Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

Technical Report

Monitoring Results (2016-2017)

Appendix A

Background Documents

Terraprobe

Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing

HYDROGEOLOGIC INVESTIGATION
SUB-AREA 6 (WALNUT GROVE)
CREDIT VALLEY SECONDARY PLAN
CITY OF BRAMPTON, ONTARIO

Prepared For:

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L4K 5X6

Attn: Ms. Laura Koyanagi

File No. 1-09-4232
April 9, 2010

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1.0 INTRODUCTION

Terraprobe was retained by The Municipal Infrastructure Group to conduct a hydrogeologic investigation for a proposed residential development. The proposed development is situated within Block Plan Area 45-6 of the Credit Valley Secondary Plan Area in the City of Brampton. The site is bounded by Block 5 of the CSVP to the north, Walnut Road to the west, the Orangeville Railway Development Corporation (ORDC) rail line to the east and existing single detached residences to the south beyond which is Steeles Avenue West. The site location is outlined in the attached Figure 1.

It is proposed to develop the subject site as a residential community consisting of approximately 70 single detached homes. The development will be fully serviced for municipal water, sewage, and roads. The current site development plan is attached as Figure 2.

The purpose of the hydrogeologic study was to provide an assessment of geologic and hydrogeologic conditions in the vicinity of the site. Based on this assessment, the potential impact of the proposed development on local ground water function, including ground water recharge and base flow was assessed.

2.0 WORK PROGRAM

The subject site is located within the Credit Valley Secondary Planning Area. The western portion of the site lies within the Springbrook Creek watershed and the eastern portion of the site falls within the watershed of Tributary 8b of the Credit River.

The following items were identified as requirements for the hydrogeologic assessment of the site:

- provide a summary of the shallow ground water setting(recharge/discharge areas, aquifers and area of ground water flow or transmission),
- calculate both pre-development and post-development water balance, and
- provide recommendations regarding suitable techniques to maintain ground water recharge and ground water function at the site.

A scope of work was developed to address the specific project requirements. The work program consisted of the following:

- Review of available background information regarding local geology and hydrogeology. This included review and compilation of Ministry of Environment well records, geologic mapping, and other sources.
- A detailed visual inspection of the site to assess site topography, drainage, and natural features.
- A subsurface investigation of the site. The subsurface investigation consisted of the completion of 15 test pits across the site and the drilling of 5 boreholes each to a depth of approximately 5.0 m below existing grades.
- Installation of nested monitoring wells at all borehole locations. Monitoring wells were installed at each borehole locations to permit monitoring of ground water levels and seasonal fluctuations and to assess vertical hydraulic gradients.
- Falling head permeability tests were performed on shallow well installations identified to be completed within a surficial sand layer to assess the percolation rate of the sand layer.

- Monitoring of ground water levels. The monitoring of ground water levels was conducted on two separate events in order to assess potential fluctuations and ground water flow directions and gradients.

- Calculation of pre-development and post-development water balance.

3.0 SITE CONDITIONS

3.1 Site Location and Description

The site is a triangular shaped area within Block Plan Area 45-6, located north of Steeles Avenue West immediately to the east of Walnut Road as shown on Figure 1 (appended). The site is approximately 5.66 ha in size. The site is located in part of Lot 2, Concession 3 WHS, Township of Chinguacousy, Ontario.

3.2 Current Land Uses

Currently, the site is comprised of approximately five residential dwellings and an abandoned greenhouse structure. The northern portion of the property consists of an open field. A small water filled depression exists in the eastern portion of the site adjacent to the rail line. The surrounding lands are generally rural or rural residential in nature.

3.3 Site Topography and Drainage

Most of the site is characterized by flat to gently rolling topography with a total change in elevation of approximately 2.5 m from the central high point of the site. The eastern portion of the site gently slopes downward to the rail line and the water filled depression located along the eastern property boundary. The western portion of the site slopes downward to the west, in the general direction of the Credit River, approximately 300 m west of the site.

The water filled depression primarily collects surface runoff from the eastern portion of the site. The depression is not connected to surface water inputs or outputs. Tributary 8b is approximately 150 m to the northeast of the site. Based on the low permeability glacial tills present in the area and the presence of the low lying depression, ground water from the site is not expected to contribute to baseflows for Tributary 8b. Construction of the rail line appears to have altered localized runoff toward the east resulting in the formation of the ponded water within the surface depression along the eastern property boundary of the site.

Surface runoff from the western portion of the site is ultimately directed to the Credit River though a series of roadside drainage ditches along Walnut Road and Churchville Road.

3.4 Regional Geology

Based on geologic maps published for the general area, the near surface overburden soil in the vicinity of the subject property consists of a locally isolated lacustrine deposits of gravelly sand to sand. The surrounding area consists primarily of glacial deposits known as Halton Till, which consists of silt to silty clay till. Overburden thickness in the area is generally less than 25 m but in the vicinity of the site depth to bedrock is approximately 45 m below ground surface due to the presence of a bedrock valley feature. Locally, a layer of sand was found overlying till deposits to varying thicknesses of up to 4.5 m below grade. Sand thickness generally increases to the south of the property. The underlying glacial till found in the vicinity of the site is characterized by isolated lenses of silt or silty sand. A zone of coarse grained sand and gravel is found above the bedrock. These materials were deposited within the bedrock valley feature found in the vicinity of the site. The majority of private water wells surrounding the site are completed within these course grained deposits.

Beneath the sequence of soil deposits is bedrock of the Queenston Formation, which consists of shale, siltstone and limestone. From a regional perspective, the bedrock surface dips gently to the south. Locally, the bedrock surface has been eroded, both as a result of past glacial action and current erosion activity by the water courses. Buried bedrock valley features are encountered in the shale bedrock in this area with bedrock occurring at a depth of approximately 45 m below ground surface.

3.5 Regional Hydrogeology

The hydrogeology of the site was determined on the basis of local geologic mapping and Ministry of Environment well records.

The regional hydrogeology is characterized by three principal hydrostratigraphic units:

- Glacial till. The glacial till is considered to be an aquitard. The glacial till is of low permeability and is aerially extensive. There are local and isolated sand and silt lenses found within the glacial till. These units generally do not form an important or continuous hydrostratigraphic unit. The glacial till is characterized by unconfined or water table conditions. The water table is typically found within several metres of the ground surface. The surficial sand unit found at the site forms a perched water table above the glacial till during periods of high water levels (i.e. spring freshet).

- Confined sand aquifer. Locally, a more continuous zone of sand and gravel found at the base of the glacial till and above the shale bedrock. This sand and gravel zone forms a local confined aquifer. Typically the sand and gravel aquifer exists in locations where the bedrock surface has been eroded by glacial action and forms a local glacial valley feature.

filled by course grained materials such as sands and gravels. The depth of overburden materials was noted at depths up to 42 m below ground surface. The yield wells within this bedrock valley feature have been noted up to 227 Lpm in the vicinity of the site.

3.7 Regional Climate

The site is located in the climatic region of Southern Ontario known as the South Slopes area. The following general climate data was obtained from Environment Canada publications. This information presents average climate data for the period of 1971 to 2000 for the nearest meteorological station (Toronto Lester B. Pearson International Airport) to the site:

Annual total precipitation	793 mm
Mean daily temperature	7.5° C
Mean annual water surplus (based on 100 mm soil storage)	239 mm
Mean annual evapotranspiration	554 mm

The climate is typical for Southern Ontario, with rainfall exceeding evapotranspiration.

3.8 Results of Subsurface Investigation

A subsurface investigation of the site was completed consisting of 15 test pits completed in December 2009 and 5 boreholes completed in February 2010. The test pit logs and grain size analysis conducted on obtained samples are attached in Appendix B, borehole logs are attached in Appendix C. The test pit and borehole locations are presented on the accompanying Figure 3.

In summary, the results of the subsurface investigation confirm the information obtained from the review of regional geologic and hydrogeologic conditions. The site is characterized by a surficial layer of sand of varying thickness overlying an extensive deposit of low permeability glacial till. The glacial till unit extended to the depth of investigation for all boreholes completed as part of the subsurface investigation. Monitoring wells were installed at each borehole location. The ground water level is typically found at depths of about 2 to 5 m below grade. The surficial layer of sand was found to be dry following the completion of drilling.

Geologic cross-sections were prepared using the borehole information and are summarized on the accompanying Figures 5 and 6. A brief summary of each of the principal hydrostratigraphic units encountered in the investigation is provided below.

3.8.1 Topsoil

A thin layer of topsoil was encountered at the ground surface at each of the borehole locations. The topsoil was typically less than 800 mm in thickness.

3.8.2 Surficial Sand Unit

A layer of surficial sand material was encountered across much of the site. The surficial sand unit was found over the south portion of the site. Sand thickness to the north and along the western extent of the site was sparse or non-existent. Slug tests were performed on shallow well installations in order to determine the hydraulic conductivity of the unit. The table below summarizes the calculated hydraulic conductivity.

Summary of Hydraulic Conductivity for Sand Unit

Monitoring Well Location	Hydraulic Conductivity (m/s)
MW-1 S	1.3×10^{-5}
MW-2 S	5.8×10^{-7}
MW-3 S	1.2×10^{-5}
MW-4 S	4.1×10^{-5}
MW-5 S	3.9×10^{-5}

Hydraulic conductivity for wells completed within the sand unit was approximately 2.6×10^{-5} m/s. Sandy soils were not encountered at MW-2. The hydraulic conductivity of 5.8×10^{-7} m/s for MW-2 S is representative of the silty clay soils underlying the surficial sand unit. The surficial sand layer provides for infiltration of precipitation, and limited storage and limited recharge to the lower permeability glacial till unit. The sand unit was found to be dry during the site inspection conducted on March 10, 2010.

3.8.3 Glacial Till

Glacial till soils were encountered at each of the borehole locations. A silty clay glacial till was observed to the depth of investigation for each completed borehole. The glacial till generally consists of silt till of the Halton series. The material comprises silt to clayey silt with a trace to some sand and embedded gravel. Locally, thin and discontinuous seams of silt, silty sand, and fine sand are found within the till. These layers are relatively small and generally occur at depth within the till unit. These seams, due to their limited thickness and extent would not provide significant amounts of lateral flow for ground water.

3.8.4 Ground Water Levels

Ground water levels in the monitoring wells were measured in March 2010. The results of the measurements are summarized in the following table:

Summary of Ground Water Levels

Monitoring Well Location	Depth (mbgl)	Elevation (masl)	Water Level (mbgl) March 10, 2010	Water Elevation (masl) March 10, 2010
MW-1 S	2.24	190.44	Dry	Dry @ 188.20
MW-1 D	4.49	190.25	3.82	186.43
MW-2 S	2.12	188.38	0.50	187.88
MW-2 D	4.59	188.50	0.88	187.62
MW-3 S	2.20	190.26	Dry	Dry @ 188.06
MW-3 D	4.58	190.14	2.30	187.84
MW-4 S	2.11	190.14	Dry	Dry @ 188.03
MW-4 D	4.61	189.93	2.28	187.65
MW-5 S	2.94	189.94	Dry	Dry @ 187.00
MW-5 D	4.46	189.92	3.31	186.61

In summary, the ground water levels are generally found at depths ranging from about 1 to 4 m below grade over most of the table land portions of the site. With the exception of MW-2 S (completed within the till unit) the shallow monitors completed within the unconfined surficial sand unit were found to be dry during the site inspection on March 10, 2010. Ground water flow within the surficial sand unit is expected to follow topography.

The overall ground water flow direction in the glacial till is influenced by the presence of a ground water divide throughout the middle of the property. Ground water on the north portion of the property flows north towards Tributary 8b and ground water from the south of the property is directed to the south toward the Credit River. The ground water elevations for the deep well installations and the inferred ground water flow direction have been plotted on Figure 7.

The vertical ground water gradients were measured each location. The ground water drainage generally indicates downward flow or ground water recharge at these locations.

3.9 Site Inspection

A detailed site inspection was conducted to assess the presence of features with potential hydrogeologic significance. In particular, the site was expected to determine areas of significant ground water seepage or discharge, and areas of closed depressions or other topographic features which may suggest enhanced infiltration.

The inspection indicates the site is generally characterized by flat to gently rolling topography. As detailed above, a water filled depression exists along the eastern boundary of the site. There were no surface inflows and outflows identified from the feature (i.e. offline pond). The depression accepts a minor component of runoff from the site and likely serves as an area of minor ground water recharge. Based upon the predominant glacial till in the vicinity of the depression significant ground water infiltration is not expected.

No ground water seeps or springs were identified across the site. Much of the property along the south and west property limits are drained by a series of roadside drainage ditches running along Walnut Road and Churchville Road and ultimately drain to the Credit River.

4.0 DISCUSSION AND ANALYSIS

4.1 Proposed Development Plan

The proposed development plan is illustrated on the accompanying Figure 3. The proposed development will consist of 70 large single family detached lots. The site will be serviced by a series of internal roadways and full municipal services for water and sewage. Storm water management will be accomplished through implementation of Low Impact Development (LID) measures. No stormwater management pond is proposed for the subject site.

4.2 Principal Hydrogeologic Features and Hydrogeologic Function

The results of the investigation indicate the following principal hydrogeologic features for the site:

- The site is characterized by surficial deposits of sand to varying thickness which is underlain by extensive deposits of glacial till. The surficial sand unit provides for a perched water table above the glacial till. The storage within the surficial sand unit provides for infiltration of precipitation and minor recharge to the underlaying till unit. The underlying glacial till is of low permeability and provides for limited recharge capability.
- Locally, there is a thin layer of surficial sandy material found at the extreme western portion of the site. This area is localized, and was dry at the time of investigation. It is not continuous to the Springbrook Creek to the east.
- There are local seams of sandy material found within the glacial till. These deposits are found at distinctly different elevations, and are not continuous throughout the site.
- MOE well records show that there is a unit of coarse grained materials at depth, filling a bedrock valley present within the area. These materials form a confined aquifer above the bedrock in the vicinity of the site. Surrounding wells are typically completed within this aquifer and can yield high quantities of water.
- There is no evidence of topographic features which would suggest areas of significant or enhanced recharge at the surface of the site. The drainage pattern for the site confirms the presence of an extensive cover of low permeability glacial till materials.

Based on the above features, the hydrogeologic functions of the site were assessed. These are summarized below:

(i) The infiltration rate through the glacial till is limited.

(ii) The sandy units found at the site generally do not perform a significant hydrogeologic function. This is the result of the following factors:

- The surficial sand layer found at the western portion of the site is dry and limited in extent. It does not connect to any significant aquatic or terrestrial features.

- No seeps or springs were found along the slopes surrounding the depression and pond located along the eastern property limit. The depression is supported by runoff.

- The sandy lenses are isolated and discontinuous. They do not contribute significantly to ground water discharge in the area. Similarly, the recharge from these lenses is limited by the low permeability of the glacial till.

- The confined aquifer zone at the site is found at an elevation considerably below the surrounding surface water features, and therefore does not contribute directly to ground water discharge or other functions.

On the basis of the above, it is considered that the most significant hydrogeologic function of the site is the maintenance of recharge through the glacial till.

4.3 Water Balance for Pre- and Post-Development

A water balance was conducted for the existing conditions at the site. The water balance was conducted using Environment Canada climate data from Sections 3.7 of this report, and are presented on the accompanying Appendix D.

The results of the water balance are summarized below. The calculations are based on the following assumptions:

- There will be no infiltration beneath road, sidewalk or roof areas.
- Infiltration beneath driveways was accounted for, due to the proposed use of permeable pavements as a construction medium for the residential development.
- There will be no additional ground water recharge as a result of lawn watering activities.
- Runoff from roofed area of the subdivision are not available for ground water discharge, as roof leaders are proposed to discharge to cisterns for use for activities such as lawn irrigation.

- Approximately 50% of the roadway runoff will be available to contribute to ground water recharge on the lot areas through the use of an infiltration trench system proposed to be installed along the curb of the right of way for the development.

	Precipitation	Evapotranspiration	Infiltration	Run-Off
Pre-Development	4,492 m³	3,138 m³	850 m³	504 m³
Post-Development	4,492 m³	1,457 m³	372 m³	2,628 m³

As noted, there is a decrease in the post-development infiltration rates at the site due to the increase of impermeable area covering the site (i.e. roads, housing envelopes) following development. LID measures proposed for subject site aim to maintain or enhance the pre-development infiltration rates following site development.

4.4 Design Measures to Protect Ground Water Function

As noted previously, the primary hydrogeologic function at the site is related to maintenance of recharge to the low permeability glacial till. It will also be ~~necessary to ensure that the~~ ground water levels at the site are not lowered as a result of drainage which may occur as a result of flow along bedding for underground services.

In order to maintain hydrogeologic function at the site several Low Impact Development features have proposed to maintain or enhance pre-development infiltration rates at the site. The following general recommendations were proposed in the Functional Servicing Report prepared by The Municipal Infrastructure Group for site design:

(i) A bioswale is proposed along the east of the site adjacent to the rail line to provide attenuation and infiltration of stormwater runoff from roads for the eastern portion of the property. The bioswale will incorporate a portion of the depression noted along the eastern property boundary. An overflow outlet from the bioswale to the storm sewer is proposed.

(ii) A perforated pipe infiltration trench system is proposed parallel to the curb underlying the boulevard of the right of way which will receive storm water runoff from impervious surfaces (i.e. roads). The infiltration trench system would allow for the storage and infiltration of stormwater from roads. Overflow from the infiltration trench system would discharge to road side drainage ditch along Churchville Road.

(iii) The implementation of permeable pavements is proposed for use for residential driveways. The use of permeable pavement for residential driveways would allow for the infiltration of precipitation events and reduce the overall impervious area of the completed development.

(iv) Roof leaders are proposed to be discharged to cisterns in order to eliminate runoff generated by small to mid sized precipitation events (up to 15 mm). It is expected that much of this stored water will be used for lawn irrigation during dry periods and will ultimately contribute to ground water recharge for the site.

(v) Soil amendments such as an increased topsoil depth is proposed providing for additional storage for runoff and ultimately increasing the potential for infiltration.

Based on the above completed water balance approximately 40 % of runoff from roadways would be required to be directed to ground water infiltration in order to maintain the pre-development infiltration rates of the site. Through the use of infiltration trenches and a bioswale it is expected that pre-development infiltration rates of the site will be enhanced following development.

5.0 SUMMARY AND CONCLUSIONS

In summary, the results of the site investigations indicate that it is feasible to develop the subject residential community without creating ground water related impact. The following specific summary and conclusions are made:

(i) The site is characterized by surficial deposits sand overlying low permeability glacial till soils. The surficial sand unit forms a perched water table above the glacial till soils providing for limited storage and infiltration of ground water. Infiltration rates into the till unit at the site are limited.

(ii) Course grained deposits underlie glacial till soils at depth and fill a bedrock valley feature that crosses the vicinity of the site. These deposits form a confined aquifer at depth, the majority of private residential water wells are completed within this aquifer. No impacts to the underlying confined aquifer are expected as a result of the proposed residential development.

(iii) The overlying sand soils were found to be dry during the spring observation. Perched ground water flow within the surficial sand unit likely follows the topography of the underlying silty clay till unit, and is directed towards the southeast of the site. Ground water flow within the till unit is influenced by the presence of a ground water divide throughout the middle of the property. Ground water on the north portion of the property flows north towards Tributary 8b and ground water from the south of the property is directed to the south toward the Credit River.

(iv) Based on the low permeability of the glacial till underlying the area, lateral movement of groundwater to surrounding surface water features would be limited. Groundwater recharge from the subject site would not significantly contribute to baseflow to Tributary 8b or the Credit River. Development of the subject site is not expected to impact groundwater baseflow to surrounding surface water features (i.e. Tributary 8b, Credit River).

(v) Falling head tests were performed on the surficial sand unit. Hydraulic conductivity rates of approximately 2.6×10^{-5} m/s are expected for the sand unit. A hydraulic conductivity of 5.8×10^{-7} m/s (based on falling head test conducted for MW-2 S completed within silty clay) is representative of the silty clay soils underlying the surficial sand unit.

(vi) The hydrogeologic function of the site is to maintain recharge to the glacial till. No areas of ground water discharge were identified on site. A water filled depression (offline pond) exists along the eastern property boundary which primarily receives surface water runoff. No seeps or springs were noted in the vicinity of the depression. A portion of the water filled depression is expected to be maintained as part of the bioswale proposed along the eastern boundary of the site adjacent to the rail line.

(vii) Infiltration rates at the site can be maintained by the implementation of LID measures at the site. Storm water at the site will be managed using Low Impact Development techniques. It is proposed to develop the following LID measures: a bioswale, a perforated pipe infiltration trench, permeable pavements, cisterns and soil amendments. The implementation of these LID measures to promote infiltration of storm water runoff are expected to maintain or enhance the pre-development infiltration rates of the site.

We trust this report meets with your requirements. Should you have any questions regarding the information presented, please do not hesitate to contact our office.

Yours truly,

Terraprobe Inc.

Paul Raepple, B.Sc.

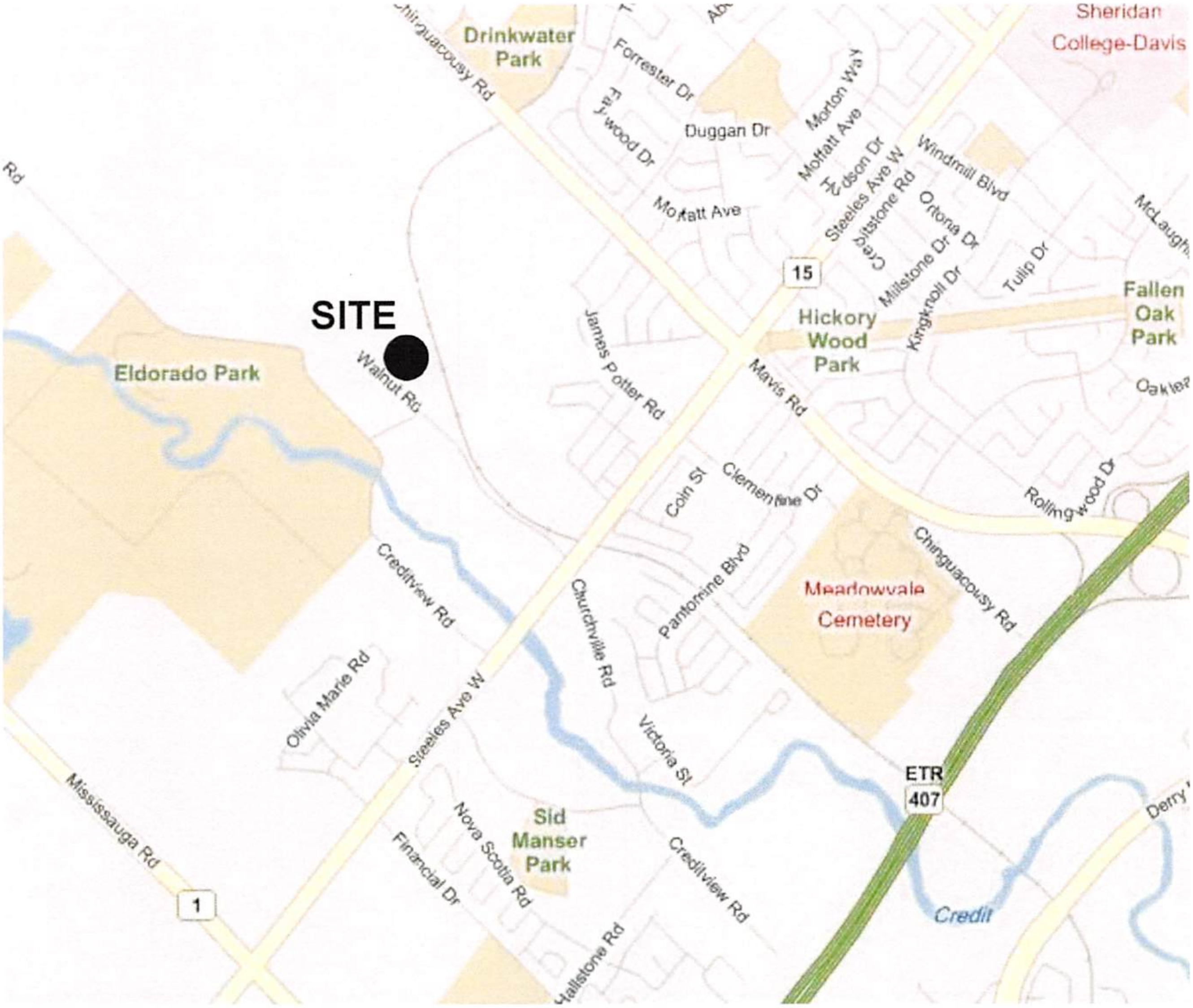
15 Apr 2010
D. A. MacGILLIVRAY

David MacGillivray, P.Eng., P.Geo.
Associate

Brampton Office

FIGURES

Terraprobe Inc.



Site Location Plan

Terraprobe
903 Barton Street, Unit 22
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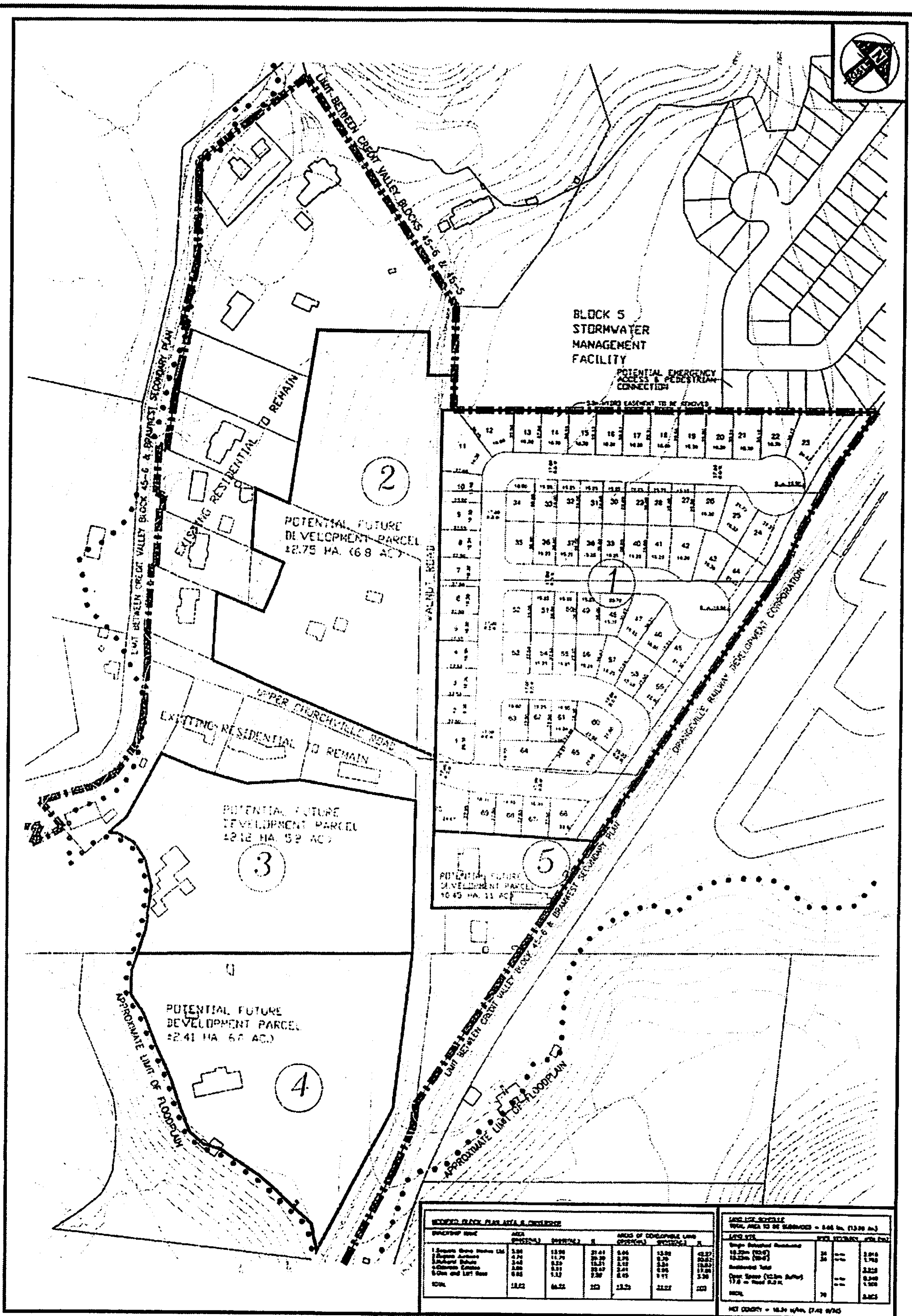
(905) 643-7560 / Fax (905) 643-7559

Drawn By: A.C.	**Scale:** N.T.S.	**Project No.:** 1-09-4232
Checked By: P.R.	**Date:** Mar. 2010	**Figure No.:** 1



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FEB. 22, 2010

File No. 1384BLOCKPLAN_FEB22_10.DWG

POTENTIAL DEVELOPMENT PARCELS
CREDIT VALLEY SECONDARY PLAN
MODIFIED BLOCK PLAN AREA 45-6
CITY OF BRAMPTON

Proposed Site Development Plan

Terraprobe

Drawn By: A.C.

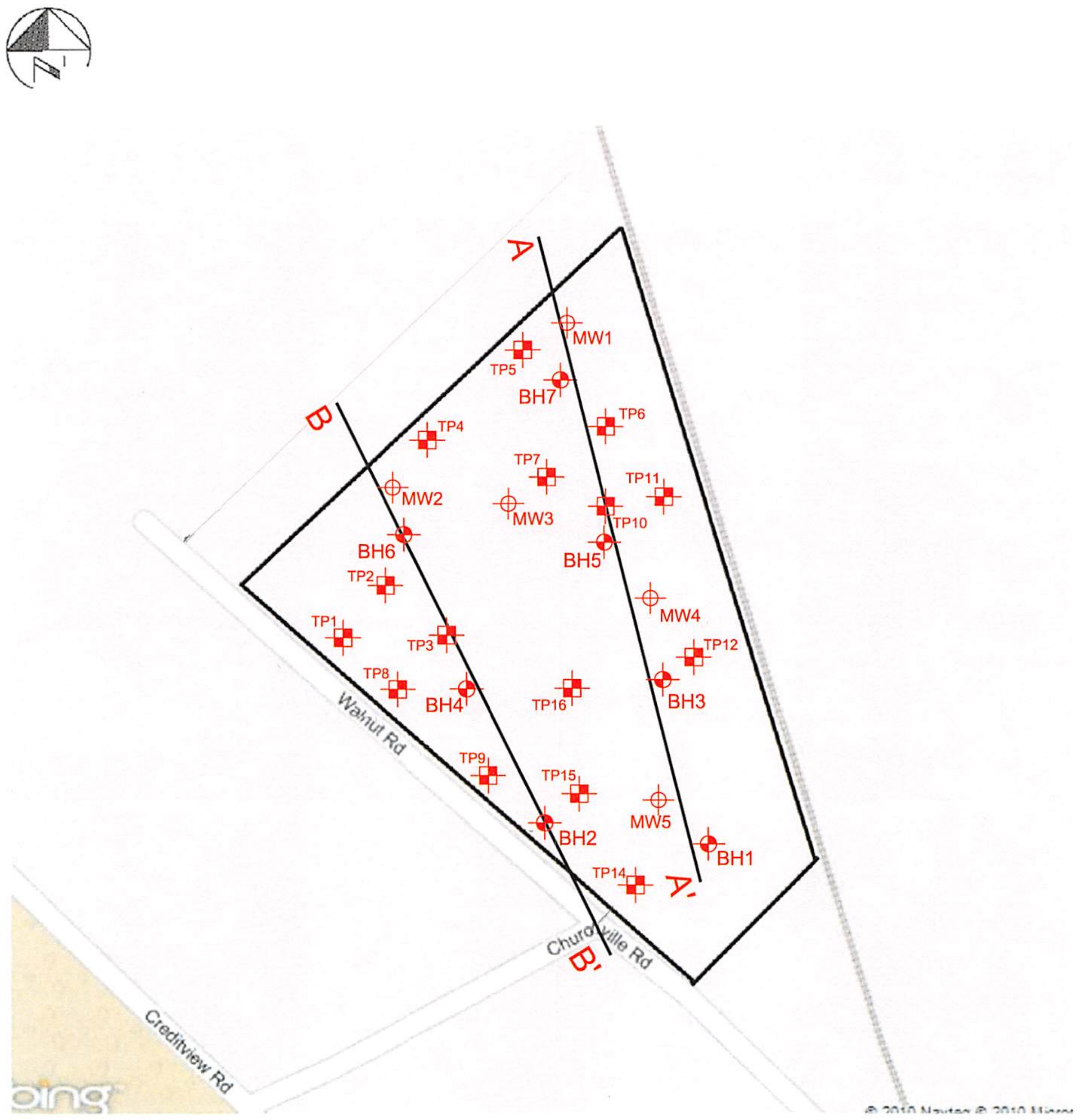
Scale: 1:2500

Project No.: 1-09-4232

Checked By: P.R.

Date: March 2010

Figure No.: 2



LEGEND:

BH1	Location of Soil Eng. BH (Jan'08)
MW1	Location of Terraprobe MW (Feb'10)
TP1	Location of Terraprobe TP (Dec'09)

NOTES:
All locations and scales are approximate.

Borehole and Test Pit Location Plan

Terraprobe
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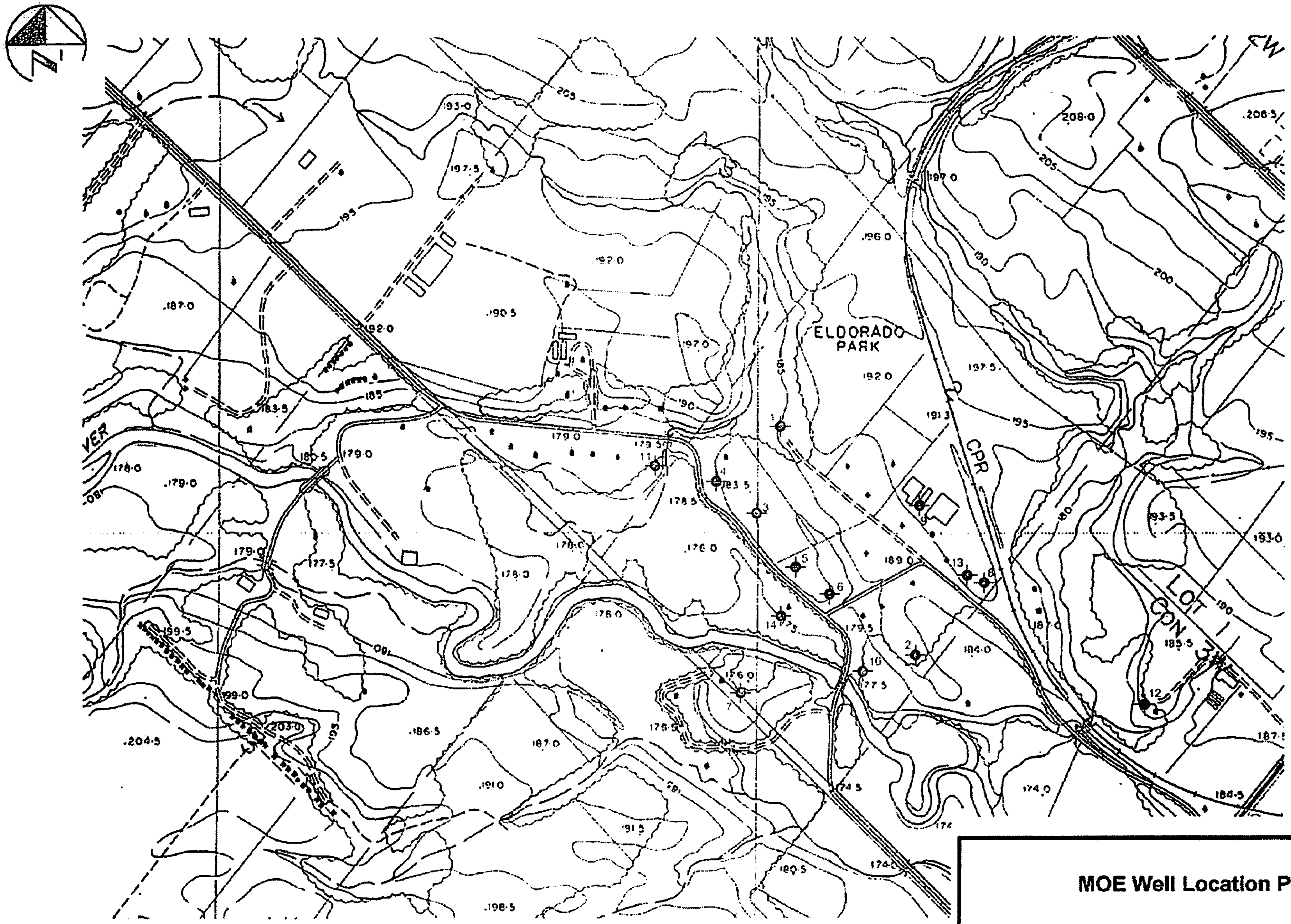
Checked By: P.R.	**Date:** Mar. 2010	**Figure No.:** 3



Legend:

1 Private Well Location

NOTES:

All locations and scales are approximate.

MOE Well Location Plan

Terraprobe

903 Barton Street, Unit 22
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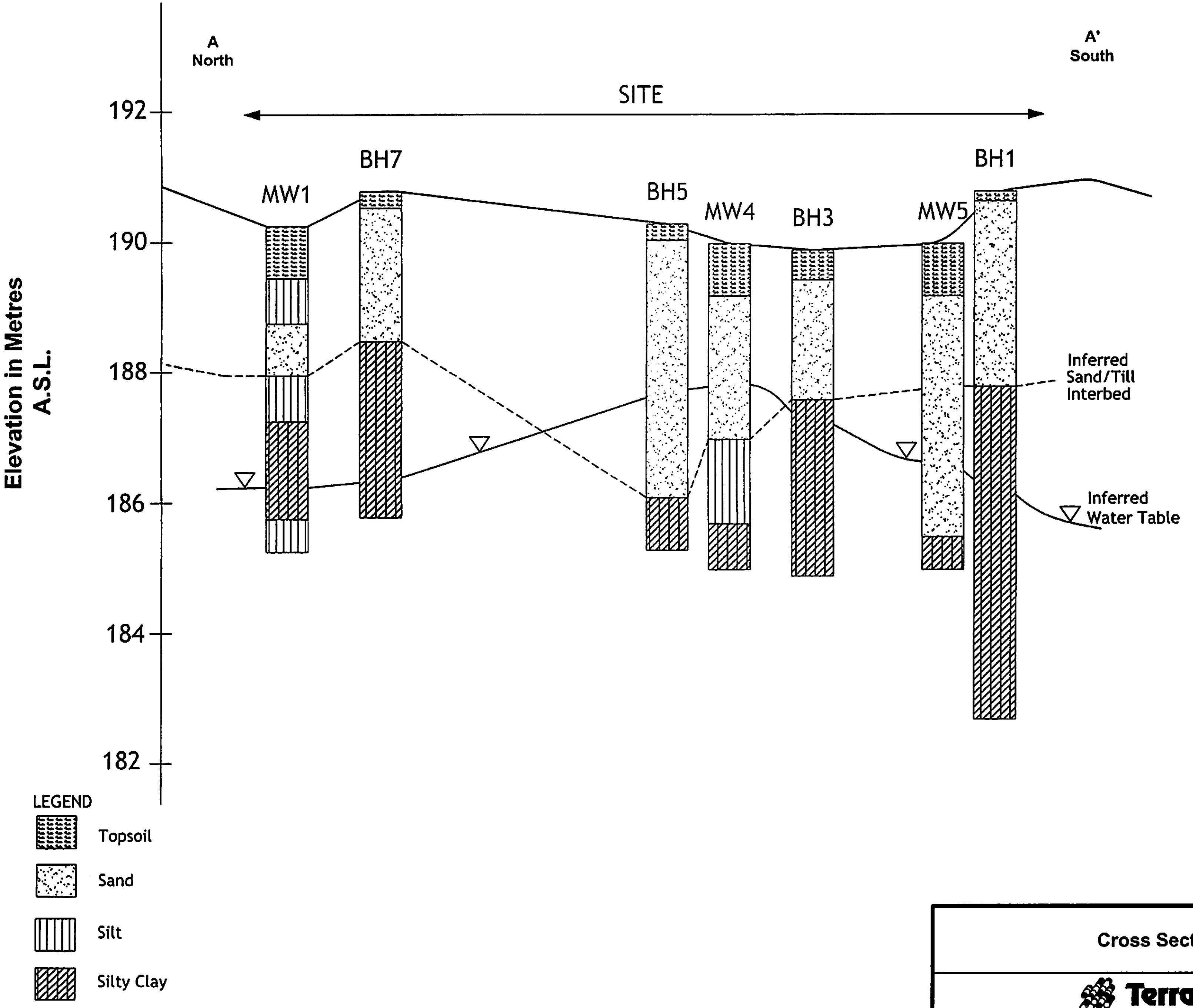

NOTES:
Refer to figure 3 for plan.
All locations and scales are approximate.

Cross Section A-A'

Terraprobe

Drawn By: A.C.
Scale: H - 1:2500 V - As Shown
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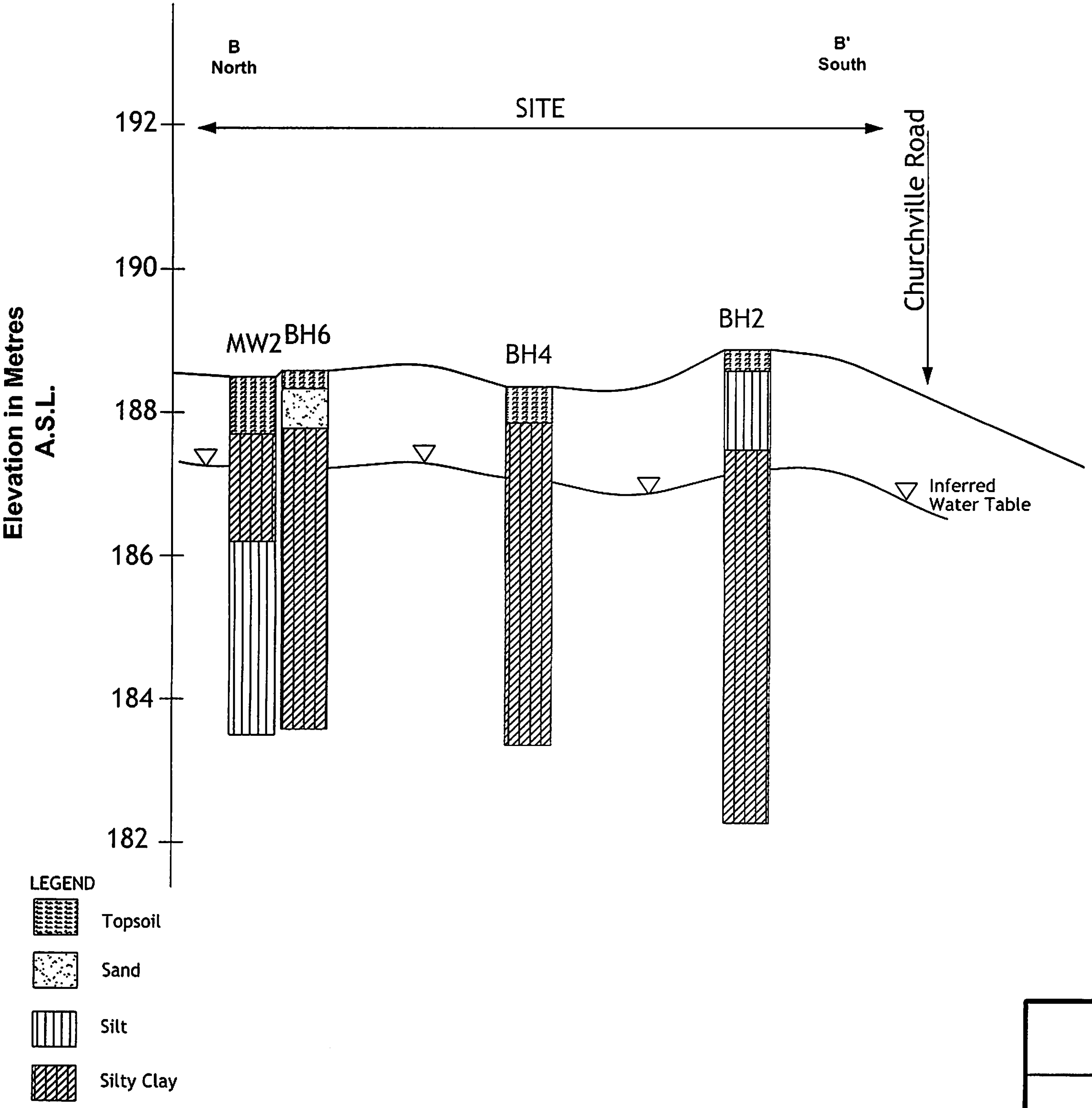
Date: Mar. 2010
Figure No.: 5



NOTES:
Refer to figure 3 for plan.
All locations and scales are approximate.

Cross Section B-B'

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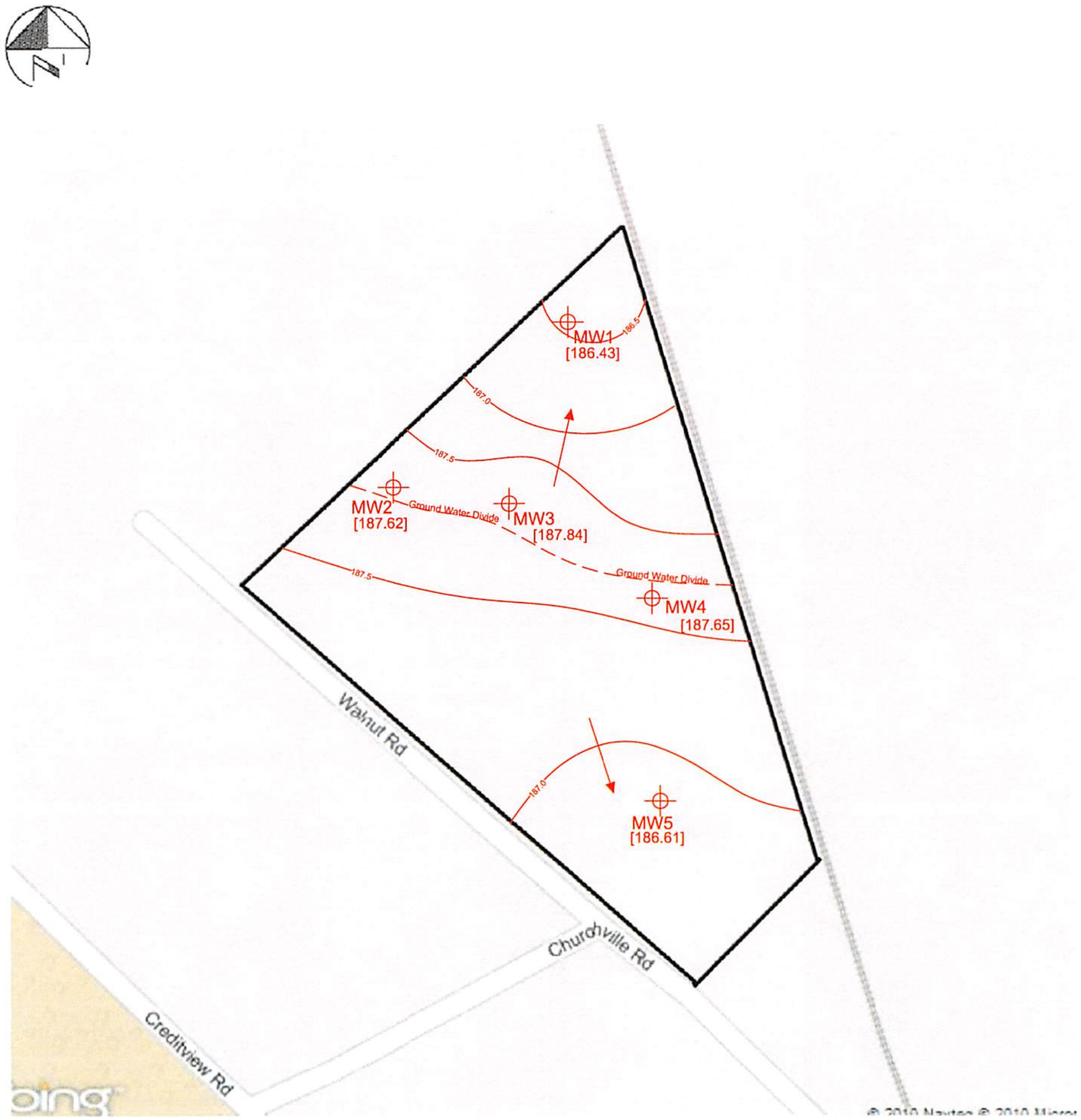

MW2 Well Location (deep installation)

→ Inferred direction of shallow ground water flow

[187.62] Water Level Elevation (m.a.s.l.)

-187.6- Topographic Contour (0.5m Interval)

NOTES:
All locations and scales are approximate.

Shallow Ground Water Flow

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Checked By: P.R.	**Date:** Mar. 2010	**Figure No.:** 7

