate of discharge (i.e. active storage volume divided by rate of discharge). The detention time of the ultimate facility is calculated as follows:

Active storage volume = 10,211 m^3

Peak outflow = 0.070 m^3/s

Detention time = 10,211 m^3 / 0.070 m^3/s = 145,871 sec or 40.5 hours > 24 hours

6.0 Conclusions

The Highland Park development and storm drainage system are located in the NE¹/₄ Sec. 17- Twp. 39- Rge. 01-W5M. A few existing buildings are located near the eastern midpoint and will be removed with the proposed development. A few offsite subcatchments had to be included in the storm drainage system as the flows currently go through the proposed Highland Park development. Detailed design is able to show that the off-site flows can be rerouted around the proposed lots and continue to function as they do today with discharging into a natural ravine that flows to Sylvan Lake.

The residential development draining to Highland Park will have an overland drainage storm system with roads, swales and culverts. Overland drainage shall conform to the City of Red Deer Design Guidelines, and also the water velocity and depth relations as outlined in the Alberta Environment (AENV) Stormwater Management Guidelines.

The wet pond will have an active depth of 1.50 m and a permanent depth of 2.5 m. The pond discharge will be controlled to the pre-development release rate of 3.1 L/s/ha, which was shown in this report.

The PCSWMM Single Event modeling demonstrates that the proposed wet pond has adequate live storage to attenuate the peak flows resulting from a 24 hour duration, 1:100 year design storm event. A basic calculation using the available active storage and discharge rate also demonstrates that the facility will provide a detention time of greater than 24 hours.

The backs of lots on the southern lots were not able to be routed to the pond due to topography. Based on the pre-development analysis this area that was currently draining south had a peak flow rate of 47 L/s. Even though the imperviousness increased slightly due to development, the total area draining south was able to be reduced (40% reduction), and the peak flow rate for the post-development rate is 45 L/s which is less than the pre-development rate.

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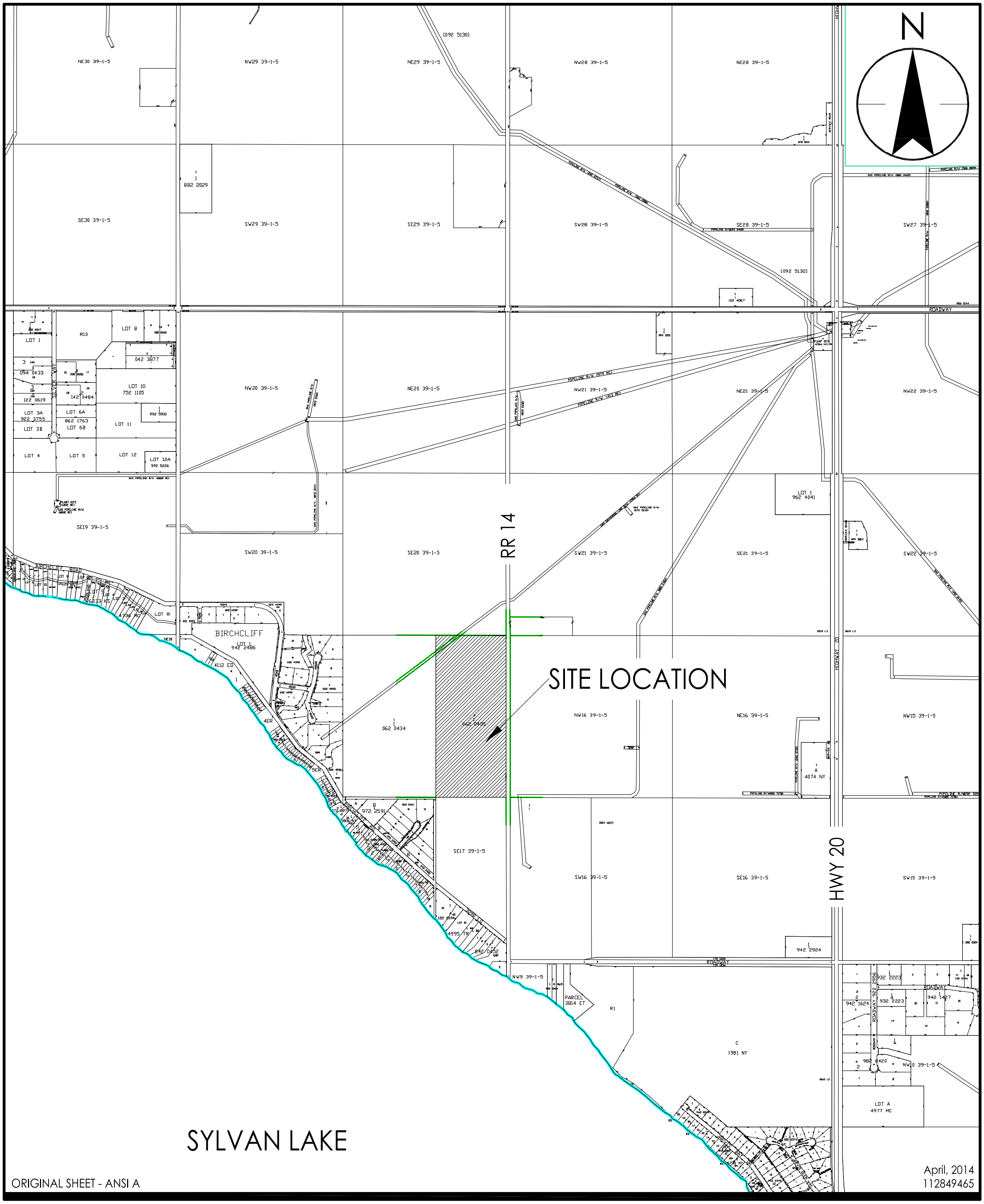

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Figure No.

1.1

Title

SITE LOCATION

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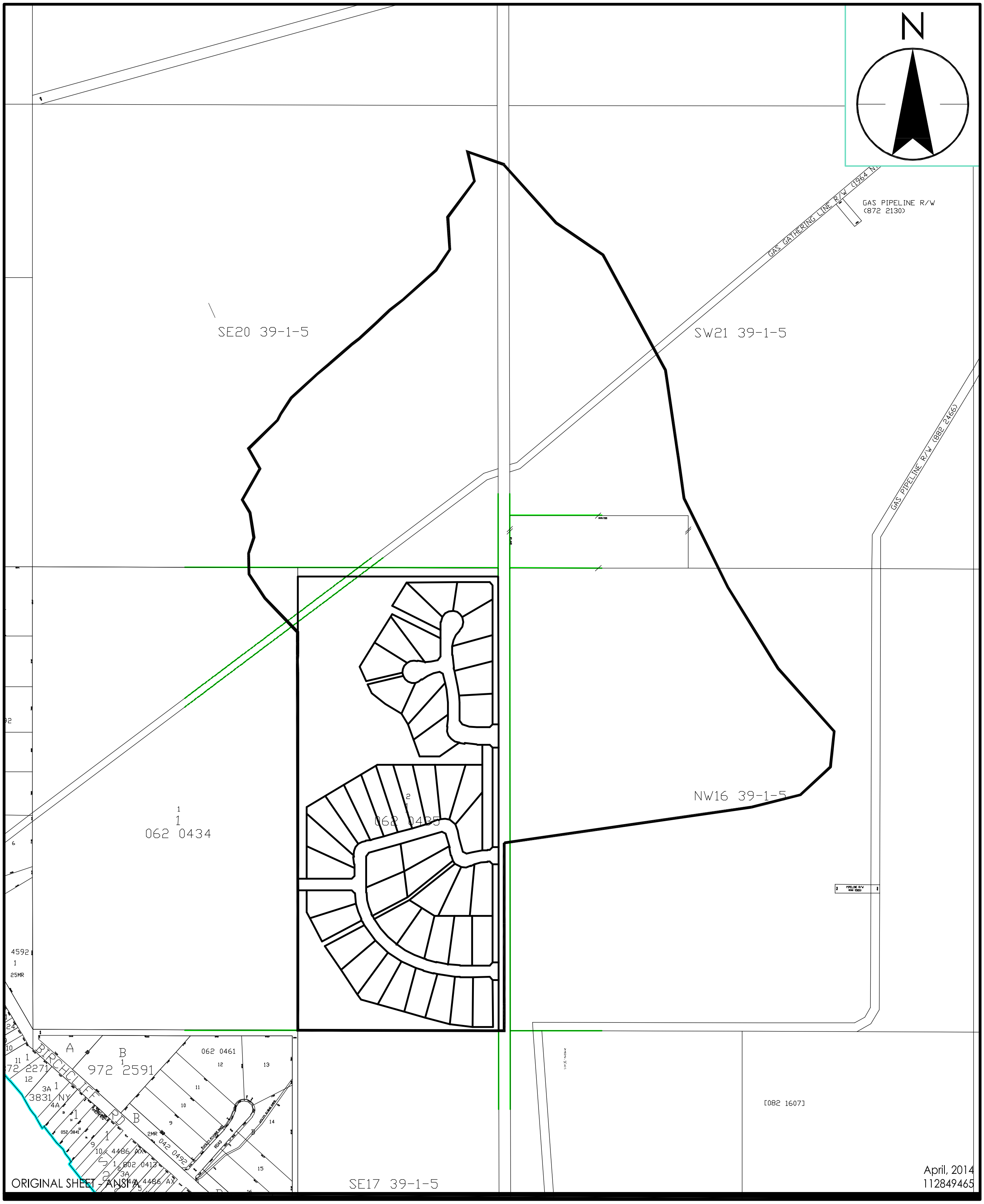

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Figure No.

