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CITY OF HAMILTON

Beach Boulevard Community Stormwater Ponding Study - Revised

Beach Boulevard, Hamilton ON

August 2019 – 17-5898

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Executive Summary

Due to recent flooding in 2017, the Hamilton Water Division initiated a study to investigate the cause of water ponding on the Rights of Way (ROW), and provide potential mitigation measures that the City of Hamilton (COH) could implement in order to reduce future flooding impacts. This study is theoretical in nature and includes a review of existing conditions, an assessment of current ponding issues, a review of the potential impact of future conditions, and generates a list of possible solutions to mitigate the current ponding, including potential costs.

Beach Boulevard has experienced flooding dating back to 1943. Previous studies have been undertaken by the COH and the Ministry of Transportation (MTO) that link the chronic flooding to several causes including but not limited to: variations in water level of Lake Ontario, the construction of the Queen Elizabeth Way (QEW), an undersized stormwater system and the lack of general operation and maintenance of catch basins and ditches. The COH Master Drainage Plan (1999) indicated that once the level of Lake Ontario exceeds 75.2 MASL, the Beach Boulevard Community will experience chronic ponding on the ROW.

The level of Lake Ontario is governed by the International Joint Commission (IJC) based on Plan 2014 (released in 2017). Plan 2014 allows the level of Lake Ontario to fluctuate 1.57m (73.56 MASL to 75.73 MASL). However, on May 29, 2017 Lake Ontario reached a record high water level of 75.88 MASL which caused widespread flooding across Ontario, Quebec and the USA. As of result of high levels on Lake Ontario and severe storms, the Beach Boulevard Community experienced large amounts of ponding on the ROW. The COH attempted to mitigate impacts by installing pumps on the majority of the side streets that moved water back into Lake Ontario. Residents also attempted to mitigate risks by dewatering their basements and discharging onto the sidewalks and ROW; this has created health and safety issues due to algae growth and slippery conditions.

Dillon Consulting Limited (Dillon) was requested by the COH to conduct a Stormwater Ponding Study for the City of Hamilton. Dillon created a baseline hydraulic model in order to analyze the capacity of the current system. The model showed that none of the existing sub-systems (except Grafton) can convey the 5-year design storm and that in the event of high water level in Lake Ontario, the capacity of the existing system would further be reduced. The original scope of the hydraulic assignment was modified to include a risk assessment to better define a preferred alternative for sub-system.

A 2D PCSWMM model was used to characterize the spatial and temporal extent of the ponding in the ROW. Sixteen scenarios were simulated, including: four storm scenarios (2, 5, 10, 100 year storm), two different lake levels (74.27 MASL, 75.88 MASL), and two different outlet conditions (existing outlet capacity one 1 barrel, increased outlet capacity with 3 barrels). The following mitigation measures were noted as preferred alternatives that required further investigation and implementation.

Operation and Maintenance: The following recommendations relating to Operation and maintenance have already been undertaken by the COH and MTO.

- There is currently no defined Maintenance Agreement between the COH and MTO for stormwater ditches, outlets and catch basins located within the in the Beach Boulevard Community. The COH and MTO should jointly formalize a Maintenance Agreements that defines responsibilities for day-to-day maintenance and emergency situations relating to the aforementioned assets.

- COH should continue to transfer ownership of landlocked properties in the ditch area between MTO Noise Barrier wall and MTO chain link fence to the MTO.

Legislation/Programs: The following recommendations relating to Legislation and/or Programs can be initiated immediately by the COH. Actual implementation of the recommendations may vary depending solution development and approvals required.

- COH should consider prohibiting all forms of below ground structures (e.g., basement, crawl spaces) and investigate the creation of a "basement filling" program for properties.
- COH should consider updating the language in By-Law 99-169 to clearly indicate that no basement or crawl spaces are allowed in the study area unless the property owner can prove the structure will have no negative impact on the stormwater system.
- COH should consider updating By-Law 99-196 to change the minimum allowable ground floor elevation from 76 MASL to 76.5 MASL to account for the increase in allowable lake level under Plan 2014.
- COH should implement program that educates the Committee of Adjustments and the general public why below-ground floors, basements and crawl spaces are prohibited in the Beach Boulevard Community.
- COH should work with the MTO to determine the design/construction feasibility of different alternatives presented in this study. A Cost Sharing Plan between the COH and MTO should be investigated by the COH.
- That a hold be placed on the sale of City of Hamilton-owned properties located in areas where future stormwater infrastructure may be installed, or areas of historical or modelled ponding. This hold is recommended until the EA is completed and preferred solutions are confirmed. Sale of other City of Hamilton owned properties in this area must be done by the Real Estate Section in consultation with the Public Works Department and should be in conformity with future Zoning By-law No. 6593 changes recommended under this study.
- COH should continue to work with the MTO, HPA and HCA to confirm the existing size and conditions of outlets within the QEW right-of-way. This study assignment did not include physical confirmation of the existing system conditions.

Lot Level

- COH should consider installing proper back water valves to protect residents from the potential risk of system surcharging.
- Residents are encouraged to install foundation drains, weeping tiles and a sump pump, if required, to address basement flooding. Water should be directed to a free draining outlet, storm sewer or storm water harvesting feature on resident's property; any direction of storm water to a sanitary/combined sewer is in violation of the existing Sewer-Use By-law.
- COH should consider installing direct connection features for private property owners that would convey basement dewatering flows directly into the storm sewer system.

Infrastructure: The existing stormwater system should be upgraded to handle the 5 year storm under a high Lake Ontario water level. This upgrade should occur in conjunction with other scheduled infrastructure works.

Based on the additional Risk Assessment, the following sub-catchment specific recommendations have been developed. The recommendations are based on an assumed level of service of the highest recorded level of Lake Ontario (75.88 MASL), a minor storm of 5 years and a major storm of 100 years. Prior to the implementation of any of the following sub-catchment recommendations, the COH will need to clearly define the desired level of service for the study area and complete an Environmental Assessment.

- Eastport System - Installation of a new single gravity outlet that matches the existing capacity.
- Hamilton Harbour System - Installation of a new gravity system that has an increased outlet capacity under the QEW.
- Dunraven System - Installation of a new pumping station that outlets to Lake Ontario or the Eastport Ditch.
- Lagoon System - Installation of a new pumping station that outlets to Lake Ontario or the Eastport Ditch.
- Townhouse System - COH to confirm DEM data. Outlet location, size and condition should be verified by staff.
- Bayside System - Installation of a new pumping station that outlets to Lake Ontario or the Eastport Ditch.
- Fletcher System - Installation of a new pumping station that outlets to Lake Ontario or the Eastport Ditch.

Conclusions

The City of Hamilton has experienced flooding in the Beach Boulevard area dating back to 1943. The intent of the Beach Boulevard Community Stormwater Ponding Study is to investigate the cause of water ponding on the Rights of Way (ROW), and provide potential mitigation measures that the City of Hamilton (COH) could implement in order to reduce future flooding impacts. Some of the recommendations listed can be implemented by the City immediately (e.g., development of Maintenance Agreements with the MTO, property transfers, etc.). Sub-Catchment specific recommendations require more consideration and may take more time to implement. The installation of a new pumping station or new outlet would require confirmation existing conditions (e.g., outlet pipes under the QEW, Eastport Ditch outlet), and may be subject to an Environmental Assessment and/or other regulatory approvals/requirements. COH is required to confirm a level of service for the Beach Boulevard Community; other areas within the COH have a level of service of a 5 year storm. COH should work with the MTO to develop cost sharing agreements for this work, similar to that agreed on for the Grafton Pumping Station.

1.0 Introduction

Ongoing street ponding in the vicinity of Beach Boulevard in Hamilton required the City of Hamilton (COH) to investigate the situation and assess potential mitigation measures for ponding on the rights-of-way (ROW), associated with lake levels, surface drainage, ground water and existing infrastructure. The COH requested Dillon Consulting Limited (Dillon) to assist with this study.

1.1 Description of Study Area

The limits of the study are as shown in Figure 1.

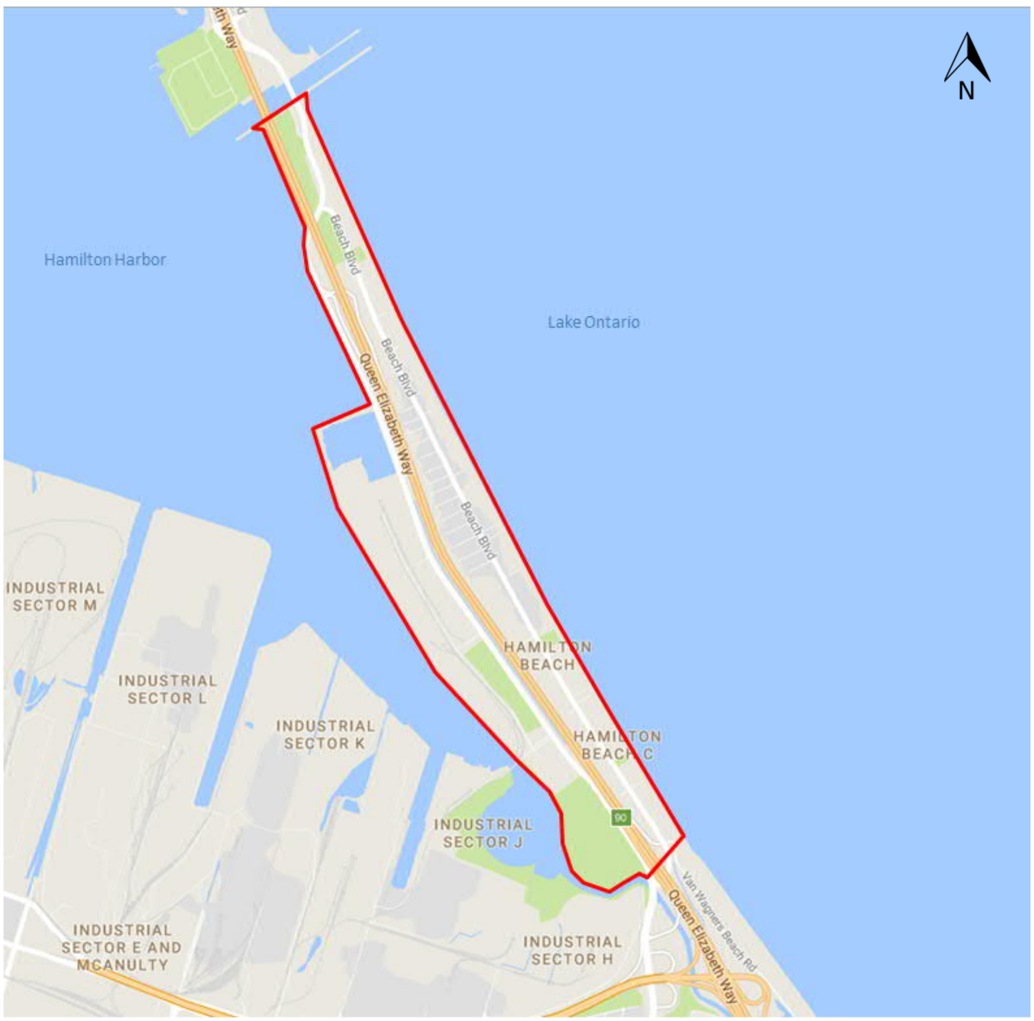

Figure 1: Study Area

1.2 Scope of Study

The scope of this study is to review existing conditions, assess the current ponding issues, review the potential impact of future conditions, and to generate a list of possible solutions to mitigate the current ponding, including potential costs. A Risk Assessment was also requested and a 2D PCSWMM Model was developed to provide a list of recommendation for various sub-systems. All ground and infrastructure coordinates are reported in NAD83 unless otherwise specified. Water levels in Lake Ontario as defined by the International Joint Commission (IJC) are referenced to the International Great Lakes Datum (IGLD). NAD83 is a horizontal coordinate system which referenced NAVD88 as a vertical datum. NAVD88 and IGLD vertical datum are one and the same.

1.3 Previous Studies and Reports

Previous studies and reports were reviewed and summarized as part of this study. The following reports were provided to Dillon by the COH and have been used as background information to inform this study in addition to any other referenced material:

- MMM Group - *Master Drainage Plan – Hamilton Beaches* (1999) – summarized in section 1.3.1
- McCormick Rankin Corporation (MRC) - *Existing Conditions Drainage Investigation & Preliminary Design of Flood Protection for Beach Boulevard Community* (2008) – summarized in section 1.3.2

According to MRC, flooding in the study area is a historical problem that dates back as far as 1943. This flooding prompted the COH to purchase properties on Beach Boulevard in 1970's with the intention to convert the residential properties into park land. However, in 1999 the COH started selling properties to be re-developed for residential use.

Reoccurring flooding led the COH to hire MMM to complete a Master Drainage Plan for the Beach Boulevard Community. This study concluded that flooding occurs in the study area when lake water levels exceed 75.2 metres above sea level (MASL). Additionally, ponding would occur on side streets during the 2-year storm frequency because the stormwater system did not have enough capacity to convey this flow. Updates were made to the stormwater system as required and By-Laws (discussed in section 1.5) were put in place to limit the number of additional basements and crawl spaces that could be built in this area.