MOE WELL RECORDS

APENDIX A

Terraprobe Inc.

```
                          UTM                               CSG KIND  WATER STAT PUMP TEST TEST              OWNER/LOG/SCREEN
 CONCESSION          WELL EASTING  ELEV                     DIA  OF   FOUND LVL  LVL  RATE TIME  WATER   DEPTHS IN FEET TO WHICH
    ETC        LOT    NO  NORTHING FEET DATE  DRILLER INS WATER FEET  FEET FEET GPM  HR/MN  USE        FORMATIONS EXTEND


 MUNICIPALITY CODE 49003  (CONTINUED...)

  HS W      3   1   49-   599880  608 06/63  2801    2  FR     31    15   19   25 48/00        BRAMPTON PUC
                    527 4832540                                                                BRWN CLAY GRVL BLDR 0011 GRVL 0013 BLUE
                                                                                               CLAY 0023 CLAY BLDR 0026 MSND GRVL 0031
                                                                                               GRVL 0037 CLAY BLDR 0040 BLDR 0041 CLAY
                                                                                               BLDR 0042 GRVL 0045 GRVL BLDR CLAY 0072
                                                                                               CLAY GRVL 0086 GRVL 0097 CLAY GRVL 0135
                                                                                               (S   0099 11 ) CLAY MSND BLDR 0198 SHLE
                                                                                               0211
  HS W      3   1   49-   599882  608 07/63  2801    2  FR     95     9                   PS    BRAMPTON PUC
                    528 4832490                                                                TPSL 0001 BRWN CLAY MSND 0012 BLUE CLAY
                                                                                               0059 CLAY GRVL BLDR 0064 CLAY 0070 CLAY
                                                                                               GRVL BLDR 0084 CLAY GRVL BLDR 0095 GRVL
                                                                                               BLDR CLAY 0110 CLAY BLDR 0140 (S   0110
                                                                                               11 )
⑫ HS W      3   1   49-   599813  618 05/58  1612    4  FR     92    12   30    2  1/00 DO    ELLISS ALBERT
                   1743 4832832                                                                TPSL 0002 BRWN CLAY 0047 BRWN MSND 0091
                                                                                               GRVL 0093
  HS W      3   1   49-   599875  608 08/63  2801    2  FR     89    14                         BRAMPTON WATER COMM
                   1744 4832580                                                                CLAY GRVL BLDR 0011 GRVL 0013 CLAY 0023
                                                                                               CLAY BLDR 0026 MSND GRVL 0037 CLAY BLDR
                                                                                               0042 GRVL BLDR CLAY 0072 CLAY GRVL 0086
                                                                                               GRVL 0097 (S   0089 10 ) CLAY BLDR 0135
                                                                                               CLAY GRVL BLDR 0198
  HS W      3   1   49-   599868  607 08/63  2801    1  FR     92    10   69   20  6/00        BRAMPTON WATER COMM
                   1745 4832577                                                                TPSL 0001 BRWN CLAY 0011 BLUE CLAY 0033
                                                                                               CLAY GRVL 0035 GREY CLAY 0070 MSND SILT
                                                                                               0092 GRVL CLAY 0096 GRVL CLAY 0120 (S
                                                                                               0097 10 ) MSND SILT 0122 CLAY GRVL 0133
                                                                                               CLAY SILT 0143 GRVL CLAY 0149 BLUE SHLE
                                                                                               0160
  HS W    x 3   1   49-   608038  641 11/67  1325   30  FR     31    17   30         /30 ST DO ELLIS ALBERTH
                   1747 4832835                                                                TPSL 0002 BRWN CLAY 0005 HPAN 0011 BLUE
                                                                                               CLAY 0023 CLAY BLDR 0030 MSND 0031 BLUE
                                                                                               CLAY 0032
  HS W      3   1   49-   599840  600 11/72  1815    6  FR     93    11   26   20  3/30 DO    LAIDLAW J
                   3959 4832460                                                                TPSL 0003 BRWN CLAY 0018 BLUE CLAY SILT
                                                                                               0061 BLUE CLAY 0085 BLUE CLAY STNS 0093
                                                                                               GRVL 0096
⑬ HS W      3   2   49-   599401  612 03/58  1612    4  FR    122    54   63    1  1/30 DO    DICKEY E E
                   1748 4832926                                                                PRDG 0018 BLUE CLAY 0118 BLUE CLAY MSND
                                                                                               0120 GRVL 0122
  HS W      3   2   49-   599958  670 04/61  4823    4        DRY                              POLLARD JAMES
                   1749 4833583                                                                TPSL 0002 CLAY BLDR 0025 MSND BLDR 0030
                                                                                               SILT MSND 0076 LMSN 0082 SHLE 0111
  HS W      3   2   49-   599962  680 04/61  4823    4  FR     52    26   28    1  6/00 DO    POLLARD JAMES
                   1750 4833613                                                                TPSL 0001 MSND CLAY 0018 BLUE CLAY GRVL
                                                                                               0051 (S   0050 04 ) MSND GRVL 0052 MSND
                                                                                               0053 MSND GRVL 0054 SILT MSND 0055
  HS W      3   2   49-   599078  565 06/65  1307   30  FR     59    10        50       DO    STEWART CHOS
                                                                                                               - CONTINUED -
⑧
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                        UTM                          CSG KIND  WATER STAT PUMP TEST TEST                OWNER/LOG/SCREEN
CONCESSION        WELL EASTING  ELEV                 DIA  OF   FOUND LVL  LVL  RATE TIME  WATER      DEPTHS IN FEET TO WHICH
   ETC       LOT   NO  NORTHING FEET DATE  DRILLER INS WATER FEET  FEET FEET GPM  HR/MN  USE          FORMATIONS EXTEND


MUNICIPALITY CODE 49003  (CONTINUED...)

                  1751 4832880                                                              BRWN TPSL CLAY 0014 GREY CLAY 0058 GREY
                                                                                            MSND 0059
①  HS W      3   2   49-  599035   609 06/65  2801    4  FR     24     6   14   10  1/00 DO MEIGHTON
                  1752 4833385                                                              MUCK 0003 CLAY SILT 0006 GRVL MSND 0011
                                                                                            FSND SILT CLAY 0024 GRVL MSND BLDR 0051
                                                                                            (S   0042 05 ) CLAY MSND GRVL 0097  RED
                                                                                            CLAY MSND FSND 0137 LMSN 0138
②  HS W      3   2   49-  599325   627 05/66  4813    4  FR     83    10   50    6  4/00 ST DO ROHRER J
                  1753 4833005                                                              PRDG 0012 SILT 0049 GRVL 0083 MSND 0088
                                                                                            (S   0084 04 )
③  HS W      3   2   49-  599017   600 06/66  4813    4  FR     81     9   12   16  4/00 IR PENGILLEY R
                  1754 4833022                                                              PRDG 0010 CLAY STNS 0057 MSND CLAY 0081
                                                                                            MSND 0088 (S   0084 04 )
   HS W      3   2   49-  599995   670 12/66  1307   30  FR     34    34         4       DO THORPE ARTHUR
                  1755 4833563                                                              BRWN TPSL CLAY 0018 GREY CLAY 0034 GRVL
                                                                                            0046 GREY CLAY 0047
   HS W      3   2   49-  599890   671 10/66  4813    7         DRY                         THORPE ARTHUR
                  1756 4833625                                                              BRWN CLAY 0018 BLUE CLAY 0043 CLAY MSND
                                                                                            0055 SILT 0087 GRVL 0103
④  HS W      3   2   49-  598959   600 07/67  4813    7  FR     95    35   50   10  4/00 DO GOWLAND FRED
                  1757 4833069                                                              GRVL 0014 BLUE CLAY 0036 CLAY STNS 0075
                                                                                            GRVL 0095 MSND 0100 (S   0096 04 )
⑤  HS W      3   2   49-  599067   600 07/67  4813    5  FR     78    24   50   12  3/00 DO PEEL ROBERT
                  1758 4832962                                                              BRWN CLAY 0004 BLUE CLAY 0056 GRVL 0078
                                                                                            MSND 0085 (S   0080 04 )
⑥  HS W      3   2   49-  599100   600 11/68  1307   30  FR     55                         DO PEEL DAVID
                  2993 4832900                                                              GRVL 0004 BRWN CLAY 0010 GREY CLAY 0054
                                                                                            MSND 0055
⑦  HS W      3   2   49-  599055   575 08/70  1660    6  FR     83   FLW         3   /30 DO MORINIS DAVID
                  3482 4832615                                                              TPSL 0001 BLUE CLAY BLDR 0025 BLUE CLAY
                                                                                            0073 MSND 0082 GRVL 0083
⑧  HS W      3   2   49-  599400   625 08/76  1307   30  FR     44    20   41    6  1/00 DO HOWARD FRIESEN
                  4935 4832950                                                              BRWN TPSL GRVL 0020 GREY CLAY 0042 CSND
                                                                                            GRVL 0044
⑨  HS W      3   2   49-  599380   625 09/77  5206    6  FR     95    32   32   50  2/00 DO VANDENBERG HANK
                  5198 4833050                                                              BRWN SAND 0009 BRWN CLAY 0028 BLUE CLAY
                                                                                            GRVL 0095 FSND 0099 SAND GRVL 0106 (S
                                                                                            0100 03 ) FSND 0120
⑩  HS W      3   2   49-  599200   645 06/78  4320   30  FR      4     4    4    3  1/00 DO PRIEBE ED
                  5366 4832600                                                              BRWN TPSL 0001 BRWN SAND 0004 GRVL SAND
                                                                                            STNS 0009 BRWN CLAY SAND 0010 GREY CLAY
                                                                                            STNS 0019 GREY CLAY 0029
   HS W      3   3   49-  599040   600 06/65  2801    4  FR     11     6   22   10  6/00 DO BRAMPTON WATER COMM
                   531 4833245                                                              MUCK 0003 CLAY SILT 0006 GRVL MSND 0011
                                                                                            FSND SILT CLAY 0024 GRVL MSND BLDR 0051
                                                                                            (S   0042 07 ) CLAY MSND GRVL 0097  RED
                                                                                            CLAY MSND FSND 0137
⑪  HS W      3   3   49-  598919   608 11/66  4813    5  FR     46    10   14   20  3/00 DO POWERS T L
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- CONTINUED -

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WATER WELL DATA SYSTEM        16 OCT 86        PAGE  221                                           GROUND WATER BULLETIN REPORT

                               UTM                           CSG KIND  WATER STAT PUMP TEST TEST                   OWNER/LOG/SCREEN
CONCESSION              WELL EASTING  ELEV                   DIA  OF   FOUND LVL  LVL  RATE TIME  WATER      DEPTHS IN FEET TO WHICH
   ETC           LOT     NO  NORTHING FEET DATE  DRILLER     INS WATER FEET  FEET FEET GPM  HR/MN  USE          FORMATIONS EXTEND


MUNICIPALITY CODE 49003  (CONTINUED...)

                        1759 4833051                                                                  BLCK TPSL MSND 0001 CLAY 0020 SILT 0046
                                                                                                      GRVL 0052 (S   0048 04 )
  HS W        3    3     49-  599398  682 03/66  5001   36  FR      8    2                    DO      BALAAM S
                        1760 4834158                                                                  TPSL CLAY 0008 GRVL 0011
  HS W        3    3     49-  599357  689 11/66  1612    7  FR     45   15   33     3  2/00  IR      AMNON AND HOZER
                        1761 4834203                                                                  TPSL 0001 BRWN CLAY 0006 SHLE 0047
  HS W        3    3     49-  598539  632 05/73  4320    4  FR     45   26   55     1 12/00  DO      MCKENZIE H
                        4296 4833735                                                                  BLCK TPSL 0001 BRWN SAND 0011  RED CLAY
                                                                                                      STNS 0017 GREY CLAY 0043  RED SHLE 0060
                                                                                                      BLUE SHLE 0069
  HS W        3    4     49-  598773  695 05/51  3514    4  SA    115   78          4        DO      ROSS L
                        1762 4834557                                                                  CLAY MSND 0032  RED SHLE 0080 GREY SHLE
                                                                                                      0118
  HS W        3    4     49-  598907  713 10/56  3211   18  FR      6    4                    DO      WILLIAMS AND JACKSON
                        1763 4834661                                                                  CLAY 0006 MSND GRVL 0007 CLAY STNS 0015
  HS W        3    4     49-  598766  713 10/62  3514       FR     40   15   15     4  4/00  DO      BURNS R
                        1764 4834748                                                                  PRDG 0020  RED SHLE 0042
  HS W        3    4     49-  597864  660 10/62  1612       FR     38    6   40     1   /30  DO      LIVINGSTON D
                        1765 4833821                                                                  PRDG 0010  RED SHLE 0040
  HS W        3    4     49-  598692  715 08/64  3513    5  FR     50   18   35     3  2/00  DO      VAN BRUMMER J
                        1766 4834890                                                                  TPSL 0001 BRWN MSND 0015  RED SHLE 0060
  HS W        3    4     49-  598573  712 06/66  3513    5  FR     75   24   60     5  4/00  DO      COOPER J E
                        1767 4834931                                                                  PRDG 0023  RED SHLE 0083
  HS W        3    5     49-  597853  681 12/50  1612    4  FR     72   12          1  1/00  DO      BRIDLE ARTHUR
                        1768 4834878                                                                  TPSL 0002 BLUE CLAY 0035  RED SHLE 0074
  HS W        3    5     49-  598048  671 05/55  1612    4  FR     68   .5   20     5  1/00  DO      CLANCY R
                        1769 4835103                                                                  TPSL 0003 GREY CLAY 0040  RED SHLE 0070
  HS W        3    5     49-  598218  728 06/55  1612    4  FR     18   18   27     4  1/00  DO      PIRSE A
                        1770 4835386                                                                  CLAY 0006 MSND 0018  RED SHLE 0050
  HS W        3    5     49-  598134  681 10/57  4838    6  FR     45   20   30     4  2/00  DO      MCKAY EARL
                        1771 4835242                    FR     61                                     CLAY 0012 CLAY GRVL 0025  RED SHLE 0067
                                                        FR     63
  HS W        3    5     49-  597398  712 11/57  1612    4  FR     76   16   70     2  2/00  DO      VEGTER H
                        1772 4834265                                                                  TPSL 0002 BRWN CLAY 0014  RED SHLE 0078
  HS W        3    5     49-  598023  712 09/58  3513    4  FR     66   25   66     3  1/00  DO      SWACKHAMMER HOMER
                        1773 4834667                                                                  PRDG 0020 CLAY GRVL 0058  RED SHLE 0070
  HS W        3    5     49-  598191  732 12/59  4838    5  FR     45   15   70     1  2/00  DO      MCKAY EARL
                        1774 4835303                    FR     63                                     BLUE CLAY 0025 BLUE CLAY GRVL 0030  RED
                                                        FR     65                                     SHLE 0070
  HS W        3    5     49-  597887  730 01/60  1325   30  FR     20   14                    DO      TOMPKINS ERIC
                        1775 4834904                                                                  BRWN CLAY MSND 0002  RED CLAY MSND BLDR
                                                                                                      0020 SHLE 0028
  HS W        3    5     49-  597591  690 09/61  1612    5  FR     40   10   35     3  1/00  DO      KROEZEN J
                        1776 4834535                                                                  TPSL 0001 BRWN CLAY 0015  RED SHLE 0040
  HS W        3    5     49-  598038  721 12/61  1307   30  FR     30   12          1        DO      WIKORSKY JOHN
                        1777 4835103                                                                  BRWN TPSL CLAY 0012  RED CLAY 0025  RED
                                                                                                      SHLE 0030
  HS W        3    5     49-  598669  712 01/62  1325   30  FR     20    8                    DO      COOPER E
                                                                                                                   - CONTINUED -
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④

TEST PIT LOGS AND GRAIN SIZE ANALYSIS

APENDIX B

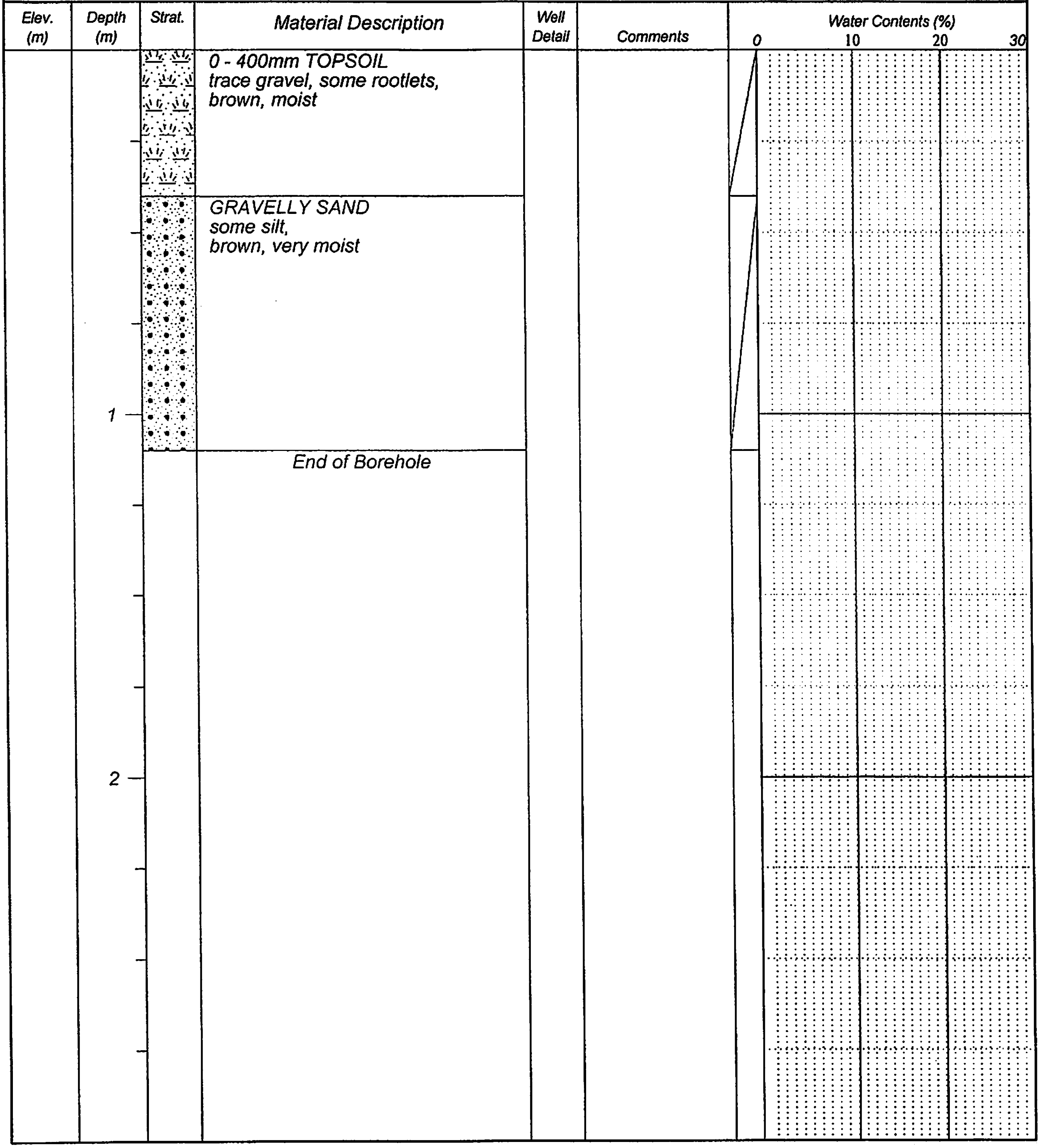
Terraprobe Inc.

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 1
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.1	*Date:* December 11, 2009

Notes: Groundwater pooling near eastern wall of test pit at 1.1m



0 - 400mm TOPSOIL
trace gravel, some rootlets,
brown, moist

GRAVELLY SAND
some silt,
brown, very moist

End of Borehole

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 2
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.0	*Date:* December 11, 2009

Notes: Groundwater pooling near eastern wall of test pit at 1.0m

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*	*Water Contents (%)* 0 10 20 30
			0 - 500mm TOPSOIL *some gravel, trace rootlets,* *brown, moist,*			
			GRAVELLY SAND *some silt,* *brown, very moist*			
	1		*End of Borehole*			
	2					

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 3
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.1	*Date:* December 11, 2009
Notes:		

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*	*Water Contents (%)* 0 10 20 30
			0 - 700mm TOPSOIL *trace gravel trace rootlets,* *brown, moist*			
			GRAVELLY SAND *some silt,* *brown, very moist*			
	1		*CLAYEY SILT* *brown, moist*			
			End of Borehole			
	2					

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 4 *Sheet No.* 1 *of* 1
Location: Brampton	Equipment: Back-Hoe	
Client: Stantec Consulting Ltd.	*Depth (m):* 2.4	*Date:* December 11, 2009
Notes:		

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*	*Water Contents (%)* 0 10 20 30
		⁂	*0 - 600mm TOPSOIL* *trace gravel, some rootlets,* *brown, moist*			
	1	▥	*SILT* *trace clay, trace sand,* *brown, very moist*			
	2	▥	*SILT* *trace clay, trace sand,* *grey, moist*			
			End of Borehole			

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 5
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 2.0	*Date:* December 11, 2009
Notes:		

Elev. (m)	Depth (m)	Strat.	Material Description	Well Detail	Comments	Water Contents (%) 0 10 20 30
			0 - 900mm TOPSOIL *trace gravel, trace rootlets,* *brown, moist*			
	1		*CLAYEY SILT* *some sand, trace gravel,* *grey - brown, moist*			
			SAND *some silt, trace clay, trace gravel,* *brown, moist*			
	2		*End of Borehole*			

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 6
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 2.2	*Date:* December 11, 2009

Notes:

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*	*Water Contents (%)* 0 10 20 30
			0 - 800mm TOPSOIL *trace gravel, some rootlets, brown, moist*			
	1		*SAND* *some silt, trace clay, trace gravel, brown, moist*			
	2		*SAND* *some silt, trace clay, trace gravel, brown, very moist*			
			End of Borehole			

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	Project Number: 1-09-4232	Test Pit No. 7
Location: Brampton	Equipment: Back-Hoe	Sheet No. 1 of 1
Client: Stantec Consulting Ltd.	Depth (m): 1.8	Date: December 11, 2009
Notes:		

Elev. (m)	Depth (m)	Strat.	Material Description	Well Detail	Comments	Water Contents (%) 0 10 20 30
		░	SAND some silt, trace clay, trace gravel, trace rootlets, brown, moist			
	1	░	SAND some silt, trace clay, trace gravel, brown, moist			
	2		End of Borehole			

Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 8
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.5	*Date:* December 11, 2009
Notes:		

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*	*Water Contents (%)* 0 10 20 30
			0 - 400mm TOPSOIL *trace rootlets,* *brown, moist*			
			SILT *trace clay, trace sand,* *brown, very moist*			
	1		*CLAYEY SILT* *some sand, trace gravel,* *brown, moist*			
			End of Borehole			
	2					

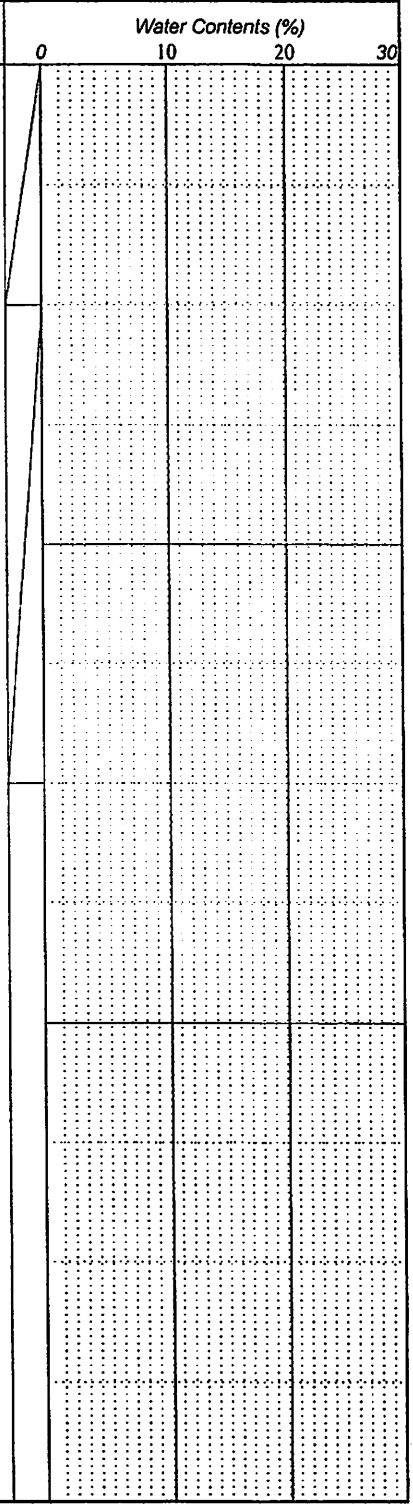
Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 9
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.0	*Date:* December 11, 2009

Notes: Groundwater pooling near eastern wall of test pit at 1.0m

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*
			0 - 500mm TOPSOIL *trace gravel, trace rootlets, brown, moist*		
			SILT *trace clay, trace sand, brown, very moist*		
	1		*End of Borehole*		
	2				



Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 10
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 0.9	*Date:* December 11, 2009

Notes:

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*	*Water Contents (%)* 0 10 20 30
			0 - 400mm TOPSOIL *trace gravel, trace rootlets, brown, moist*			
			SAND *some silt, trace clay, trace gravel, brown, moist*			
			End of Borehole			
	1					
	2					

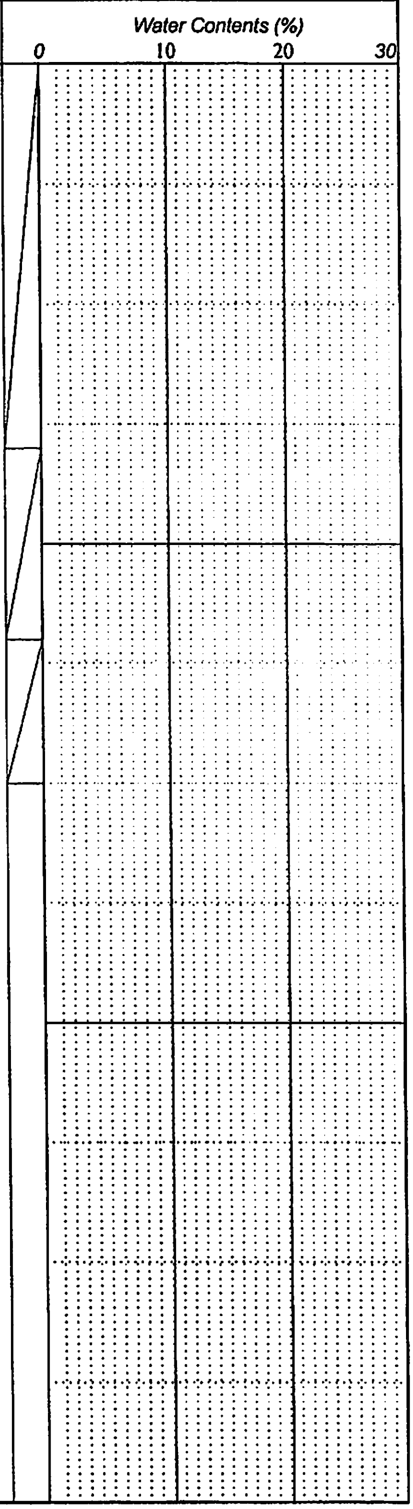
Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 11
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.5	*Date:* December 11, 2009

Notes: Terraprobe stake not found. Locaiton of TP approximated from Test Pit location map.

Elev. (m)	Depth (m)	Strat.	Material Description	Well Detail	Comments
			0 - 800mm TOPSOIL *trace gravel, some rootlets,* *brown, moist*		
	1		*SAND* *some silt, trace clay, trace gravel,* *reddish brown, moist*		
			GRAVEL AND SAND *some silt, trace clay,* *brown, moist*		
	2		*End of Borehole*		



Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 12
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.3	*Date:* December 11, 2009

Notes:

Elev. (m)	Depth (m)	Strat.	Material Description	Well Detail	Comments	Water Contents (%) 0 10 20 30
			0 - 600mm TOPSOIL *trace gravel, trace rootlets, brown, moist*			
	1		*SILT* *trace clay, trace sand, brown, moist*			
			End of Borehole			
	2					

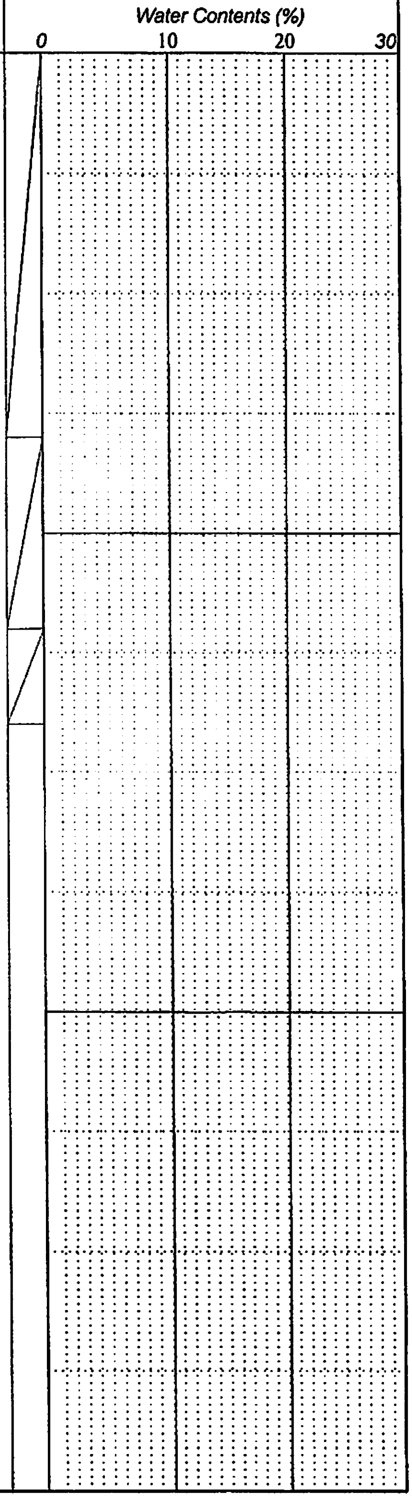
Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 13 14
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 1.4	*Date:* December 11, 2009

Notes:

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*
			0 - 800mm TOPSOIL *trace rootlets,* *brown, moist*		
	1		*GRAVEL AND SAND* *some silt, trace clay*		
			SILT *trace clay, trace sand*		
	2		*End of Borehole*		



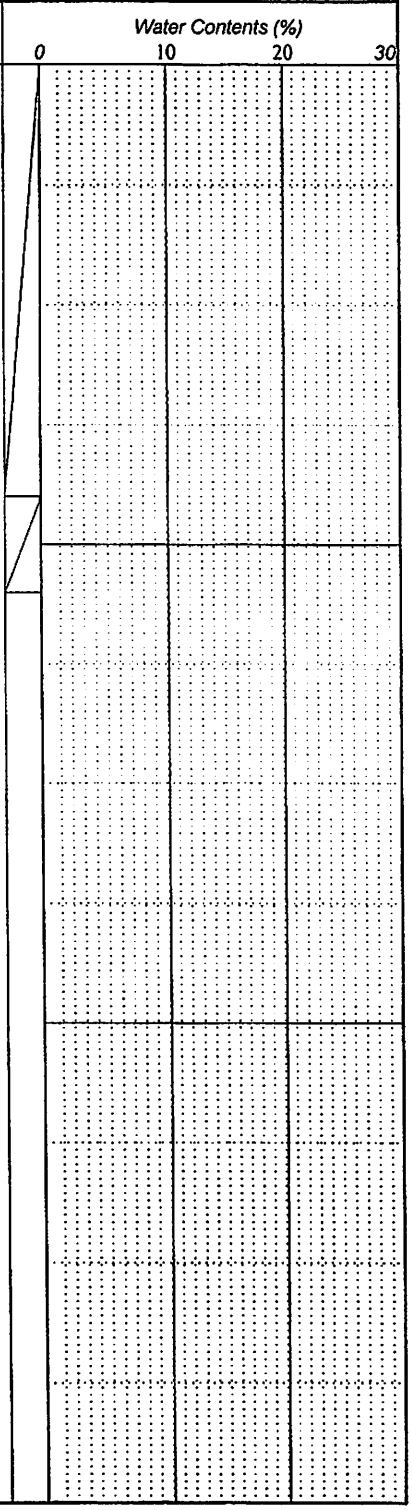
Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 14 ~~15~~ *Sheet No.* 1 *of* 1
Location: Brampton	Equipment: Back-Hoe	
Client: Stantec Consulting Ltd.	*Depth (m):* 1.1	*Date:* December 11, 2009

Notes: Groundwater pooling near eastern wall of test pit at 1.0m

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*
			0 - 900mm TOPSOIL *trace rootlets,* *brown, moist*		
	1		*SILT* *trace clay, trace sand,* *brown, very moist*		
			End of Borehole		
	2				



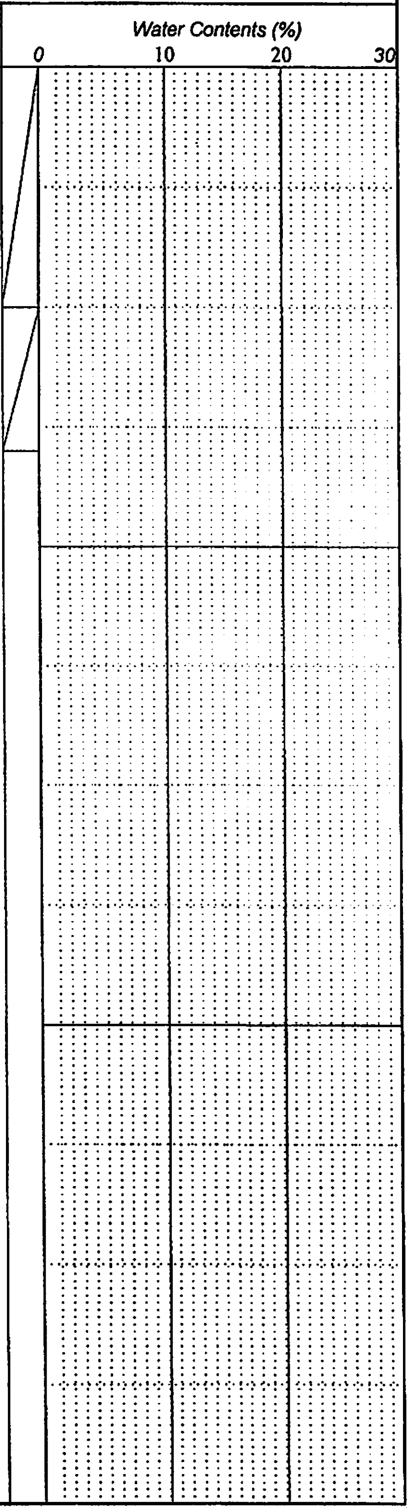
Terraprobe

TEST PIT LOG

Project: Walnut Rd, North of Steeles	*Project Number:* 1-09-4232	Test Pit No. 15 1~~6~~
Location: Brampton	Equipment: Back-Hoe	*Sheet No.* 1 *of* 1
Client: Stantec Consulting Ltd.	*Depth (m):* 0.8	*Date:* December 11, 2009

Notes:

Elev. (m)	*Depth (m)*	*Strat.*	*Material Description*	*Well Detail*	*Comments*
			0 - 500mm TOPSOIL *trace rootlets,* *brown, moist*		
			SAND *some silt, trace clay, trace gravel,* *brown, moist*		
			End of Borehole		
	1				
	2				



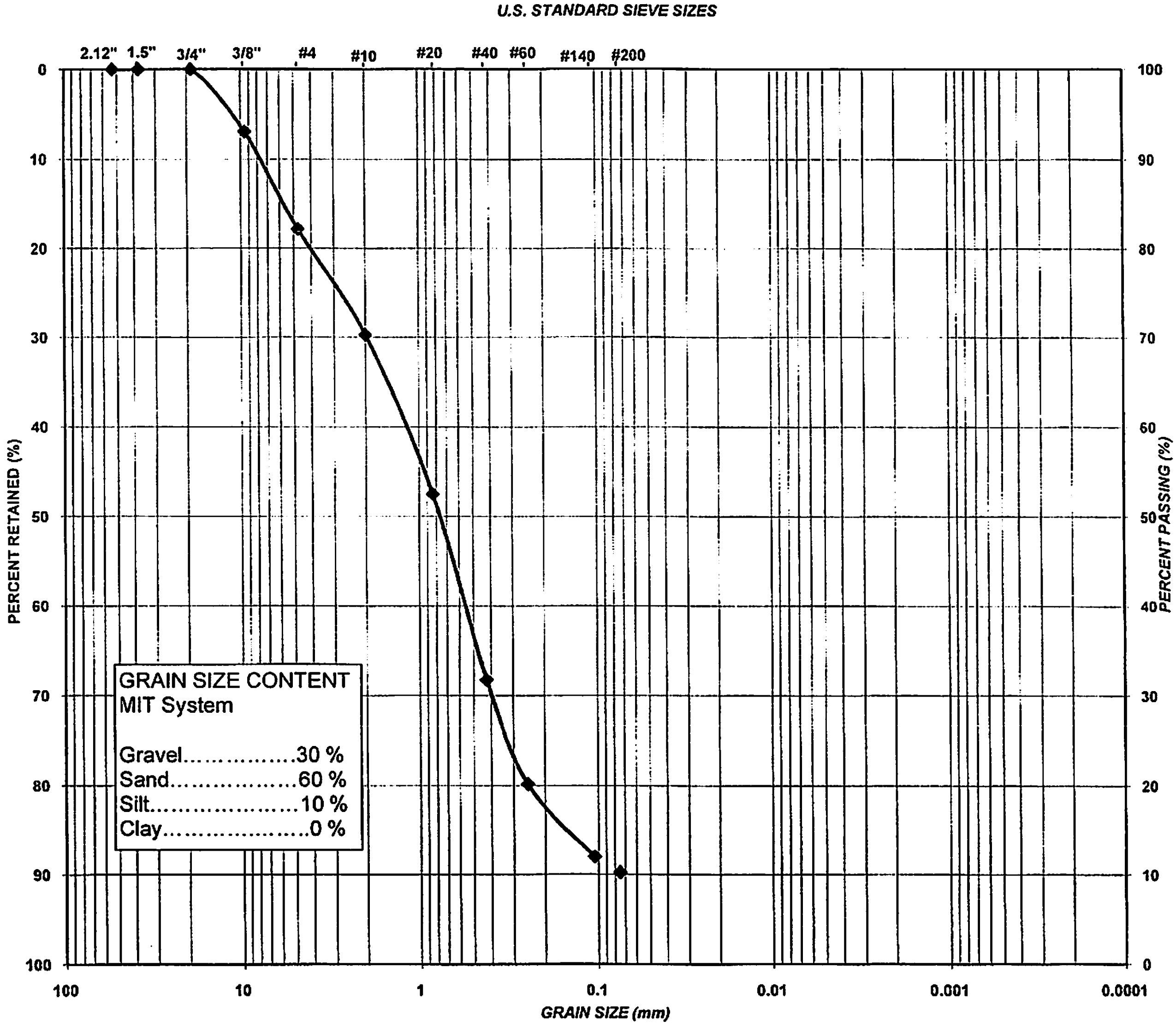
Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **2**
SAMPLE NUMBER: **2**
SAMPLE DEPTH: **1.0 m**
SAMPLE DESCRIPTION: **GRAVELLY SAND, some silt**

FILE NO.: **1-09-4232**
LAB NO.: **1308E**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**

GRAIN SIZE DISTRIBUTION



		COARSE	MEDIUM	FINE		
MIT SYSTEM	GRAVEL	SAND			SILT	CLAY

	COARSE	FINE	COARSE	MEDIUM	FINE	
UNIFIED SYSTEM	GRAVEL		SAND			SILT AND CLAY

Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST FORM

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **2**
SAMPLE NUMBER: **2**
SAMPLE DEPTH: **1.0 m**
SAMPLE DESCRIPTION: **GRAVELLY SAND, some silt**

FILE NO.: **1-09-4232**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**
TEST DATE: **Dec. 21, 2009**
TESTED BY: **SR**
LAB NO.: **1308E**

COARSE SIEVES

Dry Weight (g)		763.4		
SIEVE SIZE		CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
Standard	(mm)			
1.5"	37.5	0.00	0.0	**100.0**
3/4"	19.0	0.00	0.0	**100.0**
3/8"	9.5	52.60	6.9	**93.1**
No. 4	4.75	136.10	17.8	**82.2**
No. 10	2.00	226.70	29.7	**70.3**
PAN		535.00		
Dry Weight After Sieving (g)		761.7		
Percent Loss After Sieving		0.22		

FINE SIEVES (after washing)

Dry Weight		101.00		
Percent Passing No.4 (%)		70		
SIEVE SIZE		CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
Standard	(mm)			
No. 20	0.840	25.51	25.3	**52.5**
No. 40	0.425	55.37	54.8	**31.8**
No. 60	0.250	72.01	71.3	**20.2**
No. 140	0.105	83.74	82.9	**12.0**
No. 200	0.075	86.23	85.4	**10.3**

HYGROSCOPIC MOISTURE CONTENT

Wt. of wet soil and tare (g)	2.00
Wt. of dry soil and tare (g)	2.00
Wt. of water (g)	0.00
Wt. of tare (g)	1.00
Wt. of wet soil (g) (W_a)	1.00
Wt. of dry soil (g) (W_o)	1.00
Water content (%)	0.00

HYDROMETER

Hygroscopic Correction Factor	1.000000
Corrected Sample Weight (M_o)	101.00
Test sample represented by soil (W)	143.66
Gs Correction Factor	0.992096
Specific Gravity	2.685

Date and time	Elapsed Time	H_s in Divisions (G/L)	H_c in Divisions (G/L)	Temp. T_c (C)	Corrected Reading R = H_s-H_c	Percent Passing P in %	L in cm	n in milliPoise	K	Particle Diameter D in mm
	1									
	2									
	5									
	15									
	30									
	60									
	250									
	1440									

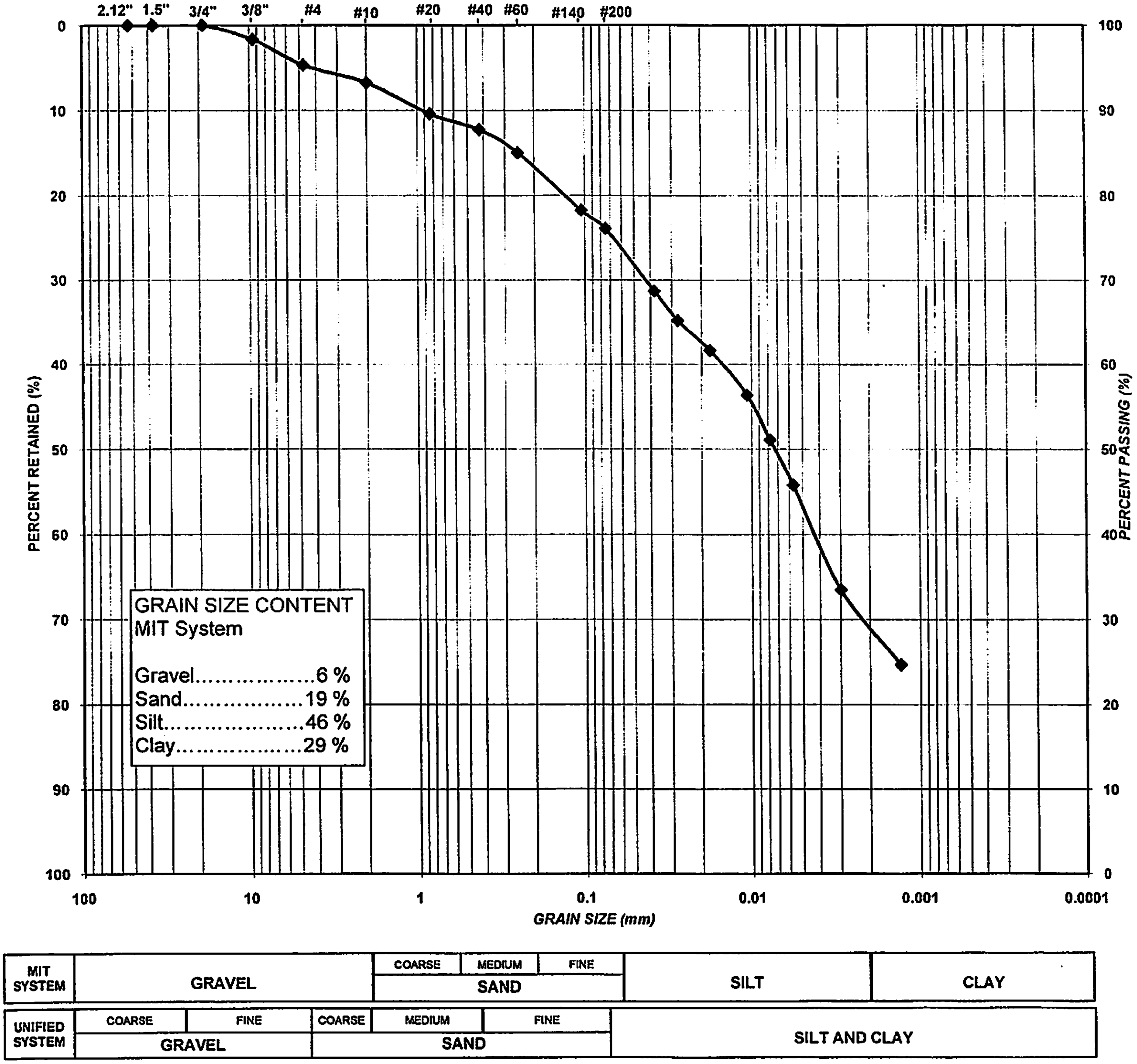
Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **8**
SAMPLE NUMBER: **3**
SAMPLE DEPTH: **0.9 m**
SAMPLE DESCRIPTION: **CLAYEY SILT, some sand, trace gravel**

FILE NO.: **1-09-4232**
LAB NO.: **1308D**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**

GRAIN SIZE DISTRIBUTION



GRAIN SIZE CONTENT
MIT System

Gravel..................6 %
Sand..................19 %
Silt.....................46 %
Clay...................29 %

Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST FORM

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **8**
SAMPLE NUMBER: **3**
SAMPLE DEPTH: **0.9 m**
SAMPLE DESCRIPTION: **CLAYEY SILT, some sand, trace gravel**

FILE NO.: **1-09-4232**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**
TEST DATE: **Dec. 21, 2009**
TESTED BY: **SR**
LAB NO.: **1308D**

COARSE SIEVES

Dry Weight (g)		353.8		
SIEVE SIZE Standard	(mm)	CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
1.5"	37.5	0.00	0.0	**100.0**
3/4"	19.0	0.00	0.0	**100.0**
3/8"	9.5	5.80	1.6	**98.4**
No. 4	4.75	16.50	4.7	**95.3**
No. 10	2.00	23.80	6.7	**93.3**
PAN		329.20		
Dry Weight After Sieving (g)		353.0		
Percent Loss After Sieving		0.23		

FINE SIEVES (after washing)

Dry Weight		52.50		
Percent Passing No.4 (%)		93		
SIEVE SIZE Standard	(mm)	CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
No. 20	0.840	2.05	3.9	**89.6**
No. 40	0.425	3.11	5.9	**87.8**
No. 60	0.250	4.61	8.8	**85.1**
No. 140	0.105	8.47	16.1	**78.3**
No. 200	0.075	9.66	18.4	**76.1**

HYGROSCOPIC MOISTURE CONTENT

Wt. of wet soil and tare (g)	2.00
Wt. of dry soil and tare (g)	2.00
Wt. of water (g)	0.00
Wt. of tare (g)	1.00
Wt. of wet soil (g) (W_A)	1.00
Wt. of dry soil (g) (W_n)	1.00
Water content (%)	0.00

HYDROMETER

Hygroscopic Correction Factor	1.000000
Corrected Sample Weight (M_o)	52.50
Test sample represented by soil (W)	56.29
Gs Correction Factor	0.992096
Specific Gravity	2.685

Date and time	**Elapsed Time**	**H_s in Divisions (G/L)**	**H_c in Divisions (G/L)**	**Temp. T_c (C)**	**Corrected Reading $R = H_s - H_c$**	**Percent Passing P in %**	**L in cm**	**n in milliPoise**	**K**	**Particle Diameter D in mm**
	1	45.0	6.0	22.2	39.0	**68.74**	8.3029	9.5703	0.0132	0.0380
	2	43.0	6.0	22.2	37.0	**65.22**	8.7029	9.5703	0.0132	0.0275
	5	41.0	6.0	22.2	35.0	**61.69**	9.1029	9.5703	0.0132	0.0178
	15	38.0	6.0	21.6	32.0	**56.40**	9.7029	9.7076	0.0133	0.0107
	30	35.0	6.0	21.3	29.0	**51.11**	10.3029	9.7775	0.0133	0.0078
	60	32.0	6.0	21.1	26.0	**45.83**	10.9029	9.8246	0.0134	0.0057
	250	25.0	6.0	20.3	19.0	**33.49**	12.3029	10.0171	0.0135	0.0030
	1440	20.0	6.0	19.5	14.0	**24.68**	13.3029	10.2162	0.0136	0.0013

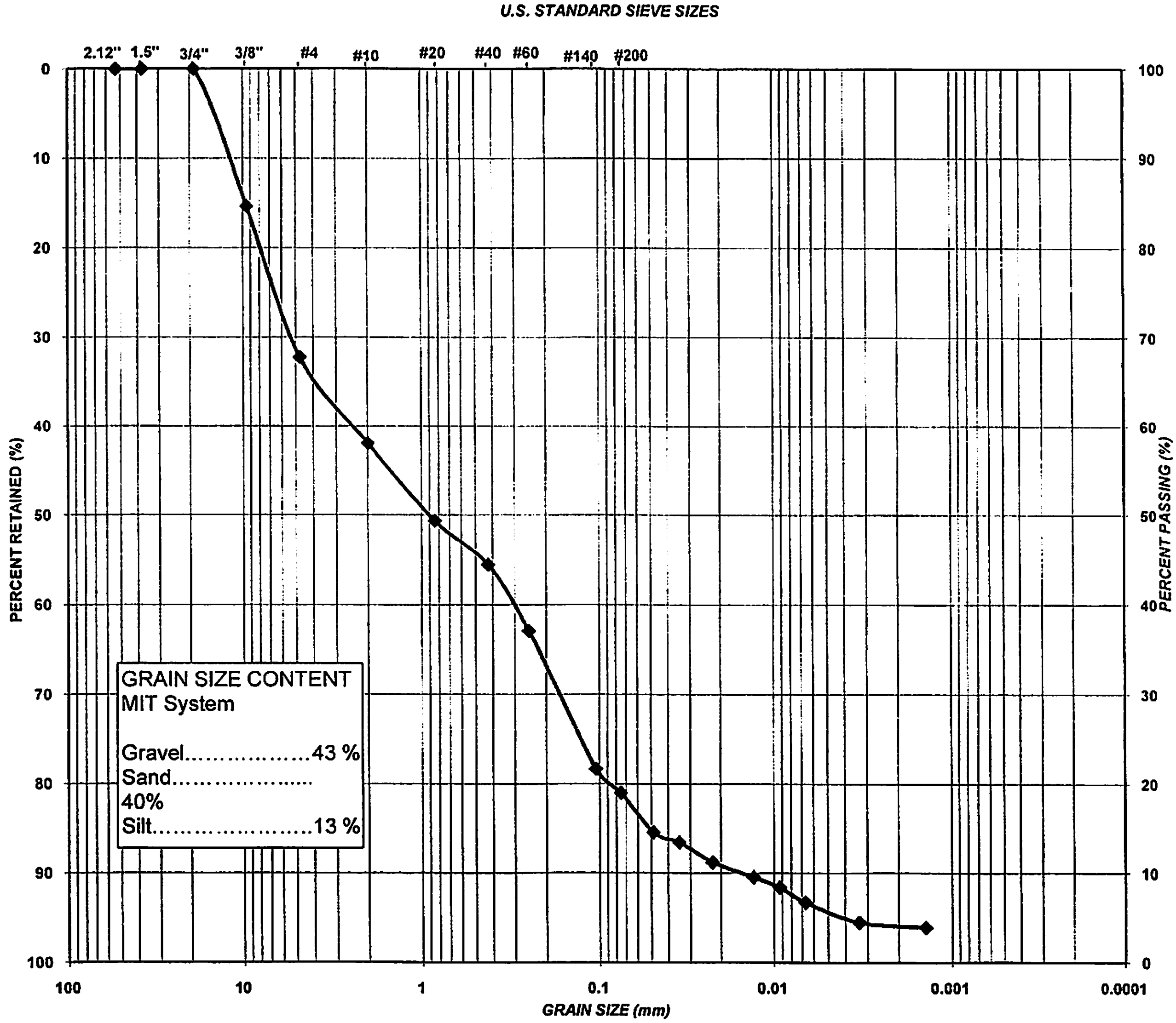
Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **11**
SAMPLE NUMBER: **3**
SAMPLE DEPTH: **1.2 m**
SAMPLE DESCRIPTION: **GRAVEL AND SAND, some silt, trace gravel**

FILE NO.: **1-09-4232**
LAB NO.: **1308C**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	COARSE	MEDIUM	FINE	SILT	CLAY
		SAND				

UNIFIED SYSTEM	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY
	GRAVEL		SAND			

Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST FORM

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **11**
SAMPLE NUMBER: **3**
SAMPLE DEPTH: **1.2 m**
SAMPLE DESCRIPTION: **GRAVEL AND SAND, some silt, trace gravel**

FILE NO.: **1-09-4232**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**
TEST DATE: **Dec. 21, 2009**
TESTED BY: **SR**
LAB NO.: **1308C**

COARSE SIEVES

Dry Weight (g)		683.4		
SIEVE SIZE		CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
Standard	(mm)			
1.5"	37.5	0.00	0.0	**100.0**
3/4"	19.0	0.00	0.0	**100.0**
3/8"	9.5	104.90	15.3	**84.7**
No. 4	4.75	220.20	32.2	**67.8**
No. 10	2.00	286.20	41.9	**58.1**
PAN		395.50		
Dry Weight After Sieving (g)		681.7		
Percent Loss After Sieving		0.25		

FINE SIEVES (after washing)

Dry Weight		51.40		
Percent Passing No.4 (%)		58		
SIEVE SIZE		CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
Standard	(mm)			
No. 20	0.840	7.77	15.1	**49.3**
No. 40	0.425	12.08	23.5	**44.5**
No. 60	0.250	18.59	36.2	**37.1**
No. 140	0.105	32.21	62.7	**21.7**
No. 200	0.075	34.59	67.3	**19.0**

HYGROSCOPIC MOISTURE CONTENT

Wt. of wet soil and tare (g)	2.00
Wt. of dry soil and tare (g)	2.00
Wt. of water (g)	0.00
Wt. of tare (g)	1.00
Wt. of wet soil (g) (W_A)	1.00
Wt. of dry soil (g) (W_D)	1.00
Water content (%)	0.00

HYDROMETER

Hygroscopic Correction Factor	1.000000
Corrected Sample Weight (M_c)	51.40
Test sample represented by soil (W)	88.44
Gs Correction Factor	0.992096
Specific Gravity	2.685

Date and time	Elapsed Time	H_s in Divisions (G/L)	H_c in Divisions (G/L)	Temp. T_c (C)	Corrected Reading $R = H_s - H_c$	Percent Passing P in %	L in cm	n in milliPoise	K	Particle Diameter D in mm
	1	19.0	6.0	21.9	13.0	**14.58**	13.5029	9.6385	0.0132	0.0486
	2	18.0	6.0	21.9	12.0	**13.46**	13.7029	9.6385	0.0132	0.0346
	5	16.0	6.0	21.9	10.0	**11.22**	14.1029	9.6385	0.0132	0.0222
	15	14.5	6.0	21.5	8.5	**9.54**	14.4029	9.7308	0.0133	0.0130
	30	13.5	6.0	21.3	7.5	**8.41**	14.6029	9.7775	0.0133	0.0093
	60	12.0	6.0	21.0	6.0	**6.73**	14.9029	9.8484	0.0134	0.0067
	250	10.0	6.0	20.3	4.0	**4.49**	15.3029	10.0171	0.0135	0.0033
	1440	9.5	6.0	19.7	3.5	**3.93**	15.4029	10.1658	0.0136	0.0014

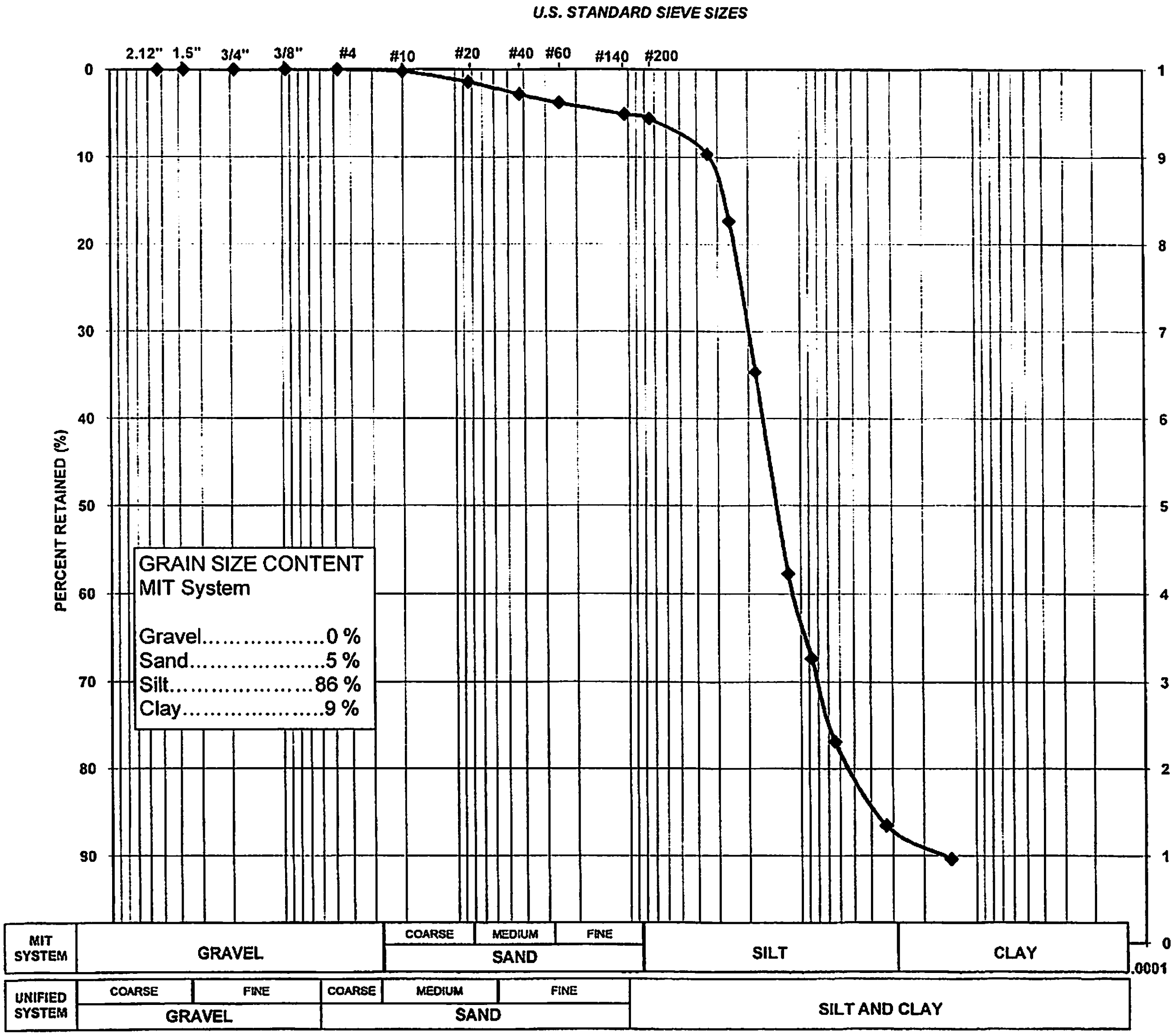
Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **15**
SAMPLE NUMBER: **2**
SAMPLE DEPTH: **0.9 m**
SAMPLE DESCRIPTION: **SILT, trace clay, trace sand**

FILE NO.: **1-09-4232**
LAB NO.: **1308B**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**

GRAIN SIZE DISTRIBUTION



GRAIN SIZE CONTENT
MIT System

Gravel……………….0 %
Sand…………………5 %
Silt…………………86 %
Clay…………………9 %

Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST FORM

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **15**
SAMPLE NUMBER: **2**
SAMPLE DEPTH: **0.9 m**
SAMPLE DESCRIPTION: **SILT, trace clay, trace sand**

FILE NO.: **1-09-4232**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**
TEST DATE: **Dec. 21, 2009**
TESTED BY: **SR**
LAB NO.: **1308B**

COARSE SIEVES

Dry Weight (g)		232.3		
SIEVE SIZE Standard	 (mm)	CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
1.5"	37.5	0.00	0.0	**100.0**
3/4"	19.0	0.00	0.0	**100.0**
3/8"	9.5	0.00	0.0	**100.0**
No. 4	4.75	0.00	0.0	**100.0**
No. 10	2.00	0.50	0.2	**99.8**
PAN		231.40		
Dry Weight After Sieving (g)		231.9		
Percent Loss After Sieving		0.17		

FINE SIEVES (after washing)

Dry Weight		51.50		
Percent Passing No.4 (%)		100		
SIEVE SIZE Standard	 (mm)	CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
No. 20	0.840	0.64	1.2	**98.6**
No. 40	0.425	1.34	2.6	**97.2**
No. 60	0.250	1.84	3.6	**96.2**
No. 140	0.105	2.52	4.9	**94.9**
No. 200	0.075	2.77	5.4	**94.4**

HYGROSCOPIC MOISTURE CONTENT

Wt. of wet soil and tare (g)	2.00
Wt. of dry soil and tare (g)	2.00
Wt. of water (g)	0.00
Wt. of tare (g)	1.00
Wt. of wet soil (g) (W_A)	1.00
Wt. of dry soil (g) (W_D)	1.00
Water content (%)	0.00

HYDROMETER

Hygroscopic Correction Factor	1.000000
Corrected Sample Weight (M_D)	51.50
Test sample represented by soil (W)	51.61
Gs Correction Factor	0.992096
Specific Gravity	2.685

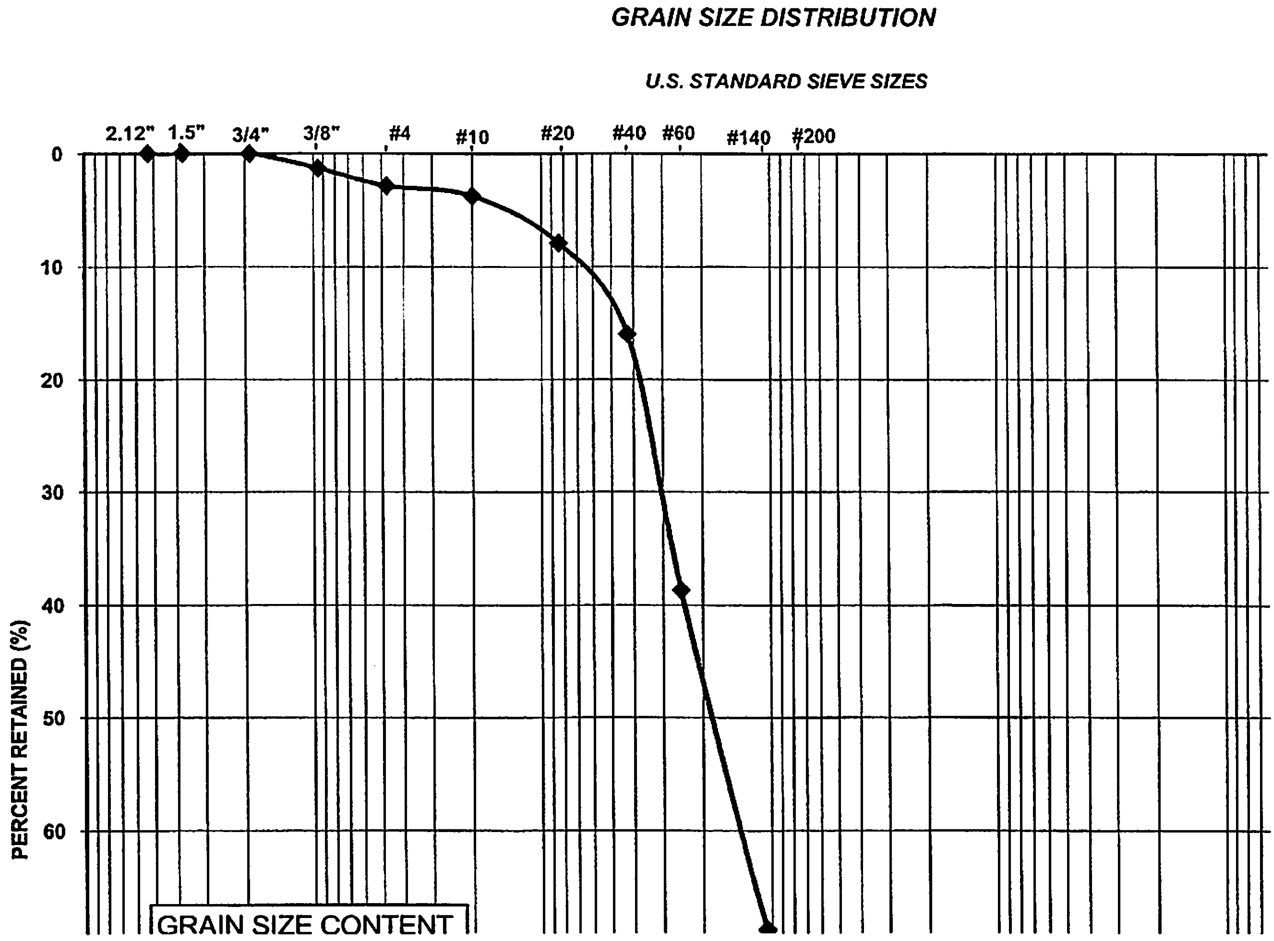
Date and time	Elapsed Time	H_s in Divisions (G/L)	H_c in Divisions (G/L)	Temp. T_c (C)	Corrected Reading $R = H_s - H_c$	Percent Passing P in %	L in cm	n in milliPoise	K	Particle Diameter D in mm
	1	53.0	6.0	21.3	47.0	**90.35**	6.7029	9.7775	0.0133	0.0345
	2	49.0	6.0	21.3	43.0	**82.66**	7.5029	9.7775	0.0133	0.0258
	5	40.0	6.0	21.3	34.0	**65.36**	9.3029	9.7775	0.0133	0.0182
	15	28.0	6.0	20.9	22.0	**42.29**	11.7029	9.8722	0.0134	0.0118
	30	23.0	6.0	20.8	17.0	**32.68**	12.7029	9.8961	0.0134	0.0087
	60	18.0	6.0	20.4	12.0	**23.07**	13.7029	9.9927	0.0135	0.0064
	250	13.0	6.0	20.1	7.0	**13.46**	14.7029	10.0663	0.0135	0.0033
	1440	11.0	6.0	19.4	5.0	**9.61**	15.1029	10.2416	0.0136	0.0014

Terraprobe

SIEVE AND HYDROMETER ANALYSIS
TEST REPORT

PROJECT: Walnut Grove
LOCATION: Walnut Road, Brampton, Ontario
CLIENT: Santec
TEST PIT NUMBER: 16
SAMPLE NUMBER: 2
SAMPLE DEPTH: 0.5 m
SAMPLE DESCRIPTION: SAND, some silt, trace clay, trace gravel

FILE NO.: 1-09-4232
LAB NO.: 1308A
SAMPLE DATE: December 11, 2009
SAMPLED BY: M.C.



Terraprobe

SIEVE AND HYDROMETER ANALYSIS
TEST FORM

PROJECT: **Walnut Grove**
LOCATION: **Walnut Road, Brampton, Ontario**
CLIENT: **Santec**
TEST PIT NUMBER: **16**
SAMPLE NUMBER: **2**
SAMPLE DEPTH: **0.5 m**
SAMPLE DESCRIPTION: **SAND, some silt, trace clay, trace gravel**

FILE NO.: **1-09-4232**
SAMPLE DATE: **December 11, 2009**
SAMPLED BY: **M.C.**
TEST DATE: **Dec. 21, 2009**
TESTED BY: **SR**
LAB NO.: **1308A**

COARSE SIEVES

Dry Weight (g)		847.2		
SIEVE SIZE		CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
Standard	(mm)			
1.5"	37.5	0.00	0.0	**100.0**
3/4"	19.0	0.00	0.0	**100.0**
3/8"	9.5	10.90	1.3	**98.7**
No. 4	4.75	23.90	2.8	**97.2**
No. 10	2.00	31.60	3.7	**96.3**
PAN		813.90		
Dry Weight After Sieving (g)		845.5		
Percent Loss After Sieving		0.20		

FINE SIEVES (after washing)

Dry Weight		51.30		
Percent Passing No.4 (%)		96		
SIEVE SIZE		CUM. WT. RET.	PERCENT RET.	PERCENT PASSING
Standard	(mm)			
No. 20	0.840	2.23	4.3	**92.1**
No. 40	0.425	6.54	12.7	**84.0**
No. 60	0.250	18.61	36.3	**61.3**
No. 140	0.105	34.64	67.5	**31.3**
No. 200	0.075	36.82	71.8	**27.1**

HYGROSCOPIC MOISTURE CONTENT

Wt. of wet soil and tare (g)	2.00
Wt. of dry soil and tare (g)	2.00
Wt. of water (g)	0.00
Wt. of tare (g)	1.00
Wt. of wet soil (g) (W_A)	1.00
Wt. of dry soil (g) (W_o)	1.00
Water content (%)	0.00

HYDROMETER

Hygroscopic Correction Factor	1.000000
Corrected Sample Weight (M_o)	51.30
Test sample represented by soil (W)	53.29
Gs Correction Factor	0.992096
Specific Gravity	2.685

Date and time	Elapsed Time	H_s in Divisions (G/L)	H_c in Divisions (G/L)	Temp. T_c (C)	Corrected Reading $R = H_s - H_c$	Percent Passing P in %	L in cm	n in milliPoise	K	Particle Diameter D in mm
	1	17.0	6.0	22.3	11.0	**20.48**	13.9029	9.5478	0.0132	0.0491
	2	16.0	6.0	22.3	10.0	**18.62**	14.1029	9.5478	0.0132	0.0350
	5	15.0	6.0	22.3	9.0	**16.76**	14.3029	9.5478	0.0132	0.0223
	15	14.0	6.0	22.0	8.0	**14.89**	14.5029	9.6157	0.0132	0.0130
	30	13.0	6.0	21.6	7.0	**13.03**	14.7029	9.7076	0.0133	0.0093
	60	12.0	6.0	21.1	6.0	**11.17**	14.9029	9.8246	0.0134	0.0067
	250	11.0	6.0	20.5	5.0	**9.31**	15.1029	9.9684	0.0135	0.0033
	1440	10.5	6.0	19.4	4.5	**8.38**	15.2029	10.2416	0.0136	0.0014

BOREHOLE LOGS

APENDIX C

Terraprobe Inc.

Terraprobe

LOG OF BOREHOLE 1

PROJECT: Walnut Road

LOCATION: Brampton

CLIENT:

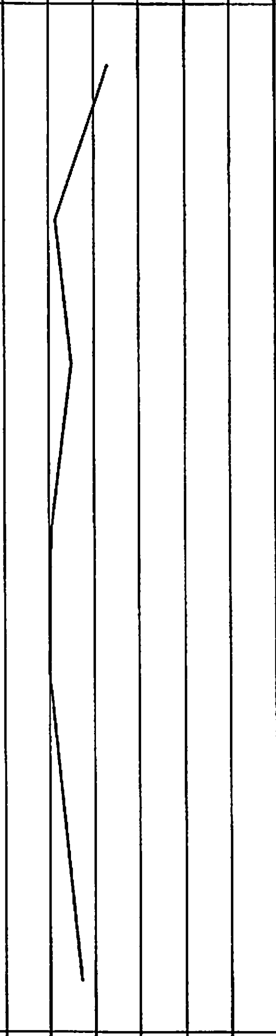
DATE: February 22, 2010

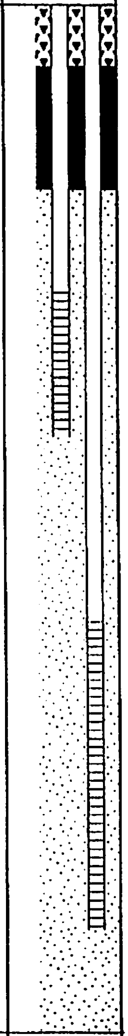
EQUIPMENT: Bombardier

ELEVATION DATUM: n/a

FILE: 1-09-4232

SOIL PROFILE			SAMPLES						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PEN. × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	ORGANIC VAPOUR (ppm)	STANDPIPE INSTALLATION OR REMARKS
0.0	750mm TOPSOIL		1	SS	46					
0.8	SILT some sand, trace gravel, compact, brown, damp		2	SS	23					
1.5	FINE SAND trace silt, compact, brown, moist		3	SS	30					
2.3	SILT some clay, trace gravel, compact, brown to grey, damp		4	SS	21					
3.0	SILTY CLAY compact, grey, moist		5	SS	20					
4.5	SILT some clay, trace gravel, trace sand, dense, grey, moist		6	SS	34					
5.0	End of Borehole									





NOTES:

Sheet 1 of 1

Terraprobe

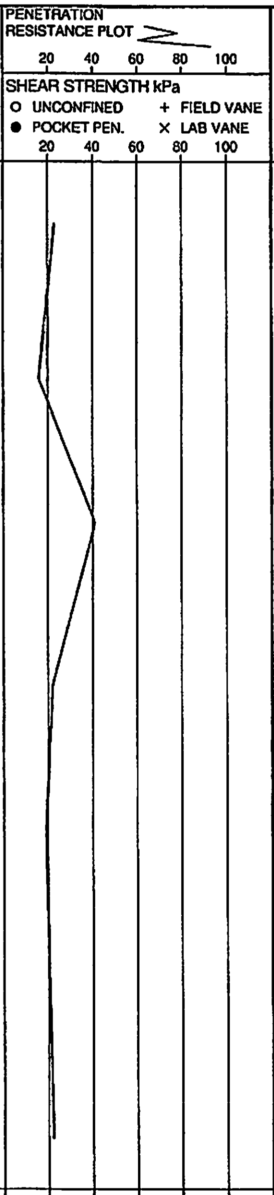
LOG OF BOREHOLE 2

PROJECT: Walnut Road
LOCATION: Brampton
CLIENT:

DATE: February 22, 2010
EQUIPMENT: Bombardier
ELEVATION DATUM: n/a
FILE: 1-09-4232

SOIL PROFILE			SAMPLES		
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES
0.0	750mm TOPSOIL		1	SS	23
0.6	SILTY CLAY compact, brown, very moist		2	SS	16
	---trace sand, trace gravel, dense, brown, moist		3	SS	41
2.3	SILT some clay, trace sand, compact, grey, moist		4	SS	22
	---trace gravel		5	SS	19
			6	SS	22
5.0	End of Borehole				

ELEVATION SCALE

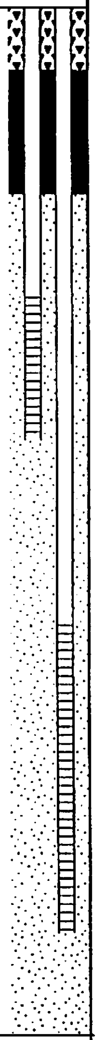


PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

ORGANIC VAPOUR (ppm)

STANDPIPE INSTALLATION OR REMARKS



NOTES:

Sheet 1 of 1

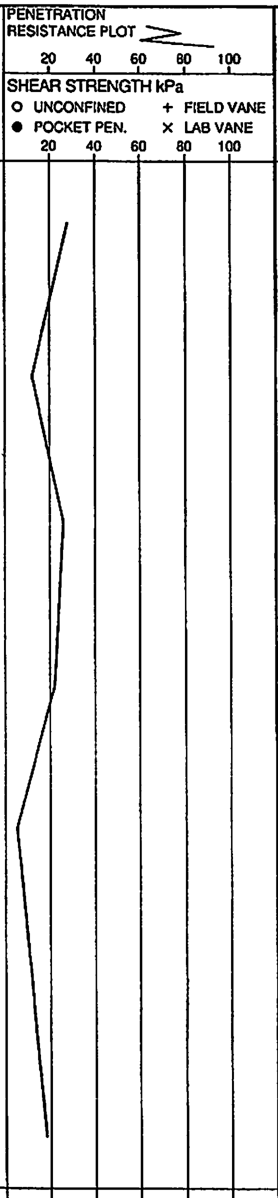
Terraprobe

LOG OF BOREHOLE 3

PROJECT: Walnut Road
LOCATION: Brampton
CLIENT:

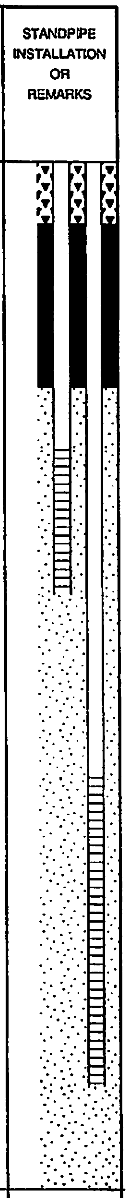
DATE: February 22, 2010
EQUIPMENT: Bombardier
ELEVATION DATUM: n/a
FILE: 1-09-4232

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	ELEVATION SCALE	ORGANIC VAPOUR (ppm)
0.0	750mm TOPSOIL	1	SS	28		
0.8	SAND trace silt, trace gravel, compact, brown	2	SS	12		
	---some gravel, moist	3	SS	26		
2.3	SILT some clay, compact, brown, very moist	4	SS	22		
3.0	SILTY CLAY loose, brown to grey, moist	5	SS	5		
	---some sand, compact	6	SS	18		
5.0	End of Borehole					



PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30



NOTES:

Terraprobe

LOG OF BOREHOLE 4

PROJECT: Walnut Road

LOCATION: Brampton

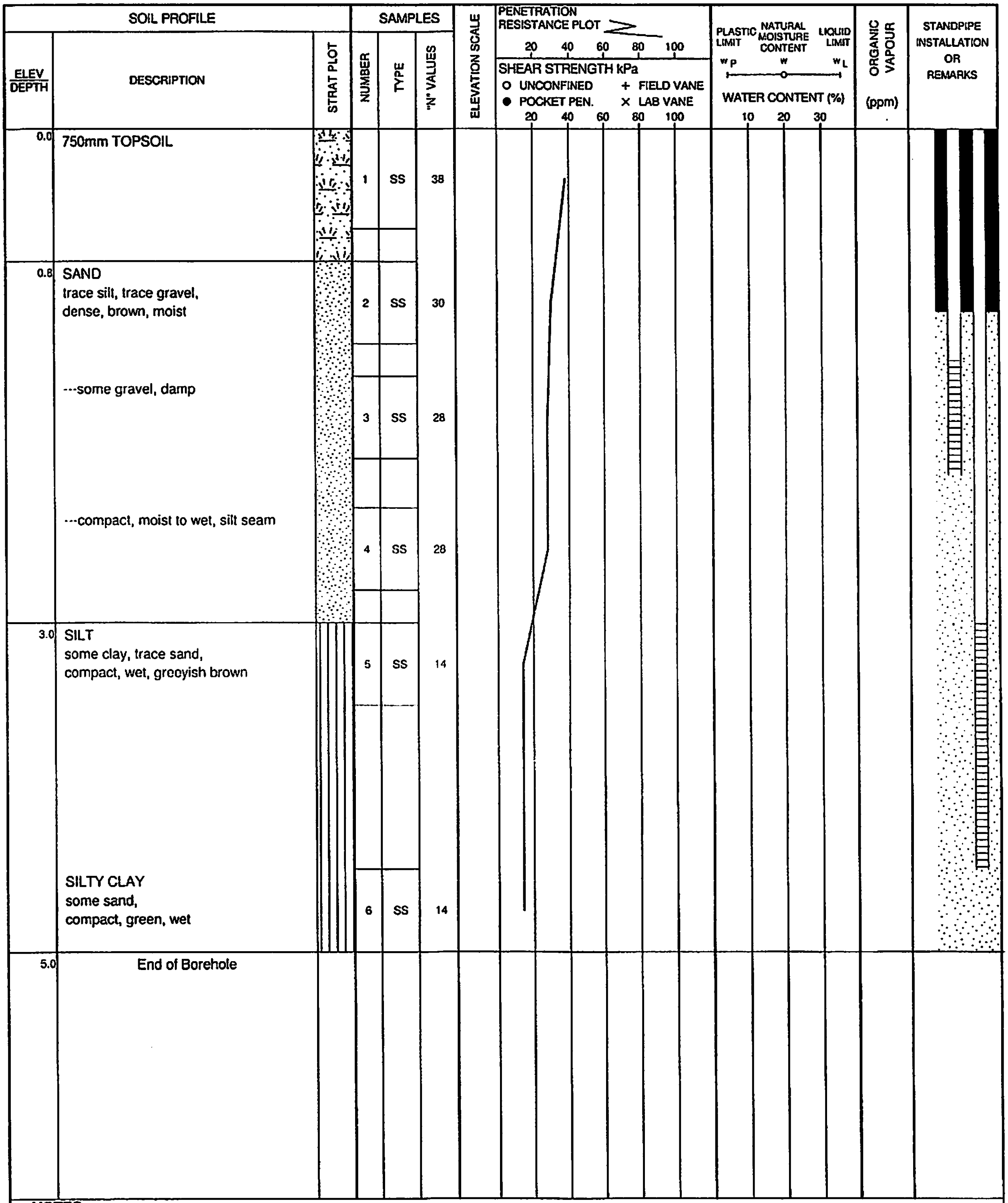
CLIENT:

DATE: February 22, 2010

EQUIPMENT: Bombardier

ELEVATION DATUM: n/a

FILE: 1-09-4232



ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
0.0	750mm TOPSOIL	1	SS	38
0.8	SAND trace silt, trace gravel, dense, brown, moist	2	SS	30
	---some gravel, damp	3	SS	28
	---compact, moist to wet, silt seam	4	SS	28
3.0	SILT some clay, trace sand, compact, wet, greeyish brown	5	SS	14
	SILTY CLAY some sand, compact, green, wet	6	SS	14
5.0	End of Borehole			

NOTES:
Borehole was caving at 3m and unstabilized water level at 3m upon completion of drilling.

Sheet 1 of 1

Terraprobe

LOG OF BOREHOLE 5

PROJECT: Walnut Road

LOCATION: Brampton

CLIENT:

DATE: February 22, 2010

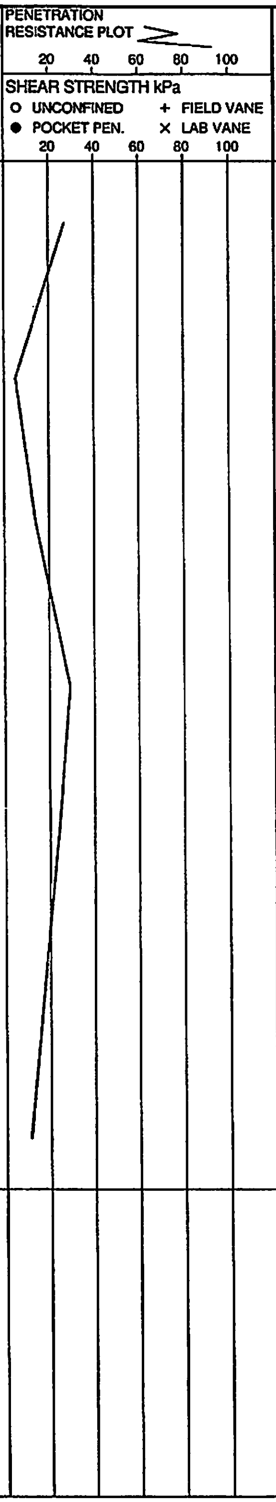
EQUIPMENT: Bombardier

ELEVATION DATUM: n/a

FILE: 1-09-4232

SOIL PROFILE		SAMPLES		
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
0.0	750mm TOPSOIL	1	SS	27
0.8	SAND trace silt, loose, brown, damp	2	SS	5
	---compact	3	SS	14
		4	SS	29
	---some gravel, trace silt	5	SS	24
4.5	SILTY CLAY trace sand, compact, grey, damp	6	SS	11
5.0	End of Borehole			

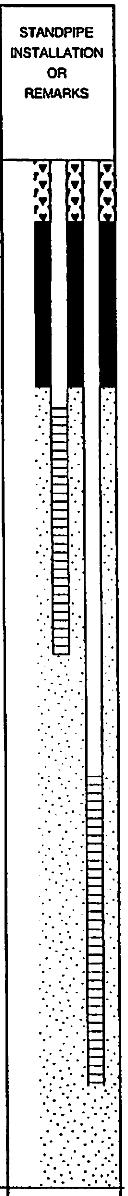
STRAT PLOT | ELEVATION SCALE



PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

ORGANIC VAPOUR (ppm)



NOTES:
Borehole was caving at 3.7m and unstabilized water level at 3.4m upon completion of drilling.

Sheet 1 of 1

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

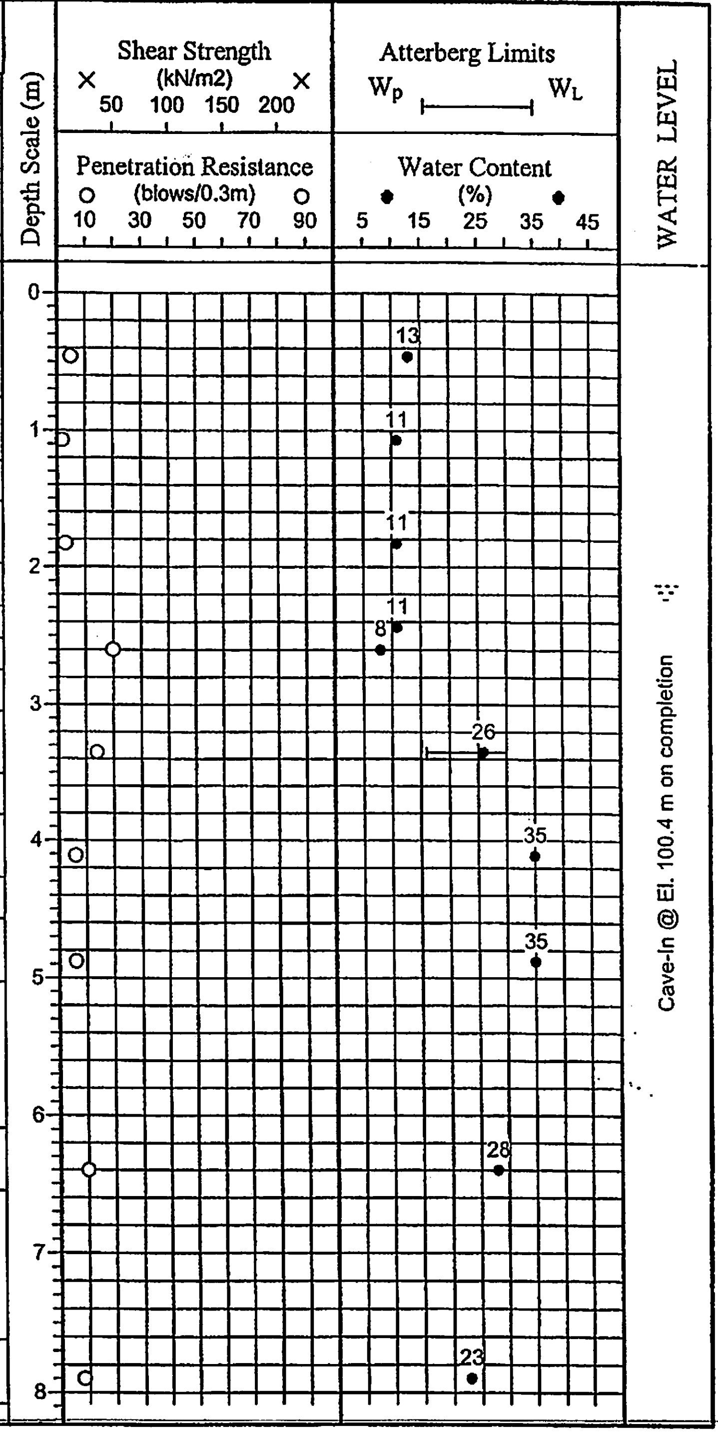
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
102.5	Ground Surface			
0.0	15cm TOPSOIL			
	SAND, Fill cobbles	1	DO	5
		2	DO	2
	traces of silt and gravel	3	DO	3
100.2 2.3	Brown, compact **FINE SAND** a trace of silt	4A 4B	DO DO	- 20
99.5 3.0	Firm to stiff **SILTY CLAY** some sand occ. sand and silt seams and layers	5	DO	14
	brown grey	6	DO	6
97.9 4.6	Grey, firm to stiff **SILTY CLAY, Till** some sand, a trace of gravel occ. sand and silt seams and layers, cobbles and boulders	7	DO	6
		8	DO	10
		9	DO	8
94.4 8.1	END OF BOREHOLE			



Soil Engineers Ltd.

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

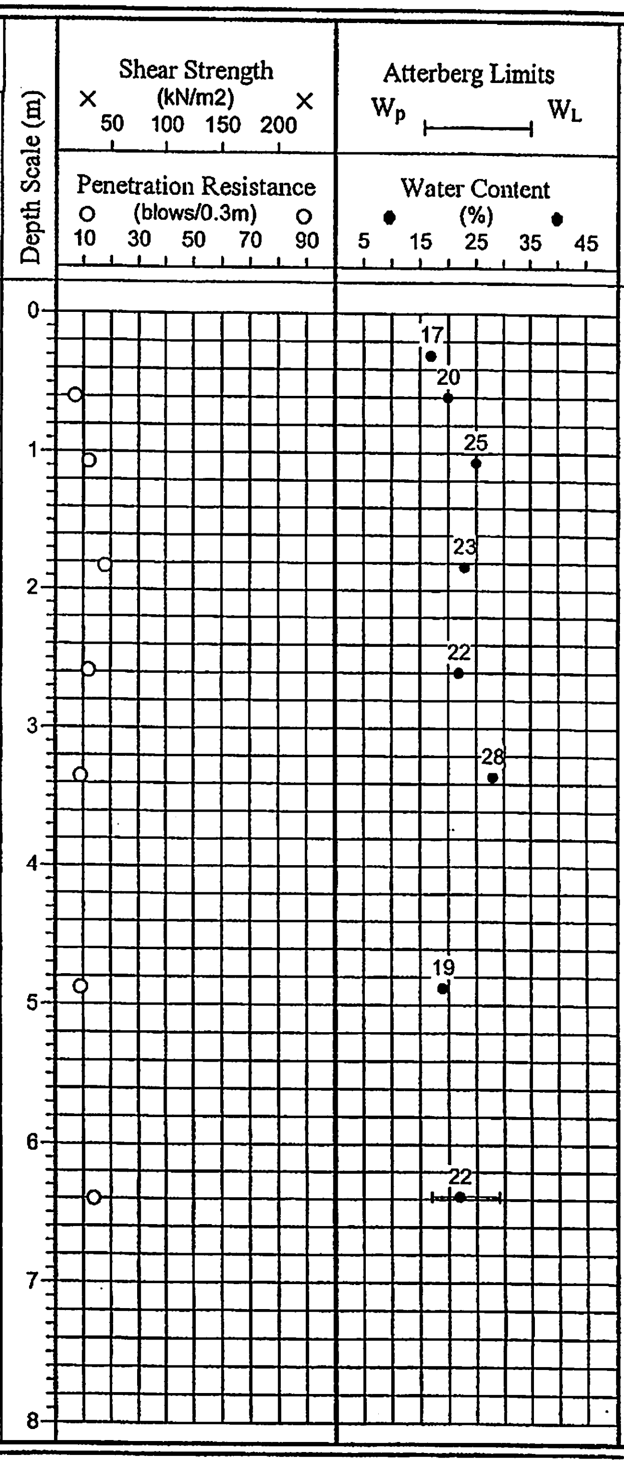
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
100.6 0.0	Ground Surface **30cm TOPSOIL**			
	Brown, loose to compact **SILT** some clay, a trace of sand	1A	DO	-
		1B	DO	7
		2	DO	12
99.2 1.4	Stiff to very stiff **SILTY CLAY** brown grey some sand occ. sand and silt seams and layers	3	DO	18
		4	DO	12
		5	DO	9
		6	DO	9
95.0 5.6	Grey, stiff **SILTY CLAY, Till** some sand, a trace of gravel occ. sand and silt seams and layers, cobbles and boulders	7	DO	14
94.0 6.6	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 95.1 m on completion

Soil Engineers Ltd.

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

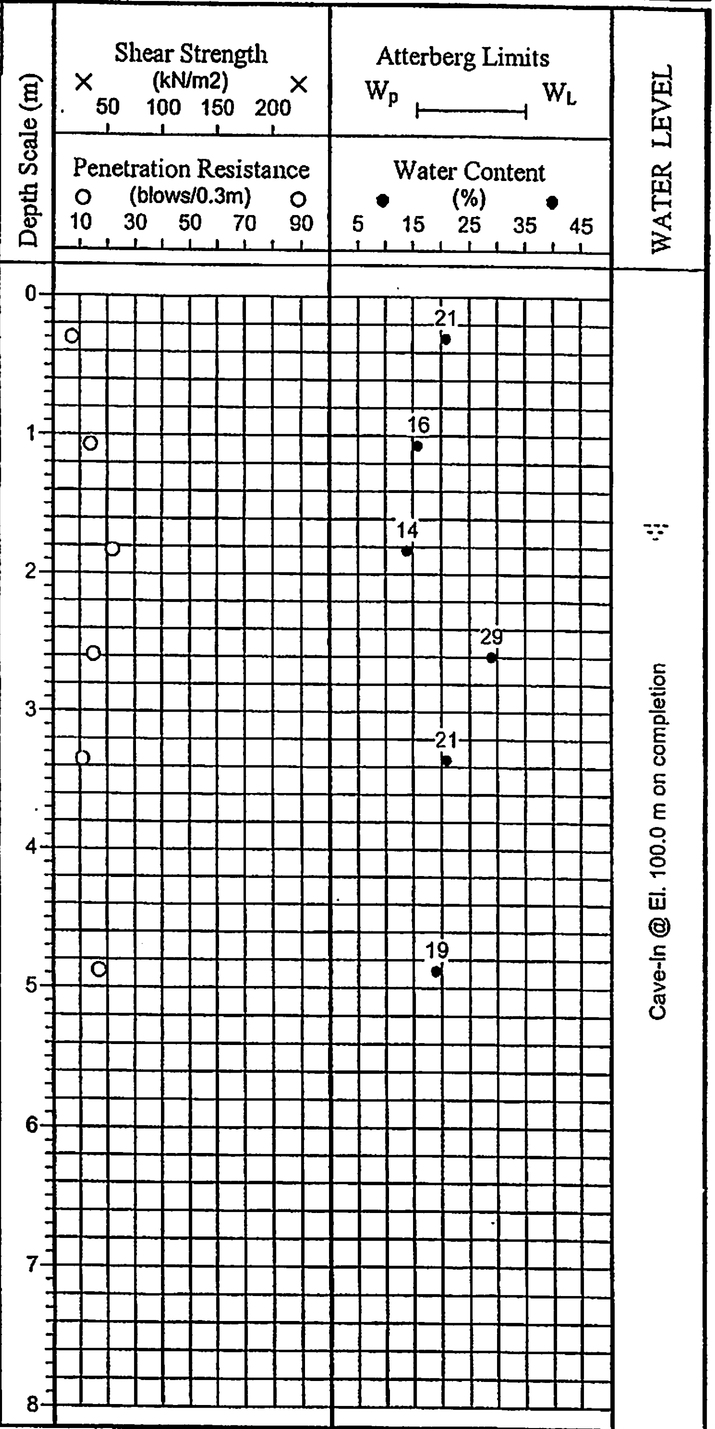
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
101.6	Ground Surface			
0.0	**46cm TOPSOIL**	1	DO	7
	Brown, loose to compact silty clay ---- **FINE TO COARSE SAND**	2	DO	14
	some gravel, a trace of clay	3	DO	22
99.3 2.3	Stiff **SILTY CLAY**	4	DO	15
	brown ---- grey some sand occ. sand and silt seams and layers	5	DO	11
97.6 4.0	Grey, very stiff **SILTY CLAY, Till** some sand, a trace of gravel occ. sand and silt seams and layers, cobbles and boulders	6	DO	17
96.6 5.0	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

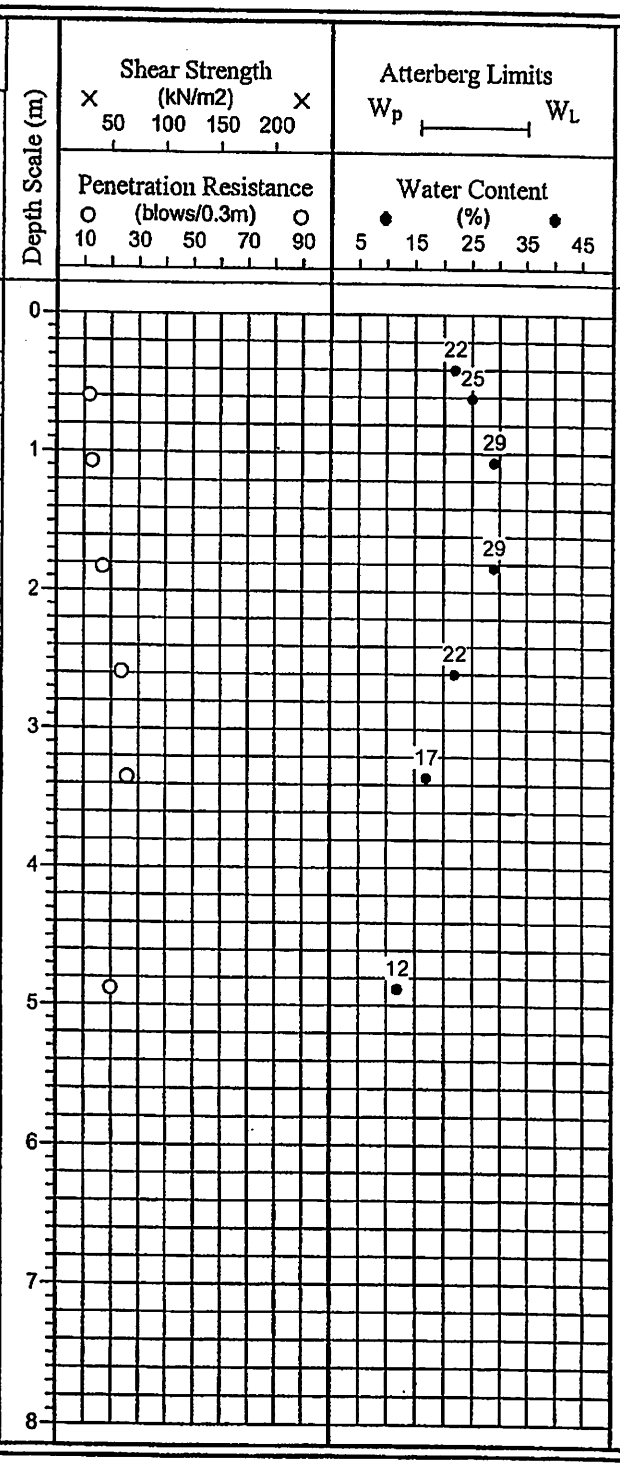
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
99.9	Ground Surface			
0.0	**50cm TOPSOIL** with silty clay and gravel	1A	DO	-
99.4 0.5	Brown, stiff to very stiff — silt layer	1B	DO	12
	SILTY CLAY some sand occ. sand and silt seams and layers	2	DO	13
		3	DO	17
97.6 2.3	Very stiff **SILTY CLAY, Till** some sand, a trace of gravel occ. sand and silt seams and layers, cobbles and boulders	4	DO	24
		5	DO	26
	brown	6	DO	20
94.9 5.0	**END OF BOREHOLE** — grey			



WATER LEVEL

Dry on completion

Soil Engineers Ltd.

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

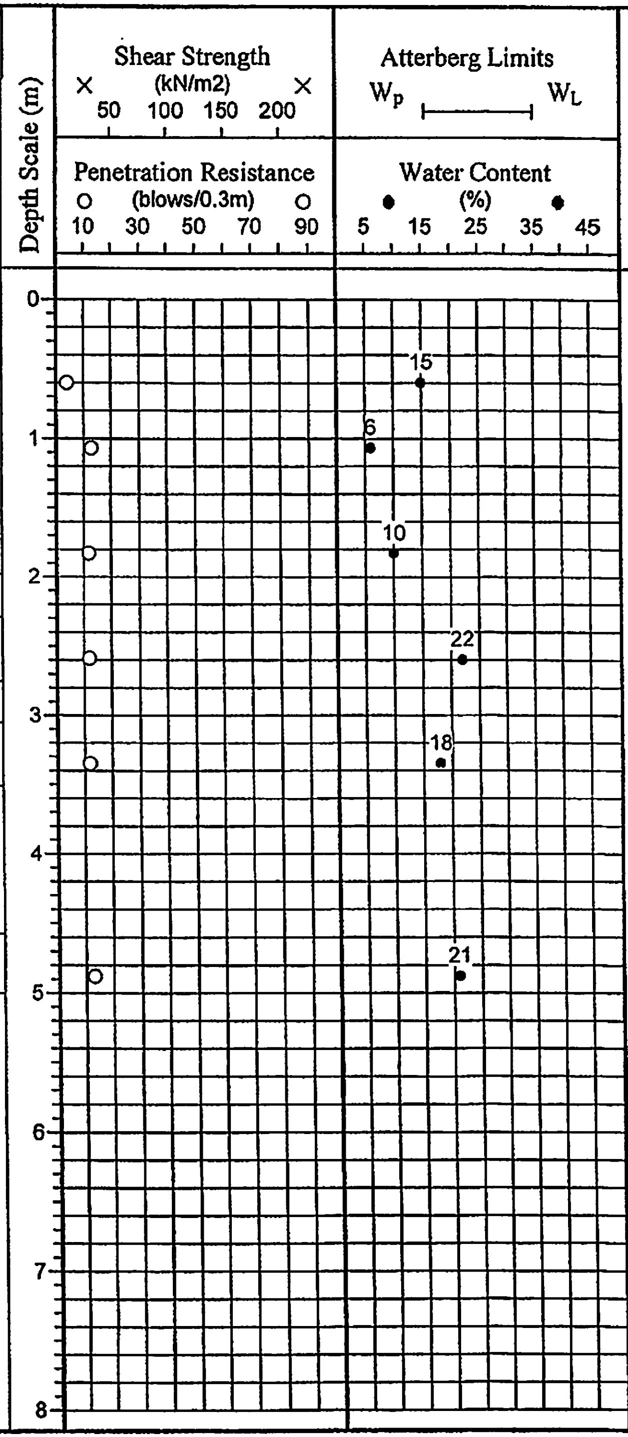
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
102.0 0.0	Ground Surface 25cm TOPSOIL			
	Brown, loose to compact **FINE TO COARSE SAND** a trace to some gravel and silt	1	DO	4
		2	DO	13
		3	DO	12
99.8 2.2	Brown, compact **FINE TO MEDIUM SAND** a trace of silt occ. silt seams	4	DO	12
		5	DO	12
97.8 4.2	Stiff **SILTY CLAY, Till** some sand, a trace of gravel occ. sand and silt seams and layers, cobbles and boulders brown grey	6	DO	13
97.0 5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 100.3 m on completion

Cave-In @ El. 100.1 m on completion

Soil Engineers Ltd.

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

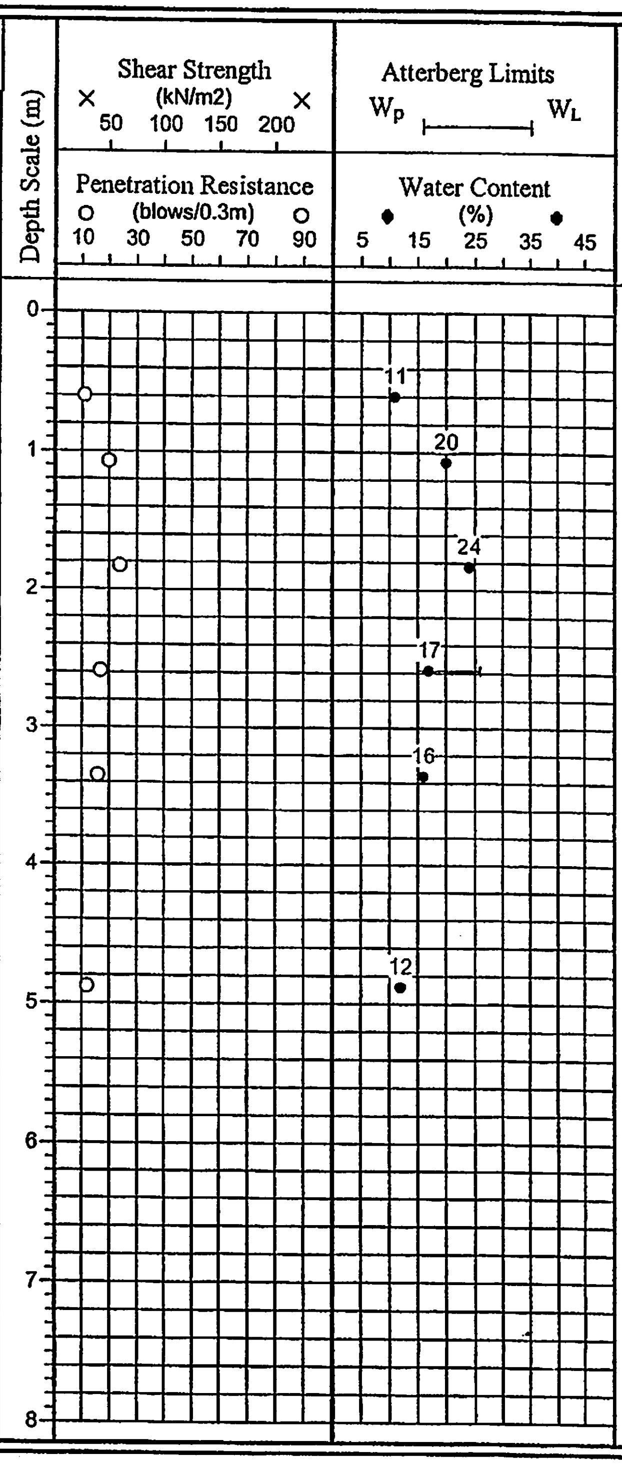
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
100.3	Ground Surface			
0.0	25cm TOPSOIL			
	Brown, compact FINE TO COARSE SAND a trace to some gravel and silt	1	DO	10
99.5 0.8	Brown, stiff SILTY CLAY some sand occ. sand and silt seams and layers silt layer	2	DO	10
98.8 1.5	Very stiff	3	DO	30
	SILTY CLAY, Till brown grey	4	DO	20
		5	DO	19
	some sand to sandy a trace of gravel occ. sand and silt seams and layers, cobbles and boulders			
		6	DO	22
95.3 5.0	END OF BOREHOLE			



WATER LEVEL

Dry on completion

Soil Engineers Ltd.

JOB NO.: 0712-S048

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

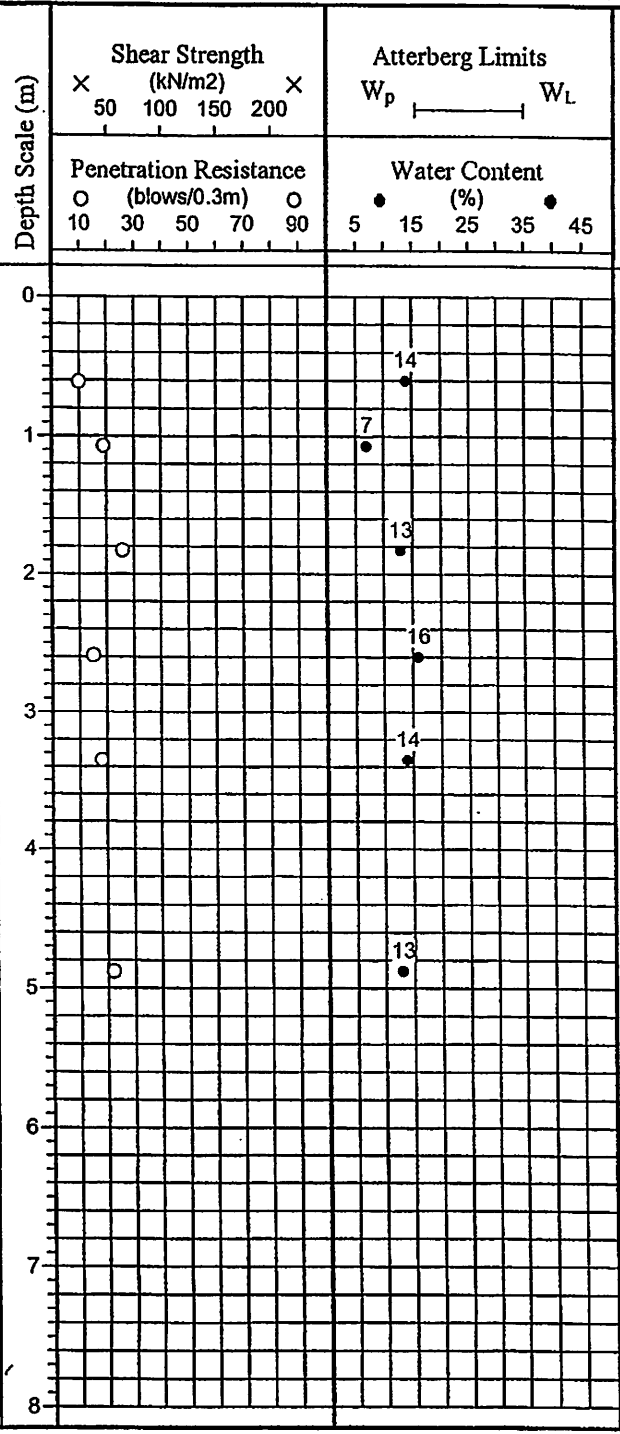
JOB DESCRIPTION: Proposed Residential Development

JOB LOCATION: Walnut Rd./Steeles Ave. W., City of Brampton

METHOD OF BORING: Flight-Auger

DATE: January 23, 2008

Elev. Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
102.5	Ground Surface				
0.0	25cm TOPSOIL				Dry on completion
	Brown, compact FINE TO COARSE SAND a trace to some gravel and silt	1	DO	10	
		2	DO	19	
101.0 1.5	Brown, compact FINE SAND a trace of silt	3	DO	26	
100.2 2.3	Stiff to very stiff SILTY CLAY, Till some sand, a trace of gravel occ. sand and silt seams and layers, cobbles and boulders	4	DO	15	
	brown ---- grey	5	DO	18	
		6	DO	22	
97.5 5.0	END OF BOREHOLE				



Soil Engineers Ltd.

WATER BALANCE CALCULATIONS

APENDIX D

Terraprobe Inc.

APPENDIX D: DETAILED WATER BALANCE - WALNUT GROVE, SEQUOIA HOMES BRAMPTON ONTARIO

1. Climate Information

Precipitation	793 mm/a
Evapotranspiration	554 mm/a
Water Surplus	239 mm/a

2. Infiltration Rates

Table 2 Approach - Infiltration Factors

Rolling Land	0.2
Open Sandy Loam	0.4
Cover-Cultivated	0.1
TOTAL	0.7

Infiltration (0.6 x 313)	167 mm/a
Run-off (313 - 188)	72 mm/a

Table 3 Approach - Typical Recharge Rates

silty sand to sandy silt	150 - 200	mm/a
silt	125 - 150	mm/a
clayey silt	100 - 125	mm/a

Site development area is underlain by a mixture of sandy fill and silty clay materials .

Based on the above, the recharge rate is approximately 150 mm/a

with runoff of 89 mm/a

3. Property Statistics

Residential Blocks	3.82 ha	3,816 m^2
Open Space	0.34 ha	340 m^2
Roads	1.51 ha	1,509 m^2
TOTAL	5.67 ha	5,665 m^2

4. Lot Coverage

Single Detached Residential

Roof coverage (40% of 3,816m^2)	1.53 ha	1,526 m^2
Driveway coverage (10% of 3,816m^2)	0.38 ha	382 m^2
TOTAL	1.91 ha	1,908 m^2

APPENDIX D: DETAILED WATER BALANCE - WALNUT GROVE, SEQUOIA HOMES BRAMPTON ONTARIO

5. Annual Pre-Development Water Balance

Land Use	Area (m^2)	Precipitation (m^3)	Evapotranspiration (m^3)	Infiltration (m^3)	Run-Off (m^3)
Undeveloped	5,665	4,492	3,138	850	504

6. Annual Post-Development Water Balance

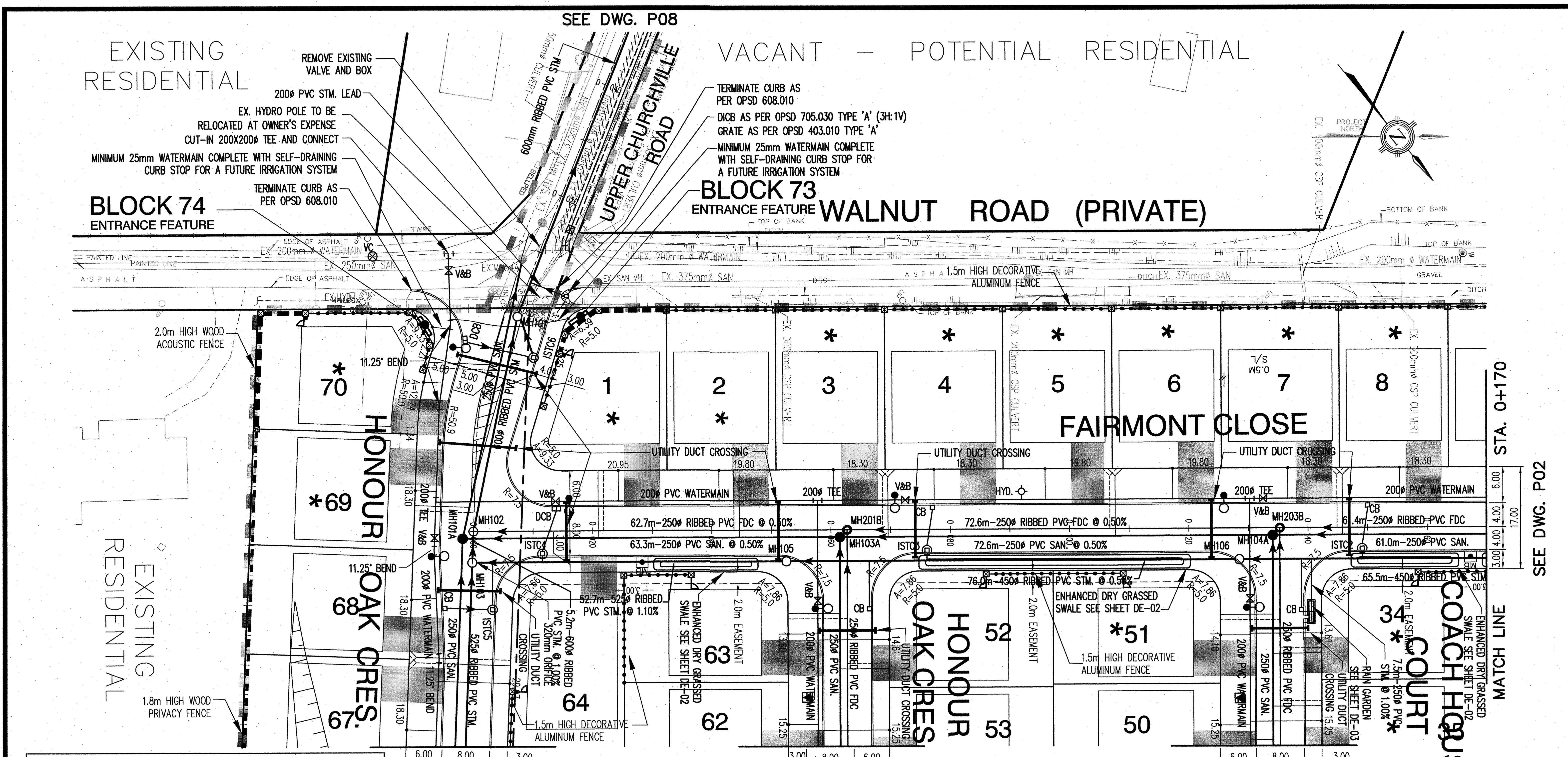
Land Use	Area (m^2)	Precipitation (m^3)	Evapotranspiration (m^3)	Infiltration (m^3)	Run-Off (m^3)
Building Coverage (Roof Area)	1,526	1,210	nil	nil	1,210
Hard surfaces (Roadways)	1,509	1,197	nil	nil	1,197
Berm/Buffer (Open Space)	340	270	188	40	24
Permeable Pavement Areas (Driveways)	382	303	211	45	27
Lots (not incl.driveway&roof)	1,908	1,513	1,057	286	170
TOTAL	5,665	4,492	1,457	372	2,628

7. Comparison of Pre-Development and Post-Development

	Precipitation (m^3)	Evapotranspiration (m^3)	Infiltration (m^3)	Run-Off (m^3)
Pre-Development	4,492	3,138	850	504
Post-Development	4,492	1,457	372	2,628

8. Requirement for Infiltration of Roof Runoff

Volume of post-development infiltration	372 m^3
Volume of pre-development Infiltration	850 m^3
Deficit from pre to post-development infiltration	478 m^3
Percentage of roadway runoff required to match pre-development infiltration	40 %



CURB STOPS AND BOXES
REGARDING REGION OF PEEL WATERMAIN DESIGN CRITERIA, ALL SERVICES SHALL HAVE CURB STOPS AND BOXES INSTALLED AT STREET LINE, BE FLUSH WITH GRADE AND ACCESSIBLE AT ALL TIME. REDUCING CURB STOPS SHALL NOT BE USED.
FOR RESIDENTIAL APPLICATIONS, ALL WATER SERVICES BOXES (CURB STOPS) SHALL BE INSTALLED IN GRASS AREAS WITH MINIMUM DISTANCE OF 1.0 meter FROM THE EDGE OF THE DRIVEWAY.

THE APPLICANT, APPLICANT'S REPRESENTATIVE, CONSULTANT, CONTRACTOR AND SUB-CONTRACTOR ARE RESPONSIBLE TO ENSURE THAT THEIR DESIGN AND CONSTRUCTION PRACTICES CONFORMS TO THE LATEST REGION OF PEEL STANDARDS, SPECIFICATIONS AND DESIGN CRITERIA, POSTED ON THE REGION OF PEELS'S WEBSITE (www. peelregion.ca/pw/standards)

LOW POINT ELEV = 189.12
LOW POINT STA = 0+014.02
PVI STA = 0+013.02
PVI ELEV = 189.06
A.D. = 3.50
K = 4.00
14.00m

ORIFICE TABLE

STRUCTURE	SIZE	INVERT
MH103	320mmø	187.24

STANDARD NOTES: (CITY OF BRAMPTON)

- a. All construction works shall comply with the Standard Drawings and Specifications of the City of Brampton and the O.P.S.
- b. All concrete and plastic sewer pipes shall have rubber gasket joints.
- c. All sewers shall be constructed with bedding in accordance with City of Brampton Standard Drawing 348 unless otherwise noted.
- d. Plastic sewer pipes shall be constructed with Ultra Rib or approved equal up to the maximum diameter of 600mm.
- e. No PVC pipe shall be used on arterial and parkway roadways.
- f. Single catchbasin leads to be 200mm unless otherwise noted. Double catchbasin leads to be 250mm unless otherwise noted. All catchbasin leads to be either C–14–ES minimum or P.V.C. type S.D.R. 28.
- g. All backfill for sewers, watermains and utilities on the road allowance must be mechanically compacted to 95% Standard Proctor Density except for top 0.3m which must be compacted to 98%.
- h. All trench cuts through asphalt will be repaired with a minimum of 1.0m beyond the edge of the full cut depth.
- i. An asphalt preservative sealer such as Re–clamite (or other approved equivalent) shall be applied after the one–year maintenance period for the top course asphalt.
- j. The City of Brampton Traffic Services Department shall be notified 48 hours prior to the installation of any traffic signal underground plants and a representative of the City's traffic signals department shall mark the underground plant and handwell locations in the fields with the consulting engineer/contractor
- k. All intersections have one utility duct on the leg of each street. Each duct shall be located 2.5m from the BC / EC and shall extend 0.5m behind the back of curb. Both ends of the utility duct shall be capped. The ducts shall be 100mm in diameter made of CSA certified Type 2 PVC. The minimum trench width of the duct shall be 300mm with 100mm sand bedding and backfill around the duct. Native backfill can be used from the sand backfill up to the granular sub–base. The duct shall have a minimum cover of 1.5 meters.
- l. No limestone permitted as bedding for weeping tile and under basement slab if FDC proposed.

WATERMAIN CONNECTION NOTES:

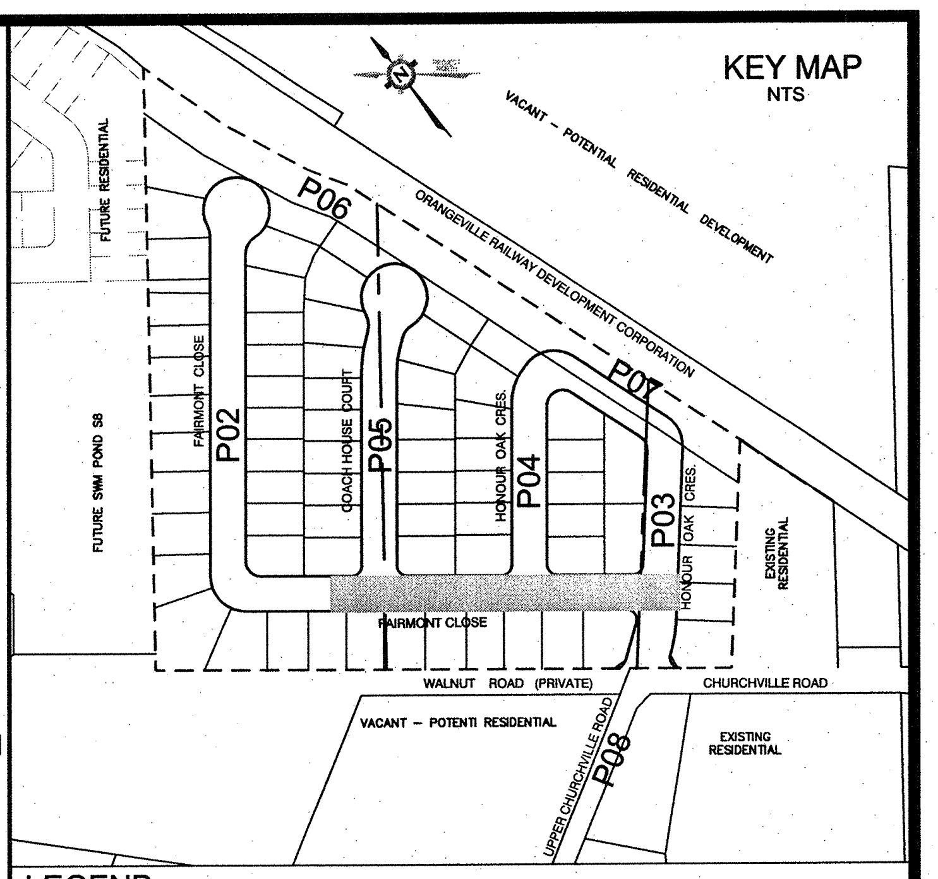
1. The minimum lateral distance between water services and other utilities shall be 1.2m.
2. All connections to pvc pipes to be made using an approved wide band service saddle. Direct tapping is not allowed.
3. All water service connections are 19mm.

ADDITIONAL NOTES:

1. Bioswale block and undeveloped blocks shall be maintained free of garbage and construction debris by the developer until assumption of the subdivision by the city.
2. All areas of bioswale block disturbed during construction shall be restored to the satisfaction of the City of Brampton.
3. Bioswale block and undeveloped blocks shall not be used for the purpose of stockpiling or for the placement of construction trailers.
4. When the temporary turning circle easement is eliminated, remove existing asphalt and granular base material (where required) and restore to a standard road cross–section to the satisfaction of the City of Brampton.
5. No rear yard gates are permitted from residential lots to bioswale block or Walnut Rd.
6. Any erosion experienced along the channel slopes throughout the construction and warranty period of this development shall be corrected by the developer to the satisfaction of the planning, design and development department.
7. When the temporary emergency access is closed, the asphalt and the granular material is to be removed and the area is to be restored to the satisfaction of the City of Brampton. Continuation of the fence is to be included with this work.
8. All sound barriers must be of solid construction with a minimum face density of 20 kg/m2 (double check noise report) with no holes, gaps or cracks.