2.1

Title

STUDY AREA

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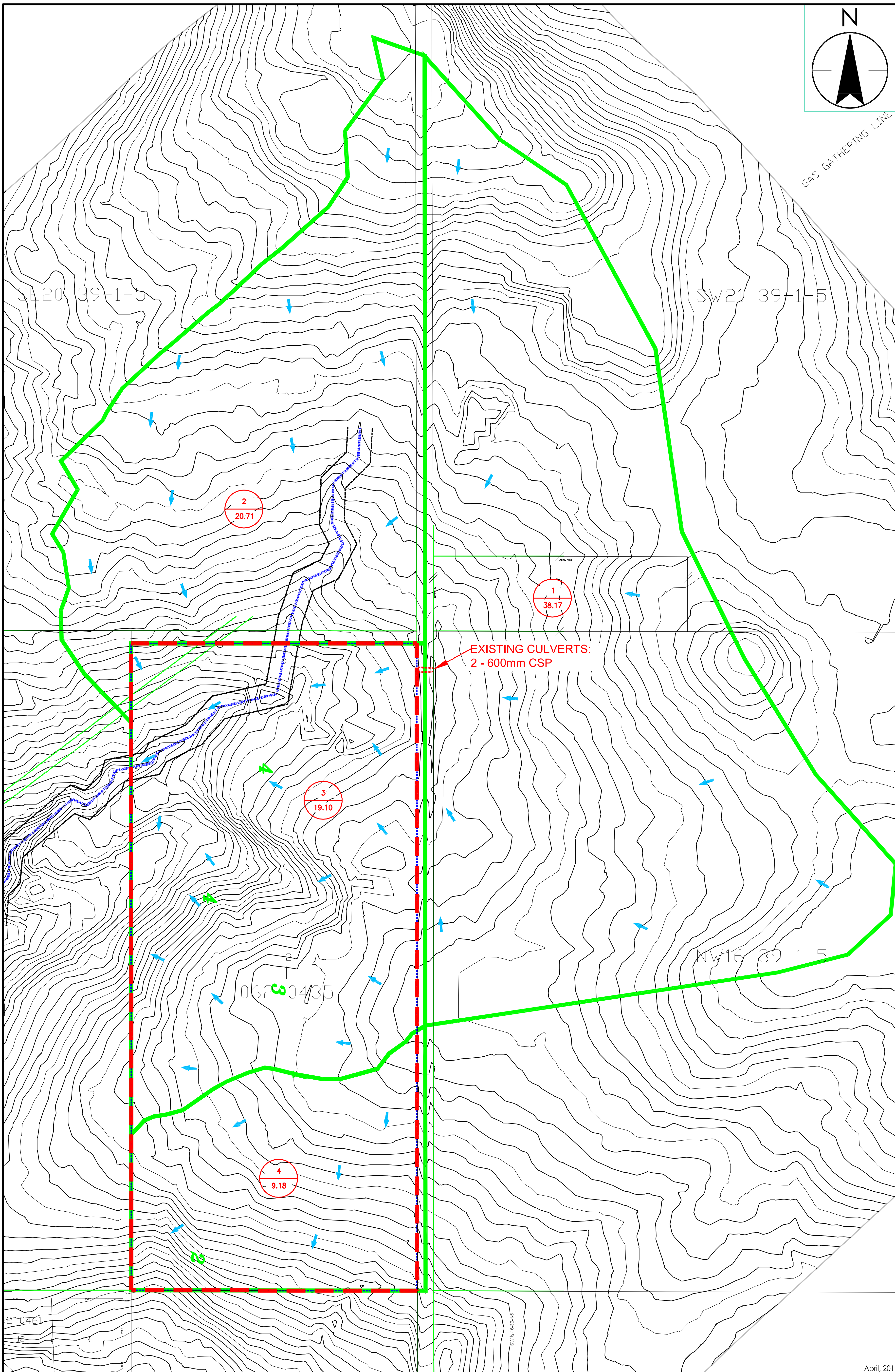
Study Catchment Area



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Site Boundary
Drainage Direction
Subcatchments
Birchcliff Creek
30m Stream buffer

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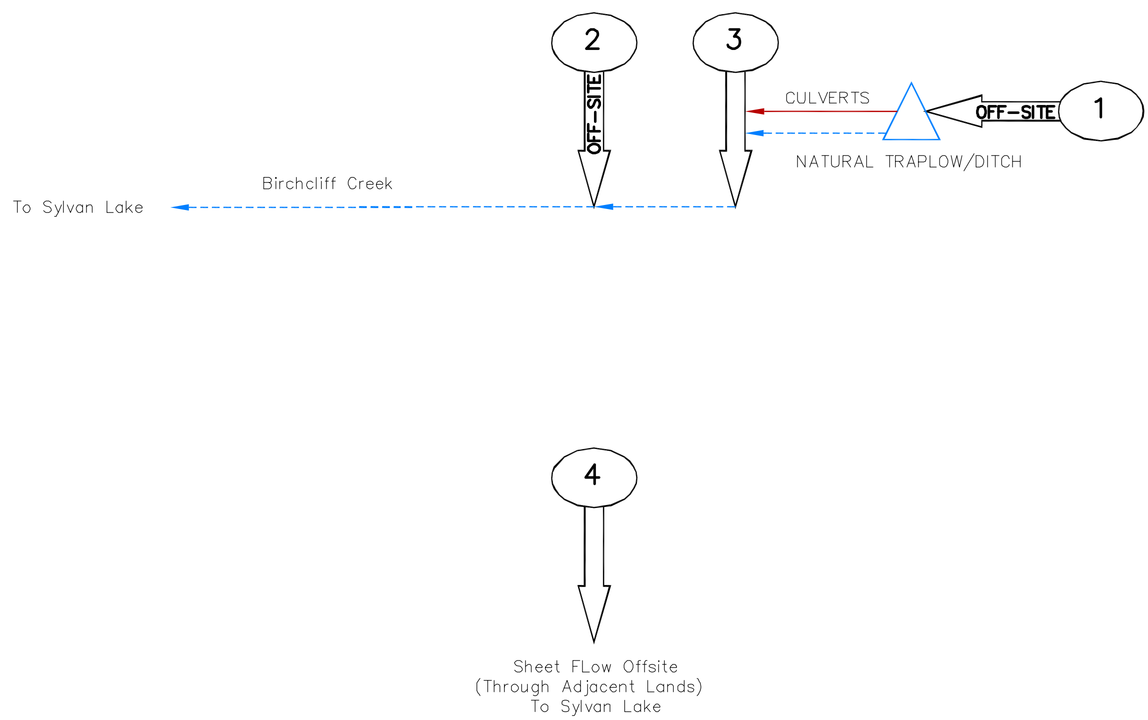
Figure No.
4.1

Title
PRE-DEVELOPMENT SUBCATCHMENTS



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14 / 114	Subcatchment
△	Trap Low (Storage)
red line	Culverts
blue dashed line	Overland Spill

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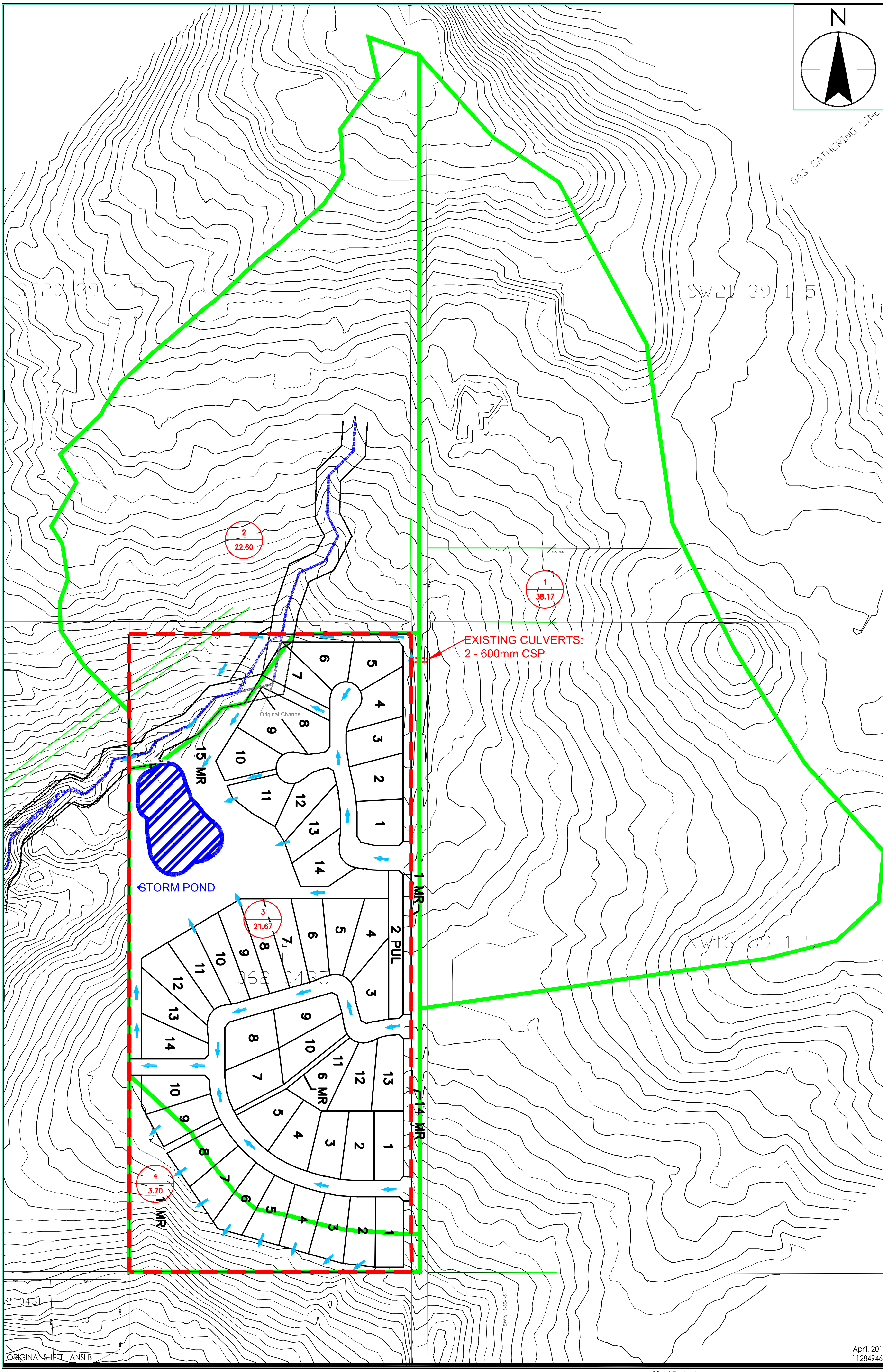
Figure No.
4.2

Title
PRE-DEVELOPMENT
SCHEMATIC



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Site Boundary	red dashed line
Drainage Direction	blue arrow
Subcatchments	green line
Birchcliff Creek	blue dotted line
30m Stream buffer	--------

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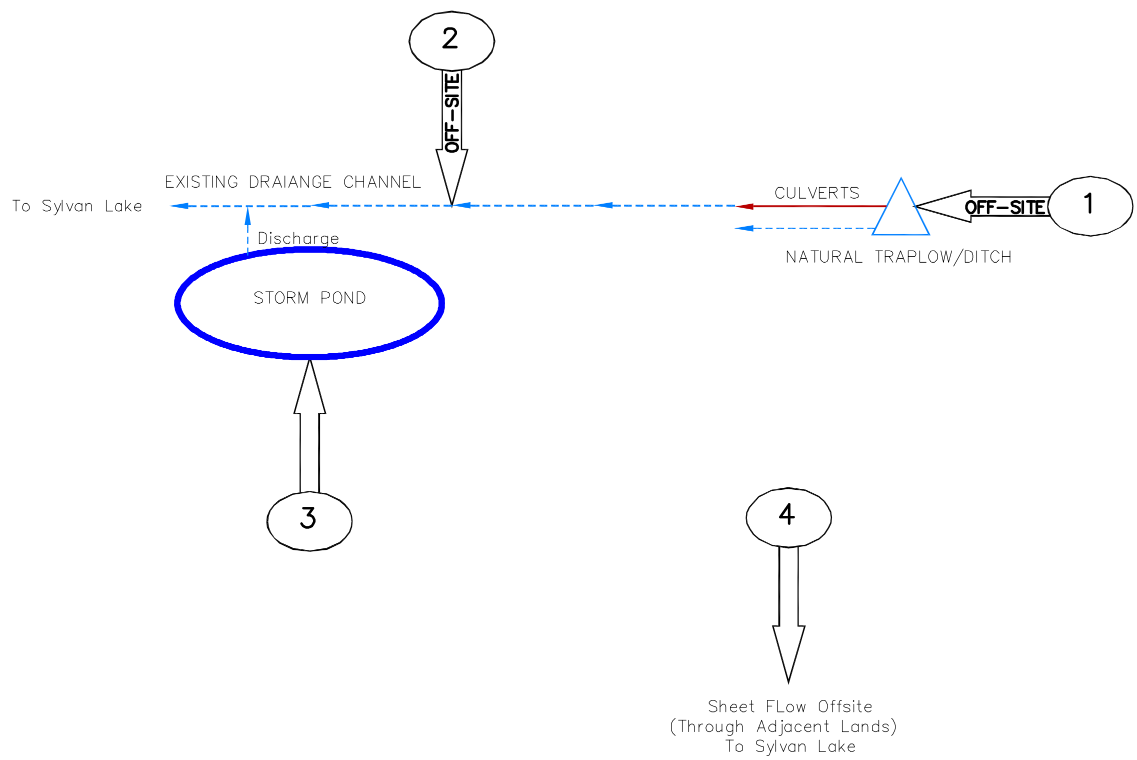
Figure No.
5.1

Title
POST-DEVELOPMENT SUBCATCHMENTS



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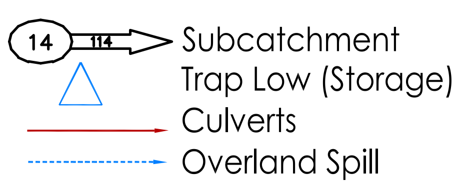

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Figure No.