In 2008, the Ministry of Transportation of Ontario (MTO) retained MRC to conduct an additional study regarding flooding of the Beach Boulevard Community in relation to the Queen Elizabeth Way (QEW) ROW. MRC concluded that the street flooding problems can be attributed to a combination of the minimal elevation difference between lake water levels and Beach Boulevard and land use changes over time. MRC also concluded that several of the end-of-street catch basins were in extremely poor condition and would require water to pool on the street before it could overflow into the pipe network because catch basins were not located at the localized lowest spot. The report recommended a pump station with a discharge outlet into a ditch on Eastport Drive.

1.3.1 Master Drainage Plan – Hamilton Beaches, MMM Group

The following are key points taken from the Master Drainage Plan – Hamilton Beaches prepared by MMM Group (1999):

- Public works staff noted that once lake levels exceed 75.2 MASL, prolonged flooding of streets and properties occur during rainfall and snowmelt events.
- Flooding was particularly chronic at Windermere Avenue, Knapmans Drive, Wickham Avenue, Grafton Avenue, Comet Avenue, Granville Avenue, Clare Avenue, Lagoon Avenue and Arden Avenue.
- The COH had site plan control for all redevelopment lots west (harbour side) of Beach Boulevard. It was recommended that the COH obtain site plan control for the east side of Beach Boulevard, since any redevelopment in this area had the potential to impact existing development.

1.3.2 Existing Conditions Drainage Investigation & Preliminary Design of Flood Protection for Beach Boulevard Community, McCormick Rankin Corporation

The following key points were noted within the Existing Conditions Drainage Investigation & Preliminary Design of Flood Protection for Beach Boulevard Community prepared by MRC (2008):

- Field investigations revealed that the as-built end-of-street drainage systems deviate from the MTO contract drawings. Many of these systems were not installed due to difficulties associated with high groundwater levels during construction. Only the following 3 of the 13 ditch inlet catch basins were installed with the correct size: Granville Avenue, Bayside Avenue, and Lagoon Avenue
- The QEW drainage system that intercepts flows from the Beach Boulevard Community operated independently of the drainage system that serves the highway. The known locations of pipes crossing the QEW are shown in Figures 1-1 to 1-5.
- Drainage contributed from the Beach Boulevard Community and QEW between Dunraven Avenue and Wickham Drive was conveyed to Hamilton Harbour by a large diameter storm sewer. Drainage contributed between Wickham Drive and Kirk Avenue was conveyed to Redhill Creek by a deep, well vegetated ditch that was filled with sediment and debris. Water levels in the ditch were coincident with water levels in Hamilton Harbour.
- Observations obtained from a 27 mm storm on November 29, 2005, included the following:
    - Windermere Avenue, Comet Avenue, Granville Avenue, and Lagoon Avenue all experienced significant flooding;
    - Low to moderate flooding was observed on Dunraven Avenue, Rembe Avenue, Wickham Avenue, Clare Avenue, Arden Avenue, and Bayside Avenue;
    - Flooding on Windermere Avenue inundated residential streets and driveways;
    - Catch basins on Comet Avenue were blocked by sediment and debris; and
    - Locarno Avenue, North Park Avenue and Kirk Avenue appeared to drain properly.
- The historical storm from August 24, 1982 that generated 94 mm of rainfall with lake levels at 74.8 MASL was used as an input to the model.
- Water detention ponds were not considered as a viable alternative because they would be difficult to construct with respect to the uplift forces produced by high groundwater elevations.
- A 920 m long gravity storm sewer system with a pumping station at Grafton Avenue and a force main with an outlet to Eastport Ditch was recommended and constructed.
- It was concluded that lake levels greatly influence the capacity of the storm sewer system. As such, during high lake levels, flooding within the Beach Boulevard Community occurs at much lower precipitation intensities than it does when lake levels are low.

1.4 Geology and Hydrogeology

The following geotechnical investigations were conducted within the study area:

- E.M. Peto Associated Limited – *Soils Report, Low Lift Pumping Station Discharge Main, Intake Line* (1961)
- Morton and Partners Limited – *Subsurface Conditions Proposed Eastport Watermain at Beach Boulevard and Eastport Arterial Road* (1986)
- Peto MacCallum LTD - *Hydrogeological Investigation, Groundwater Sampling, Beach Boulevard, Hamilton, Ontario* (1989)
- Mountainview Geotechnical LTD - *Geotechnical Investigation – Proposed Sewers at Beach Boulevard Van Wagner Beach Rd. to Lagoon Hamilton, Ontario* (1992)

These reports conclude that the subsurface of the Beach Boulevard Community is primarily highly permeable coarse sand and gravel overlying shale bedrock at elevations between 55 and 65 MASL. In addition, the groundwater elevation coincides with the surface water levels of Lake Ontario and Hamilton Harbour.

1.5 Relevant Legislation

The following regulations and plans were reviewed, those deemed applicable to this study are summarized in this section:

- City of Hamilton By-Laws: 6593, 99-169, 99-170, 10-118, and 14-090
- Plan 2014 – Lake Ontario - St. Lawrence River, *Protecting against extreme water levels, restoring wetlands and preparing for climate change* – International Joint Commission (IJC)
- Ontario Regulation 161/06, *Hamilton Conservation Authority's Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses* – under Conservation Authorities Act, R.S.O 1990, c. C.27

1.5.1 By-Law 99-169

The following are excerpts from the COH's Zoning By-Law 99-169 that apply to land on the west (harbour) side of Beach Boulevard:

- The minimum ground floor elevation of any building or any building addition shall be 76.0 m above mean sea level;
- No basement or cellar shall be permitted for any building.

A copy of the existing Zoning By-Law can be found in Appendix B.

1.5.2 Plan 2014 – Lake Ontario - St. Lawrence River

Plan 2014 replaced Plan 1958-D in January 2017 and regulates the levels of Lake Ontario by dictating the outflows under different criteria. A comparison of the Plan 2014 to the former Plan 1958-D can be found in Appendix A. The levels in these plans are targets, as such lake levels may be above or below the given criteria due to several factors including but not limited to precipitation levels and temperature.

The IJC released a set of recommended updates regarding Plan 1958-D based on a 14 year study and extensive public consultation. The following are excerpts from the updated Plan 2014:

- H4. The regulated monthly mean level of Lake Ontario shall not exceed the following elevations in the corresponding months.

TABLE 1: Plan 2014 Regulated Monthly Levels of Lake Ontario, Datum: IGLD 1985

Month	Maximum (m)	Minimum (m)
January	75.26	73.56
February	75.37	73.62
March	75.33	73.87
April	75.60	73.97
May	75.73	74.22
June	75.69	74.27
July	75.63	74.26
August	75.49	74.15
September	75.24	74.04
October	75.25	73.83
November	75.18	73.67
December	75.23	73.57

- H.11 Consistent with other requirements, the levels of Lake Ontario shall be regulated for the benefit of property owners on the shores of Lake Ontario in the United States and Canada.
- H.14 In the event that Lake Ontario water levels reach or exceed extremely high levels, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream.
- B2.2 Flow Limits
    - I Limit – maximum flows for ice formation and stability. During ice cover formation, either downstream on the Beauharnois Canal or on the critical portions of the International Section, the maximum flow is 6,230 m^3/s. Once a complete ice cover has formed on the key sections of the river, the winter flow constraints prevent the river level at Long Sault from falling lower than 71.8 MASL. The I limit also limits the maximum flow with an ice cover present in the Beauharnois and/or international channels to no more than 9,430 m^3/s.
    - L Limit – maximum flows to maintain adequate levels and safe velocities for navigation in the International Section of the river. Maximum releases are limited to 10,700 m^3/s if the Lake Ontario level should rise above 76.0 MASL during the navigation season and 11,500 m^3/s during the non-navigation season.
    - F Limit – the maximum flow to limit flooding on Lake St. Louis and near Montreal in consideration of Lake Ontario level. It is a multitier rule that attempts to balance upstream and downstream flooding damages by keeping the level of Lake St. Louis below a given stage for corresponding Lake Ontario level.

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- C.2 Minor Deviations for the St. Lawrence River
    - Minor deviations, while not necessarily limited to only these situations, could include those to address contingencies such as
        - Short-term flow capacity limitations due to hydropower unit maintenance;
        - Assistance to commercial vessels on the river due to unanticipated low water levels;
        - Assistance, when appropriate, with recreational boat haul-out on Lake St. Lawrence and Lake St. Louis at the beginning or at the end of the boating season, and
        - Unexpected ice problems on the river downstream of Montreal.
    - The intention is for minor flow deviations to be restored by equivalent offsetting deviations from the plan flow as soon as conditions permit to avoid or minimize cumulative impacts on the Lake Ontario water level and avoid changing balance of benefits under the approved regulation plan.
    - However, the Board shall not allow the cumulative effect of these minor deviations to cause the Lake Ontario water level to vary by more than +/- 2 cm from that which would have occurred had the release prescribed if the approved plan been strictly followed.
    - However, if circumstances are such that minor deviations cause the Lake Ontario level to vary more than +/- 2 cm from the level resulting from the approved plan, then the Board shall advise the Commission in advance as soon as the potential need for the long-term deviation is known.
- C.3 Major Deviations
    - Major deviations are significant departure from the approved regulation plan that are made in response to extreme high or low levels of Lake Ontario in accordance with criterion H14 of the revised Order of Approval.
    - In the event that Lake Ontario water levels reach or exceed extremely high levels, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream.

A copy of the current Plan can be found in Appendix C. Several of the maximum and minimum lake level did change as a result of Plan 2014, these variations can be seen in Appendix A.

1.6 Drawings and GIS Information Reviewed

Table 2 provides a list of key drawings that were reviewed as part of this study, a full list of all provided drawings can be found in Appendix L.

TABLE 2: Key Drawings Reviewed

Drawing Name	Agency	Contact No.	Drawing No.	Description
Beach Boulevard Interceptor	City of Hamilton	PW-09-43 (S)	09-S-11	Proposed 900mm Diameter Force Main Construction Crossing the Queen Elizabeth Way
Beach Boulevard Interceptor	City of Hamilton	PW-11-54 (S)	11-S-20	Proposed Pumping Station, Storm Sewer and Ditch Construction
Beach Boulevard Plan	City of Hamilton		B-354-S	Catch basin and Manholes South End of Skyway Bridge
East Port Industrial Park - Proposed Sanitary Sewer, Forcemain and Watermain	City of Hamilton	RHW-83-74	83-S-9	Drawings that show parts of Eastport Ditch.
QEW Crossing for Proposed Sanitary Sewer	City of Hamilton	802-111	92-S-1	Some information and about basement depths in the study area.
Proposed Sanitary Sewer - Phase 1	City of Hamilton	802-111	92-S-57	Information and about basement depths in the study area.
Proposed Sanitary Sewer - Phase 2	City of Hamilton	802-111	93-S-1	Information and about basement depths in the study area.
QEW Crossing for Proposed Sanitary Sewer	City of Hamilton		93-S-40	Some information and about basement depths in the study area.
Van Wagners' Beach Boulevard	City of Hamilton	PW-04-40 (HSW)	04-H-80	Road Reconstruction and Storm Sewer Removal near study area

Several GIS layers were provided to Dillon and have been used as background information to inform this study in addition to any other referenced material, a list of all reviewed GIS layers can be found in Appendix L.

1.7 Work Done by Others in Southern Ontario

Ponding on the ROW is a common problem for several municipalities in southern Ontario. For example the City of Toronto has several ongoing Basement Flooding Environmental Assessment Studies. The recommended solutions included the following (City of Toronto, 2017):

- Larger sewer pipes,
- Twinning of sewers,
- Underground storage tanks,
- Bio-retention sidewalks/medians swale, and
- Wet/dry ponds.

Additionally, in 2015 the Town of Essex completed a basement flooding study to address recent basement flooding that occurred as a result of storm surges in their sanitary sewer system. The following were the recommended high priority solutions (Stantec, 2015):

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- Re-commissioning Essex southwest lagoons,
- Inlet pumping station upgrades at Essex pollution control plant,
- Pumping station upgrades, and
- Increase sanitary sewer size.

Lastly, the Regional Municipality of Halton has created a long term region wide approach to reduce the risk of flooding from sewer surcharging as a result of severe flooding in 2014. Some of the systems they are planning to implement over the next 10 years include (The Region Municipality of Halton, 2015):

- $60 million dollar system improvement program,
- Inter-jurisdictional basement flooding working group,
- Permanent wastewater flow metering program,
- Voluntary downspout disconnection program based on a 100% subsidy for eligible residents,
- Voluntary weeping tile disconnection program based on a 100% subsidy for eligible residents,
- Extraneous flow reduction public education program, and
- Dedicated staff resources to develop, implement, sustain and monitor the Region Wide Basement Flooding Mitigation Program.

COH should look into joining the Inter-jurisdictional basement flooding working group.

2.0 Existing Drainage System Performance

The following sections discuss the existing conditions of the Beach Boulevard Community drainage system.

2.1 Background Information

Background information was provided by several stakeholders to assist in this study. This section will summarize some of the key information in relation to this study.

2.1.1 Ontario Lake Levels

As previously mentioned, the water level of Lake Ontario majorly affects the drainage system in the Beach Boulevard Community. It was noted in the Master Drainage Plan that once the lake level exceeds 75.2 MASL the study area will experience chronic ponding on the ROW. The IJC allows a 1.2m fluctuation of Lake Ontario's water level from 74.16 MASL to 75.38 MASL. The International Lake Ontario – St. Lawrence River Board is responsible for regulating the water level and outflow of Lake Ontario in accordance with the 2014 IJC Plan.