9. All blocks that are undeveloped within the subdivision are to be fine graded, topsoil and sodded unless otherwise noted. Developer to perform regularly scheduled maintenance on all undeveloped blocks.
10. All fences to be located 0.15m inside residential lot where abutting public land.

OIL-GRIT SEPARATORS

STRUCTURE	INVERT	GRATE	STORMCEPTOR MODEL
ISTC2	188.83	190.31	STC 300
ISTC3	188.32	189.77	STC 300
ISTC4	187.59	189.04	STC 300
ISTC5	188.21	189.66	STC 300
ISTC6	186.60	188.05	STC 300



LEGEND

●	PROPOSED SANITARY MANHOLE
○	PROPOSED STORM MANHOLE
◉	PROPOSED FDC MANHOLE
□	PROPOSED CATCHBASIN
□□	PROPOSED CATCHBASIN
⊗	PROPOSED VALVE & CHAMBER
⋈	PROPOSED VALVE & BOX
⌖	PROPOSED HYDRANT & VALVE
●	EXISTING SANITARY MANHOLE
◌	EXISTING STORM MANHOLE
⬚ EX.CB.	EXISTING CATCHBASIN
⊗ EX.V&C	EXISTING VALVE & CHAMBER
⌖ EX.H&V	EXISTING HYDRANT & VALVE
34	PROPOSED LOT NUMBERS
	WATERBOX LOCATIONS
	PROPOSED DRIVEWAY LOCATION
	125mm SANITARY SERVICE CONNECTION (TYP.)
	FDC SERVICE CONNECTION (TYP.)
▨ ▨ ▨	LIMIT OF SUBDIVISION
	RAIN GARDEN AND CURB CUT SEE SHEET DE-03 FOR DETAIL
▬ ▬ ▬	ACOUSTIC FENCE
▬ ▪ ▬	WOOD PRIVACY FENCE
–●–●–●–	METAL FENCE
–✕–✕–✕–	CHAIN LINK FENCE
–□–□–□–	P&W FENCE
○●	STREET LIGHTS
▣ MB	MAIL BOX
◪	HYDRO TRANSFORMER
◩	TV PEDESTAL
*	ENGINEERED FILL LOTS
├──┤	UTILITY DUCT

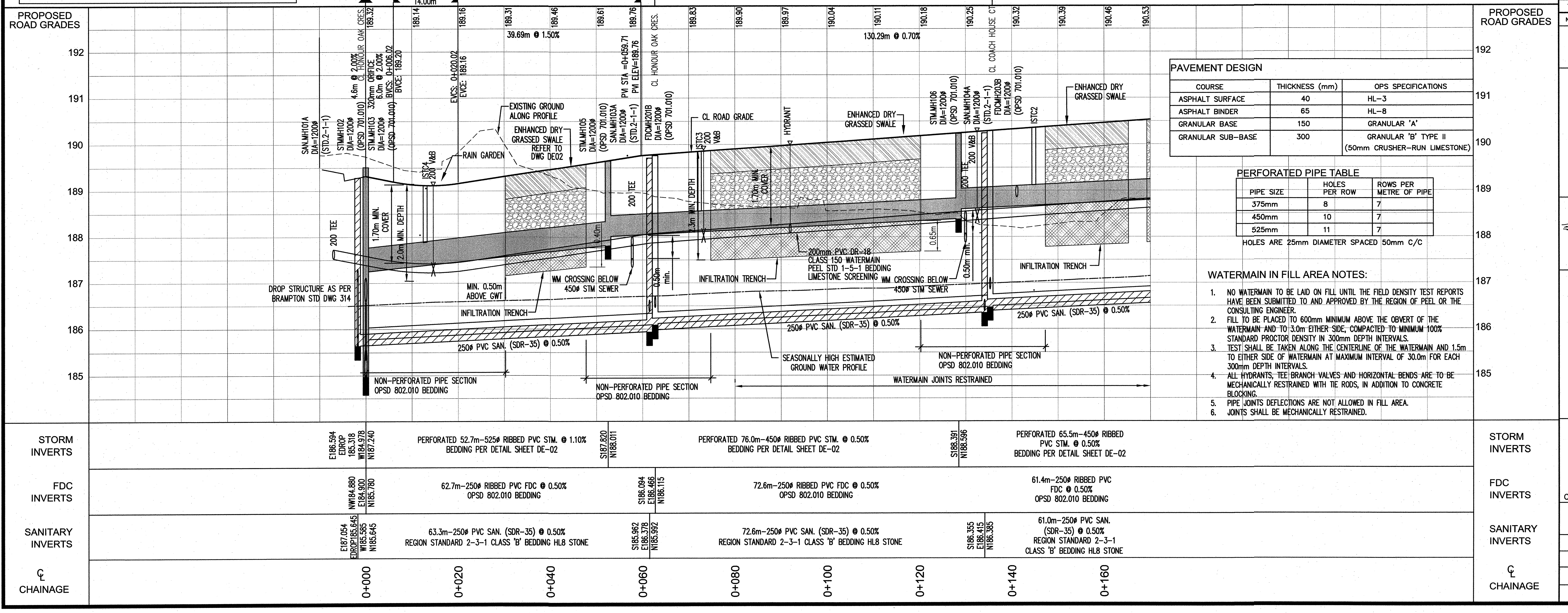
No.	REVISIONS	Date	By	Approved
5.	MYLAR SUBMISSION	APR. 2012	D.A.	
4.	FINAL SUBMISSION–ABOVE GROUND WORKS	JAN. 2012	D.A.	
3.	FINAL SUBMISSION–PRE SERVICING	NOV. 2011	D.A.	
2.	SECOND SUBMISSION	AUG. 2011	C.E.	
1.	FIRST SUBMISSION	APR. 2011	C.E.	

BENCHMARK NOTE
ELEVATIONS SHOWN HEREON ARE GEODETIC AND ARE REFERRED TO THE CITY OF BRAMPTON BENCHMARK 042050238 HAVING AN ELEVATION OF 190.177 METRES AND IS A BRASS CAP LOCATED 23.70 METRES SOUTH OF CENTRELINE OF STEELES AVENUE AND 20.70 METRES WEST OF CENTRELINE OF FINANCIAL DRIVE

April 12/12

Designed By:

Approved By P. Eng.



PAVEMENT DESIGN

COURSE	THICKNESS (mm)	OPS SPECIFICATIONS
ASPHALT SURFACE	40	HL–3
ASPHALT BINDER	65	HL–8
GRANULAR BASE	150	GRANULAR 'A'
GRANULAR SUB–BASE	300	GRANULAR 'B' TYPE II (50mm CRUSHER–RUN LIMESTONE)

PERFORATED PIPE TABLE

PIPE SIZE	HOLES PER ROW	ROWS PER METRE OF PIPE
375mm	8	7
450mm	10	7
525mm	11	7

HOLES ARE 25mm DIAMETER SPACED 50mm C/C

WATERMAIN IN FILL AREA NOTES:

1. NO WATERMAIN TO BE LAID ON FILL UNTIL THE FIELD DENSITY TEST REPORTS HAVE BEEN SUBMITTED TO AND APPROVED BY THE REGION OF PEEL OR THE CONSULTING ENGINEER.
2. FILL TO BE PLACED TO 600mm MINIMUM ABOVE THE OBVERT OF THE WATERMAIN AND TO 3.0m EITHER SIDE, COMPACTED TO MINIMUM 100% STANDARD PROCTOR DENSITY IN 300mm DEPTH INTERVALS.
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5. PIPE JOINTS DEFLECTIONS ARE NOT ALLOWED IN FILL AREA.
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The MUNICIPAL INFRASTRUCTURE Group
8800 Dufferin Street, Suite 200
Vaughan, ON L4K 0C5
Tel. 905-738-5700 Fax 905-738-0065

Region of Peel
Working for you

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BRAMPTON.CA
Brampton
PLANNING, DESIGN & DEVELOPMENT
ENGINEERING & DEVELOPMENT SERVICES, MICHAEL WON, P.ENG., DIRECTOR

WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON

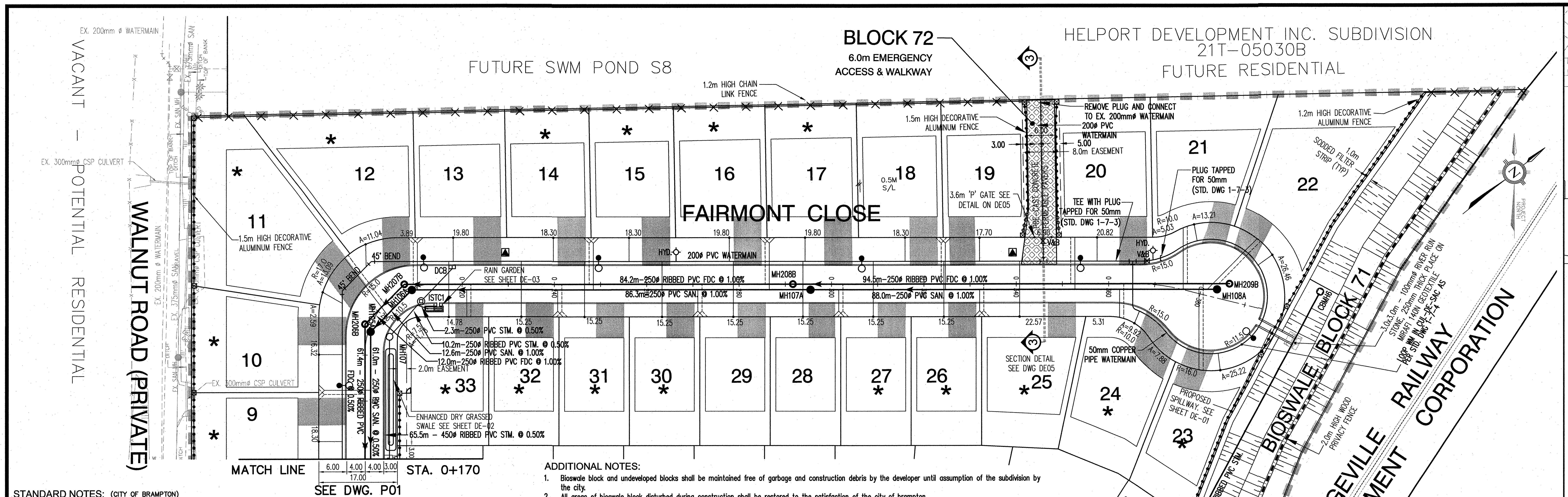
FAIRMONT CLOSE

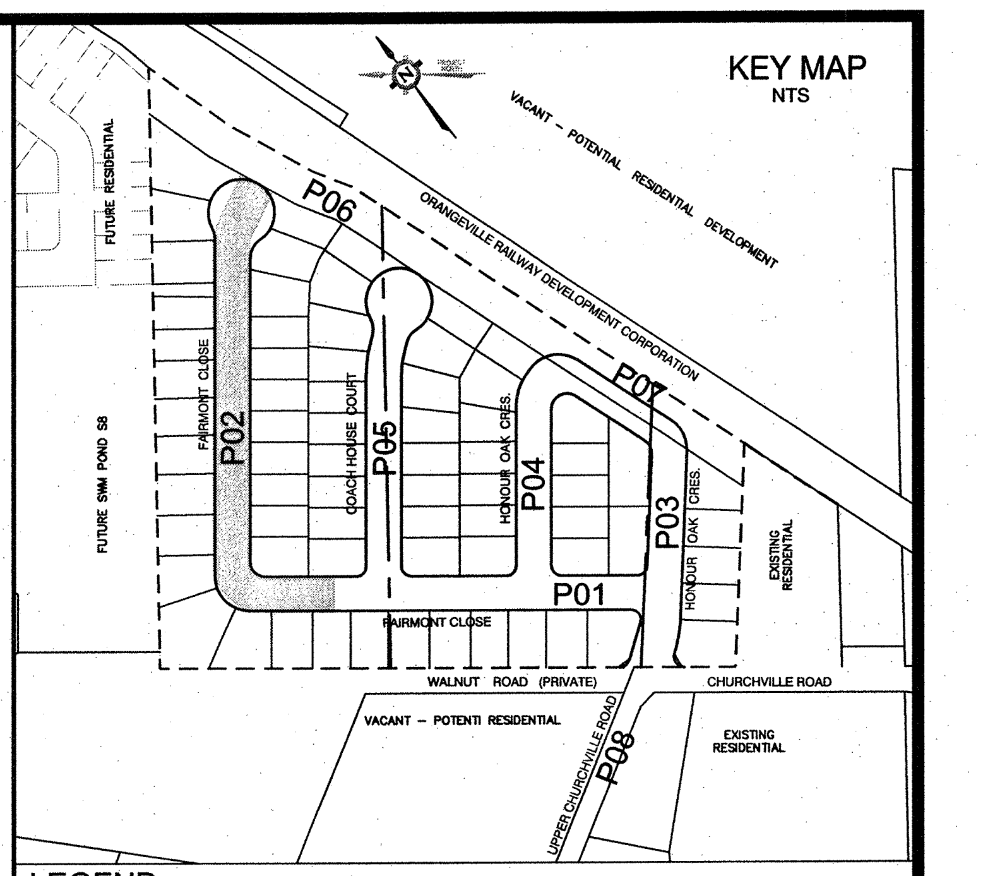
PLAN & PROFILE
STA. 0+000 TO STA. 0+170

CITY FILE # C03W02.005
REGION FILE # 21T–10010B

Scale:	HORIZ. 1:500 VERT. 1:50
Drawn By:	CAD
Designed By:	A.M.
Checked By:	C.E.
Date:	JAN 2011
Project No.	10101
Drawing No.	P01

File : G:\Projects\2010\10101 - Walnut Grove\Drawings\Plan & Profiles\PP01.dwg, Layout : PP01 Date :Apr 12, 2012 - 4:45pm, Edit By : rstone





LEGEND

● PROPOSED SANITARY MANHOLE
○ PROPOSED STORM MANHOLE
◎ PROPOSED FDC MANHOLE
☐ PROPOSED CATCHBASIN
◫ PROPOSED CATCHBASIN
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RAIN GARDEN AND CURB CUT SEE SHEET DE-03 FOR DETAIL
ACOUSTIC FENCE
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UTILITY DUCT

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c. All sewers shall be constructed with bedding in accordance with City of Brampton Standard Drawing 348 unless otherwise noted.
d. Plastic sewer pipes shall be constructed with Ultra Rib or approved equal up to the maximum diameter of 600mm.
e. No PVC pipe shall be used on arterial and parkway roadways.
f. Single catchbasin leads to be 200mm unless otherwise noted. Double catchbasin leads to be 250mm unless otherwise noted. All catchbasin leads to be either C-14-ES minimum or P.V.C. type S.D.R. 28.
g. All backfill for sewers, watermains and utilities on the road allowance must be mechanically compacted to 95% Standard Proctor Density except for top 0.3m which must be compacted to 98%.
h. All trench cuts through asphalt will be repaired with a minimum of 1.0m beyond the edge of the full cut depth.
i. An asphalt preservative sealer such as Re-clamite (or other approved equivalent) shall be applied after the one-year maintenance period for the top course asphalt.
j. The City of Brampton Traffic Services Department shall be notified 48 hours prior to the installation of any traffic signal underground plants and a representative of the City's traffic signals department shall mark the underground plant and handwell locations in the fields with the consulting engineer/contractor
k. All intersections have one utility duct on the leg of each street. Each duct shall be located 2.5m from the BC / EC and shall extend 0.5m behind the back of curb. Both ends of the utility duct shall be capped. The ducts shall be 100mm in diameter made of CSA certified Type 2 PVC. The minimum trench width of the duct shall be 300mm with 100mm sand bedding and backfill around the duct. Native backfill can be used from the sand backfill up to the granular sub-base. The duct shall have a minimum cover of 1.5 meters.
l. No limestone permitted as bedding for weeping tile and under basement slab if FDC proposed

ADDITIONAL NOTES:

1. Bioswale block and undeveloped blocks shall be maintained free of garbage and construction debris by the developer until assumption of the subdivision by the city.
2. All areas of bioswale block disturbed during construction shall be restored to the satisfaction of the city of brampton.
3. Bioswale block and undeveloped blocks shall not be used for the purpose of stockpiling or for the placement of construction trailers.
4. When the temporary turning circle easement is eliminated, remove existing asphalt and granular base material (where required) and restore to a standard road cross-section to the satisfaction of the city of brampton.
5. No rear yard gates are permitted from residential lots to bioswale block or walnut rd.
6. Any erosion experienced along the channel slopes throughout the construction and warranty period of this development shall be corrected by the developer to the satisfaction of the planning, design and development department.
7. When the temporary emergency access is closed, the asphalt and the granular material is to be removed and the area is to be restored to the satisfaction of the city of brampton. continuation of the fence is to be included with this work.
8. All sound barriers must be of solid construction with a minimum face density of 20 kg/m2 (double check noise report) with no holes, gaps or cracks.
9. All blocks that are undeveloped within the subdivision are to be fine graded, topsoil and sodded unless otherwise noted. Developer to perform regularly scheduled maintenance on all undeveloped blocks.
10. All fences to be located 0.15m inside residential lot where abutting public land.

TEMPORARY DEAD END WATERMAIN

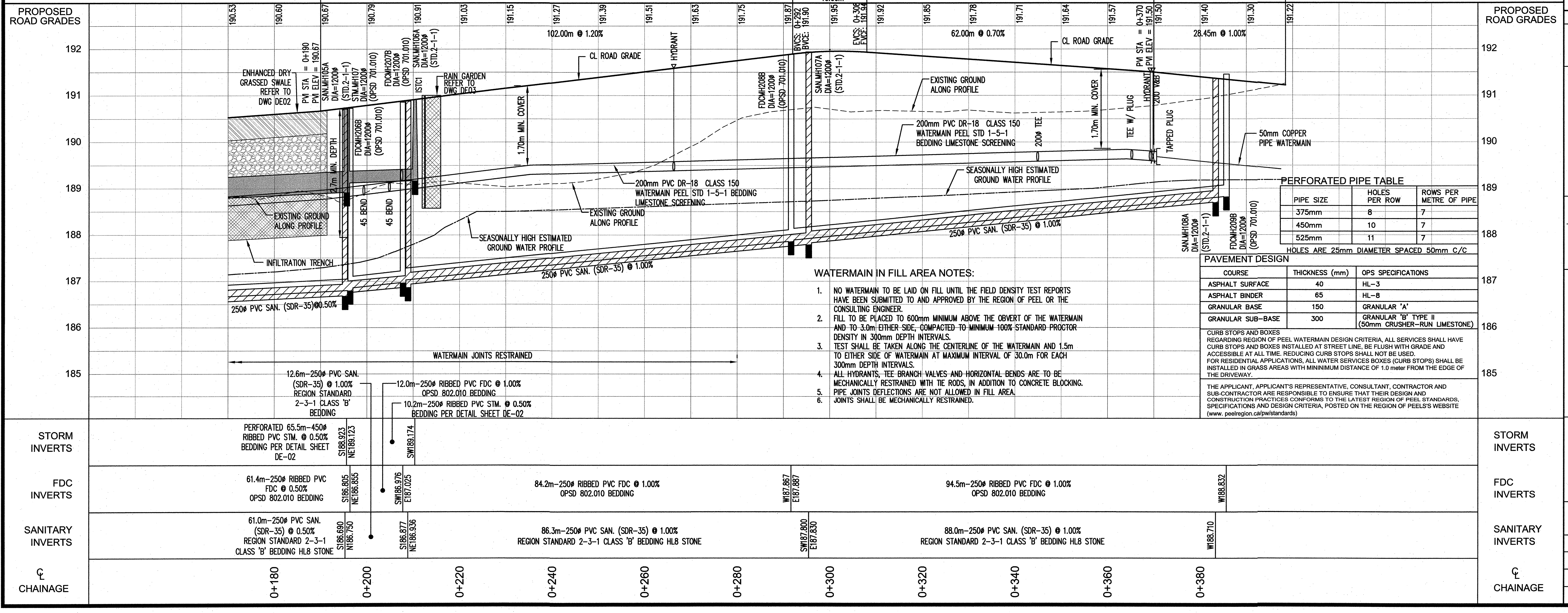
1. All dead-end 150mm diameter and larger watermains shall have a hydrant installed at their terminus instead of a blow-off for bleeding, charging and flushing of the main

WATERMAIN CONNECTION NOTES:

1. The minimum lateral distance between water services and other utilities shall be 1.2m.
2. All connections to pvc pipes to be made using an approved wide band service saddle. Direct tapping is not allowed.
3. All water service connections are 19mm.

OIL-GRIT SEPERATORS

STRUCTURE	INVERT	GRATE	STORMCEPTOR MODEL
ISTC1	189.18	190.87	STC 300



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PERFORATED PIPE TABLE

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375mm	8	7
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HOLES ARE 25mm DIAMETER SPACED 50mm C/C

PAVEMENT DESIGN

COURSE	THICKNESS (mm)	OPS SPECIFICATIONS
ASPHALT SURFACE	40	HL-3
ASPHALT BINDER	65	HL-8
GRANULAR BASE	150	GRANULAR 'A'
GRANULAR SUB-BASE	300	GRANULAR 'B' TYPE II (50mm CRUSHER-RUN LIMESTONE)

CURB STOPS AND BOXES
REGARDING REGION OF PEEL WATERMAIN DESIGN CRITERIA, ALL SERVICES SHALL HAVE CURB STOPS AND BOXES INSTALLED AT STREET LINE, BE FLUSH WITH GRADE AND ACCESSIBLE AT ALL TIME. REDUCING CURB STOPS SHALL NOT BE USED.
FOR RESIDENTIAL APPLICATIONS, ALL WATER SERVICES BOXES (CURB STOPS) SHALL BE INSTALLED IN GRASS AREAS WITH MININIMUM DISTANCE OF 1.0 meter FROM THE EDGE OF THE DRIVEWAY.

THE APPLICANT, APPLICANT'S REPRESENTATIVE, CONSULTANT, CONTRACTOR AND SUB-CONTRACTOR ARE RESPONSIBLE TO ENSURE THAT THEIR DESIGN AND CONSTRUCTION PRACTICES CONFORMS TO THE LATEST REGION OF PEEL STANDARDS, SPECIFICATIONS AND DESIGN CRITERIA, POSTED ON THE REGION OF PEELS'S WEBSITE (www. peelregion.ca/pw/standards)

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LICENSED PROFESSIONAL ENGINEER
PROVINCE OF ONTARIO
April 12/12

Designed By:

Approved By P. Eng.

The MUNICIPAL INFRASTRUCTURE Group
8800 Dufferin Street, Suite 200
Vaughan, ON L4K 0C5
Tel. 905-738-5700 Fax 905-738-0065

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WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON

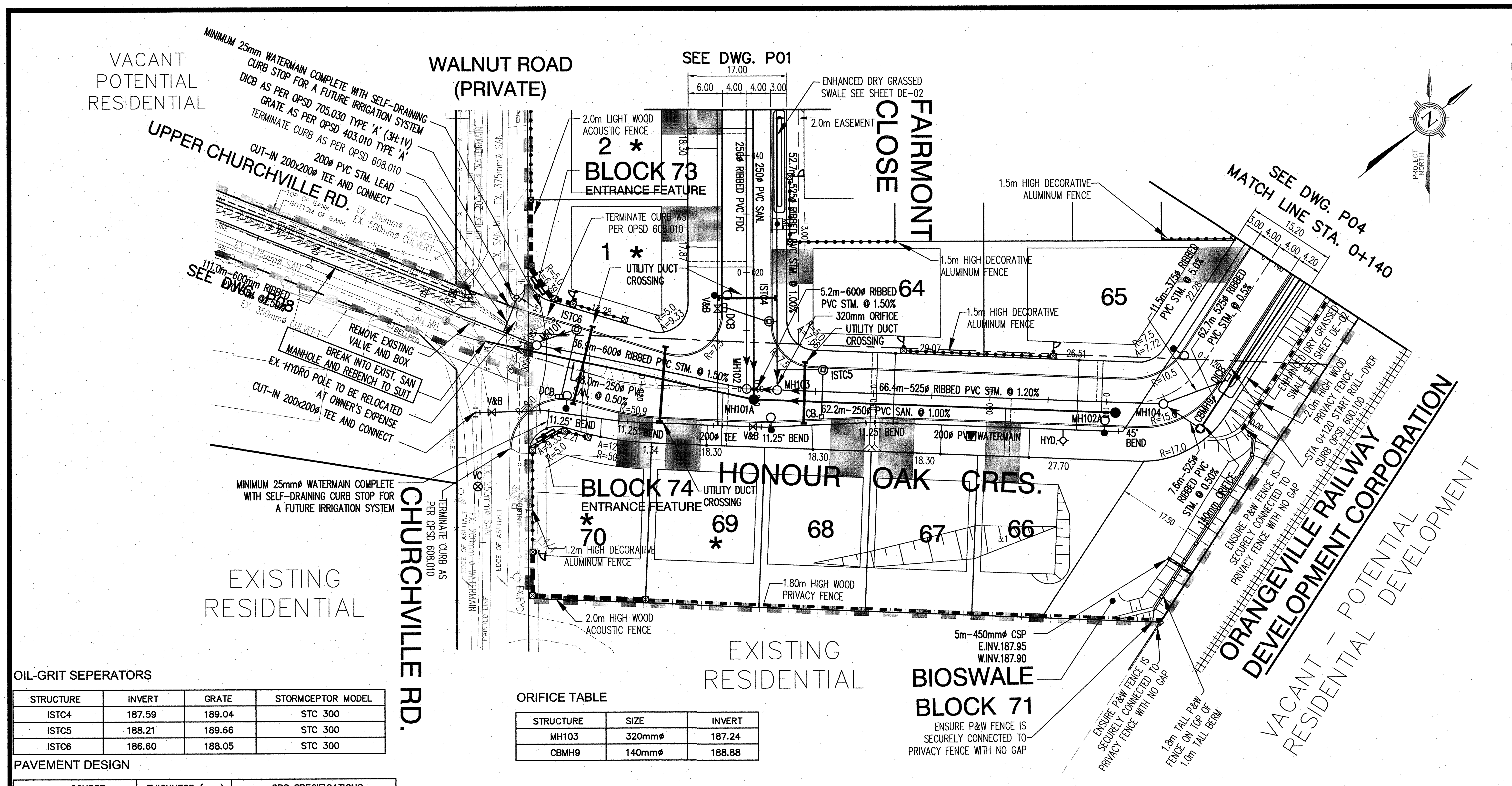
FAIRMONT CLOSE

PLAN & PROFILE
STA. 0+170 TO STA. 0+398.45

CITY FILE # C03W02.005
REGION FILE # 21T-10010B

Scale: HORIZ. 1:500 VERT. 1:50
Drawn By: CAD
Designed By: A.M.
Checked By: C.E.
Date: JAN 2011
Project No. 10101
Drawing No. P02

File : G:\Projects\2010\10101 - Walnut Grove\Drawings\Plan & Profiles\PP02.dwg, Layout : PP02 Date : Apr 12, 2012 - 4:58pm, Edit By : rstone



OIL-GRIT SEPERATORS

STRUCTURE	INVERT	GRATE	STORMCEPTOR MODEL
ISTC4	187.59	189.04	STC 300
ISTC5	188.21	189.66	STC 300
ISTC6	186.60	188.05	STC 300

PAVEMENT DESIGN

COURSE	THICKNESS (mm)	OPS SPECIFICATIONS
ASPHALT SURFACE	40	HL–3
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GRANULAR BASE	150	GRANULAR 'A'
GRANULAR SUB–BASE	300	GRANULAR 'B' TYPE II (50mm CRUSHER–RUN LIMESTONE)

ORIFICE TABLE

STRUCTURE	SIZE	INVERT
MH103	320mmø	187.24
CBMH9	140mmø	188.88

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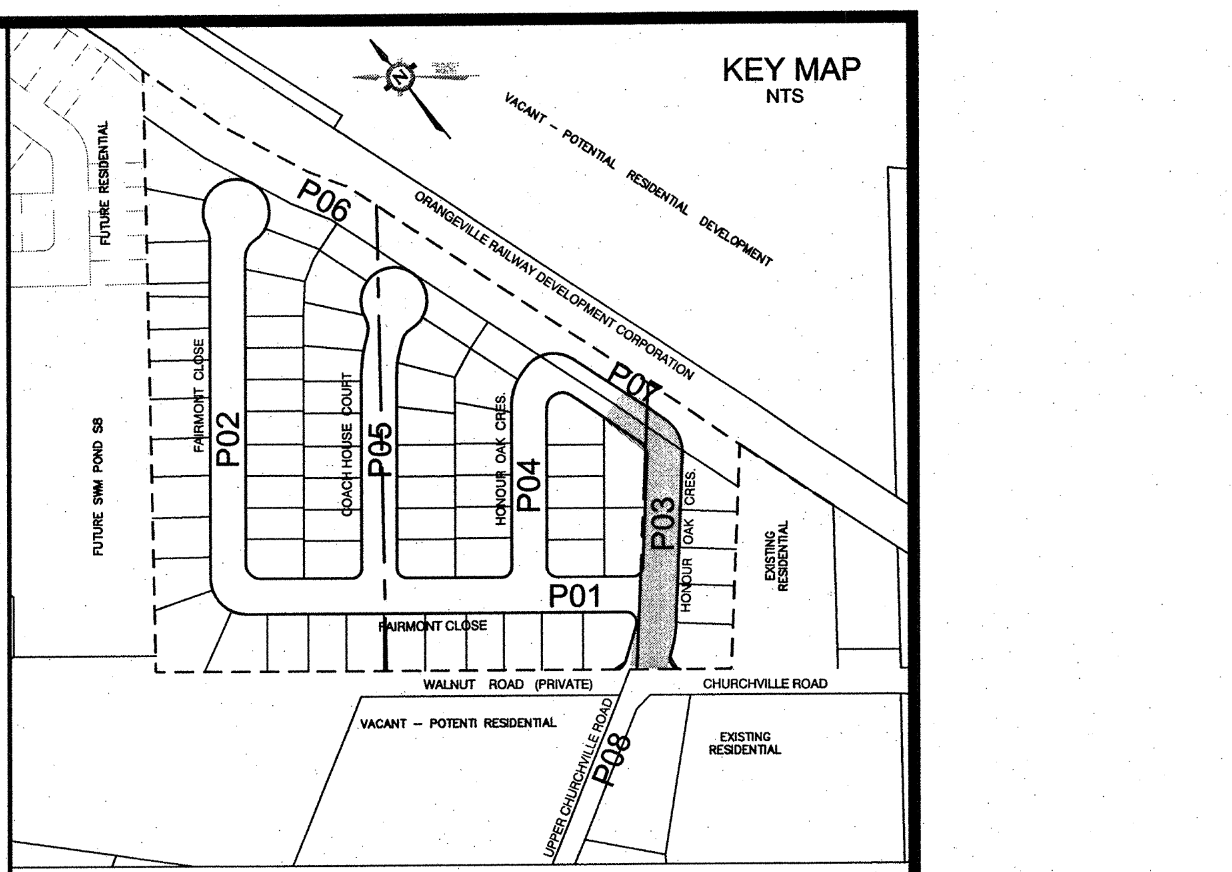
KEY MAP
NTS



LEGEND

●	PROPOSED SANITARY MANHOLE
○	PROPOSED STORM MANHOLE
◉	PROPOSED FDC MANHOLE
☐	PROPOSED CATCHBASIN
◫	PROPOSED CATCHBASIN
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	125mm SANITARY SERVICE CONNECTION (TYP.)
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▬ ▬ ▬	ACOUSTIC FENCE
▬ · ▬ · ▬	WOOD PRIVACY FENCE
–●–●–●–	METAL FENCE
–×–×–×–	CHAIN LINK FENCE
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April 12/12

P. Eng.

Designed By:

Approved By

The MUNICIPAL INFRASTRUCTURE Group
8800 Dufferin Street, Suite 200
Vaughan, ON L4K 0C5
Tel. 905-738-5700 Fax 905-738-0065

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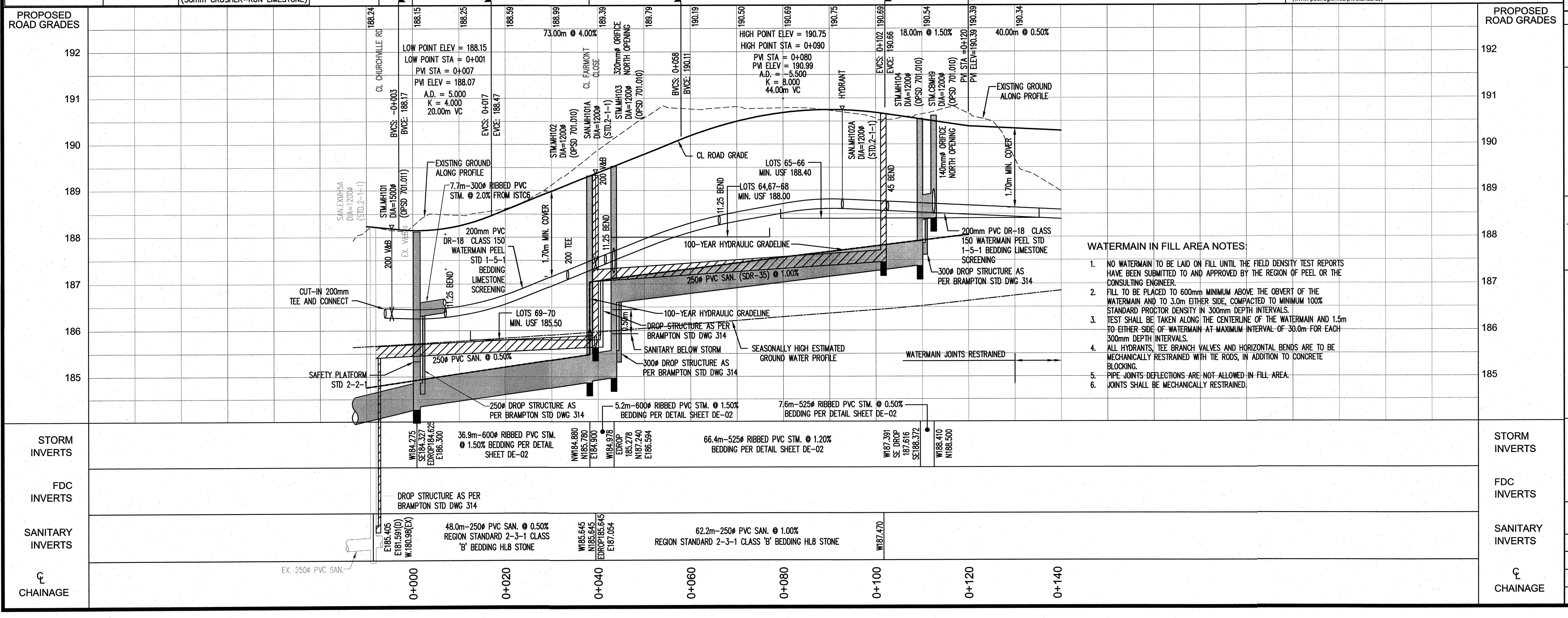

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WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON

HONOUR OAK CRESCENT

PLAN & PROFILE
STA. 0+000 TO STA. 0+140

CITY FILE # C03W02.005
REGION FILE # 21T–10010B

Scale:	HORIZ. 1:500 VERT. 1:50	Project No. 10101
Drawn By:	CAD	
Designed By:	A.M.	Drawing No. P03
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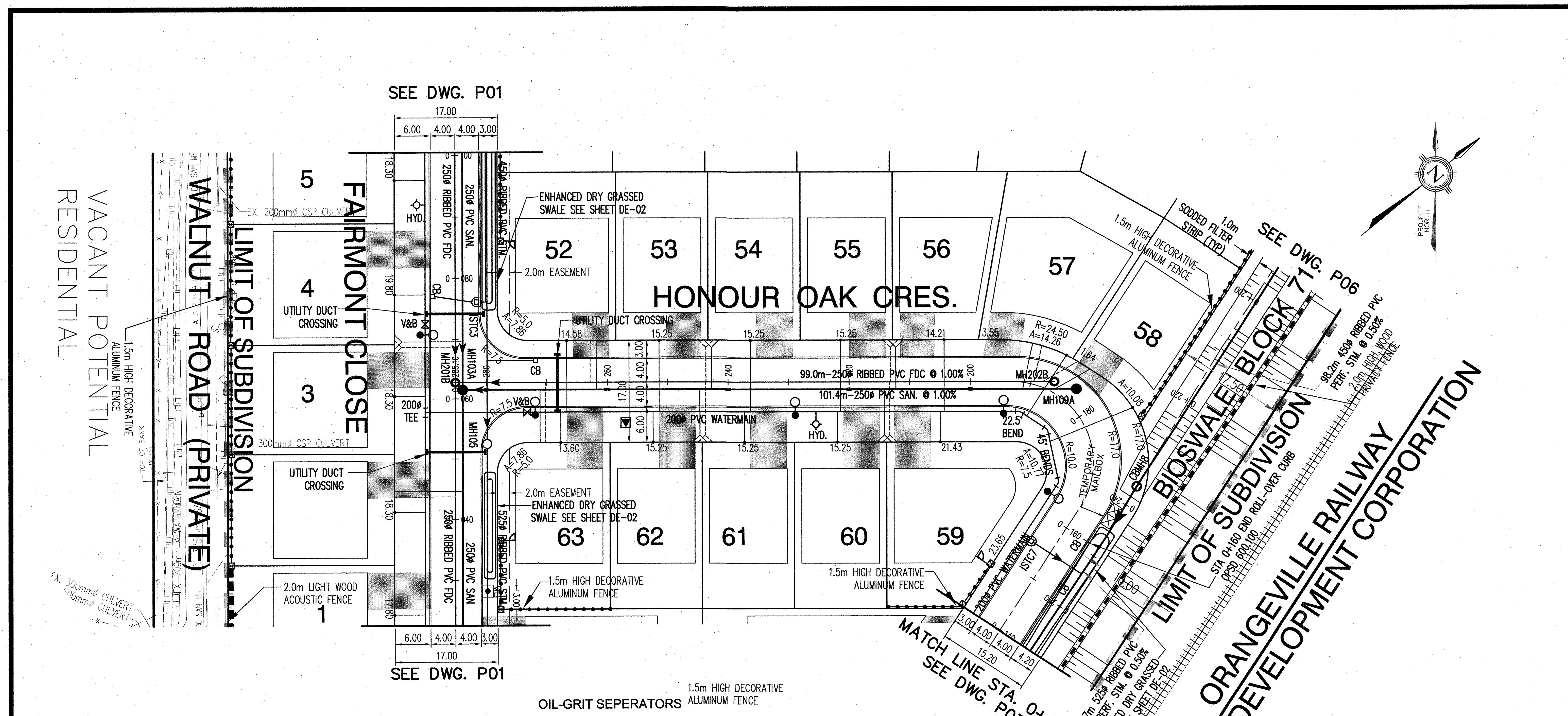

OIL-GRIT SEPERATORS

STRUCTURE	INVERT	GRATE	STORMCEPTOR MODEL
ISTC3	188.32	189.77	STC 300
ISTC7	188.95	190.15	STC 300

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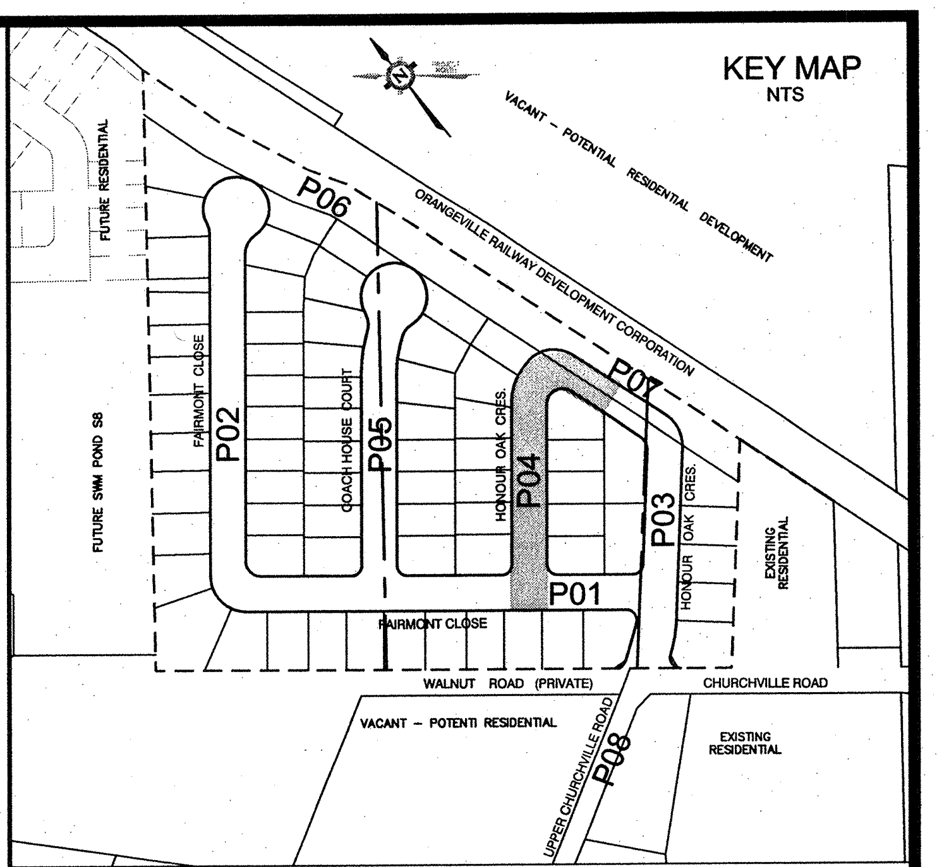
KEY MAP

NTS



LEGEND

●	PROPOSED SANITARY MANHOLE
○	PROPOSED STORM MANHOLE
◎	PROPOSED FDC MANHOLE
□	PROPOSED CATCHBASIN
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April 12/12
R. P. ASHFIELD
LICENSED PROFESSIONAL ENGINEER
PROVINCE OF ONTARIO

Designed By:

Approved By P. Eng.

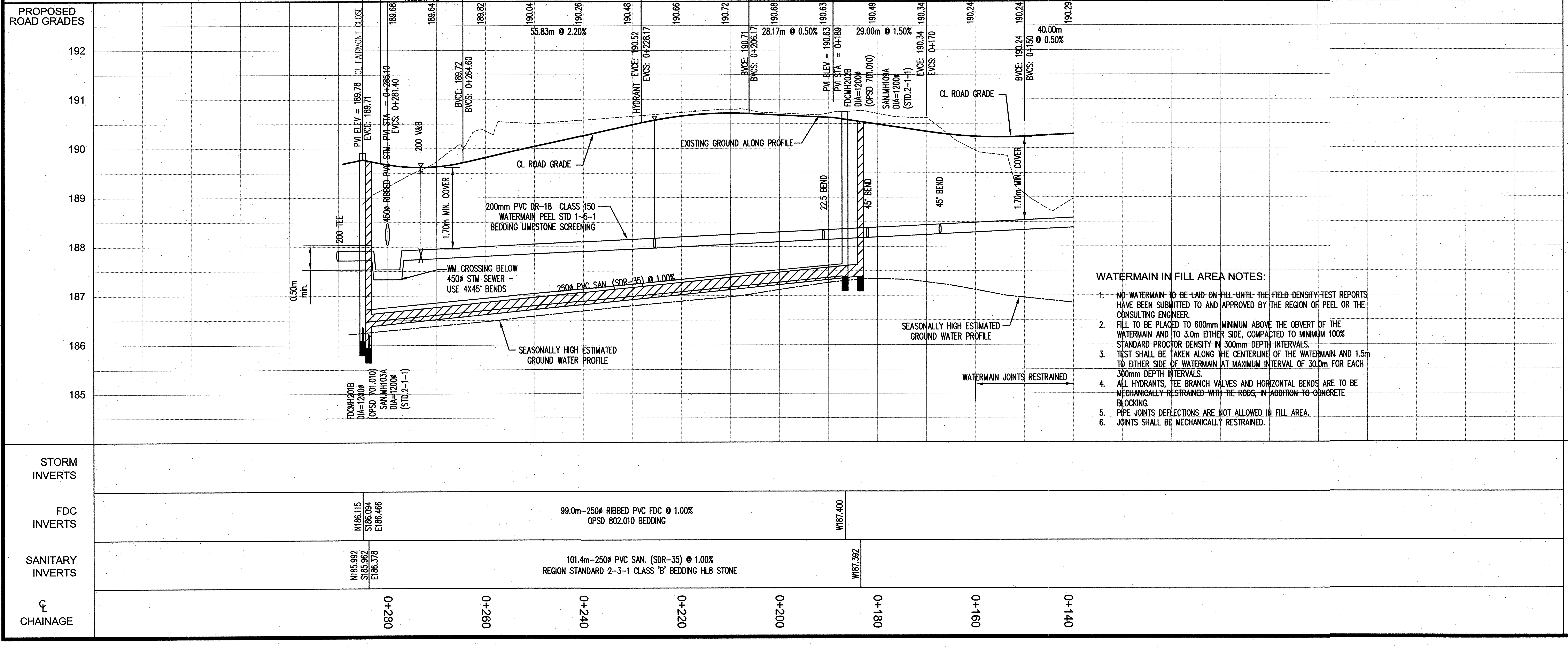
PAVEMENT DESIGN

COURSE	THICKNESS (mm)	OPS SPECIFICATIONS
ASPHALT SURFACE	40	HL-3
ASPHALT BINDER	65	HL-8
GRANULAR BASE	150	GRANULAR 'A'
GRANULAR SUB-BASE	300	GRANULAR 'B' TYPE II (50mm CRUSHER-RUN LIMESTONE)

LOW POINT ELEV = 189.63
LOW POINT STA = 0+273.40
PVI STA = 0+273
PVI ELEV = 189.54
A.D. = 4.200
K = 4.000
16.80m VC

HIGH POINT ELEV = 190.72
HIGH POINT STA = 0+210.25
PVI STA = 0+217.17
PVI ELEV = 190.77
A.D. = -2.700
K = 8.148
22.00m VC

LOW POINT ELEV = 190.23
LOW POINT STA = 0+155
PVI STA = 0+160
PVI ELEV = 190.19
A.D. = 2.000
K = 10.000
20.00m VC



WATERMAIN IN FILL AREA NOTES:

1. NO WATERMAIN TO BE LAID ON FILL UNTIL THE FIELD DENSITY TEST REPORTS HAVE BEEN SUBMITTED TO AND APPROVED BY THE REGION OF PEEL OR THE CONSULTING ENGINEER.
2. FILL TO BE PLACED TO 600mm MINIMUM ABOVE THE OBVERT OF THE WATERMAIN AND TO 3.0m EITHER SIDE, COMPACTED TO MINIMUM 100% STANDARD PROCTOR DENSITY IN 300mm DEPTH INTERVALS.
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4. ALL HYDRANTS, TEE BRANCH VALVES AND HORIZONTAL BENDS ARE TO BE MECHANICALLY RESTRAINED WITH TIE RODS, IN ADDITION TO CONCRETE BLOCKING.
5. PIPE JOINTS DEFLECTIONS ARE NOT ALLOWED IN FILL AREA.
6. JOINTS SHALL BE MECHANICALLY RESTRAINED.

The MUNICIPAL
INFRASTRUCTURE Group
8800 Dufferin Street, Suite 200
Vaughan, ON L4K 0C5
Tel. 905-738-5700 Fax 905-738-0065

Region of Peel
Working for you

FLOWER CITY
BRAMPTON.CA
Brampton
PLANNING, DESIGN & DEVELOPMENT
ENGINEERING & DEVELOPMENT SERVICES, MICHAEL WON, P.ENG., DIRECTOR

WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON
HONOUR OAK CRESCENT
PLAN & PROFILE
STA. 0+140 TO STA. 0+277.984

CITY FILE # C03W02.005
REGION FILE # 21T-10010B

Scale: HORIZ. 1:500 VERT. 1:50	Project No. 10101
Drawn By: CAD	
Designed By: A.M.	Drawing No. P04
Checked By: C.E.	
Date: JAN 2011	

STANDARD NOTES: (CITY OF BRAMPTON)

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d. Plastic sewer pipes shall be constructed with Ultra Rib or approved equal up to the maximum diameter of 600mm.
e. No PVC pipe shall be used on arterial and parkway roadways.
f. Single catchbasin leads to be 200mm unless otherwise noted. Double catchbasin leads to be 250mm unless otherwise noted. All catchbasin leads to be either C–14–ES minimum or P.V.C. type S.D.R. 28.
g. All backfill for sewers, watermains and utilities on the road allowance must be mechanically compacted to 95% Standard Proctor Density except for top 0.3m which must be compacted to 98%.
h. All trench cuts through asphalt will be repaired with a minimum of 1.0m beyond the edge of the full cut depth.
i. An asphalt preservative sealer such as Re–clamite (or other approved equivalent) shall be applied after the one–year maintenance period for the top course asphalt.
j. The City of Brampton Traffic Services Department shall be notified 48 hours prior to the installation of any traffic signal underground plants and a representative of the City's traffic signals department shall mark the underground plant and handwell locations in the fields with the consulting engineer/contractor
k. All intersections have one utility duct on the leg of each street. Each duct shall be located 2.5m from the BC / EC and shall extend 0.5m behind the back of curb. Both ends of the utility duct shall be capped. The ducts shall be 100mm in diameter made of CSA certified Type 2 PVC. The minimum trench width of the duct shall be 300mm with 100mm sand bedding and backfill around the duct. Native backfill can be used from the sand backfill up to the granular sub–base. The duct shall have a minimum cover of 1.5 meters.
l. No limestone permitted as bedding for weeping tile and under basement slab if FDC proposed.

ADDITIONAL NOTES:

1. Bioswale block and undeveloped blocks shall be maintained free of garbage and construction debris by the developer until assumption of the subdivision by the city.
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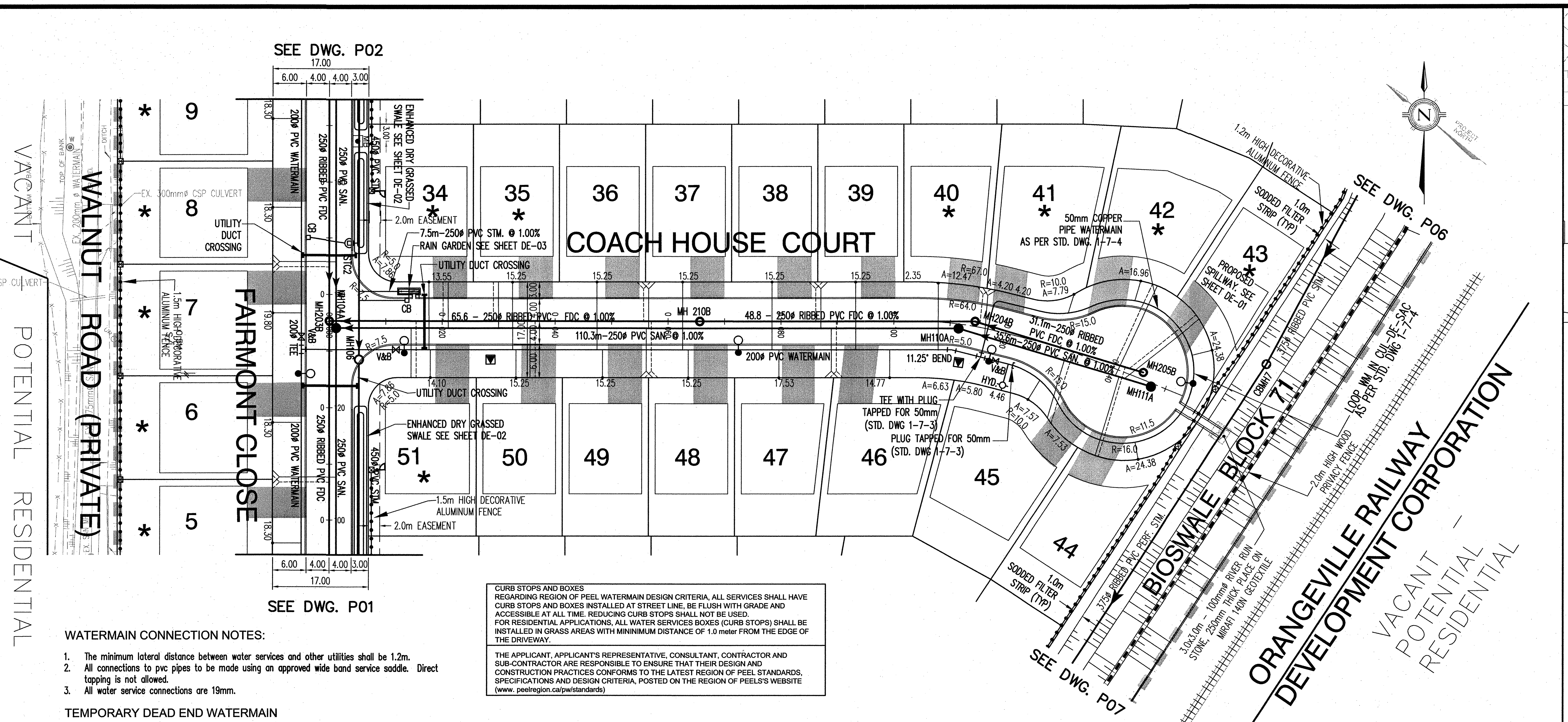

WATERMAIN CONNECTION NOTES:

1. The minimum lateral distance between water services and other utilities shall be 1.2m.
2. All connections to pvc pipes to be made using an approved wide band service saddle. Direct tapping is not allowed.
3. All water service connections are 19mm.

TEMPORARY DEAD END WATERMAIN

1. All dead–end 150mm diameter and larger watermains shall have a hydrant installed at their terminus instead of a blow–off for bleeding, charging and flushing of the main

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OIL-GRIT SEPERATORS

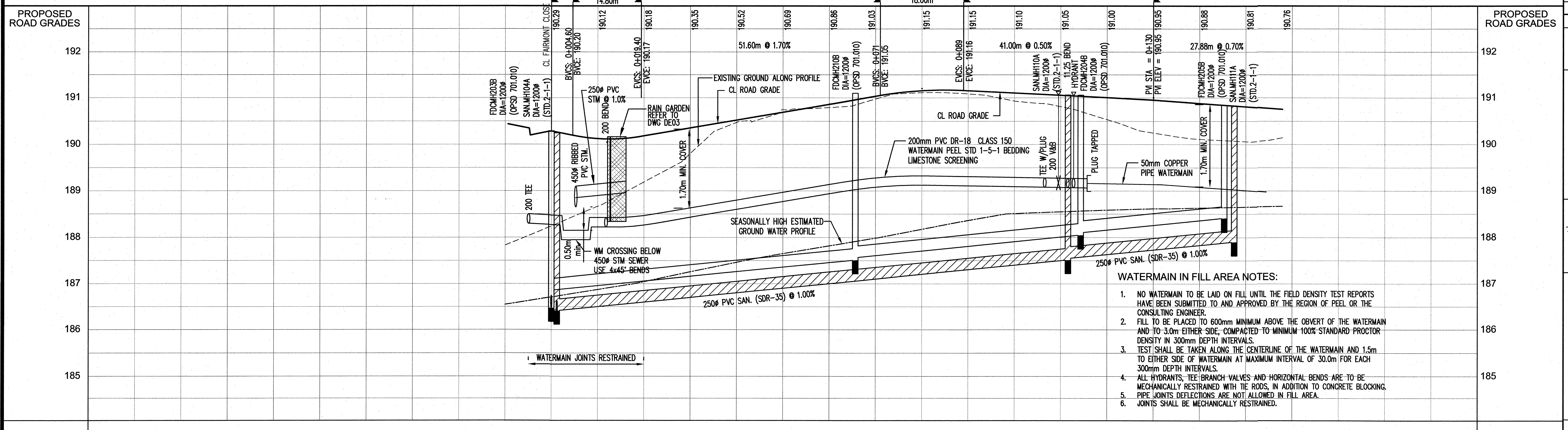
STRUCTURE	INVERT	GRATE	STORMCEPTOR MODEL
ISTC2	188.83	190.31	STC 300

PAVEMENT DESIGN

COURSE	THICKNESS (mm)	OPS SPECIFICATIONS
ASPHALT SURFACE	40	HL–3
ASPHALT BINDER	65	HL–8
GRANULAR BASE	150	GRANULAR 'A'
GRANULAR SUB–BASE	300	GRANULAR 'B' TYPE II (50mm CRUSHER–RUN LIMESTONE)

LOW POINT ELEV = 190.12
LOW POINT STA = 0+012.60
PVI STA = 0+012
PVI ELEV = 190.05
A.D. = 3.70
K = 4.00
14.80m

HIGH POINT ELEV = 191.17
HIGH POINT STA = 0+084.91
PVI STA = 0+080
PVI ELEV = 191.20
A.D. = –2.20
K = 8.18
18.00m



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STORM INVERTS

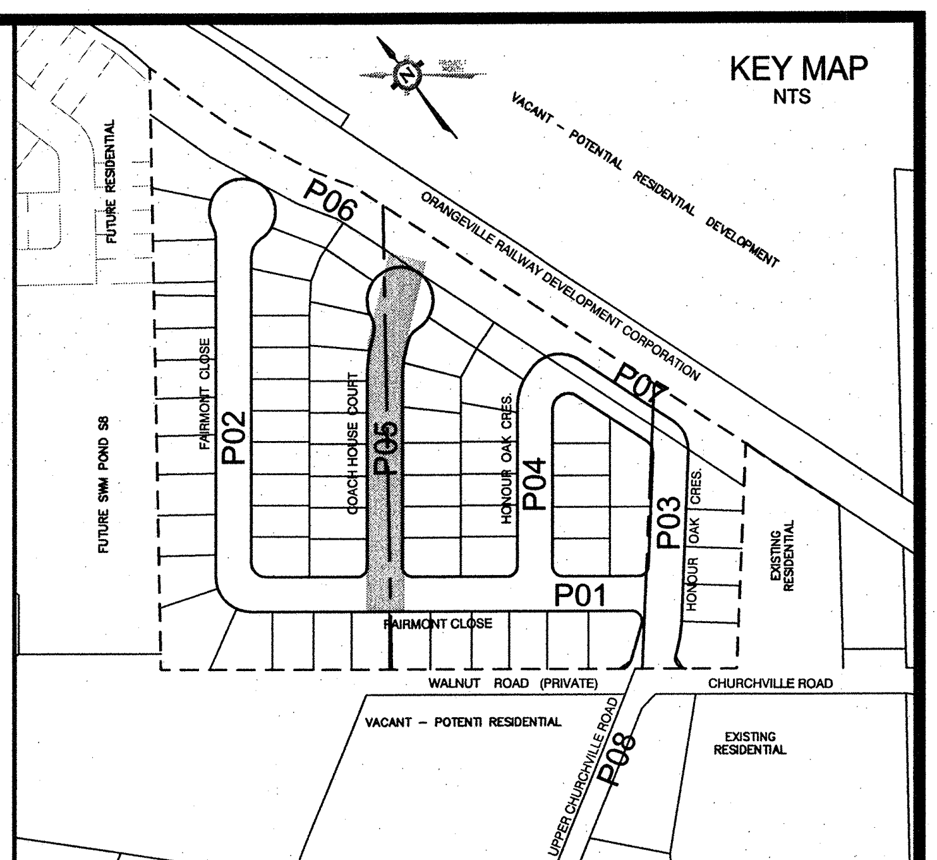
FDC INVERTS
N186.498 S186.478 E186.859 — 65.6m–250ø RIBBED PVC FDC @ 1.00% OPSD 802.010 BEDDING — W187.515 187.565 — 48.8m–250ø RIBBED PVC FDC @ 1.00% OPSD 802.010 BEDDING — W188.053 E188.103 — 31.1m–250ø RIBBED PVC FDC @ 1.00% OPSD 802.010 BEDDING — W188.414

SANITARY INVERTS
N186.385 S186.355 E186.415 — 110.3m–250ø PVC SAN. (SDR–35) @ 1.00% REGION STANDARD 2–3–1 CLASS 'B' BEDDING HL8 STONE — W187.518 SE187.548 — 35.6m–250ø PVC SAN. (SDR–35) @ 1.00% REGION STANDARD 2–3–1 CLASS 'B' BEDDING HL8 STONE — NW187.905

℄ CHAINAGE
0+000 0+020 0+040 0+060 0+080 0+100 0+120 0+140

File : G:\Projects\2010\10101 - Walnut Grove\Drawings\Plan & Profiles\PP05.dwg,   Layout : PP05   Date :Apr 12, 2012 - 4:59pm,   Edit By : rstone

KEY MAP
NTS



LEGEND

●	PROPOSED SANITARY MANHOLE
○	PROPOSED STORM MANHOLE
◉	PROPOSED FDC MANHOLE
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◫	PROPOSED CATCHBASIN
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April 12/12
D.F. ASHFIELD

Designed By:

Approved By
P. Eng.

The MUNICIPAL INFRASTRUCTURE Group Ltd.
The MUNICIPAL
INFRASTRUCTURE Group
8800 Dufferin Street, Suite 200
Vaughan, ON L4K 0C5
Tel. 905-738-5700 Fax 905-738-0065

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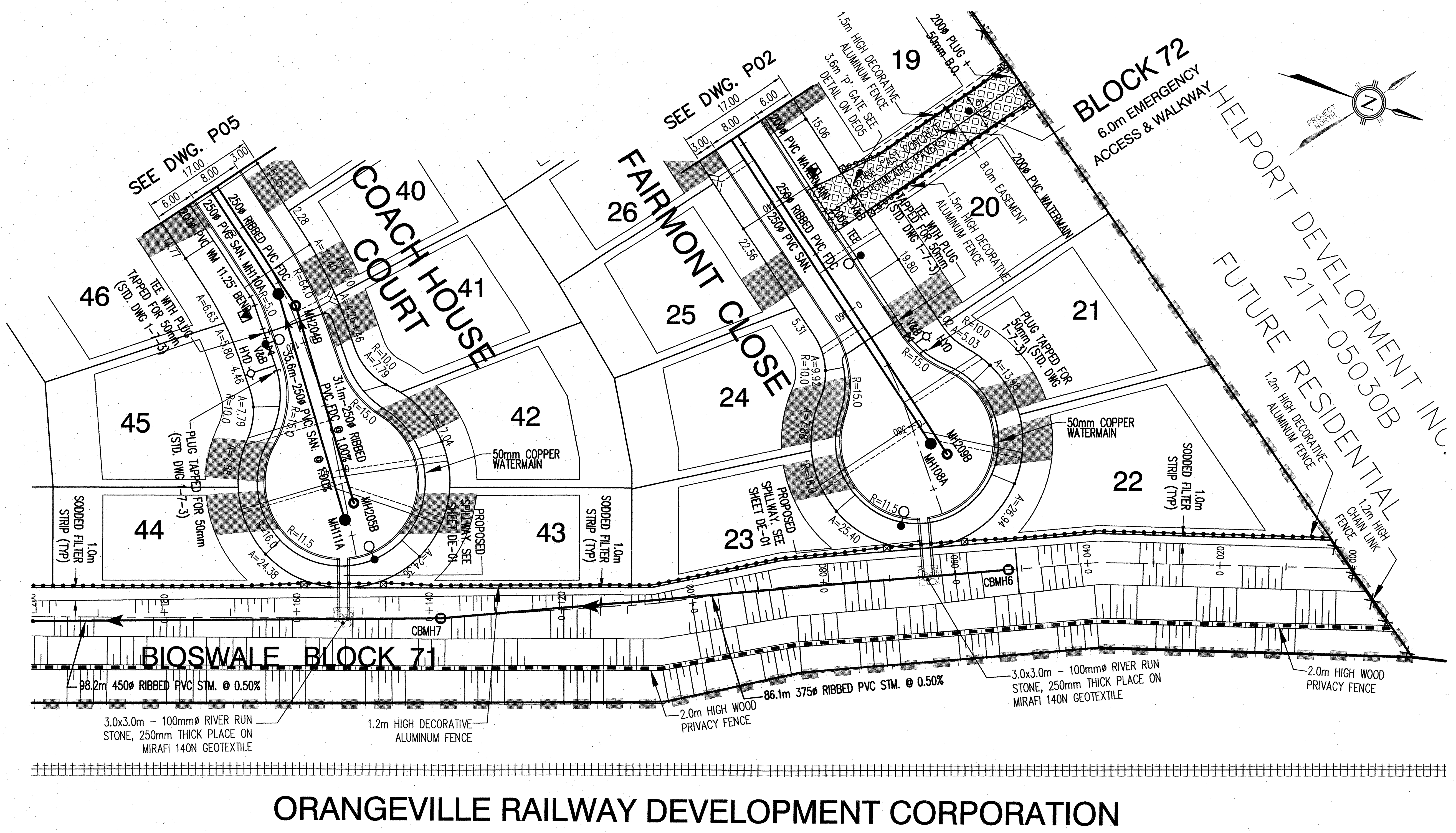
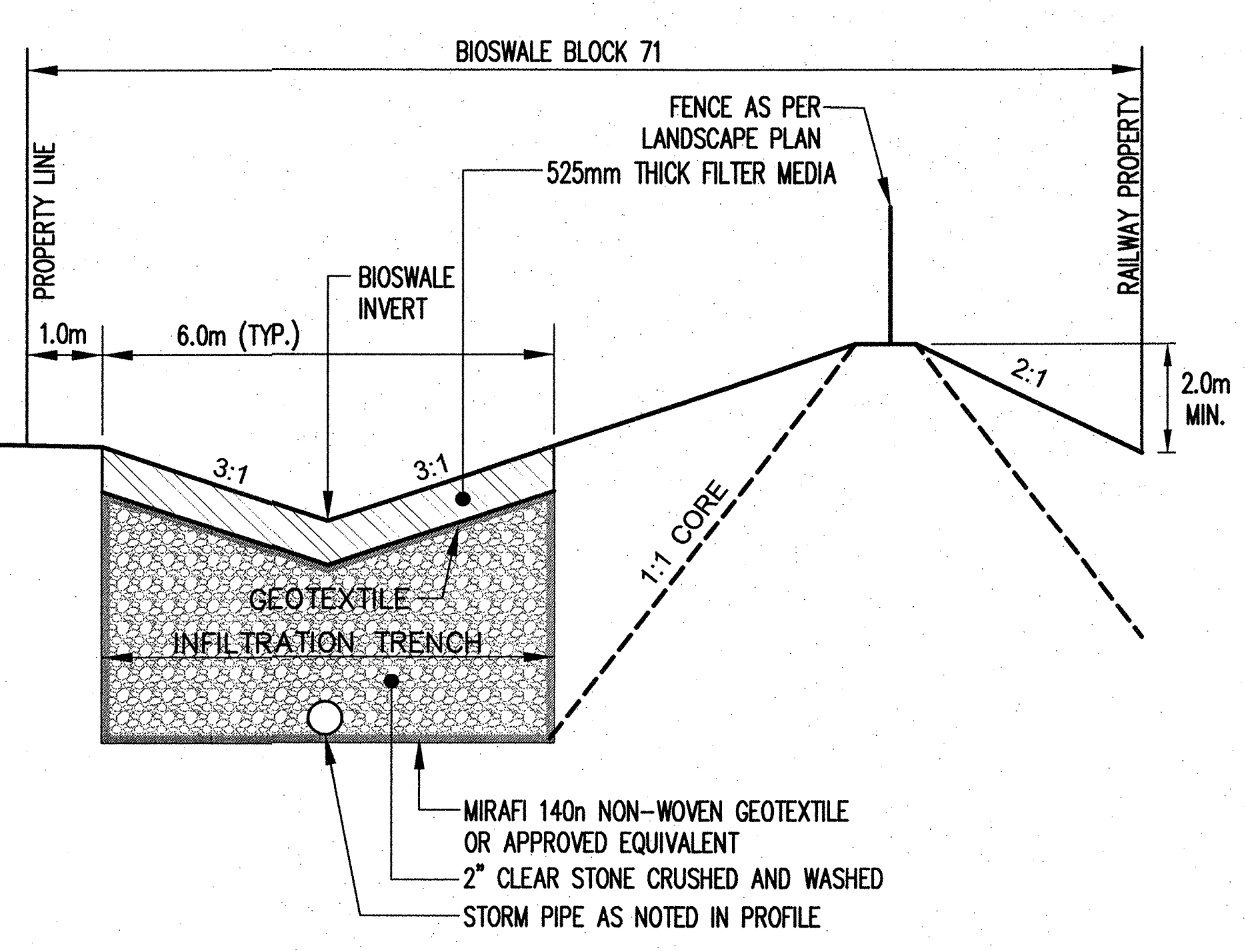
Brampton
PLANNING, DESIGN & DEVELOPMENT
ENGINEERING & DEVELOPMENT SERVICES, MICHAEL WON, P.ENG., DIRECTOR

WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON
COACH HOUSE COURT
PLAN & PROFILE
STA. 0+000 TO STA. 0+157.87
CITY FILE # C03W02.005 REGION FILE # 21T–10010B

Scale: HORIZ. 1:500 VERT. 1:50
Drawn By: CAD
Designed By: A.M.
Checked By: C.E.
Date: JAN 2011
Project No. 10101
Drawing No. P05





TYPICAL BIOSWALE/RAIL BERM SECTION

NOT TO SCALE

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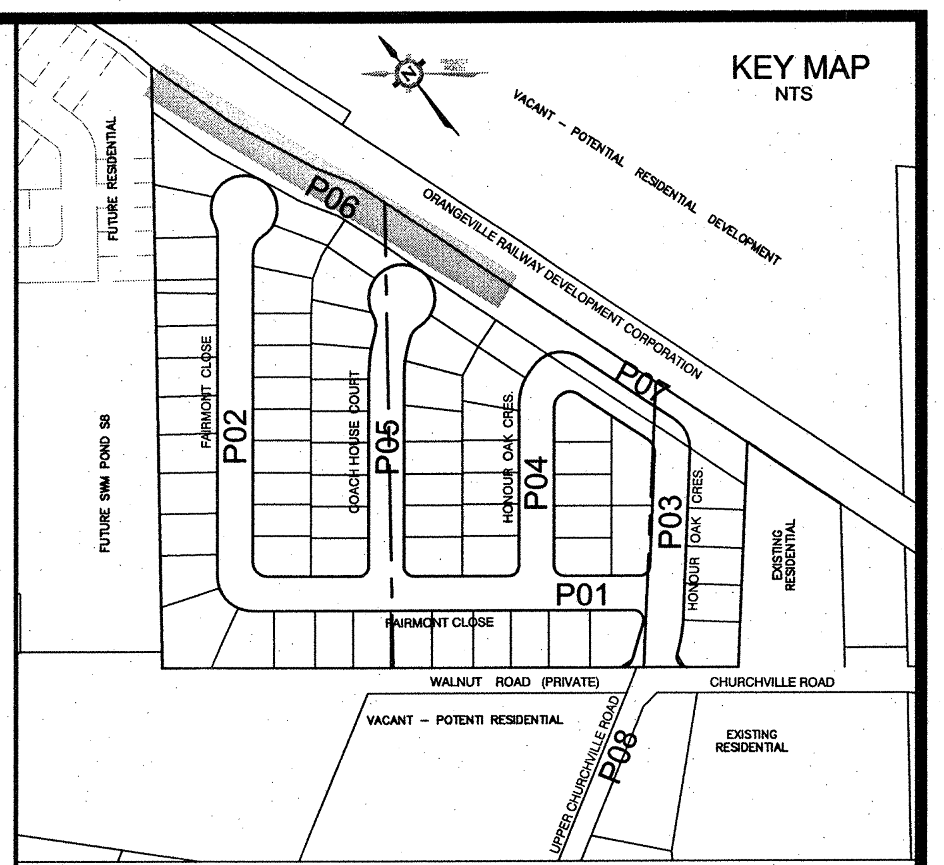

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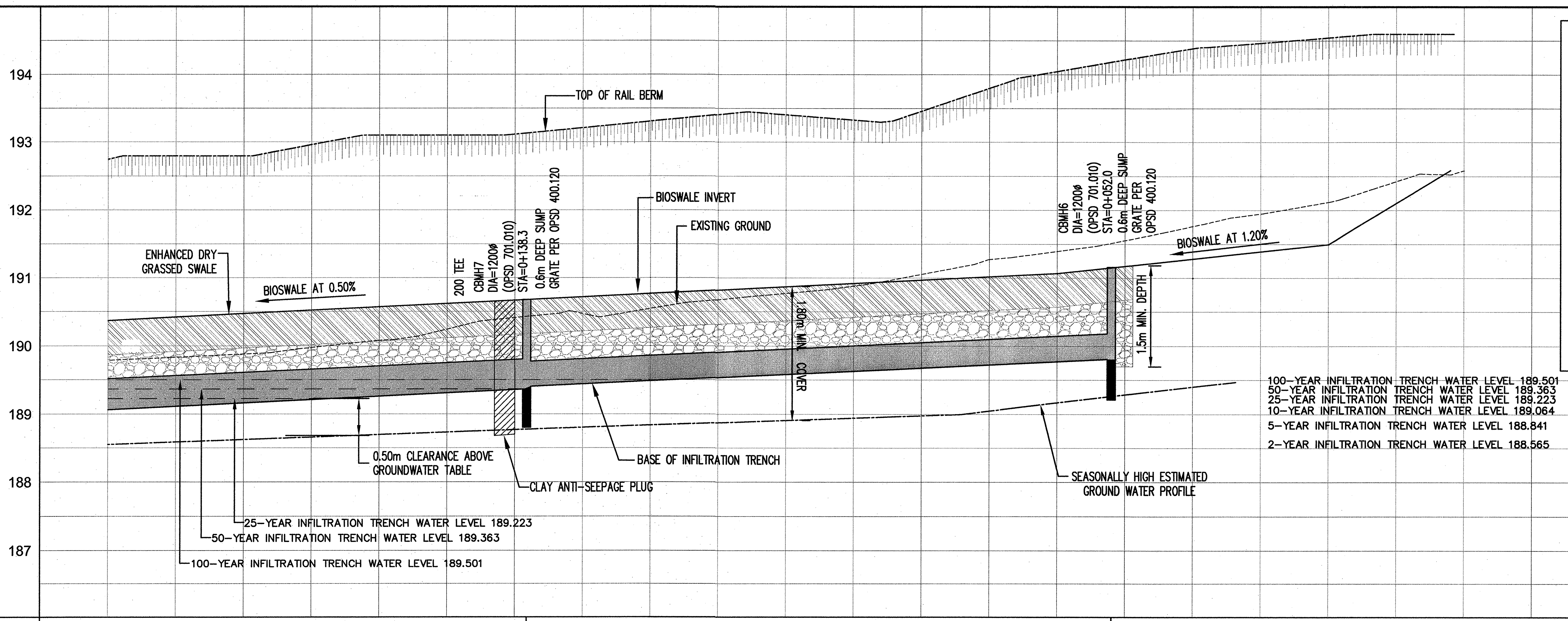
April 12 /12

Designed By:

Approved By P. Eng.



100-YEAR INFILTRATION TRENCH WATER LEVEL 189.501
50-YEAR INFILTRATION TRENCH WATER LEVEL 189.363
25-YEAR INFILTRATION TRENCH WATER LEVEL 189.223
10-YEAR INFILTRATION TRENCH WATER LEVEL 189.064
5-YEAR INFILTRATION TRENCH WATER LEVEL 188.841
2-YEAR INFILTRATION TRENCH WATER LEVEL 188.565

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PERFORATED PIPE TABLE

PIPE SIZE	HOLES PER ROW	ROWS PER METRE OF PIPE
375mm	8	7
450mm	10	7
525mm	11	7

HOLES ARE 25mm DIAMETER SPACED 50mm C/C

℄ CHAINAGE	0+200	0+180	0+160	0+140	0+120	0+100	0+080	0+060	0+040	0+020	0+000
STORM INVERTS	PERFORATED 98.2m-450ø RIBBED PVC STM @ 0.50%			S189.362 N189.399	PERFORATED 86.1m-375ø RIBBED PVC STM @ 0.50%			S189.814			
TOP OF BERM ELEVATION	192.748	192.800	193.100	193.115	193.312	193.409	193.463	194.049	194.375	194.550	194.600
BIOSWALE INVERTS	190.370	190.470	190.570	190.670	190.770	190.870	190.970	191.070	191.260	191.500	192.106

The MUNICIPAL INFRASTRUCTURE Group
8800 Dufferin Street, Suite 200
Vaughan, ON L4K 0C5
Tel. 905-738-5700 Fax 905-738-0065

Region of Peel
Working for you

FLOWER CITY
BRAMPTON.CA
Brampton
PLANNING, DESIGN & DEVELOPMENT
ENGINEERING & DEVELOPMENT SERVICES, MICHAEL WON, P.ENG., DIRECTOR

WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON
BIOSWALE
PLAN & PROFILE
STA. 0+000 TO STA. 0+200
CITY FILE # C03W02.005 REGION FILE # 21T-10010B

Scale:	HORIZ. 1:500 VERT. 1:50	Project No. 10101
Drawn By:	CAD	
Designed By:	A.M.	Drawing No. P06
Checked By:	C.E.	
Date:	JAN 2011	

File : G:\Projects\2010\10101 - Walnut Grove\Drawings\Plan & Profiles\PP06.dwg, Layout : P06 Date : Apr 12, 2012 - 4:45pm, Edit By : rstone

STANDARD NOTES: (CITY OF BRAMPTON)

- a. All construction works shall comply with the Standard Drawings and Specifications of the City of Brampton and the O.P.S.
- b. All concrete and plastic sewer pipes shall have rubber gasket joints.
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- i. An asphalt preservative sealer such as Re–clamite (or other approved equivalent) shall be applied after the one–year maintenance period for the top course asphalt.
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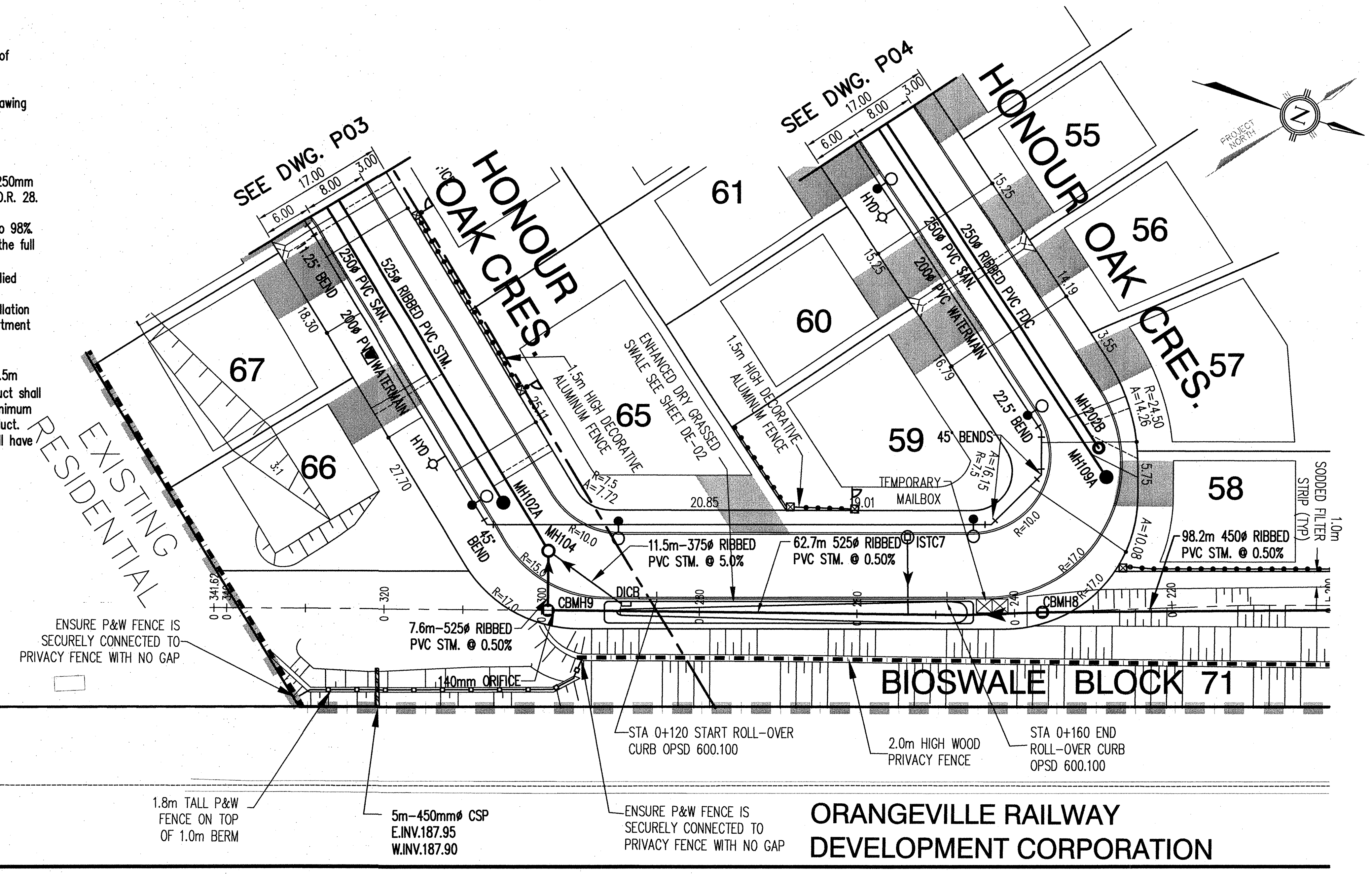
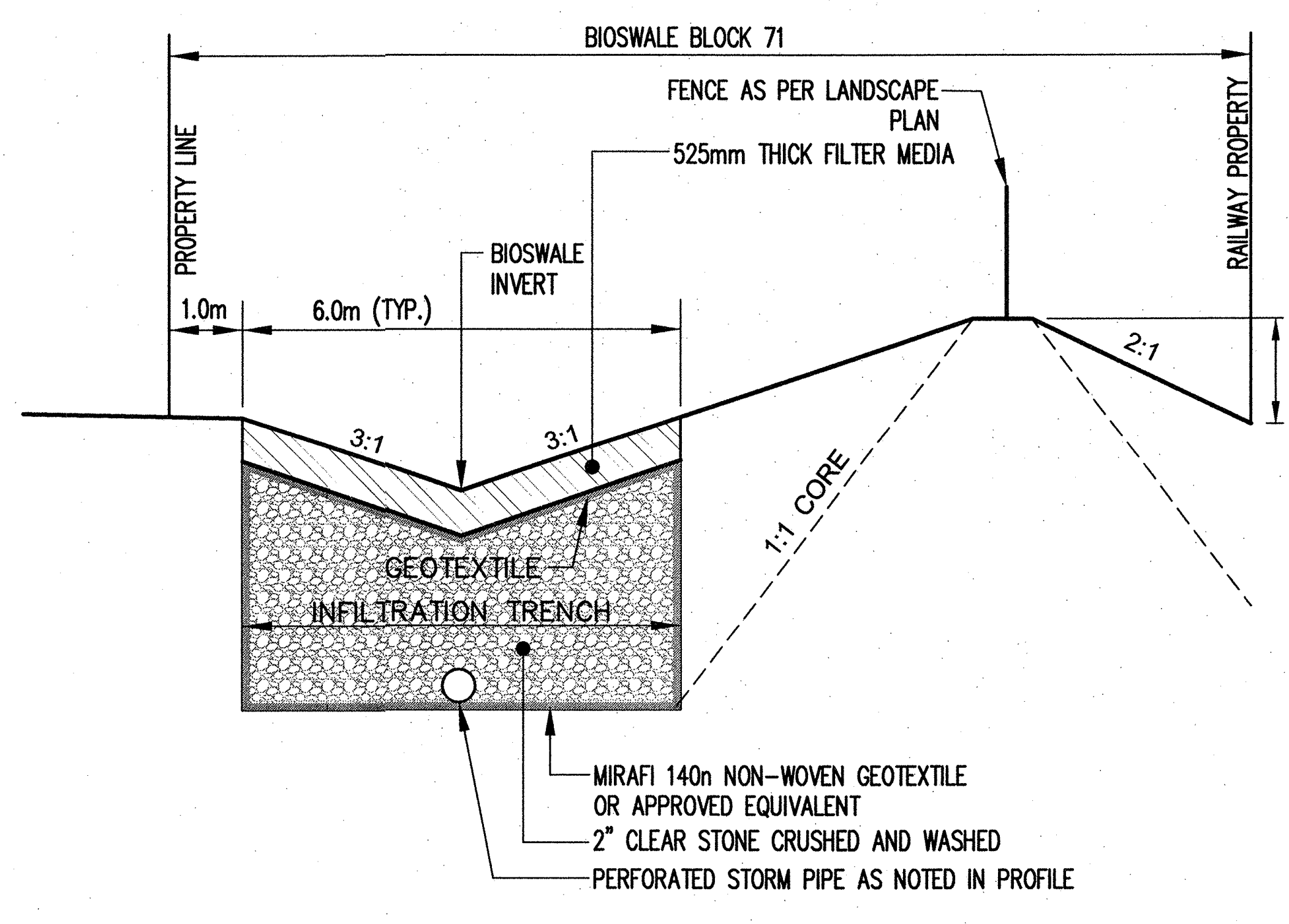
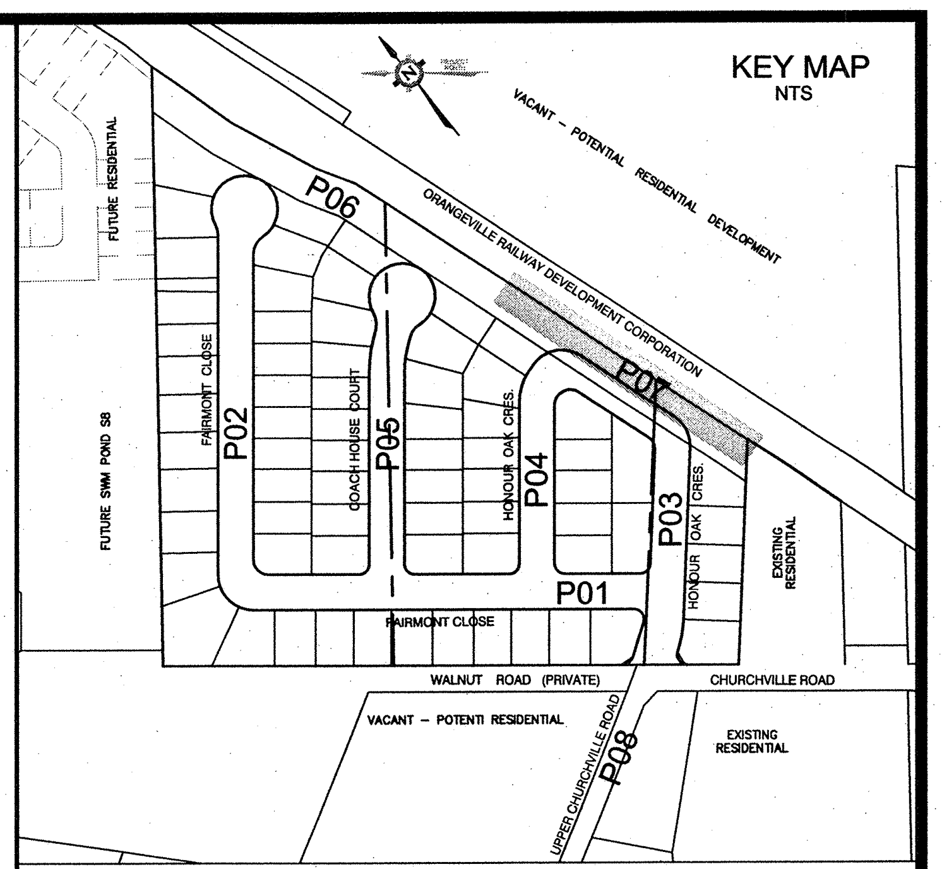
- k. All intersections have one utility duct on the leg of each street. Each duct shall be located 2.5m from the BC / EC and shall extend 0.5m behind the back of curb. Both ends of the utility duct shall be capped. The ducts shall be 100mm in diameter made of CSA certified Type 2 PVC. The minimum trench width of the duct shall be 300mm with 100mm sand bedding and backfill around the duct. Native backfill can be used from the sand backfill up to the granular sub–base. The duct shall have a minimum cover of 1.5 meters.
- l. No limestone permitted as bedding for weeping tile and under basement slab if FDC proposed.





TYPICAL BIOSWALE/RAIL BERM SECTION

NOT TO SCALE



LEGEND

- ● PROPOSED SANITARY MANHOLE
- ○ PROPOSED STORM MANHOLE
- ◉ PROPOSED FDC MANHOLE
- □ PROPOSED CATCHBASIN
- ◫ PROPOSED CATCHBASIN
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- WATERBOX LOCATIONS
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- RAIN GARDEN AND CURB CUT SEE SHEET DE-03 FOR DETAIL
- ACOUSTIC FENCE
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- METAL FENCE
- CHAIN LINK FENCE
- P&W FENCE
- ○● STREET LIGHTS
- MB MAIL BOX
- HYDRO TRANSFORMER
- TV PEDESTAL
- * ENGINEERED FILL LOTS
- UTILITY DUCT

ADDITIONAL NOTES:

1. Bioswale block and undeveloped blocks shall be maintained free of garbage and construction debris by the developer until assumption of the subdivision by the city.
2. All areas of bioswale block disturbed during construction shall be restored to the satisfaction of the City of Brampton.
3. Bioswale block and undeveloped blocks shall not be used for the purpose of stockpiling or for the placement of construction trailers.
4. When the temporary turning circle easement is eliminated, remove existing asphalt and granular base material (where required) and restore to a standard road cross–section to the satisfaction of the City of Brampton.
5. No rear yard gates are permitted from residential lots to bioswale block or walnut rd.
6. Any erosion experienced along the channel slopes throughout the construction and warranty period of this development shall be corrected by the developer to the satisfaction of the planning, design and development department.
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10. All fences to be located 0.15m inside residential lot where abutting public land.

ORIFICE TABLE

STRUCTURE	SIZE	INVERT
CBMH9	140mmø	188.88

OIL-GRIT SEPERATORS

STRUCTURE	INVERT	GRATE	STORMCEPTOR MODEL
ISTC7	188.95	190.15	STC 300

PERFORATED PIPE TABLE

PIPE SIZE	HOLES PER ROW	ROWS PER METRE OF PIPE
375mm	8	7
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525mm	11	7

HOLES ARE 25mm DIAMETER SPACED 50mm C/C

CURB STOPS AND BOXES
REGARDING REGION OF PEEL WATERMAIN DESIGN CRITERIA, ALL SERVICES SHALL HAVE CURB STOPS AND BOXES INSTALLED AT STREET LINE, BE FLUSH WITH GRADE AND ACCESSIBLE AT ALL TIME. REDUCING CURB STOPS SHALL NOT BE USED.
FOR RESIDENTIAL APPLICATIONS, ALL WATER SERVICES BOXES (CURB STOPS) SHALL BE INSTALLED IN GRASS AREAS WITH MINIMUM DISTANCE OF 1.0 meter FROM THE EDGE OF THE DRIVEWAY.

THE APPLICANT, APPLICANT'S REPRESENTATIVE, CONSULTANT, CONTRACTOR AND SUB-CONTRACTOR ARE RESPONSIBLE TO ENSURE THAT THEIR DESIGN AND CONSTRUCTION PRACTICES CONFORMS TO THE LATEST REGION OF PEEL STANDARDS, SPECIFICATIONS AND DESIGN CRITERIA, POSTED ON THE REGION OF PEELS'S WEBSITE (www. peelregion.ca/pw/standards)

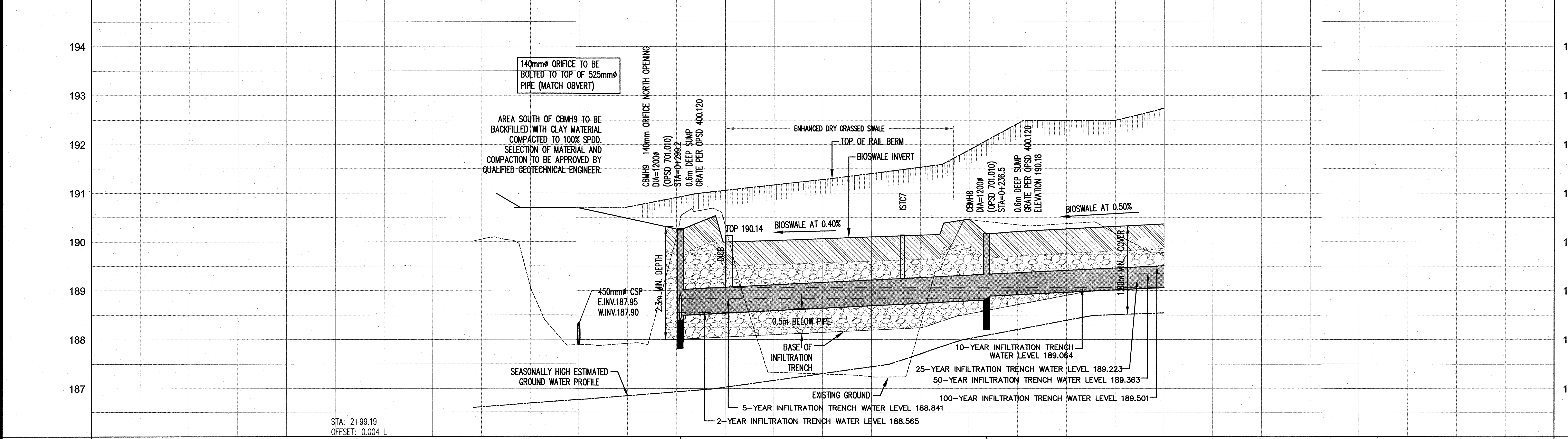
No.	REVISIONS	Date	By	Approved
5.	MYLAR SUBMISSION	APR. 2012	D.A.	
4.	FINAL SUBMISSION–ABOVE GROUND WORKS	JAN. 2012	D.A.	
3.	FINAL SUBMISSION–PRE SERVICING	NOV. 2011	D.A.	
2.	SECOND SUBMISSION	AUG. 2011	C.E.	
1.	FIRST SUBMISSION	APR. 2011	C.E.	

BENCHMARK NOTE
ELEVATIONS SHOWN HEREON ARE GEODETIC AND ARE REFERRED TO THE CITY OF BRAMPTON BENCHMARK 042050238 HAVING AN ELEVATION OF 190.177 METRES AND IS A BRASS CAP LOCATED 23.70 METRES SOUTH OF CENTRELINE OF STEELES AVENUE AND 20.70 METRES WEST OF CENTRELINE OF FINANCIAL DRIVE

LICENSED PROFESSIONAL ENGINEER
PROVINCE OF ONTARIO
April 12/12

Designed By:

Approved By
P. Eng.



STORM INVERTS				W188.410 N188.500		PERFORATED 62.7m–525ø RIBBED PVC STM @ 0.50%		S188.815 188.890	PERFORATED 98.2m–450ø RIBBED PVC STM @ 0.50%	
TOP OF BERM ELEVATION	191.000		190.698	190.918		191.177	191.413	191.897	192.500	192.748
BIOSWALE INVERTS		190.700	190.700	190.267	190.620	190.570	190.520	190.470	190.270	190.370
℄ CHAINAGE	0+340		0+320	0+300		0+280	0+260	0+240	0+220	0+200

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ENGINEERING & DEVELOPMENT SERVICES, MICHAEL WON, P.ENG., DIRECTOR

WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON
BIOSWALE
PLAN & PROFILE
STA. 0+200 TO STA. 0+340

CITY FILE # C03W02.005
REGION FILE # 21T–10010B

Scale:	HORIZ. 1:500 VERT. 1:50	Project No. 10101
Drawn By:	CAD	
Designed By:	A.M.	Drawing No. P07
Checked By:	C.E.	
Date:	JAN 2011	

File : G:\Projects\2010\10101 - Walnut Grove\Drawings\Plan & Profiles\PP07.dwg, Layout : PP07 Date : Apr 12, 2012 - 4:46pm, Edit By : rstone

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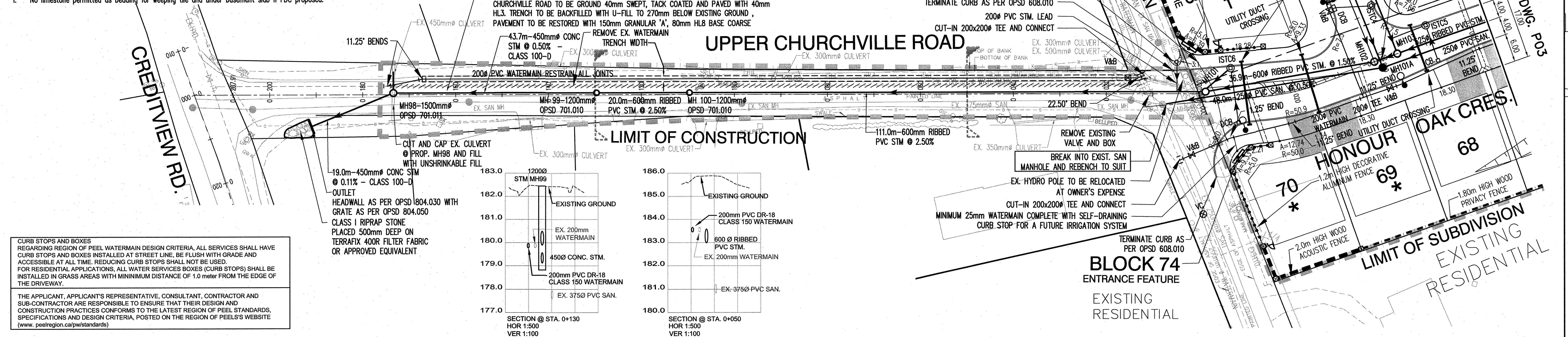

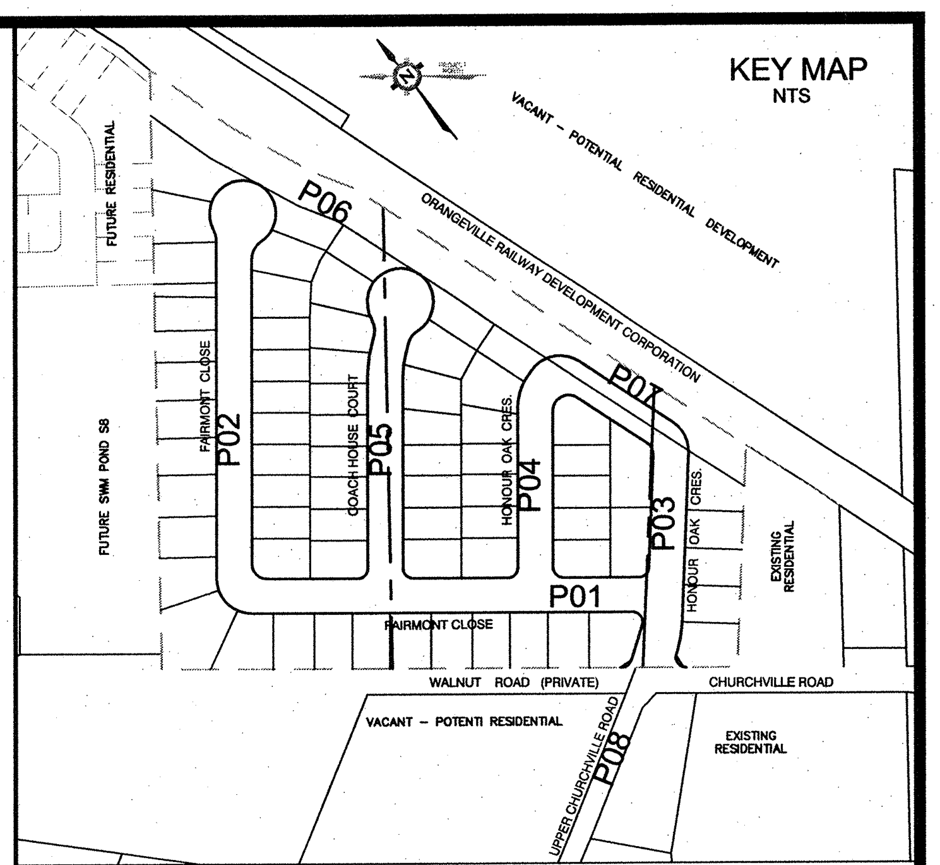

LEGEND

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LICENSED PROFESSIONAL ENGINEER
D. F. ASHFIELD
PROVINCE OF ONTARIO
April 12/12

Designed By:

Approved By P. Eng.

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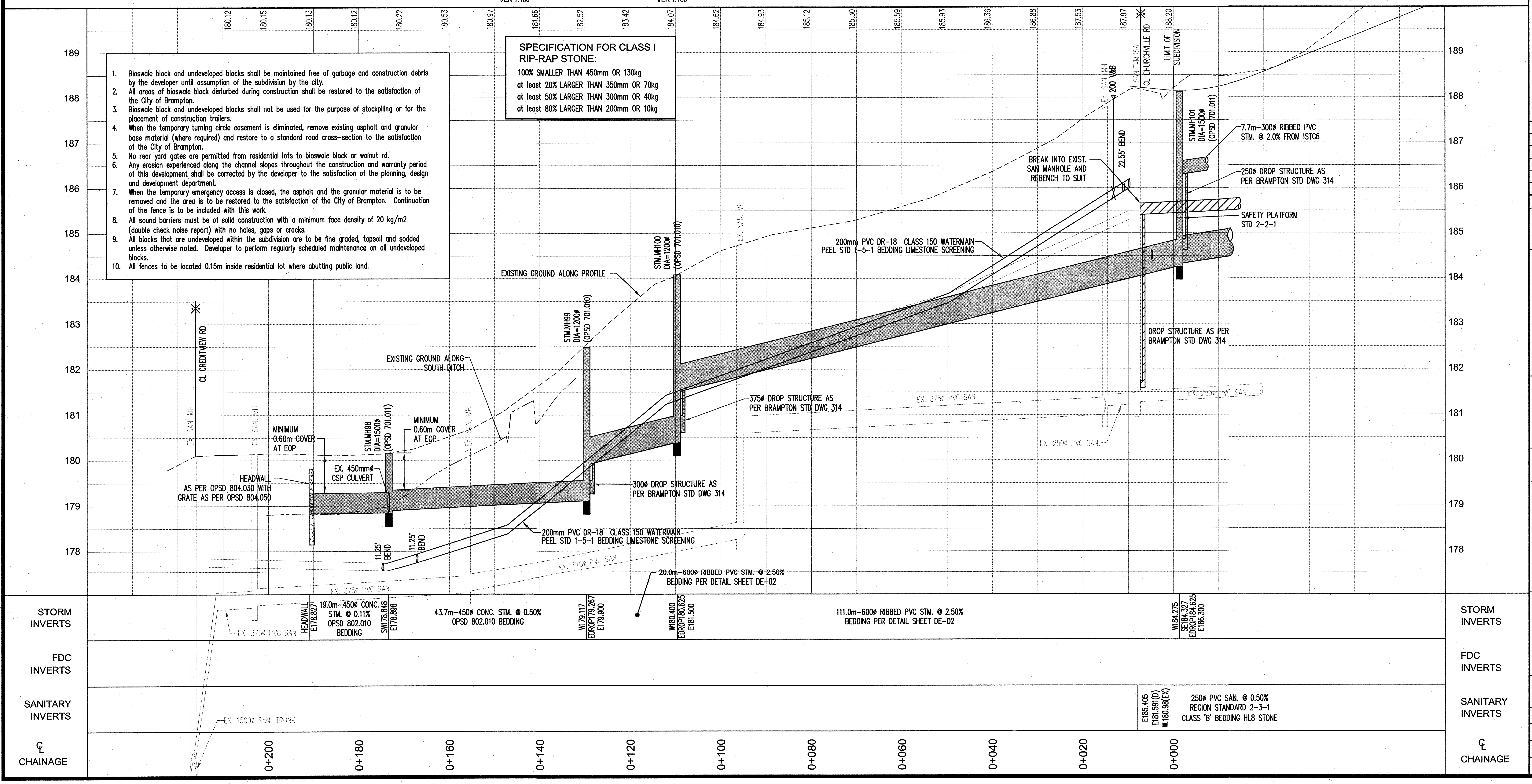
SPECIFICATION FOR CLASS I RIP-RAP STONE:
100% SMALLER THAN 450mm OR 130kg
at least 20% LARGER THAN 350mm OR 70kg
at least 50% LARGER THAN 300mm OR 40kg
at least 80% LARGER THAN 200mm OR 10kg



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WYCHWOOD BY SEQUOIA GROVE HOMES
CITY OF BRAMPTON
UPPER CHURCHVILLE ROAD
PLAN & PROFILE
STA. 0+000 TO STA. 0+220
CITY FILE # C03W02.005 REGION FILE # 21T-10010B

Scale:	HORIZ. 1:500 VERT. 1:50
Drawn By:	CAD
Designed By:	A.M.
Checked By:	C.E.
Date:	JAN 2011
Project No.	10101
Drawing No.	P08

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Ministry of the Environment
Ministère de l'Environnement

ENVIRONMENTAL COMPLIANCE APPROVAL

NUMBER 9879-8P6Q2S
Issue Date: February 16, 2012

Sequoia (Walnut Grove) Ltd.
8611 Weston Road, Suite 18
Vaughan, Ontario
L4L 9P1

Site Location: Sequoia Grove Homes
Lot 2, Concession 3
City of Brampton, Regional Municipality of Peel

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:

establishment of stormwater management Works to serve the 5.67 hectare Walnut Grove low impact development residential subdivision located between Walnut Road and the Orangeville Railway Development Corporation rail line, opposite Upper Churchville Road in the City of Brampton, for the collection, transmission, treatment and disposal of stormwater run-off, to provide enhanced level water quality control and erosion protection, and to attenuate post-development peak flows to pre-development levels for all storm events up to and including the 100-year storm event, consisting of the following;

Bioswale: - receiving and storing run-off from the eastern portion of the site of approximately 2.28 hectares, a 6 m wide bioswale located along the east side of the development immediately adjacent to the Orangeville Railway Development Corporation rail line, having a total storage volume of approximately 703 m^3, with overland flow from the major storm event captured and directed via the storm sewers on Honour Oak Crescent and Upper Churchill Road to the Credit River to the west, complete with:
- a 250 m long and 6 m wide infiltration trench under the bioswale, having an infiltration storage volume of 80 m^3, complete with 375 mm diameter to 525 mm diameter perforated pipes surrounded with clear stone wrapped on all sides with non-woven geotextile filter fabric, discharging via manhole catchbasin 9 (CBMH9) complete with a 140 mm diameter orifice plate to manhole 104 (MH104) on Honour Oak Crescent;

Oil and Grit Separators: seven (7) oil and grit separators (Stormceptor Model Number STC 300, or Approved Equivalent), each having a sediment storage capacity of 1.435 m^3, an oil storage capacity of 420 Litres (L), and a total storage volume of 1.756 m^3, discharging to the perforated storm sewers on Fairmont Close and Honour Oak Crescent;

Grass Swales: - five (5) segments of enhanced dry grassed swales, 2.2 m wide by 150 mm deep, of length 46.8 m and 17.5 m on Honour Oak Crescent, and of length 45.5 m, 18.0 m and 22.0 m on Fairmont Close; each underlain by 500 mm filter media over an infiltration trench system; each swale discharging through a roof drain (Zurn Model Number Z121 or Approved Equivalent), to the perforated storm sewers on Fairmont Close and Honour Oak Crescent;

Rain Gardens: - two (2) 4 m long by 1.2 m wide by 1.4 m deep stone or precast rain garden boxes, each containing 500 mm thick filter media over an infiltration trench system; each rain garden discharging through an overflow roof drain (Zurn Model Number Z121 or Approved Equivalent), to the perforated storm sewers on Fairmont Close and Coach House Court;

Perforated Storm Sewers and Infiltration Trenches: - receiving and storing run-off from the western portion of the site of approximately 2.57 hectares via the oil and grit separators, grass swales and rain gardens identified above, and from the 525 mm diameter perforated pipe from CBMH9 identified above, sections of 450 mm diameter to 600 mm diameter perforated pipe on Fairmont Close and Honour Oak Crescent with a granular 'A' type bedding and 2" clear stone by 2.2 m wide infiltration trenches, having a cumulative infiltration storage volume of 191 m^3, wrapped on all sides with non-woven geotextile filter fabric, discharging via manhole 106 (MH106) complete with a 163 mm diameter orifice plate, and/or manhole 105 (MH105) complete with a 239 mm diameter orifice plate, and/or manhole 103 (MH103), complete with a 214 mm diameter orifice plate, all discharging via a 900 mm diameter pipe on Upper Churchville Road and a rip rap protected outfall to the Credit River, with overland flow from the major storm event for the western area of the site directed westward along Upper Churchville Road and Creditview Road to the Credit River approximately 0.4 km distant;

Permeable Pavement: - permeable pavement sub-base depth of 83 mm for all driveways to capture the 25 mm rainfall;

Extra Topsoil in Landscaped Areas: - increased depth of topsoil by 21 mm on all right-of-way and buffer landscaped areas and increased depth of topsoil by 123 mm on all lot landscaped areas to capture the 25 mm rainfall;

including erosion/sedimentation control measures during construction and all other controls and appurtenances essential for the proper operation of the aforementioned Works;

all in accordance with the following submitted supporting documents:

1. Application for Approval of Sewage Works, submitted by The Municipal Infrastructure Group Ltd., dated August 11, 2011 and received on October 14, 2011;

2. Stormwater Management Design Brief for Walnut Grove Proposed Low Impact Residential Subdivision, City of Brampton, prepared by The Municipal Infrastructure Group Ltd., dated February 2012;

3. Stormwater Management / Low Impact Development Operations and Maintenance Report, City of Brampton, prepared by The Municipal Infrastructure Group Ltd., dated May, 2011;

4. Engineering Construction Drawings GN01, AGP1, BGP1, WGP1, MN01, STM01, STC01, FDC01, SAN01, RGB01, DS01, ES01 to 03, GR01 & 02, P01 to P08, DE01 to DE07, TC01, prepared by The Municipal Infrastructure Group Ltd., all dated January 9, 2012;

5. Engineering Construction Drawing DE05, prepared by The Municipal Infrastructure Group Ltd., dated February 4, 2012; and

6. E-mails from Amit Modi of The Municipal Infrastructure Group Ltd. to the Ministry dated January 27, 2012, February 9, 2012 and February 14, 2012.

For the purpose of this environmental compliance approval, the following definitions apply:

"Approval" means this entire document including the application and the supporting documents listed in this Approval;

"Approved Equivalent" means a substituted product that meets the required quality and performance standards of a named product and has been approved for substitution in writing by the District Manager or the Director;

"Director" means a person appointed by the Minister pursuant to section 5 of the Environmental Protection Act for the purposes of Part II.1 of the Environmental Protection Act;

"District Manager" means the District Manager of the Halton Peel District Office of the Ministry;

"Ministry" means the ministry of the government of Ontario responsible for the Environmental Protection Act and the Ontario Water Resources Act and includes all officials, employees or other persons acting on its behalf;

"Owner" means Sequoia (Walnut Grove) Ltd. and includes its successors and assignees;

"Works" means the sewage works described in the Owner's application(s) and this Approval.

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. GENERAL PROVISIONS

(1) The Owner shall ensure that any person authorized to carry out work on or operate any aspect of the Works is notified of this Approval and the Conditions herein and shall take all reasonable measures to ensure any such person complies with the same.

(2) Except as otherwise provided by these Conditions, the Owner shall design, build, install, operate and maintain the Works in accordance with the description given in this Approval, and the application for approval of the Works.

(3) The designation of the City of Brampton as the operating authority of the site on the application for approval of the Works does not relieve the Owner from the responsibility of complying with any and all of the Conditions of this Approval.

(4) Where there is a conflict between a provision of any submitted document referred to in this Approval and the Conditions of this Approval, the Conditions of this Approval shall take precedence, and where there is a conflict between the listed submitted documents, the document bearing the most recent date shall prevail.

(5) Where there is a conflict between the listed submitted documents, and the application, the application shall take precedence unless it is clear that the purpose of the document was to amend the application.

(6) The Conditions of this Approval are severable. If any Condition of this Approval, or the application of any requirement of this Approval to any circumstance, is held invalid or unenforceable, the application of such Condition to other circumstances and the remainder of this Approval shall not be affected thereby.

(7) The issuance of and compliance with the Conditions of this Approval does not:

a) relieve any person of any obligation to comply with any provision of any applicable statute, regulation or other legal requirement, including, but not limited to, the obligation to obtain approval from the local conservation authority necessary to construct or operate the sewage Works; or

b) limit in any way the authority of the Ministry to require certain steps be taken to require the Owner to furnish any further information related to compliance with this Approval.

2. EXPIRY OF APPROVAL

This Approval will cease to apply to those parts of the Works which have not been constructed within **five (5) years** of the date of this Approval.

3. CHANGE OF OWNER

The Owner shall notify the District Manager and the Director, in writing, of any of the following changes within **thirty (30) days** of the change occurring:

(a) change of Owner;

(b) change of address of the Owner;

(c) change of partners where the Owner is or at any time becomes a partnership, and a copy of the most recent declaration filed under the Business Names Act, R.S.O. 1990, c.B17 shall be included in the notification to the District Manager; and

(d) change of name of the corporation where the Owner is or at any time becomes a corporation, and a copy of the most current information filed under the Corporations Information Act, R.S.O. 1990, c. C39 shall be included in the notification to the District Manager.

4. OPERATION AND MAINTENANCE

(1) The Owner shall inspect the Works at least **once a year** and, if necessary, clean and maintain the Works to prevent the excessive build-up of sediments, oil/grit, and/or vegetation.

(2) The Owner shall prepare an operations manual, complete with a monitoring program, prior to commencement of operation of the stormwater management Works, based on the recommendations of the Stormwater Management / Low Impact Development Operations and Maintenance Report prepared by The Municipal Infrastructure Group Ltd., dated May, 2011, for the Walnut Grove proposed low impact development residential subdivision and retain a copy at the Owner's office, and, upon request, make the operations manual available to Ministry staff.

(3) The Owner shall maintain a logbook to record the results of these inspections and any cleaning and maintenance operations undertaken, and shall keep the logbook at the Owner's office for inspection by the Ministry. The logbook shall include the following:

(a) the name of the Works; and

(b) the date and results of each inspection, maintenance and cleaning, including an estimate of the quantity of any materials removed.

5. MONITORING AND REPORTING

(1) The Owner shall carry out a monitoring program and evaluate the performance of the stormwater management Works commencing at the initial completion of construction of the Works and continuing for a minimum of two (2) years after 90% of the homes in the Walnut Grove proposed low impact development residential subdivision have been occupied.

(2) The monitoring program shall include obtaining grab samples from manhole 101 (MH101) located at the intersection of Honour Oak Crescent and Churchville Road for at least two (2) rainfall wet events per year (a wet event is defined as a minimum of 15 mm of rain in the previous 24 hours). One of the events must occur within the May to September time period.

(3) Samples should be tested for Total Suspended Solids (mg/L) and results recorded.

(4) The methods and protocols for sampling, analysis and recording shall conform, in order of precedence, to the methods and protocols specified in the following:

(a) the Ministry's Procedure F-10-1, "Procedures for Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only)", as amended from time to time by more recently published editions;

(b) the Ministry's publication "Protocol for the Sampling and Analysis of Industrial/Municipal Wastewater" (January 1999), ISBN 0-7778-1880-9, as amended from time to time by more recently published editions;

(c) the publication "Standard Methods for the Examination of Water and Wastewater" (21st edition), as amended from time to time by more recently published editions.

(5) The Owner shall submit to the District Manager, **every year**, a copy of the test results as per Condition 5, Subsection (3), above.

(6) The Owner shall submit to the District Manager, **every five (5) years**, a Performance Assessment Report addressing the following:

(a) a description of any operating problems encountered and corrective actions taken during the reporting period and the need for further investigations in the following reporting period for system refinements or ways of improving the performance of the Works;

(b) measurement of the mass of accumulated sediment removed when undertaking maintenance of the Works as per Condition 4, Subsection (3), above;

(7) The measurement frequency specified in Condition 5, Subsection (2) and reporting frequency specified in Condition 5, Subsections (5) and (6), above, may, after five (5) years of monitoring in accordance with this Condition, be modified by the District Manager in writing from time to time.

6. RECORD KEEPING

The Owner shall retain for a minimum of **five (5) years** from the date of their creation, all records and information related to or resulting from the operation and maintenance activities required by this Approval.

The reasons for the imposition of these terms and conditions are as follows:

1. Condition 1 is imposed to ensure that the Works are built and operated in the manner in which they were described for review and upon which approval was granted. This Condition is also included to emphasize the precedence of the Conditions in the Approval and the practice that the Approval is based on the most current document, if several conflicting documents are submitted for review.

2. Condition 2 is included to ensure that, when the Works are constructed, the Works will meet the standards that apply at the time of construction to ensure the ongoing protection of the environment.

3. Condition 3 is included to ensure that the Ministry records are kept accurate and current with respect to approved Works and to ensure that any subsequent Owner of the Works is made aware of the Approval and continues to operate the Works in compliance with it.

4. Condition 4 is included to require that the Works be properly operated and maintained such that the environment is protected.

5. Condition 5 is included to ensure that the Ministry is made aware of problems as they arise, and to provide a performance record of the Works.

6. Condition 6 is included to require that all records are retained for a sufficient time period to adequately evaluate the long-term operation and maintenance of the Works.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me and the Environmental Review Tribunal within 15 days after receipt of this Notice, require a hearing by the Tribunal. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The environmental compliance approval number;
6. The date of the environmental compliance approval;
7. The name of the Director, and;
8. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary* Environmental Review Tribunal 655 Bay Street, Suite 1500 Toronto, Ontario M5G 1E5	AND	The Director appointed for the purposes of Part II.1 of the Environmental Protection Act Ministry of the Environment 2 St. Clair Avenue West, Floor 12A Toronto, Ontario M4V 1L5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 314-4506 or www.ert.gov.on.ca**

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 16th day of February, 2012

Ian Parrott, P.Eng.
Director
appointed for the purposes of Part II.1 of the
Environmental Protection Act

DC/
c: District Manager, MOE Halton-Peel
Chris Ewen, The Municipal Infrastructure Group Limited

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

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Appendix B

Infrastructure Performance and Risk Assessment Procedures

This section of the document presents the monitoring protocol prepared by CVC. The section also includes information relevant to potential monitoring refinements on the site.

1.1 Hydrology

Outflow from the low impact development features in the Wychwood Neighbourhood is monitored at two stations, WW-1 and WW-2, located in manholes. To determine the volume of water being discharged from the subdivision, each station manhole is equipped with an ISCO 2150 area velocity level and flow module (level logger) with a pressure transducer probe, and a compound weir. The probe is secured to the bottom of each manhole upstream of the weir to ensure accurate water level measurements. The flow module records water level at 1-minute intervals and is summarized in 5-minute intervals. Flow data is acquired from the level logger by using the recorded level data and the weir rating curve. The monitoring station is also equipped with an ISCO 6712 automatic sampler for collection of water quality samples.

A heated tipping bucket rain gauge was installed on the roof of Churchville Public School, located 1.3 km from the Wychwood neighbourhood, to provide precipitation data. Since the rain gauge has been installed on a rooftop the likelihood that the gauge will be subjected to higher winds during more severe storm events is greater. This could potentially cause the rain gauge to “undercatch” rainfall. Precipitation data collected during more severe storm events will be more closely examined for accuracy. A precipitation event is considered to occur when 2 mm or more precipitation is recorded. If more than 6 hours elapse between precipitation or flow events, they are considered to be separate events.

1.2 Surface Water Quality

CVC’s surface water quality sampling goal is to sample a minimum of five precipitation events per year from each monitoring location (WW-1 and WW-2) with an ISCO 6712 automatic sampler. The autosampler is connected to the level logger and is triggered to collect a water quality sample when the logger records a predetermined level.

The automatic sampler is programmed to collect samples that will allow for a composite sample to be compiled for water quality analysis for each event at each outflow monitoring station. The autosampler holds 24 1-litre bottles. When the sampler is triggered, all bottles are filled provided sufficient runoff is generated and outflow observed. Bottles that were filled while outflow was observed are used to generate a flow-weighted composite sample. A flow weighted sample contains representative amounts of water according to the volume of flow collected during an event; periods of lower flows constitute a smaller portion of the overall sample, while periods of higher flows constitute a representatively larger portion of the overall sample.

Figure B-1: Example of an automatic sampler base with 24 1-litre sampling bottles

Currently the autosampler is programmed to collect samples at a fixed time interval, such as every 10 minutes. CVC has developed various program lengths ranging from 6 to 48 hours, which may be shortened or lengthened depending on the expected duration of the storm event forecasted to ensure the water quality sample is representative of the entire storm hydrograph. Once the sampling program is complete, the water level data is converted to flow data by using a rating curve. The flow data is downloaded and pasted into a flow weighting Excel spreadsheet to determine the volume of water needed from each autosampler bottle for the composite sample. This type of sampling allows for event mean concentration (EMC) and load analysis.

All water quality samples were taken to the Ministry of Environment and Climate Change lab, for analysis.

Table B-1 summarizes water quality parameters and associated analytical methods.

Table B1: Quality parameters of interest[1] and MOECC method number

Water Quality Parameter	Units	MOECC Method Number[2]
Total Cadmium (Cd)	ug/L	E3497
Total Copper (Cu)	ug/L	E3497
Total Iron (Fe)	ug/L	E3497
Total Lead (Pb)	ug/L	E3497
Total Nickel (Ni)	ug/L	E3497
Total Zinc (Zn)	ug/L	E3497
Chloride (Cl)	mg/L	E3016A
Nitrate + Nitrite (NO_3 + (NO_2)	mg/L	E3364A
Phosphate (PO_4)	mg/L	E3364A

Total Phosphorus (TP)	mg/L	E3516
Total Suspended Solids (TSS)	mg/L	E3188B

[1] The water quality parameters listed are recommended parameters of interest; CVC has performed a broad screening of over 27 parameters.

[2] Method numbers are dated to time of lab analysis (2016)

1.3 Surface Water Infiltration

Infiltration testing was completed in September 2014 across the length of the bioswale, using a double ring infiltrometer. The tests where preformed to determine if the bioswale, which had been heavily impacted by adjacent residential construction, needed to be remediated. A clay based sod was used within the invert section of the bioswale and the curbside inlets into the bioswale had not been managed by appropriate erosion and sediment control measures to protect the feature during construction. Two tests were performed adjacent to the curb inlets from the cul de sac and an additional measurement was taken near the catchbasin at the downstream end of the bioswale. The minimum infiltration rate requirement for bioretention soil is reported to be 25 mm/hr. However, a safety of factor of 2 is generally accounted for when designing LID sites which results in an infiltration rate to 50 mm/hr. Studies show that in-field measured infiltration rates for bioretention soil range from 80-120 mm/hr. For an application such as Wychwood where there is no stormwater management pond, the bioswale should have an infiltration rate in the higher ranges to ensure adequate drainage of the site. Further discussion and summary tables can be found in Appendix F.

Double ring infiltration tests are conducted by hammering the rings into the soil to an equal depth. Water is poured into both the inner and outer rings, and the rate at which the water level in the inner ring decreases is tracked (such as every 30 seconds, or several minutes, depending on soil type). This continues until the infiltration rate has reached a constant value, which is calculated as the difference in water level between a given time interval.

1.4 Soil Sampling

The LID approach at Wychwood aims to minimize runoff and pollutants though the combination of permeable pavement, bioswales and rain gardens. The rain gardens and bioswales use plants and engineered filter media to chemically, physically and biologically treat pollutants. Soil sampling will help track contaminants and aid in evaluating the frequency of maintenance activities such as filter media replacement.

Initial sampling occurred December 2, 2016 after summer precipitation events but prior to the ground freezing. Soil (filter media) sampling was conducted at two depths. Samples were analyzed by Maxxam Analytics for inorganics, metals and polyaromatic hydrocarbons (PAHs).

Two composite soil samples were collected from four locations: two from the large bioswale, one from a grass bioswale, and one from a rain garden, tallying 8 samples in total. The shallow and deep samples were collected at approximately 5 cm and 40 cm below the filter media surface, respectively. In the sampled locations, three subsamples from each depth were combined to produce one composite sample. Comparison between two sampling depths provides information regarding the depth at which pollutant removal occurs for different parameters. In addition, sampling at two depths helps determine whether or not pollutants are migrating through the soil column over time. Collecting samples from multiple bioretention cells will provide insight on pollutant removal for different plant combinations and how parameter concentrations vary depending bioretention cell location (i.e different water volume inputs and sources depending on the cell). Moving forward soil sampling for contaminant tracking will occur in 2018 as a mid-project sample, and again in 2020 as an end of project sample.

Soil quality results were compared to CCME Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2014) and to the Ministry of Environment and Climate Change Environmental Protection Act, Ontario Reg. 153/04 Table 7: Generic Site Condition Standards for Shallow Soils in a Non-Potable Ground Water Condition Soil - Coarse Texture (MOECC, 2016) for the appropriate land use. A summary is found in the report, with additional tables in Appendix F.

1.5 Site Visits

CVC staff visit the site at least once every other week to check battery power, inspect equipment, and make sure the site is operating properly. Data is downloaded either remotely or in person from each piece of equipment bi-weekly or more frequently using ISCO Flowlink 5 or Hoboware. The software will automatically summarize and plot the data graphically, which can then easily be exported to a program like Microsoft Excel. During site visits, CVC staff also note any changes that have occurred on the site, any equipment adjustments/maintenance, LID maintenance activities that have occurred and any other unusual or changed circumstances at the site. Water level probe calibration is checked and adjusted as needed during each field visit.

1.6 Site Maintenance

The stormwater facilities at Wychwood are designed to provide runoff storage and water quality treatment by trapping pollutants. Understanding the maintenance needs of these systems is a priority to assess if these technologies are feasible from a wide-scale perspective. Maintenance activities are shared between individual homeowners and the City of Brampton, with homeowners taking responsibility for features on their property, and the City maintaining the oil and grit separators and the large bioswale.

CVC monitoring staff complete inspection checklists during routine site visits documenting information such as trash/debris accumulation, inlet/outlet conditions, vegetation conditions etc. Separate winter maintenance inspections are also conducted to document snow/ice cover, road salt use, and general site conditions. Although this information is being collected now, meaningful interpretation can only be made with additional years of monitoring. A description of typical maintenance procedures is included in Appendix E.