5.2

Title

POST-DEVELOPMENT SCHEMATIC

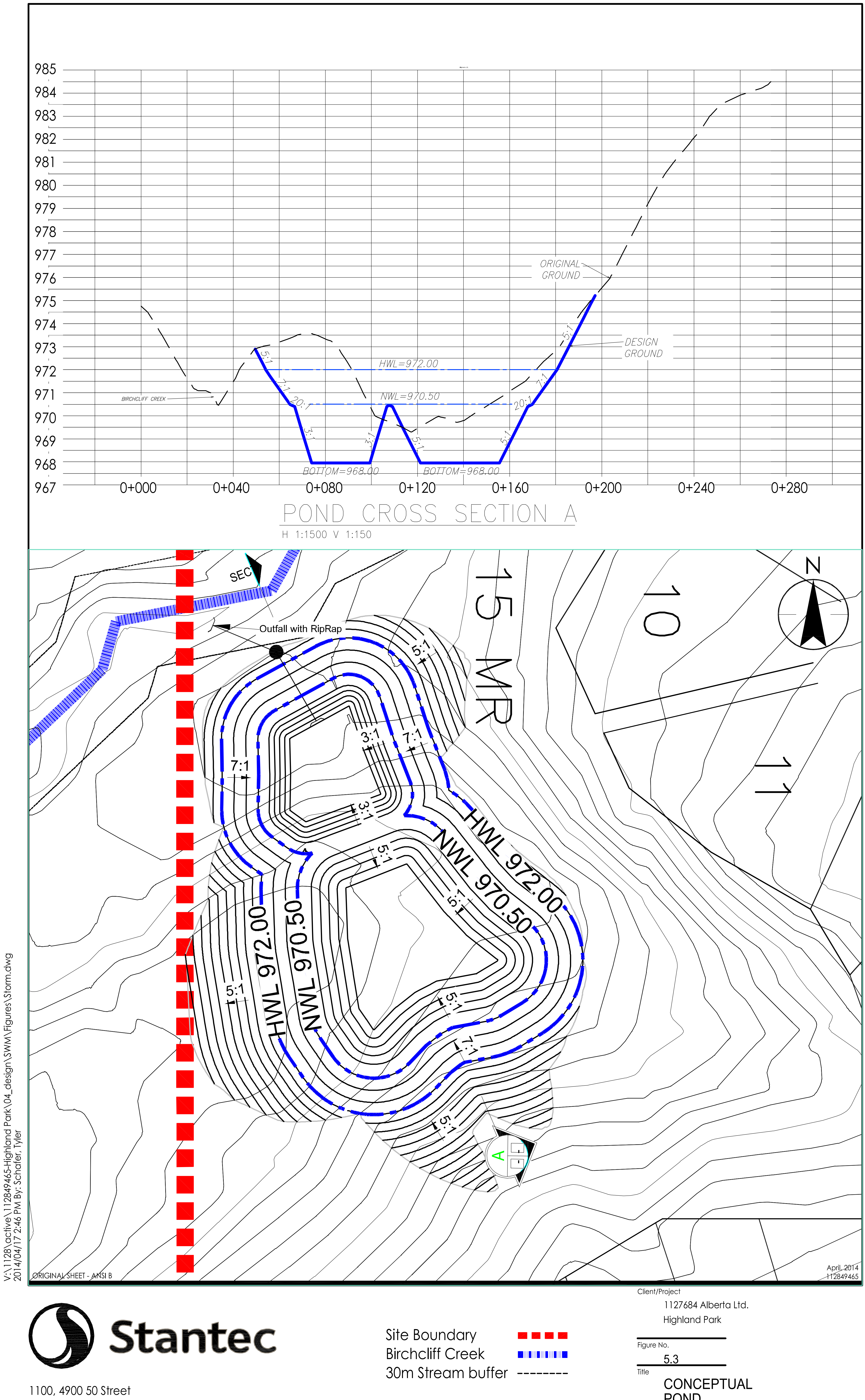

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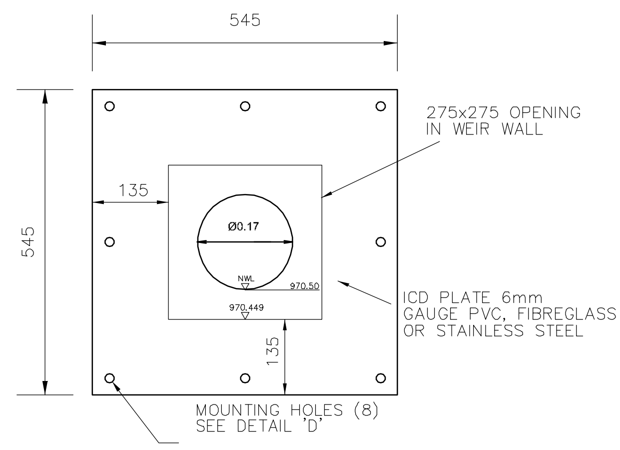
Figure No.
5.3

Title
CONCEPTUAL POND



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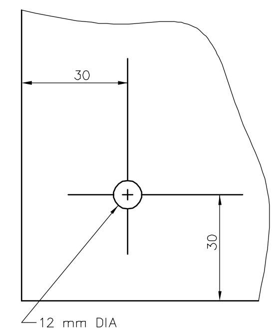

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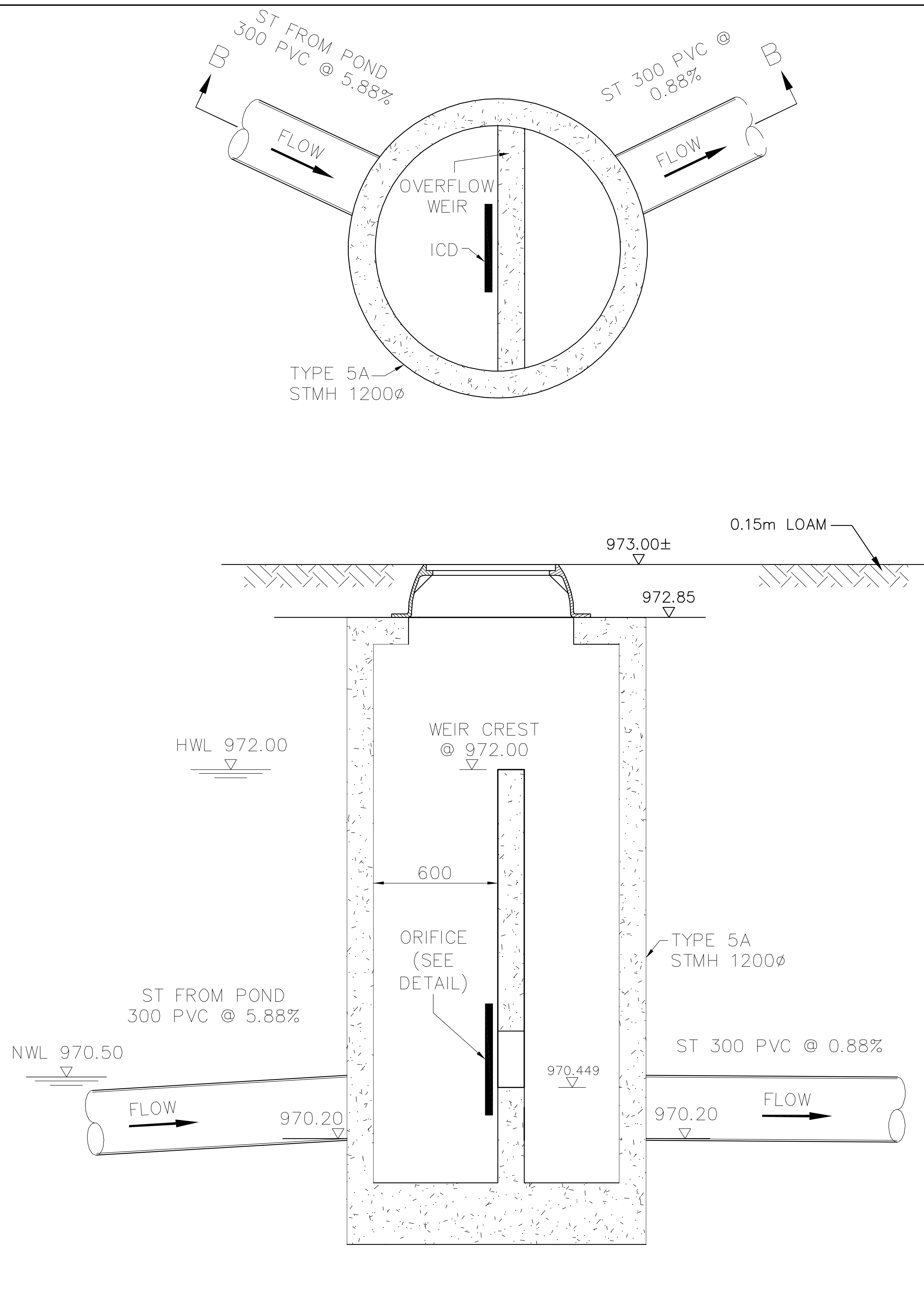

SECTION B-B

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Figure No.
5.4

Title
CONTROL
STRUCTURE

Table 3.1 24-Hour, Chicago Design Storm IDF Values

1:2 year Storm Event		1:100 Year Storm Event	
Time (min)	Intensity (mm/hr.)	Time (min)	Intensity (mm/hr.)
5	62.5	5	192.4
10	46.2	10	150.5
15	38.8	15	121.4
30	26.9	30	74.9
60	16.3	60	43.1
120	9.9	120	25.7
360	4.6	360	11.5
720	2.9	720	6.7
1440	1.8	1440	4.2

Table 4.1 Pre-Development Study Drainage Areas

Subcatchment	Description	Area (ha)	Imp. (%)	Peak Flow (m^3/s)	Runoff Volume (m^3)	Unit Area Flow Rate (L/s/ha)
1	Existing Farmland	38.17	4	0.262	635	6.86
2	Existing Farmland	20.70	3	0.107	258	5.17
3	Highland Park	19.10	3	0.099	238	5.18
Total/Average	**Birchcliff Creek[1]**	**77.97**	**3.5**	**0.301**	**1131**	**3.86**
4	Highland Park[2]	9.17	3	0.047	114	5.13

1. This is the cumulative flow that goes down the natural drainage course (Birchcliff Creek) that drains to Sylvan Lake.
2. This area drains to the south onto adjacent land (The Slopes Development).