Up until 2017 the highest recorded water level on Lake Ontario was 75.82 MASL in June 1952. According to Environment Canada, on May 29, 2017 Lake Ontario reached a record high water level of 75.88 MASL. The COH confirmed that several streets in the Beach Boulevard Community are located below this water level, specifically Tower Drive and Bayside Avenue. Historical lake levels and projected forecasts of lake levels for Lake Ontario can be seen in Figure 2. The historical lake levels are lake wide averages from several stations and therefore could be influenced by wind and storm surge conditions.

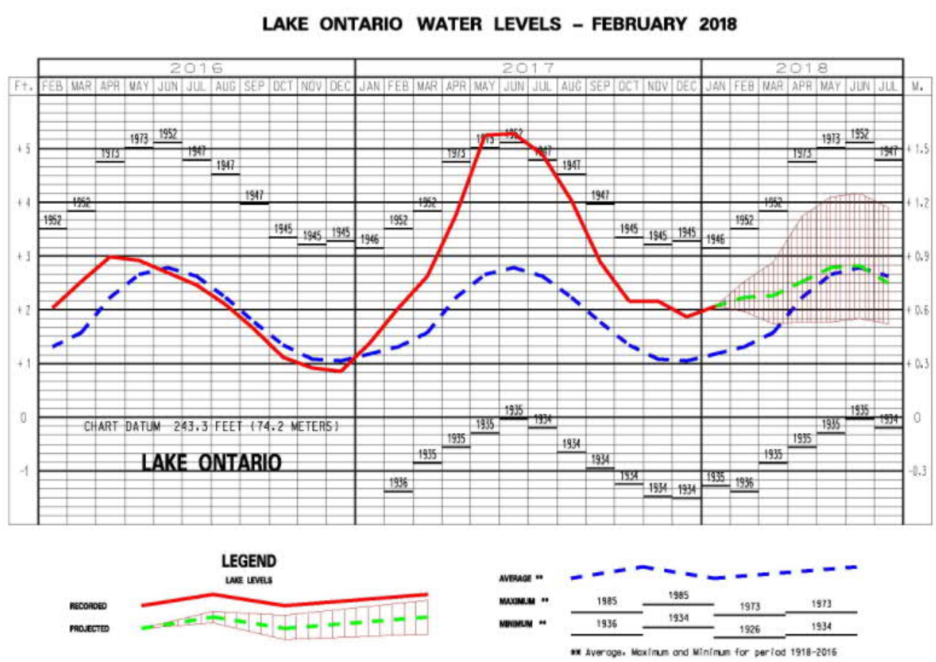

Figure 2: Historical and Forecasted (red shading) Lake Ontario Water Levels (US Army Corps of Engineers, 2018)

The Great Lakes – St. Lawrence River Adaptive Management Committee (GLAM) and the IJC attributed the 2017 high lake levels to several factors including but not limited to:

- Wet, mild and highly fluctuating winter weather conditions,
- Above-normal inflows from the upper great lakes,
- Excessive snowpack and late melt in the Ottawa River Basin,
- Record Ottawa River spring freshet, and
- Extreme rain events over the entire basin in April and May.

Fluctuating temperatures resulted in varied outflow from Lake Ontario between January and March 2017. Then due to intense storms and snow melts, the levels in Lake Ontario reached record highs and triggered criterion H14 (as defined in section 1.5.2) which authorized the board to follow an alternative strategy and alter outflows to provide all possible relief to riparian property owners living along the shorelines of the entire system. However, the board chose not to alter the outflow and to enforce the current “F-Limit” for Plan 2014. It wasn’t until June 14th, 2017 that the board decided to increase the Lake Ontario outflow to 10,400 m^3/s (Caldwell, 2017).

2.1.2 Documented Ponding Incidents

Previous studies have documented chronic ponding on the ROW in the Beach Boulevard Community dating back as far as 1943. Chronic ponding was observed on Windermere Avenue, Knapmans Drive, Wickham Avenue, Grafton Avenue, Comet Avenue, Granville Avenue, Clare Avenue, Lagoon Avenue and Arden Avenue. A summary of the affected areas can be seen in Table 3.

As a result of the high water levels in Lake Ontario, Transport Canada and Natural Resources Canada took a series of aerial photographs along the Lake Ontario shoreline to document the flooding. These photos were taken on June 8 2017, 10 days after the peak recorded lake level. Figures that indicate areas of visible ponding in the study area and are located in Appendix D, a summary of the affected areas can be found in Table 3, see reports for detailed definitions of flooding levels.

The COH has notification records of ponding on the ROW or basement flooding occurring on several of the Beach Boulevard Community streets since 2002. With the increase of water levels that have been observed in the past couple years the number of notifications the COH received has increased. A summary of the notices can be seen in Table 3, see reports for detailed definitions of flooding levels.

TABLE 3: Summary of Documented Flooding Incidents in the Beach Boulevard Community

Street	Minimum Elevation (MASL)	Master Drainage Plan Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
Eastport Drive	-	-	-	Visible Flooding	No documented Service Requests
Beach Boulevard	-	-	-	No Visible Flooding	08/11/2003 – Street Flooded 03/15/2004 – Street Flooded 01/31/2005 – Property Flooded 11/15/2005 – Street Flooded 07/18/2006 – Property Flooded 02/23/2007 – Street Flooded 05/06/2008 – Property Flooded 06/09/2008 – Street Flooded 09/28/2010 – Street Flooded 09/30/2011 – Street Flooded 06/01/2012 – Street Flooded 05/10/2013 – Street Flooded 02/21/2014 – Catch Basin Flooded 07/28/2014 – Street Flooded 04/21/2017 – Street Flooded 05/01/2017 – Street Flooded 05/04/2017 – Property Flooded 05/05/2017 – Several Basements Flooded 05/06/2017 – Street Flooded
Dunraven Avenue	75.9	No Documented Flooding	Low to Moderate Flooding	Visible Flooding	No documented Service Requests
Locarno Avenue	75.75	No Documented Flooding	Appears to Drain Properly	Visible Flooding	12/01/2006 – Sewer Flooded 01/15/2007 – Street/Property Flooded 06/29/2009 – Catch Basin Flooded 07/22/2012 – Basement Flooded
North Park Avenue	75.75	-	Appears to Drain Properly	No Visible Flooding	11/29/2011 – Street Flooded 10/28/2015 – Street Flooded
Rembe Avenue	75.8	-	Low to Moderate Flooding	No Visible Flooding	No documented Service Requests
Windermere Avenue	75.92	Chronic Flooding	Significant Flooding	No Visible Flooding	04/28/2008 – Street Flooded 05/20/2011 – Property Flooded 12/20/2013 – Street Flooded
Knapmans Drive	75.79	Chronic Flooding	No Documented Flooding	Visible Flooding	No documented Service Requests
Killarney Avenue	76.98	-	-	No Visible Flooding	No documented Service Requests

Street	Minimum Elevation (MASL)	Master Drainage Plan Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
Wickham Avenue	75.83	Chronic Flooding	Low to Moderate Flooding	Visible Flooding	05/17/2002 – Several Basements Flooded 06/01/2011 – Street Flooded 04/21/2017 – Basement Flooded
Grafton Avenue	75.77	Chronic Flooding	-	Visible Flooding	07/10/2006 – MH Flooded 07/31/2006 – Street Flooded 07/11/2009 – Street Flooded
Comet Avenue	75.66	Chronic Flooding	Significant Flooding	Visible Flooding	12/31/2004 – Street Flooded 02/16/2005 – Street Flooded 10/22/2005 – Street Flooded 09/16/2015 – Basement Flooded
Granville Avenue	75.74	Chronic Flooding	Significant Flooding	Visible Flooding	05/03/2002 – Street Flooded 6/7/2002 – COH Pumping Storm Water 11/03/2003 – Street Flooded 05/12/2004 – Street Flooded 06/01/2004 – Street Flooded
Clare Avenue	75.66	Chronic Flooding	Low to Moderate Flooding	Visible Flooding	11/03/2003 – Street Flooded 05/12/2004 – Street Flooded 12/01/2006 – Street Flooded
Woodland Avenue	77.18	-	-	No Visible Flooding	No documented Service Requests
Dexter Avenue	76.87	-	-	No Visible Flooding	No documented Service Requests
Lagoon Avenue	75.99	Chronic Flooding	Significant Flooding	Visible Flooding	No documented Service Requests
Arden Avenue	75.67	Chronic Flooding	Low to Moderate Flooding	Visible Flooding	05/05/2008 – Street Flooded 05/04/2017 – Street Flooded From Pumping 05/12/2017 – Street Flooded onto Private Property
Sierra Avenue	-	-	-	No Visible Flooding	No documented Service Requests
Tower's Drive	75.8	-	-	No Visible Flooding	05/13/2017 – Basement Flooded
Lakeside Avenue	76.72	-	-	Visible Flooding	No documented Service Requests
Bayside Avenue	75.88	-	Low to Moderate Flooding	Visible Flooding	04/01/2017 – Street/Basement Flooded 04/04/2017 – Street Flooded

Street	Minimum Elevation (MASL)	Master Drainage Plan Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
Fitch Avenue	76.78	-	-	No Visible Flooding	No documented Service Requests
Mareve Avenue	76.8	-	-	Visible Flooding	No documented Service Requests
Wark Avenue	75.75	-	-	Visible Flooding	No documented Service Requests
Kirk Avenue	-	-	Appears to Drain Properly	Visible Flooding	06/10/2013 – Street Flooded 05/12/2017 – Street/Property/ Basement Flooded

2.1.3 Basements

Although the development of new basements is restricted under the current By-Law, several below ground structures were identified in the 1993 survey that was conducted for the proposed sanitary sewer and force main. Additionally, during a site visit (September 22, 2017), several additional below ground floors were noted in newer buildings. These structures may have required approval from the Committee of Adjustments. The Committee of Adjustment is a group of volunteers that makes decisions on behalf of the COH. Figure 2-1 to 2-2 depicts the locations of known basements and their relative elevation (if known) based on available information.

The Committee of Adjustment can make minor variances to the COH's Zoning By-Law to allow the following:

- Enlargements extension or change to legal nonconforming uses;
- A parcel of land to be split into more than one lot or as a lot addition to abutting lands; and
- Mortgages, partial discharge of mortgages, validation of title, access right-of-way, easements and leases over 21 years.

The Committee can allow variances by following four main criteria:

- The variance is minor;
- It is desirable for the appropriate development or use of land, building or structure;
- General interest and purpose of the By-Law is maintained; and,
- The official plan is maintained.

If a property owner wishes to receive an amendment to the By-Law they must complete an online form and pay an application fee. They must then attend a public hearing that will be set within 30 days of the initial application. This hearing will determine the outcome of the application.

2.2 Current Operating Conditions

Due to high lake levels and intense storms, the Beach Boulevard Community experienced large amounts of ponding on the ROW in 2017. The COH installed temporary pumps on several of the side streets to aid in mitigating water damages during these events. It was estimated that the upper daily operation and maintenance costs of these pumps was approximately $10,000 per day. Several residents that live near the temporary pumps have complained about the increased noise that the pumps caused throughout the summer of 2017 and the location where the water was being discharged.

In addition, residents had been using sump pumps to dewater their basements. Most of these pumps were discharged onto the sidewalks and ROW, creating health and safety issues due to algae growth and slippery conditions. These conditions are forecasted to become worse in the winter due to ice formation which can cause further slip and trip hazards. Residents also expressed concerned that they don't have anywhere to connect their dewatering outlets.

Residential sump pumping could also create large hydraulic pressure gradients that could cause basement foundations to crack. This gradient is caused by a change in subsurface pressures as a result of groundwater pumping.

2.3 Hydraulic Analysis

The COH Comprehensive Development Guidelines and Financial Policies Manual (City of Hamilton, 2016) outlines the methodologies and parameters for storm sewer design. The COH design criteria is summarized in the Table 4.

The Rational Method and Manning's Equation have been used to complete the evaluation of the existing storm drainage infrastructure to assess the hydraulic capacity of the existing storm sewer infrastructure, which is in accordance with Comprehensive Development Guidelines. Runoff coefficients were based on those in Table F.1 Coefficient of Imperviousness Table in the Comprehensive Development Guidelines. The IDF parameters for the Mount Hope gauge were used, and were also obtained from the Comprehensive Development Guidelines.

TABLE 4: COH Design Criteria

	Design Return Period	Initial Time of Concentration
Hamilton	5-Year	10 minutes

The following sections provide some background as to the analysis taken for each outlet and the methods used to calculate appropriate discharge flows. Each outlet was separated into a sub system which created a series of eight sub-catchments that can be seen in Figures 1-1 to 1-7.

2.3.1 System Flows

System catchments and storm sewers were delineated based on available topography and grading information. The existing flow rates for each outlet were analysed to calculate the storm flows. The storm flows are based on the Mount Hope IDF parameters. These flows will be used to recommend relevant storm water management strategies for each outlet.

The current capacity of the storm systems were analyzed using the Rational Method based on the information provided including the following assumptions:

- Where pipe slope information is missing, a slope of 0.3 % was assumed based on consistency with adjacent known slopes;
- If the pipe is over capacity the velocity was assumed to be the full pipe velocity;
- C value of the sub catchment is 0.5 (-).