Long-term infrastructure assessment is needed for both quality and quantity performance to capture when a drop in performance occurs and how performance is restored once maintenance work has been done. Therefore maintenance documentation in combination with long term performance assessment is required in order to link maintenance activities to changes in performance. Some maintenance requirements may only be detectable through long-term performance such as filter media reaching saturation. This information alongside cost tracking will benefit asset management information.

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Appendix C

Data Management and Analytical Methodology

CVC compiled monitoring data consisting of water level, flow and water quality at two stations in the Wychwood subdivision. The processes for the collection of water level, flow, precipitation and water quality data are laid out in Appendix B. Provided here is a description on the data management and analysis activities for this site.

Analyses for these stations summarize available performance data and compare these data to other applicable BMP performance data sources. These analyses summarize the water quantity and quality effectiveness of the implemented BMPs, which can be used to guide CVC and municipal decision-making processes with respect to stormwater management and LID design.

1.1 Data Management

The collected site data includes time series of precipitation and flow, and composite water quality sample data. Data management includes initial processing and organizing, including identifying the site and reference input data to be analyzed and organization of the site data for event-based analysis.

1.1.1 Input Data Processing

The data analyses were completed with the Wychwood monitoring data set collected by CVC. Hydrologic and water quality data dates from 2016 and 2017.

Reference data included the following data sources:

- Lakeview neighbourhood residential curb and gutter and grass swale sites (CVC)
- National Stormwater Quality Database (NSQD)

- Ontario Provincial Water Quality Objectives (PWQO) or Canadian Councils of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Aquatic Life, whichever is more restrictive.

1.1.2 Input Data Organization

The flow and precipitation data were divided into hydrologic events associated with the collected water quality samples to provide meaningful, event-based analyses. Hydrologic events were defined using the time series of both flow and precipitation as defined in Table C-1.

Table C-1: Hydrologic Event Definition for CVC Data Analyses

Event Type	Beginning	End
Hydrologic Event	Precipitation > 2 mm	Stormflow *and* Precipitation = 0 for 6 consecutive hours

1.2 Data Analysis

Data analysis involved identifying appropriate evaluation and presentation (graphical) methods, and the data analysis tools and work flow as described in the following sections.

1.2.1 Data Analysis Evaluation Methods

The Wychwood dataset was evaluated using event-based analysis, with the event defined as previously indicated in Table C-1. Both stations were evaluated for both water quantity and water quality performance. The site was not monitored for inflow; it receives inflow as infiltration from the permeable pavement driveways, rain gardens and bioswale, making it difficult to measure inflow directly. Because of this, the Simple Method[1] was selected to estimate influent volume as a product of a calculated runoff coefficient, the drainage area, and the event precipitation. Estimated influent volume was compared to actual effluent volume to evaluate BMP estimated volume reduction. It is recommended that this method for calculating runoff could be improved through the development of a calibrated SWMM model[2]. Substantial existing flow and rainfall monitoring data could be used to calibrate and verify a hydrologic model.

Simple Method

The standard method for evaluating stormwater BMPs is to compare untreated inflows to treated outflows. This method is used in comparing both water quality and quantity parameters such as volume reduction, peak flow or contaminate loading. Using water quality and quantity monitoring equipment can be useful for monitoring inflows however; it can be impractical due to possible disruption in the intended design of the practice in diverting runoff into the LID. Additionally, many BMPs have multiple inflow points into the practice making inflow monitoring expensive and complex and may still require some form of flow estimation.

The Simple Method is a spreadsheet based runoff estimation procedure that is used for determining stormwater runoff and pollutant loading for urban areas. The Simple Method determines estimated inflow based on drainage area, amount of precipitation, and a runoff coefficient. This information is used to determine a runoff coefficient[1]. While the Simple Method is typically used to calculate annual runoff, CVC has modified the formula to determine runoff on an event-by-event basis. CVC has also added a BMP component to account for LID areas. Note that the BMP area is not considered in the runoff coefficient calculation since complete infiltration into the practice is assumed for BMP areas.

The drainage area for Wychwood was derived using orthographic imagery and site visits. This process allows the catchment area to be divided into impervious, pervious and BMP surfaces, which are used in the equation below to determine the runoff coefficient. Precipitation data was obtained from the rain gauge on the roof of nearby Churchville Public School, maintained by CVC. This data is used with the drainage area to determine event inflow runoff volume. Table C-2 and Table C-3 present the drainage area and use of the Simple Method at Wychwood for stations WW-1 (Eastern catchment) and WW-2 (Eastern and Western catchments), respectively.

The runoff coefficient is defined as:

$$Rv = 0.05 + 0.9 * la$$

Where:

Rv is the runoff coefficient

0.9 is the fraction of rainfall events that produce runoff

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[1] Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, DC

[2] EPA. (2010). "Storm Water Management Model (SWMM)." Water Supply and Water Resources Division, National Risk Management Research Laboratory, CDM.

Ia is the impervious fraction (Impervious Area/Drainage Area to the BMP)

The modified Simple Method formula used is:

Event inflow volume (L): Drainage Area to the BMP (m^2) * Rv + BMP area (m^2) * Event Precipitation (mm)

Note: the BMP area is added since precipitation on the BMP area is considered to fully infiltrate into the practice.

Table C-2: Drainage area and application of the Simple Method in the Eastern catchment at Wychwood (WW-1)

Land Use	**Area (m^2)**
Road	3190
Building	4058
Total impervious area	**7249**
Pervious to OGS7	1205
Total pervious to bioswale	7454
Total pervious area	**8660**
Total drainage area to the BMP (impervious area + pervious area)	**15909**
BMP Area	
Total bioswale	1518
Permeable pavement	1143
Total BMP area	**2661**
Ia= impervious fraction (total impervious area/total drainage area to the BMP)	0.456
Rv= 0.05 + 0.9 * Ia	0.460
Total drainage area to the BMP * Rv + total BMP area: Multiply this number by event precipitation (mm) to get event inflow volume (L)	**9980**

Table C-3: Drainage area and application of the Simple Method in the Eastern and Western catchment at Wychwood (WW-2)

Land Use	**Area (m^2)**
Road	7561
Building	9768
Total impervious area	**17329**
Pervious to OGS	4071
Pervious to rain gardens	2071
Pervious to infiltration trench	4588
Total pervious to bioswale	7454
Total pervious area	**18184**
Total drainage area to the BMP (impervious area + pervious area)	**35513**
BMP Area	
Infiltration trench/swale	244
Rain garden	6
Bioswale	1518
Permeable pavement	3625
Total BMP area	**5393**
Ia= impervious fraction (total impervious area/total drainage area to the BMP)	0.488
Rv= 0.05 + 0.9 * Ia	0.489
Total drainage area to the BMP * Rv + total BMP area: Multiply this number by event precipitation (mm) to get event inflow volume (L)	**22765**

Best results are produced when the method is used for smaller catchments at a development site scale. Further modeling would be required for determining runoff for a large watershed. Additionally, the Simple Method only provides estimates for the storm event itself and does not consider pollutant contribution from baseflow generated within the catchment.[3] Baseflow separation is further described in the following section.

Lastly, the Simple Method can overestimate inflow volume for smaller events where rainfall depths would be used up by catchment wetting and surface depression storage. This occurs because the Simple Method applies the same runoff coefficient to storms of all magnitudes. The simple method using the same runoff coefficient was also used for inflow estimations to evaluate the performance of CVCs Lakeview neighborhood. Performance results from Lakeview are used as a comparison with resutls collected from the Wychwood study.

Baseflow Separation

Due to a high groundwater table in the Western portion of the Wychwood subdivision as determined from pre-development groundwater monitoring reports (Terraprobe, 2010[4]) baseflow has been observed at the WW-2 monitoring location at the outflow of the infiltration trenches and rain gardens. In order to do event by event analysis, a baseflow separation method must be utilized to separate pre-event water from event water. There are several empirical methods to estimate the end of direct runoff stormflow and return to baseflow, such as the one derived by Linsley et al (1975)[5]. However, these are based on aggregated observations from various watersheds, and are designed for overland stream systems and not stormwater measurement. At Wychwood, it is difficult to determine the appropriate catchment area draining to WW-2. The use of an empirical approach is further complicated by the fact these methods were developed for streamflow, and are therefore not necessarily appropriate for use while monitoring flows from a storm sewer at the outlet of an infiltration trench.

Graphical approaches to baseflow separation are arbitrary in terms of how they distinguish stormflow from baseflow, because they are not physically based. It would be preferable to directly measure groundwater contributions. However, in the absence of additional groundwater data or geochemical tracers, using simple graphical methods allows for an approximation of stormflow. While the lack of physical basis may introduce a certain degree of error to the estimates, graphical methods have the benefit of producing consistent results (Nejadhashemi et al., 2009[6]). These methods are also designed for overland streams, however they will still give an adequate approximation. For these reasons it was thought that a purely graphical based method might be more appropriate at Wychwood.

The concave method is a commonly used baseflow separation method that approximates baseflow using an extrapolation of the pre-event baseflow trendline, which is extended to under the peak of the event. This line is then intersected by a line that connects to the total flow hydrograph at the defined end point for direct runoff (Figure C-1). This end point may be determined either by an empirical method such as that proposed by Linsley et al (1975), or by using a graphical method. One purely graphical approach is to define the end of direct runoff (stormflow) as the inflection point where the second derivative of the hydrograph passes through zero, and the graph goes from concave downwards to concave upwards

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[3] Centre for Watershed Protection, (2010). Stormwater Management Design Manual. New York State Department of Environmental Conservation. Albany New York

[4] Terraprobe, 2010. Hydrogeologic investigation Sub-Area 6 (Walnut Grove) Credit Valley Secondary Plan Ciy of Brampton, Ontario. Prepared for: The Municipal Infrastructure Group, 2300 Steeles Ave W, Suite 120, Vaughan Ontario L4K 5X6

[5] Linsley, R. K., Kohler, M. A., and Paulhus, J. L.: Hydrology for Engineers, 2nd ed. McGraw-Hill, New York, 1975

[6] Nejadhashemi, A.P., C.M. Smith, and W.L. Hargrove. 2009. Adaptive watershed modeling and economic analysis for agricultural watersheds, Kansas State University Agricultural Experiment Station and Cooperative Extension Service. MF- 2847

(Nejadhashemi et al., 2009[7]). This graphical approach is the method that was selected as being appropriate for baseflow separation at Wychwood, as it is based on changes in flow rate, rather than on catchment properties. However, due to the amount of noise in the flow logger data, it proved impossible to identify a singular point this way. Therefore, instead of setting the threshold strictly at when the second derivative passes through zero, the end of storm flow was determined to occur when the second derivative dropped below a threshold deemed to be close enough to zero to account for noise, and stayed there for the following six hours. While this typically picks out a point slightly later than inflection point, this is considered an acceptable approximation because it was found to be more likely to slightly underestimate baseflow contributions and therefore allow for more conservative water budget calculations.

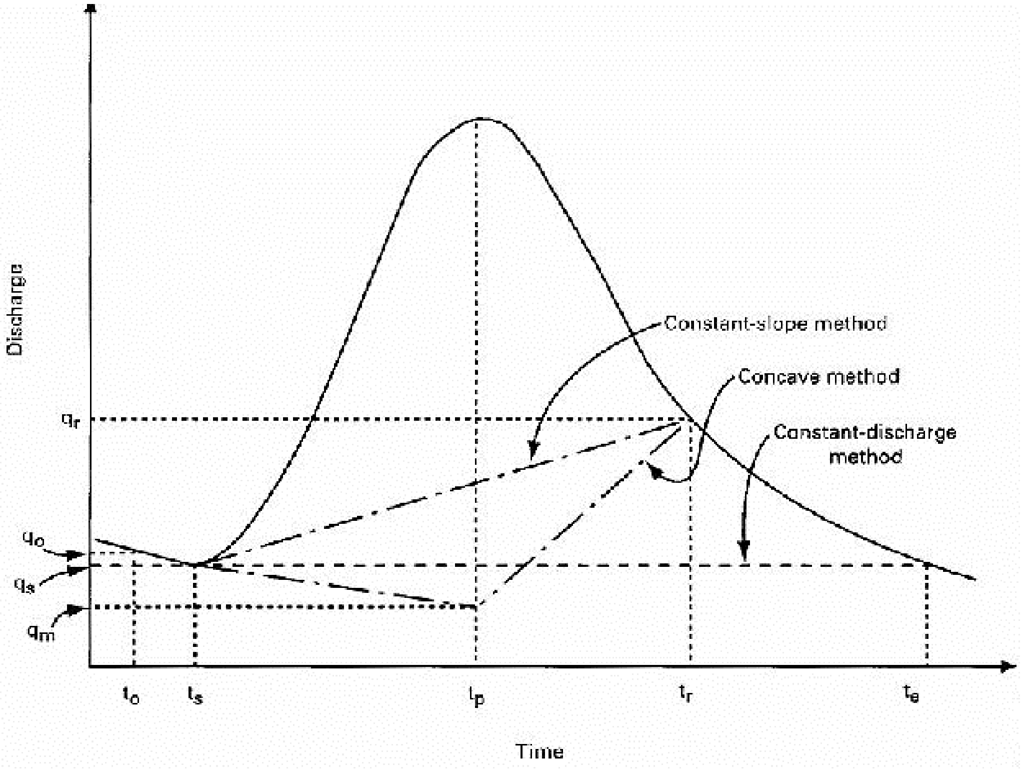

Figure C-1: Baseflow separation techniques (from McCuen, 2004[8])

Water Quality

Both contaminant loadings and discharge concentrations have been evaluated for Wychwood. Loading reduction is the best way to evaluate water quality performance. However, to understand the filtration mechanism only discharge concentration was compared to reference water quality guidelines, runoff EMCs from similar land uses, and effluent concentrations for similar BMPs. An estimated total influent load was calculated as a product of the estimated influent volume, and the NSQD Zone 1 Residential

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[7] Ibid.

[8] McCuen, R. H. 2004. Hydrologic Analysis and Design. Prentice Hall, Upper Saddle River, New Jersey, 07458, 3rd edition, 2004. ISBN 0-13-142424-6.

median EMC, as well as the Lakeview neighbourhood curb and gutter median EMC for evaluation purposes. Effluent EMCs are derived from the lab reported value of the flow proportional samples collected on site for several parameters listed below. The statistical summaries have been organized by pollutant. Data set summary statistics are presented in both tabular and graphical formats.

The recommended parameters of interest analyzed are:

- Cadmium
- Copper
- Iron
- Lead
- Nickel
- Zinc
- Dissolved Chloride
- Nitrate + Nitrite
- Total Kjeldahl Nitrogen
- Orthophosphate
- Total Phosphorus
- Total Suspended Solids

1.2.2 Arc hydro Geographical Information software (GIS) and Lidar Catchment Analysis

The MECP Stormwater Management Planning and Design Manual provides guidance on erosion control requirements for sites where infiltration facilities are used for water quality treatment. Site stormwater design measures for the Wychwood Subdivision are to detain runoff from a 4-hour 15 mm event.

Within Wychwood’s Stormwater Management Design Brief (TMIG, 2012), the total estimated catchment area of Wychwood was approximately 5.67 hectares; additionally, each land designation was designed to capture a different rain fall depth and collectively meet the 15 mm criteria. The sum of the design storage for each land designation equates to 1038 m3 with an estimated target rainfall capture volume of 850 m3 to meet the 15 mm 4hr design storm used to estimate the site erosion control criteria. Table C-4 provides an overview of how the design consultant delineated each land designation as well as the volume of precipitation that would be managed by each portion of the site.

Calculation used to determine target rainfall capture volume:

- Pre-development estimate calculation: 5.67 ha (56700m^2) multiplied by 15 mm (0.015m) equates to 850.5 m3 target capture volume for 15 mm erosion control.
- CVC evaluated the full catchment area foot-print of the Wychwood subdivision within the context of post development conditions and within the limitation in which outflow performance could be measured by monitoring infrastructure installed within the stormwater system. This exercise used

Arc hydro Geographical Information software (GIS) and a detailed Lidar analysis to delineate the discrete catchment area for each LID feature. This produced a more accurate total inflow catchment area of 4.09 hectares was used for this comparison making the new target rainfall capture volume 613 m^3. Figure C-2 presents the details results of the catchment delineations.

- Post-development estimate calculation: 4.09 ha (40915m^2) multiplied by 15 mm (0.015m) equates to 613 m3 target capture volume for 15 mm erosion control.

Figure C-2: Wychwood site lidar delineations results

Table C-4: Estimated volume and rain depth captured by land designation from Pre-Development SWM Design Brief (TMIG, 2012)

		Area (ha)	Captured Rainfall Depth (mm)	Volume (m3)
Residential Lots	Landscape	1.49	25.0	372.1
	Roof (Via Landscape	1.82	15.0	272.3
	Permeable Driveways	0.33	25.0	81.7
Buffer Area		0.36	25.0	90.0

Walkway		0.02	1.5	0.3
R.O.W	Permeable Driveway	0.2	25.0	49.5
	Landscape	0.64	25.0	160.5
	Paved	0.82	1.5	12.3
	Total	**5.67**		**1038.5**

Due to the variation in estimated rainfall depth captured from the design compared to the above estimations directed to each individual LID catchment, performance assessment is limited to 15 mm or 613 m^3 to focus specially on comparing monitored performance with the design criteria.

1.2.3 Soil Sampling Methodology

Soil sampling occurred in the bioretention material that receives runoff from the surrounding catchment area. Samples were collected from each feature within the site where bioretention soil is used for storage and filtration. Figure C-3 indicates the rain garden, grass swale and bioswale locations where soil samples were collected. Sampling occurred on December 2, 2016 after the summer precipitation events, but prior to ground freezing. Soil (filter media) sampling was conducted at two depths. Samples were analyzed by Maxxam Analytics for inorganics, metals, and polyaromatic hydrocarbons (PAHs).

Figure C-3: Bioretention Soil Sampling Locations

Eight composite soil samples were collected from three bioretention features. Four samples were collected from the bioswale whereas two samples were collected from both the rain garden and grass swale. A shallow and deep interval soil sample was collected at each sampling location. The shallow and deep samples were collected at approximately 5 cm and 40 cm below the top of the filter media surface, respectively. In the samples, three subsamples from each depth were combined to produce one composite sample. Comparison between two sampling depths provides information regarding the depth at which pollutant removal occurs for different parameters. In addition, sampling at two depths helps determine whether or not pollutants are migrating through the soil horizon over time. Collecting samples from multiple bioretention features will provide insight on pollutant removal for different filter media. The 2016 soil quality results represent the baseline condition and the next soil sampling event for Wychwood is scheduled for 2018. Soil quality results were compared to CCME Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2014) and to the Environmental Protection Act, Ontario Reg. 153/04 Table 7: Generic Site Condition Standards for Shallow Soils in a Non-Potable Ground Water Condition Soil – Coarse Texture (MOE, 2011) for the appropriate land use.

1.2.4 Data Analysis Presentation Methods

The summary tables include both parametric and non-parametric statistics. Parametric statistics operate under the assumption that data arise from a single theoretical statistical distribution that can be described mathematically using coefficients, or parameters, of that distribution. The mean and standard deviation are example parameters of the normal, or Gaussian, distribution. Non-parametric statistics, including the median, are fundamentally based on the ranks[9] of the data with no need to assume an underlying distribution. Non-parametric statistics do not depend on the magnitude of the data and are therefore resistant to the occurrence of a few extreme values (i.e., high or low values relative to other data points do not significantly alter the statistic).[10] Time series plots of the sampled EMC values are also provided. A box plot is provided to compare Wychwood TSS values with those from the NSQD sorted by land use.

1.2.5 Data Analysis

Most of the data analysis was done using Microsoft Excel. Total influent volumes due to rainfall were estimated from a storm event's total precipitation by using the Simple Method as discussed in **Section 1.2.1 Data Analysis Evaluation Methods**. Volume reductions were then computed as the difference between the estimated influent volume and measured effluent volume. Influent loads are calculated using the estimated influent EMC multiplied by the influent volume. For events sampled for water quality, effluent loads are calculated using the measured effluent volume multiplied by the measured EMC, and for events that were not sampled for water quality, the median of the sampled EMCs is multiplied by the measured effluent volume.

1.3 Table and Figure Definitions

Definitions for information found in the tables and figures presented in this report are included below for guidance.

Tables include a combination of the following results, listed in alphabetical order:

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[9] In this context, ranks refer to the positions of the data after being sorted by magnitude.

[10] Helsel, D.R. and R. M. Hirsch, 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. U.S. Geological Survey. 522 pages.

- *Antecedent Dry Period* - The amount of time with no rain or flow preceding the event.
- *Effluent EMC* - The event mean concentration of the effluent for the event.
- *Estimated Pollutant Load Reduction* - The estimated mass of a pollutant passing through the BMP; what has been removed from the system.
- *Estimated Total Influent Load* - The estimated total pollutant load carried by influent for the event, as calculated by multiplying the Estimated Total Influent Volume by the NSQD Residential EMC.
- *Estimated Total Influent Volume* - The estimated total volume of influent for the event based on an application of the Simple Method with the measured rainfall depth.
- *Estimated Volume Reduction* - The estimated amount of volume removed as calculated by the difference between the Estimated Total Influent Volume and the Total Effluent Volume.
- *Event Duration* - The total length of time for the event.
- *Lag Time* - The time as calculated from the peak of precipitation event hyetograph to the peak of effluent event hydrograph.
- *Peak Effluent Flow* - The maximum effluent flow rate for the event based on measured effluent.
- *Peak Precipitation Intensity* - The maximum rate of precipitation for the event.
- *Sample Date* - The date the water quality sample was collected.
- *Storm Date* - The start date of the hydrologic event.
- *Total Effluent Load* - The total pollutant load carried by the effluent out of the BMP for the event, as calculated by multiplying the Total Effluent Volume by the Effluent EMC.
- *Total Effluent Volume* - The total measured volume effluent for the event.
- *Total Precipitation* - The total depth of rainfall for the event.
- *WQ Guideline* - The applicable PWQO or CCME water quality guideline for the pollutant.

Hydrologic Summary Figures presented in this report include the following results:

- *Flow* - The rate of flow for the estimated influent hydrograph and measured effluent hydrograph with corresponding flow rates increasing upwards along the left chart axis.
- *10-min Precipitation Depth* - The depth of precipitation per 10-minute intervals with corresponding depths increasing downward along the right chart axis.

Tables and Comparative BMP Box Plots include the following BMPs represented in the BMPDB:

- *Bioretention* - Vegetated, shallow depressions used to temporarily store stormwater prior to infiltration, evapotranspiration, or discharge via an underdrain or surface outlet structure. Treatment is achieved through filtration, sedimentation, sorption, infiltration, biochemical processes and plant uptake.
- *Detention Basin* (a.k.a. Dry Pond) - Grass-lined basins that, while fully drainable between storm events, temporarily detain water through outlet controls to reduce peak stormwater runoff release rates and provide sedimentation treatment. Volume losses and load reductions through infiltration may also be significant.
- *Green Roof* - Vegetated roofs that provide stormwater treatment via filtration, sorption, biochemical processes and plant uptake.
- *Biofilter* - Vegetated swales or strips that provide treatment via filtration, sedimentation, infiltration, biochemical processes and plant uptake.
- *LID* - low-impact development (LID) monitored at a site-scale basis; green infrastructure.
- *Manufactured Device* - Devices that are designed to provide various treatment processes such as sedimentation, skimming, filtration, sorption, and disinfection. Treatment process subcategories within the BMPDP include biological filtration, filtration, inlet insert, multi-process, physical (with

volume control), physical (manufactured device), and oil/grit separators. The last two treatment process subcategories, which are of primary interest to CVC, are further described below:

  - Physical (manufactured device) are hydrodynamic devices that provide treatment via settling and includes proprietary devices like Stormceptors®. A performance summary[11] found statistically significant reductions for Zn and TP for physical (manufactured device) treatment processes. It was hypothesized that TSS results, showing no significant reductions, were affected by unusually low influent TSS concentrations.
  - Oil/grit separators are designed for removing floatables and coarse solids. The performance summary found statistically significant reductions for only TSS for oil/grit separators treatment processes.
- *Media Filter* - A constructed bed of filtration media that receives water at the surface and allows it to pond on the surface if inflows exceed the rate of percolation through the bed. Outflow from the media bed can be through underdrains or infiltration. Depending on the media used, treatment is provided via filtration, sorption, precipitation, ion exchange and biochemical processes.
- *Porous Pavement* - Pavement that allows for infiltration through surface void spaces into underlying material. Subcategories of porous pavement include modular block, pervious concrete, porous aggregate, porous asphalt, and porous turf. Treatment is provided via infiltration, filtration, sorption, and biodegradation.
- *Retention Pond* (a.k.a. Wet Pond) - Basins that feature a permanent pool of water (dead storage) below flood control (live storage) that is outlet controlled. Treatment is provided primarily through sedimentation; other treatment processes may include sorption and biochemical processes.
- *Wetland Basin* - Shallow basins typically designed with inflow energy dissipation and variable depths and vegetation types to promote interactions between runoff, aquatic vegetation, and wetland soils. Treatment is provided via sedimentation, sorption, biochemical processes, coagulation, flocculation, plant uptake and microbial transformations.
- *Wetland Channel* - Densely vegetated waterways used to treat and convey runoff. Treatment is provided via filtration, sedimentation, microbial transformations and plant uptake.

1.4 Statistical Significance and Hypothesis Testing Considerations

At least 35 paired events are needed to verify that a statistically significant difference in concentration of 80% has been achieved. Long-term assessment is needed to gain this confidence.

Statistical hypothesis testing is a powerful approach for evaluating stormwater BMP performance data. The most common type of statistical hypothesis testing involves comparisons of paired inflow and outflow EMC data to determine if the means significantly differ given an acceptable level of statistical confidence. This technique, which includes the paired t-Test, is commonly employed as a part of the analysis of the International Stormwater BMP Database and is a valuable statistical test for large, normally-distributed data sets. Nonparametric hypothesis testing, such as the Wilcoxon signed-rank test, can also be conducted (on medians rather than means); however, the statistical test generally is more powerful for parametric data when the normality assumptions hold (rare for stormwater). While statistical hypothesis testing is most commonly used for inflow/outflow analysis, it can be applied to any two data sets to determine if there is a statistically significant difference between the mean or median values of the two data distributions. In this case, tests

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[11] Leisenring, M., Clary, J., Hobson, P. 2012. International Stormwater Best Management Practices (BMP) Database, Manufactured Devices Performance Summary. Prepared by Geosyntec Consultants, Inc. and Wright Water Engineers, Inc. July.

on independent data sets are used (e.g., standard t-Test (parametric) and Mann-Whitney rank-sum test (non-parametric)) instead of matched pairs.

For the Wychwood site, the ability to conduct such testing is limited by the lack of measured inflow data. However, even if inflow EMCs had been measured or estimated from the initiation of monitoring, it is unlikely that the data set would be large enough for meaningful statistical hypothesis testing. To gain a sense of the size of the data set needed, consider hypothesis testing designed to detect a 75% difference between inflow and outflow mean EMC values for TSS (see Pitt and Parmer 1985[12]). Assuming a coefficient of variation of 1.5 (on the low end of variability for most stormwater parameters), a power of 80% (standard for this type of analysis) and a confidence level of 90%, more than 35 paired samples would need to be collected.

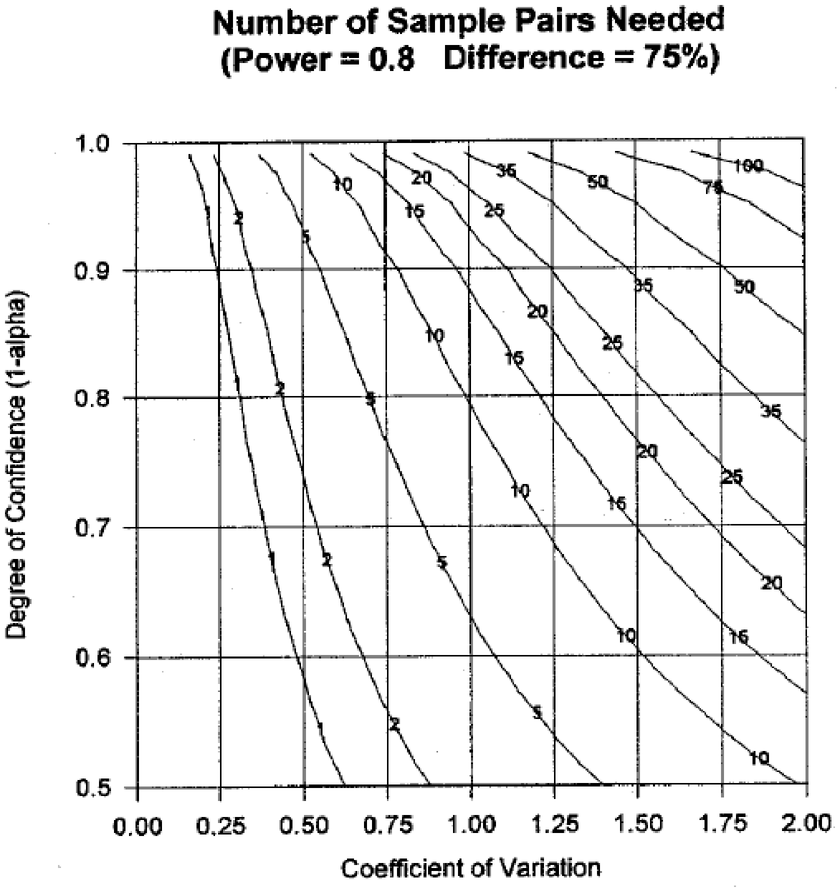

Figure C-4: Statistical Hypothesis testing paired samples required to detect 75% difference in population means for power of 80% (Pitt and Parmer 1985)

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[12] R. Pitt and K. Parmer. Quality Assurance Project Plan (QAPP) for EPA Sponsored Study on Control of Stormwater Toxicants. Department of Civil and Environmental Engineering, University of Alabama at Birmingham. 1995. Reprinted in Burton, G.A. Jr., and R. Pitt. Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

Therefore, eventually it may be possible for CVC to conduct hypothesis testing if inflow EMCs can be estimated and/or measured and paired with outflow data; however, it will take at least several years to build a data set that is sizeable enough, and will not be conducted at this stage for the Wychwood site. Furthermore, if differences between inflow and outflow EMC distribution means are smaller (e.g. 20% reduction or even 50% reduction), greater numbers of paired samples will be needed to detect differences with confidence. While a large number of events are needed for statistical hypothesis testing, the site nonetheless is currently providing useful data that can be used to calculate annual outflow loads with some associated uncertainty. CVC is evaluating methods for estimating inflow loads based on land use and EMC data from the NSQD at other monitoring locations. This will permit calculation of an annual load reduction for the facility. As the data sets grow and if inflow EMC data can be collected from land uses within the watershed or entering the LID features at other sites, the uncertainty of the comparison will decrease, permitting more accurate, and eventually statistically meaningful comparison.

If CVC is able to collect data for and/or estimate inflow EMCs, it should still be feasible to estimate inflow and outflow loads and calculate reductions on an annual basis to compare with the MOECC 80% TSS removal requirement, whether or not statistical significance holds (for small data sets, the conclusion often is that there is not a statistically significant difference; however, this finding may be reflective of the limited size of the data set rather than the lack of a true difference in population means/medians.

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

Technical Report

Monitoring Results (2016-2017)

Appendix D

Data Analysis and Summaries

1. HYDROLOGIC ANALYSIS

Table D-1a: Hydrologic Summary of Rainfall Events for WW-1

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2016-01-08 20:10	10.4	4.8	2.45	47405	8.32	0	0.00	100%	47405	100%
2016-01-10 3:20	11.3	5.8	0.86	57385	8.32	13442	1.82	78%	43943	77%
2016-01-15 21:05	4.1	2.8	5.27	27445	8.32	0	0.00	100%	27445	100%
2016-01-16 7:20	3.8	2.3	0.26	22455	8.32	0	0.00	100%	22455	100%
2016-01-18 7:00	5.7	19.3	1.83	192115	33.27	0	0.00	100%	192115	100%
2016-01-31 16:20	1.9	2.5	13.15	24950	16.63	0	0.00	100%	24950	100%
2016-02-02 21:00	9.8	8.4	2.11	83832	13.31	1	0.13	99%	83831	100%
2016-02-16 5:00	7.7	5.0	12.92	49900	8.32	0	0.00	100%	49900	100%
2016-02-19 22:45	16.0	2.3	3.42	22455	8.32	3930	0.37	96%	18525	82%
2016-02-24 7:55	17.9	31.5	3.72	314370	24.95	15853	1.30	95%	298517	95%
2016-03-10 9:10	8.8	4.0	14.31	39920	13.31	0	0.00	100%	39920	100%
2016-03-14 1:25	3.6	10.2	3.31	101796	19.96	0	0.00	100%	101796	100%
2016-03-15 1:00	4.0	3.2	0.83	31936	13.31	0	0.00	100%	31936	100%
2016-03-16 5:00	20.7	3.2	1.00	31936	19.96	0	0.00	100%	31936	100%
2016-03-22 17:40	1.9	2.6	5.67	25948	13.31	0	0.00	100%	25948	100%
2016-03-23 15:10	12.6	6.6	0.82	65868	13.31	0	0.00	100%	65868	100%
2016-03-24 14:20	6.9	17.0	0.44	169660	39.92	0	0.00	100%	169660	100%
2016-03-28 0:45	4.9	18.0	3.15	179640	39.92	850	0.51	99%	178790	100%
2016-03-31 2:30	20.0	32.8	2.87	327344	53.23	3899	1.92	96%	323445	99%
2016-04-03 6:25	2.6	9.2	2.33	91816	19.96	0	0.00	100%	91816	100%
2016-04-03 17:05	20.1	10.4	0.34	103792	19.96	0	0.00	100%	103792	100%
2016-04-06 9:15	0.3	3.8	1.84	37924	113.11	1699	2.38	98%	36225	96%
2016-04-06 17:15	14.8	10.0	0.32	99800	19.96	0	0.00	100%	99800	100%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2016-04-10 20:00	10.7	10.0	3.50	99800	66.53	0	0.00	100%	99800	100%
2016-04-21 15:25	10.8	3.6	10.36	35928	13.31	0	0.00	100%	35928	100%
2016-04-25 18:00	10.6	27.4	3.66	273452	73.19	6920	0.00	100%	266532	97%
2016-05-01 2:55	17.8	5.2	4.93	51896	13.31	0	0.00	100%	51896	100%
2016-05-12 21:50	8.9	23.2	11.05	231536	179.64	10983	4.11	98%	220553	95%
2016-05-14 3:45	7.1	5.2	0.88	51896	13.31	336	0.09	99%	51560	99%
2016-05-16 5:20	3.3	11.4	1.77	113772	73.19	0	0.00	100%	113772	100%
2016-05-16 15:55	3.5	2.6	0.31	25948	26.61	0	0.00	100%	25948	100%
2016-05-26 11:10	4.2	7.8	9.66	77844	33.27	0	0.00	100%	77844	100%
2016-06-02 5:05	3.8	13.4	6.57	133732	46.57	0	0.00	100%	133732	100%
2016-06-04 22:35	16.7	17.0	2.57	169660	39.92	2038	1.20	97%	167622	99%
2016-06-11 3:10	1.6	5.2	5.50	51896	93.15	623	1.01	99%	51273	99%
2016-06-26 20:25	1.8	7.8	15.65	77844	106.45	426	0.44	100%	77418	99%
2016-06-28 17:10	0.4	5.2	1.79	51896	66.53	0	0.00	100%	51896	100%
2016-07-01 7:35	1.2	2.0	2.58	19960	13.31	0	0.00	100%	19960	100%
2016-07-13 23:35	8.4	8.2	5.07	81836	79.84	4445	3.34	96%	77391	95%
2016-07-14 18:00	4.9	7.4	0.42	73852	66.53	1120	1.01	98%	72732	98%
2016-07-25 3:30	1.8	10.2	10.19	101796	133.07	1311	1.60	99%	100485	99%
2016-08-03 5:05	0.7	2.2	8.99	21956	13.31	0	0.00	100%	21956	100%
2016-08-13 11:30	8.9	19.6	10.24	195608	106.45	3374	0.83	99%	192235	98%
2016-08-16 1:35	8.1	14.6	2.22	145708	53.23	685	0.37	99%	145023	100%
2016-08-20 0:55	1.9	2.2	3.64	21956	13.31	0	0.00	100%	21956	100%
2016-08-25 0:35	1.2	11.0	4.91	109780	93.15	1490	1.92	98%	108291	99%
2016-08-25 15:50	1.9	15.2	0.58	151696	139.72	1373	1.10	99%	150324	99%
2016-09-07 21:15	1.5	17.2	13.15	171656	133.07	14477	6.21	95%	157180	92%
2016-09-17 4:55	11.2	7.0	9.26	69860	26.61	34	0.02	100%	69826	100%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2016-09-26 10:40	1.8	7.2	8.77	71856	26.61	23	0.05	100%	71833	100%
2016-09-29 8:40	10.3	11.6	2.84	115768	19.96	83	0.09	100%	115686	100%
2016-10-01 7:35	2.2	2.0	1.53	19960	13.31	0	0.00	100%	19960	100%
2016-10-01 16:05	10.4	2.2	0.26	21956	19.96	0	0.00	100%	21956	100%
2016-10-02 11:05	1.1	2.2	0.36	21956	13.31	263	0.66	95%	21694	99%
2016-10-08 5:20	1.3	5.4	5.72	53892	33.27	0	0.00	100%	53892	100%
2016-10-20 2:15	11.8	18.2	11.82	181636	13.31	19	0.02	100%	181617	100%
2016-10-26 23:50	13.0	8.4	6.41	83832	13.31	0	0.00	100%	83832	100%
2016-11-02 14:55	16.9	34.6	6.09	345308	46.57	15677	2.73	94%	329631	95%
2016-11-19 11:00	3.6	4.0	16.13	39920	6.65	0	0.00	100%	39920	100%
2016-11-23 21:50	15.7	4.8	4.30	47904	13.31	0	0.00	100%	47904	100%
2016-11-24 23:30	6.4	2.2	0.42	21956	13.31	0	0.00	100%	21956	100%
2016-11-26 2:10	3.9	2.2	0.84	21956	6.65	0	0.00	100%	21956	100%
2016-11-28 22:40	4.8	5.6	2.69	55888	19.96	0	0.00	100%	55888	100%
2016-11-30 19:40	3.8	4.4	1.67	43912	13.31	0	0.00	100%	43912	100%
2016-12-04 22:35	10.8	8.2	3.96	81836	13.31	0	0.00	100%	81836	100%
2016-12-06 17:55	10.2	3.4	1.35	33932	6.65	0	0.00	100%	33932	100%
2016-12-11 12:10	16.7	13.2	4.34	131736	13.31	0	0.00	100%	131736	100%
2016-12-16 21:20	31.3	8.8	4.69	87824	13.31	0	0.00	100%	87824	100%
2016-12-19 7:10	1.2	2.8	1.10	27944	13.31	0	0.00	100%	27944	100%
2016-12-24 1:50	4.9	4.2	4.73	41916	13.31	0	0.00	100%	41916	100%
2016-12-26 5:55	15.6	21.0	1.97	209580	33.27	0	0.00	100%	209580	100%
2016-12-29 2:45	9.7	6.8	2.22	67864	6.65	0	0.00	100%	67864	100%
2017-01-01 5:10	2.9	2.4	0.37	23952	3.33	0	0.00	100%	23952	100%
2017-01-03 0:45	19.7	18.2	1.69	181636	6.65	0	0.00	100%	181636	100%
2017-01-10 6:35	23.1	16.4	6.42	163672	13.31	49235	3.22	76%	114437	70%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2017-01-11 22:00	14.6	15.8	0.85	157684	19.96	97276	13.76	31%	60408	38%
2017-01-13 6:05	2.8	3.2	0.73	31936	6.65	0	0.00	100%	31936	100%
2017-01-17 2:40	30.4	12.6	3.74	125748	13.31	19720	3.85	71%	106028	84%
2017-01-23 2:05	6.6	2.8	4.71	27944	3.33	0	0.00	100%	27944	100%
2017-01-25 18:15	8.4	2.0	2.40	19960	3.33	0	0.00	100%	19960	100%
2017-02-07 4:55	21.8	17.0	12.09	169660	9.98	3370	0.75	93%	166290	98%
2017-02-18 12:40	4.9	N/A	10.60	N/A	N/A	2064	0.24	N/A	N/A	N/A
2017-02-24 6:55	2.0	2.2	16.36	21956	6.65	0	0.00	100%	21956	100%
2017-02-24 18:45	13.6	12.4	0.41	123752	19.96	1431	1.10	94%	122321	99%
2017-02-28 20:30	13.6	22.0	3.51	219560	16.63	4968	1.92	88%	214592	98%
2017-03-07 0:30	21.1	8.4	5.60	83832	6.65	0	0.00	100%	83832	100%
2017-03-24 4:20	0.6	2.2	16.28	21956	9.98	0	0.00	100%	21956	100%
2017-03-25 0:20	10.7	4.0	0.81	39920	6.65	0	0.00	100%	39920	100%
2017-03-26 21:10	16.7	4.8	1.42	47904	3.33	0	0.00	100%	47904	100%
2017-03-30 15:50	27.9	16.8	3.08	167664	9.98	0	0.00	100%	167664	100%
2017-04-03 20:50	16.1	19.4	3.05	193612	9.98	667	1.01	90%	192945	100%
2017-04-06 9:15	17.1	30.8	1.85	307385	9.98	13437	1.50	85%	293948	96%
2017-04-10 21:10	1.5	3.0	3.78	29940	16.63	0	0.00	100%	29940	100%
2017-04-15 8:00	6.7	5.0	4.39	49900	6.65	0	0.00	100%	49900	100%
2017-04-20 8:55	16.4	25.6	4.76	255489	13.31	2906	0.59	96%	252583	99%
2017-04-27 17:20	1.3	3.4	6.67	33932	9.98	0	0.00	100%	33932	100%
2017-04-30 16:20	9.8	17.4	2.90	173652	19.96	0	0.00	100%	173652	100%
2017-05-01 9:20	8.9	14.0	0.30	139720	16.63	15959	3.72	78%	123762	89%
2017-05-04 12:45	57.2	37.4	2.89	373253	6.65	26116	0.44	93%	347137	93%
2017-05-21 6:15	16.0	23.0	14.35	229540	33.27	4457	2.61	92%	225083	98%
2017-05-24 21:20	30.0	39.6	2.96	395208	9.98	9146	1.20	88%	386062	98%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2017-06-04 4:50	3.6	6.4	9.06	63872	6.65	0	0.00	100%	63872	100%
2017-06-16 19:00	2.9	5.4	12.44	53892	19.96	0	0.00	100%	53892	100%
2017-06-17 9:30	4.7	6.0	0.48	59880	49.90	0	0.00	100%	59880	100%
2017-06-18 7:15	5.4	4.0	0.71	39920	36.59	540	1.50	96%	39380	99%
2017-06-22 10:25	1.0	2.6	3.91	25948	9.98	0	0.00	100%	25948	100%
2017-06-22 22:45	12.1	37.6	0.47	375248	53.23	28891	5.18	90%	346357	92%
2017-06-29 0:35	9.9	5.2	5.58	51896	9.98	0	0.00	100%	51896	100%
2017-06-30 3:45	3.4	7.6	0.72	75848	36.59	2643	2.85	92%	73205	97%
2017-07-12 12:05	3.2	5.0	12.20	49900	36.59	188	0.37	99%	49712	100%
2017-07-13 22:50	2.0	13.0	1.32	129740	56.55	124	0.18	100%	129616	100%
2017-07-20 9:30	2.3	13.4	6.36	133732	56.55	2801	2.73	95%	130931	98%
2017-07-26 18:30	14.6	6.6	6.32	65868	6.65	0	0.00	100%	65868	100%
2017-07-31 15:15	0.6	3.6	4.26	35928	33.27	0	0.00	100%	35928	100%
2017-08-01 13:45	0.8	8.2	0.91	81836	99.80	936	2.15	98%	80900	99%
2017-08-04 0:20	6.0	3.0	2.43	29940	16.63	0	0.00	100%	29940	100%
2017-08-04 14:55	2.7	17.8	0.36	177644	83.17	3845	2.85	97%	173799	98%
2017-08-12 13:20	1.5	3.8	7.86	37924	26.61	0	0.00	100%	37924	100%
2017-08-17 13:20	7.2	13.6	4.94	135728	23.29	506	0.75	97%	135222	100%
2017-08-22 8:20	4.8	16.2	4.49	161676	86.49	1415	2.49	97%	160261	99%
2017-08-31 0:40	1.8	3.8	8.49	37924	9.98	0	0.00	100%	37924	100%
2017-09-03 2:05	3.2	9.6	2.98	95808	9.98	5	0.02	100%	95803	100%
2017-09-04 17:50	2.4	10.4	1.52	103792	56.55	380	0.66	99%	103413	100%
2017-09-05 12:30	0.7	4.2	0.68	41916	59.88	78	0.18	100%	41838	100%
2017-09-07 13:25	3.3	1.2	2.03	11976	6.65	0	0.00	100%	11976	100%

Table D-1b: Hydrologic Summary of Rainfall Events for WW-2

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2016-01-08 20:10	21.1	4.8	2.45	108134	18.97	7529	0.67	96%	100604	93%
2016-01-10 3:20	36.2	5.8	0.86	130899	18.97	187825	9.69	49%	-56926	-43%
2016-01-15 21:05	6.8	5.0	3.60	113825	18.97	2624	0.47	98%	111201	98%
2016-01-18 7:00	5.7	19.3	2.13	438226	75.90	0	0.00	100%	438226	100%
2016-01-31 16:20	2.2	2.5	13.15	56913	37.95	3715	1.60	96%	53198	93%
2016-02-02 21:00	31.2	8.4	2.10	191226	30.36	26667	1.47	95%	164559	86%
2016-02-16 5:00	7.7	5.0	12.03	113825	18.97	0	0.00	100%	113825	100%
2016-02-19 22:45	6.1	2.3	3.42	51221	18.97	16093	2.04	89%	35128	69%
2016-02-24 7:55	50.3	31.5	4.13	717098	56.92	213208	5.79	90%	503889	70%
2016-03-10 9:10	12.6	4.0	12.95	91060	30.36	5663	0.68	98%	85397	94%
2016-03-14 1:25	73.4	17.4	3.15	396111	45.54	88085	5.00	89%	308026	78%
2016-03-22 17:40	3.2	2.6	5.62	59189	30.36	3604	0.98	97%	55585	94%
2016-03-23 15:10	70.6	23.8	0.76	541807	91.08	196033	7.07	92%	345774	64%
2016-03-28 0:45	32.7	18.0	1.46	409770	91.08	132291	9.16	90%	277479	68%
2016-03-31 2:30	44.2	32.8	1.71	746692	121.44	285617	16.49	86%	461076	62%
2016-04-03 6:25	2.6	9.2	1.32	209438	45.54	0	0.00	100%	209438	100%
2016-04-03 17:05	25.8	10.4	1.77	236756	15.18	8497	0.97	94%	228259	96%
2016-04-06 9:15	57.3	13.8	1.60	314157	258.06	202968	4.15	98%	111189	35%
2016-04-10 20:00	63.7	11.4	2.06	259521	151.80	95647	4.96	97%	163874	63%
2016-08-16 1:35	31.2	14.6	20.66	332369	121.44	97248	11.31	91%	235121	71%
2016-08-20 0:55	11.5	2.2	1.11	50083	30.36	12561	3.38	89%	37522	75%
2016-08-25 0:35	3.3	11.0	4.51	250415	212.52	45212	37.65	82%	205203	82%
2016-08-25 15:50	16.8	15.2	0.50	346028	318.78	46399	18.37	94%	299629	87%
2016-09-07 21:10	33.3	17.2	12.52	391558	303.60	195704	98.61	68%	195854	50%
2016-09-17 4:55	12.1	7.0	7.94	159355	60.72	25198	8.54	86%	134157	84%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2016-09-26 10:40	7.1	7.2	8.74	163908	60.72	38591	12.59	79%	125317	76%
2016-09-29 8:40	15.4	11.6	2.62	264074	45.54	68608	6.85	85%	195467	74%
2016-10-01 7:35	19.9	4.2	1.31	95613	45.54	10990	2.08	95%	84623	89%
2016-10-02 11:05	9.1	2.2	0.32	50083	30.36	21473	15.57	49%	28610	57%
2016-10-08 5:20	2.9	5.4	5.38	122931	75.90	20728	9.31	88%	102203	83%
2016-10-20 2:15	40.2	18.2	11.75	414323	30.36	77083	4.21	86%	337240	81%
2016-10-26 23:50	38.6	8.8	5.23	200332	30.36	36037	4.12	86%	164295	82%
2016-11-02 14:55	44.3	34.6	5.02	787669	106.26	274017	21.09	80%	513652	65%
2016-12-06 17:55	11.3	3.4	1.35	77401	15.18	4978	1.12	93%	72423	94%
2016-12-29 2:45	9.7	6.8	1.59	154802	15.18	0	0.00	100%	154802	100%
2017-01-16 20:50	49.8	12.6	18.35	286839	30.36	187330	18.42	39%	99509	35%
2017-04-06 0:40	1.3	0.6	N/A	13659	7.59	565	0.37	95%	13094	96%
2017-04-06 9:20	48.8	31.0	0.33	705716	22.77	413158	12.93	43%	292558	41%
2017-06-04 4:55	6.2	6.4	56.99	145696	15.18	17034	3.25	79%	128662	88%
2017-06-05 2:20	6.3	0.6	0.75	13659	15.18	472	0.44	97%	13187	97%
2017-06-06 6:15	1.0	0.4	1.06	9106	7.59	403	0.37	95%	8703	96%
2017-06-06 13:30	5.8	0.8	0.29	18212	15.18	2549	2.64	83%	15663	86%
2017-06-16 19:05	26.2	11.4	10.01	259521	113.85	21698	11.71	90%	237823	92%
2017-06-18 7:20	5.6	4.0	0.72	91060	83.49	21611	25.70	69%	69449	76%
2017-06-19 23:50	3.4	0.8	1.47	18212	15.18	2706	2.52	83%	15506	85%
2017-06-20 19:35	9.8	1.6	0.68	36424	7.59	3361	1.02	87%	33063	91%
2017-06-22 10:30	1.2	2.6	1.22	59189	22.77	4337	2.76	88%	54852	93%
2017-06-22 22:50	35.8	37.6	0.48	855964	121.44	368943	53.61	56%	487021	57%
2017-06-25 10:40	3.4	0.8	2.00	18212	30.36	5052	7.61	75%	13160	72%
2017-06-26 13:00	6.5	1.4	1.10	31871	37.95	742	0.13	100%	31129	98%
2017-06-29 0:40	65.4	14.8	2.42	336922	83.49	120519	67.65	19%	216403	64%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2017-07-12 12:05	5.1	5.0	10.91	113825	83.49	28172	17.27	79%	85653	75%
2017-07-13 7:40	7.6	1.6	0.68	36424	22.77	7771	6.93	70%	28653	79%
2017-07-13 22:55	6.3	13.0	0.52	295945	129.03	21032	17.95	86%	274913	93%
2017-07-20 9:35	20.9	13.4	6.37	305051	129.03	89719	47.50	63%	215332	71%
2017-07-26 18:35	25.3	6.6	6.33	150249	15.18	15880	3.51	77%	134369	89%
2017-07-31 15:15	5.8	4.0	4.26	91060	75.90	6428	8.31	89%	84632	93%
2017-08-01 13:50	21.1	8.4	0.92	191226	227.70	53977	59.79	74%	137250	72%
2017-08-03 14:20	16.1	3.2	1.15	72848	37.95	4672	3.00	92%	68176	94%
2017-08-04 15:00	24.3	17.8	0.36	405217	189.75	144628	62.51	67%	260589	64%
2017-08-11 18:30	9.8	1.4	7.08	31871	15.18	2738	1.21	92%	29133	91%
2017-08-12 13:25	6.1	3.8	0.66	86507	60.72	3434	2.76	95%	83073	96%
2017-08-15 2:25	2.6	1.8	2.48	40977	15.18	3839	2.17	86%	37139	91%
2017-08-17 13:25	13.5	13.8	2.42	314157	53.13	59178	25.15	53%	254979	81%
2017-08-22 8:25	14.7	16.2	4.23	368793	197.34	76719	50.25	75%	292074	79%
2017-08-31 0:40	4.1	3.8	8.49	86507	22.77	8338	2.88	87%	78169	90%
2017-09-03 2:05	5.5	9.6	2.99	218544	22.77	36436	6.27	72%	182108	83%
2017-09-04 17:25	7.7	10.4	1.51	236756	129.03	38854	31.39	76%	197902	84%
2017-09-05 12:30	3.3	4.2	0.69	95613	121.44	11464	16.15	87%	84149	88%
2017-09-07 13:25	3.8	1.2	2.03	27318	15.18	1709	1.73	89%	25609	94%
2017-09-29 8:15	13.4	3.0	21.65	68295	22.77	4375	1.12	95%	63920	94%
2017-10-04 9:00	8.8	6.6	4.84	150249	75.90	11272	4.97	93%	138977	92%
2017-10-07 2:20	4.3	1.6	2.38	36424	7.59	540	0.24	97%	35884	99%
2017-10-07 23:45	5.8	3.0	0.72	68295	22.77	12868	5.38	76%	55427	81%
2017-10-09 1:50	25.0	14.6	0.98	332369	30.36	98451	11.12	63%	233918	70%
2017-10-11 7:45	10.2	3.0	1.62	68295	15.18	4489	2.88	81%	63806	93%
2017-10-14 15:50	34.3	19.2	2.94	437088	113.85	67419	28.58	75%	369669	85%

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction	
									(L)	(%)
2017-10-23 16:15	13.2	9.2	7.96	209438	37.95	22530	4.16	89%	186908	89%
2017-10-28 5:55	8.7	4.0	4.06	91060	15.18	2535	0.37	98%	88525	97%
2017-11-01 15:00	23.8	14.8	4.02	336922	15.18	33366	4.29	72%	303556	90%
2017-11-02 21:45	26.9	3.4	0.30	77401	15.18	11603	2.29	85%	65798	85%
2017-11-04 20:10	44.6	16.6	1.62	377899	45.54	174123	19.59	57%	203776	54%
2017-11-15 18:35	7.5	3.6	9.82	81954	15.18	3245	0.93	94%	78709	96%
2017-11-18 4:20	46.0	21.6	2.13	491724	30.36	175421	8.31	73%	316303	64%
2017-11-25 20:05	1.3	0.6	6.59	13659	7.59	1325	1.21	84%	12334	90%
2017-11-30 12:35	5.8	2.4	4.68	54636	7.59	4041	1.73	77%	50595	93%
2017-12-04 22:25	24.9	9.0	4.20	204885	22.77	25026	3.13	86%	179859	88%
2017-12-18 14:15	7.3	6.6	13.22	150249	83.49	0	0.24	100%	150249	100%
2017-12-24 11:05	2.7	2.6	5.57	59189	7.59	0	0.18	98%	59189	100%

2. WATER QUALITY PERFORMANCE

Table D-2a: EMC Summary for All Events for WW-1

Starting Date and Time	Precipitation Depth (mm)	TSS (mg/L)	TP (mg/L)	PO_4 (mg/L)	NO_2+NO_3 (mg/L)	Al (µg/L)	Cu (µg/L)	Fe (µg/L)	Zn (µg/L)	Cl^- (mg/L)
2016-02-24 7:55	31.5	7.1	0.25	0.195	0.166	132	13.4	222	12.8	68.2
2016-03-31 2:30	32.8	15.6	0.218	0.213	0.2	245	10.3	309	20	65.9
2016-06-26 20:25	7.8	39.4	0.274	0.0197	0.12	310	13.1	806	71.1	13.1
2016-07-13 23:35	8.2	48.8	0.332	0.0198	0.171	449	11.3	627	65.2	12
2016-07-25 3:30	10.2	41.5	0.232	0.0315	0.438	393	11.6	642	79.6	16
2016-08-13 11:30	19.6	19.3	0.114	0.052	0.24	186	11.2	344	58.4	6.9
2016-08-16 1:35	14.6	4.7	0.044	0.0174	0.302	83.3	7.45	76.8	37.8	2.6
2016-08-25 0:35	11.0	25.6	0.095	0.0192	0.221	183	5.27	389	39.6	4.5
2016-08-25 15:50	15.2	6.5	0.053	0.0153	0.249	96.4	4.75	137	29.3	2
2016-09-07 21:15	17.2	37.7	0.515	0.402	0.663	259	19.9	461	48.6	5.2
2016-10-02 11:05	2.2	18.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2016-11-02 14:55	34.6	16.2	0.254	0.214	0.848	311	14.6	398	17.4	100
2017-01-10 6:35	16.4	10.1	0.284	0.254	0.599	175	23.6	268	22	522
2017-01-11 22:00	15.8	27.9	0.38	0.364	0.384	452	25.2	588	24.3	57.9
2017-01-17 2:40	12.6	12.9	0.3	0.214	0.263	246	14.9	347	18	164
2017-02-07 4:55	17.0	8.1	0.22	0.13	0.27	150	7.99	164	11.2	214
2017-02-24 18:45	12.4	41.7	0.288	0.189	0.436	N/A	N/A	N/A	N/A	93.9
2017-02-28 20:30	22.0	19.9	0.155	0.108	0.221	375	9.15	488	19.3	23
2017-04-20 8:55	25.6	14.2	0.3	0.253	1.64	296	18.3	337	26.8	31
2017-05-01 9:20	14.0	19.9	0.224	0.178	0.713	486	20.9	583	22.7	17.2
2017-05-24 21:20	39.6	9.6	0.186	0.156	0.931	194	8.86	232	24.6	4.9
2017-08-22 8:20	16.2	114	0.2	0.0803	0.316	951	13.6	1420	93.2	3.7
Count	22	22	21	21	21	20	20	20	20	21
Minimum	2.2	4.7	0.044	0.0153	0.12	83.3	4.75	76.8	11.2	2
25 Percentile	12.5	10.8	0.186	0.0315	0.221	181	9.08	259	19.8	5.2
Median	16.0	19.1	0.232	0.1560	0.302	253	12.4	368	25.7	17.2
75 Percentile	21.4	35.3	0.288	0.2140	0.599	380	15.8	584	51.1	68.2
Maximum	39.6	114	0.515	0.4020	1.64	951	25.2	1420	93.2	522
Mean	18.0	25.4	0.234	0.1488	0.447	299	13.3	442	37.1	68.0
Std. Deviation	9.48	23.7	0.109	0.1150	0.359	194	5.78	298	24.1	119

Table D-2b: EMC Summary for All Events for WW-2

Starting Date and Time	Precipitation Depth (mm)	TSS (mg/L)	TP (mg/L)	PO_4 (mg/L)	NO_2+NO_3 (mg/L)	Al (µg/L)	Cu (µg/L)	Fe (µg/L)	Zn (µg/L)	Cl^- (mg/L)
2016-02-24 7:55	31.5	70.7	0.12	0.0377	0.86	423	11.4	521	22.1	440
2016-03-31 2:30	32.8	19.3	0.163	0.174	0.583	303	14.3	307	22.8	122
2016-08-16 1:35	14.6	26.5	0.142	0.0764	0.488	358	10.8	386	32.3	9.5
2016-08-25 0:35	11.0	34.6	0.234	0.106	1.45	316	12.2	378	50.2	40.7
2016-08-25 15:50	15.2	12.1	0.123	0.0737	0.8	182	20.6	207	34.7	17.2
2016-09-17 4:55	7.0	14	0.198	0.0989	0.347	174	21.1	236	29.1	15.6
2016-09-26 10:40	7.2	32.8	0.236	0.0876	0.795	307	13	394	44.5	17.7
2016-09-29 8:40	11.6	11.8	0.128	0.0328	0.456	168	10.5	223	28.2	6.3
2016-11-02 14:55	34.6	32.3	0.176	0.213	0.665	347	15.2	411	24.8	26.4
2017-01-16 20:50	12.6	19.4	0.195	0.162	0.18	304	16.2	393	27.6	239
2017-06-04 04:55	6.4	14.9	0.11	0.0613	1.26	113	13.9	130	34.3	N/A
2017-07-20 09:35	13.4	33.9	0.146	0.0696	1.12	313	17.8	416	54.6	20.4
2017-08-17 13:25	13.8	40.7	0.131	0.0512	0.66	484	14.1	587	61.1	6.4
2017-08-22 08:25	16.2	50.8	0.15	0.0606	0.893	402	22.8	552	47.2	11.8
2017-10-04 09:00	6.6	31.3	0.146	0.0538	0.785	322	18	514	49.9	24.3
2017-10-23 16:15	9.2	12.4	0.108	0.051	0.534	230	9.09	342	29.3	34.5
2017-11-01 15:00	14.8	12.4	0.087	0.0298	0.948	172	5.68	295	20	10.5
2017-11-04 20:10	16.6	26	0.14	0.0861	1.77	314	7.94	419	24.3	14.9
Count	18	18	18	18	18	18	18	18	18	17
Minimum	6.4	11.8	0.087	0.0298	0.18	113	5.68	130	20	6.3
25 Percentile	9.7	14.2	0.124	0.0519	0.546	194	11.0	298	25.5	11.8
Median	13.6	26.3	0.144	0.0717	0.790	310	14.0	390	30.8	17.7
75 Percentile	16.0	33.6	0.173	0.0961	0.934	341	17.4	418	46.5	34.5
Maximum	34.6	70.7	0.236	0.213	1.77	484	22.8	587	61.1	440
Mean	15.3	27.6	0.152	0.0848	0.811	291	14.1	373	35.4	62.2
Std. Deviation	8.8	15.6	0.042	0.0507	0.396	99	4.67	125	12.6	113

Table D-3a: Water Quality Performance for Total Suspended Solids (TSS) for WW-1

Starting Date and Time	Precipitation Depth (mm)	TSS EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction (g)	(%)
2016-02-24 7:55	31.5	7.1	314370	14461.02	15853	112.56	14348.46	99%
2016-03-31 2:30	32.8	15.6	327344	15057.82	3899	60.82	14997.00	100%
2016-06-26 20:25	7.8	39.4	77844	3580.82	426	16.77	3564.05	100%
2016-07-13 23:35	8.2	48.8	81836	3764.46	4445	216.94	3547.52	94%
2016-07-25 3:30	10.2	41.5	101796	4682.62	1311	54.42	4628.20	99%
2016-08-13 11:30	19.6	19.3	195608	8997.97	3374	65.11	8932.86	99%
2016-08-16 1:35	14.6	4.7	145708	6702.57	685	3.22	6699.35	100%
2016-08-25 0:35	11.0	25.6	109780	5049.88	1490	38.13	5011.75	99%
2016-08-25 15:50	15.2	6.5	151696	6978.02	1373	8.92	6969.09	100%
2016-09-07 21:15	17.2	37.7	171656	7896.18	14477	545.76	7350.41	93%
2016-10-02 11:05	2.2	18.9	21956	1009.98	263	4.96	1005.01	100%
2016-11-02 14:55	34.6	16.2	345308	15884.17	15677	253.97	15630.19	98%
2017-01-10 6:35	16.4	10.1	163672	7528.91	49235	497.27	7031.64	93%
2017-01-11 22:00	15.8	27.9	157684	7253.46	97276	2714.00	4539.47	63%
2017-01-17 2:40	12.6	12.9	125748	5784.41	19720	254.38	5530.03	96%
2017-02-07 4:55	17.0	8.1	169660	7804.36	3370	27.30	7777.06	100%
2017-02-24 18:45	12.4	41.7	123752	5692.59	1431	59.69	5632.91	99%
2017-02-28 20:30	22.0	19.9	219560	10099.76	4968	98.86	10000.90	99%
2017-04-20 8:55	25.6	14.2	255489	11752.47	2906	41.26	11711.21	100%
2017-05-01 9:20	14.0	19.9	139720	6427.13	15959	317.57	6109.56	95%
2017-05-24 21:20	39.6	9.6	395208	18179.57	9146	87.81	18091.76	100%
2017-08-22 8:20	16.2	114	161676	7437.10	1415	161.29	7275.81	98%
Count	22	22	22	22	22	22	22	22
Minimum	2.2	4.7	21956	1009.98	263	3.22	1005.01	63%
25 Percentile	12.5	10.8	124251	5715.55	1419	38.91	5141.32	96%
Median	16.0	19.1	159680	7345.28	3636	76.46	7000.37	99%
75 Percentile	21.4	35.3	213572	9824.31	15377	244.71	9733.89	100%
Maximum	39.6	114	395208	18179.57	97276	2714.00	18091.76	100%
Mean	18.0	25.4	179867	8273.88	12213	256.41	8017.47	96%
Std. Deviation	9.5	23.7	94615	4352.31	21974	569.74	4411.22	8%

Table D-3b: Water Quality Performance for Total Suspended Solids (TSS) for WW-2

Starting Date and Time	Precipitation Depth (mm)	TSS EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	70.7	717098	32986.49	213208	15073.82	17912.67	54%
2016-03-31 2:30	32.8	19.3	746692	34347.84	285617	5512.40	28835.44	84%
2016-08-16 1:35	14.6	26.5	332369	15288.98	97248	2577.08	12711.90	83%