Table 4.2 Culvert Data

Segment No.	Length (m)	Slope (%)	Material	Manning *n*	Diameter (mm)	Peak Flow (m^3/s)
Culvert_1	23.7	3.08	CSP	0.024	600	0.122
Culvert_2	24.0	2.74	CSP	0.024	600	0.123

Table 4.3 Ditch/Culvert Inlet Storage Rating

Elevation	Depth (m)	Area (m^2)	Inc. Volume	Total Volume	
987.25	0.00	2	0	0	
987.50	0.25	52	7	7	
988.00	0.75	514	142	148	
988.25	1.00	1634	268	417	Spills over Road
988.50	1.25	2753	548	965	

Table 5.1 Post-Development Study Drainage Areas

Subcatchment	Description	Area (ha)	Imp. (%)	Peak Flow (m^3/s)	Runoff Volume (m^3)	Unit Area Flow Rate (L/s/ha)
1	Existing Farmland	38.17	4	0.262	635	6.86
2	Existing Farmland	22.60	3	0.117	282	5.18
Total/Average	**Off-Site Drainage[1]**	**60.77**	**3.6**	**0.261**	**919**	**4.29**
3	Highland Park	22.67	40	1.302	13140	57.43
	Pond Discharge[2]	**22.67**	**40**	**0.070**	**13140**	**3.09**
Total/Average	**Birchcliff Creek[3]**	**83.44**	**13.5**	**0.299**	**14050**	**3.58**
4	Highland Park[4]	3.70	7	0.045	108	12.16

1. This is the offsite drainage that is being routed around the proposed development and bypassing the pond, these flows match pre-development flows.
2. Subcatchment 3 drain to the pond which treats and discharges at a controlled rate.
3. This is the cumulative flow (Existing offsite + discharge from proposed pond) that goes down the natural drainage course (Birchcliff Creek) that drains to Sylvan Lake.
4. This area drains to the south onto adjacent land (The Slopes Development).

Table 5.2 Stormwater Facility Characteristics

Description	Elevation (m)	Active Depth (m)	Surface Area (m²)	Total Volume (m³)	Active Volume (m³)	Outfall Discharge (L/s)
	968.00	-2.50	1697	0	0	0.0
NWL	970.50	0.00	5401	4501	0	0.0
	970.75	0.25	6090	6223	1723	28.0
	971.00	0.50	6560	7488	2987	38.9
	971.20	0.70	7041	8878	4347	47.3
	971.40	0.90	7532	10305	5804	54.5
	971.60	1.10	8035	11861	7361	60.8
	971.80	1.30	8549	13520	9019	66.5
HWL	972.00	1.50	9076	15282	10781	71.8
Orifice Diameter (mm)		170				
Orifice Elevation (m)		970.50				
PCSWMM 1:100 (m³)					10211	

REFERENCES

1. Computational Hydraulics International; User's Guide to SWMM5; 2010

2. Stormwater Management Guidelines for the Province of Alberta, Alberta Environmental Protection, January 1999.

3. City of Calgary; Stormwater Management & Design Manual; Wastewater & Drainage; September 2011

4. Sylvan Lake Water Quality Assessment and Watershed Management Considerations, AXYS Environmental Consulting Ltd.; 2005

5. Municipal Policies and Procedures Manual, Alberta Environmental Protection, April 2001.

Appendix A

PCSWMM Model Data

April, 2014

A.1 INPUT DATA

Highland Park Pre-Development.dat

```
[TITLE]

[OPTIONS]
FLOW_UNITS           CMS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           06/01/2013
START_TIME           00:00:00
REPORT_START_DATE    06/01/2013
REPORT_START_TIME    00:00:00
END_DATE             06/02/2013
END_TIME             12:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          0:00:05
WET_STEP             0:05:00
DRY_STEP             0:05:00
ROUTING_STEP         5
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         ELEVATION
MIN_SLOPE            0

[EVAPORATION]
;;Type          Parameters
;;------------- ----------
CONSTANT     0.0
DRY_ONLY     NO

[RAINGAGES]
;;               Rain      Time   Snow   Data
;;Name           Type      Intrvl Catch  Source
;;-------------- --------- ------ ------ ----------
Chicago_24hr:2   INTENSITY 0:05   1.0    TIMESERIES Chicago_24hr:2

[SUBCATCHMENTS]
;;                                                Total    Pcnt.             Pcnt.    Curb     Snow
;;Name           Raingage         Outlet           Area     Imperv   Width    Slope    Length   Pack
;;-------------- ---------------- ---------------- -------- -------- -------- -------- -------- --------
1                Chicago_24hr:2   Culvert_Inlet    38.17    4        1192.812 3        0
2                Chicago_24hr:2   SU3              20.7     3        591.429  5        0
3                Chicago_24hr:2   OF3              19.1     3        764      6.5      0
4                Chicago_24hr:2   OF7              9.17     3        458.5    6.5      0

[SUBAREAS]
;;Subcatchment   N-Imperv   N-Perv     S-Imperv   S-Perv     PctZero    RouteTo    PctRouted
;;-------------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
1                0.015      0.25       1.6        3.2        0          OUTLET
2                0.015      0.25       1.6        3.2        0          OUTLET
3                0.015      0.25       1.6        3.2        0          OUTLET
4                0.015      0.25       1.6        3.2        0          OUTLET

[INFILTRATION]
;;Subcatchment   MaxRate    MinRate    Decay      DryTime    MaxInfil
;;-------------- ---------- ---------- ---------- ---------- ----------
1                75         7.5        4.14       7          0
2                75         7.5        4.14       7          0
3                75         7.5        4.14       7          0
4                75         7.5        4.14       7          0

[JUNCTIONS]
;;               Invert     Max.       Init.      Surcharge  Ponded
;;Name           Elev.      Depth      Depth      Depth      Area
;;-------------- ---------- ---------- ---------- ---------- ----------
Culvert_Outlet   986.411    5          0          0          0
OF3              967.5      0          0          0          0
SU3              969.5      1          0          0          0
SU4              958        0          0          0          0
```

```
[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
OF4              957.5      FREE                         NO
OF7              0          FREE                         NO

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                        Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                       Area     Frac.
Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------
------------
Culvert_Inlet    987.25   5        0        TABULAR    Ditch_Storage                0        0        220
1.524    0.26

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- -----
-----
101              Culvert_Outlet   SU3              275        0.05       986.411    969.5      0          0
103              SU3              SU4              230        0.05       969.5      958        0          0
104              OF3              SU4              150        0.05       967.5      958        0          0
105              SU4              OF4              10         0.05       958        957.5      0          0
Culvert_1        Culvert_Inlet    Culvert_Outlet   23.7       0.024      987.248    986.518    0          0
Culvert_2        Culvert_Inlet    Culvert_Outlet   24         0.024      987.068    986.411    0          0

[WEIRS]
;;               Inlet            Outlet           Weir         Crest      Disch.     Flap End      End
;;Name           Node             Node             Type         Height     Coeff.     Gate Con.     Coeff.
;;-------------- ---------------- ---------------- ------------ ---------- ---------- ---- -------- ----------
W1               Culvert_Inlet    Culvert_Outlet   TRANSVERSE   988.25     1.6        NO   0        0

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
101              PARABOLIC    2                10         0          0          1
103              PARABOLIC    2                10         0          0          1
104              PARABOLIC    2                10         0          0          1
105              PARABOLIC    2                10         0          0          1
Culvert_1        CIRCULAR     0.6              0          0          0          1          6
Culvert_2        CIRCULAR     0.6              0          0          0          1          6
W1               RECT_OPEN    1                10         0          0

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate
;;-------------- ---------- ---------- ---------- ----------

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
Ditch_Storage    Storage    0.00       2
Ditch_Storage                0.25       52
Ditch_Storage                0.75       514
Ditch_Storage                1.00       1634
Ditch_Storage                1.25       2753

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
;Chicago design storm, a = 380.746, b = 6.656, c = 0.736, Duration = 1440 minutes, r = 0.3, rain units = mm/hr.
Chicago_24hr:2              0:00       0.483
Chicago_24hr:2              0:05       0.487
Chicago_24hr:2              0:10       0.491
Chicago_24hr:2              0:15       0.496
Chicago_24hr:2              0:20       0.5
Chicago_24hr:2              0:25       0.505
Chicago_24hr:2              0:30       0.509
Chicago_24hr:2              0:35       0.514
Chicago_24hr:2              0:40       0.519
Chicago_24hr:2              0:45       0.524
Chicago_24hr:2              0:50       0.529
Chicago_24hr:2              0:55       0.535
Chicago_24hr:2              1:00       0.54
Chicago_24hr:2              1:05       0.546
Chicago_24hr:2              1:10       0.551
Chicago_24hr:2              1:15       0.557
Chicago_24hr:2              1:20       0.563
Chicago_24hr:2              1:25       0.569
Chicago_24hr:2              1:30       0.575
Chicago_24hr:2              1:35       0.582
Chicago_24hr:2              1:40       0.588
Chicago_24hr:2              1:45       0.595
Chicago_24hr:2              1:50       0.602
Chicago_24hr:2              1:55       0.609
Chicago_24hr:2              2:00       0.616
```

Chicago_24hr:2	2:05	0.624
Chicago_24hr:2	2:10	0.632
Chicago_24hr:2	2:15	0.64
Chicago_24hr:2	2:20	0.648
Chicago_24hr:2	2:25	0.657
Chicago_24hr:2	2:30	0.665
Chicago_24hr:2	2:35	0.674
Chicago_24hr:2	2:40	0.684
Chicago_24hr:2	2:45	0.694
Chicago_24hr:2	2:50	0.704
Chicago_24hr:2	2:55	0.714
Chicago_24hr:2	3:00	0.725
Chicago_24hr:2	3:05	0.736
Chicago_24hr:2	3:10	0.747
Chicago_24hr:2	3:15	0.759
Chicago_24hr:2	3:20	0.772
Chicago_24hr:2	3:25	0.785
Chicago_24hr:2	3:30	0.798
Chicago_24hr:2	3:35	0.812
Chicago_24hr:2	3:40	0.827
Chicago_24hr:2	3:45	0.842
Chicago_24hr:2	3:50	0.858
Chicago_24hr:2	3:55	0.874
Chicago_24hr:2	4:00	0.892
Chicago_24hr:2	4:05	0.91
Chicago_24hr:2	4:10	0.929
Chicago_24hr:2	4:15	0.949
Chicago_24hr:2	4:20	0.97
Chicago_24hr:2	4:25	0.993
Chicago_24hr:2	4:30	1.016
Chicago_24hr:2	4:35	1.041
Chicago_24hr:2	4:40	1.067
Chicago_24hr:2	4:45	1.095
Chicago_24hr:2	4:50	1.125
Chicago_24hr:2	4:55	1.157
Chicago_24hr:2	5:00	1.191
Chicago_24hr:2	5:05	1.227
Chicago_24hr:2	5:10	1.267
Chicago_24hr:2	5:15	1.309
Chicago_24hr:2	5:20	1.355
Chicago_24hr:2	5:25	1.404
Chicago_24hr:2	5:30	1.458
Chicago_24hr:2	5:35	1.518
Chicago_24hr:2	5:40	1.583
Chicago_24hr:2	5:45	1.656
Chicago_24hr:2	5:50	1.736
Chicago_24hr:2	5:55	1.827
Chicago_24hr:2	6:00	1.929
Chicago_24hr:2	6:05	2.046
Chicago_24hr:2	6:10	2.181
Chicago_24hr:2	6:15	2.339
Chicago_24hr:2	6:20	2.526
Chicago_24hr:2	6:25	2.752
Chicago_24hr:2	6:30	3.031
Chicago_24hr:2	6:35	3.387
Chicago_24hr:2	6:40	3.856
Chicago_24hr:2	6:45	4.508
Chicago_24hr:2	6:50	5.48
Chicago_24hr:2	6:55	7.101
Chicago_24hr:2	7:00	10.394
Chicago_24hr:2	7:05	20.977
Chicago_24hr:2	7:10	61.913
Chicago_24hr:2	7:15	33.073
Chicago_24hr:2	7:20	19.669
Chicago_24hr:2	7:25	14.031
Chicago_24hr:2	7:30	10.961
Chicago_24hr:2	7:35	9.038
Chicago_24hr:2	7:40	7.722
Chicago_24hr:2	7:45	6.763
Chicago_24hr:2	7:50	6.034
Chicago_24hr:2	7:55	5.459
Chicago_24hr:2	8:00	4.995
Chicago_24hr:2	8:05	4.611
Chicago_24hr:2	8:10	4.288
Chicago_24hr:2	8:15	4.013
Chicago_24hr:2	8:20	3.775
Chicago_24hr:2	8:25	3.567
Chicago_24hr:2	8:30	3.383
Chicago_24hr:2	8:35	3.22
Chicago_24hr:2	8:40	3.074
Chicago_24hr:2	8:45	2.943
Chicago_24hr:2	8:50	2.824
Chicago_24hr:2	8:55	2.715
Chicago_24hr:2	9:00	2.616
Chicago_24hr:2	9:05	2.524
Chicago_24hr:2	9:10	2.44
Chicago_24hr:2	9:15	2.362