2.3.2 Basement Pumping Flows

Basement dewatering flow rates were calculated based on the lake water level and the relative depths of the known basements. The basement geometry was analyzed to determine the three dimensional dewatering area. The following assumptions were made in order to complete the basement pumping analysis:

- Hydraulic conductivity of 1.45×10^{-3} m/s was used (Morton & Partners Limited, 1986).
- Due to the highly conductive ground material, it was assumed that pumping drawdown cones would not influence each other.
- Each resident would pump water from the four corners of their home until the groundwater level was below that of their basement, they would then continue to pump at this rate until the lake water level decreased to below their basement level.
- Radius of pumping well is 5 cm in diameter.
- The basements would be pumped dry regardless of the pump size required to accomplish this.
- The basement distribution is representative of the Beach Boulevard Community and represents half of the number of basements present.

Due to the assumptions that were made, this is a conservative approach that may overestimate pumping volumes. To ensure that the system is not oversized during a more detailed design, an additional basement survey and pumping questionnaire should be conducted to more accurately estimate the pumping rate. The effect of the lake level on the overall pumping rate can be seen in Figure 3. Figure 3 is the combined total pumping for all buildings located north of the QEW.

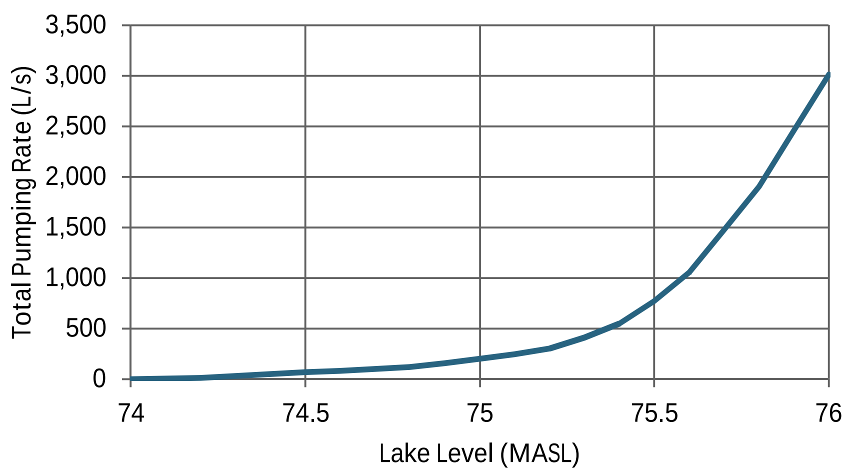

Figure 3: Estimated Basement Pumping Rate Curve for Entire Beaches System

2.3.3 Current Capacity

Several combinations of storm frequencies and lake levels were analyzed to determine the current conditions of the storm systems. Each of the 8 sub-systems were analyzed to determine the maximum storm, lake level and combination that they could convey. Only one sub-system can convey the 2-year storm interval and none can convey the 5-year storm interval. This would indicate that most of the systems are not sufficiently sized to convey the minor storm flows. In addition to pipes being undersized several outlets would be submerged during high lake levels which would further decrease the pipe capacity. Flows are then forced to above ground flow on the ROW. Outputs from the various analyses can be seen in Appendix E.

The minimum lake level that causes basement pumping was approximately 74 MASL, once above this level, basement pumping rates increased exponentially as the lake level continued to rise. All systems could convey the basement pumping rate corresponding with a lake level of 75.5 MASL without additional storm flows (except two pipes in the Grafton sub-system). However, once the lake level surpassed 75.5 MASL, sub-systems began surcharging. Table 5 summarizes the lake levels at which each sub system surcharges.

TABLE 5: Sub-System Summary

Sub-System	Critical Lake Level (MASL)	Flow at Failure Point (L/s)	Max System Flow at Critical Lake Level (L/s)
Eastport Outlet	76.4	336	336
Hamilton Harbour Outlet	75.6	46	336
Dunraven Outlet	75.8	46	336
Grafton Outlet	75.4	27	1496
Lagoon Outlet	75.7	336	336
Townhouse Outlet	75.7	204	204
Bayside Outlet	75.6	336	336
Fletcher Outlet	75.8	336	336

Since most system could not convey the two year storm and no smaller storm IDF curves were provided, lake levels and storm results were not combined for this analysis.

2.3.4 Service Level

In order to determine the most effective mitigation strategy a stormwater service level needs to be defined. In the majority of the COH the service level for the stormwater system is the 5 year design storm. However, most other subdivisions don’t have other significant inputs of storm water (basement pumping or groundwater infiltration), therefore the same approach for defining the service level in the Beach Boulevard Community may not be appropriate. Great care needs to be taken when the COH decides what service level they want to provide to their residents. It is suggested that a service level be defined for the Beach Boulevard Community. Overland flow routes on the Lake side of the QEW are restricted in their outlet by the presence of the QEW. Pipes under the QEW provide the only means of outlet. Based on available information, the pipes are not able to handle the major storm and could cause ponding on the upstream ends of the culverts.

2.3.5 Effects of Lake Level on Operational Capacity

In addition to the increased storm intensities and basement pumping, higher lake levels may have a negative impact on the capacity of the stormwater systems. Several of the outlets are located in the Eastport Ditch on the harbour side of the QEW. When the level in Lake Ontario rises the groundwater levels in the Beach Boulevard Community will rise as well. Several of the outlets in the Eastport Ditch are below the highest allowable lake level (as defined by Plan 2014). This decreases the outlet capacity of the system and may cause backwater flooding to occur in several of the sub catchments due to reduced capacities.

2.4 Planning Review

The following is a summary of the Planning Review, a full copy of this review can be found in Appendix H.

The COH's Official Plan includes a special policy (UH-2) identifying the potential for additional development risks related to shoreline erosion and flooding resulting from Lake-based storm events. The Zoning By-Law features a specific regulation prohibiting new basements for certain lands on the east side of Beaches Boulevard (By-Law 99-169) and west side of Beaches Boulevard (By-Law 99-170). While there has been a continuous level of development in the Study Area over the last decade, there have only been a handful of new basements constructed. It does not appear as though additional major planning policies or regulations could be implemented to resolve or address issues related to increased basement flooding in the Study Area. The COH could consider the following minor adjustments:

- Updating Special Policy Area designation UH-2 to reference the potential risks related to basement flooding so as to align with the language/restrictions in the Zoning By-Law;
- Reviewing the geographic limits of By-Law 99-169 and 99-170 to ensure that all properties which could be vulnerable to basement flooding are covered by the basement prohibition regulation (which appears to be the case, but should be confirmed).

3.0 Future Conditions

As part of the evaluation of the existing system, future conditions, such as climate change and lake level increases were considered. Increased lake levels and storm intensities would impact the current capacity of the stormwater system. Additionally, with high lake levels in combination with wave uprush, water could be driven inland past the 100-year flood level limit. It was noted that the current high point (a pedestrian and bike path) which protects the Beach Boulevard Community was close to being over topped in the recent high water period. Due to the topography in the area if this were the happen the water could pool in the Beach Boulevard Community. Therefore, mitigation measures also considered potential solutions to this problem should it occur in the future.

The Ontario Ministry of Natural Resources (MNR) outlined in their guide for public health and safe policies regarding the Great Lakes – St Lawrence River System that flood allowances on Lake Ontario should include a 15 m allowance for wake uprush or other related hazards.

This distance does not take into account wave protection features such as dikes or wave breakers. Mitigation measures to address this type of flooding risk are addressed in the next sections.

The COH is working with several other municipalities to reduce their GHG emissions in response to the climate change initiatives. They have acknowledged that climate change increases the stresses and costs on infrastructure including storm water management assets. In addition, all infrastructure is at risk of increased damage due to extreme weather events. These considerations have been taken into account in the creation and evaluation of alternatives.

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4.0 Mitigation Measures

The following mitigation measures have been identified as potential solutions to improve/reduce flooding and ponding in the Beach Boulevard Community. They have been analysed based on their feasibility and effectiveness in the study area. Mitigation measures are separated based on their implementation method and ability to address the three different types of flooding that have the potential to negatively impact the Beach Boulevard Community.

- Stormwater refers to the flow that surcharges from the storm sewers during times of large rain events.
- Surface water refers lake inundation (water that comes from the lake flooding the Beach Boulevard Community).
- Groundwater refers to the water that is entering resident’s basements or that is being pumped on the street. If pumped, groundwater tends to pond in low spots or could enter directly into the storm water pipes. In addition, at times of high lake level (when the lake level/groundwater level is higher than the ground surface) groundwater can seep out of the ground and pond at low points on the street.

Some mitigation measures will not be relevant for addressing the ponding on the ROW but they have still been summarized in the following sections.

4.1 Legislative Mitigation Measures

The following mitigation measures address changes or updates to the legislative system.

4.1.1 By-Law Updates

The COH currently has By-Law 99-169 in place for a portion of the Beach Boulevard Community that prohibits basement (living space) construction. However, property owners can obtain approval from the Committee of Adjustments which would allow the construction of a basement. In addition there is currently a minimum elevation required for the first floor ground level of 76 MASL which with the old Lake Ontario maximum water level of 75.23 MASL would give a freeboard of 0.77 m. However the new IJC Plan 2014 has a Lake Ontario maximum water level of 75.73 MASL (allowable in May), therefore if the COH wishes to maintain the same freeboard of 0.77 m then they would need to update the By-Law to allow a higher minimum ground floor elevation (76.50 MASL).

In addition to updating this section of the By-Law, regulations regarding lot level remediation measures (as discussed in the section 4.3) could be added to either require or encourage property owners to implement lot level stormwater management practices. For instance, the Region of Peel implemented a “Basement Flooding Remediation Subsidy Program” which helps cover the costs of sump pumps and back water valve installation (Region of Peel, 2010).

The province of British Columbia has provincial guidelines that state that all new construction containing habitable space must be located above the historical 1 in 200 year flood event plus an additional safety margin. This elevation is referred to as the flood construction level (FCL). The FCL is mainly applied to variations in sea level and the potential for sea level rise but a similar concept could be applied to the level of the Great Lakes (The Arlington Group Planning + Architecture Inc., 2013).

The City of Vancouver also regulates building on lands subject to the FCL and specifies construction materials, service equipment installation and allowing for covenants on a property title which acknowledge the risk of flooding (The Arlington Group Planning + Architecture Inc., 2013). This ensures that property owners are aware of the flooding risk and take the responsibility of choosing to build or live in below grade structures on the property.

Another option would be to implement a basement filling program; this would eliminate the need for dewatering and protect the residents from flooding risks.

4.1.2 Community and Committee of Adjustment Education

Educating the Beach Boulevard Community (public and developers) as to why certain By-Laws are in place and about stormwater management practices could benefit the community. Additionally, educating the Committee of Adjustments as to why certain By-Laws are in place could lower the amount of adjustments that are approved that may negatively impact the stormwater system.

4.2 Non-Structural Mitigation Measures

The following are non-structural mitigation measures that were considered when formulating alternative solutions.

4.2.1 Property Acquisition

The COH previously purchased properties in the 1970's with the intention of creating recreational space due to chronic surface ponding concerns. This alternative would be very costly but could minimize impact on residents. HCA recommend temporarily halting the sale of some municipal properties within the community until the proper mitigation measures are implemented. Specific Hamilton-owned properties located in areas where future stormwater infrastructure may be installed, where ponding has historically occurred or where modelling indicates a likelihood of ponding. This hold is recommended until the EA is completed and preferred solutions are confirmed. Sale of other City of Hamilton owned properties in this area must be done by the Real Estate Section in consultation with the Public Works Department and should be in conformity with future Zoning By-law No. 6593 changes recommended under this study.

4.3 Lot Level Mitigation Measures

The risk of ROW ponding is influenced by basement pumping flows and basement pumping rates are dependent on many variables related to building construction, lot development, and service to these lots. Reducing basement pumping rates begins with lot-level control. The following is a list of lot-level techniques that individual homeowners should consider to help reduce the rate of basement pumping. The following list is not an exhaustive, but rather a list of suggestions that are relevant for home owners, business owners and developers in the study area to consider given the nature of basement pumping that were observed in this assessment. Many of the following recommendations require little effort and cost, while others that are highly effective may require more resources.

4.3.1 Improve Lot Grading

Improving lot grading by reducing minimum lot grades from 2% to 0.5% away from the building foundation can decrease the amount of surface runoff, an example of this can be seen in Figure 4. Such a change would require revising the municipality's development standards related to lot grading and private drainage systems. This may be difficult to achieve, especially in existing homes that are already level with or below the adjacent street. Active drainage systems (i.e. trench drains) can help where natural overland drainage is not possible, however this can be costly. In addition to lot re-grading the ground elevation of the property could be raised to ensure that the house sits above the flood elevation. Similarly to lot regrading, this would be difficult to achieve, with existing development.