2016-08-25 0:35	11.0	34.6	250415	11519.09	45212	1564.35	9954.74	86%
2016-08-25 15:50	15.2	12.1	346028	15917.29	46399	561.42	15355.86	96%
2016-09-17 4:55	7.0	14	159355	7330.33	25198	352.77	6977.56	95%
2016-09-26 10:40	7.2	32.8	163908	7539.77	38591	1265.79	6273.98	83%
2016-09-29 8:40	11.6	11.8	264074	12147.41	68608	809.57	11337.84	93%
2016-11-02 14:55	34.6	32.3	787669	36232.78	274017	8850.74	27382.04	76%
2017-01-16 20:50	12.6	19.4	286839	13194.60	187330	3634.20	9560.40	72%
2017-06-04 4:55	6.4	14.9	145696	6702.02	17034	253.81	6448.21	96%
2017-07-20 9:35	13.4	33.9	305051	14032.35	89719	3041.49	10990.86	78%
2017-08-17 13:25	13.8	40.7	314157	14451.22	59178	2408.56	12042.67	83%
2017-08-22 8:25	16.2	50.8	368793	16964.48	76719	3897.35	13067.13	77%
2017-10-04 9:00	6.6	31.3	150249	6911.45	11272	352.81	6558.65	95%
2017-10-23 16:15	9.2	12.4	209438	9634.15	22530	279.37	9354.78	97%
2017-11-01 15:00	14.8	12.4	336922	15498.41	33366	413.74	15084.67	97%
2017-11-04 20:10	16.6	26	377899	17383.36	174123	4527.20	12856.16	74%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	11.8	145696	6702.02	11272	253.81	6273.98	54%
25 Percentile	9.7	14.2	219682	10105.38	34672	450.66	9406.18	77%
Median	13.6	26.3	309604	14241.79	63893	1986.45	11690.25	84%
75 Percentile	16.0	33.6	363102	16702.68	154904	3831.56	14580.29	95%
Maximum	34.6	70.7	787669	36232.78	285617	15073.82	28835.44	97%
Mean	15.3	27.6	347925	16004.56	98076	3076.47	12928.09	85%
Std. Deviation	8.8	15.6	200323	9214.87	88899	3770.99	6415.44	12%

Table D-4a: Water Quality Performance for Total Phosphorus (TP) for WW-1

Starting Date and Time	Precipitation Depth (mm)	TP EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	0.25	314370	81.74	15853	3.96	77.77	95%
2016-03-31 2:30	32.8	0.218	327344	85.11	3899	0.85	84.26	99%
2016-06-26 20:25	7.8	0.274	77844	20.24	426	0.12	20.12	99%
2016-07-13 23:35	8.2	0.332	81836	21.28	4445	1.48	19.80	93%
2016-07-25 3:30	10.2	0.232	101796	26.47	1311	0.30	26.16	99%
2016-08-13 11:30	19.6	0.114	195608	50.86	3374	0.38	50.47	99%
2016-08-16 1:35	14.6	0.044	145708	37.88	685	0.03	37.85	100%
2016-08-25 0:35	11.0	0.095	109780	28.54	1490	0.14	28.40	100%
2016-08-25 15:50	15.2	0.053	151696	39.44	1373	0.07	39.37	100%
2016-09-07 21:15	17.2	0.515	171656	44.63	14477	7.46	37.18	83%
2016-11-02 14:55	34.6	0.254	345308	89.78	15677	3.98	85.80	96%
2017-01-10 6:35	16.4	0.284	163672	42.55	49235	13.98	28.57	67%
2017-01-11 22:00	15.8	0.38	157684	41.00	97276	36.96	4.03	10%
2017-01-17 2:40	12.6	0.3	125748	32.69	19720	5.92	26.78	82%
2017-02-07 4:55	17.0	0.22	169660	44.11	3370	0.74	43.37	98%
2017-02-24 18:45	12.4	0.288	123752	32.18	1431	0.41	31.76	99%
2017-02-28 20:30	22.0	0.155	219560	57.09	4968	0.77	56.32	99%
2017-04-20 8:55	25.6	0.3	255489	66.43	2906	0.87	65.56	99%
2017-05-01 9:20	14.0	0.224	139720	36.33	15959	3.57	32.75	90%
2017-05-24 21:20	39.6	0.186	395208	102.75	9146	1.70	101.05	98%
2017-08-22 8:20	16.2	0.2	161676	42.04	1415	0.28	41.75	99%
Count	21	21	21	21	21	21	21	21
Minimum	7.8	0.044	77844	20.24	426	0.03	4.03	10%
25 Percentile	12.6	0.186	125748	32.69	1431	0.30	28.40	93%
Median	16.2	0.232	161676	42.04	3899	0.85	37.85	99%
75 Percentile	22.0	0.288	219560	57.09	15677	3.96	56.32	99%
Maximum	39.6	0.515	395208	102.75	97276	36.96	101.05	100%
Mean	18.8	0.234	187386	48.72	12783	4.00	44.72	91%
Std. Deviation	9.0	0.109	89964	23.39	22350	8.27	25.15	20%

Table D-4b: Water Quality Performance for Total Phosphorus (TP) for WW-2

Starting Date and Time	Precipitation Depth (mm)	TP EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction (g)	(%)
2016-02-24 7:55	31.5	0.0377	717098	186.45	213208	25.58	160.86	86%
2016-03-31 2:30	32.8	0.174	746692	194.14	285617	46.56	147.58	76%
2016-08-16 1:35	14.6	0.0764	332369	86.42	97248	13.81	72.61	84%
2016-08-25 0:35	11.0	0.106	250415	65.11	45212	10.58	54.53	84%
2016-08-25 15:50	15.2	0.0737	346028	89.97	46399	5.71	84.26	94%
2016-09-17 4:55	7.0	0.0989	159355	41.43	25198	4.99	36.44	88%
2016-09-26 10:40	7.2	0.0876	163908	42.62	38591	9.11	33.51	79%
2016-09-29 8:40	11.6	0.0328	264074	68.66	68608	8.78	59.88	87%
2016-11-02 14:55	34.6	0.213	787669	204.79	274017	48.23	156.57	76%
2017-01-16 20:50	12.6	0.162	286839	74.58	187330	36.53	38.05	51%
2017-06-04 4:55	6.4	0.0613	145696	37.88	17034	1.87	36.01	95%
2017-07-20 9:35	13.4	0.0696	305051	79.31	89719	13.10	66.21	83%
2017-08-17 13:25	13.8	0.0512	314157	81.68	59178	7.75	73.93	91%
2017-08-22 8:25	16.2	0.0606	368793	95.89	76719	11.51	84.38	88%
2017-10-04 9:00	6.6	0.0538	150249	39.06	11272	1.65	37.42	96%
2017-10-23 16:15	9.2	0.051	209438	54.45	22530	2.43	52.02	96%
2017-11-01 15:00	14.8	0.0298	336922	87.60	33366	2.90	84.70	97%
2017-11-04 20:10	16.6	0.0861	377899	98.25	174123	24.38	73.88	75%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	0.030	145696	37.88	11272	1.65	33.51	51%
25 Percentile	9.7	0.052	219682	57.12	34672	5.17	41.54	80%
Median	13.6	0.072	309604	80.50	63893	9.84	69.41	87%
75 Percentile	16.0	0.096	363102	94.41	154904	21.74	84.35	93%
Maximum	34.6	0.213	787669	204.79	285617	48.23	160.86	97%
Mean	15.3	0.085	347925	90.46	98076	15.30	75.16	85%
Std. Deviation	8.8	0.051	200323	52.08	88899	14.88	40.82	11%

Table D-5a: Water Quality Performance for Phosphate (PO_4) for WW-1

Starting Date and Time	Precipitation Depth (mm)	PO_4 EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction (g)	(%)
2016-02-24 7:55	31.5	0.195	314370	37.72	15853	3.09	34.63	92%
2016-03-31 2:30	32.8	0.213	327344	39.28	3899	0.83	38.45	98%
2016-06-26 20:25	7.8	0.0197	77844	9.34	426	0.01	9.33	100%
2016-07-13 23:35	8.2	0.0198	81836	9.82	4445	0.09	9.73	99%
2016-07-25 3:30	10.2	0.0315	101796	12.22	1311	0.04	12.17	100%
2016-08-13 11:30	19.6	0.052	195608	23.47	3374	0.18	23.3	99%
2016-08-16 1:35	14.6	0.0174	145708	17.48	685	0.01	17.47	100%
2016-08-25 0:35	11.0	0.0192	109780	13.17	1490	0.03	13.15	100%
2016-08-25 15:50	15.2	0.0153	151696	18.20	1373	0.02	18.18	100%
2016-09-07 21:15	17.2	0.402	171656	20.60	14477	5.82	14.78	72%
2016-11-02 14:55	34.6	0.214	345308	41.44	15677	3.35	38.08	92%
2017-01-10 6:35	16.4	0.254	163672	19.64	49235	12.51	7.14	36%
2017-01-11 22:00	15.8	0.364	157684	18.92	97276	35.41	-16.49	-87%
2017-01-17 2:40	12.6	0.214	125748	15.09	19720	4.22	10.87	72%
2017-02-07 4:55	17.0	0.13	169660	20.36	3370	0.44	19.92	98%
2017-02-24 18:45	12.4	0.189	123752	14.85	1431	0.27	14.58	98%
2017-02-28 20:30	22.0	0.108	219560	26.35	4968	0.54	25.81	98%
2017-04-20 8:55	25.6	0.253	255489	30.66	2906	0.74	29.92	98%
2017-05-01 9:20	14.0	0.178	139720	16.77	15959	2.84	13.93	83%
2017-05-24 21:20	39.6	0.156	395208	47.42	9146	1.43	46.00	97%
2017-08-22 8:20	16.2	0.0803	161676	19.40	1415	0.11	19.29	99%
Count	21	21	21	21	21	21	21	21
Minimum	7.8	0.0153	77844	9.34	426	0.01	-16.49	-87%
25 Percentile	12.6	0.0315	125748	15.09	1431	0.09	12.17	92%
Median	16.2	0.1560	161676	19.40	3899	0.54	17.47	98%
75 Percentile	22.0	0.2140	219560	26.35	15677	3.09	25.81	99%
Maximum	39.6	0.4020	395208	47.42	97276	35.41	46.00	100%
Mean	18.8	0.1488	187386	22.49	12783	3.43	19.06	83%
Std. Deviation	9.0	0.1150	89964	10.80	22350	7.90	13.59	42%

Table D-5b: Water Quality Performance for Phosphate (PO_4) for WW-2

Starting Date and Time	Precipitation Depth (mm)	PO_4 EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	0.0377	717098	86.05	213208	8.04	78.01	91%
2016-03-31 2:30	32.8	0.174	746692	89.60	285617	49.70	39.91	45%
2016-08-16 1:35	14.6	0.0764	332369	39.88	97248	7.43	32.45	81%
2016-08-25 0:35	11.0	0.106	250415	30.05	45212	4.79	25.26	84%
2016-08-25 15:50	15.2	0.0737	346028	41.52	46399	3.42	38.10	92%
2016-09-17 4:55	7.0	0.0989	159355	19.12	25198	2.49	16.6	87%
2016-09-26 10:40	7.2	0.0876	163908	19.67	38591	3.38	16.29	83%
2016-09-29 8:40	11.6	0.0328	264074	31.69	68608	2.25	29.44	93%
2016-11-02 14:55	34.6	0.213	787669	94.52	274017	58.37	36.15	38%
2017-01-16 20:50	12.6	0.162	286839	34.42	187330	30.35	4.07	12%
2017-06-04 4:55	6.4	0.0613	145696	17.48	17034	1.04	16.44	94%
2017-07-20 9:35	13.4	0.0696	305051	36.61	89719	6.24	30.36	83%
2017-08-17 13:25	13.8	0.0512	314157	37.70	59178	3.03	34.67	92%
2017-08-22 8:25	16.2	0.0606	368793	44.26	76719	4.65	39.61	89%
2017-10-04 9:00	6.6	0.0538	150249	18.03	11272	0.61	17.42	97%
2017-10-23 16:15	9.2	0.051	209438	25.13	22530	1.15	23.98	95%
2017-11-01 15:00	14.8	0.0298	336922	40.43	33366	0.99	39.44	98%
2017-11-04 20:10	16.6	0.0861	377899	45.35	174123	14.99	30.36	67%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	0.0298	145696	17.48	11272	0.61	4.07	12%
25 Percentile	9.7	0.0519	219682	26.36	34672	2.31	19.06	82%
Median	13.6	0.0717	309604	37.15	63893	4.03	30.36	88%
75 Percentile	16.0	0.0961	363102	43.57	154904	7.89	37.62	93%
Maximum	34.6	0.213	787669	94.52	285617	58.37	78.01	98%
Mean	15.3	0.0848	347925	41.75	98076	11.27	30.48	79%
Std. Deviation	8.8	0.0507	200323	24.04	88899	17.12	15.63	24%

Table D-6a: Water Quality Performance for Nitrite + Nitrate (NO_2 + NO_3) for WW-1

Starting Date and Time	Precipitation Depth (mm)	NO_2+NO_3 EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	0.166	314370	97.45	15853	2.63	94.82	97%
2016-03-31 2:30	32.8	0.2	327344	101.48	3899	0.78	100.70	99%
2016-06-26 20:25	7.8	0.12	77844	24.13	426	0.05	24.08	100%
2016-07-13 23:35	8.2	0.171	81836	25.37	4445	0.76	24.61	97%
2016-07-25 3:30	10.2	0.438	101796	31.56	1311	0.57	30.98	98%
2016-08-13 11:30	19.6	0.24	195608	60.64	3374	0.81	59.8	99%
2016-08-16 1:35	14.6	0.302	145708	45.17	685	0.21	44.96	100%
2016-08-25 0:35	11.0	0.221	109780	34.03	1490	0.33	33.70	99%
2016-08-25 15:50	15.2	0.249	151696	47.03	1373	0.34	46.68	99%
2016-09-07 21:15	17.2	0.663	171656	53.21	14477	9.60	43.62	82%
2016-11-02 14:55	34.6	0.848	345308	107.05	15677	13.29	93.75	88%
2017-01-10 6:35	16.4	0.599	163672	50.74	49235	29.49	21.25	42%
2017-01-11 22:00	15.8	0.384	157684	48.88	97276	37.35	11.53	24%
2017-01-17 2:40	12.6	0.263	125748	38.98	19720	5.19	33.80	87%
2017-02-07 4:55	17.0	0.27	169660	52.59	3370	0.91	51.68	98%
2017-02-24 18:45	12.4	0.436	123752	38.36	1431	0.62	37.74	98%
2017-02-28 20:30	22.0	0.221	219560	68.06	4968	1.10	66.97	98%
2017-04-20 8:55	25.6	1.64	255489	79.20	2906	4.77	74.44	94%
2017-05-01 9:20	14.0	0.713	139720	43.31	15959	11.38	31.93	74%
2017-05-24 21:20	39.6	0.931	395208	122.51	9146	8.52	114.00	93%
2017-08-22 8:20	16.2	0.316	161676	50.12	1415	0.45	49.67	99%
Count	21	21	21	21	21	21	21	21
Minimum	7.8	0.12	77844	24.13	426	0.05	11.53	24%
25 Percentile	12.6	0.221	125748	38.98	1431	0.57	31.93	88%
Median	16.2	0.302	161676	50.12	3899	0.91	44.96	98%
75 Percentile	22.0	0.599	219560	68.06	15677	8.52	66.97	99%
Maximum	39.6	1.64	395208	122.51	97276	37.35	114.00	100%
Mean	18.8	0.447	187386	58.09	12783	6.15	51.94	89%
Std. Deviation	9.0	0.359	89964	27.89	22350	10.01	28.78	20%

Table D-6b: Water Quality Performance for Nitrite + Nitrate ($NO_2 + NO_3$) for WW-2

Starting Date and Time	Precipitation Depth (mm)	NO_2+NO_3 EMC (mg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction (g)	(%)
2016-02-24 7:55	31.5	0.86	717098	222.30	213208	183.36	38.94	18%
2016-03-31 2:30	32.8	0.583	746692	231.47	285617	166.51	64.96	28%
2016-08-16 1:35	14.6	0.488	332369	103.03	97248	47.46	55.58	54%
2016-08-25 0:35	11.0	1.45	250415	77.63	45212	65.56	12.07	16%
2016-08-25 15:50	15.2	0.8	346028	107.27	46399	37.12	70.15	65%
2016-09-17 4:55	7.0	0.347	159355	49.40	25198	8.74	40.7	82%
2016-09-26 10:40	7.2	0.795	163908	50.81	38591	30.68	20.13	40%
2016-09-29 8:40	11.6	0.456	264074	81.86	68608	31.29	50.58	62%
2016-11-02 14:55	34.6	0.665	787669	244.18	274017	182.22	61.96	25%
2017-01-16 20:50	12.6	0.18	286839	88.92	187330	33.72	55.20	62%
2017-06-04 4:55	6.4	1.26	145696	45.17	17034	21.46	23.70	52%
2017-07-20 9:35	13.4	1.12	305051	94.57	89719	100.49	-5.92	-6%
2017-08-17 13:25	13.8	0.66	314157	97.39	59178	39.06	58.33	60%
2017-08-22 8:25	16.2	0.893	368793	114.33	76719	68.51	45.82	40%
2017-10-04 9:00	6.6	0.785	150249	46.58	11272	8.85	37.73	81%
2017-10-23 16:15	9.2	0.534	209438	64.93	22530	12.03	52.89	81%
2017-11-01 15:00	14.8	0.948	336922	104.45	33366	31.63	72.81	70%
2017-11-04 20:10	16.6	1.77	377899	117.15	174123	308.20	-191.05	-163%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	0.18	145696	45.17	11272	8.74	-191.05	-163%
25 Percentile	9.7	0.546	219682	68.10	34672	30.83	27.21	26%
Median	13.6	0.790	309604	95.98	63893	38.09	48.20	53%
75 Percentile	16.0	0.934	363102	112.56	154904	92.49	57.64	65%
Maximum	34.6	1.77	787669	244.18	285617	308.20	72.81	82%
Mean	15.3	0.811	347925	107.86	98076	76.49	31.36	37%
Std. Deviation	8.8	0.396	200323	62.10	88899	81.63	59.31	56%

Table D-7a: Water Quality Performance for Aluminum (Al) for WW-1

Starting Date and Time	Precipitation Depth (mm)	Al EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	132	314370	88.65	15853	2.09	86.56	98%
2016-03-31 2:30	32.8	245	327344	92.31	3899	0.96	91.36	99%
2016-06-26 20:25	7.8	310	77844	21.95	426	0.13	21.82	99%
2016-07-13 23:35	8.2	449	81836	23.08	4445	2.00	21.08	91%
2016-07-25 3:30	10.2	393	101796	28.71	1311	0.52	28.19	98%
2016-08-13 11:30	19.6	186	195608	55.16	3374	0.63	54.53	99%
2016-08-16 1:35	14.6	83.3	145708	41.09	685	0.06	41.03	100%
2016-08-25 0:35	11.0	183	109780	30.96	1490	0.27	30.69	99%
2016-08-25 15:50	15.2	96.4	151696	42.78	1373	0.13	42.65	100%
2016-09-07 21:15	17.2	259	171656	48.41	14477	3.75	44.66	92%
2016-11-02 14:55	34.6	311	345308	97.38	15677	4.88	92.50	95%
2017-01-10 6:35	16.4	175	163672	46.16	49235	8.62	37.54	81%
2017-01-11 22:00	15.8	452	157684	44.47	97276	43.97	0.50	1%
2017-01-17 2:40	12.6	246	125748	35.46	19720	4.85	30.61	86%
2017-02-07 4:55	17.0	150	169660	47.84	3370	0.51	47.34	99%
2017-02-28 20:30	22.0	375	219560	61.92	4968	1.86	60.05	97%
2017-04-20 8:55	25.6	296	255489	72.05	2906	0.86	71.19	99%
2017-05-01 9:20	14.0	486	139720	39.40	15959	7.76	31.65	80%
2017-05-24 21:20	39.6	194	395208	111.45	9146	1.77	109.67	98%
2017-08-22 8:20	16.2	951	161676	45.59	1415	1.35	44.25	97%
Count	20	20	20	20	20	20	20	20
Minimum	7.8	83.3	77844	21.95	425.7	0.06	0.50	1%
25 Percentile	13.7	181	136227	38.42	1471	0.51	30.67	92%
Median	16.3	253	162674	45.87	4172	1.56	43.45	98%
75 Percentile	22.9	380	228542	64.45	15721	4.02	62.84	99%
Maximum	39.6	951	395208	111.45	97276	43.97	109.67	100%
Mean	19.1	299	190568	53.74	13350	4.35	49.39	90%
Std. Deviation	9.1	194	91081	25.68	22775	9.65	28.08	22%

Table D-7b: Water Quality Performance for Aluminum (Al) for WW-2

Starting Date and Time	Precipitation Depth (mm)	Al EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	423	717098	202.22	213208	90.19	112.03	55%
2016-03-31 2:30	32.8	303	746692	210.57	285617	86.54	124.03	59%
2016-08-16 1:35	14.6	358	332369	93.73	97248	34.81	58.91	63%
2016-08-25 0:35	11.0	316	250415	70.62	45212	14.29	56.33	80%
2016-08-25 15:50	15.2	182	346028	97.58	46399	8.44	89.14	91%
2016-09-17 4:55	7.0	174	159355	44.94	25198	4.38	40.55	90%
2016-09-26 10:40	7.2	307	163908	46.22	38591	11.85	34.37	74%
2016-09-29 8:40	11.6	168	264074	74.47	68608	11.53	62.94	85%
2016-11-02 14:55	34.6	347	787669	222.12	274017	95.08	127.04	57%
2017-01-16 20:50	12.6	304	286839	80.89	187330	56.95	23.94	30%
2017-06-04 4:55	6.4	113	145696	41.09	17034	1.92	39.16	95%
2017-07-20 9:35	13.4	313	305051	86.02	89719	28.08	57.94	67%
2017-08-17 13:25	13.8	484	314157	88.59	59178	28.64	59.95	68%
2017-08-22 8:25	16.2	402	368793	104.00	76719	30.84	73.16	70%
2017-10-04 9:00	6.6	322	150249	42.37	11272	3.63	38.74	91%
2017-10-23 16:15	9.2	230	209438	59.06	22530	5.18	53.88	91%
2017-11-01 15:00	14.8	172	336922	95.01	33366	5.74	89.27	94%
2017-11-04 20:10	16.6	314	377899	106.57	174123	54.67	51.89	49%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	113	145696	41.09	11272	1.92	23.94	30%
25 Percentile	9.7	194	219682	61.95	34672	6.42	43.39	60%
Median	13.6	310	309604	87.31	63893	21.18	58.43	72%
75 Percentile	16.0	341	363102	102.39	154904	49.71	85.14	91%
Maximum	34.6	484	787669	222.12	285617	95.08	127.04	95%
Mean	15.3	291	347925	98.11	98076	31.82	66.29	73%
Std. Deviation	8.8	99	200323	56.49	88899	31.70	30.50	19%

Table D-8a: Water Quality Performance for Copper (Cu) for WW-1

Starting Date and Time	Precipitation Depth (mm)	Cu EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	13.4	314370	5.03	15853	0.21	4.82	96%
2016-03-31 2:30	32.8	10.3	327344	5.24	3899	0.04	5.20	99%
2016-06-26 20:25	7.8	13.1	77844	1.25	426	0.01	1.24	100%
2016-07-13 23:35	8.2	11.3	81836	1.31	4445	0.05	1.26	96%
2016-07-25 3:30	10.2	11.6	101796	1.63	1311	0.02	1.61	99%
2016-08-13 11:30	19.6	11.2	195608	3.13	3374	0.04	3.09	99%
2016-08-16 1:35	14.6	7.45	145708	2.33	685	0.01	2.33	100%
2016-08-25 0:35	11.0	5.27	109780	1.76	1490	0.01	1.75	100%
2016-08-25 15:50	15.2	4.75	151696	2.43	1373	0.01	2.42	100%
2016-09-07 21:15	17.2	19.9	171656	2.75	14477	0.29	2.46	90%
2016-11-02 14:55	34.6	14.6	345308	5.52	15677	0.23	5.30	96%
2017-01-10 6:35	16.4	23.6	163672	2.62	49235	1.16	1.46	56%
2017-01-11 22:00	15.8	25.2	157684	2.52	97276	2.45	0.07	3%
2017-01-17 2:40	12.6	14.9	125748	2.01	19720	0.29	1.72	85%
2017-02-07 4:55	17.0	7.99	169660	2.71	3370	0.03	2.69	99%
2017-02-28 20:30	22.0	9.15	219560	3.51	4968	0.05	3.47	99%
2017-04-20 8:55	25.6	18.3	255489	4.09	2906	0.05	4.03	99%
2017-05-01 9:20	14.0	20.9	139720	2.24	15959	0.33	1.90	85%
2017-05-24 21:20	39.6	8.86	395208	6.32	9146	0.08	6.24	99%
2017-08-22 8:20	16.2	13.6	161676	2.59	1415	0.02	2.57	99%
Count	20	20	20	20	20	20	20	20
Minimum	7.8	4.75	77844	1.25	426	0.01	0.07	3%
25 Percentile	13.7	9.08	136227	2.18	1471	0.02	1.69	94%
Median	16.3	12.4	162674	2.60	4172	0.05	2.44	99%
75 Percentile	22.9	15.8	228542	3.66	15721	0.24	3.61	99%
Maximum	39.6	25.2	395208	6.32	97276	2.45	6.24	100%
Mean	19.1	13.3	190568	3.05	13350	0.27	2.78	90%
Std. Deviation	9.1	5.78	91081	1.46	22775	0.58	1.61	23%

Table D-8b: Water Quality Performance for Copper (Cu) for WW-2

Starting Date and Time	Precipitation Depth (mm)	Cu EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	11.4	717098	11.47	213208	2.43	9.04	79%
2016-03-31 2:30	32.8	14.3	746692	11.95	285617	4.08	7.86	66%
2016-08-16 1:35	14.6	10.8	332369	5.32	97248	1.05	4.27	80%
2016-08-25 0:35	11.0	12.2	250415	4.01	45212	0.55	3.46	86%
2016-08-25 15:50	15.2	20.6	346028	5.54	46399	0.96	4.58	83%
2016-09-17 4:55	7.0	21.1	159355	2.55	25198	0.53	2.02	79%
2016-09-26 10:40	7.2	13	163908	2.62	38591	0.50	2.12	81%
2016-09-29 8:40	11.6	10.5	264074	4.23	68608	0.72	3.50	83%
2016-11-02 14:55	34.6	15.2	787669	12.60	274017	4.17	8.44	67%
2017-01-16 20:50	12.6	16.2	286839	4.59	187330	3.03	1.55	34%
2017-06-04 4:55	6.4	13.9	145696	2.33	17034	0.24	2.09	90%
2017-07-20 9:35	13.4	17.8	305051	4.88	89719	1.60	3.28	67%
2017-08-17 13:25	13.8	14.1	314157	5.03	59178	0.83	4.19	83%
2017-08-22 8:25	16.2	22.8	368793	5.90	76719	1.75	4.15	70%
2017-10-04 9:00	6.6	18	150249	2.40	11272	0.20	2.20	92%
2017-10-23 16:15	9.2	9.09	209438	3.35	22530	0.20	3.15	94%
2017-11-01 15:00	14.8	5.68	336922	5.39	33366	0.19	5.20	96%
2017-11-04 20:10	16.6	7.94	377899	6.05	174123	1.38	4.66	77%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	5.68	145696	2.33	11272	0.19	1.55	34%
25 Percentile	9.7	11.0	219682	3.51	34672	0.51	2.44	72%
Median	13.6	14.0	309604	4.95	63893	0.90	3.83	81%
75 Percentile	16.0	17.4	363102	5.81	154904	1.71	4.64	86%
Maximum	34.6	22.8	787669	12.60	285617	4.17	9.04	96%
Mean	15.3	14.1	347925	5.57	98076	1.36	4.21	78%
Std. Deviation	8.8	4.67	200323	3.21	88899	1.28	2.22	14%

Table D-9a: Water Quality Performance for Iron (Fe) for WW-1

Starting Date and Time	Precipitation Depth (mm)	Fe EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	222	314370	170.39	15853	3.52	166.87	98%
2016-03-31 2:30	32.8	309	327344	177.42	3899	1.20	176.22	99%
2016-06-26 20:25	7.8	806	77844	42.19	426	0.34	41.85	99%
2016-07-13 23:35	8.2	627	81836	44.36	4445	2.79	41.57	94%
2016-07-25 3:30	10.2	642	101796	55.17	1311	0.84	54.33	98%
2016-08-13 11:30	19.6	344	195608	106.02	3374	1.16	104.86	99%
2016-08-16 1:35	14.6	76.8	145708	78.97	685	0.05	78.92	100%
2016-08-25 0:35	11.0	389	109780	59.50	1490	0.58	58.92	99%
2016-08-25 15:50	15.2	137	151696	82.22	1373	0.19	82.03	100%
2016-09-07 21:15	17.2	461	171656	93.04	14477	6.67	86.36	93%
2016-11-02 14:55	34.6	398	345308	187.16	15677	6.24	180.92	97%
2017-01-10 6:35	16.4	268	163672	88.71	49235	13.19	75.52	85%
2017-01-11 22:00	15.8	588	157684	85.46	97276	57.20	28.27	33%
2017-01-17 2:40	12.6	347	125748	68.16	19720	6.84	61.31	90%
2017-02-07 4:55	17.0	164	169660	91.96	3370	0.55	91.40	99%
2017-02-28 20:30	22.0	488	219560	119.00	4968	2.42	116.58	98%
2017-04-20 8:55	25.6	337	255489	138.47	2906	0.98	137.50	99%
2017-05-01 9:20	14.0	583	139720	75.73	15959	9.30	66.42	88%
2017-05-24 21:20	39.6	232	395208	214.20	9146	2.12	212.08	99%
2017-08-22 8:20	16.2	1420	161676	87.63	1415	2.01	85.62	98%
Count	20	20	20	20	20	20	20	20
Minimum	7.8	76.8	77844	42.19	426	0.05	28.27	33%
25 Percentile	13.7	259	136227	73.84	1471	0.78	60.71	93%
Median	16.3	368	162674	88.17	4172	2.07	83.83	98%
75 Percentile	22.9	584	228542	123.87	15721	6.35	121.81	99%
Maximum	39.6	1420	395208	214.20	97276	57.20	212.08	100%
Mean	19.1	442	190568	103.29	13350	5.91	97.38	93%
Std. Deviation	9.1	298	91081	49.37	22775	12.57	51.87	15%

Table D-9b: Water Quality Performance for Iron (Fe) for WW-2

Starting Date and Time	Precipitation Depth (mm)	Fe EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	521	717098	388.67	213208	111.08	277.59	71%
2016-03-31 2:30	32.8	307	746692	404.71	285617	87.68	317.02	78%
2016-08-16 1:35	14.6	386	332369	180.14	97248	37.54	142.61	79%
2016-08-25 0:35	11.0	378	250415	135.72	45212	17.09	118.63	87%
2016-08-25 15:50	15.2	207	346028	187.55	46399	9.60	177.94	95%
2016-09-17 4:55	7.0	236	159355	86.37	25198	5.95	80.42	93%
2016-09-26 10:40	7.2	394	163908	88.84	38591	15.20	73.63	83%
2016-09-29 8:40	11.6	223	264074	143.13	68608	15.30	127.83	89%
2016-11-02 14:55	34.6	411	787669	426.92	274017	112.62	314.30	74%
2017-01-16 20:50	12.6	393	286839	155.47	187330	73.62	81.85	53%
2017-06-04 4:55	6.4	130	145696	78.97	17034	2.21	76.75	97%
2017-07-20 9:35	13.4	416	305051	165.34	89719	37.32	128.01	77%
2017-08-17 13:25	13.8	587	314157	170.27	59178	34.74	135.54	80%
2017-08-22 8:25	16.2	552	368793	199.89	76719	42.35	157.54	79%
2017-10-04 9:00	6.6	514	150249	81.43	11272	5.79	75.64	93%
2017-10-23 16:15	9.2	342	209438	113.52	22530	7.71	105.81	93%
2017-11-01 15:00	14.8	295	336922	182.61	33366	9.84	172.77	95%
2017-11-04 20:10	16.6	419	377899	204.82	174123	72.96	131.86	64%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	130	145696	78.97	11272	2.21	73.63	53%
25 Percentile	9.7	298	219682	119.07	34672	9.66	87.84	78%
Median	13.6	390	309604	167.81	63893	25.91	129.94	81%
75 Percentile	16.0	418	363102	196.80	154904	65.31	168.96	93%
Maximum	34.6	587	787669	426.92	285617	112.62	317.02	97%
Mean	15.3	373	347925	188.58	98076	38.81	149.76	82%
Std. Deviation	8.8	125	200323	108.58	88899	36.96	77.93	12%

Table D-10a: Water Quality Performance for Zinc (Zn) for WW-1

Starting Date and Time	Precipitation Depth	Zn EMC	Total Estimated Influent Volume	Total Estimated Influent Load	Total Measured Effluent Volume	Total Measured Effluent Load	Estimated Pollutant Load Reduction	
	(mm)	(µg/L)	(L)	(g)	(L)	(g)	(g)	(%)
2016-02-24 7:55	31.5	12.8	314370	21.66	15853	0.20	21.46	99%
2016-03-31 2:30	32.8	20	327344	22.55	3899	0.08	22.48	100%
2016-06-26 20:25	7.8	71.1	77844	5.36	426	0.03	5.33	99%
2016-07-13 23:35	8.2	65.2	81836	5.64	4445	0.29	5.35	95%
2016-07-25 3:30	10.2	79.6	101796	7.01	1311	0.10	6.91	99%
2016-08-13 11:30	19.6	58.4	195608	13.48	3374	0.20	13.28	99%
2016-08-16 1:35	14.6	37.8	145708	10.04	685	0.03	10.01	100%
2016-08-25 0:35	11.0	39.6	109780	7.56	1490	0.06	7.50	99%
2016-08-25 15:50	15.2	29.3	151696	10.45	1373	0.04	10.41	100%
2016-09-07 21:15	17.2	48.6	171656	11.83	14477	0.70	11.12	94%
2016-11-02 14:55	34.6	17.4	345308	23.79	15677	0.27	23.52	99%
2017-01-10 6:35	16.4	22	163672	11.28	49235	1.08	10.19	90%
2017-01-11 22:00	15.8	24.3	157684	10.86	97276	2.36	8.50	78%
2017-01-17 2:40	12.6	18	125748	8.66	19720	0.35	8.31	96%
2017-02-07 4:55	17.0	11.2	169660	11.69	3370	0.04	11.65	100%
2017-02-28 20:30	22.0	19.3	219560	15.13	4968	0.10	15.03	99%
2017-04-20 8:55	25.6	26.8	255489	17.60	2906	0.08	17.53	100%
2017-05-01 9:20	14.0	22.7	139720	9.63	15959	0.36	9.26	96%
2017-05-24 21:20	39.6	24.6	395208	27.23	9146	0.23	27.00	99%
2017-08-22 8:20	16.2	93.2	161676	11.14	1415	0.13	11.01	99%
Count	20	20	20	20	20	20	20	20
Minimum	7.8	11.2	77844	5.36	426	0.03	5.33	78%
25 Percentile	13.7	19.8	136227	9.39	1471	0.07	8.45	96%
Median	16.3	25.7	162674	11.21	4172	0.16	10.71	99%
75 Percentile	22.9	51.1	228542	15.75	15721	0.31	15.66	99%
Maximum	39.6	93.2	395208	27.23	97276	2.36	27.00	100%
Mean	19.1	37.1	190568	13.13	13350	0.34	12.79	97%
Std. Deviation	9.1	24.1	91081	6.28	22775	0.54	6.35	5%

Table D-10b: Water Quality Performance for Zinc (Zn) for WW-2

Starting Date and Time	Precipitation Depth (mm)	Zn EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction	
							(g)	(%)
2016-02-24 7:55	31.5	22.1	717098	49.41	213208	4.71	44.70	90%
2016-03-31 2:30	32.8	22.8	746692	51.45	285617	6.51	44.94	87%
2016-08-16 1:35	14.6	32.3	332369	22.90	97248	3.14	19.76	86%
2016-08-25 0:35	11.0	50.2	250415	17.25	45212	2.27	14.98	87%
2016-08-25 15:50	15.2	34.7	346028	23.84	46399	1.61	22.23	93%
2016-09-17 4:55	7.0	29.1	159355	10.98	25198	0.73	10.25	93%
2016-09-26 10:40	7.2	44.5	163908	11.29	38591	1.72	9.58	85%
2016-09-29 8:40	11.6	28.2	264074	18.19	68608	1.93	16.26	89%
2016-11-02 14:55	34.6	24.8	787669	54.27	274017	6.80	47.47	87%
2017-01-16 20:50	12.6	27.6	286839	19.76	187330	5.17	14.59	74%
2017-06-04 4:55	6.4	34.3	145696	10.04	17034	0.58	9.45	94%
2017-07-20 9:35	13.4	54.6	305051	21.02	89719	4.90	16.12	77%
2017-08-17 13:25	13.8	61.1	314157	21.65	59178	3.62	18.03	83%
2017-08-22 8:25	16.2	47.2	368793	25.41	76719	3.62	21.79	86%
2017-10-04 9:00	6.6	49.9	150249	10.35	11272	0.56	9.79	95%
2017-10-23 16:15	9.2	29.3	209438	14.43	22530	0.66	13.77	95%
2017-11-01 15:00	14.8	20	336922	23.21	33366	0.67	22.55	97%
2017-11-04 20:10	16.6	24.3	377899	26.04	174123	4.23	21.81	84%
Count	18	18	18	18	18	18	18	18
Minimum	6.4	20	145696	10.04	11272	0.56	9.45	74%
25 Percentile	9.7	25.5	219682	15.14	34672	0.95	13.98	85%
Median	13.6	30.8	309604	21.33	63893	2.71	17.14	87%
75 Percentile	16.0	46.5	363102	25.02	154904	4.59	22.12	93%
Maximum	34.6	61.1	787669	54.27	285617	6.80	47.47	97%
Mean	15.3	35.4	347925	23.97	98076	2.97	21.00	88%
Std. Deviation	8.8	12.6	200323	13.80	88899	2.08	12.20	6%

Table D-11a: Water Quality Performance for Chloride (Cl^-) for WW-1

Starting Date and Time	Precipitation Depth (mm)	Cl^- EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction (g)	(%)
2016-02-24 7:55	31.5	68.2	314370	3772.44	15853	1081.19	2691.25	71%
2016-03-31 2:30	32.8	65.9	327344	3928.13	3899	256.93	3671.20	93%
2016-06-26 20:25	7.8	13.1	77844	934.13	426	5.58	928.55	99%
2016-07-13 23:35	8.2	12	81836	982.03	4445	53.34	928.69	95%
2016-07-25 3:30	10.2	16	101796	1221.55	1311	20.98	1200.57	98%
2016-08-13 11:30	19.6	6.9	195608	2347.30	3374	23.28	2324.02	99%
2016-08-16 1:35	14.6	2.6	145708	1748.50	685	1.78	1746.71	100%
2016-08-25 0:35	11.0	4.5	109780	1317.36	1490	6.70	1310.66	99%
2016-08-25 15:50	15.2	2	151696	1820.35	1373	2.75	1817.61	100%
2016-09-07 21:15	17.2	5.2	171656	2059.87	14477	75.28	1984.59	96%
2016-11-02 14:55	34.6	100	345308	4143.70	15677	1567.74	2575.96	62%
2017-01-10 6:35	16.4	522	163672	1964.06	49235	25700.57	-23736.50	-1209%
2017-01-11 22:00	15.8	57.9	157684	1892.21	97276	5632.27	-3740.07	-198%
2017-01-17 2:40	12.6	164	125748	1508.98	19720	3234.01	-1725.04	-114%
2017-02-07 4:55	17.0	214	169660	2035.92	3370	721.22	1314.70	65%
2017-02-24 18:45	12.4	93.9	123752	1485.02	1431	134.40	1350.62	91%
2017-02-28 20:30	22.0	23	219560	2634.72	4968	114.26	2520.46	96%
2017-04-20 8:55	25.6	31	255489	3065.86	2906	90.07	2975.79	97%
2017-05-01 9:20	14.0	17.2	139720	1676.64	15959	274.49	1402.16	84%
2017-05-24 21:20	39.6	4.9	395208	4742.50	9146	44.82	4697.68	99%
2017-08-22 8:20	16.2	3.7	161676	1940.11	1415	5.23	1934.88	100%
Count	21	21	21	21	21	21	21	21
Minimum	7.8	2	77844	934.13	426	1.78	-23736.50	-1209%
25 Percentile	12.6	5.2	125748	1508.98	1431	20.98	1200.57	71%
Median	16.2	17.2	161676	1940.11	3899	90.07	1746.71	96%
75 Percentile	22.0	68.2	219560	2634.72	15677	721.22	2520.46	99%
Maximum	39.6	522	395208	4742.50	97276	25700.57	4697.68	100%
Mean	18.8	68.0	187386	2248.64	12783	1859.38	389.26	6%
Std. Deviation	9.0	119	89964	1079.57	22350	5632.21	5795.15	289%

Table D-11b: Water Quality Performance for Chloride (Cl^-) for WW-2

Starting Date and Time	Precipitation Depth (mm)	Cl^- EMC (µg/L)	Total Estimated Influent Volume (L)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (L)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction (g)	(%)
2016-02-24 7:55	31.5	440	717098	8605.17	213208	93811.61	-85206.44	-990%
2016-03-31 2:30	32.8	122	746692	8960.31	285617	34845.21	-25884.91	-289%
2016-08-16 1:35	14.6	9.5	332369	3988.43	97248	923.86	3064.57	77%
2016-08-25 0:35	11.0	40.7	250415	3004.98	45212	1840.15	1164.83	39%
2016-08-25 15:50	15.2	17.2	346028	4152.34	46399	798.06	3354.28	81%
2016-09-17 4:55	7.0	15.6	159355	1912.26	25198	393.09	1519.17	79%
2016-09-26 10:40	7.2	17.7	163908	1966.90	38591	683.06	1283.83	65%
2016-09-29 8:40	11.6	6.3	264074	3168.89	68608	432.23	2736.66	86%
2016-11-02 14:55	34.6	26.4	787669	9452.03	274017	7234.04	2217.99	23%
2017-01-16 20:50	12.6	239	286839	3442.07	187330	44771.81	-41329.74	-1201%
2017-07-20 9:35	13.4	20.4	305051	3660.61	89719	1830.27	1830.34	50%
2017-08-17 13:25	13.8	6.4	314157	3769.88	59178	378.74	3391.14	90%
2017-08-22 8:25	16.2	11.8	368793	4425.52	76719	905.29	3520.23	80%
2017-10-04 9:00	6.6	24.3	150249	1802.99	11272	273.90	1529.08	85%
2017-10-23 16:15	9.2	34.5	209438	2513.26	22530	777.28	1735.98	69%
2017-11-01 15:00	14.8	10.5	336922	4043.06	33366	350.35	3692.72	91%
2017-11-04 20:10	16.6	14.9	377899	4534.79	174123	2594.43	1940.36	43%
Count	17	17	17	17	17	17	17	17
Minimum	6.6	6.3	150249	1802.99	11272	273.90	-85206.44	-1201%
25 Percentile	11.0	11.8	250415	3004.98	38591	432.23	1283.83	39%
Median	13.8	17.7	314157	3769.88	68608	905.29	1830.34	69%
75 Percentile	16.2	34.5	368793	4425.52	174123	2594.43	3064.57	81%
Maximum	34.6	440	787669	9452.03	285617	93811.61	3692.72	91%
Mean	15.8	62.2	359821	4317.85	102843	11343.73	-7025.88	-89%
Std. Deviation	8.8	113	199828	2397.93	89232	24876.72	23568.39	391%

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

Technical Report

Monitoring Results (2016-2017)

Appendix E

Site Maintenance and Inspection Log

A brief description of maintenance activities for Wychwood is provided along with the inspection logs used by CVC monitoring staff for site inspections.

1. BIORETENTION MAINTENANCE

The primary maintenance objective for bioretention practices is to keep vegetation healthy, remove sediments and trash, and ensure that the facility is draining properly (i.e. inlets and outlets can accept flow). The growing medium may need to be replaced to maintain performance. Typical recommended maintenance activities for bioretention cells include the following[1]:

- Inspect the infiltrating surface at least twice annually following precipitation events to determine if the bioretention area is providing acceptable infiltration. If standing water persists for more than 24 hours after runoff has ceased, clogging should be further investigated and remedied. Additionally, check for erosion and repair as necessary.
- Remove debris and litter from the infiltrating surface to minimize clogging of the media. Remove debris and litter from the overflow structure.
- Maintain healthy, weed-free vegetation. Weeds should be removed before they flower. The frequency of weeding will depend on the planting scheme and cover. When the growing media is covered with mulch or densely vegetated, less frequent weeding will be required.
- Replace mulch (wood recommended) only when needed to maintain a mulch depth of up to approximately 75 mm.
- If ponded water is observed in a bioretention cell more than 24 hours after the end of a runoff event, check underdrain outfall locations and clean-outs for blockages. Maintenance activities to restore infiltration capacity of bioretention facilities will vary with the degree and nature of the clogging.
    - If clogging is primarily related to sediment accumulation on the filter surface, infiltration may be improved by removing excess accumulated sediment and scarifying the surface of the filter with a rake.

If clogging is due to migration of sediments deeper into the pore space of the media, removal, safe disposal and replacement of all or a portion of the media may be required. The frequency of media replacement will depend on site-specific pollutant loading characteristics. Since bioretention technologies have only recently seen more widespread application, the frequency of media replacement has not yet been well established. Although the surface clogging of the media is expected over time, established root systems promote infiltration. This means that mature vegetation that covers the filter surface should increase the span of the growing media, serving to promote infiltration even as the media surface clogs.

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[1] Urban Drainage and Flood Control District (UDFCD). 2010. Urban Storm Drainage Criteria Manual, Volume 3.

2. PERMEABLE PAVEMENT MAINTENANCE

The key maintenance objective for a permeable pavement system is to know when runoff is no longer rapidly infiltrating into the surface, which is typically due to void spaces becoming clogged and requiring sediment removal. Inspect pavement condition and observe infiltration at least annually, either during a rain event or with a garden hose to ensure that water infiltrates into the surface. Video, photographs, or notes can be helpful in measuring loss of infiltration over time. Typical recommended maintenance activities for permeable pavement include:

- Debris should be removed, routinely, as a source control measure, and sweeping is recommended as a part of an ongoing maintenance program. This is frequently performed with a broom sweeper. Although this type of sweeper can be effective at removing solids and debris from the surface, it will not remove solids from the void space of permeable pavement. Use a vacuum or regenerative air sweeper to help maintain or restore infiltration. If the pavement has not been properly maintained, a vacuum sweeper will likely be needed.

- Use a regenerative air or vacuum sweeper after any significant site work (e.g., landscaping) and approximately twice per year to maintain infiltration rates. This should be done on a warm dry day for best results. Do not use water with the sweeper. The frequency is site specific and inspections of the pavement may show that biannual vacuuming is more frequent than necessary.

- In general, permeable pavements do not form ice to the same extent as conventional pavements. Because of this and the character of water drainage from permeable pavement surfaces, much less salt is required compared to asphalt surfaces. Simply stated, when water drains off of asphalt, salt can dissolve and become part of the solution and little to no residual salt granules remain. When water drains off of permeable pavement, it drains to the nearest permeable pavement joint, therefore there is less of an opportunity for the salt to dissolve, increasing the potential for salt granules to remain on the permeable pavement surface after the water has drained. Similarly conventional liquid treatments (deicers) will not stay at the surface of a permeable pavement as it can reduce infiltration. Plowing is the recommended snow removal process. Conventional plowing operations should not cause damage to the pavements. Deicers may be used; however, they may not be effective for the reason stated above. Sand should not be used. If sand is accidently used, use a vacuum sweeper to remove the sand.

- Permeable pavers, when installed correctly, should have a long service life. If a repair is required, it is frequently due to poor placement of the paver blocks. Follow industry guidelines for installation and replacement after underground repairs. If surface is completely clogged and rendering a minimal surface infiltration rate, restoration of surface infiltration can be achieved by removing the first 12-25 mm of soiled aggregate infill material with a vacuum sweeper. After cleaning, the openings between the pavers will need to be refilled with clean aggregate infill materials. Replacement of the infill is best accomplished with push brooms.

3. OIL AND GRIT SEPARATOR MAINTENANCE

The Wychwood neighbourhood uses several oil and grit separators (OGS) to treat stormwater by using gravity to remove particles that may settle and phase separator to remove buoyant materials. These features are not designed to provide quantity control, and as such are used in combination with other LID features at Wychwood that provide quantity control.

Due to their design and purpose, these sorts of features may require more frequent maintenance to ensure they are functioning optimally. Maintenance for OGS units may include the following:

- Inspection of the unit, looking for clogging and structural integrity
    - Routine inspections are suggested to assess sediment accumulation from the site. A maintenance plan should be developed to future inspect the feature to ensure performance.
- Cleanout of the feature; this is completed from the ground surface by using a vacuum truck to remove sediment.

For detailed procedure explanations, refer to the manufactuer's instructions, such as Imbrium's Stormceptor Owner's Manual, and the Stormceptor Technical Manual.

4. DOCUMENTATION OF MAINTENANCE ACTIVITIES AND COSTS

Because of the significance of maintenance over the life of a facility, in terms of performance, appearance and cost, and the fact that documentation of actual maintenance costs for bioretention facilities is lacking in the region (and across most of North America), documentation of maintenance is a critical component of the stormwater monitoring that is being conducted at Wychwood. To document maintenance, CVC will evaluate and note maintenance needs during site visits and will coordinate with those responsible for performing maintenance and repair to maintain a record of maintenance activities and costs. The following data collection efforts will aid in characterizing maintenance requirements and costs:

- Take photos from reference locations every time an inspection checklist is completed (biweekly in the spring, summer, and fall, monthly in winter) and before and after maintenance.
- Keep logs of site visits, inspections and maintenance dates, activities performed, observations and associated costs.
- Look for common issues and maintenance tasks associated with LID such as trash accumulation, sediment deposition, erosion, and vegetation health to watch for changes over time.
- Inspect different areas of the LID feature such as the drainage area, inlets, outlets, and vegetation, to ensure nothing is overlooked and that the site can perform optimally.
- Outline any maintenance issues that need to be addressed and whether they are urgent or routine so that the appropriate actions can take place.
- Monitor the duration of standing water in the bioswale periodically. As the duration of standing water grows longer, it will be a sign that infiltration capacity is reduced and maintenance may be needed.

5. SITE MAINTENANCE AND INSPECTION LOG

Below is the checklist templates used by monitoring staff to note maintenance needs during routine site visits. A photo log is also kept to supplement this information.

LID Inspection Checklist

Site: Wychwood

Inspector: ___________________________

Date: ________________________________

Site Characteristics:

Wychwood	
Drainage Area	Wychwood-Eastern Drainage Area
LID Features	Permeable Pavers, Bioswale, CB OGS
Date and Type of Last Precipitation	Date:________________ Type:__________

Bioswale Facility:

Category: **Notes:**

Fairmount close inlet - Coach Horse Court inlet

% of Trash/Debris Present 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

% of Erosion 0% --- 5% --- 10% --- 15% --- 20% +

% Exposed Soil 0% --- 5% --- 10% --- 15% --- 20% +

Bypass CB

Is outlet clear and able to accept overflow? Yes or No (if No Explain)

Coach Horse Court inlet-Rolled Curb

% of Trash/Debris Present 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

% of Erosion 0% --- 5% --- 10% --- 15% --- 20% +

% Exposed Soil 0% --- 5% --- 10% --- 15% --- 20% +

Bypass CB

Is outlet clear and able to accept overflow? Yes or No (if No Explain)

Rolled Curb Section

% of Trash/Debris Present 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

% of Erosion 0% --- 5% --- 10% --- 15% --- 20% +

% Exposed Soil 0% --- 5% --- 10% --- 15% --- 20% +

Vegetation (changes seasonally):

% Vegetation Cover: 0% --- 25% --- 50% --- 75% --- 100%

% Dead Vegetation: 0% --- 5% --- 10% --- 15% --- 20% +

Inlets:

Inlets (Fairmount Close

Inlet):

% of Trash/Debris Present 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

% of Erosion 0% --- 5% --- 10% --- 15% --- 20% +

Approx. depth of Ponding ____________________

Structural damage? Yes or No

Inlets (Coach Horse Court Inlet):

% of Trash/Debris Present 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

% of Erosion 0% --- 5% --- 10% --- 15% --- 20% +

Approx. depth of Ponding ______________________

Structural damage? Yes or No

Rolled Curb Inlet

% of Trash/Debris Present 0% --- 5% --- 10% --- 15% --- 20% +

% Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

0% --- 5% --- 10% --- 15% --- 20% +

% of Erosion

Approx. depth of Ponding ______________________

Structural Damage Yes or No

Rolled Curb Section Overflow:

% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +
% of Erosion	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No
Is outlet clear and able to accept overflow?	Yes or No

PERMEABLE PAVERS:

Permanent Stations (Driveways):

1) Honour Oak Cres#5

% vegetation in gaps	0% --- 5% --- 10% --- 15% --- 20% +
Area of broken/cracked/heaving pavers or curbs	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No
Evidence of Clogging	Yes or No

2) Coach House Court #16

% vegetation in gaps	0% --- 5% --- 10% --- 15% --- 20% +
Area of broken/cracked/heaving pavers or curbs	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +

Structural damage? Yes or No

Evidence of Clogging Yes or No

3) Fairmount Close #40

% vegetation in gaps 0% --- 5% --- 10% --- 15% --- 20% +

Area of broken/cracked/heaving pavers or curbs 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

Structural damage? Yes or No

Evidence of Clogging Yes or No

B) Rotating Stations: Driveways

Temporary 1: Address

% vegetation in gaps 0% --- 5% --- 10% --- 15% --- 20% +

Area of broken/cracked/heaving pavers or curbs 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation 0% --- 5% --- 10% --- 15% --- 20% +

Structural damage? Yes or No

Evidence of Clogging Yes or No

Temporary 2: Address

% vegetation in gaps 0% --- 5% --- 10% --- 15% --- 20% +

Area of broken/cracked/heaving pavers or curbs 0% --- 5% --- 10% --- 15% --- 20% +

% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No
Evidence of Clogging	Yes or No

Temporary 3: Address ______________________

% vegetation in gaps	0% --- 5% --- 10% --- 15% --- 20% +
Area of broken/cracked/heaving pavers or curbs	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No
Evidence of Clogging	Yes or No

CB OGS ISTC 7

% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No

Non-LID Feature:

Sign on Site	Yes or No
Damage to Sign	Yes or No

Maintenance:

Is maintenance required?	Yes or No

What needs to be done? ____________________

How much time was spent on maintenance? _____________________

Regular maintenance, long-term maintenance _____________________ or emergency maintenance?

Who is responsible? ____________________

How often is regular maintenance done? ____________________

Site Comments:

6. ADDITIONAL MAINTENANCE AND INSPECTION RESULTS

Below are the additional results from the maintenance and inspection results for the 2016-2017 inspection period discussed in section 5.

Table E-1: Permeable Pavement Maintenance Survey Results

Feature	Attribute	Average Category	% Good	%Mild	%Moderate	%Severe
Rotating Permeable Pavement - Driveways	Broken/Cracked/Heaving	Good	81%	17%	0%	2%
	Sediment	Mild	75%	23%	2%	0%
	Vegetation in Gaps	Good	85%	15%	0%	0%
Permanent Permeable Pavement - Driveways	Broken/Cracked/Heaving	Mild	69%	16%	0%	16%
	Sediment	Mild	66%	29%	5%	0%
	Vegetation in Gaps	Mild	72%	26%	2%	0%

***Examples for each ranking; a visual legend is included at the end of this Appendix.**

Table E-2: Bioswale Maintenance Survey Results

Feature	Attribute	Average Category	% Good	%Mild	%Moderate	%Severe
Bioswale section 1	Bare Soil	Mild	40%	20%	40%	0%
	Erosion	Mild	20%	70%	10%	0%
	Sediment	Good	90%	10%	0%	0%
	Trash/Debris	Good	50%	50%	0%	0%
Bioswale section 2	Bare Soil	Mild	30%	60%	10%	0%
	Erosion	Mild	40%	40%	20%	0%
	Sediment	Mild	60%	30%	10%	0%
	Trash/Debris	Good	70%	30%	0%	0%
Bioswale section 3	Bare Soil	Good	100%	0%	0%	0%
	Erosion	Mild	70%	30%	0%	0%
	Sediment	Mild	60%	40%	0%	0%
	Trash/Debris	Mild	50%	50%	0%	0%
Bioswale Inlet 1	Erosion	Mild	40%	60%	0%	0%
	Sediment	Severe	0%	50%	50%	0%
	Trash/Debris	Mild	50%	50%	0%	0%
Bioswale Inlet 2	Erosion	Mild	40%	60%	0%	0%
	Sediment	Moderate	0%	0%	20%	80%
	Trash/Debris	Mild	60%	30%	10%	0%
Bioswale Inlet 3	Erosion	Mild	60%	20%	20%	0%
	Sediment	Moderate	0%	40%	30%	30%
	Trash/Debris	Good	90%	10%	0%	0%
Vegetation	Dead Vegetation	Mild	67%	22%	11%	0%
	Vegetation Cover	Good	11%	89%	0%	0%

***Examples for each ranking; a visual legend is included at the end of this Appendix.**

Table E-3: Grass Swale Maintenance Survey Results

Feature	Attribute	Average Category	% Good	%Mild	%Moderate	%Severe
Grass Swale Section 1	Dead/Damaged Sod	Good	100%	0%	0%	0%
	Erosion	Good	100%	0%	0%	0%
	Sediment	Mild	60%	30%	0%	10%
	Trash/Debris	Good	100%	0%	0%	0%
Grass Swale Section 2	Dead/Damaged Sod	Good	90%	0%	0%	10%
	Erosion	Good	100%	0%	0%	0%
	Sediment	Mild	80%	20%	0%	0%
	Trash/Debris	Good	100%	0%	0%	0%
Grass Swale Section 3	Dead/Damaged Sod	Good	100%	0%	0%	0%
	Erosion	Good	100%	0%	0%	0%
	Sediment	Mild	70%	30%	0%	0%
	Trash/Debris	Good	90%	10%	0%	0%

***Examples for each ranking; a visual legend is included at the end of this Appendix.**

Table E-4: Rain Gardens Maintenance Survey Results

Feature	Component	Attribute	Average Category	% Good	%Mild	%Moderate	%Severe
Rain Garden 1	Facility	Erosion	Mild	60%	10%	20%	10%
		Sediment	Mild	70%	10%	10%	10%
		Trash/Debris	Good	90%	10%	0%	0%
	Vegetation	Dead Vegetation	Good	90%	0%	10%	0%
		Invasives/Weeds	Good	90%	10%	0%	0%
		Vegetation Cover	Good	60%	30%	0%	10%
	Overflow	Sediment	Moderate	10%	70%	10%	10%
		Trash/Debris	Mild	80%	10%	10%	0%
Rain Garden 2	Facility	Erosion	Moderate	40%	10%	10%	0%
		Sediment	Moderate	60%	0%	10%	30%
		Trash/Debris	Good	90%	10%	0%	0%
	Vegetation	Dead Vegetation	Good	90%	10%	0%	0%
		Invasives/Weeds	Mild	40%	20%	40%	0%
		Vegetation Cover	Moderate	10%	10%	50%	30%
	Overflow	Sediment	Moderate	20%	50%	10%	20%
		Trash/Debris	Mild	70%	20%	0%	10%

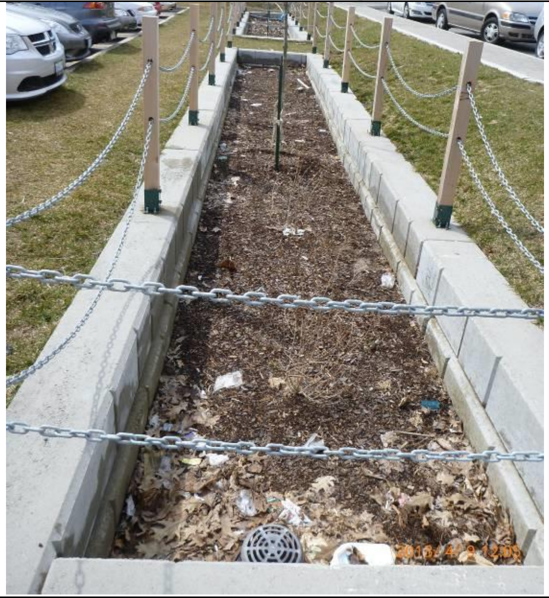
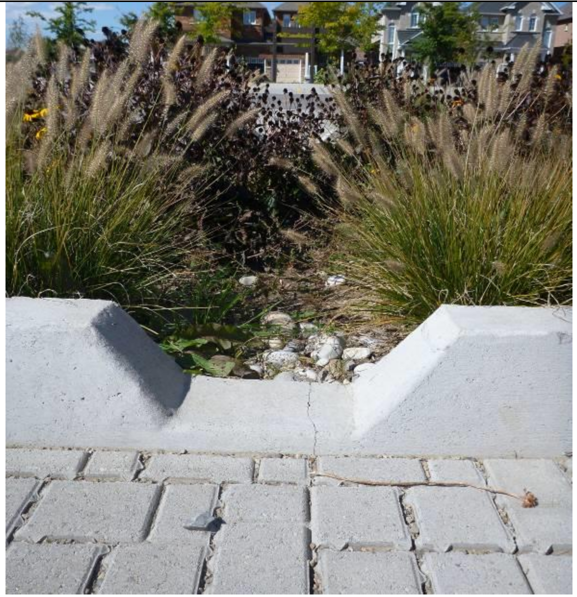
***Examples for each ranking; a visual legend is included at the end of this Appendix.**

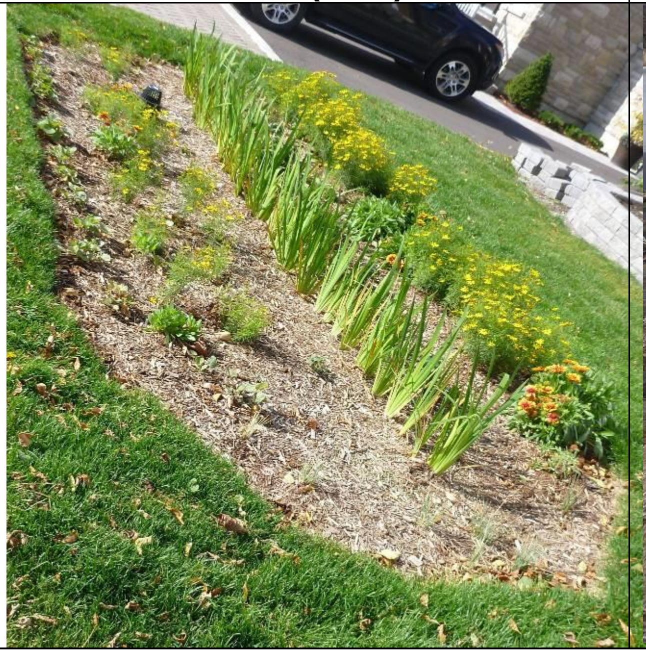
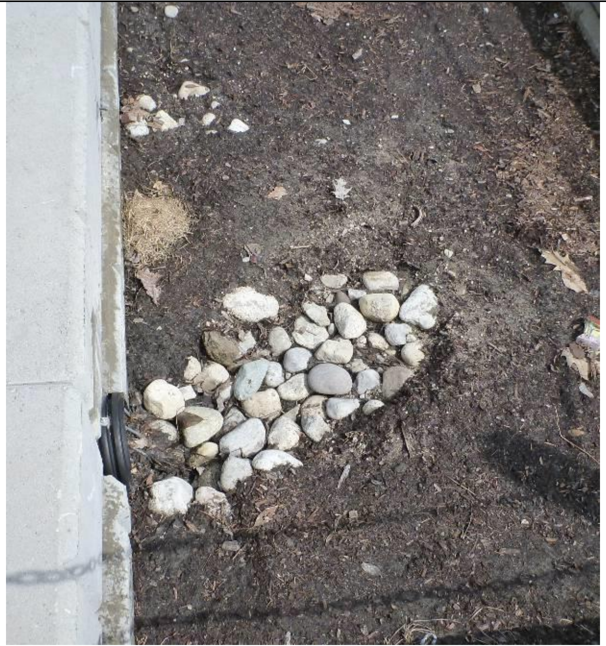
Table E-5: OGS Maintenance Survey Results

Feature	Attribute	Average Category	% Good	%Mild	%Moderate	%Severe
OGS 2	Sediment	Moderate	20%	40%	20%	20%
	Trash/Debris	Mild	60%	20%	0%	20%
OGS 3	Sediment	Mild	60%	30%	10%	0%
	Trash/Debris	Good	90%	10%	0%	0%
OGS 4	Sediment	Mild	56%	33%	0%	11%
	Trash/Debris	Good	89%	0%	0%	11%
OGS 5	Sediment	Moderate	0%	67%	0%	33%
	Trash/Debris	Mild	67%	0%	0%	33%
OGS 6	Sediment	Moderate	0%	0%	67%	33%
	Trash/Debris	Mild	33%	0%	33%	33%
OGS 7	Sediment	Mild	40%	60%	0%	0%
	Trash/Debris	Good	100%	0%	0%	0%

***Examples for each ranking; a visual legend is included at the end of this Appendix.**

LID Inspection Checklist Legend

Trash and Debris			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			
Inlet Blockage			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			

<table>
<tr><th colspan="4">Erosion</th></tr>
<tr><th>Good (0-5%)</th><th>Mild (5-10%)</th><th>Moderate (10-20%)</th><th>Severe (+ 20%)</th></tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr><th colspan="4">Sediment Accumulation</th></tr>
<tr><th>Good (0-5%)</th><th>Mild (5-10%)</th><th>Moderate (10-15%)</th><th>Severe (+ 20%)</th></tr>
<tr>
<td></td>
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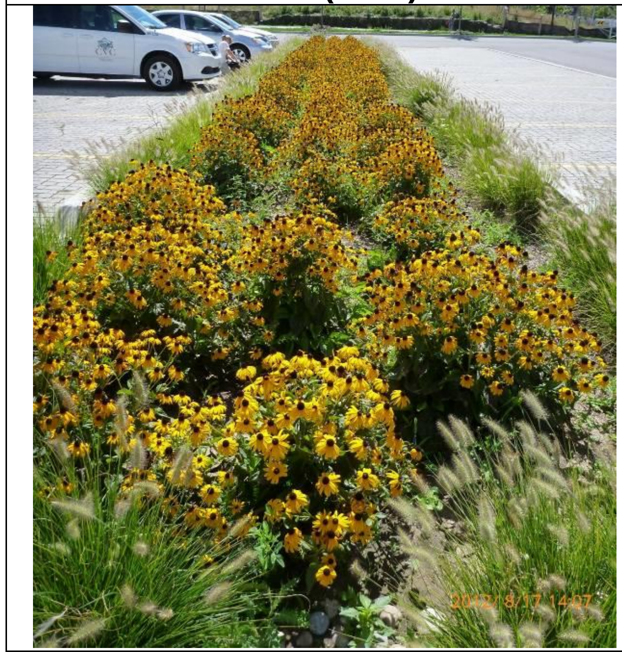
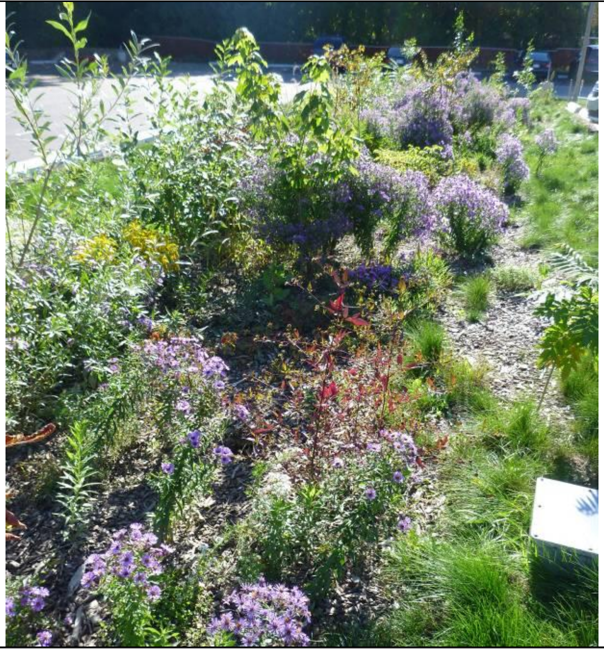
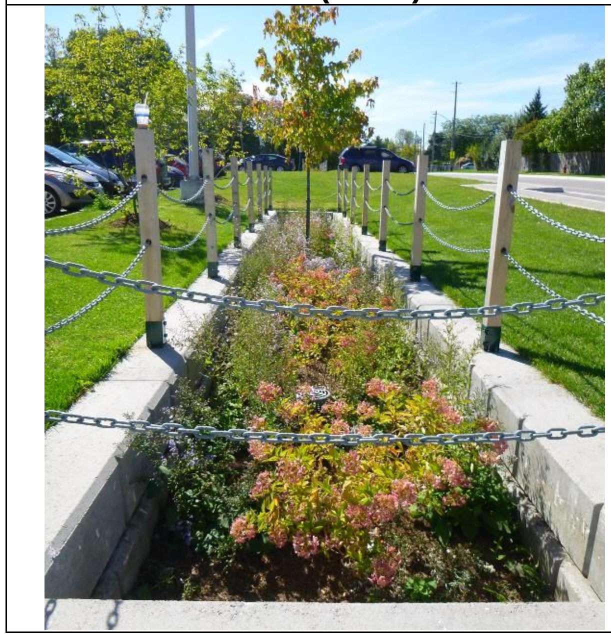
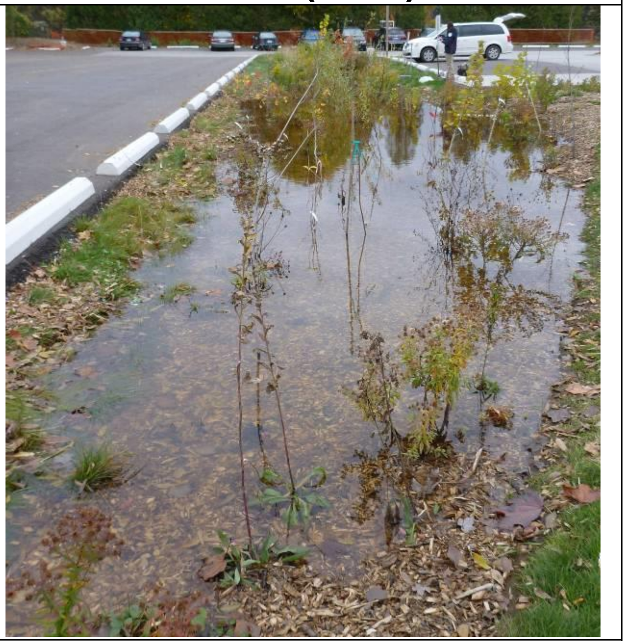
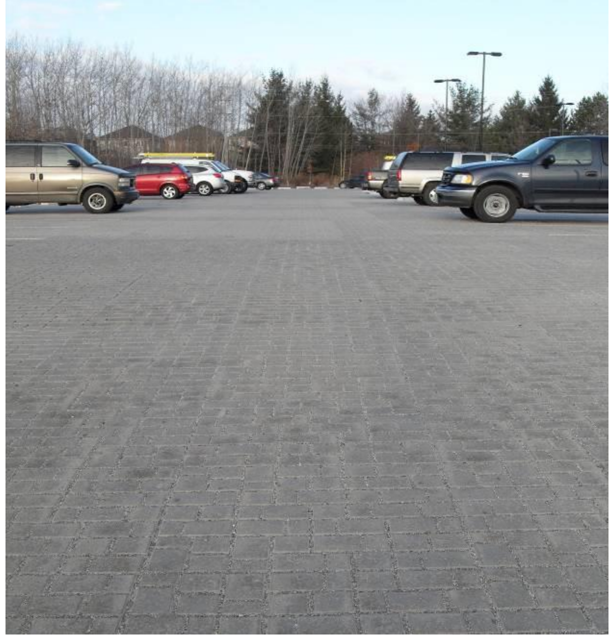
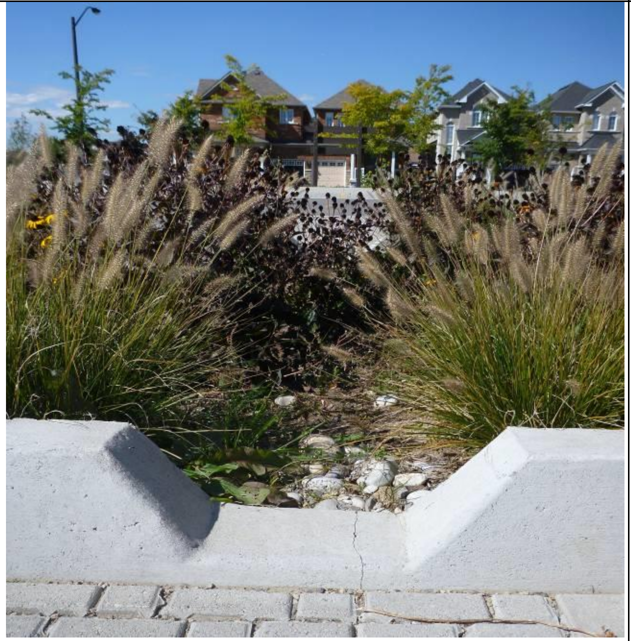
</tr>
</table>

Vegetation (Invasive/Weeds)			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			
Vegetation Cover			
Good (>75%)	**Mild (65-75%)**	**Moderate (50-65%)**	**Severe (0-50%)**
			

Ponding Area			
Good (0-5%)	Mild (5-10%)	Moderate (10-15%)	Severe (+ 20%)
			
Structural Damage			
Good (0%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+20%)**
			

Outlet Blockage			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

Technical Report

Monitoring Results (2016-2017)

Appendix F

Infiltration Test and Soil Quality Results

1.0 INFILTRATION ANALYSIS

1.1 Filter Media

Infiltration testing was completed in September 2014 across the length of the bioswale, using a double ring infiltrometer. The tests where preformed to determine if the bioswale, which had been heavily impacted by adjacent residential construction, needed to be remediated. A clay based sod was used within the invert section of the bioswale and the curbside inlets into the bioswale had not been managed by appropriate erosion and sediment control measures to protect the feature during construction. Two tests were performed adjacent to the curb inlets from the cul de sac and an additional measurement was taken near the catchbasin at the downstream end of the bioswale. The minimum infiltration rate requirement for bioretention soil is reported to be 25 mm/hr. However, a safety of factor of 2 is generally accounted for when designing LID sites which results in an infiltration rate to 50 mm/hr. Studies show that in-field measured infiltration rates for bioretention soil range from 80-120 mm/hr. For an application such as Wychwood where there is no stormwater management pond, the bioswale should have an infiltration rate in the higher ranges to ensure adequate drainage of the site

Double ring infiltration tests are conducted by hammering the rings into the soil to an equal depth. Water is poured into both the inner and outer rings, and the rate at which the water level in the inner ring decreases is tracked (such as every 30 seconds, or several minutes, depending on soil type). This continues until the infiltration rate has reached a constant value, which is calculated as the difference in water level between a given time interval.

1.2 Results

The results from the three infiltration tests are summarized in the table below. A fourth test was conducted, however it was not included as there was a major leak around the double ring. Infiltration tests confirmed the belief that the bioswale had not been protected during construction due to the infiltration rates. As a result of the infiltration tests, some sections of the bioswale were remediated by the developer.

Table F-1: Infiltration Testing Summary

Material	Threshold (mm/hr)	Average Rate (mm/hr)	Range (mm/hr)	Number of Tests
Bioretention filter media	> 25	44	12 – 60	3

2.0 Soil Analysis

Presented below are the tabular results for soil samples collecte din 2016. Refer to the report for discussion.

Table F-2: Bioretention inorganics soil sampling results, 2016

Parameter	**Units**	**Detection Limit**	**CCME Guideline (Residential/Parkland)**	**MOE Guideline (Shallow soil, Not Potable, Residential/Parkland/Institutional /Coarse Texture)**	**Rain Garden**	**Rain Garden**	**Grass Swale**	**Grass Swale**	**Bioswale 1 (Shallow)**	**Bioswale 1 (Deep)**	**Bioswale 2 (Shallow)**	**Bioswale 2 (Deep)**
					WW-RG-1-S	**WW-RG-1-D**	**WW-GS-1-S**	**WW-GS-1-D**	**WW-BS-1-S**	**WW-BS-1-D**	**WW-BS-2-S**	**WW-BS-2-D**
Nitrite (N)	ug/g	0.5	*	*	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Orthophosphate (P)	ug/g	0.2	*	*	18	6.9	7.5	8.8	3/3.2 [a]	1.2	6.5	7.9
Total Organic Carbon	mg/kg	500	*	*	22000	17000	17000	32000	25000	7100	13000	26000
Available (CaCl2) pH	pH	0	*	*	7/6.96 [a]	7.38	7.11	7.18	7.4	7.84	7.32	7.28
Conductivity	umho/cm	2	*	700	250	170	248	258	180/184 [a]	133	219	179
Moisture	%	1	*	*	21	18	20	24	12	9.5	18	20
Total Ammonia-N	ug/g	20	*	*	<20	<20	<20	36	<20	<20	<20	<20
Soluble (20:1) Chloride (Cl)	ug/g	20	*	*	36	32	70	83	<20	<20	51	<20
Nitrate + Nitrite (N)	ug/g	3	*	*	<3	<3	<3	<3	<3	<3	<3	<3
Nitrate (N)	ug/g	2	*	*	<2	<2	<2	<2	<2	<2	<2	<2
Total Kjeldahl Nitrogen	ug/g	10	*	*	1650	1950	2800	2700	1090	190	1960	2010

[a] Lab duplicate for specific parameter

Table F-3: Bioretention metals soil sampling results, 2016

Parameter	Units	Detection Limit	CCME Guideline (Residential/Parkland)	MOE Guideline (Shallow soil, Not Potable, Residential/Parkland/Institutional /Coarse Texture)	Rain Garden	Rain Garden	Grass Swale	Grass Swale	Bioswale 1 (Shallow)	Bioswale 1 (Deep)	Bioswale 2 (Shallow)	Bioswale 2 (Deep)
					WW-RG-1-S	WW-RG-1-D	WW-GS-1-S	WW-GS-1-D	WW-BS-1-S	WW-BS-1-D	WW-BS-2-S	WW-BS-2-D
Acid Extractable Aluminum (Al)	ug/g	50	*	*	1900	1700	2000	1800	7400	4300	1900	1700
Acid Extractable Chromium (Cr)	ug/g	1	64	160	4.5	4.1	4.2	4.6	12	7	4.4	4.5
Acid Extractable Cobalt (Co)	ug/g	2	50	22	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Acid Extractable Copper (Cu)	ug/g	2	63	140	8.5	6.8	7.5	11	20	14	8.9	11
Acid Extractable Iron (Fe)	ug/g	50	*	*	4800	4600	5300	4500	12000	9100	4800	4700
Acid Extractable Lead (Pb)	ug/g	5	140	120	<5.0	<5.0	<5.0	<5.0	12	5.6	<5.0	<5.0
Soluble Magnesium (Mg)	mg/L	0.5	*	*	5.5	2	2.1	1.9	1.7/1.7 [a]	1.3	1.4	1.2
Acid Extractable Magnesium (Mg)	ug/g	50	*	*	3300	3200	3400	3200	5800	6600	3100	3200
Acid Extractable Manganese (Mn)	ug/g	1	*	*	150	130	140	140	440	310	140	140
Acid Extractable Molybdenum (Mo)	ug/g	2.0	10	6.9	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Acid Extractable Nickel (Ni)	ug/g	5.0	45	100	<5.0	<5.0	<5.0	<5.0	11	6.8	<5.0	<5.0
Acid Extractable Phosphorus (P)	ug/g	20	*	*	530	530	650	680	720	390	490	610
Acid Extractable Potassium (K)	ug/g	200	*	*	440	340	320	350	1100	710	360	360
Acid Extractable Silver (Ag)	ug/g	1	20	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Soluble Sodium (Na)	mg/L	5	*	*	6	5	8	<5.0	11/12 [a]	15	11	<5.0
Acid Extractable Sodium (Na)	ug/g	100	*	*	110	110	110	110	150	170	110	110
Acid Extractable Strontium (Sr)	ug/g	1	*	*	140	140	150	140	89	98	140	150
Acid Extractable Sulphur (S)	ug/g	50	*	*	310	280	290	390	320	140	240	360
Acid Extractable Tin (Sn)	ug/g	20	50	*	<20	<20	<20	<20	<20	<20	<20	<20