Chicago_24hr:2	9:20	2.29
Chicago_24hr:2	9:25	2.223
Chicago_24hr:2	9:30	2.16
Chicago_24hr:2	9:35	2.101
Chicago_24hr:2	9:40	2.045
Chicago_24hr:2	9:45	1.993
Chicago_24hr:2	9:50	1.944
Chicago_24hr:2	9:55	1.898
Chicago_24hr:2	10:00	1.854
Chicago_24hr:2	10:05	1.813
Chicago_24hr:2	10:10	1.773
Chicago_24hr:2	10:15	1.736
Chicago_24hr:2	10:20	1.7
Chicago_24hr:2	10:25	1.666
Chicago_24hr:2	10:30	1.634
Chicago_24hr:2	10:35	1.603
Chicago_24hr:2	10:40	1.573
Chicago_24hr:2	10:45	1.545
Chicago_24hr:2	10:50	1.518
Chicago_24hr:2	10:55	1.492
Chicago_24hr:2	11:00	1.466
Chicago_24hr:2	11:05	1.442
Chicago_24hr:2	11:10	1.419
Chicago_24hr:2	11:15	1.397
Chicago_24hr:2	11:20	1.375
Chicago_24hr:2	11:25	1.355
Chicago_24hr:2	11:30	1.334
Chicago_24hr:2	11:35	1.315
Chicago_24hr:2	11:40	1.296
Chicago_24hr:2	11:45	1.278
Chicago_24hr:2	11:50	1.261
Chicago_24hr:2	11:55	1.244
Chicago_24hr:2	12:00	1.227
Chicago_24hr:2	12:05	1.211
Chicago_24hr:2	12:10	1.196
Chicago_24hr:2	12:15	1.181
Chicago_24hr:2	12:20	1.166
Chicago_24hr:2	12:25	1.152
Chicago_24hr:2	12:30	1.139
Chicago_24hr:2	12:35	1.125
Chicago_24hr:2	12:40	1.112
Chicago_24hr:2	12:45	1.099
Chicago_24hr:2	12:50	1.087
Chicago_24hr:2	12:55	1.075
Chicago_24hr:2	13:00	1.063
Chicago_24hr:2	13:05	1.052
Chicago_24hr:2	13:10	1.041
Chicago_24hr:2	13:15	1.03
Chicago_24hr:2	13:20	1.02
Chicago_24hr:2	13:25	1.009
Chicago_24hr:2	13:30	0.999
Chicago_24hr:2	13:35	0.989
Chicago_24hr:2	13:40	0.98
Chicago_24hr:2	13:45	0.97
Chicago_24hr:2	13:50	0.961
Chicago_24hr:2	13:55	0.952
Chicago_24hr:2	14:00	0.943
Chicago_24hr:2	14:05	0.935
Chicago_24hr:2	14:10	0.926
Chicago_24hr:2	14:15	0.918
Chicago_24hr:2	14:20	0.91
Chicago_24hr:2	14:25	0.902
Chicago_24hr:2	14:30	0.894
Chicago_24hr:2	14:35	0.887
Chicago_24hr:2	14:40	0.879
Chicago_24hr:2	14:45	0.872
Chicago_24hr:2	14:50	0.865
Chicago_24hr:2	14:55	0.858
Chicago_24hr:2	15:00	0.851
Chicago_24hr:2	15:05	0.844
Chicago_24hr:2	15:10	0.837
Chicago_24hr:2	15:15	0.831
Chicago_24hr:2	15:20	0.824
Chicago_24hr:2	15:25	0.818
Chicago_24hr:2	15:30	0.812
Chicago_24hr:2	15:35	0.806
Chicago_24hr:2	15:40	0.8
Chicago_24hr:2	15:45	0.794
Chicago_24hr:2	15:50	0.788
Chicago_24hr:2	15:55	0.783
Chicago_24hr:2	16:00	0.777
Chicago_24hr:2	16:05	0.772
Chicago_24hr:2	16:10	0.766
Chicago_24hr:2	16:15	0.761
Chicago_24hr:2	16:20	0.756
Chicago_24hr:2	16:25	0.751
Chicago_24hr:2	16:30	0.746

Chicago_24hr:2	16:35	0.741
Chicago_24hr:2	16:40	0.736
Chicago_24hr:2	16:45	0.731
Chicago_24hr:2	16:50	0.726
Chicago_24hr:2	16:55	0.722
Chicago_24hr:2	17:00	0.717
Chicago_24hr:2	17:05	0.712
Chicago_24hr:2	17:10	0.708
Chicago_24hr:2	17:15	0.704
Chicago_24hr:2	17:20	0.699
Chicago_24hr:2	17:25	0.695
Chicago_24hr:2	17:30	0.691
Chicago_24hr:2	17:35	0.687
Chicago_24hr:2	17:40	0.683
Chicago_24hr:2	17:45	0.678
Chicago_24hr:2	17:50	0.674
Chicago_24hr:2	17:55	0.671
Chicago_24hr:2	18:00	0.667
Chicago_24hr:2	18:05	0.663
Chicago_24hr:2	18:10	0.659
Chicago_24hr:2	18:15	0.655
Chicago_24hr:2	18:20	0.652
Chicago_24hr:2	18:25	0.648
Chicago_24hr:2	18:30	0.645
Chicago_24hr:2	18:35	0.641
Chicago_24hr:2	18:40	0.638
Chicago_24hr:2	18:45	0.634
Chicago_24hr:2	18:50	0.631
Chicago_24hr:2	18:55	0.627
Chicago_24hr:2	19:00	0.624
Chicago_24hr:2	19:05	0.621
Chicago_24hr:2	19:10	0.618
Chicago_24hr:2	19:15	0.614
Chicago_24hr:2	19:20	0.611
Chicago_24hr:2	19:25	0.608
Chicago_24hr:2	19:30	0.605
Chicago_24hr:2	19:35	0.602
Chicago_24hr:2	19:40	0.599
Chicago_24hr:2	19:45	0.596
Chicago_24hr:2	19:50	0.593
Chicago_24hr:2	19:55	0.59
Chicago_24hr:2	20:00	0.587
Chicago_24hr:2	20:05	0.584
Chicago_24hr:2	20:10	0.582
Chicago_24hr:2	20:15	0.579
Chicago_24hr:2	20:20	0.576
Chicago_24hr:2	20:25	0.573
Chicago_24hr:2	20:30	0.571
Chicago_24hr:2	20:35	0.568
Chicago_24hr:2	20:40	0.565
Chicago_24hr:2	20:45	0.563
Chicago_24hr:2	20:50	0.56
Chicago_24hr:2	20:55	0.558
Chicago_24hr:2	21:00	0.555
Chicago_24hr:2	21:05	0.553
Chicago_24hr:2	21:10	0.55
Chicago_24hr:2	21:15	0.548
Chicago_24hr:2	21:20	0.545
Chicago_24hr:2	21:25	0.543
Chicago_24hr:2	21:30	0.541
Chicago_24hr:2	21:35	0.538
Chicago_24hr:2	21:40	0.536
Chicago_24hr:2	21:45	0.534
Chicago_24hr:2	21:50	0.532
Chicago_24hr:2	21:55	0.529
Chicago_24hr:2	22:00	0.527
Chicago_24hr:2	22:05	0.525
Chicago_24hr:2	22:10	0.523
Chicago_24hr:2	22:15	0.521
Chicago_24hr:2	22:20	0.518
Chicago_24hr:2	22:25	0.516
Chicago_24hr:2	22:30	0.514
Chicago_24hr:2	22:35	0.512
Chicago_24hr:2	22:40	0.51
Chicago_24hr:2	22:45	0.508
Chicago_24hr:2	22:50	0.506
Chicago_24hr:2	22:55	0.504
Chicago_24hr:2	23:00	0.502
Chicago_24hr:2	23:05	0.5
Chicago_24hr:2	23:10	0.498
Chicago_24hr:2	23:15	0.496
Chicago_24hr:2	23:20	0.494
Chicago_24hr:2	23:25	0.492
Chicago_24hr:2	23:30	0.491
Chicago_24hr:2	23:35	0.489
Chicago_24hr:2	23:40	0.487
Chicago_24hr:2	23:45	0.485

```
Chicago_24hr:2              23:50      0.483
Chicago_24hr:2              23:55      0.481
Chicago_24hr:2              24:00      0

[REPORT]
INPUT      YES
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

A.2 OUTPUT DATA

Highland Park Pre-Development.out

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)
--------------------------------------------------------------


*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JUN-01-2013 00:00:00
Ending Date .............. JUN-02-2013 12:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:00:05
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 5.00 sec


WARNING 03: negative offset ignored for Link Culvert_1

WARNING 03: negative offset ignored for Link Culvert_2

WARNING 02: maximum depth increased for Node SU3

*************
Element Count
*************
Number of rain gages ...... 1
Number of subcatchments ... 4
Number of nodes ........... 7
Number of links ........... 7
Number of pollutants ...... 0
Number of land uses ....... 0


****************
Raingage Summary
****************
                                        Data        Recording
Name               Data Source          Type        Interval
-------------------------------------------------------------
Chicago_24hr:2     Chicago_24hr:2       INTENSITY     5 min.


********************
Subcatchment Summary
********************
Name                      Area     Width   %Imperv    %Slope    Rain Gage            Outlet
----------------------------------------------------------------------------------------------------------
1                        38.17   1192.81      4.00    3.0000    Chicago_24hr:2       Culvert_Inlet
2                        20.70    591.43      3.00    5.0000    Chicago_24hr:2       SU3
3                        19.10    764.00      3.00    6.5000    Chicago_24hr:2       OF3
4                         9.17    458.50      3.00    6.5000    Chicago_24hr:2       OF7
```

```
************
Node Summary
************
                                     Invert      Max.    Ponded    External
Name                 Type             Elev.     Depth      Area    Inflow
-------------------------------------------------------------------------------
Culvert_Outlet       JUNCTION        986.41      5.00       0.0
OF3                  JUNCTION        967.50      2.00       0.0
SU3                  JUNCTION        969.50      2.00       0.0
SU4                  JUNCTION        958.00      2.00       0.0
OF4                  OUTFALL         957.50      2.00       0.0
OF7                  OUTFALL           0.00      0.00       0.0
Culvert_Inlet        STORAGE         987.25      5.00       0.0


************
Link Summary
************
Name            From Node       To Node         Type            Length    %Slope Roughness
---------------------------------------------------------------------------------------------
101             Culvert_Outlet  SU3             CONDUIT          275.0    6.1611    0.0500
103             SU3             SU4             CONDUIT          230.0    5.0063    0.0500
104             OF3             SU4             CONDUIT          150.0    6.3461    0.0500
105             SU4             OF4             CONDUIT           10.0    5.0063    0.0500
Culvert_1       Culvert_Inlet   Culvert_Outlet  CONDUIT           23.7    3.0901    0.0240
Culvert_2       Culvert_Inlet   Culvert_Outlet  CONDUIT           24.0    3.4980    0.0240
W1              Culvert_Inlet   Culvert_Outlet  WEIR


*********************
Cross Section Summary
*********************
                                        Full     Full     Hyd.     Max.   No. of     Full
Conduit          Shape                 Depth     Area     Rad.    Width  Barrels     Flow
---------------------------------------------------------------------------------------
101              PARABOLIC              2.00    13.33     1.21    10.00        1    75.34
103              PARABOLIC              2.00    13.33     1.21    10.00        1    67.91
104              PARABOLIC              2.00    13.33     1.21    10.00        1    76.46
105              PARABOLIC              2.00    13.33     1.21    10.00        1    67.91
Culvert_1        CIRCULAR               0.60     0.28     0.15     0.60        1     0.58
Culvert_2        CIRCULAR               0.60     0.28     0.15     0.60        1     0.62


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......         3.759        43.134
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         3.629        41.651
Surface Runoff ...........         0.125         1.429
Final Surface Storage ....         0.005         0.055
Continuity Error (%) .....        -0.003


**************************        Volume        Volume
Flow Routing Continuity        hectare-m      10^6 ltr
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         0.125         1.245
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         0.125         1.245
Internal Outflow .........         0.000         0.000
Storage Losses ...........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.000         0.000
Continuity Error (%) .....         0.000


***************************
Time-Step Critical Elements
***************************
None


********************************
Highest Flow Instability Indexes
********************************
Link Culvert_2 (3)
Link Culvert_1 (1)
```

```
*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     5.00 sec
Average Time Step           :     5.00 sec
Maximum Time Step           :     5.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.00
```

```
***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
1	43.13	0.00	0.00	41.41	1.66	0.63	0.26	0.039
2	43.13	0.00	0.00	41.84	1.25	0.26	0.11	0.029
3	43.13	0.00	0.00	41.84	1.25	0.24	0.10	0.029
4	43.13	0.00	0.00	41.84	1.25	0.11	0.05	0.029