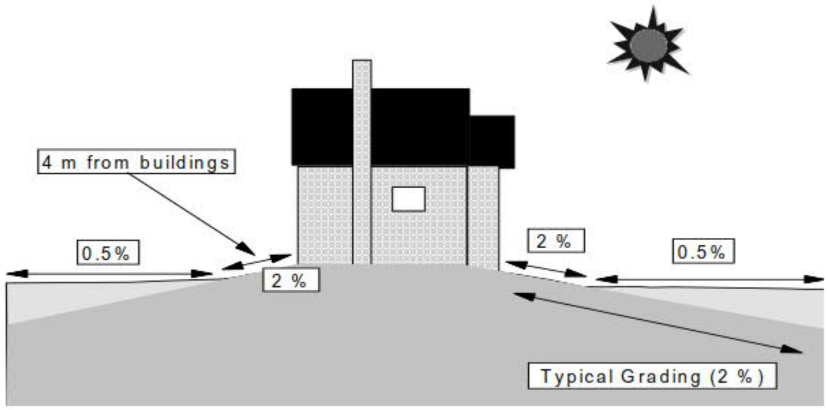

Figure 4: Lot Grading Recommendations (Ontario Ministry of the Environment, 2003)

4.3.2 Installation of Foundations Drains and Sump Pumps

If homes do not have a foundation drain installed, there is an increased risk of basement flooding from foundation infiltration. This can be significantly reduced by installing weeping tiles around the building's foundation and directing water to a free-draining outlet or to a municipal storm sewer. Alternatively, a sump pump may be installed to actively pump water collected by the weeping tile. A basement sump pump can directly discharge to the storm sewer system, but it prohibited from discharging to the sanitary sewer system (as per COH By-Laws 10-118 and 14-090).

4.3.3 Increased Vegetation

Planting new trees and other vegetation along streets can reduce stormwater runoff and peak flows. Additionally, canopies can provide cover of impermeable surfaces and divert water onto lawns or other stormwater features.

4.3.4 Installation of Rear Lawn Ponding

Creating a ponding area in the rear yard or along the lot line can detain water and decrease the peak runoff rates. This may be difficult to achieve, especially because it would require regrading of lots and portions of private property to be flooded during peak flow events. A typical layout for this mitigation measure can be seen in Figure 5.

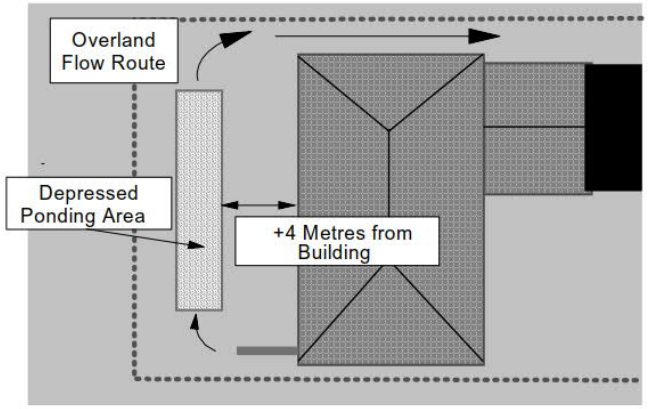

Figure 5: Rear Lot Ponding (Ontario Ministry of the Environment, 2003)

4.3.5 Installation of Soak Away Pits

Soak away pits infiltrate water through below grade infiltration trenches and can decrease the volume of water directed into the storm system. Roof leaders and sump pumps can be directed to these pits instead of into the storm water system which can be seen in Figure 6. Soak away pits do not perform well in areas with high water tables because the bottom of the soak away pit ideally needs to be 1 m above the seasonal high water table. Additionally, this may be difficult to achieve because it would involve excavation and installation of soak away pits on private property.

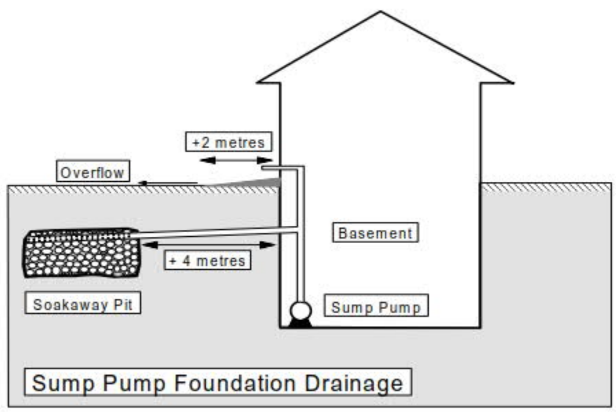

Figure 6: Soak away Pits (Ontario Ministry of the Environment, 2003)

4.3.6 Installation of Stormwater Harvesting

Stormwater harvesting is the collection and utilization of runoff which can drastically reduce the amount of runoff produced by a property. Typically, roof runoff is collected and stored onsite; it can then be used for irrigation of lawns or gardens or as part of a grey water system. Incentives can put in place to encourage home owner to implement this type of technology.

4.4 Stormwater System Mitigation Measures

The following are stormwater system mitigation measures that could improve the functionality of the Beach Boulevard Community stormwater system. Most mitigation measures on this list can be implemented as standalone solutions or could be implemented together as a combined alternative.

4.4.1 Increase Inlet Capacity

Increasing inlet capacities could allow more runoff to enter the storm sewer system. This could help prevent ponding on the ROW due to blocked inlets. However, if the system does not have capacity to convey the increase in inflow then this alternative will have limited impact on the system. Increasing inlet capacity should only be implemented if the storm sewer pipe sizes are upgraded as well.

4.4.2 Increase Pipe Size

Increasing the pipe sizes could increase the capacity of the current systems. This method could be used in conjunction with other recommended stormwater management practices. In addition to increasing the pipe sizes, the slope of the pipes could also be altered to achieve a similar result. However, with high groundwater levels construction of new pipe systems can be very costly, therefore this method would be relatively costly and would disturb the municipal roads in the area.

4.4.3 Pervious Pipe System

Pervious pipe systems are used in place of, or in conjunction with traditional storm sewer system. The use of perforated sewer allows exfiltration of water through the pipe wall and into the surrounding soil. Pervious pipe systems are not recommended in areas with high water tables and therefore it would be difficult or impossible to implement this type of stormwater management technology in the Beach Boulevard Community.

4.4.4 Installation of System Storage

System storage can decrease the peak flow volumes by retaining runoff and releasing it slowly over time. System storage can be as simple as oversized pipes or underground storage tanks depending on the detention volumes and implementation locations. Oversized pipes could be implemented throughout the system by installing one size up at all locations or by installing a section of very large pipes towards the end of the system. Since system storage is a flexible alternative it would be feasible to implement in the Beach Boulevard Community. However, space limitations need to be considered when selecting a location. The COH currently owns several properties in the study area that could be used as system storage. Additionally, pumps may be required to move water to and from the proposed storage locations.

4.4.5 Construction of Storm Ponds

Both dry and wet stormwater ponds can act as a form of surface water storage and can provide regulation of peak flows. However, stormwater ponds require large areas of land and perform better in areas with low water tables. Therefore, the implementation of stormwater ponds could be complicated for this study area. However, the COH owns some properties at the ends of the following streets: Renfrew, Rembe, Windermere, Knapmans, Wickham, Grafton, Comet, Granville, Clare, Lagoon, and

Arden. In combination with strategic property acquisition of non-COH owned properties could be used as several smaller stormwater management facilities.

4.4.6 Construction of Pumping Stations

Pumping stations allow gravity systems to move up gradient by putting additional energy into the stormwater system. There is one pumping station located on Grafton Avenue that conveys the runoff under the QEW. Pumping stations overcome issues associated with gravity flow limits such as the restricted capacity of pipe outlets.

4.4.7 Increase Outlet Capacity

Increasing the outlet capacity of substandard outlets could allow more stormwater to exit the system. This could involve relocating the outlet to another location, expanding the size of the current outlets or creating additional outlet locations. In addition to updating infrastructure, proper documentation would need to be created concerning maintenance of the outlet structures.

4.4.8 Operation and Maintenance

Several of the existing inlets and ditches require regular maintenance by the COH and/or MTO. Ensuring that the system is properly maintained can increase the performance and lifetime of the system. It is advised that an operation and maintenance agreement between the COH and MTO is created in addition to a list of assets.

4.5 Lake Overtopping Mitigation Measures

The following lake level mitigation measures address the concern of high Lake Ontario levels from overtopping the localized high point and negatively impacting the Beach Boulevard Community. This has never been reported but with higher allowable lake levels under Plan 2014 the COH may want to consider the risk of barrier overtopping. Additional approval from the Hamilton Conservation Authority (HCA) would be required for any of the following mitigation measures.

4.5.1 Barrier Grading / Dike Construction

Currently, the study area is protected by an elevated bike path that runs along the lake side of the Beach Boulevard Community. It could be possible to increase the elevation of this bike path to provide sufficient protection from potential wave action. This would require coordination with various COH departments and utilities located within this corridor. Significant elevation increases of the path would be limited by the existing structures adjacent to the path. Due to reduced wave action and the size of open water on the harbour side of the study area, there is not expected to be a benefit to constructing a barrier or dike on the harbour side.

4.5.2 Construction of Seawalls

Seawalls are large vertical structures that block wave action from hitting land. They are typically steel sheet piles or ridged poured concrete. Once installed, seawalls require relatively low operation and maintenance, however they do have a relatively high initial capital cost. A typical schematic of this mitigation measure can be seen in Figure 7.

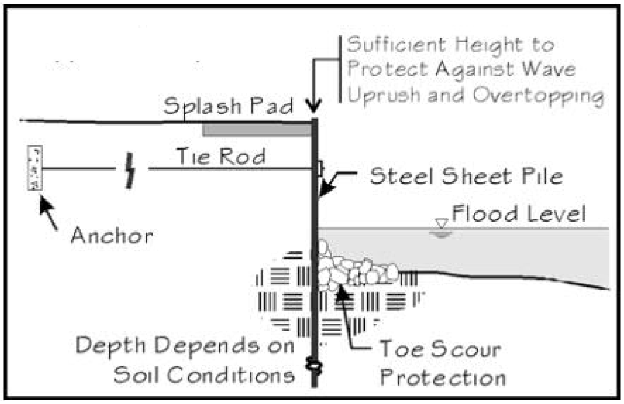

Figure 7: Seawalls (Manitoba Conservation, 2001)

4.5.3 Construction of Breakwater Structures

Breakwaters are offshore structures that absorb the energy of waves that hit them. They are typically located 100 m to 600 m offshore and are typically made of large rocks or concrete. These structures may reduce to level of wave uprush.

4.6 Groundwater Control Mitigation Measures

The following mitigation measures address the groundwater driven basement flooding which in turn contributes to the stormwater system ponding.

4.6.1 Sump Pump Dewatering

The installation of sump pumps would protect property owners from basement flooding but would require major upgrades to COH infrastructure due to increased flows. The COH would also need to supply private connections to the storm sewer system that the residents could outlet their sump pumps to. Additionally, there is currently no way to regulate the amount of dewatering each property owner is undertaking. Additional investigations should be completed to provide more accurate estimations of the dewatering volumes prior to completing the design of new infrastructure.

4.6.2 COH Driven Dewatering

COH driven dewatering would require the COH to install pumping wells throughout the Beach Boulevard Community to lower the groundwater table of the area. This would allow the COH to regulate the volumes of water removed and where the discharge is directed. Additionally, wells would be located strategically to maximize the efficiency of the process but would have high annual maintenance and operational costs. However, this would put a large strain on the current infrastructure and would require additional work to manage the groundwater pumping discharge.

4.6.3 Installation of Groundwater Barrier

Groundwater barriers could be installed around the perimeter of the study area. They would act as a barrier between Lake Ontario and the groundwater system. This would allow better control of the groundwater system by hindering the recharge of groundwater from the lake. However, the barrier would need to be installed down to bedrock and therefore is only cost effective in areas with shallow depths to bedrock which is not the case in the Beach Boulevard Community.