Acid Extractable Vanadium (V)	ug/g	5	130	86	7.9	8.1	9.1	7.3	19	14	8.5	7.9
Acid Extractable Zinc (Zn)	ug/g	5	200	340	17	14	17	21	43	20	15	20
Acid Extractable Barium (Ba)	ug/g	2	500	390	15	13	12	15	42	25	12	15
Acid Extractable Beryllium (Be)	ug/g	0.5	4	4	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Acid Extractable Cadmium (Cd)	ug/g	0.5	10	1.2	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Soluble Calcium (Ca)	mg/L	0.5	*	*	32.7	26.7	36.5	43.6	24.8/25.1 [a]	15.8	28.3	34
Acid Extractable Calcium (Ca)	ug/g	50	*	*	99000	100000	100000	100000	63000	79000	97000	100000
Sodium Adsorption Ratio	N/A	0	*	5	0.26	0.26	0.34	0.2	0.59	0.97	0.56	0.23

[a] Lab duplicate for specific parameter

Table F-4: Bioretention PAHs soil sampling results, 2016

Parameter	Units	Detection Limit	CCME Guideline (Residential/Parkland)	MOE Guideline (Shallow soil, Not Potable, Residential/Parkland/Institutional /Coarse Texture)	Rain Garden	Rain Garden	Grass Swale	Grass Swale	Bioswale 1 (Shallow)	Bioswale 1 (Deep)	Bioswale 2 (Shallow)	Bioswale 2 (Deep)
					WW-RG-1-S	WW-RG-1-D	WW-GS-1-S	WW-GS-1-D	WW-BS-1-S	WW-BS-1-D	WW-BS-2-S	WW-BS-2-D
D10-Anthracene	%	-	*	*	101	104	100	99	101	102	100	101
D14-Terphenyl (FS)	%	-	*	*	99	105	102	98	103	109	104	102
D8-Acenaphthylene	%	-	*	*	101	104	100	99	101	99	101	100
Naphthalene	ug/g	0.005	0.6	0.6	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chrysene	ug/g	0.005	*	7	0.0073	0.017	0.015	0.016	<0.0050	<0.0050	0.007	0.016
Benzo(k)fluoranthene	ug/g	0.005	*	0.78	0.0058	0.012	0.013	0.012	<0.0050	<0.0050	0.0051	0.0079
Benzo(a)pyrene	ug/g	0.005	0.7	0.3	0.011	0.02	0.019	0.015	<0.0050	<0.0050	0.0086	0.012
Acenaphthylene	ug/g	0.005	*	0.15	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Indeno(1,2,3-cd)pyrene	ug/g	0.005	*	0.38	0.016	0.026	0.025	0.022	0.0078	<0.0050	0.014	0.018
Dibenz(a,h)anthracene	ug/g	0.005	*	0.1	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Benzo(g,h,i)perylene	ug/g	0.005	*	6.6	0.017	0.025	0.025	0.023	0.011	<0.0050	0.016	0.019
2-Methylnaphthalene	ug/g	0.005	*	0.99	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Acenaphthene	ug/g	0.005	*	7.9	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Benzo(b/j)fluoranthene	ug/g	0.005	*	0.78	0.027	0.042	0.046	0.044	0.014	<0.0050	0.026	0.036
Fluorene	ug/g	0.005	*	62	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
1-Methylnaphthalene	ug/g	0.005	*	0.99	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Benzo(a)anthracene	ug/g	0.005	*	0.5	<0.0050	0.011	0.011	0.0077	<0.0050	<0.0050	<0.0050	0.0075
Phenanthrene	ug/g	0.005	*	6.2	<0.0050	0.0061	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Anthracene	ug/g	0.005	*	0.67	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Fluoranthene	ug/g	0.005	*	0.69	0.0061	0.02	0.015	0.01	0.0059	<0.0050	0.007	0.017
Pyrene	ug/g	0.005	*	78	0.0067	0.019	0.014	0.011	0.0059	<0.0050	0.0079	0.018

Your Project #: MB6Q3671
Site Location: WYCHWOOD
Your C.O.C. #: B6Q3671

Attention:SUB CONTRACTOR

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2016/12/13
Report #: R2316098
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6A9546
Received: 2016/12/06, 08:48

Sample Matrix: Soil
Samples Received: 8

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Cation Exchange Capacity	8	2016/12/13	2016/12/13	AB WI-00065	Auto Calc

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Maxxam
REPORT AUTOMATION ENGINE
13 Dec 2016 17:19:20

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Joyce Kimani, Project Manager Assistant
Email: JKimani@maxxam.ca
Phone# (403)735-2287

==

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Total Cover Pages : 1

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QF2290	QF2290	QF2291		
Sampling Date						
COC Number		B6Q3671	B6Q3671	B6Q3671		
	UNITS	**WW-RG-1-S (DOK038-02R)**	**WW-RG-1-S (DOK038-02R) Lab-Dup**	**WW-RG-1-D (DOK039-02R)**	**RDL**	**QC Batch**
Elements						
Cation exchange capacity	cmol+/Kg	12	13	<10	10	8502595

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate

Maxxam ID		QF2292	QF2293	QF2294		
Sampling Date						
COC Number		B6Q3671	B6Q3671	B6Q3671		
	UNITS	**WW-GS-1-S (DOK040-02R)**	**WW-GS-1-D (DOK041-02R)**	**WW-BS-1-S (DOK042-02R)**	**RDL**	**QC Batch**
Elements						
Cation exchange capacity	cmol+/Kg	18	18	12	10	8502595

RDL = Reportable Detection Limit

Maxxam ID		QF2295	QF2296	QF2297		
Sampling Date						
COC Number		B6Q3671	B6Q3671	B6Q3671		
	UNITS	**WW-BS-1-D (DOK043-02R)**	**WW-BS-2-S (DOK044-02R)**	**WW-BS-2-D (DOK045-02R)**	**RDL**	**QC Batch**
Elements						
Cation exchange capacity	cmol+/Kg	<10	15	18	10	8502595

RDL = Reportable Detection Limit

TEST SUMMARY

Maxxam ID: QF2290
Sample ID: WW-RG-1-S (DOK038-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2290 Dup
Sample ID: WW-RG-1-S (DOK038-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2291
Sample ID: WW-RG-1-D (DOK039-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2292
Sample ID: WW-GS-1-S (DOK040-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2293
Sample ID: WW-GS-1-D (DOK041-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2294
Sample ID: WW-BS-1-S (DOK042-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2295
Sample ID: WW-BS-1-D (DOK043-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

TEST SUMMARY

Maxxam ID: QF2296
Sample ID: WW-BS-2-S (DOK044-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

Maxxam ID: QF2297
Sample ID: WW-BS-2-D (DOK045-02R)
Matrix: Soil

Collected:
Shipped: 2016/12/06
Received: 2016/12/06

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Cation Exchange Capacity	ICPA	8502595	2016/12/13	2016/12/13	Harry (Peng) Liang

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	4.0°C

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

			RPD	
QC Batch	Parameter	Date	Value (%)	QC Limits
8502595	Cation exchange capacity	2016/12/13	NC	35

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Peng Liang

Harry (Peng) Liang, Senior Analyst

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MAXXAM ANALYTICS
6740 Campobello Road
Mississauga, Ontario, L5N 2L8
(905) 817-5700
(905) 817-5777

166

1/2

Credit Valley Conservation
Maxxam PM Sara Singh

SUBCONTRACTING REQUEST FORM

To: Campo to Calgary Subcontract

Job# B6Q3671

☐ Yes ☒ No International Sample/BioHazard (if yes, add copy of Movement Cert., heat treat is required prior to disposal)
☐ Yes ☑ No Special Protocol (if yes, Protocol ____________)

Sample ID	Matrix	Test(s) Required	Container	Date Sampled	Date Required
DOK038-02R\WW-RG-1-S	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK039-02R\WW-RG-1-D	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK040-02R\WW-GS-1-S	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK041-02R\WW-GS-1-D	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK042-02R\WW-BS-1-S	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK043-02R\WW-BS-1-D	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK044-02R\WW-BS-2-S	S	Cation Exchange Capacity	1-INOT		2016/12/13
DOK045-02R\WW-BS-2-D	S	Cation Exchange Capacity	1-INOT		2016/12/13

	Temp. 1	Temp. 2	Temp. 3			
Cooler #1	2	5	5	Custody Seal Present	[✓ YES]	NO
				Custody Seal Intact	[✓ YES]	NO
				Ice Present Upon Receipt	[✓ YES]	NO
Cooler #2				Custody Seal Present	YES	NO
				Custody Seal Intact	YES	NO
				Ice Present Upon Receipt	YES	NO
Cooler #3				Custody Seal Present	YES	NO
				Custody Seal Intact	YES	NO
				Ice Present Upon Receipt	YES	NO

Receiving Maxxam Location: Campo to Calgary Subcontract JOB # ____________

Relinquished by (Sign) Harwin (print) HARWIN GREWAL Date and Time 2016/12/05 09:20

Received by (Sign) (print) WENCHUN LIU Date and Time 2016/12/06 08:48

Subcontract Comments:
SUB-CAT-S FOR CATION EXCHANGE CAPACITY GOING TO CALGARY

NOTES:

1) Please call us if due date cannot be met. Please reference Sample ID on your report.
2) Include copy of this completed form, Client COC & signed final report to scontractor@maxxam.ca

Reporting Requirements:
National:

B6A9541

Maxxam
A Bureau Veritas Group Company

Your P.O. #: 13782
Site Location: WYCHWOOD
Your C.O.C. #: 586253-04-01

Attention:Bill Trenouth

Credit Valley Conservation
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4

Report Date: 2016/12/14
Report #: R4286555
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6Q3671
Received: 2016/12/02, 16:09

Sample Matrix: Soil
Samples Received: 8

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	8	N/A	2016/12/09	CAM SOP-00463	EPA 325.2 m
Conductivity	8	N/A	2016/12/09	CAM SOP-00414	OMOE E3530 v1 m
Acid Extractable Metals Analysis by ICP	8	2016/12/08	2016/12/09	CAM SOP-00408	EPA 6010C m
Moisture	8	N/A	2016/12/07	CAM SOP-00445	Carter 2nd ed 51.2 m
Ammonia-N	8	2016/12/08	2016/12/12	CAM SOP-00441	Carter, SS&A
Nitrate (NO3) and Nitrite (NO2) in Soil	8	N/A	2016/12/09	CAM SOP-00440	SM 22 4500-NO3I/NO2B
PAH Compounds in Soil by GC/MS (SIM)	8	2016/12/08	2016/12/09	CAM SOP-00318	EPA 8270D m
pH CaCl2 EXTRACT	8	2016/12/07	2016/12/07	CAM SOP-00413	EPA 9045 D m
Orthophosphate Analysis	8	N/A	2016/12/09	CAM SOP-00461	EPA 365.1 m
Sodium Adsorption Ratio (SAR)	8	N/A	2016/12/09	CAM SOP-00102	EPA 6010C
SAR - ICP Metals	8	2016/12/09	2016/12/09	CAM SOP-00408	EPA 6010C m
Total Kjeldahl Nitrogen - Soil	8	2016/12/07	2016/12/08	CAM SOP-00454	EPA 351.2 m
Total Organic Carbon in Soil	8	N/A	2016/12/09	CAM SOP-00468	BCMOE TOC Aug 2014

Remarks:

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Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

Your P.O. #: 13782
Site Location: WYCHWOOD
Your C.O.C. #: 586253-04-01

Attention:Bill Trenouth

Credit Valley Conservation
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4

Report Date: 2016/12/14
Report #: R4286555
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6Q3671
Received: 2016/12/02, 16:09

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key Sara Singh
Sara Singh
Senior Project Manager
14 Dec 2016 13:15:03

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Sara Singh, B.Sc, Senior Project Manager
Email: sarasingh@maxxam.ca
Phone# (905)817-5730

===

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RESULTS OF ANALYSES OF SOIL

Maxxam ID		DOK038		DOK038	DOK039	DOK040	DOK041		
Sampling Date									
COC Number		586253-04-01		586253-04-01	586253-04-01	586253-04-01	586253-04-01		
	UNITS	**WW-RG-1-S**	**RDL**	**WW-RG-1-S Lab-Dup**	**WW-RG-1-D**	**WW-GS-1-S**	**WW-GS-1-D**	**RDL**	**QC Batch**
Calculated Parameters									
Sodium Adsorption Ratio	N/A	0.26			0.26	0.34	0.20		4776598
Inorganics									
Total Ammonia-N	ug/g	<20	20		<20	<20	36	20	4783865
Soluble (20:1) Chloride (Cl)	ug/g	36	20		32	70	83	20	4784297
Conductivity	umho/cm	250	2		170	248	258	2	4784499
Moisture	%	21	1.0		18	20	24	1.0	4782361
Total Organic Carbon	mg/kg	22000	500		17000	17000	32000	500	4785693
Orthophosphate (P)	ug/g	18	0.2		6.9	7.5	8.8	0.2	4784298
Available (CaCl2) pH	pH	7.00		6.96	7.38	7.11	7.18		4782348
Total Kjeldahl Nitrogen	ug/g	1650	50		1950	2800	2700	50	4781777
Nitrite (N)	ug/g	0.6	0.5		<0.5	<0.5	<0.5	0.5	4784300
Nitrate (N)	ug/g	<2	2		<2	<2	<2	2	4784300
Nitrate + Nitrite (N)	ug/g	<3	3		<3	<3	<3	3	4784300
Metals									
Soluble Calcium (Ca)	mg/L	32.7	0.5		26.7	36.5	43.6	0.5	4784488
Soluble Magnesium (Mg)	mg/L	5.5	0.5		2.0	2.1	1.9	0.5	4784488
Soluble Sodium (Na)	mg/L	6	5		5	8	<5	5	4784488

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

RESULTS OF ANALYSES OF SOIL

Maxxam ID		DOK042	DOK042	DOK043		DOK044	DOK044		
Sampling Date									
COC Number		586253-04-01	586253-04-01	586253-04-01		586253-04-01	586253-04-01		
	UNITS	**WW-BS-1-S**	**WW-BS-1-S Lab-Dup**	**WW-BS-1-D**	**RDL**	**WW-BS-2-S**	**WW-BS-2-S Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters									
Sodium Adsorption Ratio	N/A	0.59		0.97		0.56			4776598
Inorganics									
Total Ammonia-N	ug/g	<20		<20	20	<20	<20	20	4783865
Soluble (20:1) Chloride (Cl)	ug/g	<20		<20	20	51		20	4784297
Conductivity	umho/cm	184	180	133	2	219		2	4784499
Moisture	%	12		9.5	1.0	18		1.0	4782361
Total Organic Carbon	mg/kg	25000		7100	500	13000		500	4785693
Orthophosphate (P)	ug/g	3.2	3.0	1.2	0.2	6.5		0.2	4784298
Available (CaCl2) pH	pH	7.40		7.84		7.32			4782348
Total Kjeldahl Nitrogen	ug/g	1090		190	10	1960		50	4781777
Nitrite (N)	ug/g	<0.5		<0.5	0.5	<0.5		0.5	4784300
Nitrate (N)	ug/g	<2		<2	2	<2		2	4784300
Nitrate + Nitrite (N)	ug/g	<3		<3	3	<3		3	4784300
Metals									
Soluble Calcium (Ca)	mg/L	25.1	24.8	15.8	0.5	28.3		0.5	4784488
Soluble Magnesium (Mg)	mg/L	1.7	1.7	1.3	0.5	1.4		0.5	4784488
Soluble Sodium (Na)	mg/L	11	12	15	5	11		5	4784488

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

RESULTS OF ANALYSES OF SOIL

Maxxam ID		DOK045		
Sampling Date				
COC Number		586253-04-01		
	UNITS	**WW-BS-2-D**	**RDL**	**QC Batch**
Calculated Parameters				
Sodium Adsorption Ratio	N/A	0.23		4776598
Inorganics				
Total Ammonia-N	ug/g	<20	20	4783865
Soluble (20:1) Chloride (Cl)	ug/g	<20	20	4784297
Conductivity	umho/cm	179	2	4784499
Moisture	%	20	1.0	4782361
Total Organic Carbon	mg/kg	26000	500	4785693
Orthophosphate (P)	ug/g	7.9	0.2	4784298
Available (CaCl2) pH	pH	7.28		4782348
Total Kjeldahl Nitrogen	ug/g	2010	50	4781777
Nitrite (N)	ug/g	<0.5	0.5	4784300
Nitrate (N)	ug/g	<2	2	4784300
Nitrate + Nitrite (N)	ug/g	<3	3	4784300
Metals				
Soluble Calcium (Ca)	mg/L	34.0	0.5	4784488
Soluble Magnesium (Mg)	mg/L	1.2	0.5	4784488
Soluble Sodium (Na)	mg/L	<5	5	4784488

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

ELEMENTS BY ATOMIC SPECTROSCOPY (SOIL)

Maxxam ID		DOK038	DOK039	DOK040	DOK041	DOK042		
Sampling Date								
COC Number		586253-04-01	586253-04-01	586253-04-01	586253-04-01	586253-04-01		
	UNITS	**WW-RG-1-S**	**WW-RG-1-D**	**WW-GS-1-S**	**WW-GS-1-D**	**WW-BS-1-S**	**RDL**	**QC Batch**
Metals								
Acid Extractable Aluminum (Al)	ug/g	1900	1700	2000	1800	7400	50	4784423
Acid Extractable Barium (Ba)	ug/g	15	13	12	15	42	2.0	4784423
Acid Extractable Beryllium (Be)	ug/g	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	4784423
Acid Extractable Cadmium (Cd)	ug/g	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	4784423
Acid Extractable Calcium (Ca)	ug/g	99000	100000	100000	100000	63000	500	4784423
Acid Extractable Chromium (Cr)	ug/g	4.5	4.1	4.2	4.6	12	1.0	4784423
Acid Extractable Cobalt (Co)	ug/g	<2.0	<2.0	<2.0	<2.0	4.7	2.0	4784423
Acid Extractable Copper (Cu)	ug/g	8.5	6.8	7.5	11	20	2.0	4784423
Acid Extractable Iron (Fe)	ug/g	4800	4600	5300	4500	12000	50	4784423
Acid Extractable Lead (Pb)	ug/g	<5.0	<5.0	<5.0	<5.0	12	5.0	4784423
Acid Extractable Magnesium (Mg)	ug/g	3300	3200	3400	3200	5800	50	4784423
Acid Extractable Manganese (Mn)	ug/g	150	130	140	140	440	1.0	4784423
Acid Extractable Molybdenum (Mo)	ug/g	<2.0	<2.0	<2.0	<2.0	<2.0	2.0	4784423
Acid Extractable Nickel (Ni)	ug/g	<5.0	<5.0	<5.0	<5.0	11	5.0	4784423
Acid Extractable Phosphorus (P)	ug/g	530	530	650	680	720	20	4784423
Acid Extractable Potassium (K)	ug/g	440	340	320	350	1100	200	4784423
Acid Extractable Silver (Ag)	ug/g	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	4784423
Acid Extractable Sodium (Na)	ug/g	110	110	110	110	150	100	4784423
Acid Extractable Strontium (Sr)	ug/g	140	140	150	140	89	1.0	4784423
Acid Extractable Sulphur (S)	ug/g	310	280	290	390	320	50	4784423
Acid Extractable Tin (Sn)	ug/g	<20	<20	<20	<20	<20	20	4784423
Acid Extractable Vanadium (V)	ug/g	7.9	8.1	9.1	7.3	19	5.0	4784423
Acid Extractable Zinc (Zn)	ug/g	17	14	17	21	43	5.0	4784423

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

ELEMENTS BY ATOMIC SPECTROSCOPY (SOIL)

Maxxam ID		DOK043	DOK044	DOK045		
Sampling Date						
COC Number		586253-04-01	586253-04-01	586253-04-01		
	UNITS	**WW-BS-1-D**	**WW-BS-2-S**	**WW-BS-2-D**	**RDL**	**QC Batch**
Metals						
Acid Extractable Aluminum (Al)	ug/g	4300	1900	1700	50	4784423
Acid Extractable Barium (Ba)	ug/g	25	12	15	2.0	4784423
Acid Extractable Beryllium (Be)	ug/g	<0.50	<0.50	<0.50	0.50	4784423
Acid Extractable Cadmium (Cd)	ug/g	<0.50	<0.50	<0.50	0.50	4784423
Acid Extractable Calcium (Ca)	ug/g	79000	97000	100000	500	4784423
Acid Extractable Chromium (Cr)	ug/g	7.0	4.4	4.5	1.0	4784423
Acid Extractable Cobalt (Co)	ug/g	3.0	<2.0	<2.0	2.0	4784423
Acid Extractable Copper (Cu)	ug/g	14	8.9	11	2.0	4784423
Acid Extractable Iron (Fe)	ug/g	9100	4800	4700	50	4784423
Acid Extractable Lead (Pb)	ug/g	5.6	<5.0	<5.0	5.0	4784423
Acid Extractable Magnesium (Mg)	ug/g	6600	3100	3200	50	4784423
Acid Extractable Manganese (Mn)	ug/g	310	140	140	1.0	4784423
Acid Extractable Molybdenum (Mo)	ug/g	<2.0	<2.0	<2.0	2.0	4784423
Acid Extractable Nickel (Ni)	ug/g	6.8	<5.0	<5.0	5.0	4784423
Acid Extractable Phosphorus (P)	ug/g	390	490	610	20	4784423
Acid Extractable Potassium (K)	ug/g	710	360	360	200	4784423
Acid Extractable Silver (Ag)	ug/g	<1.0	<1.0	<1.0	1.0	4784423
Acid Extractable Sodium (Na)	ug/g	170	110	110	100	4784423
Acid Extractable Strontium (Sr)	ug/g	98	140	150	1.0	4784423
Acid Extractable Sulphur (S)	ug/g	140	240	360	50	4784423
Acid Extractable Tin (Sn)	ug/g	<20	<20	<20	20	4784423
Acid Extractable Vanadium (V)	ug/g	14	8.5	7.9	5.0	4784423
Acid Extractable Zinc (Zn)	ug/g	20	15	20	5.0	4784423

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

SEMI-VOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		DOK038	DOK039	DOK040	DOK041	DOK042	DOK043		
Sampling Date									
COC Number		586253-04-01	586253-04-01	586253-04-01	586253-04-01	586253-04-01	586253-04-01		
	UNITS	**WW-RG-1-S**	**WW-RG-1-D**	**WW-GS-1-S**	**WW-GS-1-D**	**WW-BS-1-S**	**WW-BS-1-D**	**RDL**	**QC Batch**
Polyaromatic Hydrocarbons									
Acenaphthene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Acenaphthylene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Anthracene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Benzo(a)anthracene	ug/g	<0.0050	0.011	0.011	0.0077	<0.0050	<0.0050	0.0050	4784709
Benzo(a)pyrene	ug/g	0.011	0.020	0.019	0.015	<0.0050	<0.0050	0.0050	4784709
Benzo(b/j)fluoranthene	ug/g	0.027	0.042	0.046	0.044	0.014	<0.0050	0.0050	4784709
Benzo(g,h,i)perylene	ug/g	0.017	0.025	0.025	0.023	0.011	<0.0050	0.0050	4784709
Benzo(k)fluoranthene	ug/g	0.0058	0.012	0.013	0.012	<0.0050	<0.0050	0.0050	4784709
Chrysene	ug/g	0.0073	0.017	0.015	0.016	<0.0050	<0.0050	0.0050	4784709
Dibenz(a,h)anthracene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Fluoranthene	ug/g	0.0061	0.020	0.015	0.010	0.0059	<0.0050	0.0050	4784709
Fluorene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Indeno(1,2,3-cd)pyrene	ug/g	0.016	0.026	0.025	0.022	0.0078	<0.0050	0.0050	4784709
1-Methylnaphthalene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
2-Methylnaphthalene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Naphthalene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Phenanthrene	ug/g	<0.0050	0.0061	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	4784709
Pyrene	ug/g	0.0067	0.019	0.014	0.011	0.0059	<0.0050	0.0050	4784709
Surrogate Recovery (%)									
D10-Anthracene	%	101	104	100	99	101	102		4784709
D14-Terphenyl (FS)	%	99	105	102	98	103	109		4784709
D8-Acenaphthylene	%	101	104	100	99	101	99		4784709

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

SEMI-VOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		DOK044	DOK045		
Sampling Date					
COC Number		586253-04-01	586253-04-01		
	UNITS	**WW-BS-2-S**	**WW-BS-2-D**	**RDL**	**QC Batch**
Polyaromatic Hydrocarbons					
Acenaphthene	ug/g	<0.0050	<0.0050	0.0050	4784709
Acenaphthylene	ug/g	<0.0050	<0.0050	0.0050	4784709
Anthracene	ug/g	<0.0050	<0.0050	0.0050	4784709
Benzo(a)anthracene	ug/g	<0.0050	0.0075	0.0050	4784709
Benzo(a)pyrene	ug/g	0.0086	0.012	0.0050	4784709
Benzo(b/j)fluoranthene	ug/g	0.026	0.036	0.0050	4784709
Benzo(g,h,i)perylene	ug/g	0.016	0.019	0.0050	4784709
Benzo(k)fluoranthene	ug/g	0.0051	0.0079	0.0050	4784709
Chrysene	ug/g	0.0070	0.016	0.0050	4784709
Dibenz(a,h)anthracene	ug/g	<0.0050	<0.0050	0.0050	4784709
Fluoranthene	ug/g	0.0070	0.017	0.0050	4784709
Fluorene	ug/g	<0.0050	<0.0050	0.0050	4784709
Indeno(1,2,3-cd)pyrene	ug/g	0.014	0.018	0.0050	4784709
1-Methylnaphthalene	ug/g	<0.0050	<0.0050	0.0050	4784709
2-Methylnaphthalene	ug/g	<0.0050	<0.0050	0.0050	4784709
Naphthalene	ug/g	<0.0050	<0.0050	0.0050	4784709
Phenanthrene	ug/g	<0.0050	<0.0050	0.0050	4784709
Pyrene	ug/g	0.0079	0.018	0.0050	4784709
Surrogate Recovery (%)					
D10-Anthracene	%	100	101		4784709
D14-Terphenyl (FS)	%	104	102		4784709
D8-Acenaphthylene	%	101	100		4784709

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.3°C

Sample DOK041 [WW-GS-1-D] : SAR Analysis: Sodium was not detected. To report SAR the sodium detection limit was used in the calculation. This value represents a maximum ratio.

Sample DOK045 [WW-BS-2-D] : SAR Analysis: Sodium was not detected. To report SAR the sodium detection limit was used in the calculation. This value represents a maximum ratio.

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
4781777	COP	Matrix Spike	Total Kjeldahl Nitrogen	2016/12/08		92	%	80 - 120
4781777	COP	QC Standard	Total Kjeldahl Nitrogen	2016/12/08		105	%	80 - 120
4781777	COP	Spiked Blank	Total Kjeldahl Nitrogen	2016/12/08		99	%	80 - 120
4781777	COP	Method Blank	Total Kjeldahl Nitrogen	2016/12/08	<10		ug/g	
4781777	COP	RPD	Total Kjeldahl Nitrogen	2016/12/08	6.9		%	40
4782348	SAU	Spiked Blank	Available (CaCl2) pH	2016/12/07		99	%	97 - 103
4782348	SAU	RPD [DOK038-01]	Available (CaCl2) pH	2016/12/07	0.48		%	N/A
4782361	GYA	RPD	Moisture	2016/12/07	4.2		%	20
4783865	COP	Matrix Spike [DOK044-01]	Total Ammonia-N	2016/12/12		102	%	75 - 125
4783865	COP	Spiked Blank	Total Ammonia-N	2016/12/12		104	%	80 - 120
4783865	COP	Method Blank	Total Ammonia-N	2016/12/12	<20		ug/g	
4783865	COP	RPD [DOK044-01]	Total Ammonia-N	2016/12/12	NC		%	35
4784297	DRM	Matrix Spike	Soluble (20:1) Chloride (Cl)	2016/12/09		NC	%	70 - 130
4784297	DRM	Spiked Blank	Soluble (20:1) Chloride (Cl)	2016/12/09		103	%	70 - 130
4784297	DRM	Method Blank	Soluble (20:1) Chloride (Cl)	2016/12/09	<20		ug/g	
4784297	DRM	RPD	Soluble (20:1) Chloride (Cl)	2016/12/09	14		%	35
4784298	ADB	Matrix Spike [DOK042-01]	Orthophosphate (P)	2016/12/09		NC	%	70 - 130
4784298	ADB	Spiked Blank	Orthophosphate (P)	2016/12/09		111	%	70 - 130
4784298	ADB	Method Blank	Orthophosphate (P)	2016/12/09	0.2, RDL=0.2		ug/g	
4784298	ADB	RPD [DOK042-01]	Orthophosphate (P)	2016/12/09	6.4		%	35
4784300	C_N	Matrix Spike	Nitrite (N)	2016/12/09		NC	%	75 - 125
			Nitrate (N)	2016/12/09		99	%	75 - 125
			Nitrate + Nitrite (N)	2016/12/09		99	%	75 - 125
4784300	C_N	QC Standard	Nitrate + Nitrite (N)	2016/12/09		92	%	75 - 125
4784300	C_N	Spiked Blank	Nitrite (N)	2016/12/09		98	%	75 - 125
			Nitrate (N)	2016/12/09		98	%	75 - 125
			Nitrate + Nitrite (N)	2016/12/09		98	%	75 - 125
4784300	C_N	Method Blank	Nitrite (N)	2016/12/09	<0.5		ug/g	
			Nitrate (N)	2016/12/09	<2		ug/g	
			Nitrate + Nitrite (N)	2016/12/09	<3		ug/g	
4784300	C_N	RPD	Nitrite (N)	2016/12/09	NC		%	25
			Nitrate (N)	2016/12/09	NC		%	25
			Nitrate + Nitrite (N)	2016/12/09	NC		%	25
4784423	AFZ	Matrix Spike	Acid Extractable Aluminum (Al)	2016/12/08		NC	%	75 - 125
			Acid Extractable Barium (Ba)	2016/12/08		NC	%	75 - 125
			Acid Extractable Beryllium (Be)	2016/12/08		94	%	75 - 125
			Acid Extractable Cadmium (Cd)	2016/12/08		92	%	75 - 125
			Acid Extractable Calcium (Ca)	2016/12/08		NC	%	75 - 125
			Acid Extractable Chromium (Cr)	2016/12/08		NC	%	75 - 125
			Acid Extractable Cobalt (Co)	2016/12/08		NC	%	75 - 125
			Acid Extractable Copper (Cu)	2016/12/08		NC	%	75 - 125
			Acid Extractable Iron (Fe)	2016/12/08		NC	%	75 - 125
			Acid Extractable Lead (Pb)	2016/12/08		NC	%	75 - 125
			Acid Extractable Magnesium (Mg)	2016/12/08		NC	%	75 - 125
			Acid Extractable Manganese (Mn)	2016/12/08		NC	%	75 - 125
			Acid Extractable Molybdenum (Mo)	2016/12/08		93	%	75 - 125
			Acid Extractable Nickel (Ni)	2016/12/08		NC	%	75 - 125
			Acid Extractable Phosphorus (P)	2016/12/08		NC	%	75 - 125
			Acid Extractable Potassium (K)	2016/12/08		NC	%	75 - 125
			Acid Extractable Silver (Ag)	2016/12/08		94	%	75 - 125
			Acid Extractable Sodium (Na)	2016/12/08		NC	%	75 - 125
			Acid Extractable Strontium (Sr)	2016/12/08		NC	%	75 - 125

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
			Acid Extractable Sulphur (S)	2016/12/08		NC	%	75 - 125
			Acid Extractable Tin (Sn)	2016/12/08		NC	%	75 - 125
			Acid Extractable Vanadium (V)	2016/12/08		NC	%	75 - 125
			Acid Extractable Zinc (Zn)	2016/12/08		NC	%	75 - 125
4784423	AFZ	Spiked Blank	Acid Extractable Aluminum (Al)	2016/12/08		99	%	80 - 120
			Acid Extractable Barium (Ba)	2016/12/08		99	%	80 - 120
			Acid Extractable Beryllium (Be)	2016/12/08		98	%	80 - 120
			Acid Extractable Cadmium (Cd)	2016/12/08		95	%	80 - 120
			Acid Extractable Calcium (Ca)	2016/12/08		103	%	80 - 120
			Acid Extractable Chromium (Cr)	2016/12/08		101	%	80 - 120
			Acid Extractable Cobalt (Co)	2016/12/08		98	%	80 - 120
			Acid Extractable Copper (Cu)	2016/12/08		101	%	80 - 120
			Acid Extractable Iron (Fe)	2016/12/08		100	%	80 - 120
			Acid Extractable Lead (Pb)	2016/12/08		99	%	80 - 120
			Acid Extractable Magnesium (Mg)	2016/12/08		98	%	80 - 120
			Acid Extractable Manganese (Mn)	2016/12/08		99	%	80 - 120
			Acid Extractable Molybdenum (Mo)	2016/12/08		97	%	80 - 120
			Acid Extractable Nickel (Ni)	2016/12/08		98	%	80 - 120
			Acid Extractable Phosphorus (P)	2016/12/08		93	%	80 - 120
			Acid Extractable Potassium (K)	2016/12/08		101	%	80 - 120
			Acid Extractable Silver (Ag)	2016/12/08		99	%	80 - 120
			Acid Extractable Sodium (Na)	2016/12/08		108	%	80 - 120
			Acid Extractable Strontium (Sr)	2016/12/08		101	%	80 - 120
			Acid Extractable Sulphur (S)	2016/12/08		98	%	80 - 120
			Acid Extractable Tin (Sn)	2016/12/08		98	%	80 - 120
			Acid Extractable Vanadium (V)	2016/12/08		99	%	80 - 120
			Acid Extractable Zinc (Zn)	2016/12/08		98	%	80 - 120
4784423	AFZ	Method Blank	Acid Extractable Aluminum (Al)	2016/12/08	<50		ug/g	
			Acid Extractable Barium (Ba)	2016/12/08	<2.0		ug/g	
			Acid Extractable Beryllium (Be)	2016/12/08	<0.50		ug/g	
			Acid Extractable Cadmium (Cd)	2016/12/08	<0.50		ug/g	
			Acid Extractable Calcium (Ca)	2016/12/08	<50		ug/g	
			Acid Extractable Chromium (Cr)	2016/12/08	<1.0		ug/g	
			Acid Extractable Cobalt (Co)	2016/12/08	<2.0		ug/g	
			Acid Extractable Copper (Cu)	2016/12/08	<2.0		ug/g	
			Acid Extractable Iron (Fe)	2016/12/08	<50		ug/g	
			Acid Extractable Lead (Pb)	2016/12/08	<5.0		ug/g	
			Acid Extractable Magnesium (Mg)	2016/12/08	<50		ug/g	
			Acid Extractable Manganese (Mn)	2016/12/08	<1.0		ug/g	
			Acid Extractable Molybdenum (Mo)	2016/12/08	<2.0		ug/g	
			Acid Extractable Nickel (Ni)	2016/12/08	<5.0		ug/g	
			Acid Extractable Phosphorus (P)	2016/12/08	<20		ug/g	
			Acid Extractable Potassium (K)	2016/12/08	<200		ug/g	
			Acid Extractable Silver (Ag)	2016/12/08	<1.0		ug/g	
			Acid Extractable Sodium (Na)	2016/12/08	<100		ug/g	
			Acid Extractable Strontium (Sr)	2016/12/08	<1.0		ug/g	
			Acid Extractable Sulphur (S)	2016/12/08	<50		ug/g	
			Acid Extractable Tin (Sn)	2016/12/08	<20		ug/g	
			Acid Extractable Vanadium (V)	2016/12/08	<5.0		ug/g	
			Acid Extractable Zinc (Zn)	2016/12/08	<5.0		ug/g	
4784423	AFZ	RPD	Acid Extractable Sulphur (S)	2016/12/08	NC		%	30
4784488	SUK	Spiked Blank	Soluble Calcium (Ca)	2016/12/09		92	%	80 - 120
			Soluble Magnesium (Mg)	2016/12/09		99	%	80 - 120

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
			Soluble Sodium (Na)	2016/12/09		103	%	80 - 120
4784488	SUK	Method Blank	Soluble Calcium (Ca)	2016/12/09	<0.5		mg/L	
			Soluble Magnesium (Mg)	2016/12/09	<0.5		mg/L	
			Soluble Sodium (Na)	2016/12/09	<5		mg/L	
4784488	SUK	RPD [DOK042-01]	Soluble Calcium (Ca)	2016/12/09	1.3		%	30
			Soluble Magnesium (Mg)	2016/12/09	NC		%	30
			Soluble Sodium (Na)	2016/12/09	NC		%	30
4784499	TA1	Spiked Blank	Conductivity	2016/12/09		100	%	90 - 110
4784499	TA1	Method Blank	Conductivity	2016/12/09	<2		umho/c	
4784499	TA1	RPD [DOK042-01]	Conductivity	2016/12/09	2.5		%	10
4784709	RAJ	Matrix Spike	D10-Anthracene	2016/12/09		96	%	50 - 130
			D14-Terphenyl (FS)	2016/12/09		98	%	50 - 130
			D8-Acenaphthylene	2016/12/09		97	%	50 - 130
			Acenaphthene	2016/12/09		87	%	50 - 130
			Acenaphthylene	2016/12/09		88	%	50 - 130
			Anthracene	2016/12/09		85	%	50 - 130
			Benzo(a)anthracene	2016/12/09		94	%	50 - 130
			Benzo(a)pyrene	2016/12/09		92	%	50 - 130
			Benzo(b/j)fluoranthene	2016/12/09		88	%	50 - 130
			Benzo(g,h,i)perylene	2016/12/09		94	%	50 - 130
			Benzo(k)fluoranthene	2016/12/09		91	%	50 - 130
			Chrysene	2016/12/09		89	%	50 - 130
			Dibenz(a,h)anthracene	2016/12/09		96	%	50 - 130
			Fluoranthene	2016/12/09		91	%	50 - 130
			Fluorene	2016/12/09		89	%	50 - 130
			Indeno(1,2,3-cd)pyrene	2016/12/09		94	%	50 - 130
			1-Methylnaphthalene	2016/12/09		88	%	50 - 130
			2-Methylnaphthalene	2016/12/09		89	%	50 - 130
			Naphthalene	2016/12/09		85	%	50 - 130
			Phenanthrene	2016/12/09		86	%	50 - 130
			Pyrene	2016/12/09		93	%	50 - 130
4784709	RAJ	Spiked Blank	D10-Anthracene	2016/12/09		98	%	50 - 130
			D14-Terphenyl (FS)	2016/12/09		101	%	50 - 130
			D8-Acenaphthylene	2016/12/09		98	%	50 - 130
			Acenaphthene	2016/12/09		87	%	50 - 130
			Acenaphthylene	2016/12/09		89	%	50 - 130
			Anthracene	2016/12/09		88	%	50 - 130
			Benzo(a)anthracene	2016/12/09		96	%	50 - 130
			Benzo(a)pyrene	2016/12/09		96	%	50 - 130
			Benzo(b/j)fluoranthene	2016/12/09		89	%	50 - 130
			Benzo(g,h,i)perylene	2016/12/09		96	%	50 - 130
			Benzo(k)fluoranthene	2016/12/09		99	%	50 - 130
			Chrysene	2016/12/09		91	%	50 - 130
			Dibenz(a,h)anthracene	2016/12/09		100	%	50 - 130
			Fluoranthene	2016/12/09		93	%	50 - 130
			Fluorene	2016/12/09		90	%	50 - 130
			Indeno(1,2,3-cd)pyrene	2016/12/09		97	%	50 - 130
			1-Methylnaphthalene	2016/12/09		88	%	50 - 130
			2-Methylnaphthalene	2016/12/09		90	%	50 - 130
			Naphthalene	2016/12/09		86	%	50 - 130
			Phenanthrene	2016/12/09		88	%	50 - 130
			Pyrene	2016/12/09		96	%	50 - 130
4784709	RAJ	Method Blank	D10-Anthracene	2016/12/09		101	%	50 - 130

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
			D14-Terphenyl (FS)	2016/12/09		103	%	50 - 130
			D8-Acenaphthylene	2016/12/09		97	%	50 - 130
			Acenaphthene	2016/12/09	<0.0050		ug/g	
			Acenaphthylene	2016/12/09	<0.0050		ug/g	
			Anthracene	2016/12/09	<0.0050		ug/g	
			Benzo(a)anthracene	2016/12/09	<0.0050		ug/g	
			Benzo(a)pyrene	2016/12/09	<0.0050		ug/g	
			Benzo(b/j)fluoranthene	2016/12/09	<0.0050		ug/g	
			Benzo(g,h,i)perylene	2016/12/09	<0.0050		ug/g	
			Benzo(k)fluoranthene	2016/12/09	<0.0050		ug/g	
			Chrysene	2016/12/09	<0.0050		ug/g	
			Dibenz(a,h)anthracene	2016/12/09	<0.0050		ug/g	
			Fluoranthene	2016/12/09	<0.0050		ug/g	
			Fluorene	2016/12/09	<0.0050		ug/g	
			Indeno(1,2,3-cd)pyrene	2016/12/09	<0.0050		ug/g	
			1-Methylnaphthalene	2016/12/09	<0.0050		ug/g	
			2-Methylnaphthalene	2016/12/09	<0.0050		ug/g	
			Naphthalene	2016/12/09	<0.0050		ug/g	
			Phenanthrene	2016/12/09	<0.0050		ug/g	
			Pyrene	2016/12/09	<0.0050		ug/g	
4784709	RAJ	RPD	Acenaphthene	2016/12/09	NC		%	40
			Acenaphthylene	2016/12/09	NC		%	40
			Anthracene	2016/12/09	NC		%	40
			Benzo(a)anthracene	2016/12/09	NC		%	40
			Benzo(a)pyrene	2016/12/09	NC		%	40
			Benzo(b/j)fluoranthene	2016/12/09	NC		%	40
			Benzo(g,h,i)perylene	2016/12/09	NC		%	40
			Benzo(k)fluoranthene	2016/12/09	NC		%	40
			Chrysene	2016/12/09	NC		%	40
			Dibenz(a,h)anthracene	2016/12/09	NC		%	40
			Fluoranthene	2016/12/09	NC		%	40
			Fluorene	2016/12/09	NC		%	40
			Indeno(1,2,3-cd)pyrene	2016/12/09	NC		%	40
			1-Methylnaphthalene	2016/12/09	NC		%	40
			2-Methylnaphthalene	2016/12/09	NC		%	40
			Naphthalene	2016/12/09	NC		%	40
			Phenanthrene	2016/12/09	NC		%	40
			Pyrene	2016/12/09	NC		%	40
4785693	BMO	QC Standard	Total Organic Carbon	2016/12/09		104	%	75 - 125
4785693	BMO	Method Blank	Total Organic Carbon	2016/12/09	<500		mg/kg	

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
4785693	BMO	RPD	Total Organic Carbon	2016/12/09	4.6		%	35

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

FUNDAMENTAL LABORATORY ACCEPTANCE GUIDELINE

Maxxam Job #:	B6Q3671
Date Received:	2016/12/02
Your C.O.C. #:	586253-04-01
Your P.O. #:	13782
Maxxam Project Manager:	Sara Singh
Quote #:	B58115

Invoice To:
Credit Valley Conservation
ATTN: Bill Trenouth
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4
Client Contact:
Bill Trenouth

No discrepancies noted.

Report Comments

Received Date:	**2016/12/02**	**Time:**	**16:09**	**By:**	
Inspected Date:		**Time:**		**By:**	
FLAG Created Date:		**Time:**		**By:**	

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Eva Pranjic

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

Technical Report

Monitoring Results (2016-2017)

Appendix G

Thermal Mitigation Analysis and Methodology

The following methodology is an example step-by-step calculation used to determine thermal loading performance at the Wychwood LID performance site. Please note, data within the methodology is from the 2013 Elm Drive LID Treatment Train analysis.

Impervious surfaces such as parking lots, roads and rooftops represent a large portion of land cover in urbanized areas. The materials used in building these areas have a very high thermal capacity and readily absorb solar radiation. When precipitation events occur on warm sunny days, the stormwater flows along these surfaces and absorbs the heat stored within the impervious surface through conduction. This stormwater becomes warmer and in most cases flows into the nearest stormwater sewer system where it flows into the local stream and river catchments.

1.0 METHODOLOGY

The bioretention cells at Elm Drive are being evaluated for thermal mitigation potential by developing event mean temperatures and thermal loads of inflows and outflows. In order to assess thermal mitigation and calculate event mean temperatures, HOBO pendent temperature loggers were deployed at the inflow catch basin and at the outflow manhole. Both loggers are set to record temperatures at ten minute intervals and are downloaded every two weeks.

The catchment runoff flowing into the LID practices was not measured directly, however, calculated using the runoff method suggested in the Elm Drive Monitoring Report[1] and by Schueler[2]. Outflows were monitored using an ISCO 4150 logger and level probe with a compound weir.

1.1 Calculation Steps

The following steps were taken to estimate thermal mitigation and EMTs. Sample calculations are presented in Table G-1.

Step 1: Inflow Estimate

The flow entering the LID treatment train (Q_{in}) was estimated using Equation (1) suggested in the Elm Drive Monitoring Report[3].

$$Q_{in} = A * P * Rv * ConversionFactor \quad (1)$$

Where:

A is the Total catchment area (m^2) = ---- m^2

P is Precipitation (mm)

Rv is Runoff Coefficient (unitless) = ----

Conversion Factor is 1.0

---

[1] Credit Valley Conservation Watershed Protection and Restoration Team, Wright Water Engineers, Inc, Geosyntec Consultants. 2013. Elm Drive City of Mississauga, Low Impact Development Infrastructure Performance and Risk Assessment. Interim Technical Report 2011-2013

[2] Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, DC

[3] CVC et. al., 2013

Finally,

Q_{in} = insert site catchment in m^2 * P

Table G-1 provides precipitation data in column 2 and the results of the inflow estimation in column 4.

Step 2: Inflow Event Mean Temperature (EMT_{in}) Calculation

Inflow EMT is the event mean temperature of the runoff entering treatment train. The EMT was calculated using equation (2)[4, 5]:

$$EMT_{in} = \frac{\sum T_{in} Q_{in} dt}{\sum Q_{in} dt} \quad (2)$$

Where:

Q_{in} is the measured stormwater flow rate

T_{in} is water temperature

dt is the time duration of the event.

Column 5 of Table G-1 shows the calculations of numerator of equation (2) which is then summed for one event and then divided by total flow estimated for that event (EMT row of Table G-1)

Step 3: Inflow Thermal Loading (TL_{in}) Calculations

The TL_{in} is calculated using equation (3)[6]:

$$TL_{in} = Q_{in} * p * T_{in} * C * t \quad (3)$$

Where:

Q_{in} is the flow rate in (m^3/s)

p is the density of water (assumed constant at 1000 kg/m^3)

T_{in} is inflow water temperature (ºC)

C is the heat capacity of water (assumed constant at 4186 J/kg/ºC)

t is time(s)

The TL_{in} calculations are shown in column 6 of Table G-1 and an example is given below:

---

[4] Sabouri, F & Gharabagi, B & Mahboubu, A.A, McBean, E.A. 2013. Impervious surfaces and sewer pipe effects on stormwater runoff temperature. Journal of Hydrology, 2013. 502: 10-17

[5] Natarajan, P & Davis, A.P. 2010. Thermal Reduction by an Underground Storm-Water Detention System. Journal of Environmental Engineering, 2010.136:520-526.

[6] Winston, R.J. & Hunt, W.F. & Lord, W.G. 2011. Thermal Mitigation of Urban Storm Water by Level Spreader-Vegetative Filter Strips. Journal of Environmental Engineering, 2011.137:707-716

Example: Thermal Load Inflows

- Unit conversion from litres to m^3: 581.73/1000 (column 4)
- Multiply by constants 4186 J/kg/ºC and 1000 kg/m³, EMT_{in} = 22.52ºC, and divide by 10^6 to convert Joules to Mega Joules (Column 6)
- Sum the product in column 6 for total inflow TL_{in}.

Step 4: Outflow Estimates

The out flows are collected at the bioretention outlet. A level sensor and a compound weir is used to measure flows. The flows are then corrected for drainage area (the drainage area of the site is larger than that draining into the catch basins on the northern side of the LID practices) using an area proportion factor. The contributing area on the north side of the LID is approximately 75% of the total catchment. Therefore the area factor is 0.75.

Step 5: Outflow Event Mean Temperature EMTout Calculation

The outlet is the event mean temperature leaving the treatment train. The EMT was calculated using equation (2) (Sabouri et al., 2013; Natatajan et al., 2012):

Where:

Q_{out} is the measured stormwater flow rate

T_{out} is water temperature

dt is the time duration of the event.

Column 9 shows the calculation of numerator of equation 2 which is then summed for one event and then divided by total out flow estimated for that event (EMT row of Table G-1).

Step 6: Outflow Thermal Loading TLout Calculation

The TL_{out} is calculated using equation (3)[7]:

Where:

Q_{out} is the outflow rate in (m³/s)

p is the density of water (assumed constant at 1000 kg/m³)

T_{out} is outflow water temperature (ºC)

C is the heat capacity of water (assumed constant at 4186 J/kg/ºC)

t is time(s)

The TL_{out} calculations are shown in column 10 for Table G-1 and an example is given below

Example: Thermal Load Outlet

- Unit Conversions from liters to m³: 0.518 l/s/1000 for m^3 (column 8)
- 0.000518*catchment factor of 0.75 **if applicable to site (this is a function of the number of potential inlets and where inlet temperature is collected)

---

[7] Winston et. al., 2011

- Multiply by constants 4186 J/kg/°C and 1000 kg/m³, EMT_{out} = 18.31°C, and divide by 10^6 to convert Joules to Mega Joules (Column 6)
- Sum the product in column 10 for total outflow TL_{out}.

Step 7: Thermal Mitigation

To calculate the total thermal mitigation from inflow to outflow of the LID, column 6 and column 10 are totalled and subtracted. The thermal mitigation is given in the TL reduction row of Table G-1.

Table G-1: EMT and thermal loading calculation summary for July 27th, 2013 event

Date/Time	Inflow Precipitation (mm)	Inflow Temp T_{in}	Col 2 x 2908.65	Col 4 x Col 3	Thermal Load TL_{in} (MJ)	Outlet Temp T_{out} °C	Outflow (l/s) Qout	Col 7x8	Thermal Load TL_{out} (MJ)
1	2	3	4	5	6	7	8	9	10
2013-07-27 13:00	0.2	22.525	581.73	13103.46825	54.83	18.521	0	0	0
2013-07-27 13:10	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 13:20	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 13:30	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 13:40	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 13:50	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 14:00	0.2	22.525	581.73	13103.46825	54.83	18.521	0	0	0
2013-07-27 14:10	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 14:20	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 14:30	0	22.525	0	0	0	18.521	0	0	0
2013-07-27 14:40	0	22.525	0	0	0	18.616	0	0	0
2013-07-27 14:50	0	22.525	0	0	0	18.616	0	0	0
2013-07-27 15:00	0.8	22.621	2326.92	52637.25732	219.32	18.616	0	0	0
2013-07-27 15:10	0.2	22.525	581.73	13103.46825	54.83	18.616	0	0	0
2013-07-27 15:20	13	22.621	37812.45	855355.4315	3563.94	18.616	0	0	0
2013-07-27 15:30	3.2	21.664	9307.68	201641.5795	877.28	18.901	0	0	0
2013-07-27 15:40	0.4	25.708	1163.46	29910.22968	109.66	19.282	0	0	0
2013-07-27 15:50	0	27.173	0	0	0	18.901	0	0	0
2013-07-27 16:00	0	27.665	0	0	0	18.711	0	0	0
2013-07-27 16:10	0	27.665	0	0	0	18.521	0.518	9.593878	17.86
2013-07-27 16:20	0	27.567	0	0	0	18.426	0.567	10.447542	19.55
2013-07-27 16:30	0	27.468	0	0	0	18.236	0.518	9.446248	17.86
2013-07-27 16:40	0	27.272	0	0	0	18.236	0.38	6.92968	13.1
2013-07-27 16:50	0	27.173	0	0	0	18.14	0.257	4.66198	8.86
2013-07-27 17:00	0	27.075	0	0	0	18.14	0.185	3.3559	6.38
2013-07-27 17:10	0	27.075	0	0	0	18.14	0.12	2.1768	4.14
2013-07-27 17:20	0	26.977	0	0	0	18.14	0.091	1.65074	3.14
2013-07-27-17:30	0	26.879	0	0	0	18.14	0.023	0.41722	0.79
Total			**52355.7**	**1178854.903**	**4934.69**		**2.659**	**48.679988**	**91.7**
EMT	**22.52 In**					**18.31 Out**			
TL Reduction Total Col 6- Total Col 10	**4842.99 MJ**								

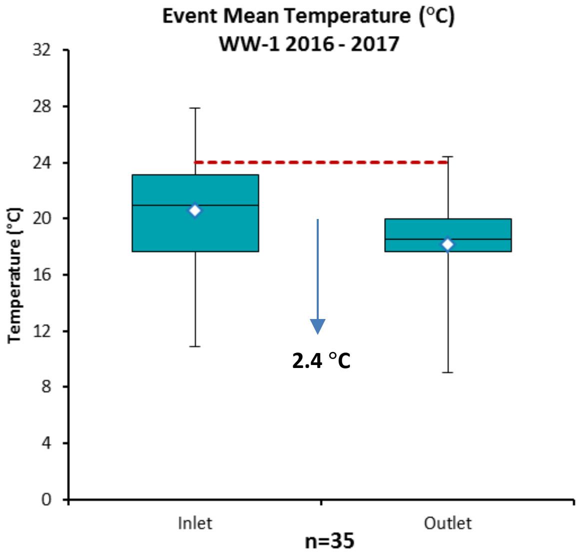
2.0 RESULTS AND DISCUSSION

This section discusses the thermal analysis from the 2016 - 2017 study period at Wychwood. Table G-2 is a summary of all 35 precipitation events analyzed at WW-1 for thermal reduction potential at the Wychwood LID subdivision during the 2016 and 2017 monitoring period. 22 of the events in Table G-2 generated outflows, indicated by check marks and 82 percent of the events were 20 mm or less.

Table G-2: May to September event precipitation summary for 2016 to 2017

Beginning of Precipitation	Total Precipitation mm	0-10 mm	10-20 mm	20-30 mm	>30 mm
Number of Events from each Range		**21**	**10**	**1**	**3**
Number of Events with Outflow		**8**	**10**	**1**	**3**
2016-08-25 15:50	15.2		√		
2016-09-07 18:15	17.2		√		
2016-09-17 4:55	7	√			
2016-09-26 10:40	7.2	√			
2016-09-29 8:40	11.6		√		
2017-05-01 0:10	3.8				
2017-05-01 9:25	14		√		
2017-05-04 12:50	37.4				√
2017-05-21 12:20	23			√	
2017-05-24 21:25	39.6				√
2017-05-29 19:10	2				
2017-05-30 12:55	3.6				
2017-06-04 4:55	6.4				
2017-06-16 19:05	5.4				
2017-06-17 9:35	6				
2017-06-18 7:20	3.8	√			
2017-06-22 10:30	2.6				
2017-06-22 22:50	37.6				√
2017-06-29 0:40	3.8				
2017-06-30 3:50	7.6	√			
2017-07-12 12:10	5	√			
2017-07-13 22:55	13		√		
2017-07-20 9:35	13.4		√		
2017-07-26 18:35	6.6				
2017-07-31 15:15	4				
2017-08-01 13:50	8.2	√			
2017-08-04 0:25	3				
2017-08-04 15:00	17.8		√		
2017-08-12 13:25	3.8				
2017-08-17 13:25	13.8		√		
2017-08-22 8:25	16.2		√		
2017-08-31 0:40	3.8				
2017-09-03 2:05	9.6	√			
2017-09-04 17:50	10.4		√		
2017-09-05 12:30	4.2	√			

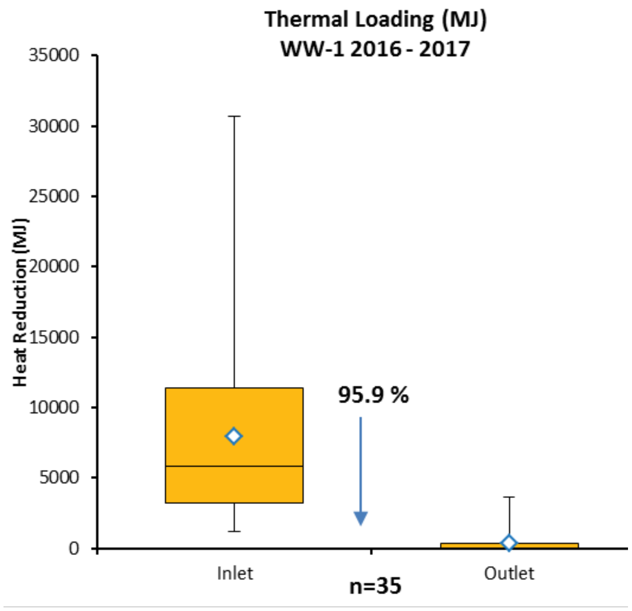
Figure G-1 and Table GO3 show the average EMT reduction for the 35 precipitation events analyzed for the 2016 and 2017 monitoring period. 22 of the events generated outflow. The bioswale has a high rate of flow retention, resulting in median and maximum EMT reductions. There was an overall 2.4 °C EMT reduction for all 35 events. Table G-3 shows that the mean and median for both the EMTin and EMTout are approximately equal indicating that the dataset is normally distributed.



	EMTin	EMTout
Count	35	22
Min	10.90	9.00
25th	17.85	17.70
Median	20.97	18.53
75th	23.06	19.91
Max	27.84	24.44
Mean	20.53	18.14
SD	4.23	3.90
Total Average Reduction (°C)	2.4	

Figure G-1: Inlet and outlet event mean temperature reduction for 2016 and 2017 events
Table G-3: Summary of temperature reduction data in Figure G-1

Figure G-2 and Table G-4 show the thermal load reduction for the 35 precipitation events analyzed. Median and maximum thermal load reductions for the events analyzed are evident. The average thermal load reduction is 7596.61 MJ, or 95.9 percent, for all 35 events combined. Table G-4 shows that the mean and median thermal load reduction for both the inlet and outlet are not exactly equal, indicating that some level of skewness is present in the dataset. This skewness is likely a result of some outlying data points due to the small number of events being analyzed. In addition, the outliers in the dataset may be present due to seasonal differences. 2016 was a warmer year compared to 2017, so the air temperatures may have contributed to warmer flows through the LID feature in 2016.



	TL in	TL out
Count	35	35
Min	1226.01	0.00
25th	3192.42	0.00
Median	5791.05	9.16
75th	10944.36	261.79
Max	30712.24	3651.67
Mean	7921.77	325.16
SD	6521.28	746.13
Total Average Reduction (MJ)	7596.61	

Figure G-2: Inlet and outlet thermal load reduction for 2016 and 2017 events
Table G-4: Summary of thermal load reduction data in Figure G-3

A summary of all of the EMTs and total thermal load data collected from May to September 2016 and 2017 can be seen in Table G-5. Included is the approximate hourly duration each event occurred. In the summer months, the average air temperature is usually lower than the inlet EMT, indicating the ground surface is typically warmer than the air. The negative values for % EMT and TL reduction indicate a true temperature or loading decrease, while the positive values indicate a temperature or loading increase. Due to seasonal temperature variation and the amount of precipitation during any given event the thermal load reduction fluctuates throughout the year.

Table G- 5: Summary of 2016 and 2017 WW-1 events

Beginning of Precipitation	End of Precipitation	Duration (hours)	Average Air Temp (C)	Total Precipitation mm	Inlet		Outlet		% EMT Reduction	% TL Reduction
					EMT	Thermal Load Totals (MJ)	EMT	Thermal Load Totals (MJ)		
2016-08-25 15:50	2016-08-25 16:55	1:05	26.1	15.2	27.839	15467.803	24.445	210.665	12.2	98.64
2016-09-07 18:15	2016-09-08 0:50	6:35	28.5	17.2	24.141	15177.821	24.379	2216.010	-1.0	85.40
2016-09-17 4:55	2016-09-17 16:20	11:25	20.7	7	21.744	5563.770	19.975	4.214	8.1	99.92
2016-09-26 10:40	2016-09-26 16:10	5:30	14.8	7.2	17.615	4635.990	18.179	2.671	-3.2	99.94
2016-09-29 8:40	2016-09-29 21:50	13:10	15.2	11.6	16.312	6916.700	17.686	9.162	-8.4	99.87
2017-05-01 0:10	2017-05-01 2:05	1:55	4.7	3.8	11.626	1614.871	No Outflow	0.00	N/A	100.00
2017-05-01 9:25	2017-05-01 18:10	8:45	8.4	14	11.606	5939.621	9.555	957.407	17.7	83.88
2017-05-04 12:50	2017-05-06 21:55	9:05	6.9	37.4	10.905	14907.770	8.997	1475.311	17.5	90.10
2017-05-21 6:20	2017-05-21 22:15	15:55	13.0	23	15.436	12977.756	14.312	400.576	7.3	96.91
2017-05-24 21:25	2017-05-26 3:20	5:55	12.4	39.6	16.017	23185.500	12.683	728.413	20.8	96.86
2017-05-29 19:10	2017-05-30 2:40	7:30	13.7	2	16.770	1226.008	No Outflow	0.00	N/A	100.00
2017-05-30 12:55	2017-05-30 21:25	8:30	20.1	3.6	18.589	2446.248	No Outflow	0.00	N/A	100.00
2017-06-04 4:55	2017-06-04 8:25	3:30	12.2	6.4	17.147	4011.512	No Outflow	0.00	N/A	100.00
2017-06-16 19:05	2017-06-16 21:55	2:50	22.2	5.4	26.411	5213.351	No Outflow	0.00	N/A	100.00
2017-06-17 9:35	2017-06-17 14:10	4:35	32.2	6	26.424	5795.361	No Outflow	0.00	N/A	100.00
2017-06-18 7:20	2017-06-18 7:55	0:35	23.9	3.8	22.964	3189.789	17.780	98.110	22.6	96.92
2017-06-22 10:30	2017-06-22 11:25	0:55	19.8	2.6	20.659	1963.423	No Outflow	0.00	N/A	100.00
2017-06-22 22:50	2017-06-23 10:45	11:55	20.2	37.6	22.346	30712.240	20.130	3651.665	9.9	88.11
2017-06-29 0:40	2017-06-29 3:05	2:25	14.9	3.8	20.013	2779.889	No Outflow	0.00	N/A	100.00
2017-06-30 3:50	2017-06-30 7:10	3:20	19.5	7.6	20.845	5791.047	18.856	312.923	9.5	94.60
2017-07-12 12:10	2017-07-12 15:15	3:05	27.7	5	27.021	4938.590	20.988	24.828	22.3	99.50
2017-07-13 22:55	2017-07-14 0:45	1:50	16.7	13	20.345	9667.983	18.202	14.195	10.5	99.85
2017-07-20 9:35	2017-07-20 11:40	2:05	18.2	13.4	21.458	10510.526	19.428	341.669	9.5	96.75
2017-07-26 18:35	2017-07-27 9:05	14:30	18.5	6.6	22.006	5309.151	No Outflow	0.00	N/A	100.00
2017-07-31 15:15	2017-07-31 15:50	0:35	30.1	4	22.449	3282.314	No Outflow	0.00	N/A	100.00
2017-08-01 13:50	2017-08-01 14:30	0:40	29.3	8.2	24.062	7212.523	19.350	113.686	19.6	98.42
2017-08-04 0:25	2017-08-04 6:20	5:55	19.1	3	23.626	2590.833	No Outflow	0.00	N/A	100.00
2017-08-04 15:00	2017-08-04 17:30	2:30	20.4	17.8	24.258	15783.869	21.925	529.346	9.6	96.65
2017-08-12 13:25	2017-08-12 14:50	1:25	25.3	3.8	23.002	3195.046	No Outflow	0.00	N/A	100.00
2017-08-17 13:25	2017-08-18 2:50	13:25	19.5	13.8	22.556	11378.190	19.589	62.285	13.2	99.45
2017-08-22 8:25	2017-08-22 13:05	4:40	24.8	16.2	23.127	13695.322	19.728	175.252	14.7	98.72
2017-08-31 0:40	2017-08-31 2:25	1:45	16.9	3.8	20.449	2840.459	No Outflow	0.00	N/A	100.00
2017-09-03 2:05	2017-09-03 5:15	3:10	14.3	9.6	18.079	6344.209	17.284	0.521	4.4	99.99
2017-09-04 17:50	2017-09-04 20:10	2:20	20.8	10.4	20.974	7973.640	17.985	42.855	14.3	99.46
2017-09-05 12:30	2017-09-05 13:05	0:35	23.6	4.2	19.689	3022.841	17.723	8.680	10.0	99.71

As seen in Figures G-3 and G-4, a correlation between EMTs and thermal loads exists, where EMT reductions are a function of thermal load reductions. A significant reduction in EMTs and thermal loads are expected to occur during the summer months of May to September where the potential for thermal pollution into fresh water catchments is greater. Once more data becomes available for analysis, looking at the reduction potential for more event size ranges throughout the entire summer period will shed more light on the ability of Wychwood's LID features to reduce EMTs and thermal loads.

Figure G-4 depicts the 17.2 mm event that occurred on September 7, 2016. High thermal reductions are typically expected to occur for events that are less than 25 mm. This was experienced during the September 7th event, where a total thermal load reduction of 12961.8 MJ occurred. In addition, the EMT value from the inlet to outlet actually increased by 0.24 °C. The event lasted a duration of 6 hours and 35 minutes, and was fairly intense with a maximum precipitation value of 4 mm within 5 minutes. In addition, the air temperature was 7.8 °C warmer than that of the September 17th event.

Figure G-4 further demonstrates that when intense precipitation events occur and inlet and outlet EMTs remain approximately the same, there is still a thermal benefit whereby a portion of the volume is stored in the bioswale reducing the thermal load. In addition, this event demonstrates the effectiveness of catch basins in relation to directing runoff into the infiltration trench quickly. However, when shorter, more intense events like the September 7th event occur, there is not enough time for the runoff to infiltrate through the perforated pipe, resulting in EMT inlet and outlet results remaining approximately the same or EMT outlet results may even be warmer than the EMT inlet results.

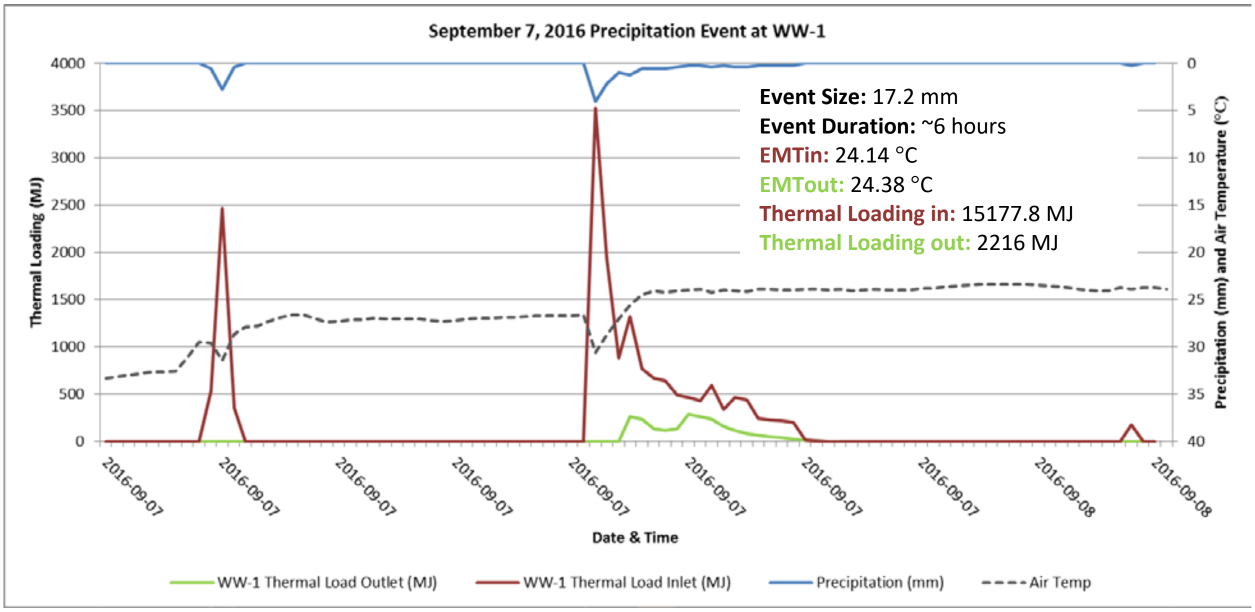


Figure G-3: Thermal loading results from September 7, 2016 event of 17.2mm

Nearly 100 percent thermal reductions occurred during the smaller events such as the one that took place on September 17th, 2016 with a total of 7 mm of rainfall. This event is depicted in Figure G-4. A total thermal reduction of 5559.6 MJ occurred and the EMT from inlet to outlet decreased by 1.76 °C. The event lasted a duration of 11 hours and 25 minutes, and was much less intense in comparison to the larger September 7th event. This longer and less intense event likely provided the runoff with sufficient time and opportunity to infiltrate into the perforated pipe and effectively reduce the outlet EMT. In addition, compared to the September 7th event, during which the EMT increased, the air temperature on September 17th was 7.8 °C cooler.

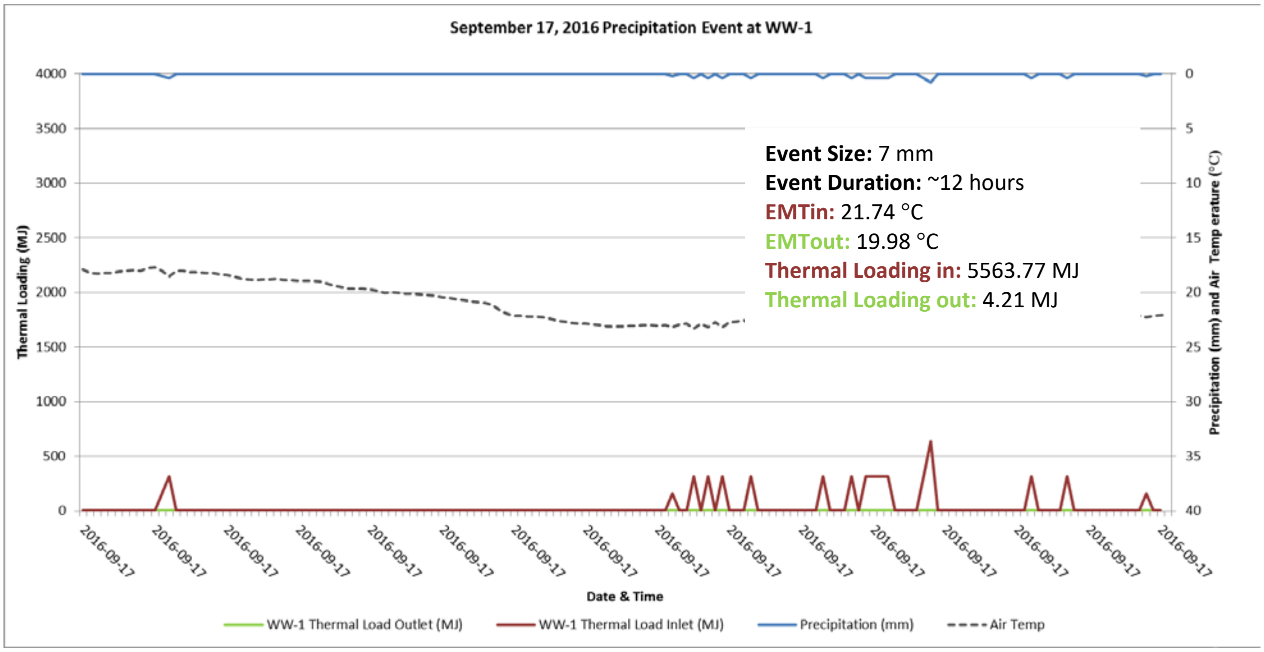


Figure G-4: Thermal loading results from September 17, 2016 event of 7mm

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Appendix H

Intensification of Urban Water Cycle

1. INTENSIFICATION OF URBAN WATER CYCLE

It is expected that the population of the Greater Toronto Area (GTA) will grow from 6.4 million in 2012 to 8.9 million by 2036[1]. This ongoing urbanization of our environment by increasing imperviousness results in a phenomenon commonly known as the "urban stream syndrome"[2], where hydrographs become flashier (i.e., increased flow variability), baseflow decline, water quality is degraded, stream channels are eroded, water temperatures rise, and biological richness declines. Figure H-1 shows a hydrograph comparing stream flow rates before, during, and after a storm under pre- and post-development conditions[3]. As indicated, streams with developed watersheds have substantially higher peak flows, and these peak flows occur more quickly than under predevelopment conditions. This is reflective of typical urban conditions, where runoff moves quickly over impervious surfaces and drains into a channel.

Impervious surfaces such as streets, sidewalks and driveways contribute 65-75% of total loadings of suspended solids, total phosphorus, and metals to our receiving streams and lakes (Bannerman et al., 1992). Furthermore, beach closures and reductions in recreational fishing due to pollutant loading from urban stormwater and have resulted in up to $87 million a year in lost revenue to local economies (Marbek, 2010).

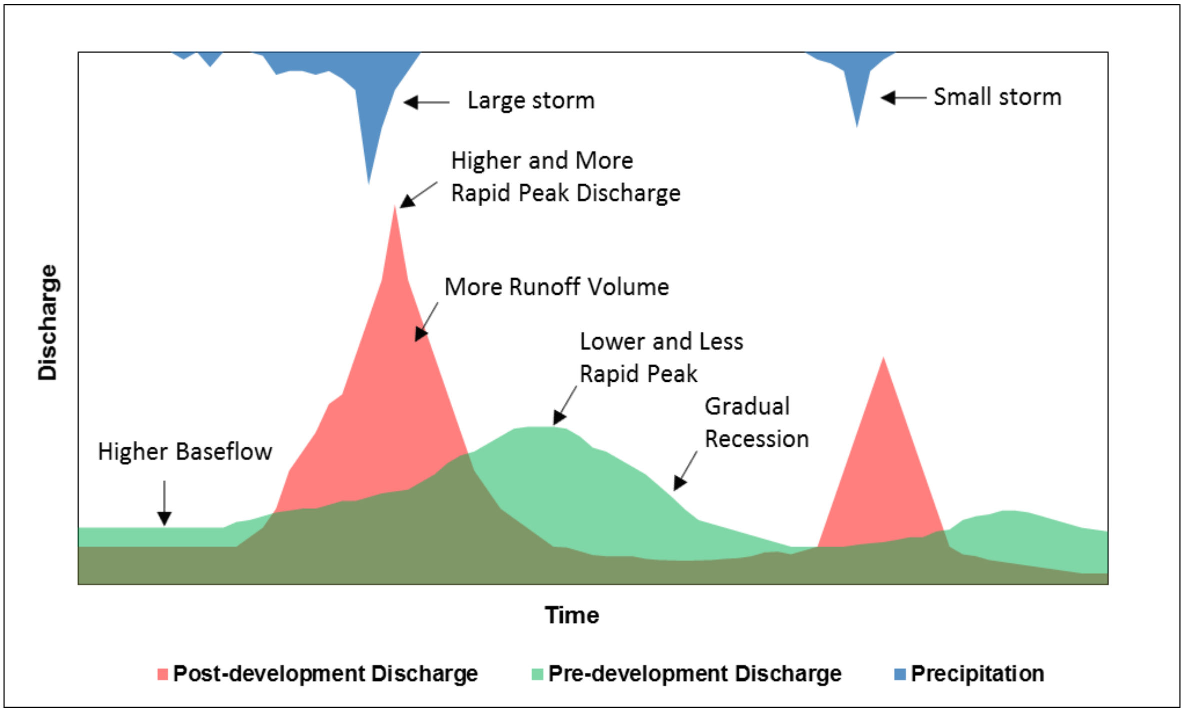

Figure H-1: Changes in stream flow hydrograph as a result of urbanization (adapted from Schueler, 1987)

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[1] Ministry of Finance (MOF). 2013. Ontario Population Projections Update. http://www.fin.gov.on.ca/en/economy/demographics/projections/projections2012-2036.pdf

[2] Walsh CJ, Roy AH, Feminella JW, Cottingham PD, Groffman PM, Morgan RP II. 2005. The urban stream syndrome: Current knowledge and the search for a cure. Journal of the North American Benthological Society 24(3):706-723

[3] Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. Metropolitan Washington Council of Governments, Washington, DC.

This ongoing urbanization of our environment by increasing imperviousness also corresponds to a significant alteration to the water cycle. Continued development with structured conveyance and impervious pathways redistributes the water budget to favour runoff over evaporation, infiltration, and recharge for streams and groundwater. The figures below illustrate how four important components in the water cycle are affected by increasing levels of imperviousness[4].