```
******************
Node Depth Summary
******************
```

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min
Culvert_Outlet	JUNCTION	0.01	0.13	986.54	0 07:18
OF3	JUNCTION	0.01	0.09	967.59	0 07:16
SU3	JUNCTION	0.02	0.15	969.65	0 07:20
SU4	JUNCTION	0.02	0.16	958.16	0 07:21
OF4	OUTFALL	0.02	0.16	957.66	0 07:21
OF7	OUTFALL	0.00	0.00	0.00	0 00:00
Culvert_Inlet	STORAGE	0.03	0.30	987.55	0 07:16

```
*******************
Node Inflow Summary
*******************
```

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr
Culvert_Outlet	JUNCTION	0.000	0.244	0 07:15	0.000	0.635
OF3	JUNCTION	0.098	0.098	0 07:15	0.238	0.238
SU3	JUNCTION	0.107	0.291	0 07:17	0.258	0.894
SU4	JUNCTION	0.000	0.321	0 07:19	0.000	1.132
OF4	OUTFALL	0.000	0.301	0 07:21	0.000	1.131
OF7	OUTFALL	0.047	0.047	0 07:15	0.114	0.114
Culvert_Inlet	STORAGE	0.262	0.262	0 07:15	0.635	0.635

```
**********************
Node Surcharge Summary
**********************

No nodes were surcharged.

*********************
Node Flooding Summary
*********************

No nodes were flooded.
```

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	E&I Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
Culvert_Inlet	0.000	0	0	0.011	0	0 07:16	0.244

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6 ltr
OF4	69.95	0.012	0.301	1.131
OF7	59.62	0.001	0.047	0.114
System	64.79	0.014	0.323	1.245

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	0.212	0 07:18	0.91	0.00	0.07
103	CONDUIT	0.253	0 07:20	0.91	0.00	0.08
104	CONDUIT	0.088	0 07:16	0.55	0.00	0.06
105	CONDUIT	0.301	0 07:21	1.01	0.00	0.08
Culvert_1	CONDUIT	0.122	0 07:15	1.19	0.21	0.40
Culvert_2	CONDUIT	0.123	0 07:16	1.49	0.20	0.36
W1	WEIR	0.000	0 00:00			0.00

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
101	1.00	0.08	0.00	0.00	0.92	0.00	0.00	0.00	0.43	0.0000
103	1.00	0.08	0.00	0.00	0.92	0.00	0.00	0.00	0.44	0.0000
104	1.00	0.08	0.00	0.00	0.92	0.01	0.00	0.00	0.18	0.0000
105	1.00	0.08	0.00	0.00	0.92	0.00	0.00	0.00	0.63	0.0000
Culvert_1	1.00	0.27	0.00	0.00	0.00	0.00	0.00	0.73	0.57	0.0001
Culvert_2	1.00	0.08	0.19	0.00	0.51	0.22	0.00	0.00	0.66	0.0001

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Thu Apr 17 06:00:01 2014
Analysis ended on: Thu Apr 17 06:00:02 2014
Total elapsed time: 00:00:01

A.3 INPUT DATA

Highland Park Post-Development.dat

```
[TITLE]

[OPTIONS]
FLOW_UNITS           CMS
INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
START_DATE           06/01/2013
START_TIME           00:00:00
REPORT_START_DATE    06/01/2013
REPORT_START_TIME    00:00:00
END_DATE             06/19/2013
END_TIME             04:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          0:00:05
WET_STEP             0:05:00
DRY_STEP             0:05:00
ROUTING_STEP         5
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         ELEVATION
MIN_SLOPE            0

[EVAPORATION]
;;Type          Parameters
;;------------- ----------
CONSTANT     0.0
DRY_ONLY     NO

[RAINGAGES]
;;               Rain      Time   Snow   Data
;;Name           Type      Intrvl Catch  Source
;;-------------- --------- ------ ------ ----------
Chicago_24hr:100 INTENSITY 0:05   1.0    TIMESERIES Chicago_24hr:100
Chicago_24hr:2   INTENSITY 0:05   1.0    TIMESERIES Chicago_24hr:2

[SUBCATCHMENTS]
;;                                                 Total    Pcnt.             Pcnt.    Curb     Snow
;;Name           Raingage         Outlet           Area     Imperv   Width    Slope    Length   Pack
;;-------------- ---------------- ---------------- -------- -------- -------- -------- -------- --------
1                Chicago_24hr:2   Culvert_Inlet    38.17    4        1192.812 3        0
2                Chicago_24hr:2   SU3              22.6     3        645.714  5        0
3                Chicago_24hr:100 POND             22.67    40       906.8    4        0
4                Chicago_24hr:2   OF7              3.7      7        185      7        0

[SUBAREAS]
;;Subcatchment   N-Imperv   N-Perv     S-Imperv   S-Perv     PctZero    RouteTo    PctRouted
;;-------------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
1                0.015      0.25       1.6        3.2        0          OUTLET
2                0.015      0.25       1.6        3.2        0          OUTLET
3                0.015      0.25       1.6        3.2        0          OUTLET
4                0.015      0.25       1.6        3.2        0          OUTLET

[INFILTRATION]
;;Subcatchment   MaxRate    MinRate    Decay      DryTime    MaxInfil
;;-------------- ---------- ---------- ---------- ---------- ----------
1                75         7.5        4.14       7          0
2                75         7.5        4.14       7          0
3                75         7.5        4.14       7          0
4                75         7.5        4.14       7          0

[JUNCTIONS]
;;               Invert     Max.       Init.      Surcharge  Ponded
;;Name           Elev.      Depth      Depth      Depth      Area
;;-------------- ---------- ---------- ---------- ---------- ----------
Culvert_Outlet   986.411    5          0          0          0
SU3              969.5      1          0          0          0
SU4              958        0          0          0          0
```

```
[OUTFALLS]
;;               Invert     Outfall    Stage/Table      Tide
;;Name           Elev.      Type       Time Series      Gate
;;-------------- ---------- ---------- ---------------- ----
OF4              957.5      FREE                         NO
OF7              0          FREE                         NO

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.
Infiltration Parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- -----------
------------
Culvert_Inlet    987.25   5        0        TABULAR    Ditch_Storage              0        0        220
1.524    0.26
POND             970.5    1.5      0        TABULAR    Storm_Pond                 0        0

[CONDUITS]
;;               Inlet            Outlet                      Manning    Inlet      Outlet     Init.      Max.
;;Name           Node             Node             Length     N          Offset     Offset     Flow       Flow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- -----
-----
102              Culvert_Outlet   SU3              275        0.05       986.411    969.5      0          0
103              SU3              SU4              230        0.05       969.5      958        0          0
105              SU4              OF4              10         0.05       958        957.5      0          0
Culvert_1        Culvert_Inlet    Culvert_Outlet   23.7       0.024      987.248    986.518    0          0
Culvert_2        Culvert_Inlet    Culvert_Outlet   24         0.024      987.068    986.411    0          0

[ORIFICES]
;;               Inlet            Outlet           Orifice      Crest      Disch.     Flap Open/Close
;;Name           Node             Node             Type         Height     Coeff.     Gate Time
;;-------------- ---------------- ---------------- ------------ ---------- ---------- ---- ----------
104              POND             SU4              SIDE         970.5      0.6        NO   0

[WEIRS]
;;               Inlet            Outlet           Weir         Crest      Disch.     Flap End      End
;;Name           Node             Node             Type         Height     Coeff.     Gate Con.     Coeff.
;;-------------- ---------------- ---------------- ------------ ---------- ---------- ---- -------- ----------
W1               Culvert_Inlet    Culvert_Outlet   TRANSVERSE   988.25     1.6        NO   0        0

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
102              PARABOLIC    2                10         0          0          1
103              PARABOLIC    2                10         0          0          1
105              PARABOLIC    2                10         0          0          1
Culvert_1        CIRCULAR     0.6              0          0          0          1          6
Culvert_2        CIRCULAR     0.6              0          0          0          1          6
104              CIRCULAR     0.17             0          0          0
W1               RECT_OPEN    1                10         0          0

[LOSSES]
;;Link           Inlet      Outlet     Average    Flap Gate
;;-------------- ---------- ---------- ---------- ----------

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
Ditch_Storage    Storage    0.00       2
Ditch_Storage                0.25       52
Ditch_Storage                0.75       514
Ditch_Storage                1.00       1634
Ditch_Storage                1.25       2753