4.7 Screening of Mitigation Measures

TABLE 6: Screening of Mitigation Measures

Control Type	Control Measure	Responsibility	Advantage	Disadvantage	Relative Cost	Relative Impact	Relative Time of Implementation	Comment	Recommended for Further Investigation
Legislative Mitigation Measures	By-Law Updates	COH	Could prevent further basements from being installed and increasing potential dewatering.	Difficult to enforce and monitor effectiveness of changes.	Low	Moderate	Short Term	Would prevent further increase in dewatering. Does not reduce current dewatering.	Recommended
	Community and Committee of Adjustments Education	COH	Would increase the awareness and causes of basement flooding in area. Potentially decrease the number of approved basement being constructed.	None.	Low	Low	Short Term	Could prevent further problems from developing. Does not fix current problems. Should educate Committee of Adjustments in addition to Residents.	Recommended
Non-Structural Mitigation Measures	Property Acquisition	COH	No new infrastructure required. Would reduce the amount of water being pumped into sewer system through private connections and reduce run-off.	Costly option that would displace a community from their homes. Low public acceptance.	High	High	Long Term / Ongoing	Could buy all properties or select properties in study area.	Recommended
Lot Level Mitigation Measures	Improve Lot Grading	COH/Home Owner	Reduce local ponding, high inflow/infiltration into foundation drain and peak flow rates.	Requires co-operation of home owners. Potential for long term ponding on private property, an increase of overland flow.	Low to Moderate	Low	Short Term / Ongoing	Recommended implementation where possible and for all new development.	Recommended Where Possible
	Installation of Foundation Drains and Sump Pumps	Home Owner	Decrease the amount of flooding experienced by home owners with floors located below the water table.	Requires installation in basement and regular inspection to ensure proper operation. Requires emergency energy backup supply to be installed. Could put a strain on the stormwater system if discharge is not managed properly. Requires co-operation of home owners.	Low to Moderate	Low	Short Term / Ongoing	Could improve localized problems but would not be a standalone solution.	Recommended Where Possible
	Increased Vegetation	Home Owner	Reduction of stormwater runoff volume and peak flow.	Requires maintenance year round. Requires co-operation of home owners. Negligible impact.	Low to Moderate	Low	Short Term / Ongoing	Could improve localized problems but would not be a standalone solution.	Recommended Where Possible
Lot Level Mitigation Measures	Installation of Rear Lawn Ponding	Home Owner	Reduces local ponding, high inflow/infiltration into foundation drain and system peak flow rates.	Requires co-operation of home owners. Potential for long term ponding on private property, an increase of overland flow.	Low to Moderate	Moderate	Short Term / Ongoing	Would not be effective due to high water table.	Not Recommended
	Installation of Soak Away Pits	Home Owner	Effective at lowering the volume of storm water entering the sewer system from roof leaders and/or sump pumps.	Requires operation and maintenance year round. Requires co-operation of home owners.	Low to Moderate	Low	Short Term / Ongoing	Would not be effective due to high water table.	Not Recommended

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Control Type	Control Measure	Responsibility	Advantage	Disadvantage	Relative Cost	Relative Impact	Relative Time of Implementation	Comment	Recommended for Further Investigation
	Installation of Stormwater Harvesting	Home Owner	Retains stormwater for later use by the property owner. Would decrease the peak runoff flows into the storm system.	Requires co-operation of home owners. Depending on storage type could increase the potential for mosquitos.	Low to Moderate	Low	Short Term / Ongoing	Could improve localized problems but would not be a standalone solution.	Recommended Where Possible
Stormwater System Mitigation Measures Stormwater System Mitigation Measures	Increase Inlet Capacity	COH	Effective at conveying runoff into the stormwater system.	Can cause surcharging in the system if not properly implemented. High capital costs of associated pipe improvements.	Moderate	Moderate	Short Term	If the capacity of the system increases, this could be applied.	Recommended
	Increase Pipe Size	COH	Effective at preventing surcharges in the system and increasing the overall capacity of the system.	High capital costs and construction requirements. Long implementation time frame.	Moderate	Moderate	Long Term	Would increase the capacity of the current system.	Recommended
	Pervious Pipe System	COH	Aid in mitigating pipe surcharging by infiltrating excess storm water.	Requires water table to be well below pipe depth. High capital cost and high operation and maintenance cost.	Moderate	Low	Long Term	Would not be effective due to high water table.	Not Recommended
	Installation of System Storage	COH	Reduces/regulates peak flow rates by providing storage in the system.	High material costs and requires space to store runoff either above or below ground.	Moderate	High	Long Term	Recommended for retention of runoff during peak flow events.	Recommended
	Installation of Storm Pond	COH	Decreases peak flow rates and improves quality of storm water.	Not effective in areas with high water tables. Requires large surface area and can create habitats for mosquitos.	Moderate	High	Long Term	Would not be effective due to high water table.	Recommended
	Pumping Station	COH	Increase the total energy in the system and allow for transport of flow up gradient.	High capital and operational cost	High	High	Long Term	Could be effective at increasing the system capacity.	Recommended
	Increase Outlet Capacity	COH/MTO	Increase the outlet capacity of the system.	Is not be a standalone solution, would need to be implemented with other remedial measures.	Moderate	Moderate	Short Term / Long Term	Could be effective at increasing the system capacity.	Recommended
	Operation and Maintenance	COH/MTO	Increases the capacity and lifespan of the system.	None.	Low	High	Short Term	Recommended for all components of storm system.	Recommended
Lake Overtopping Mitigation Measures	Barrier Grading / Dike Construction	COH	Could provide protection for the Beach Boulevard Community.	May require the closure of a public recreational path.	Medium	Low	Long Term	Not recommended as part of the current study. However, if future studies regarding lake overtopping is a concern, then this should be revisited as an alternative. Further consultation with regulatory bodies and stakeholders would be required as part of any required works.	Not Recommended
	Installation of Seawalls	COH	New construction required.	High capital cost.	Medium to High	Low	Long Term	Not recommended due to high capital cost.	Not Recommended

Control Type	Control Measure	Responsibility	Advantage	Disadvantage	Relative Cost	Relative Impact	Relative Time of Implementation	Comment	Recommended for Further Investigation
	Installation of Breakwater Structures	COH	Breaks up waves before they reach shore.	High capital cost and could cause negative impacts to the aquatic environment.	Medium to High	Low	Long Term	Not recommended as part of the current study. However, if future studies regarding Lake overtopping is a concern, then this should be revisited as an alternative. Further consultation with regulatory bodies and stakeholders would be required as part of any required works.	Not Recommended
Groundwater Control Mitigation Measures	Sump Pump Dewatering	Home Owner	Provides relief for property owners based on an as need basis. Low capital cost for the COH.	Can put strain on the storm system depending on how discharge is managed. Puts cost on home owners.	Low to Moderate	Moderate	Ongoing	Recommended for property owners to continue to pump water as needed however this cannot be discharged onto sidewalks, roadways, adjacent properties or sanitary sewers (as per COH By-Laws 10-118 and 14-090). COH should consider providing private connections to storm sewers to avoid overland discharge.	Recommended
	COH Driven Dewatering	COH	Provides protection for homeowners from groundwater driven ponding. Allows the COH to control and regulate pumping rates and water discharge.	Creates responsibility and ongoing costs for the COH. Creates problems with water disposal and environmental permits to take water.	Moderate to High	Moderate	Ongoing	Would put liability on the COH and therefore would not be recommended.	Not Recommended
	Installation of a Groundwater Barrier	COH	Effective at eliminating the connection between the lake level and groundwater level.	High capital cost. Would require maintenance and observation for proper functionality.	High	Moderate	Long Term	Not recommended due to deep bedrock depths.	Not Recommended

4.8 Recommended For Further Investigation

The following sections describe the recommended mitigation measure and how they can be applied to the Beach Boulevard Community.

4.8.1 Legislative Mitigation Measures

It is recommended that the following legislative mitigation measures are considered in the alternative generation process:

- By-Law Updates, and
- Community Education.

It is recommended that that COH consider updating the By-Law to address the ponding issues on the Lake side of the Beach Boulevard Community. Educating the Committee of Adjustments and the general public as to why belowground floors, basements and crawl spaces are prohibited could prevent additional problems occurring in the future. The COH could also consider changing the language in the By-Laws to prevent the approval of basement structures and crawl spaces unless the property owner can prove it will have no negative impact drainage pathways, the water system or neighbouring properties. The property owner should also take full responsibility if such impacts occur. This would also need to be added to property titles to ensure the owners were aware of their responsibilities when purchasing a property. Another alternative would be to ban all forms of below ground floors and start a “basement filling” program to address existing basements. Lastly, the COH should consider updating the minimum allowable ground floor elevation to 76.5 MASL (from 76 MASL) to account for the increase in allowable lake level by the IJC under Plan 2014.

Neither of these mitigation measures will solve the current ponding on the ROW problems and therefore will not be considered in the generation of alternatives. Therefore, these mitigation measures should be considered in addition to the recommended alternatives.

4.8.2 Non-Structural Mitigation Measures

It is recommended that the following non-structural mitigation measure be considered in the alternative generation process:

- Property Acquisition

Strategic property acquisition is recommended because it will eliminate the some problem areas (if properties are within areas of concern). In addition, select properties could be acquired by the COH to create stormwater management facilities as needed. This mitigation measure will be considered in Alternative 1 and Alternative 2. COH should place a hold on that future sales of all COH owned properties along the side streets in the Beach Boulevard community (from the MTO chain-link fence to Beach Boulevard) until the recommendations of this study have been further investigated for design/construction feasibility and the desired mitigation measures are approved by Council. . The COH will need to define service levels for the Beach Boulevard Community and will need to comply with all

Federal/Provincial legislation related to the recommendation chosen to implement (e.g., Ministry of the Environment, Conservation and Parks (MECP, formerly MOECC) approval, MTO approval, EA).

4.8.3 Lot Level Mitigation Measures

It is recommended that the following lot level mitigation measures are considered in the alternative generation process:

- Improve lot grading;
- Install foundation drains and sump pumps;
- Increase vegetation, and
- Stormwater Harvesting.

All the above mentioned lot level mitigation measures could be effective at reducing peak runoff in the Beach Boulevard Community but because they require co-operation and maintenance from the property owners they were not considered in the generation of alternatives. However, the COH should set up incentive programs to encourage the installation of these stormwater management practices in new and old developments.

4.8.4 Stormwater System Mitigation Measures

It is recommended that the following stormwater system mitigation measures are considered in the alternative generation process:

- Increase inlet capacity;
- Increase pipe size;
- System storage;
- Pumping stations;
- Increase outlet capacity, and
- Operation and Maintenance.

These recommended mitigation measures help remove the water from the study area by altering the capacity of the current stormwater system. Different combinations of these mitigation measures will be evaluated in Alternative 3, Section 5.5.

4.8.5 Lake Overtopping Mitigation Measures

No lake overtopping mitigation measures were recommended in this report because there are no reported incidents of this happening. However with a higher allowable lake level the risk of a storm event that could overtop the current barrier are higher. It is recommended that an additional study is completed by the COH to assess the associated risks of such an event occurring.

4.8.6 Groundwater Control Mitigation Measures

It is recommended that the following groundwater control mitigation measure be considered in the alternative generation process:

- Privately operated sump pump dewatering.

It will be assumed for all alternative generation that residents will continue to pump their basements dry when lake water levels are high. This amount of water will be considered when designing and evaluating alternatives in combination with the design storms. However, as per COH By-Laws 14-090 and 10-118, residents must not discharge pumped water onto sidewalks, ROW, adjacent properties or into sanitary sewers.

5.0 Stormwater System Alternative Solutions

The following are alternatives solutions that have been generated based on the analyzed mitigation measures. They may be implemented as standalone solutions or in conjunction with another alternative. These alternatives effectively mitigate ponding on the ROW under minor (5 year) and major (100 year) storm events in addition to residential pumping and fluctuating lake levels. The alternatives costs and feasibility was estimated based on the available information.

5.1 Assumptions

To determine which potential options are to be recommended for implementation or further study, a number of assumptions had to be agreed to by the study team. These assumptions include input parameters, service levels and overall approach methods.

For the purpose of designing minor flow systems, the 5 year return frequency storm will be used. The minor storm will be managed primarily using storm sewers. The major storm, 100 year return frequency, will be managed using a combination of storm sewers and overland flow.

Each storm water system within the study area eventually discharges to a large ditch across the QEW which runs along Eastport Drive. For the purpose of this study, it is assumed that this ditch has sufficient capacity and depth. During detailed design, the capacity of this ditch should be verified. To assess potential capacity of the outlets beneath the QEW, each outlet will be assumed to have a 0.25% slope, a minimum cover of 0.6m and no water input from the QEW. The elevation of the low spots of the perpendicular streets to Beach Boulevard range from 75.66 MASL to 77.18 MASL.

It is assumed that residents will continue to use dewatering techniques to keep their basements dry using their own private infrastructure. Residents currently discharge this water onto the roads and sidewalks within the Beach Boulevard Community. Provisions should be provided to allow for residents to discharge this water into the storm sewer system without resorting to overland flow. This could be accomplished using direct connections to storm sewers or via catchbasins on private property. Catchbasins located on private property should remain the responsibility of the homeowners. The storm sewer system may have to be extended to provide connections to residents. Residents shall continue to be responsible for their own pumping infrastructure (sump pumps).

The assumed lake elevation will have a great impact on the assessment of options and recommendations. This elevation will impact the capacity of the outfalls beneath the QEW to the Eastport ditch, and the amount of water that will be discharge from homeowner dewatering to the storm sewer system. Under high water level scenarios, the capacity of the outlets to drain via gravity can be reduced to zero. Additionally, the flows from dewatering increase exponentially the higher the lake level rises.

For this study, a Lake Ontario level of 75.88 MASL, representing the highest Lake Ontario level of record and the highest minimum allowable Lake Ontario level (under Plan 2014) of 74.56 MASL was used for modeling and recommendations, as high and low levels respectively

5.2 Operation and Maintenance

Currently the ditch system between the end of streets and the noise wall is in poor condition due to lack of maintenance. The MTO requested that the COH confirm ownership of properties in this ditched area between the MTO Fence and the MTO noise barrier wall. The COH has confirmed ownership and the majority of ditch is owed by the MTO. There are pockets of properties owned by the COH which cannot be accessed by COH staff without entering property owned by the MTO. It is recommended that the pockets of COH owned land which are landlocked between MTO properties, and are inaccessible, are transferred to the MTO to facilitate MTO operation and maintenance of this area. Figures 1-1 to 1-7 illustrate current property ownership and further detail can be found in Appendix M.

It is recommended that the MTO install access gates on the MTO owned chain-link fence to facilitate maintenance work in the area between the MTO chain-link fence and the MTO noise barrier wall. It is recommended that the COH and MTO work together to develop and maintain a Maintenance Agreement for this area. This agreement should address day to day maintenance and emergency situations to expedite response.