In natural and rural environments with vegetated soils, surface runoff is generally low and represents a low fraction (10 to 20%) of the total fallen precipitation[5]. Water either percolates into the ground or is returned to the atmosphere by evaporation and transpiration. A considerable percentage of the rainfall infiltrates into the soil and contributes to the groundwater. The local water table is often connected to nearby streams, providing seepage to streams and wetlands during dry periods and maintaining base flow essential to the biological and habitat integrity of streams. Water that is evaporated into the atmosphere behaves like an air conditioner for the urban atmosphere, thereby more water in the atmosphere reduces the urban heat island effect, mitigating high air temperatures (Figure H-2a).

Figure H-2a: Hydrologic Cycle: Natural ground cover - Predevelopment Conditions

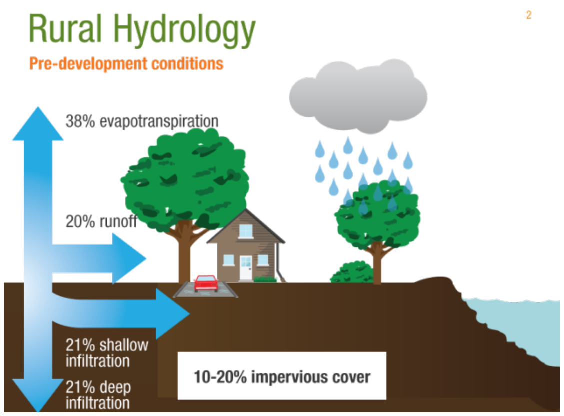

Figure 2b: Hydrologic Cycle: 10-20% Impervious cover – Predevelopment Conditions

(Adapted from FIRSWG, 1998)

Land development converts permeable land into increasing impermeable surfaces. During urbanization, natural channels are replaced by artificial drainage pipes and channels that decrease the amount of water infiltration and storage within the soil column. This alters the hydrologic regime by allowing less rainfall infiltration into the ground, and more channeled runoff through the urban infrastructure. Alterations to site runoff characteristics can cause an increase in the volume and frequency of runoff flows (discharge), velocities that cause flooding, and accelerated erosion (Figure H-3a). This also decreases the amount of water available for evapotranspiration and infiltration. Evaporation decreases because there is less time for it to occur when runoff moves quickly off impervious surfaces. Transpiration decreases because vegetation has been removed. In addition, urban infrastructure removes water from shallow ponds and

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[4] Adapted from Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. PB98-158348LUW.

[5] Prince George's County, Maryland Department of Environmental Resources Programs and Planning Division. 1999. Low-Impact Development Hydrologic Analysis

wetlands that could have otherwise been used to replenish the water table and maintain low flow conditions in local watercourses. Headwater streams, with small contributing drainage areas, are especially sensitive to localized changes in groundwater recharge and base flow.

As a much larger percentage of rainwater hits impervious surfaces including roofs, sidewalks, parking lots, driveways, and streets, it must be controlled through storm water management techniques. Traditional approaches have focused on collection and conveyance to quickly transport stormwater to the nearest watercourse to prevent property damage (Figure H-3a). Current stormwater management has taken an "end of pipe" approach, using gutters and piping systems to carry rainwater into ponds or detention basins (Figure H-3b). This approach does not mitigate or alter the runoff volume component of the water cycle which is the driving force over flood risk and drought due to decreases in subsurface flows.

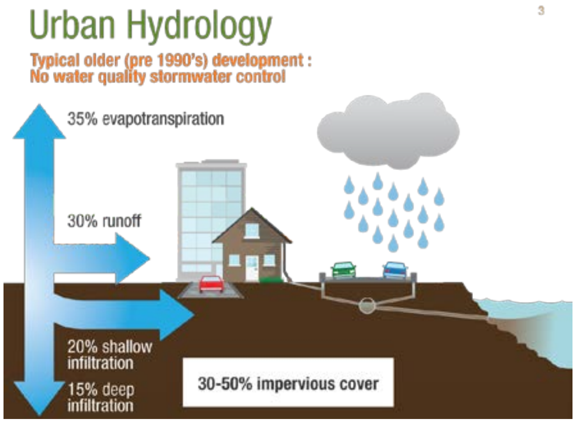

Figure H-3a: Stormwater Management with no water quality control

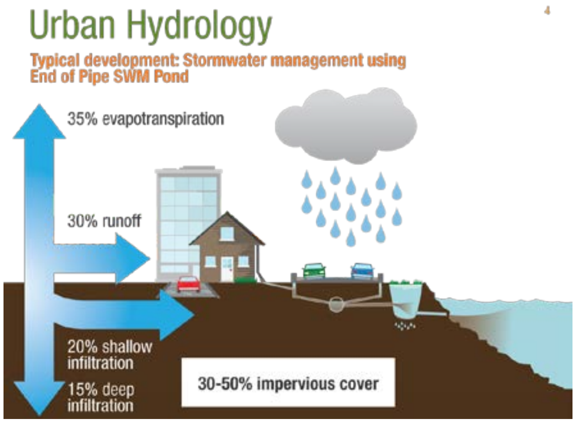

Figure H-3b: Stormwater management using SWM ponds.

(Adapted from FIRSWG, 1998)

Urban areas are particularly susceptible to flooding due to a high concentration of impervious surfaces that channel precipitation runoff into the city's underground infrastructure. During rainfall events of high intensity, duration and/or frequency, the runoff component of the water balance will be overwhelmed and not mitigated by infiltration, creating flood-prone areas in urbanized zones (Figure H-4).

Figure H-4: Flood prone area in Cooksville Creek watershed

As part of adaptive management, stormwater management has evolved over time in Ontario, from flood control requirements in the 1970s, to water quality and erosion requirements in the 1980s, to water balance requirements in 2012. The cost and complexity of these engineered systems has increased. In light of the current spot light on climate change and aging infrastructure there is growing awareness that stormwater management has become more than just treating a storm event it's also about maintaining stream flows during dry weather periods for wastewater assimilation, fisheries, and water takings. Through the Great Lakes Protection Act, Water Opportunities Act and Redside Dace legislation, stormwater is being recognized as a resource to be treated at source, conveyance and prior to entering waterways.

A robust stormwater management system that meets all environmental and economic goals must include both conventional stormwater management facilities and source based Low Impact Development (LID) practices. Conventional facilities are typically effective at achieving flood control by providing large volumes of stormwater detention. Conventional facilities however lack the ability to provide water balance benefits or reduce the volume of runoff from heavily urbanized areas. As a result they offer little benefits with respect to infiltration and erosion mitigation. LID practices excel where conventional systems fail by allowing for natural hydrologic processes including infiltration and evapotranspiration as close to the source as possible.

LID practices are designed to mitigate the rapidly changing water cycle by mimicking nature within the urban environment. LID strategies strive to allow natural infiltration to occur as close as possible to the original area of rainfall. By engineering terrain, vegetation, and soil features to perform this function, the landscape can retain more of its natural hydrological function (Figure H-5). Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale can also have a positive impact.

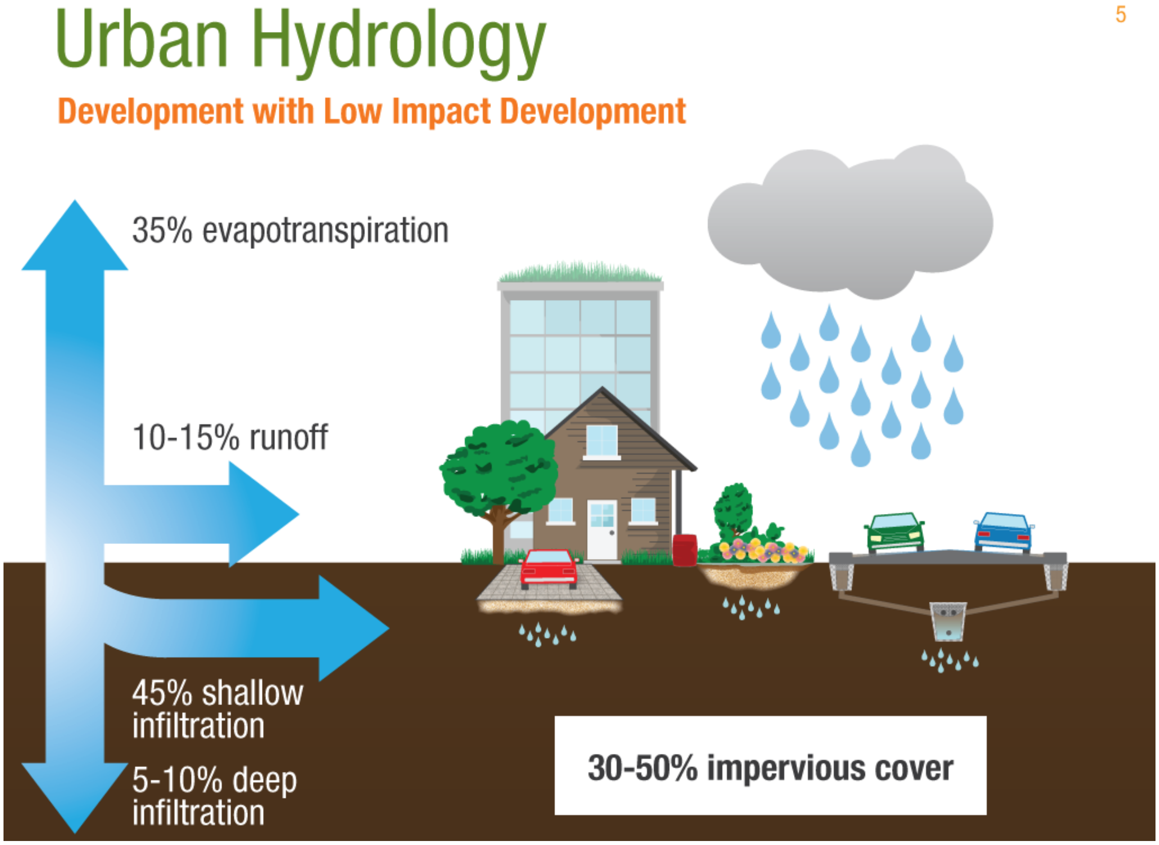

Figure H-5: Urban water cycle with Low Impact Development stormwater Management - (Adapted from FIRSWG, 1998)

2. UNEXPECTED CONSEQUENCES OF URBAN DEVELOPMENT

As might be expected, there is a linear relationship between the amount of impervious surfaces in a given area and the amount of runoff generated. What is unexpected is what this means in terms of both the volume of water generated and the rate at which it exits the surface. Depending on the degree of impervious cover, the annual volume of storm water runoff can increase to anywhere from 2 to 16 times the predevelopment amount[6]. Impervious surface coverage as low as 10% can destabilize a stream channel, raise water temperatures, and reduce water quality and biodiversity[7].

The longer duration of higher flows due to increased volume combines with that from downstream tributaries to increase the downstream peaks. As a result, the portions of Fletchers Creek is experiencing extensive bank slumping and erosion (Figure H-6).

In a natural setting, typically 6-9 events per year produce runoff that enters the stream. With LID stormwater management, very little to no runoff is produced during precipitation events less than 25 mm in depth, that is 90% of all precipitation events. What this means is that 69% of all the rain to fall will not produce runoff. In fact, LID sites can prevent runoff for events up to 25 mm in depth (Figure H-7). For rainfall events with a depth greater than 25 mm, in which runoff is produced, it was previously thought that LID would have little effect in mitigating flows. However, monitoring data has shown that there is runoff volume reductions and peak flow reductions even for large storm events.

Figure H-6: High stream flow in Fletcher's Creek

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[6] Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1(3):1'00-111.

[7] Schueler, T. 1995. Site Planning for Urban Stream Protection. Metropolitan WashingtonCouncil of Governments, Washington, DC.

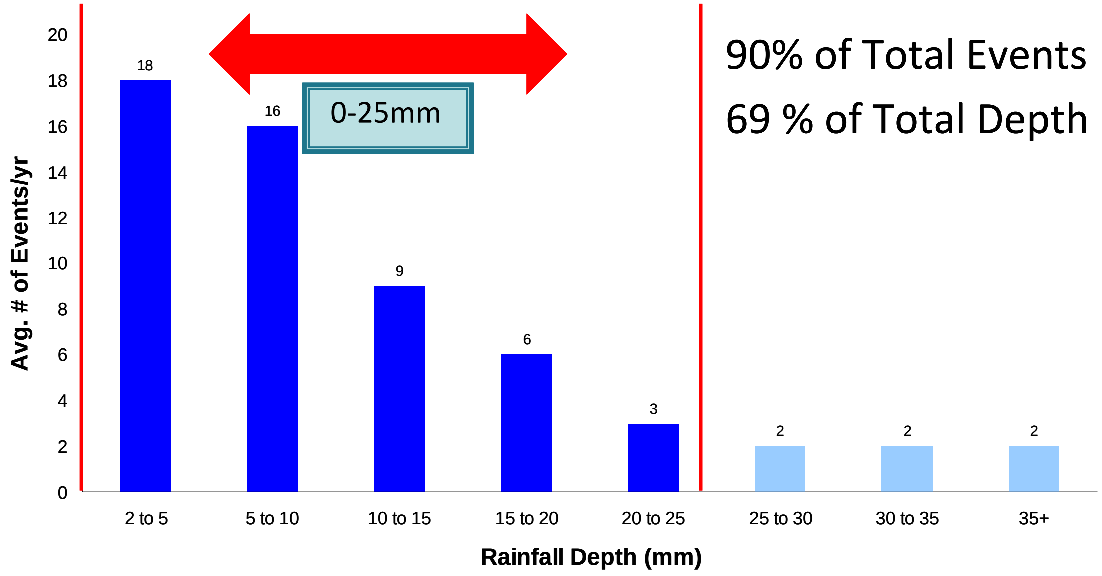

Figure H-7: Typical Annual Rainfall Frequency Distribution for Toronto Lester B. Pearson 1960-2012

3. CHANGES IN WATER QUALITY

Pollution from storm water runoff can also be a major concern in urban areas. Rainwater washing across streets and sidewalks can pick up spilled oil, detergents, solvents, de-icing salt, pesticides, fertilizer, and bacteria from pet waste. Carried untreated into streams and waterways, these materials become "non-point source pollutants" which can increase water temperature, algae content, impact aquatic habitats, cause beach closures and require additional costly treatment to make the water potable for drinking water systems. Beach closures and reductions in recreational fishing due to pollutant loading from urban stormwater and have resulted in up to $87 million a year in lost revenue to local economies[8].

Figure H-8: Sediment Plume from Credit River to Lake Ontario (Photo Credit: Aquafor Beech, 1990)

During last three decades, Ontario developers and municipalities have constructed end-of-pipe wet facilities (i.e. wet ponds, wetlands and hybrid ponds) as standalone stormwater management facilities to provide water quality control through the removal of total suspended solids. Conventional end-of-pipe wet stormwater management ponds, in which the main treatment mechanism is capture of particulates through settling, are not effective in removing the fine particles that carry most of the nutrients as well as most of the dissolved pollutants and hydrocarbons. The increase in water temperature as result of the increase in impervious surfaces is also a major water quality concern in urban streams. Retention of stormwater in conventional wet ponds allows stormwater to warm up, causing thermal impacts on receiving water bodies. Because temperature plays a central role in the rate and timing of instream biotic and abiotic reactions, such increases have an adverse impact on streams. In some regions, summer stream warming can irreversibly shift a cold-water stream to a cool-water or even warm-water stream, resulting in deleterious effects on salmonids and other temperature-sensitive organisms.

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[8] Marbek (submitted to Ontario Ministry of Environment). 2010. Assessing the Economic Value of Protecting the Great Lakes: Rouge River Case Study for Nutrient Reduction and Nearshore Health Protection. http://www.greeninfrastructureontario.org/sites/greeninfrastructureontario.org/files/Final%20Rouge%20Report%20Nov%2030.pdf

In the Credit River Watershed, the difference in the concentration of total suspended solids (TSS) in an urban stream that was receiving stormwater from upland developments with conventional end-of-pipe wet facilities and a rural stream with only 10 - 20% impervious cover during dry ambient condition is shown in Figure H-10. The comparison demonstrated that there are higher levels of TSS in the stream draining the developed area with conventional stormwater management wet facilities than in the rural area. This is due to the lack of runoff volume control in the stormwater management ponds.

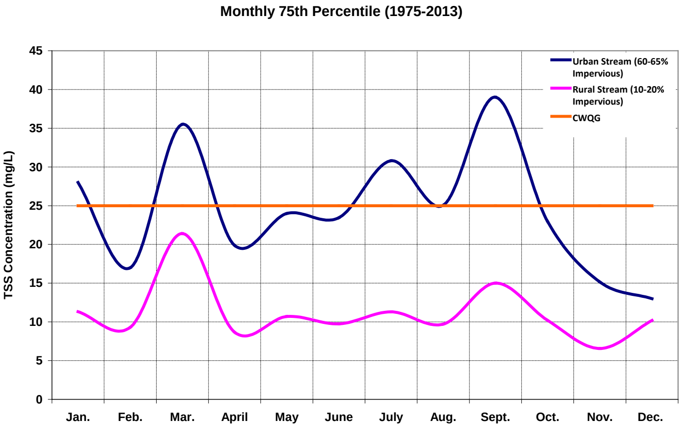

Figure H-9: Monthly 75th Percentile Total Suspended Solids concentration compared at an urban vs. rural

There is also significant concern about phosphorus loading from urban areas. Phosphorus is one of main pollutants of concern in urban drainage. Phosphorus and other nutrients are transported by runoff in a particulate-bound and dissolved phosphorus form.

Note: Different urban/rural stream have unique responses to development. The example graphs how scenarios observed for one rural and one urban watercourse in CVC's jurisdiction.

The Total Phosphorus (TP) concentration in two monitored streams within CVC's watershed showed similar results to those observed for TSS. Higher phosphorous concentrations were observed in the urban stream that was receiving stormwater from upland developments into a conventional end-of-pipe SWM facility than in the rural stream that had only 10 - 20% impervious cover during the summer months. Peak concentrations were seen in the rural stream during the spring season whereas peak concentrations were seen in the urban stream during the summer season (Figure H-10). This is due to the greater level of impervious surfaces and lack of stormwater volume control in the urban stream. Elevated concentrations of nutrients in the summer season is the major factor contributing to excess algae growth and depressed dissolved oxygen in receiving streams[9].

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[9] Aquafor Beech (for Conservation Halton). 2005. LOSAAAC Water Quality Study. Aquafor Beech reference 64353. https://halton.ca/living_in_halton/water_wastewater/water_quality_protection/lake_ontario/LOSAAAC/

Currently there is a significant concern about phosphorus loading from urban areas. Phosphorus is considered as one of main pollutants of concern in urban drainage. Phosphorus and other nutrients are transported by runoff in a particulate-bound and dissolved phosphorus form.

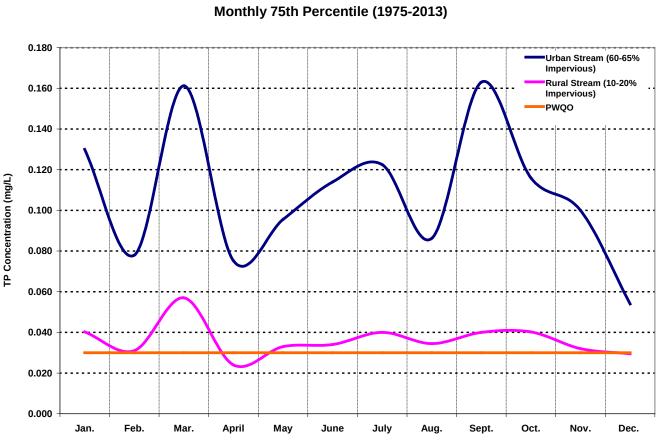

Figure H-11: Monthly 75th Percentile Total Phosphorus concentration compared at an urban vs. rural catchment

New York State SWM Design Manual also states that “Based on the best available data, it has been observed that particles less than 10 µm tend to have substantially higher associated phosphorus concentrations than larger particle sizes”. This raises concerns with respect to the ability of wet ponds to remove particulate phosphorus as they are not efficient in removing particles less than 10 µm[10]. Moreover, treatment mechanisms focused on capture of particulates does not address dissolved phosphorus removal. This is consistent with the *2003 MOE Stormwater Design Guidelines*, which state that while end-of-pipe facilities are typically designed to remove 60-80% suspended solids, the typical removal efficiency for total phosphorus is 40-50%.

Section 4.4 of the *2003 MOE Stormwater Design Guidelines* also recognize that the use of stormwater ponds for water quantity and quality control can impair receiving stream habitat because of the heating of the discharge water. Because a municipality may have hundreds of wet stormwater management facilities within a single watershed, the cumulative impacts on aquatic systems can be significant.

In streams containing Redside Dace, Ministry of Natural Resources requires that there be no storm runoff from rainfall events in the range of 5 to 15 mm, considering the recommendations of the subwatershed plans and soil permeability[11]. In such circumstances, low impact development strategies to promote infiltration and stormwater reuse should be utilized to match post development water balance with the pre-development condition.

Figure H-12: High TSS from urban runoff in Springbrook Creek habitat of Redside Dace

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[10] Greb, S. and Bannerman, R. 1997. Influence of particle size on wet pond effectiveness. Water Environment Research, 69 (6): 1134-1138.

[11] Ministry of Natural Resources (MNR). 2011. DRAFT Guidance for Development Activities in Redside Dace Protected Habitat. Ontario Ministry of Natural Resources, Peterborough, Ontario. ii+42 pp

4. RESOURCE INFORMATION

Literature reviews show that LID practices mitigate the impacts of urbanization by mimicking pre-development hydrology. CVC/TRCA's *Low Impact Development Stormwater Management Planning and Design Guide* provides planning and design guidance on a wide range of stormwater management practices such as bioretention, disconnection of downspouts, rain harvesting, swales, permeable pavement, and green roofs.

Prevention of urban runoff is an effective means to achieve a broad range of stormwater management objectives such as maintaining pre-development runoff volume, frequency and duration for frequent storm events, reducing runoff temperature, reducing the concentration of TSS and reducing the loading of phosphorus into surface waters. Reducing imperviousness and disconnection of impervious areas can be achieved through alternative design standards for road widths, road right of ways, minimum numbers of parking lot, varied front and rear lots, the use of pervious materials and the use of source controls as discussed in the above document.

For detailed information on preventative and mitigation measures to address thermal impacts of urban developments, refer to *CVC's Study Report: Thermal Impacts of Urbanization including Preventative and Mitigation Techniques* and *CVC/TRCA Low Impact Development Stormwater Management Planning and Design Guide*.

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

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Monitoring Results (2016-2017)

Appendix I

Site Assumption Protocols

CREDIT VALLEY CONSERVATION
1255 Old Derry Road,
Mississauga, Ontario
L5N 6R4
Tel: (905) 670-1615 Fax: (905) 670-2210
1-800-668 5557

Date:	September, 2015
To:	Giulio Bianchi – Sequoia Grove Homes
From:	Kyle Vander Linden and Jakub Wrobel
CC:	Tim Mereu, Phil James, Christine Zimmer, Amanjot Singh, Gayle Soo-Chan
RE:	**Summary of LID remediation and Site Visit on September 16, 2015**

Representatives from Credit Valley Conservation visited the site on Wednesday, September 16th to observe the condition of the LID features at the Sequoia Grove development (Wychwood). CVC's conducts site visits in an aim to ensure proper construction and to preserve the infiltration capacity of the LID features (bioswales, rain gardens, permeable pavers) by identifying protection measures needed during the construction phase.

CVC and Sequoia Grove Homes have been engaged in ongoing inspection of the site and performance monitoring is intended for the future. Based on recommendations from site visits and meeting memo's provided to Sequioa Grove Homes on Oct 10, 2013, May 23, 2014, Sept 18, 2014, Oct 9, 2014, May 15, 2015, and now Sept 16, 2015 CVC identified impacts to LID features and recommended rehabilitation work and guidance to restore the LID features prior to assumption.

Sequoia Grove Homes has completed some restoration work and have responded quickly to requests. Sequoia Grove Homes also noted that other restoration activities will take place after the installation of the top asphalt layer. The top asphalt coat has now been applied. In order to assist Sequoia Grove Homes in the restoration of the LID features, a summary of action items identified over the inspection period is described in Table 1. CVC can provide guidance to Sequoia Grove Homes for restoration activities and very willing to answer any questions that they may have.

ORIFICE TABLE

STRUCTURE	SIZE	INVERT
MH103	320mmø	187.24
CBMH9	140mmø	188.88

While inspecting site dry weather conditions, CVC monitoring staff have observed the following issues which may reduce LID performance. CVC monitoring staff will collect wet weather videos to confirm potential concerns listed below:

1. Improper soil height within each rain garden will impede surface flows from entering each garden through the curbside inlets. Flows are diverted directly into adjacent catch basin untreated.
2. Asphalt grading towards catch basin on Honour Oak Crescent near the south end of the bioswale is excessive and will significantly reduce flows from entering the bioswale on the opposing side of the roadway.
3. Temporary location of mail box has prompted residents to use east bioswale as a walkway to collect their mail. This action may cause compaction from foot traffic decreasing infiltration performance

Table 1: Summary of action items for LID features at Wychwood

LID Feature	Action Item	Status	Implications and remediation recommendation
Entire Site	Completion of sod placement on front and backyards to minimize movement of dirt into bioswale area.	Sod placement with back and front yards complete.	N/A
East Bioswale	Completion of the fence to completely restrict access to public to the bioswale	Posts and fence installed, task is complete.	N/A
East Bioswale	Restriction of heavy equipment and materials within the east bioswale area to avoid compaction. Materials were stored within east bioswale noted on May 15th, 2015 site visit.	Materials and equipment were removed based on email correspondence between CVC and Sequoia Grove Homes on May 27, 2015. Routine visit on July 28th, 2015 had construction equipment still in the bioswale. Site visit on September 16th, 2015 confirmed that all materials and equipment have been removed. However a sod waste bin was present during the site visit.	• If bioswale is compacted, infiltration performance could be reduced. • Infiltration tests recommended along length of east bioswale • Removal of sod, sediment and tilling of bioretention media in compacted areas. • Relaying of RPF sod
East Bioswale	Clean up of sediment and garbage at and around inlets within the bioswale and extension of curb inlet into bioswale	Incomplete based on May 15th, 2015 site visit. Past memos have identified ponding in around inlet areas of bioswale (Oct. 9, 2014). Infiltration test from Sept. 5, 2014, noted failure at inlets. May 15, 2015 site visit notes	• Ponded water within bioswale for more than 24 hours indicates failure of the system. • Recommend removal of sod and sediment and tilling of bioretention media. • Infiltration test required to verify

		current construction of curb inlet into bioswale. September 16, 2015 Site visit notes that most garbage and debris have been cleaned out. Sediment is present in inlets but does not appear to be from construction practices.	success of rehabilitation.
East Bioswale	Improvement of east bioswale infiltration	September 5th, 2014 memo noted average infiltration rates of 44 mm/hr (Range of 12 mm/hr low – 60 mm/hr). Past LID studies indicate an infiltration rate of 80 – 120 mm/hr is ideal to account for decreasing performance through operational lifespan Bioswale was aerated in September 2014. May 15, 2015 site visit noted compacted areas and sediment contamination at surface of bioswale. September 16th, 2015 site visit noted that compacted areas and sediment is still present. Sediment has been minimized.	• Poor infiltration rates at assumption could lead to shortened operational lifespan. • Future Recommendation – if aeration does not improve infiltrations, complete infiltration tests within bioswale, identify problem areas, and remove sod, sediment, and tilling of bioretention media to improve infiltration. • Re-stabilize with RPF, sod, or grass seed
Bioswale and rain gardens	All construction activities are complete	May 15, 2015 site visit noted the removal of curb sections at east bioswale. September 16, 2015 site visit noted the inlets have been constructed.	• Could result in clogging of the bioswale/rain gardens and impacting infiltration rates. • Sediment removed • Infiltration testing to verify

		Some compaction was noticed around the perimeter of the installations from construction of the inlets.	infiltration rates are not impacted • Exposed soils should be stabilized as soon as possible
Bioswale and rain gardens	Video-scoping of perforated pipes should be conducted to ensure no clogging by construction sediment.	Incomplete or not within CVC records – noted on May 23, 2014 memo September 16, 2015 cannot confirm whether this was done.	• Clogged pipes could prevent water from flowing through the system even if soil infiltration rates are satisfactory. • If perforated pipes are clogged or damaged than removal of sediment and possibly their replacement is recommended.
West Rain gardens on	Ensure as-built grades meet design grades for LID features.	Incomplete based on May 15, 2015 site visit. As noted in the September 5th memo there should be a 2" (50 mm) drop from finished curb to sod or bioretention media. See photos below table. September 16, 2015 site visit indicated that some rain gardens had the correct grade drop however some still did not (See photos below table). Completing this task as soon as possible is recommended to ensure drainage from the road enters the swale.	• Final coat of asphalt has been applied, verify grade drop from finished curb to bioswale. • A grade drop will ensure positive drainage into the LID features. If there is insufficient grade drop, by pass or blockage could happen. See pictures below. • Recommended re-grading if to design grades to allow flow of runoff into LID feature

Site Visit on September 16, 2015

East Bioswale

East Bioswale on Honour Oak Cres appears to be in good condition. Grade drop from curb to bioswale is present throughout majority of the swale. There was a sod bin with some dirt leftover on the road.

Figure 1: Bioswale with sod bin nearby

As CVC inspected along bioswale, large inlet has been constructed with stones at the end. No ponding issues currently, however sediment was present within inlet. Soil was still heavily compacted around new inlet as result of construction of the feature. As noted in previous memo's from May 23, 2014, Sept 18, 2014, Oct 9, 2014, and May 15, 2015. It is CVC's recommendation that the dirt be removed and area aerated to encourage proper infiltration. Infiltration testing should be conducted afterwards to verify improvement of infiltration rates.

Figure 2 Sediment Buildup within Inlet

The last bioswale on East side also has a newly constructed inlet with stones at the end. Much more sediment was present in this inlet than the one on Coach House. It is

CVC's recommendation that the area aerated to encourage proper infiltration. Infiltration testing should be conducted afterwards to verify improvement of infiltration rates.

Figure 3: New inlet sediment and view north naturalized area

Rain Gardens

Upon inspection of the rain gardens within the road right of way, CVC noted that the grade of plants within small rain gardens is too high at certain points which will block water from entering. Grading of the plants is critical as these features are dependent on sheet flow from the roadway. As noted previous memo's there should be a 2" (50 mm) drop from finished curb to sod or bioretention media. It is CVC's recommendation that the landscape company re-grade these features to ensure positive grade from finish curb to rain gardens per the design drawings. The additional mulch in the rain gardens has added a substantial amount of material above the grade of the inlet that will definitely impede flow.

Figure 4: Rain Garden inlets blocked with high soil, plantings, mulch

West Bioswales

CVC also noted that the grade of sod within the large rain gardens is too high at certain points which will block water from entering. Grading of the sod is critical as these features are dependent on sheet flow from the roadway. As noted previous memo's there should be a 2" (50 mm) drop from finished curb to sod or bioretention media. It is CVC's recommendation that the landscape company re-grade these features to ensure positive grade from finish curb to rain gardens per the design drawings.

Figure 5: West rain gardens sod height

As noted in the previous memo, there has also been some construction at the adjacent property of one of the rain gardens, which may have impacted the rain garden. The bioretention media and perforated pipe system could have been affected and could impact infiltration rates and flows within the system. The site visit on September 16th, 2015 noted that a concrete walkway was constructed in this area. Infiltration testing should be conducted.

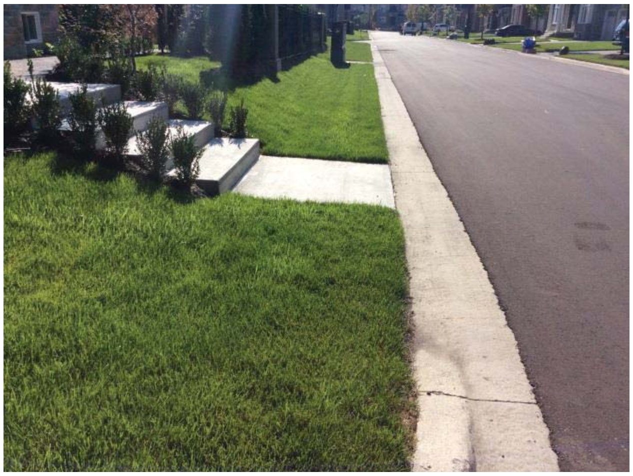

Figure 6: New walkway constructed directly in bioswale

Please let me know if you have any questions or concerns. You can reach me at 905 670 1615 X 279 or kvanderlinden@creditvalleyca.ca

Best Regards.

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Credit Valley Conservation

Wychwood Subdivision, City of Brampton

Low Impact Development Infrastructure Performance and Risk Assessment

Technical Report

Monitoring Results (2016-2017)

Appendix J

Wychwood Model Report

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Figures

1. Introduction

The Credit Valley Conservation (CVC) has undertaken this study to develop a stormwater management (SWM) model for the Wychwood subdivision (site). This site uses low impact development (LID) practices to control stormwater runoff volume and quality. The purpose of this study is to develop a representative hydrologic model based on monitoring flow and water quality data. Key objectives include:

- Complement the original design and modeling analysis,
- Build a robust hydrologic model based on calibration with monitoring data,
- Estimate stormwater quantity control achieved by LIDs on an event basis, and under different return period storms,
- Estimate water quality control on an annual basis

The intent is to be able to use the model to estimate stormwater quantity and quality performance for the site under different storm events and on a continuous basis in the future.

1.1. Study Area

The study area is the Wychwood development which is a residential subdivision located in Brampton, Ontario and occupies an area of approximately 4.1 hectares (ha). The site uses multiple LID features such as permeable pavement, rain gardens (RG), swales and bioswale to control stormwater runoff on site. Other stormwater Best Management Practices (BMP) such as Oil Grit Separators (OGS) are also used on site to provide filtration before runoff enters LID facilities. All roof area in the subdivision is disconnected and routed to lawn. All driveways are permeable pavement.

The site has a major drainage divide along the centre which separates surface drainage from the east and west areas. Under pre-development conditions, the eastern areas drained towards the Orangeville Development Corporation rail line and ultimately to Tributary 8b. The western areas drained to the Credit River through ditches and overland flow.

Post development flows from eastern area are routed through a bioswale, while flows from western drainage area are routed through a series of swales (also referred to as infiltration trenches). Flows leaving the east bioswale are conveyed to the west via a storm sewer at which point both east and west flows combine and are conveyed through a storm sewer into the Churchville Tributary and eventually to the Credit River. For detailed assessment of the study side and flow routing between different BMP's please refer to the drawings in Appendix A.

The site consists of sand to silt to silty clay type soils as per the Hydrogeologic investigation undertaken during the design process. Based on the collected monitoring well data the water table is 2-3 metres below ground surface with the exception of one location where water was contacted at 0.88 metres below ground surface. This location is in the northwest area of the site and contributes baseflow to the west swales. As a result baseflow separation is performed on monitoring data collected from this site to avoid overestimating outflow from these practices during storm events.

1.2. Stormwater Design Criteria

The site was designed for the following stormwater criteria:

- Water quality control – Enhanced water quality treatment as per the MOECC Stormwater Management Planning and Design Manual, i.e. long term removal of 80% suspended solids
- Erosion control – Manage, detain or reuse all rainfall events up to 15 mm storm event over the entire site
- Water quantity control – Reduce the 2 to 100 year post development flows to pre development levels
- Water balance – Retain the average annual infiltration depth to pre development levels.

1.3. Monitoring locations

Flow monitoring is being conducted at Wychwood since fall 2015 at two locations – one downstream of the west bioswale at Manhole 104 which collects all flow from the bioswale and contributing catchment. This location is titled ‘WW-1’. The other monitoring location is downstream of the east swales in manhole 102 and collects all runoff from the eastern areas plus flow from manhole 104. This location is called ‘WW-2’. Baseflow separation is performed at WW-2 only. Water quality samples are collected for individual storm events at both locations.

For the purpose of this study observed and modeled flows are compared at these two monitoring locations for calibration and validation of the model.

2. Hydrologic Model

The LID Treatment Trail Tool (LID TTT) and EPA’s Stormwater Management Model (EPA-SWMM or SWMM5 or SWMM) have been used to develop the model for this site. The LID TTT is a conceptual stage model developed by Ontario’s Conservation authorities to estimate stormwater quantity and quality control achieved by LIDs. It relies on the SWMM model engine for computational output and has the capability to generate an input file for SWMM for further detailed modeling and analysis.

EPA-SWMM is a dynamic hydrology-hydraulic water quality simulation model. It is used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component operates on a collection of sub-catchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. It has the capability to design and model LID features.

Model development began in the LID TTT and the files were exported to EPA-SWMM for detailed model set-up. The current study requires the set-up of major and minor system components and flow restriction devices which were not possible in the LID TTT. The LID TTT is meant to be a conceptual level model and not all detailed design capabilities of SWMM have been included in the tool.

2.1. Model Development

This section outlines the model set-up under pre development and post development conditions for Wychwood. A Visual OTTHYMO (VO2) model was set up for Wychwood during the design process and has been briefly discussed in this section as well. Peak flow results from VO2 for the 2 to 100 year storm have also been used for calibration of the SWMM model.

2.1.1. Original VISUAL OTTHYMO post development model

A modeling analysis was undertaken as part of the design process for the current site to estimate peak flows for the 2 to 100 year storm under pre and post development conditions. The goal is to ensure that post development peak flows match pre development peak flows for the site. A VO2 model was set up in order to model the hydrology of the site under pre and post development conditions. This section outlines the setup of the post development VO2 model. The 2 to 100 year storm used in the VO2 model is based on the SCS 24 hour storm distribution.

Post development VO2 model

The post development total area of the site modeled in VO2 is 5.47 ha. Out of this 2.34 ha of area in the west is to be controlled by the swales. In the east 2.35 ha is to be controlled by the bioswale. The remaining 0.78 ha from the west is uncontrolled flow from the site (Figure 1).

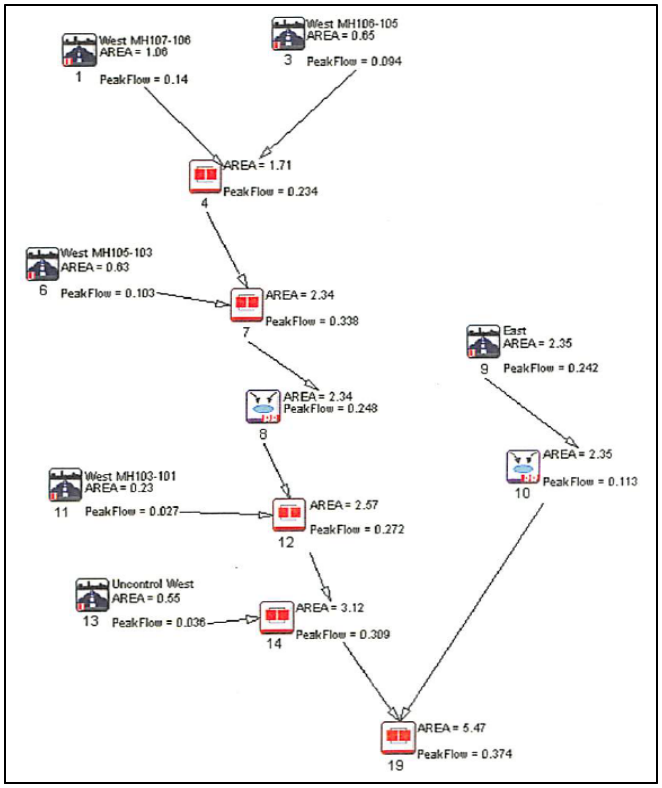

Figure 1 Post development VO2 model schematic

Under post development conditions it has been estimated that 37 – 44% of the site is covered by impervious surfaces like roof, driveway and roads. Out of this 13 – 31% is assumed to be directly connected impervious area. The central drainage area divide separating the western and eastern areas is retained. Average slope of all areas is taken as 1%. Depression storage of 1 mm and 5 mm for impervious and pervious surfaces, respectively, is assumed.

The post development model required inclusion of LID measures on site and the stormwater control offered by these features. As discussed before these include rooftop disconnection and increased topsoil depth, permeable pavement, rain gardens, swales, and bioswale. Because setting up LID features is not directly possible in VO2, reductions achieved by each of the LID features was estimated outside of the model. Certain model parameters were then modified to account for the reduction provided by LIDs on site.

Rooftop disconnection and control provided by increased topsoil depth for the 25 mm storm was represented in the model through a modified runoff coefficient. Base runoff coefficient for roof runoff (0.90) was modified for each of the design storms to represent runoff minus 25 mm retention. Similarly, in order to represent permeable pavement capture of 25 mm of runoff on site, runoff coefficient for permeable driveway was modified to represent runoff minus 25 mm retention. The limitation of using this approach to estimate storage provided by LIDs is that it may underestimate the amount of control provided by LIDs. Storage space becomes available within these features due to seepage from these features into native soils. And since the native soils are quite porous at this site that would mean storage becomes available more quickly, and therefore there is a greater capacity to retain stormwater on site than simply the total volume of the LID.

Storage features were used to model stormwater control provided by the swales in the west and the bioswale in the east. A stage-storage-discharge curve was developed separately for each of the features. Storage available at different stages was estimated based on geometry of the features. Details of the LID facilities used to estimate storage volume in the model are presented in Table 1. The discharge from each feature was estimated based on infiltration losses from each of the facilities and outlet configuration. An orifice is included at the downstream end of both the features. Orifice downstream of the east bioswale is 140 mm. Orifice downstream of the west swales is 320 mm.

Table 1 LID design specifications used in VO2 model

LID	Length (m)	Porosity	Width (m)	Depth below underdrain (mm)	Size of underdrain (mm)	Storage provided (m^3)
Bioswale	Not specified	0.4	Not specified	Not specified	Not specified	703
RG 1	4.00	0.4	2.2	600	Not specified	2
RG 2	4.00	0.4	2.2	600	Not specified	2
Swale 1	40.1	0.4	2.2	20	450	54
Swale 2	45.5	0.4	2.2	650	450	69
Swale 3	17.6	0.4	2.2	320	525	63

2.1.2. Post development SWMM model

In order to model post development conditions at Wychwood a dual drainage model was set up for the site. This means that minor flows were routed through underground facilities into LID whereas major flows were routed through the road surface to the outfall.

Drainage area discretization

Drainage area to each LID was delineated using LIDAR data in ArcGIS software. Figure 2 shows drainage area plus area of each LID at Wychwood. Table 2 presents model input for each catchment for the post development SWMM model. The Green and Ampt infiltration method was used to calculate infiltration in SWMM. Choice of soils was based on borehole logs and monitoring wells. Based on this information, the western area consists of silt and silty clay soils. The eastern area consists of sand and silt soils. The lower groundwater loss rate is an input parameter for the aquifer associated with each catchment. This was a sensitive parameter and was calibrated based on observed flows at WW-1 and 2.

Drainage area to the west bioswale was split into three catchments to better capture the catchment area draining to each section of the bioswale. Resultantly the bioswale was also split into three catchments. It was also found in an infiltration test conducted at the site post construction that the infiltration rate was variable along the length of the bioswale. That was likely due to failure to properly construct LID. Splitting the bioswale into 3 smaller areas allows this to be built in.

The drainage area to OGS 7 was split into two catchments: one catchment (To_OGS7_1) is routed to the surface of the bioswale and allowed to be filtered through the bioswale; the other area (To_OGS7_2) is connected directly to the bioswale's outlet through a leaky pipe (conduit with seepage). This split was based on calibration of flows at the outlet of the west bioswale.

All catchments have slope 1%. Manning's roughness for impervious surfaces is assumed to be 0.013 and for pervious surface is taken as 0.25. Depression storage of impervious surfaces is taken as 2 mm and of pervious surfaces is 25 mm due to increased topsoil depth. A schematic of the post development SWMM model is shown in Figure 3.

Figure 2 Drainage area delineation for post development SWMM model

Table 2 Post development SWMM model catchment details

Catchment	Area (ha)	Imperviousness		Soil saturated hydraulic conductivity (mm/h)	Lower Groundwater loss rate (mm/h)
		Total	DCIA		
To_Bioswale1	0.499	38%	17%	47	0.5
To_Bioswale2	0.587	38%	17%	47	0.5
To_Bioswale3	0.381	38%	17%	60	0.5
To_OGS1	0.127	34%	25%	0.51	0.1
To_OGS2	0.158	34%	26%	0.51	0.1
To_OGS3	0.115	32%	24%	0.51	0.1
To_OGS4	0.105	35%	26%	0.51	0.1
To_OGS5	0.149	45%	26%	0.51	0.1
To_OGS7_1	0.17	43%	17%	60	0.5
To_OGS7_2	0.069	43%	17%	60	0.5
To_RG1	0.273	54%	15%	0.51	0.1
To_RG2	0.261	51%	13%	0.51	0.1
To_Swale1	0.134	37%	26%	0.51	0.1
To_Swale2	0.349	48%	17%	0.51	0.1
To_Swale3	0.536	49%	18%	0.51	0.1

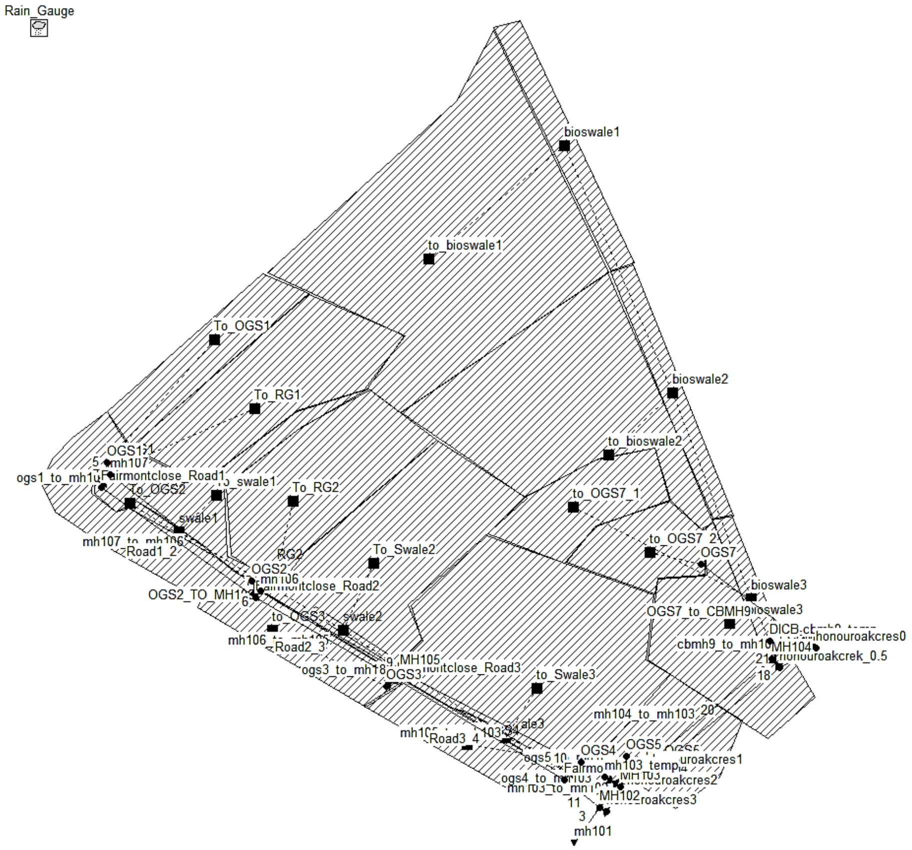

Figure 3 Post development SWMM model schematic

Low Impact Development Treatment Train

The LIDs on site were modeled using SWMM's LID control editor. Input parameters for each of the LID features at Wychwood are presented in Table 3. The underdrain offset height is based on calibration of flows at WW-2. Soil media conductivity for bioswales 1 and 2 was dropped based on infiltration tests conducted on site post construction. The seepage rate from storage layer is based on native soil infiltration rates. All other LID parameters are based on design drawings and typical soil and storage media used in infiltration practices.

Table 3 LID parameteres used in SWMM model

	RG 1 and 2	Swale 1	Swale 2	Swale 3	Bioswale 1 and 2	Bioswale 3
Surface layer						
Surface berm height	150	150	150	150	0	200
Vegetation volume fraction	0.3	0.3	0.3	0.3	0.3	0.3
Surface Roughness	0.25	0.25	0.25	0.25	0.25	0.25
Surface slope	2	0.5	0.5	1.1	0.5	0.45
Soil media layer						
Soil thickness	525	525	525	525	525	525
Soil Porosity	0.453	0.453	0.453	0.453	0.453	0.453
Field Capacity	0.190	0.190	0.190	0.190	0.190	0.190
Wilting Point	0.085	0.085	0.085	0.085	0.085	0.085
Conductivity	60	300	300	300	12	60
Conductivity slope	45	45	45	45	45	45
Suction head	110	110	110	110	110	110
Storage media layer						
Storage thickness	1925	2075	1975	1675	975	1200
Void ratio	0.4	0.4	0.4	0.4	0.4	0.4
Seepage rate	2	6	6	6	43	150
Clogging factor	0	0	0	0	0	0
Drain layer						
Drain flow coefficient	2	2	2	2	2	2
Flow exponent	0.5	0.5	0.5	0.5	0.5	0.5
Offset height	625	240	195	120	0	500

The OGS's and swales in the east and the OGS and bioswale in the west are set up in a treatment train, respectively. It was challenging to set up the routing between these features in SWMM because outflow from the OGS features is directly connected to the underdrain of the LIDs. SWMM5 does not currently allow flows from catchments or nodes to be routed directly to LID underdrain. A workaround for this limitation was to connect OGS to nodes separately through conduits while allowing seepage from the connecting conduits. The swales in the east are routed to each other with reduced storage capacity below the underdrain to account for storage being occupied by inflow from OGS features. A simple schematic of the routing of LID elements used in the model is presented in Figure 4.

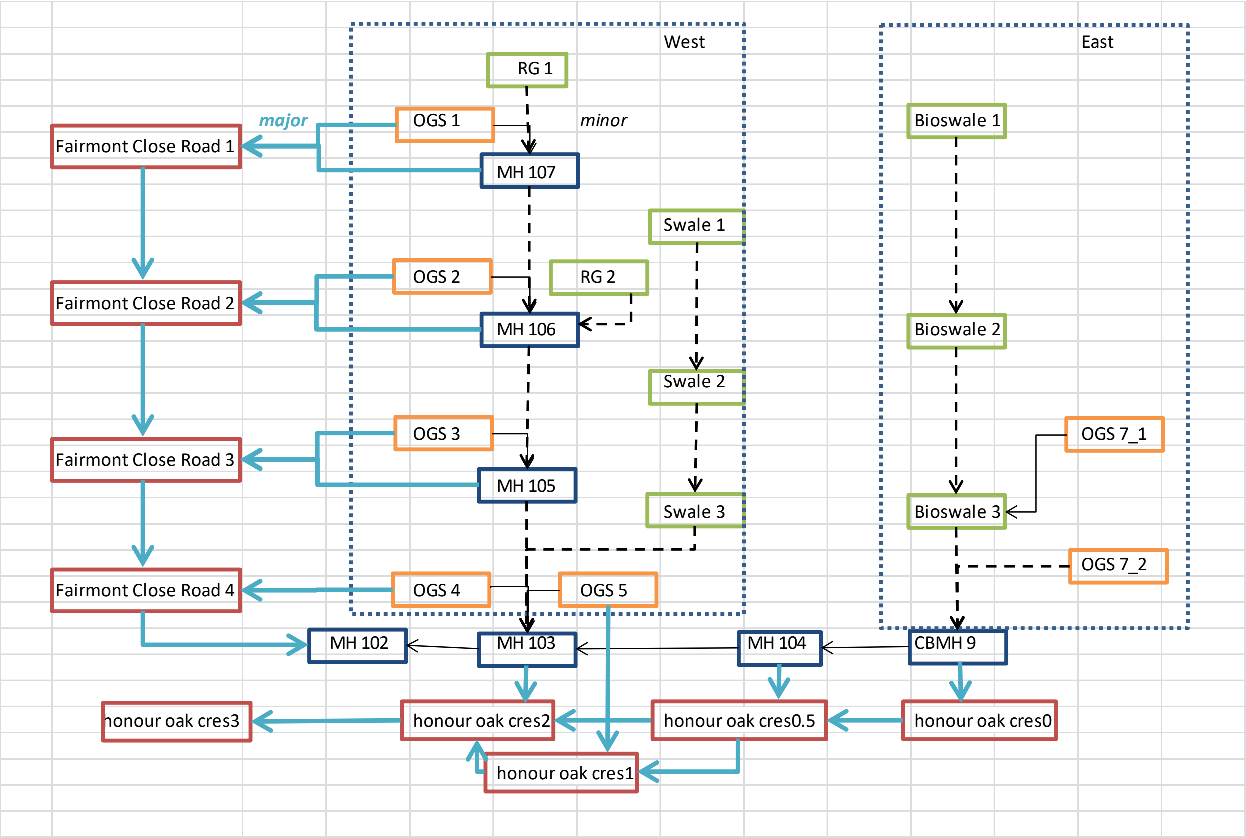

Figure 4 LID treatment train schematic for post development SWMM model

Water Quality

The pollutants modeled in the current study are Total Suspended Solids (TSS) and Total Phosphorus (TP). To simulate water quality in the SWMM model, land use-based event mean concentrations (EMC) and concentration-based removal efficiencies have been used. EMC values for TSS and TP are derived from the Lakeview control site. Lakeview is a residential subdivision in Mississauga which has been monitored for water quantity and quality. EMC values from Lakeview used in the current model are 46 mg/L for TSS and 0.26 mg/L for TP. These values were selected based on calibration of pollutant effluent loading at WW-2, and in consistency with monitoring data analysis.

The median effluent concentration of TSS at WW-2 is 45 mg/L and for TP is 0.142 mg/L for January – April based on 2 sampled events. The median effluent concentration of TSS at WW-2 is 26.5 mg/L and for TP is 0.176 mg/L for August – December based on 7 sampled events.

Removal efficiencies used in the model were derived from values currently being used by the LID Treatment Train Tool. Removal efficiency of Infiltration systems was used for the swales and bioswale, i.e. 75% TSS removal and 60% TP removal. Removal efficiency of Enhanced Swales was used for rain gardens, i.e. 40% TSS removal and 25% TP removal. Removal efficiency of 50% TSS was used for Oil Grit Separators and no removal of TP was assigned.

2.2. Model Calibration and Validation

Model calibration and validation involved running a continuous simulation from September 2015 to December 2016 for the calibration period, and January 2017 to August 2017 for validation, and looking at select storm events and periods during which monitoring data is expected to be accurate.

Data for some of the monitoring period is being omitted from the results of this analysis due to leakage at the weir during those periods. This calibration exercise focused on summer storm events, annual outflow (WW-1 only) as well as the following continuous flow periods (for WW-2):

- January 2016 – April 13, 2016,
- August 16, 2016 – December 2016 for calibration, and
- January 2017 – March 16, 2017,
- June 6, 2017 – August 22, 2017 for validation

It was important to have a good calibration of peak flows as well as total outflow at both monitoring locations but greater focus was on WW-2.

2.2.1. WW-1 flow calibration

Storm events with a magnitude of 10-30 mm with reliable flow data, and observed peak flows in excess of 1 litre per second (lps) were selected for calibration at the WW-1 location. Observed and modeled outflow for the calibration storms is presented in Table 4.

Table 4 Observed and modeled runoff volume and peak flow for storm events at WW-1

Date	Rainfall depth	Observed Runoff Volume (L)	Modeled Runoff Volume (L)	Difference	Observed peak flow (lps)	Modeled peak flow (lps)	Difference
2016-06-04 22:35	17.0	2038	1725	**15%**	1.20	0.37	**69%**

2016-07-25 3:30	10.2	1311	1614	**-23%**	1.60	2.92	**-83%**
2016-08-13 11:30	19.6	3374	3192	**5%**	1.10	2.52	**-129%**
2016-08-25 0:35	11.0	1490	1824	**-22%**	1.92	2.10	**-9%**
Average				**-6.3%**			**-38%**

It was not possible to achieve a very good calibration at this location due to uncertainty in hydraulic conductivity of soils within the bioswale, as well as due to the routing mechanism employed in the model to simulate hydraulic connectivity between OGS 7 and bioswale.

On average the model underestimates performance of the bioswale in capturing runoff and controlling peak flows on an event basis. This is largely because the catchment of OGS 7, which is connected directly to the bioswale’s underdrain, was modeled as going through two different mediums: some area was routed directly to the bioswale’s outlet receiving no control; the other was routed onto the bioswale’s surface receiving full control before entering the underdrain. The variability in difference between modeled and observed flows at WW-1 makes calibration for all events difficult at this location.

Annual modeled outflow for 2016 at WW-1 is approximately 87 m^3 whereas observed annual outflow is 114 m^3, a difference of 24%.

Adding a component in the SWMM model to allow routing from nodes and catchments directly to an LID underdrain would improve the event-based and continuous calibration at this location. This recommendation has been made to the development team of EPA-SWMM.

2.2.2. WW-2 flow calibration

Storm events with a magnitude of 5-30 mm with reliable flow data were selected for calibration at the WW-2 location.

Table 5 Observed and modeled runoff volume and peak flow for storm events at WW-2

Date	Rainfall depth (mm)	Observed Runoff Volume (L)	Modeled Runoff Volume (L)	Difference	Observed peak flow (lps)	Modeled peak flow (lps)	Difference
2016-08-16 1:35	14.6	97248	100536	**-3%**	11.31	10.96	**3%**
2016-08-25 0:35	11.0	45212	76344	**-69%**	37.65	42.63	**-13%**
2016-09-07 21:10	17.2	195704	123258	**37%**	98.60	41.25	**58%**

2016-09-17 4:55	7.0	25198	25290	**0%**	8.54	5.64	**34%**
2016-09-26 10:40	7.2	38591	32079	**17%**	12.59	7.29	**42%**
2016-09-29 8:40	11.6	68608	61785	**10%**	6.85	6.55	**4%**
2016-10-08 5:20	5.4	20728	26004	**-25%**	9.31	8.16	**12%**
2016-10-20 2:15	18.2	77083	127398	**-65%**	4.21	5.16	**-23%**
2016-10-26 23:50	8.8	36037	47865	**-33%**	4.12	4.14	**0%**
2016-11-02 14:55	34.6	274017	319602	**-17%**	21.09	21.82	**-3%**
Average				**-15%**			**11%**

On average modeled runoff volume and peak flow compared quite well with observed values. The model is generally overestimating runoff volume and underestimating peak flow. Figure 5 to Figure 14 show graphs comparing observed and modeled outflow at WW-2 for the calibration storm events. Figure 15 and Figure 16 show the regression of observed peak flows and runoff volume vs. modeled peak flow and runoff volume, respectively, for the calibration events. Linear regression equations are also presented in the graph. As illustrated with the R^2, good results were achieved for the various calibration storms for runoff volume, whereas peak flow calibration can be made better.

For the continuous flow periods, the calibration was not as successful as the model seems to be overestimating runoff volume. During January 2016 – April 13, 2016, observed outflow at WW-2 was 1478 m^3 whereas the model predicts total outflow of 2128 m^3, a difference of -44%. August 16, 2016 – December 2016 observed flow was 1211 m^3 and modeled flow is 2009 m^3, a difference of -66%. However there is some uncertainty in the monitored flows at this location due to baseflow separation. It is possible that baseflow is being overestimated at the site which may be cutting off smaller stormflows between the calibration storms and therefore driving down total stormwater outflow. It is recommended that baseflow separation calculations for WW-2 be further examined.

A sensitivity analysis was performed to verify that the poor calibration at WW-1 is not affecting flow calibration at WW-2. This was done by adding the observed flow time series from WW-1 upstream of WW-2. A visual analysis of the event hydrographs indicated no difference in modeled flows at WW-2 with observed versus modeled flows from WW-1.

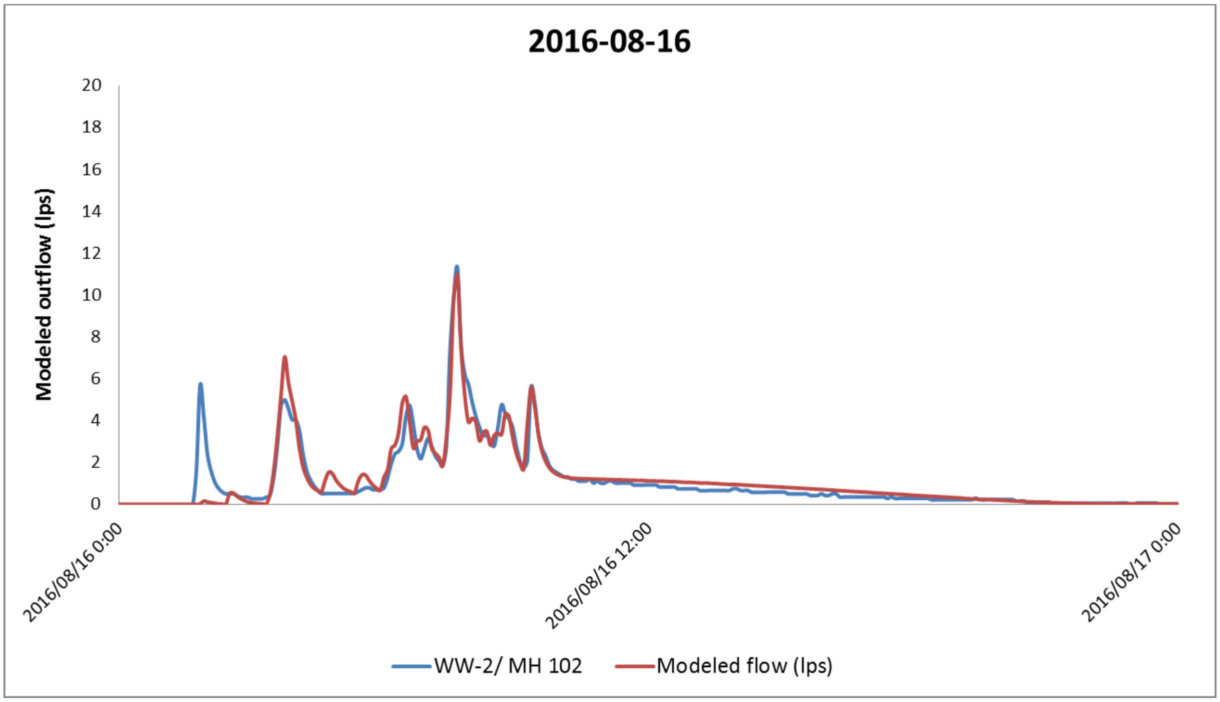

Figure 5 Observed and modeled outflow at WW-2 for 2016-08-16

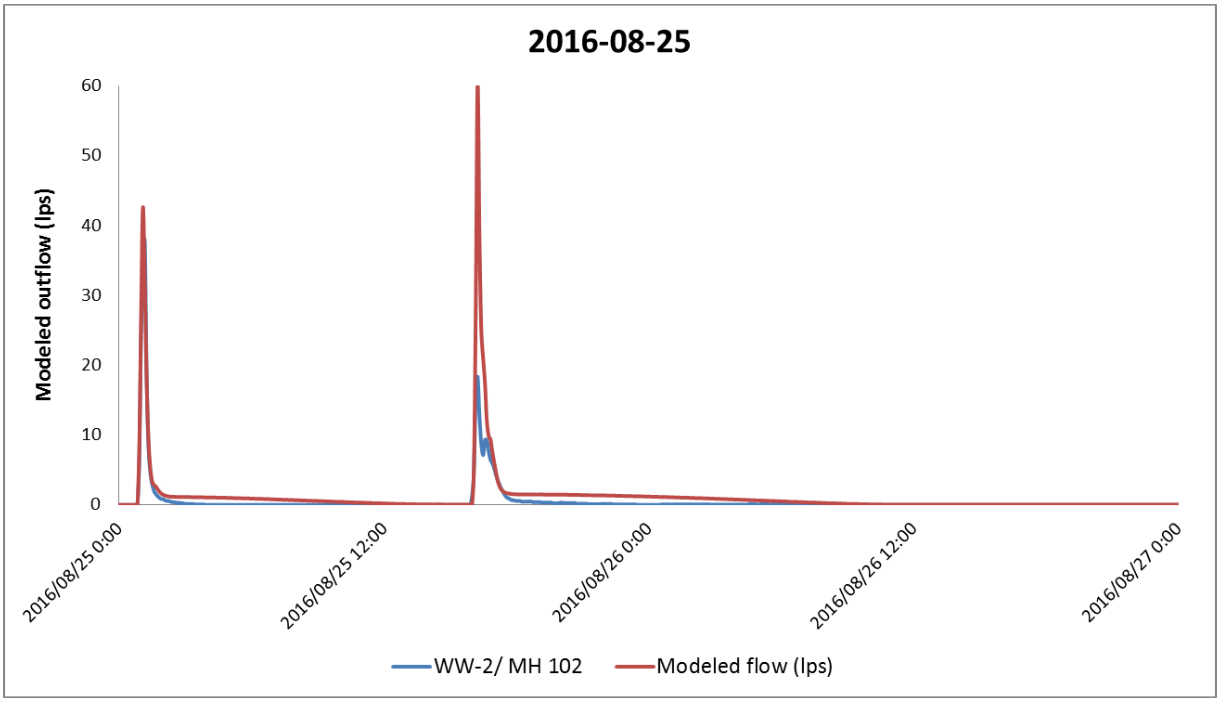

Figure 6 Observed and modeled outflow at WW-2 for 2016-08-25

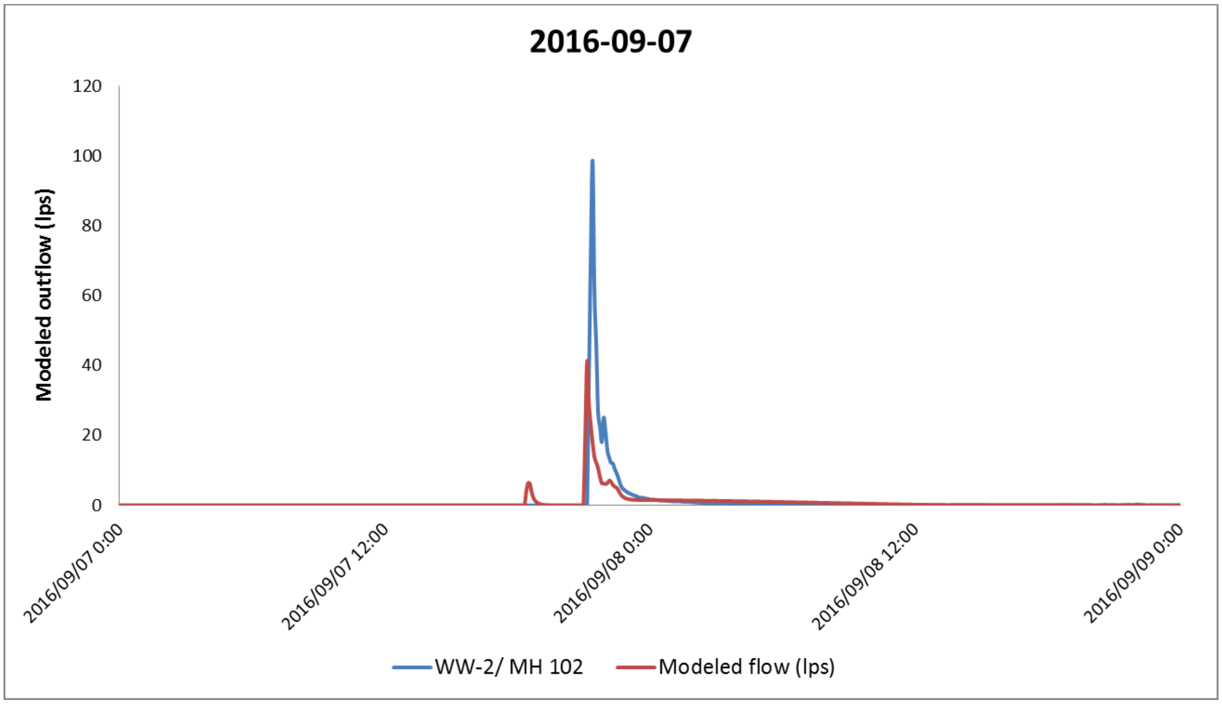

Figure 7 Observed and modeled outflow at WW-2 for 2016-09-07

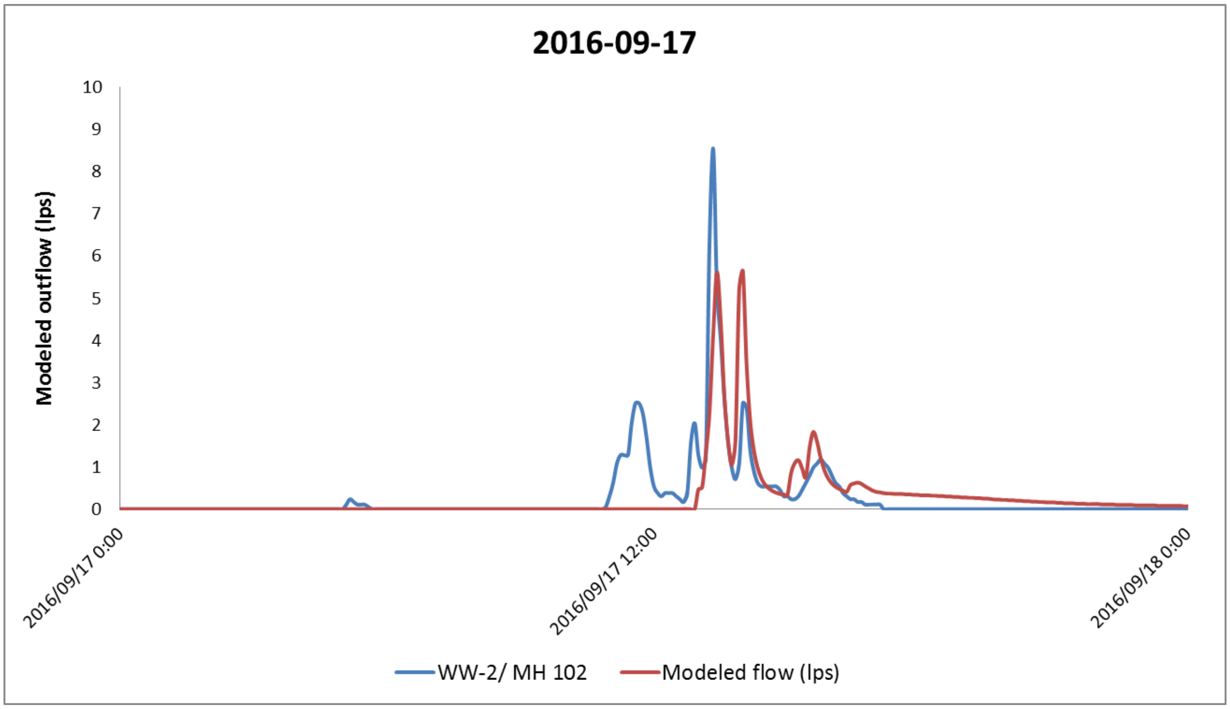

Figure 8 Observed and modeled outflow at WW-2 for 2016-09-17

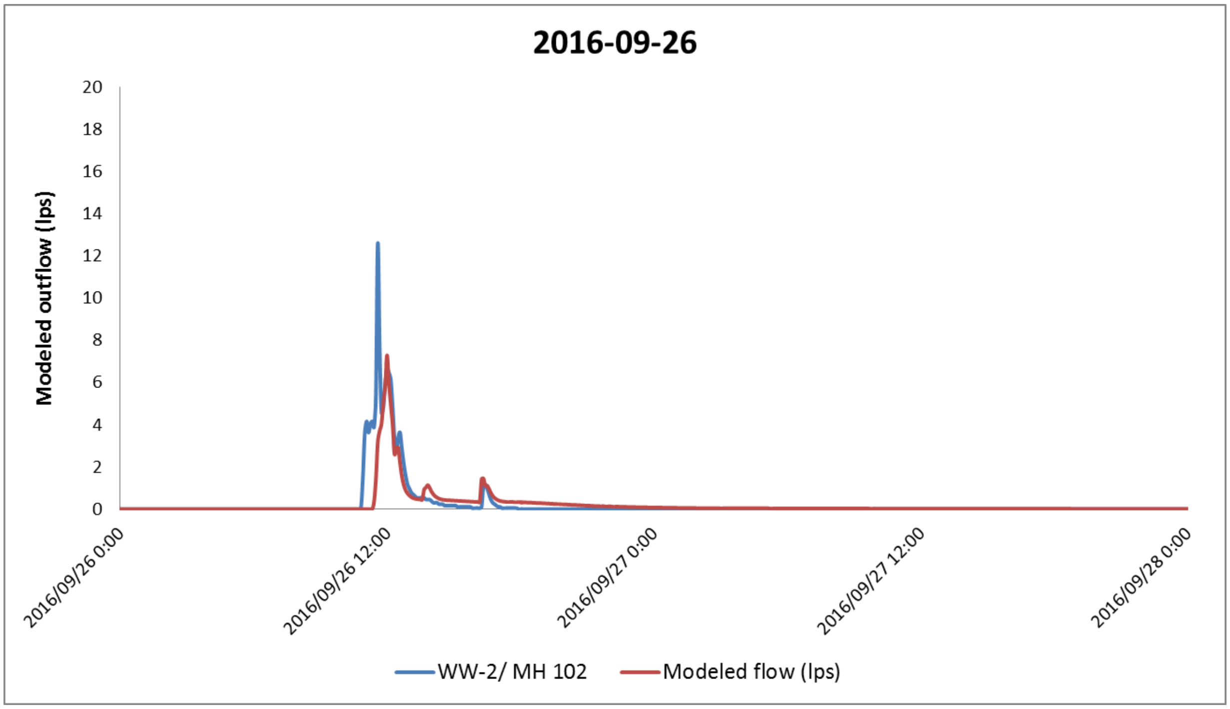

Figure 9 Observed and modeled outflow at WW-2 for 2016-09-26

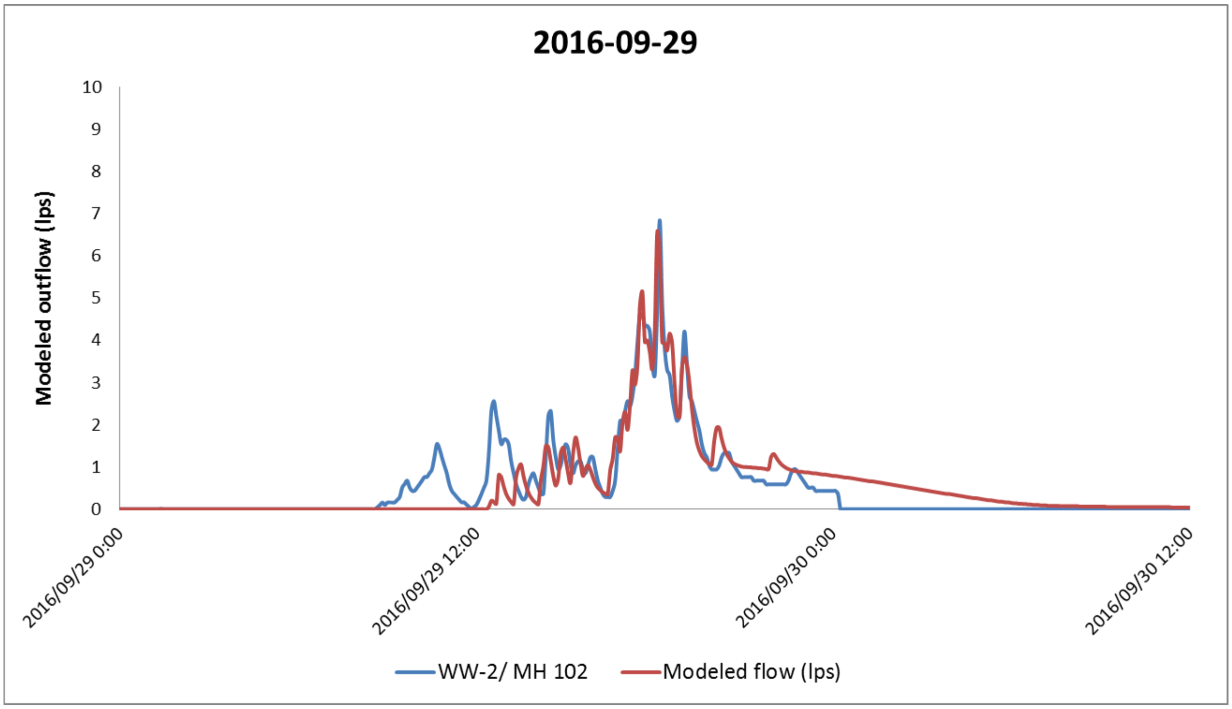

Figure 10 Observed and modeled outflow at WW-2 for 2016-09-29

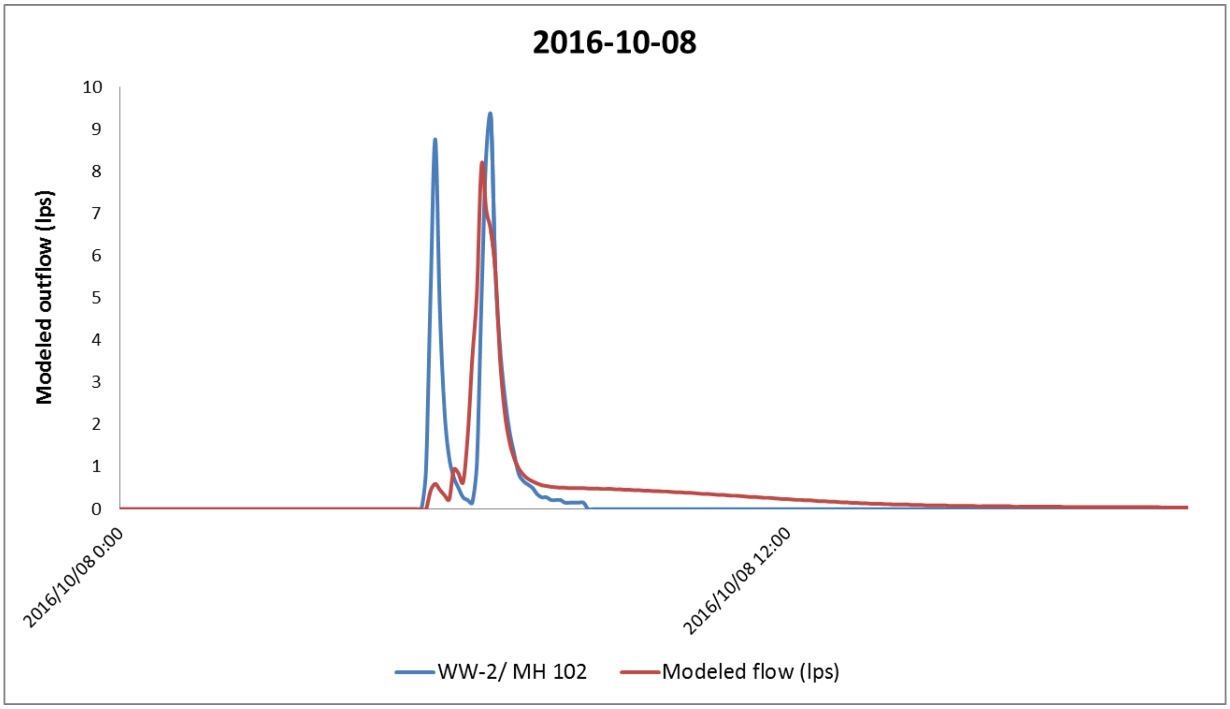

Figure 11 Observed and modeled outflow at WW-2 for 2016-10-08

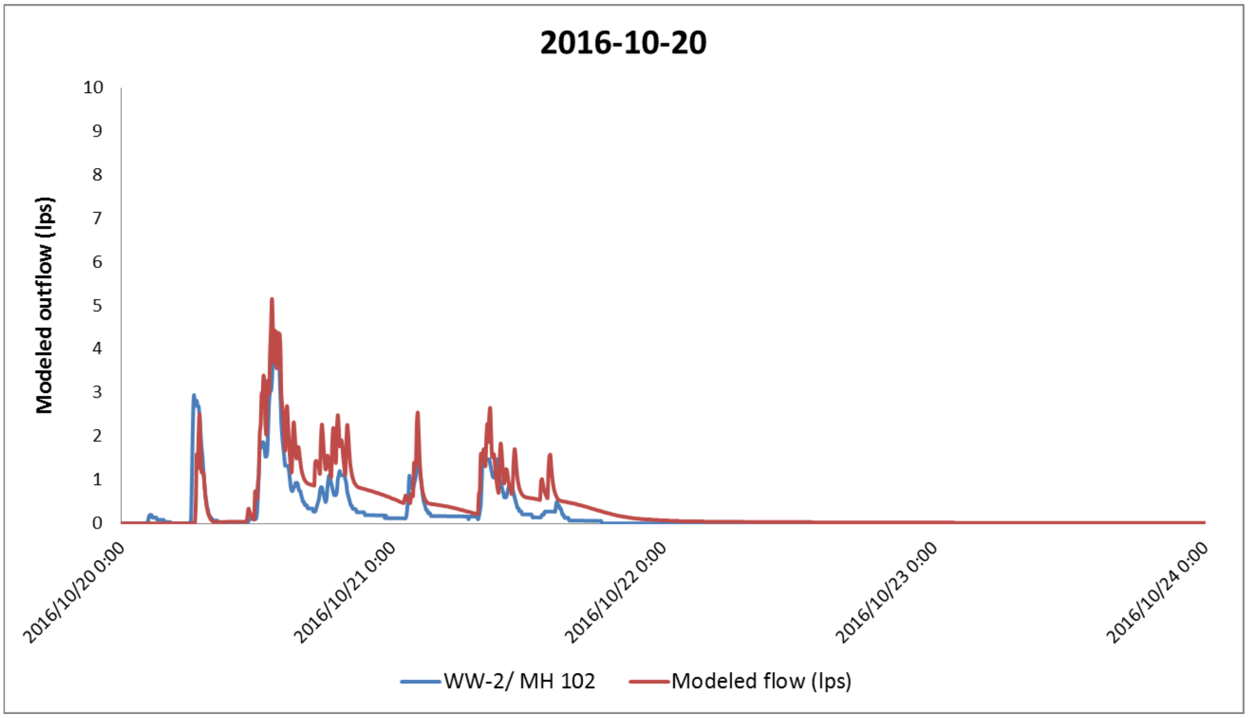

Figure 12 Observed and modeled outflow at WW-2 for 2016-10-20

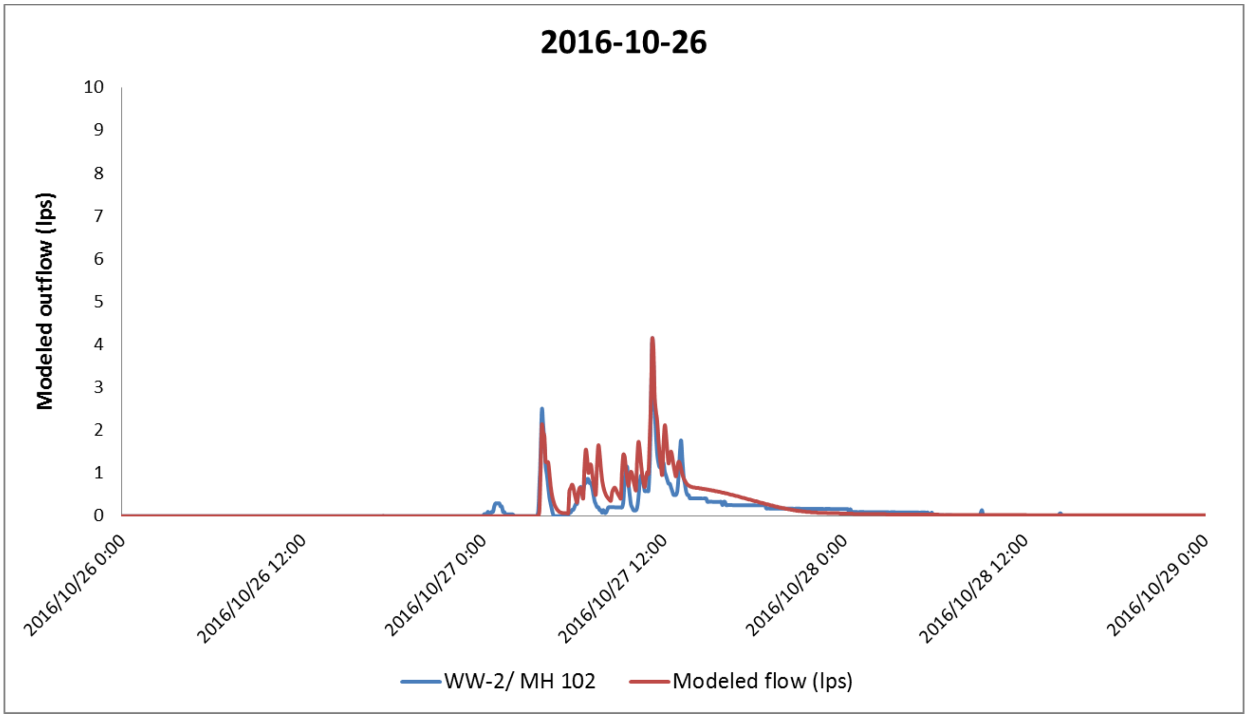

Figure 13 Observed and modeled outflow at WW-2 for 2016-10-26

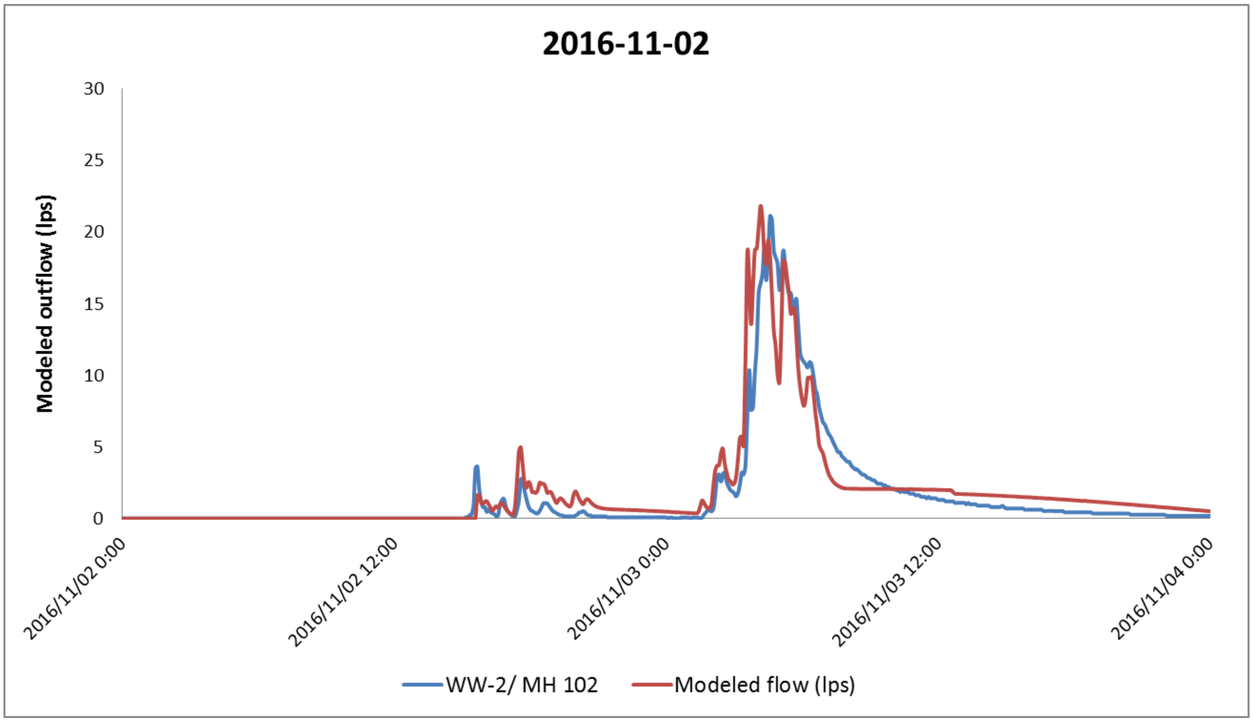

Figure 14 Observed and modeled outflow at WW-2 for 2016-11-02

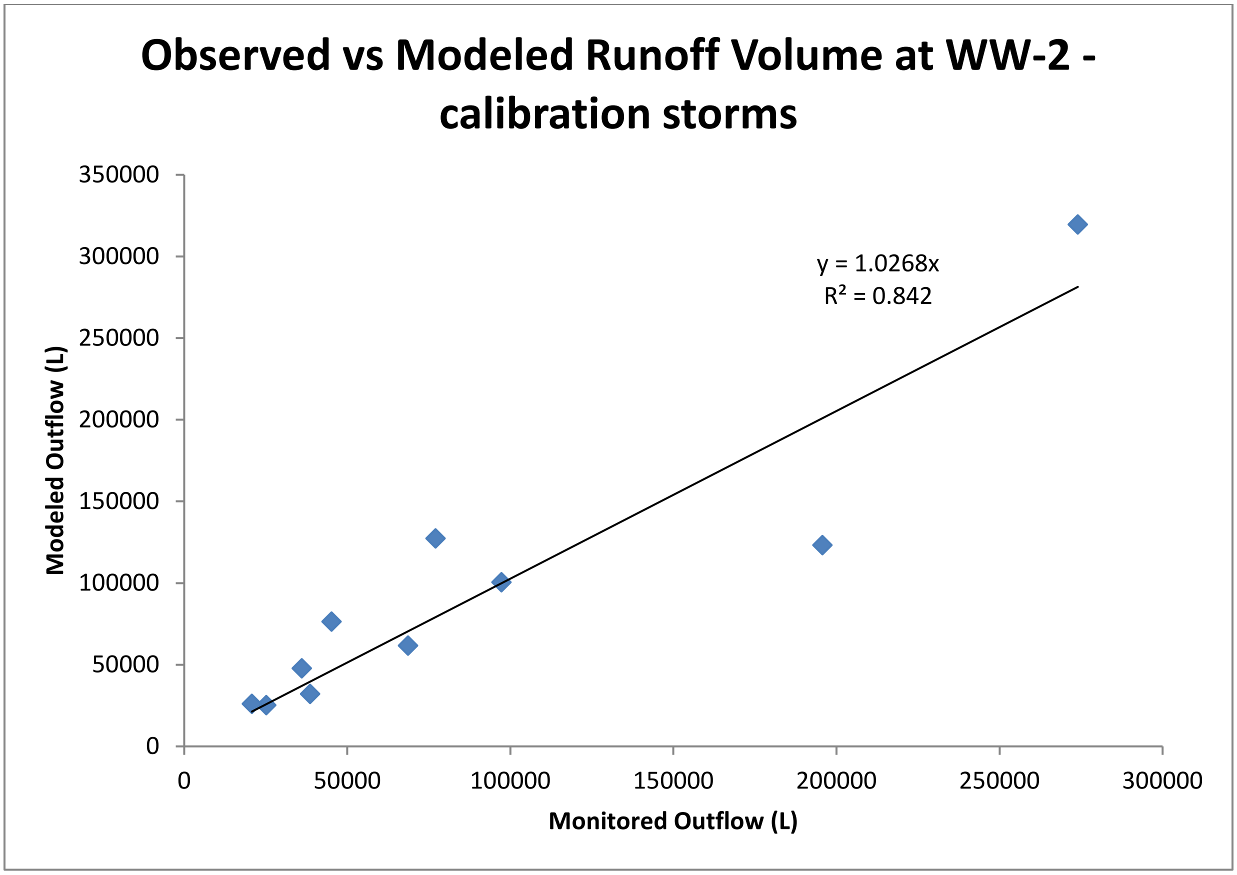

Figure 15 WW-2 Observed vs Modeled Runoff Volume / Outflow Regression Plot – calibration events

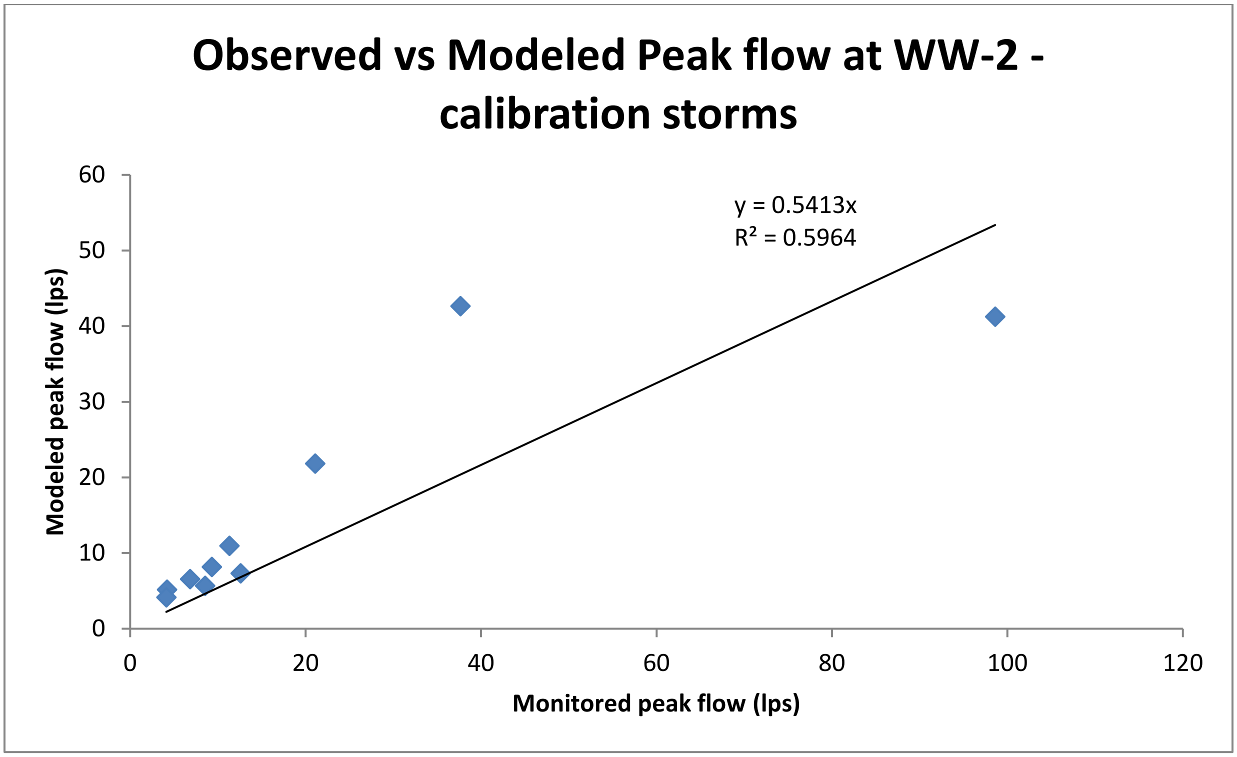

Figure 16 WW-2 Observed vs Modeled peak flow Regression Plot – calibration events

2.2.3. WW-2 flow validation

Since 2016 storm events and continuous flows were used for calibration of the model, a different period was selected for validation.

For the period of January 2017 – March 16, 2017, observed outflow at WW-2 was 1589 m^3 whereas the model predicts total outflow of 1255 m^3, a difference of 21%. For the summer period of June 6, 2017 – August 22, 2017 observed flow was 1057 m^3 and modeled flow is 1097 m^3, a difference of 4%. It is anticipated that these results are better than 2016 because there may not have been many smaller events between the validation storms. Additionally, it is anticipated that because April could not be used in the validation period due to leakage at the weir, flow due to snow melt could not be compared between observed and modeled results; the model generally does not handle melt periods well, and with baseflow separation it could lead to a bigger discrepancy between observed and modeled results.

Validation results for runoff volume and peak flow for select 2017 storm events are presented in Table 6.

Table 6 Validation of modeled outflow at WW-2 for 2017 storm events

Date	Rainfall depth (mm)	Observed Runoff volume (L)	Modeled Runoff volume (L)	Difference	Observed peak flow (lps)	Modeled peak flow (lps)	Difference
2017-06-16 19:05	5.4	13322	14775	**-11%**	8.08	9.83	**-22%**
2017-06-23 1:35	36.8	354600	370236	**-4%**	53.5	52.2	**2%**
2017-06-29 0:40	6.2	14664	9696	**34%**	4.90	2.43	**50%**
2017-07-20 9:35	13.4	94551	94278	**0%**	47.4	37.6	**21%**
2017-08-01 13:50	8.2	50472	57132	**-13%**	59.7	44.7	**25%**
2017-08-04 0:25	20.8	137352	132555	**3%**	62.3	54.8	**12%**
2017-08-17 13:25	13.6	64701	83391	**-29%**	25.8	21.7	**16%**
2017-08-22 8:25	16.2	75388	126837	**-68%**	50.2	38.5	**23%**
Average				**-11%**			**16%**

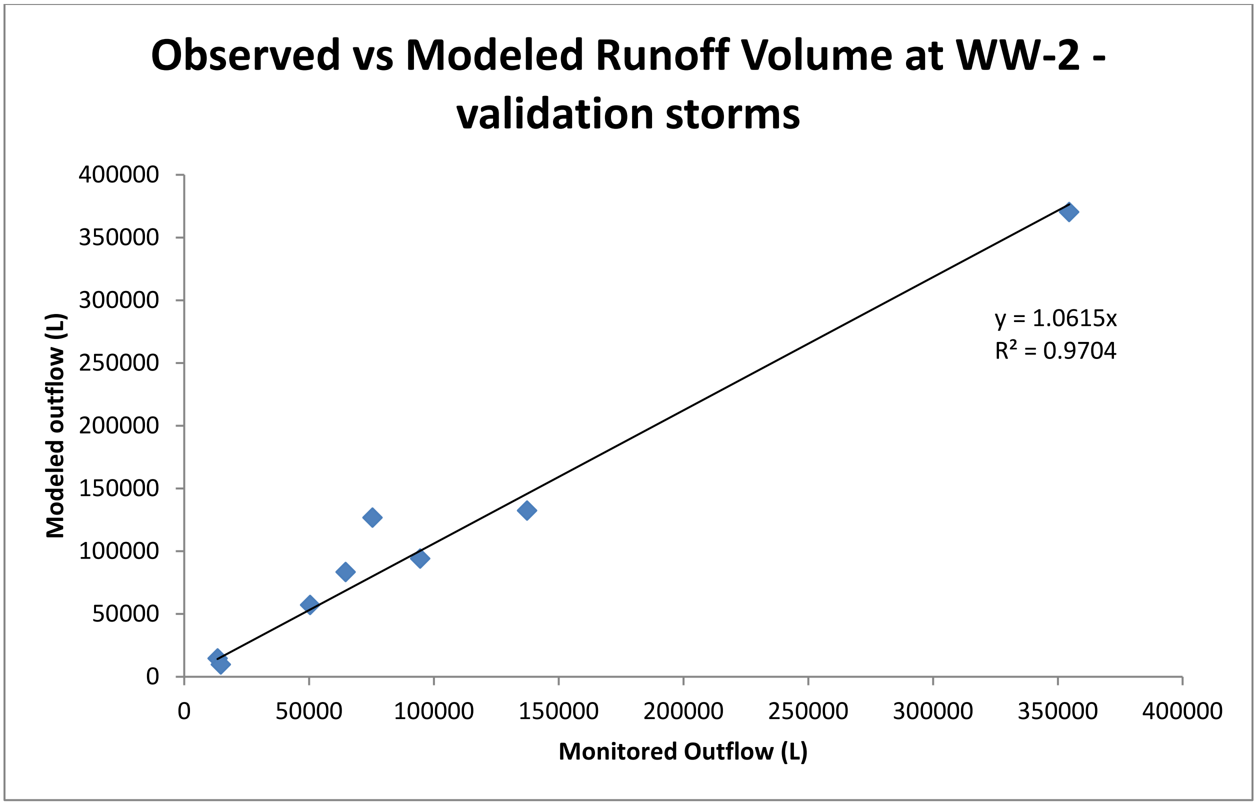

Figure 17 WW-2 Observed vs Modeled Runoff Volume / Outflow Regression Plot – validation events

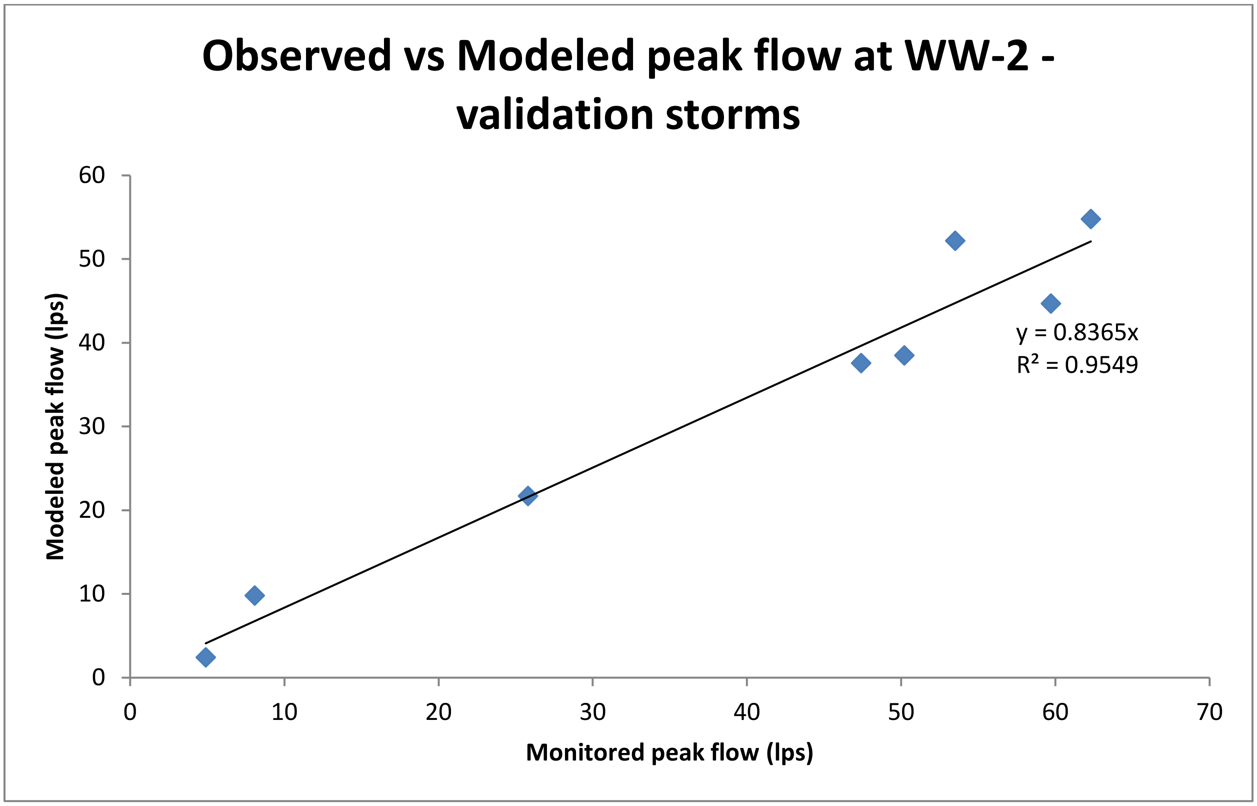

Figure 18 WW-2 Observed vs Modeled peak flow Regression Plot – validation events

2.2.4. WW-2 water quality control

Water quality sampling at both monitoring locations allows collection of composite samples through which TSS and TP concentrations in the observed outflow during an event can be determined. For this study, only TSS and TP load results will be analyzed for sampled events and continuous flow period during summer and fall of 2016 at WW-2. The pollutant load out can be determined by taking the product of monitored runoff volume and effluent concentration. Load in is determined by taking the product of Simple Method Inflow volume and influent concentration. Modeled pollutant load in and out are direct outputs from SWMM and are calculated at each time step and summed over the observed period of flow. Load reduction is calculated by taking the difference between load in and load out.