Storm_Pond       Storage    0.000      5401.0
Storm_Pond                   0.300      6090.0
Storm_Pond                   0.500      6560.0
Storm_Pond                   0.700      7041.0
Storm_Pond                   0.900      7532.0
Storm_Pond                   1.100      8035.0
Storm_Pond                   1.300      8549.0
Storm_Pond                   1.500      9076.0
Storm_Pond                   1.800      9603.0

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
;Chicago design storm, a = 1201.148, b = 5.55, c = 0.777, Duration = 1440 minutes, r = 0.3, rain units = mm/hr.
Chicago_24hr:100            0:00       0.956
Chicago_24hr:100            0:05       0.965
Chicago_24hr:100            0:10       0.974
Chicago_24hr:100            0:15       0.983
Chicago_24hr:100            0:20       0.992
Chicago_24hr:100            0:25       1.002
Chicago_24hr:100            0:30       1.012
Chicago_24hr:100            0:35       1.022
Chicago_24hr:100            0:40       1.032
```

Chicago_24hr:100	0:45	1.043
Chicago_24hr:100	0:50	1.054
Chicago_24hr:100	0:55	1.065
Chicago_24hr:100	1:00	1.076
Chicago_24hr:100	1:05	1.088
Chicago_24hr:100	1:10	1.1
Chicago_24hr:100	1:15	1.112
Chicago_24hr:100	1:20	1.124
Chicago_24hr:100	1:25	1.137
Chicago_24hr:100	1:30	1.15
Chicago_24hr:100	1:35	1.164
Chicago_24hr:100	1:40	1.178
Chicago_24hr:100	1:45	1.192
Chicago_24hr:100	1:50	1.207
Chicago_24hr:100	1:55	1.222
Chicago_24hr:100	2:00	1.238
Chicago_24hr:100	2:05	1.254
Chicago_24hr:100	2:10	1.27
Chicago_24hr:100	2:15	1.287
Chicago_24hr:100	2:20	1.305
Chicago_24hr:100	2:25	1.323
Chicago_24hr:100	2:30	1.342
Chicago_24hr:100	2:35	1.361
Chicago_24hr:100	2:40	1.381
Chicago_24hr:100	2:45	1.402
Chicago_24hr:100	2:50	1.423
Chicago_24hr:100	2:55	1.445
Chicago_24hr:100	3:00	1.468
Chicago_24hr:100	3:05	1.492
Chicago_24hr:100	3:10	1.517
Chicago_24hr:100	3:15	1.542
Chicago_24hr:100	3:20	1.569
Chicago_24hr:100	3:25	1.597
Chicago_24hr:100	3:30	1.626
Chicago_24hr:100	3:35	1.656
Chicago_24hr:100	3:40	1.687
Chicago_24hr:100	3:45	1.72
Chicago_24hr:100	3:50	1.754
Chicago_24hr:100	3:55	1.79
Chicago_24hr:100	4:00	1.828
Chicago_24hr:100	4:05	1.867
Chicago_24hr:100	4:10	1.909
Chicago_24hr:100	4:15	1.953
Chicago_24hr:100	4:20	1.999
Chicago_24hr:100	4:25	2.047
Chicago_24hr:100	4:30	2.099
Chicago_24hr:100	4:35	2.153
Chicago_24hr:100	4:40	2.211
Chicago_24hr:100	4:45	2.272
Chicago_24hr:100	4:50	2.338
Chicago_24hr:100	4:55	2.408
Chicago_24hr:100	5:00	2.483
Chicago_24hr:100	5:05	2.563
Chicago_24hr:100	5:10	2.65
Chicago_24hr:100	5:15	2.743
Chicago_24hr:100	5:20	2.845
Chicago_24hr:100	5:25	2.955
Chicago_24hr:100	5:30	3.076
Chicago_24hr:100	5:35	3.209
Chicago_24hr:100	5:40	3.355
Chicago_24hr:100	5:45	3.518
Chicago_24hr:100	5:50	3.699
Chicago_24hr:100	5:55	3.904
Chicago_24hr:100	6:00	4.136
Chicago_24hr:100	6:05	4.402
Chicago_24hr:100	6:10	4.711
Chicago_24hr:100	6:15	5.073
Chicago_24hr:100	6:20	5.504
Chicago_24hr:100	6:25	6.029
Chicago_24hr:100	6:30	6.682
Chicago_24hr:100	6:35	7.518
Chicago_24hr:100	6:40	8.632
Chicago_24hr:100	6:45	10.195
Chicago_24hr:100	6:50	12.56
Chicago_24hr:100	6:55	16.589
Chicago_24hr:100	7:00	25.053
Chicago_24hr:100	7:05	54.532
Chicago_24hr:100	7:10	190.716
Chicago_24hr:100	7:15	90.861
Chicago_24hr:100	7:20	50.44
Chicago_24hr:100	7:25	34.726
Chicago_24hr:100	7:30	26.518
Chicago_24hr:100	7:35	21.512
Chicago_24hr:100	7:40	18.149
Chicago_24hr:100	7:45	15.738
Chicago_24hr:100	7:50	13.924
Chicago_24hr:100	7:55	12.509

Chicago_24hr:100	8:00	11.374
Chicago_24hr:100	8:05	10.443
Chicago_24hr:100	8:10	9.665
Chicago_24hr:100	8:15	9.005
Chicago_24hr:100	8:20	8.437
Chicago_24hr:100	8:25	7.943
Chicago_24hr:100	8:30	7.509
Chicago_24hr:100	8:35	7.125
Chicago_24hr:100	8:40	6.782
Chicago_24hr:100	8:45	6.474
Chicago_24hr:100	8:50	6.196
Chicago_24hr:100	8:55	5.943
Chicago_24hr:100	9:00	5.712
Chicago_24hr:100	9:05	5.501
Chicago_24hr:100	9:10	5.307
Chicago_24hr:100	9:15	5.127
Chicago_24hr:100	9:20	4.961
Chicago_24hr:100	9:25	4.806
Chicago_24hr:100	9:30	4.662
Chicago_24hr:100	9:35	4.527
Chicago_24hr:100	9:40	4.401
Chicago_24hr:100	9:45	4.282
Chicago_24hr:100	9:50	4.171
Chicago_24hr:100	9:55	4.066
Chicago_24hr:100	10:00	3.966
Chicago_24hr:100	10:05	3.872
Chicago_24hr:100	10:10	3.783
Chicago_24hr:100	10:15	3.699
Chicago_24hr:100	10:20	3.618
Chicago_24hr:100	10:25	3.542
Chicago_24hr:100	10:30	3.469
Chicago_24hr:100	10:35	3.399
Chicago_24hr:100	10:40	3.333
Chicago_24hr:100	10:45	3.269
Chicago_24hr:100	10:50	3.208
Chicago_24hr:100	10:55	3.15
Chicago_24hr:100	11:00	3.094
Chicago_24hr:100	11:05	3.04
Chicago_24hr:100	11:10	2.988
Chicago_24hr:100	11:15	2.939
Chicago_24hr:100	11:20	2.891
Chicago_24hr:100	11:25	2.845
Chicago_24hr:100	11:30	2.8
Chicago_24hr:100	11:35	2.757
Chicago_24hr:100	11:40	2.716
Chicago_24hr:100	11:45	2.675
Chicago_24hr:100	11:50	2.637
Chicago_24hr:100	11:55	2.599
Chicago_24hr:100	12:00	2.563
Chicago_24hr:100	12:05	2.528
Chicago_24hr:100	12:10	2.494
Chicago_24hr:100	12:15	2.461
Chicago_24hr:100	12:20	2.428
Chicago_24hr:100	12:25	2.397
Chicago_24hr:100	12:30	2.367
Chicago_24hr:100	12:35	2.338
Chicago_24hr:100	12:40	2.309
Chicago_24hr:100	12:45	2.281
Chicago_24hr:100	12:50	2.254
Chicago_24hr:100	12:55	2.228
Chicago_24hr:100	13:00	2.202
Chicago_24hr:100	13:05	2.177
Chicago_24hr:100	13:10	2.153
Chicago_24hr:100	13:15	2.129
Chicago_24hr:100	13:20	2.106
Chicago_24hr:100	13:25	2.084
Chicago_24hr:100	13:30	2.062
Chicago_24hr:100	13:35	2.04
Chicago_24hr:100	13:40	2.019
Chicago_24hr:100	13:45	1.999
Chicago_24hr:100	13:50	1.979
Chicago_24hr:100	13:55	1.959
Chicago_24hr:100	14:00	1.94
Chicago_24hr:100	14:05	1.921
Chicago_24hr:100	14:10	1.903
Chicago_24hr:100	14:15	1.885
Chicago_24hr:100	14:20	1.867
Chicago_24hr:100	14:25	1.85
Chicago_24hr:100	14:30	1.833
Chicago_24hr:100	14:35	1.817
Chicago_24hr:100	14:40	1.801
Chicago_24hr:100	14:45	1.785
Chicago_24hr:100	14:50	1.77
Chicago_24hr:100	14:55	1.754
Chicago_24hr:100	15:00	1.739
Chicago_24hr:100	15:05	1.725
Chicago_24hr:100	15:10	1.71

Chicago_24hr:100	15:15	1.696
Chicago_24hr:100	15:20	1.683
Chicago_24hr:100	15:25	1.669
Chicago_24hr:100	15:30	1.656
Chicago_24hr:100	15:35	1.643
Chicago_24hr:100	15:40	1.63
Chicago_24hr:100	15:45	1.617
Chicago_24hr:100	15:50	1.605
Chicago_24hr:100	15:55	1.593
Chicago_24hr:100	16:00	1.581
Chicago_24hr:100	16:05	1.569
Chicago_24hr:100	16:10	1.557
Chicago_24hr:100	16:15	1.546
Chicago_24hr:100	16:20	1.535
Chicago_24hr:100	16:25	1.524
Chicago_24hr:100	16:30	1.513
Chicago_24hr:100	16:35	1.502
Chicago_24hr:100	16:40	1.492
Chicago_24hr:100	16:45	1.482
Chicago_24hr:100	16:50	1.472
Chicago_24hr:100	16:55	1.462
Chicago_24hr:100	17:00	1.452
Chicago_24hr:100	17:05	1.442
Chicago_24hr:100	17:10	1.432
Chicago_24hr:100	17:15	1.423
Chicago_24hr:100	17:20	1.414
Chicago_24hr:100	17:25	1.405
Chicago_24hr:100	17:30	1.396
Chicago_24hr:100	17:35	1.387
Chicago_24hr:100	17:40	1.378
Chicago_24hr:100	17:45	1.37
Chicago_24hr:100	17:50	1.361
Chicago_24hr:100	17:55	1.353
Chicago_24hr:100	18:00	1.344
Chicago_24hr:100	18:05	1.336
Chicago_24hr:100	18:10	1.328
Chicago_24hr:100	18:15	1.32
Chicago_24hr:100	18:20	1.313
Chicago_24hr:100	18:25	1.305
Chicago_24hr:100	18:30	1.297
Chicago_24hr:100	18:35	1.29
Chicago_24hr:100	18:40	1.282
Chicago_24hr:100	18:45	1.275
Chicago_24hr:100	18:50	1.268
Chicago_24hr:100	18:55	1.261
Chicago_24hr:100	19:00	1.254
Chicago_24hr:100	19:05	1.247
Chicago_24hr:100	19:10	1.24
Chicago_24hr:100	19:15	1.233
Chicago_24hr:100	19:20	1.226
Chicago_24hr:100	19:25	1.22
Chicago_24hr:100	19:30	1.213
Chicago_24hr:100	19:35	1.207
Chicago_24hr:100	19:40	1.201
Chicago_24hr:100	19:45	1.194
Chicago_24hr:100	19:50	1.188
Chicago_24hr:100	19:55	1.182
Chicago_24hr:100	20:00	1.176
Chicago_24hr:100	20:05	1.17
Chicago_24hr:100	20:10	1.164
Chicago_24hr:100	20:15	1.158
Chicago_24hr:100	20:20	1.152
Chicago_24hr:100	20:25	1.147
Chicago_24hr:100	20:30	1.141
Chicago_24hr:100	20:35	1.135
Chicago_24hr:100	20:40	1.13
Chicago_24hr:100	20:45	1.124
Chicago_24hr:100	20:50	1.119
Chicago_24hr:100	20:55	1.114
Chicago_24hr:100	21:00	1.108
Chicago_24hr:100	21:05	1.103
Chicago_24hr:100	21:10	1.098
Chicago_24hr:100	21:15	1.093
Chicago_24hr:100	21:20	1.088
Chicago_24hr:100	21:25	1.083
Chicago_24hr:100	21:30	1.078
Chicago_24hr:100	21:35	1.073
Chicago_24hr:100	21:40	1.068
Chicago_24hr:100	21:45	1.063
Chicago_24hr:100	21:50	1.058
Chicago_24hr:100	21:55	1.054
Chicago_24hr:100	22:00	1.049
Chicago_24hr:100	22:05	1.044
Chicago_24hr:100	22:10	1.04
Chicago_24hr:100	22:15	1.035
Chicago_24hr:100	22:20	1.031
Chicago_24hr:100	22:25	1.026