Proper operation and maintenance will not be a standalone solution to the ponding problems but can have an immediate impact on ponding within the ROW. Regardless of what alternative is selected these ditches should be maintained to allow proper drainage of the side streets. This consists of clearing the over grown vegetation and regrading ditches to ensure proper drainage to ditch inlets. Residential pumping of basements should temporarily be directed to these areas to address health and safety concerns.

5.3 Sump Pump Connections

Residents are currently utilizing sump pumps to dewater below ground floors (including both crawl spaces and basements). The groundwater is currently being discharged onto the ROW which is causing several health and safety problems related to algae and ice (primarily slipping hazards). It is recommended that the COH put in direct or private connections that would allow residents to outlet their pumps into the storm system or offline storage systems. Proper backwater valves will need to be installed to protect residents from the potential risk of system surcharging. One option for private connections are called “birdcage catchbasin” (OPSD 400.120) the cost of these systems can range from $5,000 to 7,500 per location.

5.4 Stormwater System Alternative 1 – Purchase Residential Land

Stormwater System Alternative 1 consists of the COH purchasing all or some the properties in the Beach Boulevard Community which would require the residents to be relocated. The COH could turn the land into recreational space or use it as non-residential land. Property acquisition can occur in three different capacities, buying all the properties, buying a portion of the properties or buying properties as they are being sold.

5.5 Stormwater System Alternative 2 – Stormwater Management Facility

Stormwater System Alternative 2 consists of the COH purchasing properties (if required) at the end of the side streets and converting them into several central stormwater management facilities. These facilities could consist of storage features, swales or ditched channels. This alternative could store major flows and dewatering from residential occupants and release it back into the system or to an outlet after the peak event. The intention of this alternative is to decrease peak flow rates during major storm events. This alternative could be implemented with other recommended solutions that would handle the minor flow rates.

This system could be designed to handle up to the 100 year event in conjunction with the storm sewer system or could be designed to handle the residential pumping and overland flows during high lake levels when the functionality of the outlets are compromised.

The COH currently owns several properties along the ends of the following side streets: Renfrew, Rembe, Windermere, Knapmans, Wickham, Grafton, Comet, Granville, Clare, Lagoon, and Arden. With some strategic property acquisition this alternative could be implemented with limited impacts to residents. A summary of properties the COH currently owns can be seen in Figures 1-1 to 1-7, Dillon has advised the COH to put a hold of all properties on the harbour side of Beach Boulevard until a decision is made regarding the storm water management plans.

The volume of storage required was calculated based on the following assumptions for each catchment in additional to the assumptions made in the rational method flow calculations described previously:

- The storm system can convey the 5 year storm with no lake level influence.
- The required storage service level is the 100 year storm with a lake level of 76 MASL and no basement pumping inflow.
- Minimum initial time of concentration is equal to 10 minutes.

Copies of the storage volume calculations can be seen in Appendix F. The following assumptions were made to estimate requires storage area for each catchment:

- The maximum allowable height of water corresponds to the lowest land elevation in the vicinity of the proposed ponding area. This will ensure no ponding will occur on the ROW.
- A freeboard of 0.2 m is required.
- A graded slope of 5:1.

The relative dimensions of storage can be found in Appendix F.

5.6 Stormwater System Alternative 3 – Upgrade Stormwater System

The following three alternatives involve upgrading the current storm system to convey the major storm flows or the minor storm flows in conjunction with other alternatives. Basement pumping rates and varying lake levels will be considered in designing for all alternatives. Direct connection for sump pumps should also be considered as part of the upgrades for the following alternatives.

5.6.1 Stormwater System Alterative 3A – Gravity System

Stormwater System Alternative 3A would consist of upgrading the storm pipe system to convey all major and/or minor flows through a gravity sewer system. This would require large pipe size upgrades that could convey storm flows to an outlet point where it will be stored or released. The Beach Boulevard Community is very flat and therefore could require deep excavation to achieve the required grade of the storm pipes. With increasing lake levels the elevation of the outlets becomes a concern that could limit the conveyance of the system. If the Eastport ditch is selected as an outlet location check valves could be installed to ensure lake level flooding of the ditch would not backflow into the system.

The main constraint associated with this alternative is the low elevation gradient of the study area. Gravity systems require sufficient slopes to ensure proper drainage; the Beach Boulevard's current grade is not large enough to implement gravity sewers without a large amount of excavation which is then influenced by the high groundwater table. All of this increases the potential cost of gravity storm sewer installations.

The existing conditions model was used to determine the necessary pipe size upgrades for the various potential service levels. The following assumptions were made relating to pipe sizing in additional to the assumptions made in the rational method flow calculations described above:

- All pipes will be replaced regardless of size upgrades,
- Standard pipe sizes were used ,
- Pipes were designed to flow at 95%, and
- Dewatering flows were added to storm flows relative to Lake Ontario levels.

In addition, the cost of materials associated with each level of service was calculated. Different scaling factors were used to estimate the installation costs. The following assumptions were used in determining the relative costs of each service level:

- All manholes would be replaced and no additional manholes would be installed,
- No inlet or outlet structures would be replaced (included in road work in required),
- No major dewatering would be required, and
- Costs are exclusive of taxes and other potential fees.

The detailed cost breakdown for each catchment area can be seen in Appendix G and a comparison of the total cost for different storm return frequencies can be seen in Figure 8.

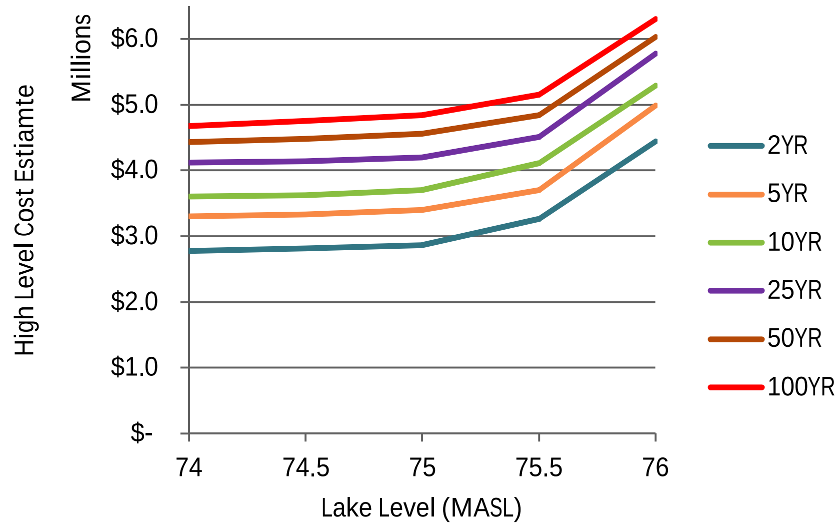

Figure 8: Relative Cost of Upgrading the Stormwater System

5.6.2 Alternative 3B – Pumping Stations

Alternative 3B would consist of upgrading the storm pipe system to convey major and/or minor flows to a few larger pumping stations which would move water to a storage or outfall location. There is currently one pumping station located on Grafton Avenue that connects to the gravity storm system. This pumping system currently has a capacity of 3,468 L/s and cost $6.5 million CAD to construct. The installation of new pumping systems could use the current gravity infrastructure and could pump water from a holding ditch to an outlet up gradient. This outlet would be at a higher elevation and therefore may be protected from rising lake levels. The outlet location could be the Hamilton Harbour, the Eastport Ditch, Lake Ontario or a new storm water management facility. The current gravity system would require upgrades or modifications to move water to a few centralized pumping locations.

It is estimated the Beach Boulevard Community would require at least two additional pumping stations to service the current systems (one to the east and west of the current Grafton pumping station). Based on the capital cost of the Grafton pumping station this could cost $13 million CAD.

5.6.3 Alternative 3C – Individual Street Pumping with Larger Header

Alternative 3C would consist of upgrading the storm pipe system to convey major and/or minor flows to the end of each small street where it would be pumped to an outfall or larger collection system. All side streets would drain overland to a localized low point at the end of the right away. From here smaller pumps would send the water to a larger stormwater storage facility or connection system located up gradient (most likely along Beach Boulevard). From here the system would carry the stormwater to an outlet located either across the QEW on the harbour side of the Beach Boulevard Community or directly to Lake Ontario (providing proper permits could be obtained).

This would allow several small systems to operate independently of each other but would require upgrades and/or modifications of the current gravity storm sewer system. However, since this alternative allows all the storm systems to be independent of each other it could be implemented over time or on an as needed basis. Lastly, this would allow the connection of larger pumping systems to be connected if needed during larger ponding incidents.

5.7 Alternative 4 – Do Nothing

Doing nothing may continue to cost the COH operational costs of pumping the Beach Boulevard Community storm system (10,000 CAD per day) and upkeep of the current stormwater ditch system. Additionally, health and safety concerns would continue to occur due to residential pumping of basements. Doing nothing would also increase the potential risk to the COH due to water related issues such as but not limited to flooding, premature wear of infrastructure, increase maintenance, increased insurance costs, and additional staff time to address the associated issues.

5.8 Gravity System Information - 2018

With the assumptions stated in section 5.1 the feasibility of several gravity outlet into the Eastport ditch were analyzed for each system (with the exception of Grafton due to the already constructed pumping station). Only two of the seven catchments could freely drain with a lake level of 74.88 MASL under the physical constraints. Both systems require an outlet pipe diameter of 300 mm, this would not have capacity to drain the two subsystems with the assumed service level. Table 7 shows the lake level and outlet pipe size required to drain the 5-Year system with the assumed basement pumping level with free flowing pipes, full details can be seen in Appendix I.

TABLE 7: Free Flowing Outlet Summary

Catchment	Flow L/s	D mm	Ground MASL	Length m	Lake Level m
Eastport	223	600	76.00	106.4	74.44
Hamilton Harbour	521	750	76.00	152.3	74.16
Dunraven	604	825	75.90	109.0	74.09
Lagoon	799	900	75.99	95.6	74.13
Townhouse	557	750	76.00	103.0	74.28
Bayside	1232	1050	75.88	80.0	73.90
Fletcher	682	825	76.00	167.5	74.04

However, if the COH wishes to have flow through submerged pipe outlets the systems can convey the design flow with a lake level of 74.88 MASL with outlet pipe diameters summarized in Table 8, full details can be seen in Appendix I.

TABLE 8: Submerged Outlet Summary

Catchment	$Q_{required}$ L/s	D mm	Ground MASL	Length m	Obvert MASL	ΔH m	Q_{actual} L/s
Eastport	223	300	76.00	106.4	74.76	1.15	378
Hamilton Harbour	521	375	76.00	152.3	74.57	1.15	574
Dunraven	565	375	75.90	109.0	74.58	1.05	635
Lagoon	751	450	75.99	95.6	74.64	1.14	1111
Townhouse	528	375	76.00	103.0	74.69	1.15	680
Bayside	1154	450	75.88	80.0	74.57	1.03	1132
Fletcher	638	450	76.00	167.5	74.47	1.15	883

5.9 Agency Liaison

The following sections summarize comments received from Agency Liaisons.

5.9.1 Hamilton Conservation Authority (HCA)

The HCA was provided a draft copy of the Stormwater Ponding Study Report. On March 26, 2018, the HCA provided formal comments on the report to the COH. The comments were incorporated into the draft Stormwater Ponding Study Report. In general, the HCA was supportive of the recommendations noted in Section 4, with the exception of the Lake Overtopping Mitigation measures. HCA has stated they do not support these methods because the Beach Boulevard Community is located in a dynamic beach system. In addition, HCA believes that the COH should put emphasis on not selling any additional municipal properties in the Beach Boulevard Community in order to not aggravate the existing problem and to enable the provision of additional stormwater retention or Low Impact Development (LID) measures.

Future projects in the area may be subject to HCA approval. COH project teams will need to include HCA in preliminary discussions to ensure HCA legal approvals are obtained prior to work commencing.

5.9.2 Hamilton Ports Authority (HPA)

HPA was contacted to determine the location and condition of outlets. HPA will need to be involved in future assessment as HPA activities may encumber the future capacity of the outlets Future HPA activities may encumber the capacity of outlets due to continued filling and development. The location and conditions of outlets on HPA properties are not well known or understood at this time. HPA's property drains towards the Hamilton Harbour. To their knowledge there is no stormwater conveyance from HPA's properties under the QEW or Eastport Drive. In addition, HPA is not aware of any stormwater conveyance from the Beach Boulevard Community properties onto HPA's property. Figures provided by HPA are located in Appendix J.

5.9.3 Ministry of Transportation Ontario (MTO)

MTO and COH staff conducted a site visit on September 18, 2017 to discuss asset ownership and maintenance responsibilities of the ditch between the MTO noise barrier wall and the MTO chain-link fence. During the site visit, MTO staff noted that they owned property in the vicinity of Fletcher Avenue. MTO requested that the COH provides property ownership information prior to any further discussion regarding asset ownership and maintenance.

In July 2018, the MTO contacted COH staff to address flooding/maintenance concerns of the ditch behind 170 Beach Boulevard. It was confirmed that the ditch is not owned by the COH and that the COH is not able to maintain the area on behalf of the MTO.

The COH did locate a section of ditch that they owned behind 144 Beach Boulevard which was located between two MTO owned portions of land. The COH transferred this section of ditch to the MTO which will allow unhindered maintenance of the ditch.