For continuous flow periods, the median effluent concentration of 9 sampled events in 2016 was determined for the winter/spring and summer/fall period. Taking the product of the median effluent concentration and the total monitored outflow gives the total effluent load for each continuous period.

For January – April 2016 the TSS loading was estimated to be 66.5 kg and TP loading was 0.210 kg. Modeled results estimated TSS loading at 56.7 kg (-17% different from observed) and TP loading at 0.321 kg (34% difference). For August – December 2016, observed effluent TSS loading is 32.1 kg and TP loading is 0.213 kg. Modeled estimates are 51.6 kg (38% difference) for TSS and 0.292 kg (21% difference) for TP.

Observed and modeled load results for individual sampled events are presented in Table 7.

Sampled event	Inflow Volume [1] (L)	TSS influent concentration [2] (mg/L)	TSS load in (kg)	Monitored Outflow Volume (L)	Monitored TSS effluent concentration (mg/L)	TSS load out (kg)	Estimated TSS load reduction	Modeled TSS load in (kg)	Modeled TSS load out (kg)	Modeled TSS load reduction
2016-08-16 1:35	332369	46	15.3	97248	26.5	2.58	83%	8.20	2.05	75%
2016-08-25 0:35	250415	46	11.5	45212	34.6	1.56	86%	16.4	5.47	67%
2016-09-17 4:55	159355	46	7.33	25198	14	0.35	95%	2.78	0.51	82%
2016-09-26 10:40	163908	46	7.54	38591	32.8	1.27	83%	3.36	0.64	81%
2016-09-29 8:40	264074	46	12.1	68608	11.8	0.81	93%	6.63	1.33	80%
2016-11-02 14:55	787669	46	36.2	274017	32.3	8.85	76%	24.5	8.02	65%

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[1] Estimated using Simple Method
[2] Estimated using National Stormwater Quality Database

Table 7 TSS and TP load results at WW-2 for 2016 storm events

Sampled event	Inflow Volume (L)	TP influent concentration (mg/L)	TP load in (kg)	Monitored Outflow Volume (L)	Monitored TP effluent concentration (mg/L)	TP load out (kg)	Estimated TP load reduction	Modeled TP load in (kg)	Modeled TP load out (kg)	Modeled TP load reduction
2016-08-16 1:35	332369	0.26	0.086	97248	0.142	0.014	84%	0.046	0.012	74%
2016-08-25 0:35	250415	0.26	0.065	45212	0.234	0.011	83%	0.092	0.031	66%
2016-09-17 4:55	159355	0.26	0.041	25198	0.198	0.005	88%	0.014	0.003	78%
2016-09-26 10:40	163908	0.26	0.043	38591	0.236	0.009	79%	0.021	0.004	81%
2016-09-29 8:40	264074	0.26	0.069	68608	0.128	0.009	87%	0.038	0.008	79%
2016-11-02 14:55	787669	0.26	0.204	274017	0.176	0.048	77%	0.139	0.045	68%

For the continuous flow periods the model is generally overestimating TSS and TP load out. The modeled outflow is well calibrated; therefore it is anticipated that the influent concentration used at this site may be too high, or the removal efficiency of BMPs may be underestimated. For the event-based results the model is underestimating load reduction mainly because the modeled load in is generally lower than estimated load in. Since the concentration used to estimate load in is same for both modeled and estimated results, this discrepancy may be due to difference in inflow volumes. Because the model is physically-based it is better at estimating inflow from the site compared to the Simple method.

The current model has not been calibrated for water quality and it is recommended that removal efficiency be revised in future updates.

3. Other Modeling Results

3.1. Design storm performance

This section outlines peak flow results from the VO2 model and the calibrated SWMM model for the 2 to 100 year design storms. Short-duration high-intensity design storm events are helpful in estimating performance of these systems during convective storm events (thunderstorms). The 24 hour SCS Type II distribution is used to be consistent with the original VO2 model. Results are presented in Table 8.

Table 8 Post development peak flow estimates by VO2 and SWMM models

Return period	Rainfall depth (mm)	Peak flow out (cms)		Difference
		VO2	SWMM	
2	50	0.14	0.115	18%
5	68	0.2	0.173	14%

10	83	0.26	0.252	3%
25	95	0.31	0.336	-8%
50	107	0.35	0.422	-21%
100	119	0.38	0.566	-49%

The original VO2 model overestimates peak flow for the smaller storms and underestimates peak flow for larger storms compared to original model predictions. Although different calibration techniques were tried for peak flows to match VO2 model, e.g. revising catchment width to quicken or delay time of concentration, it did not change this pattern. Since the SWMM model is calibrated with actual events at Wychwood, peak flow values from this model would be more trustable than the original design model using VO2.

3.2. Water balance

Water balance is another stormwater management criterion that is primary to design of stormwater management systems. Typically it has to do with maintenance of pre development infiltration rates. Table 9 summarizes water balance estimated for pre and post development conditions by the VO2 model and the pre and post development water balance estimated by the SWMM model.

Infiltration and evapotranspiration make up 71% of the total precipitation under pre development conditions. The SWMM model estimated 80% of annual precipitation is reduced through infiltration and evapotranspiration under post development conditions. Therefore the calibrated model predicts the water balance criterion is being met at this site.

Table 9 Post development water balance comparison between original design and SWMM model

Model	Area (ha)	Precipitation (mm)	Evapotranspiration (mm)	Infiltration (mm)	Runoff (mm)
Original design Pre-Devp	5.67	793	443 (56%)	120 (15%)	230 (29%)
Original design Post Devp	5.67	793	335 (42%)	280 (35%)	179 (23%)
As-built calibrated SWMM	4.09	753	334 (44%)	274 (36%)	140 (19%)

4. Conclusion and Recommendation

This study takes the reader through observed and modeled runoff volume, peak flow, TSS and TP load results for observed storm events, as well as design storm and annual water balance performance at the Wychwood site. It has been demonstrated through the calibration and validation exercise that the model is on average doing well at estimating stormwater quantity control provided by the LID treatment train at this site.

The following recommendations are being made to improve model calibration and confidence in results:

- Re-coding of the SWMM model to allow routing from nodes and catchments directly to LID underdrain would help improve the event-based and continuous calibration at this location. This would have to be done by EPA-SWMM development team.
- It is recommended that baseflow separation calculations for WW-2 be further examined. The LID Monitoring team would be heavily involved in this.
- The current model has not been calibrated for water quality and it is recommended that removal efficiency be revised in future update.

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Appendix K

Pond vs LID Cost Comparison

1.0 Stormwater Management Pond Costs

Since the MECP released the Stormwater Management Practices Planning and Design Planning in 1994, municipalities have encouraged the installation of wet ponds (Drake & Guo, 2013). According to a study completed on ponds in Ontario, a typical wet pond has an operational lifecycle between 5 to 15 years; therefore, many Ontario ponds will be approaching their expected capacity within 5 years (Drake & Guo, 2013). Typically, the local municipality is responsible for the cost of cleaning out the ponds and sediment disposal (Drake & Guo, 2013). Although some municipalities are starting to clean out their stormwater ponds, there is no doubt that these activities are associated with large cost constraints due to the quantity of stormwater ponds that municipalities own.

The Wychwood subdivision does not include a traditional stormwater management pond. Instead, LID features were constructed to treat and manage runoff. Ponds and LID options both require routine maintenance throughout their lifecycles to ensure that they are working, however, the routine maintenance differs depending on which option is implemented.

For stormwater ponds, the essential maintenance activities include conducting regular inspections of the facility (pond and surrounding area) and sediment removal. Other general maintenance activities may include grass cutting, vegetation maintenance, trash removal as well as potential structural maintenance if inlets and outlets show signs of deterioration. The costliest maintenance requirement for stormwater ponds is typically the removal of sediments. Stormwater ponds are designed to collect and store sediments which will eventually need to be removed to maintain the design depth of the pond (Drake and Guo, 2013). Sediment removal costs can vary depending on site accessibility, extent of site clearing and preparation, level of in-situ sediment accumulation, dewatering method/time, bulking method/time, volume of sediment to be removed, disposal of re-use options based on sediment contamination level, distance of transportation to disposal site, amount of restoration required after completion, and need for retrofit elements (TRCA and CH2M, 2016).

The City of Vaughan released a City-Wide Stormwater Management Plan in 2014, which includes a pond maintenance cost estimate of approximately $13,100 - $16,600/year. This cost is based on a sediment clean out period of 13 years as well as annual inspection, regular maintenance, and repairs (Cole Engineering, 2014). If a site is easy to access, the sediment can be disposed of locally. In addition, if an analysis of sediment quality passes current regulated criteria, sediment removal costs can be reasonably low at a cost of $100 per cubic metre, according to a 2012 report for the Town of Whitby. If the sediment quality exceeds the guidelines and needs to be disposed of in a registered landfill, costs can increase more than 30-fold (Town of Whitby, 2012). An additional cost around $25,000 for the development of a sediment removal plan may also be added to cover costs for equipment, permits, transportation and sampling (Town of Whitby, 2012). For cost comparison, a report in 2016 by TRCA and CH2M on stormwater pond maintenance costs stated that maintenance inspections (four per year) would range between $713 and $1425 (TRCA and CH2M, 2016). The cost to remove sediments ranged from $53 to $512 per cubic metre of sediment removed (TRCA and CH2M, 2016).

A report commissioned by the City of Guelph in 2008 prepared an inventory and maintenance needs plan for all City owned wet ponds (28), dry ponds (38), and greenways (37) used forsediment removal and landfill disposal activities the cost ranged between $68,300 and $227,300. Most activities required for sediment removal were estimated to cost the same and the difference in cost was due to the quantity of sediment removed from each pond. Additional pond maintenance costs identified through a literature review are outlined in Appendix E.

Case Studies

A local example from the City of Mississauga was the Lake Wabukayne 1.8 hectare man-made in-stream storm water retention pond maintenance project. The sediment removal took over two years to complete and cost approximately $1.3 million dollars with 5,613 cubic metres of sediment removed when the project finished (City of Mississauga, 2008).

A review of the City of Vaughan's approved 2016 Budget and 2017-2018 financial plan indicated that three stormwater ponds are to be cleaned for an anticipated cost of $500,000 (City of Vaughan, 2016). The City of Vaughan estimates that they have 144 stormwater ponds under their ownership (City of Vaughan 2017).

Although it is yet to be determined if LID features are more cost effective over their life-cycle compared to traditional stormwater ponds, these case studies demonstrate that costs can vary depending on methods used and the size of the pond being maintained. In an effort to understand the ongoing maintenance costs of LID features, CVC is committed to track each site's maintenance needs over time and how maintenance activities impact performance. This data will be used to anticipate maintenance activities, budget for them in advanced and attempt to stream line maintenance activities to be part of owner/operators regular maintenance activities.

1.1 LID Facility Costs

Since Wychwood was recently constructed, the site specific maintenance costs are not known at this time. However, the following activities and anticipated costs provide an estimate of the routine maintenance activities required for upkeep of the LID features implemented at the site:

Grass swales

Based on a review of available literature grass swales have an annual maintenance cost of $500/year (TRCA et al., 2013). Some maintenance activities include but are not limited to cutting the grass, weeding, re-seeding, sodding, and clearing trash and debris. The grass swales are maintained by the residents as they make up a portion of their lawn; therefore, if they opt to maintain the swale themselves, not by a paid landscaper, the cost would be the time to complete the maintenance activities.

Bioswales

Maintenance of the bioswale includes but is not limited to cutting the grass, weeding, re-seeding or sodding, clearing trash and debris. The bioswale media will eventually need to be replaced after it deteriorates to a level that no longer provides sufficient infiltration (>25mm/hr). Based on a review of available literature annual maintenance was anticipated to be a maximum of $952/year and would also need one major rehabilitation procedure (i.e. replacement) during the 25-year period at an estimated cost of $6,345 (TRCA et al., 2013). The City of Brampton maintains the bioswale and the maintenance cost would be how much it costs to send out a landscaping crew to maintain the feature.

OGS Units

Maintenance of the OGS units includes but is not limited to a clean out as well as a visual inspection. Eventual repairs and potential replacement may be required if the structure deteriorates to a level that it can no longer meet its removal efficiencies. The City of Vaughan's City-Wide Stormwater Management Master Plan recommends that the OGS units are cleaned out every 12-15 months at a cost of $12,000 - $20,000/year per unit, depending on the condition and size of its catchment area (Cole Engineering, 2014). Currently, the OGS units are maintained by the developer but the City of Brampton will eventually assume this infrastructure. The cost related to maintaining the infrastructure is the cost for a stormwater service contractor to inspect and clean out the units. At Wychwood the estimated cost provided by the maintenance contractor is $350.00 for inspection and $3000.00 for cleaning, excluding HST (Personal communication, Minotaur Stormwater Services Ltd). These estimates are only for the STC-300 stormceptor models installed at Wychwood.

Permeable Pavement

Minor maintenance activities for the permeable pavement include clearing trash, leaves, debris and accumulated sediment on an annual or as needed basis (Cole Engineering, 2014). Additionally, the paving stones may need to be levelled again as the stones can sink or shift with time. Broken stones would also need to be replaced on an ongoing basis. Based on a review of available literature annual maintenance costs were estimated to be a maximum of $436/year (TRCA et al., 2013).The paving stones and base material would also need to be replaced in 30 years at an estimated cost of $72,990 for a 1000 m^2 area (TRCA et al., 2013). The driveways at Wychwood are approximately 263 m^2 equating to a cost of $19,196 for total driveway replacement. The permeable pavement is maintained by the owner therefore there may not be a direct cost for maintenance, but it would be a function of the time spent to clear trash and debris from the pavement. More intensive maintenance activities such as levelling and shifting stones would most likely be completed by a contractor and paid by the owner.

Rain Gardens

Rain garden maintenance activities includes but are not limited to trash and debris removal, as well as frequent plant watering during the establishment period, vegetation pruning, and weeding. Mulch may need to be re-applied every few years as well, however, these features are not supposed to require as much maintenance as other LID features. Although no specific cost estimates for rain gardens were found it is thought that the cost would be similar to the grass swale (~$500/year) as it performs a similar function. The cost will still vary however, depending on the level of maintenance the resident intends to conduct.

1.2 Cost Comparison

Based on a review of the available literature the cost of maintaining LID features are expected to be lower than the cost of maintaining stormwater ponds due to the potentially large costs of sediment removal for stormwater ponds. The table below provides a brief summary of the approximate range of maintenance costs of LIDS and ponds, however, more detailed costing information is provided in Appendix E. The variability between the costs is be due to numerous factors and the table below is not an exhaustive list of maintenance costs (i.e. size of the stormwater management feature, amount of sediment accumulated for ponds, ect.).

Table K-1: Maintenance cost comparison

LID Feature	Anticipated Costs	Pond Feature	Anticipated Costs
Bioretention	Annual Maintenance Cost: $436 - $4,940	Wet Pond	Annual Maintenance Cost: $713 - $7,830
Swale (Vegetated/Grass)	Annual Maintenance Cost: $500 - $2,280		Every 5 Years: $4,160
OGS (Oil & Grit Separator)	Annual Maintenance Cost: $12,000 - $20,000	Dry Pond	Annual Maintenance Cost: $713 - $5,880
Permeable Pavement	Annual Maintenance Cost: $436		Every 5 Years: $2,660
	Every 30 Years: $72,990	Sediment Removal	$53- $512 /m^3
		Sediment Disposal (offsite)	$300/m^3

The Municipal Infrastructure Group Ltd. provided anticipated costs for the installation of various LID features at the Wychwood subdivision, prior to construction. The costs for the actual LID features implemented at Wychwood are provided below.

Table K-2: LID Feature Installation Costs

LID Feature	Anticipated Installation Costs
Permeable Pavement	$60 - $2000/m^2
Grass Channel Swale	$120 for seed $300 for sod
Soil Amendments	$525 - $2625
Bioretention/Rain Garden	$1300/garden $195,000 to implement site wide

Source: (TMIG, 2010)

Wychwood is unique as the costs are shared between the City of Brampton and the individual owners therefore not all maintenance costs fall on one party. To date the approximate maintenance costs have been provided by the developer, home owner surveys and the City of Brampton which includes the following:

- Annual OGS inspection $350 per OGS (plus applicable taxes) (Minotaur, 2017)
- Clean out an OGS $3,000 per OGS (plus applicable taxes) (Minotaur, 2017)
- Cutting and trimming of the bioswale $1,732 per year (4 events at $433/event) (City of Brampton, 2017)
- Data collected from resident interviews determine approximately $5/year spent on chip stone per driveway. However not all residents are maintaining their driveway

These costs represent the first year of collecting maintenance costs for the Wychwood subdivision. It is expected that these costs will grow as the features require additional maintenance as they age. It is important to note that the actual cost to clean out an OGS is dependent on several factors including geographical location, confined space entry requirements and volume of contaminated sludge if present in OGS.

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Appendix L

Advantages of the LID Approach

1.0 ADVANTAGES OF THE LID APPROACH

In addition to the stormwater design criteria and monitoring objectives, there are added benefits of implementing LID stormwater controls as part of a site management system. Urban development techniques significantly alter the natural hydrology and impact existing pre-development baseflow recharge rates. Additionally, at source stormwater management provided by LIDs will impact the life-span and resiliency of existing stormwater infrastructure. These benefits should also be discussed when evaluating LID performance.

There are many questions surrounding the life-cycle costs of LID in comparison to traditional stormwater management facilities. However, data collected from the site developer has provided some information on the initial cost benefits of using low impact development.

1.1 Recharge

In many areas within the watershed, recharge is important to sustain baseflow levels that feed into natural heritage systems such as streams and wetlands. Baseflow not only maintains the water levels within stream and wetlands but also helps to stabilize the in-stream temperature regime. Collectively, the LID features at Wychwood produced a 73 per cent volume reduction for all stormwater events. This reduction is achieved partly through infiltration of stored stormwater within the feature into the surrounding soil material. Evapotranspiration also contributes to achieving volume reduction, as stored runoff is absorbed by vegetation within the feature and released into the atmosphere.

The bioswale design includes a storage depth of 0.50 m below the invert of the underdrain. Water which is not intercepted by the underdrain and enters this storage layer has the potential to infiltrate into the underlining soil material. With a porosity of 0.3, a substantial depth of water can still infiltrate over hours and days. The observed baseflow at the total site monitoring station between March and January, confirm that subsurface water levels are already higher than the base of the infiltration trench. Even if groundwater levels remain high for most of the year, recharge occurred when groundwater levels decrease and within the other sub-surface infiltration features across the site.

1.2 Resilience of Stormwater Infrastructure

Green infrastructure such as permeable pavement and bioretention systems can reduce runoff frequency and volume rates. This reduces stress on the downstream stormwater conveyance system which will provide a cost benefit over the life-cycle of the system. Although designed for most moderate sized events, the detention storage provided by these systems can help to reduce peak flows during large events. This can reduce the frequency of surcharging in the downstream storm sewers which can reduce the frequency of maintenance activities and extend their lifespan.

85 events (summarized in Figure 4-9) with magnitudes of 25 mm or less, occurred during the monitoring period. For these events, an average peak flow reduction of 82 per cent was provided by the LID features. 5 events occurred within the monitoring period with precipitation volumes >30 mm, within this range, total peak flow reduction of 74 per cent was observed for these events.

Infrastructure resiliency is provided by the LID features at Wychwood by reducing the hydrologic response of more frequent events and events with high intensities. It is anticipated that due to climate change, the frequency of high intensity events will increase, indicting the benefits of volume and peak flow reduction provided by green infrastructure will have a lasting positive impact.

1.3 Stormwater Management Cost Comparison

It is yet to be determined if the cost of implementing LID features is more cost effective on a full subdivision scale than traditional stormwater management facilities. In both cases within the subdivision, valuable developable land is taken up by either stormwater management practices but at very different scales. Within the GTA the cost of land is between $2-5 million per acre depending on the municipality. Ponds take up significant space within the development block whereas LIDs can utilize limited surface space and provide storage volume within the design depth of the feature. In the case of Wychwood, the size of the management pond would have taken up 5% of the developable land, which is standard for developments less than 50 acres. In the absence of a pond an additional 0.6 acres was available to be developed within Wychwood. However, additional revenue generated from the added lots would have been invested into the design and installation of the unique LID management features (Personal Communication, Giulio Bianchi, 2017). As LID designs become standardized, design costs are anticipated to decrease allowing for further financial incentives for developers to use a LID approach. Over the process of monitoring the life-cycle of the of the LID features, the total life cycle costs will be calculated.

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Appendix M

Construction Inspection Reports

CVC
CREDIT VALLEY
CONSERVATION

SITE VISIT MEMO

To: **Giulio Bianchi**
cc:
From: **Chris Despins, Water Resources Specialist**
Kyle Vander Linden, Water Resources Specialist
Date: **October 10, 2013**
Re: **Site Visit on October 7, 2013**

Hi Giulio,

We stopped by and visited the site on October 7th to see if we could be of assistance, while there we happened to notice some items we thought we could offer advice on to improve the performance of the bioswale and ensure that it does not become clogged.

We appreciate that you and your staff are busy, so we have provided some recommendations and were hoping that perhaps we could come out again and offer you any assistance. We have learned a lot from constructing these techniques in Mississauga so if we can offer you any of our tips or share our lessons learned we would be happy to as we want this to be a positive experience for you.

If you have any questions, please feel free to contact me at 905-670-1615 x.288 or cdespins@creditvalleyca.ca or Christine at ex 229 or czimmer@creditvalleyca.ca

Thanks,

Chris

Cul-de-sac inlets to the Bioswale

Cul-de-sac on Fairmont Close – there is fine construction debris accumulating in front of the inlets to the bioswale (this could clog and/or reduce the performance of the system

We observed some ponding at the inlet and in the puddle in the background of this photograph. Ponding water can mean that the bioretention soil media is becoming clogged with fine debris and is not draining properly.

At the cul-de-sac inlets to the bioswale it looks like debris is accumulating on the road, and possibly entering the bioswale via the inlet. We've provided a few photos above which tries to show this. This debris can get washed into the bioswale, which in turn can plug up the sand, preventing it from draining. It also looks as though the mulch has been pushed aside from the inlet – this is a sign that the flow of water is too strong and is lifting up the mulch and depositing it downstream.

To fix this, we recommend:

- Installing fiber logs at each of the inlets to the bioswale, and on the inlets to the rain gardens on the south-western part of the subdivision (the fiber logs should be installed on the 'road side'). This will prevent many of those fines from entering the bioswale.
- To prevent any of the fine debris from clogging up the bioswale, it is recommended you excavate and remove the clogged media. Clogged media would be the soil near the inlets and in the section of the bioswale where ponding water was observed – where you see ponding in the photos these are sections where you can scrape off this clogged material.

- At the end of the concrete channel, we recommend you replace the clogged soil that was scraped off with river run stone, placed on top of geotextile fabric, as per the design drawings. Extend river run stone to the ‘base’ of the bioswale (all of the area where the mulch has been pushed aside)

Downspouts on Houses near the Bioswale

The downspouts of the houses along the swale are pointed towards the bioswale and the flow of water from them is causing some washout of the mulch and the bioretention soil media. This is similar to the inlets – the flow is too concentrated. The problem is that the mulch and seed isn’t getting a chance to become established and help hold together that side slope. Like with the inlets the flow needs to be spread out to prevent this issue.

Washout of mulch is occurring because the flow from the downspouts is not being spread out by a splash pad and by sod.

To fix this, we recommend:

- In the short term, the downspouts can be directed towards the rear lots, and not discharge into to the bioswale.
- While the downspouts aren’t draining to the bioswale, a 1 metre wide sodded filter strip should be installed along the houses on the exposed soil (as per the design drawings)
- Downspout splash pads which ‘fan out’ to spread the flow can be utilized
- Once the sod is installed and the mulch/seed in the bioswale more established the downspouts can be switched back.

Soil stockpiles

Soil is being stockpiled adjacent to the bioswale in multiple spots

There are multiple stockpiles of soil that are just too close to the bioswale. During a rain event this soil can be washed into the bioretention media, clogging it.

To fix this, we recommend moving the soil to another location where it cannot run-off into the bioswale.

Construction Traffic Contaminating Permeable Pavers

Permeable paver pathway near adjoining subdivision

It looks like construction traffic drove over the permeable paver walkway, this can clog the pavers. To fix this we recommend that signage can be installed informing contractors that they should not drive over or otherwise track soil onto the permeable pavers to prevent contaminating them.

Catch Basins

Catch basins are missing, or have damaged geotextile fabric

We noticed that many of the catch basins throughout the Wychwood subdivision were missing geotextile filter fabric. This fabric helps to filter out contaminants from getting into the Credit River.

To fix this, we recommend that you check all catch basins within the subdivision, and if geotextile fabric is missing or torn, it should be replaced.

CVC
CREDIT VALLEY
CONSERVATION

MEMORANDUM

To: Giulio Bianchi
Cc: Phil James, Christine Zimmer
From: Jennifer Dougherty, Robb Lukes, Jordan Wiedrick
Date: May 23, 2014
Re: Onsite meeting summary regarding final stages of construction at Wychwood

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Thank you for taking the time to meet with us and to go over the scheduling for stabilization and landscaping of the site. The following memo provides a summary of our discussion and recommendations on protecting the stormwater practices through the final stages of construction and initiating stormwater monitoring.

1. Activities to finish construction will generally follow this schedule:

- completion of driveway construction - July 2014
- backyard sod installation – June
- construction of rain gardens - beginning of July (**recommend delaying to August/September**)
    - Giulio/Tony will inform CVC (Robb) when the rain gardens are to begin construction
- Asphalt topcoat laid - end of August
- front yard sod installation - September
- completion of cul-de-sac inlet/splash pads - September
- The warranty and assumption period will begin around September and last 2 years.

2. Monitoring station installation schedule (flexible):

- Monitoring equipment, including a temporary weir structure, will need to be installed in Manhole104 and Manhole 102.
- Manhole assessment/measurements for the weir will be made in August. CVC will inform Giulio when contractor is coming to the site.
- Weir installation which could take 2 to 4 hours and will take place **after** the stormsewer structures are cleaned out, September/early October.
- A traffic safety/management plan for manhole access will be provided to Giulio for review in September.
- CVC will obtain written confirmation from the City of Brampton that monitoring equipment installed in the manholes during the warrantee period will not affect their warrantee
- Flow monitoring equipment installation and data collection will begin in October

3. At the meeting, Giulio confirmed the following:

- All groundwater wells were decommissioned and removed.
- Monitoring funds have been transferred from Sequoia Grove Homes to the City of Brampton.

4. Commissioning and assumption of stormwater practices

- CVC will coordinate with Brampton staff on expectations for stormwater management assumption (e.g. visual inspections, as-built survey requirements, sewer pipe video-scoping, infiltration testing).

- Flushing storm sewer structures could drive sediment into the perforated pipe openings or down sewer to the Credit River and must be avoided. Vacuum truck removal of sediment from the system would be an option.
- Video-scoping of perforated pipes should be conducted to ensure no clogging by construction sediment.

5. Erosion & Sediment Control Recommendations

- Preserving the infiltration capacity of the bioswale soils and preventing clogging of the perforated pipe and gravel trenches by construction sediment is critical to ensuring the practices will function and be assumed by the City.
- Bioswale - 1-2" of fine construction sediment was found in the areas near the cul-de-sac inlet and at the downstream end of the bioswale (see pictures). The following approach is recommended:
  - Prevent additional sediment from entering the bioswale with sediment controls at the cul-de-sac inlets. A sediment trap (OPSD 219.220) with a geotextile filter sock in the space between the inlet and bioswale could work well. The high performance bedding used in the permeable pavement base would make a good media to fill the filter sock with.
  - After the front yards have been stabilized with sod, the riprap inlet channels can be installed and the areas of the bioswale where construction sediment built up can be restored. Construction sediment and contaminated sections of sod should be removed (these can be used on other areas of the site). A sand based sod should be installed in the restored areas.

Coach House Court Cul-de-sac

Fairmont Close Cul-de-sac

- Stockpiles - Stockpile (on lot 64&65) is not isolated and stabilized as per the plans. The plan states "Stockpiles shall be surrounded with sedimentation control fencing. All piles which are stocked for more than 30 days shall be seeded."
- Perforated Pipes - Ensure that the openings to the perforated pipe system are plugged and appropriate sediment control is in place within the catchbasins to prevent sediment from washing downpipe to the Credit River.

Again, Giulio, we appreciate you being a flexible partner on this first of its kind project. Let me know if you have any corrections or additions to this meeting summary. Feel free to contact us to follow-up.

Robb Lukes
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905-6701615 x414

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Date:	September 8th, 2014
To:	Giulio Bianchi – Sequoia Grove Homes , Matthew Gehres,- Strybos Barron King, Marc De Leion – Salivan Landscape Ltd
From:	Kyle Vander Linden
CC:	Amna Tariq, Phil James Christine Zimmer, Jennifer Dougherty, Lana Durham, Jakub Wrobel, Jordan Wiedrick
RE:	**Wychwood Site Meeting on September 5th, 2014 & Infiltration Test Results**

Representatives from Sequoia Grove Homes, Strybos Barron King, Salivan Landscaping and Credit Valley Conservation met on Friday, September 5th to inspect and discuss the condition of the LID features (bioswales and rain gardens) at the Sequoia Grove development (Wychwood). CVC and Sequoia have been engaged in ongoing monitoring of the site and formal water quantity and quality monitoring will begin in late October/early November. Results from monitoring will be shared with professionals and governments across Ontario and Canada to advance the use of low impact development.

Prior to the September 5th meeting, CVC had undergone infiltration testing of the bioswale feature to determine infiltration performance and whether rehabilitation is needed. The average infiltration rate noted at the meeting for the bioswale was 44 mm/hr (Details can be found in Appendix A). However, infiltration rates should be in the range of 80 – 120 mm/hr based on existing field studies. Prior to monitoring, CVC wants to ensure that bioswale and rain garden infiltration are functioning optimally as reduction in performance is expected over the long term.

During inspection of the bioswale by the group, it was noted that reduction of the bioswales infiltration is likely due to the compaction of the sod from foot traffic and heavy equipment use, sediment accumulation at the inlets and use of sod with what appears to be a clay base soil (see photos below).

Compaction in bioswale and blocked inlets due to sediment accumulation

Remediation of the bioswale to improve infiltration as discussed by the group will include:

- Completion of the fence to completely restrict access to public to the bioswale
- Restriction of heavy equipment within the bioswale area to avoid further compaction
- Completion of sod placement on front and backyards to minimize movement of dirt into bioswale area
- Clean up of sediment at inlets and within the bioswale
- Removal of sod for the entire length of the base of the bioswale
- After removal of sod, removal of any sediment within the bioswale prior to scouring of bioretention media
- Scouring of bioretention soil media to rehabilitate any compacted media
- Seeding of bioswale with rpf grass seed and addition of compost on top to encourage rapid germination.

In addition to the above activities, erosion and sediment control logs should be used at all bioswale and rain garden inlets and at roll curbs to prevent sediment from entering bioswale and rain garden areas.

The timeline discussed by the group for rehabilitation of bioswale is the last week of September/ first week of October. Matthew Gehres will contact CVC to confirm start of bioswale rehabilitation.

Rain Gardens

In addition to protecting the infiltration capacity of the newly constructed rain gardens, careful attention should be paid to the grading of the rain garden along the road sides so that there is appropriate depth to allow for sheet flow off the roadway and ponding at the surface during a rain event to give time for infiltration. Furthermore, there should be a 2” (5 cm) drop between the finished roll curb and sod to account for sediment accumulation and grass height.

Rain garden with finished curb with respect to media grade

For smaller rain gardens, Matthew Gehres will provide cross section detail to CVC to determine if clear stone is placed at the bottom of the rain garden.

Permeable Paver Driveways

To ensure the optimal performance of the permeable paver driveways, it is critical that roads are swept regularly to clean up loose dirt. On some driveways, dirt was observed on top.

Appendix A – Infiltration Testing

Double ring infiltrometer tests were performed in three areas across the length of the bioswale. Two tests were performed adjacent to the curb inlets from the cul de sac and an additional measurement was taken near the catchbasin at the downstream end of the bioswale. Studies show that in-field measured infiltration rates for bioretention soil range from 80-120 mm/hr. For an application such as Wychwood where there is no stormwater management pond, the bioswale should have an infiltration rate in the higher ranges to ensure adequate drainage of the site.

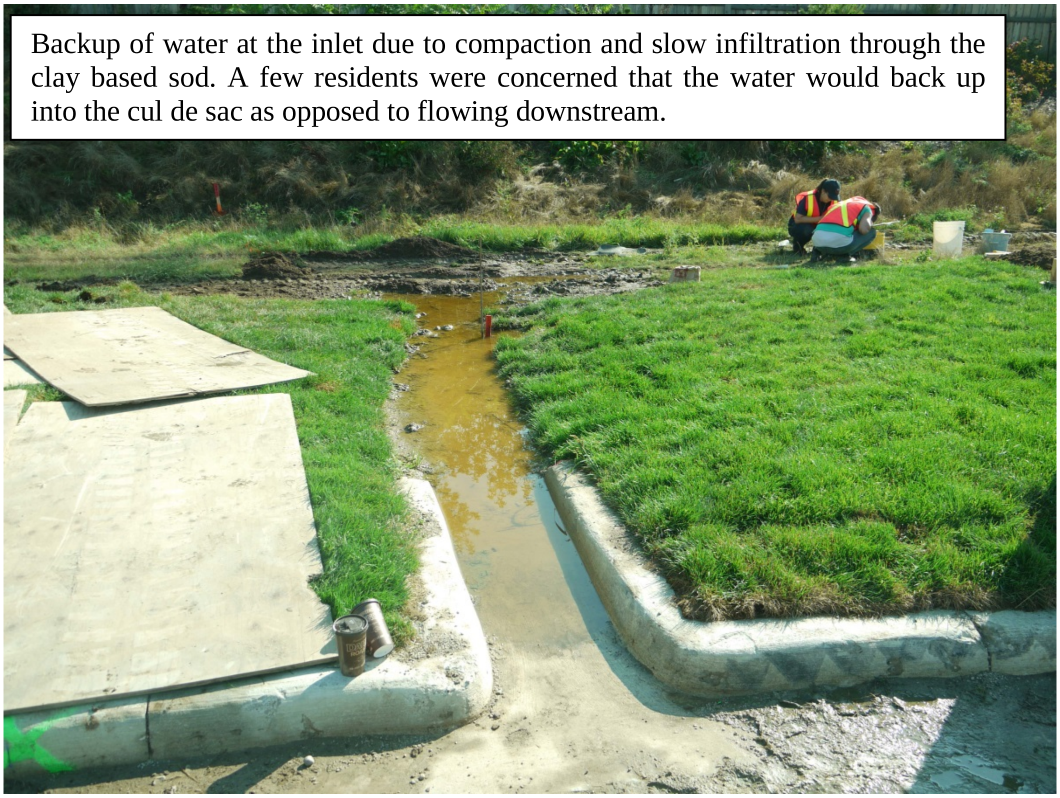
The average infiltration rate of the bioswale was ***44 mm/hr*** with the highest infiltration rate of 60 mm/hr and the lowest infiltration rate of 12 mm/hr. The lowest infiltration rate was measured near the curb inlet which had standing water indicating clogging and need for remediation. Furthermore, the bioretention soil is buried below the clay based sod with holding its true infiltration capacity. At all three test sites, when water was poured on the surface, it would travel downstream as opposed to infiltrating into the ground (see pictures below). The infiltration tests conclude that the bioswale performance is in the lower range earlier in its life as infiltration rates are supposed to reduce over time when compaction takes place. For best performance, the clay based sod should be removed exposing the bioretention media and the area show be seeded. A similar subdivision application in Halton Hills has a bioretention cell with an average infiltration rate of 1200 mm/hr

Test #1 – Adjacent to 1st curb inlet (upstream end) – Measured infiltration rate of 60 mm/hr

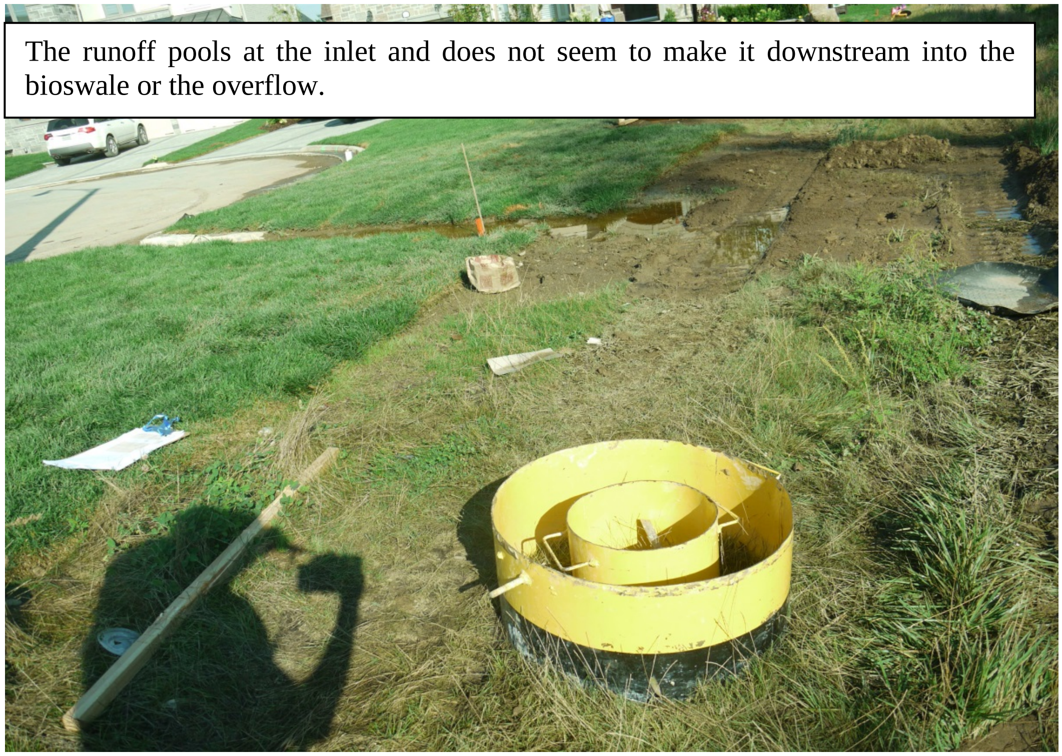
Backup of water at the inlet due to compaction and slow infiltration through the clay based sod. A few residents were concerned that the water would back up into the cul de sac as opposed to flowing downstream.

Double ring infiltrometer measures the rate of water level drop over time and determines an infiltration rate.

Test #2 – Adjacent to 2nd curb inlet (downstream end) –Measured infiltration rate of 12 mm/hr



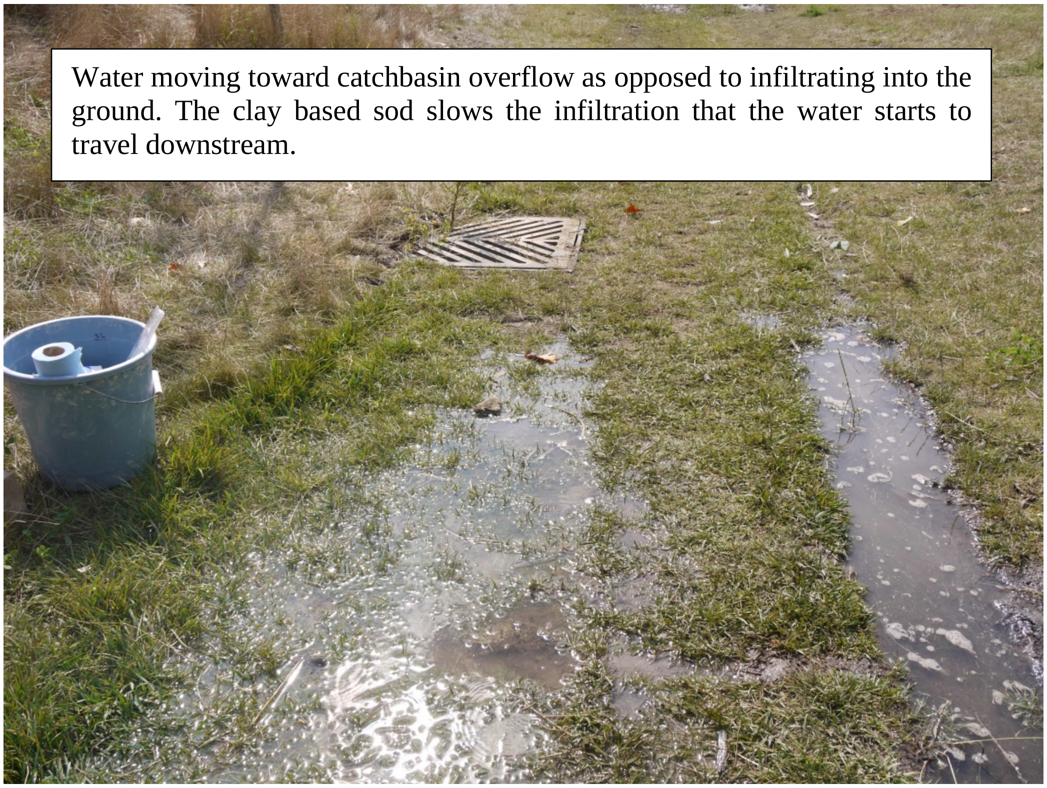
Backup of water at the inlet due to compaction and slow infiltration through the clay based sod. A few residents were concerned that the water would back up into the cul de sac as opposed to flowing downstream.



The runoff pools at the inlet and does not seem to make it downstream into the bioswale or the overflow.

Test #3 – Adjacent to 2nd last catchbasin at the downstream end of bioswale – Measured infiltration rate of 60 mm/hr

Double ring infiltrometer test set up.



Water moving toward catchbasin overflow as opposed to infiltrating into the ground. The clay based sod slows the infiltration that the water starts to travel downstream.

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Date:	October 9th, 2014
To:	Giulio Bianchi – Sequoia Grove Homes , Tony – Sequoia Grove Homes Matthew Gehres,- Strybos Barron King,
From:	Kyle Vander Linden
CC:	Amna Tariq, Phil James Christine Zimmer, Jennifer Dougherty, Lana Durham, Jakub Wrobel, Jordan Wiedrick
RE:	**Wychwood Site Visit on October 9, 2014**

Representatives from Credit Valley Conservation visited the site on Thursday, October 9th to inspect the condition of the LID features (bioswales and rain gardens) at the Sequoia Grove development (Wychwood). CVC and Sequoia have been engaged in ongoing monitoring of the site and formal water quantity and quality monitoring will begin in late October/early November. Based on recommendations from the September 5th Meeting memo, rehabilitation work for the bioswale and construction guidance was provided for the rain gardens.

Below is a table outlining action items for the bioswale based on the September 5 Meeting Memo and its status based on CVC's October 9th visit

Table 1: Rehabilitation Activities

Action Item	Status
• Completion of the fence to completely restrict access to public to the bioswale	Posts installed, but fence still needs to be installed entire length of bioswale
• Restriction of heavy equipment within the bioswale area to avoid further compaction	No heavy equipment present in bioswale, however tracks still present
• Completion of sod placement on front and backyards to minimize movement of dirt into bioswale area	Complete

- Clean up of sediment and garbage at and around inlets within the bioswale	Incomplete
- Removal of sod for the entire length of the base of the bioswale	Future Recommendation – if aeration does not improve infiltrations
- After removal of sod, removal of any sediment within the bioswale prior to scouring of bioretention media	Future Recommendation – if aeration does not improve infiltrations
- Scouring of bioretention soil media to rehabilitate any compacted media	Future Recommendation – if aeration does not improve infiltrations
- Seeding of bioswale with rpf grass seed and addition of compost on top to encourage rapid germination.	Future Recommendation – if aeration does not improve infiltrations

Clean up of the inlets with the extension of the curb is still outstanding. Please see picture pictures below. CVC recommends that remediation to the inlets and area around the inlet with exposed and compacted soil be removed to expose bioretention media. By cleaning up the inlets and removing sediment and garbage, the infiltration of bioswale should improve in these areas.

Compaction in bioswale and blocked inlets due to sediment accumulation and garbage

As CVC inspected downstream from the inlets, piles of dirt and sediment were also noted on top of the sod. It is CVC's recommendation that the dirt be removed and area aerated to encourage proper infiltration. Please see the photos below

Sediment Buildup Downstream of Inlets

Rain Gardens

Upon inspection of the rain gardens within the road right of way, CVC noted that the grade of both sod and plants within large and small rain gardens is too high at certain points which will block water from entering. Grading of the sod and plants is critical as these features are dependent on sheet flow from the roadway. As noted in the September 5th memo there should be a 2" (50 mm) drop from finished curb to sod or bioretention media. It is CVC's recommendation that the landscape company regrade these features to ensure positive grade from finish curb to rain gardens.

Rain garden with finished curb with respect to media grade

Please let me know if you have any questions or concerns. You can reach me 905 670 1615 X 279 or kvanderlinden@creditvalleyca.ca

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Date:	May 27, 2015
To:	Giulio Bianchi – Sequoia Grove Homes
From:	Kyle Vander Linden and Jakub Wrobel
CC:	Tim Mereu, Phil James, Christine Zimmer, Amanjot Singh, Gayle Soo-Chan
RE:	**Summary of LID remediation and Site Visit on May 15, 2015**

Representatives from Credit Valley Conservation visited the site on Thursday, May 15th to observe the condition of the LID features at the Sequoia Grove development (Wychwood). CVC's conducts site visits in an aim to ensure proper construction and to preserve the infiltration capacity of the LID features (bioswales, rain gardens, permeable pavers) by identifying protection measures needed during the construction phase.

CVC and Sequoia Grove Homes have been engaged in ongoing inspection of the site and performance monitoring is intended for the future. Based on recommendations from site visits and meeting memo's provided to Sequioa Grove Homes on Oct 10, 2013, May 23, 2014, Sept 18, 2014, Oct 9, 2014, and now May 15, 2015, CVC identified impacts to LID features and recommended rehabilitation work and guidance to restore the LID features prior to assumption.

Sequoia Grove Homes has completed some restoration work and have responded quickly to requests. Sequoia Grove Homes also noted that other restoration activities will take place after the installation of the top asphalt layer. The top asphalt coat is planned for June, 2015. In order to assist Sequoia Grove Homes in the restoration of the LID features, a summary of action items identified over the inspection period is described in Table 1. CVC can provide guidance to Sequoia Grove Homes for restoration activities and very willing to answer any questions that they may have

Table 1: Summary of action items for LID features at Wychwood

LID Feature	**Action Item**	**Status**	**Implications and remediation recommendation**
Entire Site	Completion of sod placement on front and backyards to minimize movement of dirt into bioswale area.	Sod placement with back and front yards complete.	N/A
East Bioswale	Completion of the fence to completely restrict access to public to the bioswale	Posts and fence installed	N/A
East Bioswale	Restriction of heavy equipment and materials within the east bioswale area to avoid compaction. Materials were stored within east bioswale noted on May 15th, 2015 site visit.	Materials and equipment were removed based on email correspondence between CVC and Sequoia Grove Homes on May 27, 2015	• If bioswale is compacted, infiltration performance could be reduced. • Infiltration tests recommended along length of east bioswale • Removal of sod, sediment and tilling of bioretention media in compacted areas. • Relaying of RPF sod
East Bioswale	Clean up of sediment and garbage at and around inlets within the bioswale and extension of curb inlet into bioswale	Incomplete based on May 15th, 2015 site visit. Past memos have identified ponding in around inlet areas of bioswale (Oct. 9, 2014). I Infiltration test from Sept. 5, 2014, noted failure at inlets. May 15, 2015 site visit notes current construction of curb inlet into bioswale.	• Ponded water within bioswale for more than 24 hours indicates failure of the system. • Recommend removal of sod and sediment and tilling of bioretention media. • Infiltration test required to verify success of rehabilitation.

			- Current construction of inlets presents opportunity to address issue
East Bioswale	Improvement of east bioswale infiltration	September 5th, 2014 memo noted average infiltration rates of 44 mm/hr (Range of 12 mm/hr low – 60 mm/hr). Past LID studies indicate an infiltration rate of 80 – 120 mm/hr is ideal to account for decreasing performance through operational lifespan Bioswale was aerated in September 2014. May 15, 2015 site visit noted compacted areas and sediment contamination at surface of bioswale.	- Poor infiltration rates at assumption could lead to shortened operational lifespan. - Future Recommendation – if aeration does not improve infiltrations, complete infiltration tests within bioswale, identify problem areas, and remove sod, sediment, and tilling of bioretention media to improve infiltration. - Re-stabilize with ESC, RPF sod or grass seed
Bioswale and rain gardens	Erosion and sediment control to remain in place until all construction activities are complete to protect LID features	ESC not present at inlets of east bioswale. May 15, 2015 site visit noted the removal of curb sections at east bioswale. Sediment can get into LID practices (see pictures below table). Westside rain gardens impacted by construction on adjoining residential property (see pictures below table).	- Could result in clogging of the bioswale/rain gardens and impacting infiltration rates. - ESC should be reinstalled as soon as possible - Sediment removed - Infiltration testing to verify infiltration rates are not impacted - Exposed soils should be stabilized as soon as possible
Bioswale and rain gardens	Video-scoping of perforated pipes should be conducted	Incomplete or not within CVC records – noted on May 23, 2014 memo	- Clogged pipes could prevent water from flowing through the

	to ensure no clogging by construction sediment.		system even if soil infiltration rates are satisfactory. • If perforated pipes are clogged or damaged than removal of sediment and possibly their replacement is recommended.
West Rain gardens on	Ensure as-built grades meet design grades for LID features.	Incomplete based on May 15, 2015 site visit. As noted in the September 5th memo there should be a 2” (50 mm) drop from finished curb to sod or bioretention media. See photos below table.	• Once final coat of asphalt is applied, verify grade drop from finished curb to bioswale. • A grade drop will ensure positive drainage into the LID features. If there is insufficient grade drop, by pass or blockage could happen. See pictures below. • Recommended re-grading if to design grades to allow flow of runoff into LID feature

Site Visit on May 15, 2015

East Bioswale

East Bioswale was being used as a staging area. Stockpiles, debris, and gasoline/oil/chemicals were being stored directly on top of the bioswale. Sequoia Grove Homes was made aware of the situation and have removed the materials as communicated by Giulio Bianchi on May 27, 2015. As per CVC's LID Construction Guide, good practice of erosion and sediment control is to "identify pollution prevention management measures to address proper storage, collection and disposal of solid waste, oil, paint, gasoline and other hazardous materials".

Figure 1: Bioswale used as staging area

As CVC inspected along bioswale, piles of dirt and sediment were also noted on top of the sod close to inlet features. These have also been identified in previous memo's from May 23, 2014, Sept 18, 2014, Oct 9, 2014. It is CVC's recommendation that the dirt be removed and area aerated to encourage proper infiltration. Infiltration testing should be conducted afterwards to verify improvement of infiltration rates.

Figure 2 Sediment Buildup Downstream of Inlets. Oct 9, 2014 Left. May 15, 2015 Right.

Removal of the existing curbs appears to have begun, with extension of inlet being constructed in place. At the time of the site visit, only one was under construction. See photos below. Removal of sediment from bioswale and stabilizing of exposed soil highly recommended.

Figure 3: Replacement of existing inlets

It appears as though removal of the other inlet will also be taking place, CVC recommends cleanup of sediment in and around inlet area. Construction within inlet areas provides opportunity to improve infiltration by removing compacted sod, sediment, and tilling soil. See photos below.

Figure 4: Preparation of inlet for construction

Rain Gardens

Upon inspection of the rain gardens within the road right of way, CVC noted that the grade of both sod and plants within large and small rain gardens is too high at certain points which will block water from entering. Grading of the sod and plants is critical as these features are dependent on sheet flow from the roadway. As noted in the September 5th memo there should be a 2” (50 mm) drop from finished curb to sod or bioretention media. It is CVC’s recommendation that the landscape company re-grade these features to ensure positive grade from finish curb to rain gardens per the design drawings. The additional mulch in one of the rain gardens has added a substantial amount of material above the grade of the inlet that will definitely impede flow.

There has also been some construction at the adjacent property of one of the rain gardens, which may have impacted the rain garden. It would appear that the rain garden within the road right of way was impacted by construction at adjacent site. The bioretention media and perforated pipe system could have been affected and could impact infiltration rates and flows within the system. Infiltration testing should be conducted and erosion and sediment control installed to stabilize disturbed area.

Figure 5 Rain garden with finished curb with respect to media grade (left) and impacted rain garden due to adjacent construction (right)

Please let me know if you have any questions or concerns. You can reach me at 905 670 1615 X 279 or kvanderlinden@creditvalleyca.ca

Best Regards.

Kyle Vander Linden

Water Resources Specialist (LID)

Credit Valley Conservation