```
Chicago_24hr:100            22:30       1.022
Chicago_24hr:100            22:35       1.018
Chicago_24hr:100            22:40       1.013
Chicago_24hr:100            22:45       1.009
Chicago_24hr:100            22:50       1.005
Chicago_24hr:100            22:55       1.001
Chicago_24hr:100            23:00       0.996
Chicago_24hr:100            23:05       0.992
Chicago_24hr:100            23:10       0.988
Chicago_24hr:100            23:15       0.984
Chicago_24hr:100            23:20       0.98
Chicago_24hr:100            23:25       0.976
Chicago_24hr:100            23:30       0.972
Chicago_24hr:100            23:35       0.968
Chicago_24hr:100            23:40       0.965
Chicago_24hr:100            23:45       0.961
Chicago_24hr:100            23:50       0.957
Chicago_24hr:100            23:55       0.953
Chicago_24hr:100            24:00       0

[REPORT]
INPUT      YES
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

A.4 OUTPUT DATA

Highland Park Pre-Development.out

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)
--------------------------------------------------------------


*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JUN-01-2013 00:00:00
Ending Date .............. JUN-19-2013 04:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:00:05
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 5.00 sec


WARNING 03: negative offset ignored for Link Culvert_1

WARNING 03: negative offset ignored for Link Culvert_2

WARNING 02: maximum depth increased for Node SU3

*************
Element Count
*************
Number of rain gages ...... 2
Number of subcatchments ... 4
Number of nodes ........... 7
Number of links ........... 7
Number of pollutants ...... 0
Number of land uses ....... 0


****************
Raingage Summary
****************
                                        Data        Recording
Name                Data Source         Type        Interval
------------------------------------------------------------
Chicago_24hr:100    Chicago_24hr:100    INTENSITY     5 min.
Chicago_24hr:2      Chicago_24hr:2      INTENSITY     5 min.


********************
Subcatchment Summary
********************
Name                          Area     Width   %Imperv    %Slope    Rain Gage            Outlet
----------------------------------------------------------------------------------------------------------
1                            38.17   1192.81      4.00    3.0000    Chicago_24hr:2       Culvert_Inlet
2                            22.60    645.71      3.00    5.0000    Chicago_24hr:2       SU3
3                            22.67    906.80     40.00    4.0000    Chicago_24hr:100     POND
4                             3.70    185.00      7.00    7.0000    Chicago_24hr:2       OF7
```

```
************
Node Summary
************
                                        Invert      Max.    Ponded    External
Name                 Type                Elev.     Depth      Area    Inflow
-------------------------------------------------------------------------------
Culvert_Outlet       JUNCTION           986.41      5.00       0.0
SU3                  JUNCTION           969.50      2.00       0.0
SU4                  JUNCTION           958.00      2.00       0.0
OF4                  OUTFALL            957.50      2.00       0.0
OF7                  OUTFALL              0.00      0.00       0.0
Culvert_Inlet        STORAGE            987.25      5.00       0.0
POND                 STORAGE            970.50      1.50       0.0


************
Link Summary
************
Name             From Node        To Node          Type            Length    %Slope Roughness
---------------------------------------------------------------------------------------------
102              Culvert_Outlet   SU3              CONDUIT          275.0    6.1611    0.0500
103              SU3              SU4              CONDUIT          230.0    5.0063    0.0500
105              SU4              OF4              CONDUIT           10.0    5.0063    0.0500
Culvert_1        Culvert_Inlet    Culvert_Outlet   CONDUIT           23.7    3.0901    0.0240
Culvert_2        Culvert_Inlet    Culvert_Outlet   CONDUIT           24.0    3.4980    0.0240
104              POND             SU4              ORIFICE
W1               Culvert_Inlet    Culvert_Outlet   WEIR


*********************
Cross Section Summary
*********************
                                        Full     Full     Hyd.     Max.   No. of     Full
Conduit          Shape                 Depth     Area     Rad.    Width  Barrels     Flow
---------------------------------------------------------------------------------------
102              PARABOLIC              2.00    13.33     1.21    10.00      1      75.34
103              PARABOLIC              2.00    13.33     1.21    10.00      1      67.91
105              PARABOLIC              2.00    13.33     1.21    10.00      1      67.91
Culvert_1        CIRCULAR               0.60     0.28     0.15     0.60      1       0.58
Culvert_2        CIRCULAR               0.60     0.28     0.15     0.60      1       0.62


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......         5.071        58.197
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         3.644        41.813
Surface Runoff ...........         1.416        16.254
Final Surface Storage ....         0.018         0.212
Continuity Error (%) .....        -0.141


**************************        Volume        Volume
Flow Routing Continuity        hectare-m      10^6 ltr
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         1.416        14.164
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         1.416        14.158
Internal Outflow .........         0.000         0.000
Storage Losses ...........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.001         0.005
Continuity Error (%) .....         0.000


***************************
Time-Step Critical Elements
***************************
None


********************************
Highest Flow Instability Indexes
********************************
All links are stable.
```

****
Routing Time Step Summary
****

Minimum Time Step	:	5.00 sec
Average Time Step	:	5.00 sec
Maximum Time Step	:	5.00 sec
Percent in Steady State	:	0.00
Average Iterations per Step	:	2.00

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
1	43.13	0.00	0.00	41.41	1.66	0.63	0.26	0.039
2	43.13	0.00	0.00	41.84	1.25	0.28	0.12	0.029
3	101.03	0.00	0.00	42.74	57.96	13.14	1.30	0.574
4	43.13	0.00	0.00	40.11	2.91	0.11	0.04	0.067

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min
Culvert_Outlet	JUNCTION	0.00	0.13	986.54	0 07:18
SU3	JUNCTION	0.00	0.15	969.65	0 07:20
SU4	JUNCTION	0.02	0.16	958.16	0 07:21
OF4	OUTFALL	0.01	0.16	957.66	0 07:21
OF7	OUTFALL	0.00	0.00	0.00	0 00:00
Culvert_Inlet	STORAGE	0.00	0.30	987.55	0 07:16
POND	STORAGE	0.14	1.44	971.94	0 11:44

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr
Culvert_Outlet	JUNCTION	0.000	0.244	0 07:15	0.000	0.635
SU3	JUNCTION	0.116	0.299	0 07:17	0.282	0.917
SU4	JUNCTION	0.000	0.306	0 07:20	0.000	14.053
OF4	OUTFALL	0.000	0.299	0 07:21	0.000	14.051
OF7	OUTFALL	0.044	0.044	0 07:15	0.108	0.108
Culvert_Inlet	STORAGE	0.262	0.262	0 07:15	0.635	0.635
POND	STORAGE	5.201	5.201	0 07:15	13.139	13.139

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Meters	Min. Depth Below Rim Meters
POND	STORAGE	68.17	1.266	0.064

****
Node Flooding Summary
****

No nodes were flooded.

```
**********************
Storage Volume Summary
**********************
```

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	E&I Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
Culvert_Inlet	0.000	0	0	0.011	0	0 07:16	0.244
POND	0.920	9	0	10.211	95	0 11:44	0.070

```
***********************
Outfall Loading Summary
***********************
```

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6 ltr
OF4	67.31	0.013	0.299	14.051
OF7	4.95	0.001	0.044	0.108
System	36.13	0.015	0.319	14.158

```
********************
Link Flow Summary
********************
```

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
102	CONDUIT	0.212	0 07:18	0.89	0.00	0.07
103	CONDUIT	0.261	0 07:20	0.94	0.00	0.08
105	CONDUIT	0.299	0 07:21	1.00	0.00	0.08
Culvert_1	CONDUIT	0.122	0 07:15	1.19	0.21	0.40
Culvert_2	CONDUIT	0.123	0 07:16	1.49	0.20	0.36
104	ORIFICE	0.070	0 11:44			1.00
W1	WEIR	0.000	0 00:00			0.00

```
***************************
Flow Classification Summary
***************************
```

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change
102	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.03	0.0000
103	1.00	0.00	0.59	0.00	0.41	0.00	0.00	0.00	0.01	0.0000
105	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.60	0.0000
Culvert_1	1.00	0.94	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.0000
Culvert_2	1.00	0.01	0.93	0.00	0.04	0.02	0.00	0.00	0.05	0.0000

```
*************************
Conduit Surcharge Summary
*************************

No conduits were surcharged.


Analysis begun on:  Thu Apr 17 06:00:42 2014
Analysis ended on:  Thu Apr 17 06:00:49 2014
Total elapsed time: 00:00:07
```

Appendix B

Forebay Sizing Calculations

Stantec

April, 2014

APPENDIX B: FOREBAY SIZING

Stantec Consulting
Highland Park
Stormwater Management Report, March 2014
Requirements as per City of Calgary and AENV Stormwater Guidelines

Forebay Characteristics:

(1)	30	Forebay Length at NWL (m)
(2)	15	Forebay Width at NWL (m)
(3)	2.0	Length to width ratio of forebay (m)
(4)	2.5	Forebay depth at NWL (m)
(5)	0.073	Maximum discharge rate from facility (m^3/s)
(6)	1.320	Maximum inflow to facility (m^3/s)
(7)	0.0003	Design settling velocity (m/s)
(8)	0.5	Dispersion velocity at end of forebay (m/s)

Forebay Requirements:

$L_{settling} = [rQ_p/V_s]^{0.5} = [(3)x(5)/(7)]^{0.5} =$	**22.1**	<	30	Adequately Sized

r = Length to width ratio of forebay
Q_p = Maximum discharge rate from facility during the design storm
V_s = Design settling velocity; dependent on the desired particle size to settle

$L_{dispersion} = (8Q)/(dV_f) = [8x(6)]/[(4)x(8)] =$	**8.4**	<	30	Adequately Sized

Q = Maximum inflow to facility
d = Forebay depth at NWL
V_f = Dispersion velocity at end of forebay

$W = L_{dispersion} / 8$	**1.056**	<	10	Adequately Sized

W = Forebay bottom width