The COH Geomatics and Corridor Management staff conducted a further assessment of COH/MTO ownership between Fletcher Avenue and Dunraven Avenue to confirm if there were any COH owned sections of ditch. There were portions of COH owned land located between MTO land. It is recommended that these parcels of land, which are not easily accessible for maintenance, be transferred to the MTO in a similar fashion to 144 Beach Boulevard.

A future discussion is recommended between the COH and MTO to develop a Maintenance Agreement.

Future projects in the area will be subject to MTO approval. COH project teams working in the area will be required to communicate with the MTO Corridor Management representative to ensure any MTO legal approvals are obtained. Cost sharing between the MTO and COH for proposed infrastructure updates (similar to the Grafton Pumping Station) is an option that should be explored for any municipal works in the Beach Boulevard Community.

A conference call occurred on January 23rd, 2019 between the MTO, COH and Dillon to review the report and recommendations. A revised report was issued to the MTO on February 13th, 2019 for review and comment. As of the date of issue of this report, comments have not been received from the MTO for inclusion in the report.

5.9.4 Environment Canada (EC)

EC was provided a draft copy of the Stormwater Ponding Study Report. On October 15, 2018, EC provided formal comments on the report to the COH. The comments were incorporated into the draft Stormwater Ponding Study Report.

EC was provided a second copy of the Final Stormwater Ponding Study Report. On March 14, 2019, EC forwarded a copy of a report created by the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee entitled *Summary of 2017 Great Lake Basin Conditions and Water Level Impacts to Support Ongoing Regulation Plan Evaluation* (Appendix N). This report concluded the 2017 outcomes under Plan 2014 would have been comparable to the outcomes that would have occurred under Plan

1958D. Additionally, Plan 2014 performed as it was intended to in order to reduce (not eliminate) costal damages and flooding.

5.9.5 Canadian Center for Inlands Water (CCIW)

No comments have been received to date

6.0 Additional 2D Hydraulic Modeling

Dillon was requested by the COH to perform a risk assessment as part of an additional study to better define the preferred option to address the ponding within the ROW within the Beach Boulevard Community. This information can also be used by the COH to determine an appropriate level of service and will guide the recommendation of the overall study. A 2D PCSWMM model was chosen to characterize the spatial and temporal extent of the ponding on the ROW. The desired outcome of the model was to delineate the amount of surface ponding that would occur during the various design storm frequencies and chosen lake water levels combinations. In addition, the model will assess ponding duration for each scenario.

6.1 Modeling Methods

The Stormwater Management Model (SWMM) was first developed in 1971 by the USEPA, the current modeling software (SWMM 5) is used throughout the world for planning, analysis, design, management and litigation related to stormwater runoff, combined sewers, sanitary sewers and other drainage systems (James, Rossman, & James, 2010). The following sections describe the components of the PCSWMM model and discuss key assumptions.

6.1.1 Hydrology

Runoff

Subcatchments were discretized based on existing data for the stormwater system provided by the COH, with additional catchments added to define the QEW and adjacent ditches. A total of 57 catchments are present in the model. Surface slopes were assumed to be 0.01% throughout the model, based on topography data provided by the COH. Subcatchment flow lengths were estimated using a measuring tool within PCSWMM to determine a representative flow length for each subcatchment. Flow lengths ranged from 77 to 1,930 m. Percent imperviousness was estimated using 2015 aerial photos obtained from the COH. Percent imperviousness ranged from 35% to 75%. Manning's roughness and depression storage values were assumed to be the same for each subcatchment. The values used in the model are listed in Table 9.

TABLE 9: Manning's roughness and depression storage volumes

Parameter	Value	Reference
Manning's n (Impervious)	0.11	(McCuen, Johnson, & Ragan, 2002)
Manning's n (Pervious)	0.15	(McCuen, Johnson, & Ragan, 2002)
Depression Storage (Impervious)	1.5 mm	(ASCE, 1992)
Depression Storage (Pervious)	3.5 mm	(ASCE, 1992)

Infiltration

The Green-Ampt method was selected to represent infiltration. Through site observations, sand was found to be the predominant soil cover on the subsurface. Infiltration parameters were determined based on Rawls (1983) data for sand, and are presented in Table 10.

TABLE 10: Infiltration Parameter Values (Rawls, ASCE, Brakensiek, & Miller, 1983)

Parameter	Value
Suction head (mm)	49.02
Hydraulic Conductivity (mm/hr)	120.34
Initial deficit (fraction)	0.413

Precipitation

IDF curve data was provided for the nearby Mount Hope station. This data was used to determine a 6 hour Chicago storm. Since only one event is being modeled, evaporation and snowmelt were not considered.

6.1.2 Hydraulics

Both 1D and 2D components were created for the model. The 1D component of the model represents the piped system within the subdivisions as well as the ditch system along the QEW. The 2D component of the model represents surface flow and ponding. The model inventory is listed Table 11 below.

TABLE 11: Model inventory

Layer	Number of Entries (1D)	Number of Entries (1D+2D)
Junctions	160	39,704
Outfalls	14	439
Storages	1	1
Conduits	156	108,197
Pumps	1	1
Outlets	7	81

Junctions

Junctions were used to represent both manholes and catchbasins in the 1D system. Elevations were determined using a digital elevation model (DEM) created from contours provided by the COH. In the Grafton area, where drawings were available, elevations were input from site data. Catch basins were assumed to be located at the lowest point in the ROW; where catch basins were not located there the locations were edited to ensure the system would fully drain.

Backwater effects were added as initial depths in 1D and 2D junctions upstream of fixed stage outfalls. Initial depths varied based on the invert elevation and the lake level. A baseline flow value was applied to junctions to represent pumping from residential properties. Pumping was only applied to models running lake levels higher than 74 MASL. Pumping rates were determined using the procedure described in section 2.3.2. Pumping rates were divided by 8 to represent an equal amount of water being pumped into each catchment. Figure 3 in section 2.3.2 shows the pumping rate vs. lake level.

Outfalls
Outfalls were used to represent boundary conditions for Lake Ontario. Two kinds of outfalls were used; fixed and normal. Fixed outfalls were used to represent 1D boundary conditions. The fixed stage was assigned as the lake level of the simulation. Normal outfalls were used to represent the 2D boundary condition. The outfall stage in these nodes was based on normal flow depth in the connecting conduit. Elevations were assigned based on the DEM.

Storages
One storage unit was used in the model to represent the reservoir at the Grafton pumping station. The storage unit was given a footprint area of 44.46 m^2, and depth of 2.55 m for a total volume of 113.37 m^3. Based on drawings, the invert elevation of the reservoir was set at 75.3 MASL with a rim elevation of 77.85 MASL.

Conduits
To represent the underground storm network, a series of circular conduits were used. Conduit geometries, elevations and Manning's roughness values were input using GIS data provided by the COH and the DEM.

Trapezoidal conduits were used to represent ditches adjacent to the QEW. Ditch dimensions were approximated based on site observations and correspondence with the COH. A maximum depth of 2.5 m, bottom width of 1 m, and side slopes of 3:1 (horizontal:vertical) were assumed. A Manning's roughness of 0.013 was assumed based on values in ASCE (1982) for unmaintained channels. A seepage rate of 1.02 mm/hr was also assumed for the ditches to represent infiltration within the ditch.

To represent flow on the surface, rectangular open conduits were used as created using PCSWMM's 2D mesh creator. Elevations were determined using the DEM. Mesh resolutions, seepage rates, and Manning's roughness values are summarized in Table 11. Manning's roughness estimates were based on ASCE (1992) values. Connections between the 1D and 2D models differed based on the existing 1D system. To connect 1D stormwater pipes, connections via SWMM5 outlets, were used. Information on the outlets is provided in Table 12. To connect ditches with 2D surface channels, direct connections were used. Direct connections allow 1D and 2D conduits to share a node.

TABLE 12: 2D Mesh Parameters

Type	Mesh Style	Resolution (m)	Roughness	Seepage Rate (mm/hr)
Parcels	Hexagonal	5	0.06	1.02
Roads	Hexagonal/ Rectangular	5-10	0.011	0
QEW	Directional	5-10	0.011	0

Pumps
One pump was modeled to represent the Grafton pumping station. An ideal SMWM5 pump was used to represent pumping conditions. Ideal pumps assume the inflow rate at the upstream node is equal to the pumping rate. A start-up depth of 1 m was used with a shut-off depth of 0 m, to assume the pump is operating during all rainfall events at a capacity that prohibits flooding in Grafton. Inlet and outlet elevations were determined from site drawings.

Outlets

Outlets were used to represent catchbasins connections between the 1D stormwater pipe and 2D overland flow system. A rating curve was developed to represent flow through conditions and is shown in Table 13.

TABLE 13: Catch-basin Outlet Rating Curve

Head (m)	Outflow (m^3/s)
0	0
0.01	0.05
0.23	0.05

6.2 Modeled Scenarios

A series of sixteen scenarios were simulated using two different lake levels, four different storm frequencies and two different outlet conditions. The two lake levels represent the highest recorded lake level (75.88 MASL) and the highest minimum target lake level under plan 2014 (74.56 MASL). The four storms that were selected represent the 2 year, 5 year, 10 year and 100 year return intervals. Lastly, two different outlet conditions were modeled. The first was the existing configurations for single gravity outlet, with the exception of the Grafton subcatchment that was modeled with the existing pumping station. The next outlet condition was used to assess the feasibility of a gravity system for each catchment. To do this the existing outlets were tripled to determine if the system could operate assuming sufficient gravity capacity under the QEW. A summary of the modeled scenarios are as follow:

- 2 year, 5 year, 10 year and 100 year High Low Lake Level (74.56 MASL) with single barrel outlets
- 2 year, 5 year, 10 year and 100 year High High Lake Level (75.88 MASL) with single barrel outlets
- 2 year, 5 year, 10 year and 100 year High Low Lake Level (74.56 MASL) with triple barrel outlets
- 2 year, 5 year, 10 year and 100 year High High Lake Level (75.88 MASL) with triple barrel outlets

A summary of the ponding depths for each modeling scenario can be seen in Appendix K.

6.3 Model Results and Option Alternative Evaluation

The model outputs from each subcatchment were assessed individually to determine the preferred recommendation. The following are the three options that were considered for each catchment.

1. Existing single outlet gravity system that has sufficient capacity under the 5 year high lake level design scenario.
2. Upgraded gravity system with larger capacity under the QEW that has sufficient capacity under the 5 year high lake level design scenario.
3. Pumping station that outlets either into Hamilton Harbour or Lake Ontario and has sufficient capacity under the 100 year high lake level design scenario.

The options were deemed feasible if the level of ponding present is acceptable to the COH. The estimated cost and associated service level for the feasible options were compared to determine a single preferred alternative for each subcatchment.

TABLE 14: Summary of the model results and evaluations

System	5YR-HH Single Outlet Gravity System	5YR-HH Triple Outlet Gravity System	100YR-HH Pumping Required
Eastport	• Ponding occurs on private property owned by COH and on Eastport Drive with a maximum depth of 0.29m. Outlet pipes pass under the QEW in a raised portion and outlet into Hamilton Harbour. • A single 0.6m gravity outlet is sufficient for the Eastport system if the aforementioned ponding is deemed acceptable. [2] • Estimated cost range o Capital Cost (if new outlet and pipe crossing needed): $200,000 o Operational Cost: Regular cleaning and pipe maintenance • Future Activities o Confirmation of current outlet location, size and condition.	Single outlet provides sufficient capacity for the Eastport system if the aforementioned ponding is deemed acceptable. [2]	Gravity provides sufficient capacity for the Eastport system if the aforementioned ponding is deemed acceptable.[2]
Hamilton Harbour	• Ponding occurs on private property owned privately and by the COH. No ponding occurs on ROW. Outlet pipes pass under the QEW in a raised portion and outlets into Hamilton Harbour. • Single 0.6m gravity outlet is not sufficient for the Hamilton Harbour system.	• Limited ponding occurs and could be an artifact of the DEM. • Gravity drainage for the Hamilton Harbour System is feasible if the capacity of the outlet is increased and the aforementioned ponding is deemed acceptable. [2] • Estimated cost range o Capital Cost: $300,000 o Operational Cost: Regular cleaning and pipe maintenance • Future Activities o Further calculations required to confirm necessary capacity of gravity outfall.	• Gravity provides sufficient capacity for the Hamilton Harbour system if the capacity of the outlet is increased and we accept the aforementioned ponding is deemed acceptable. • Constructing a pumping station would increase the capacity of the system from to 100YR-HH capacity. The pumping station could either outlet into Lake Ontario or under the QEW into the Hamilton Harbour. This outlet would not be impacted by backwater effects caused by high lake levels. o Capital Cost (Hamilton Harbour Outlet): $2,200,000 o Capital Cost (Lake Ontario Outlet)[1]: $2,400,000 o Operational Cost: $15,000/year plus regular cleaning and pipe maintenance.
Dunraven	• Ponding occurs on private property owned privately, by the COH and MTO. Ponding occurs on Dunraven Avenue, Locarno Avenue and Renfrew Avenue with a maximum depth of 0.30m. • A single 0.6m gravity outlet is not sufficient for the Dunraven system.	• Ponding occurs on the lower portion of Dunraven Avenue (maximum depth of 0.27m) and on an undeveloped parcel owned by MTO (PIN 17568-0019, maximum depth of 0.23m). Limited ponding is present on the edge of a privately owned parcel (PIN 17568-0013, maximum depth 0.06m) but could be an artifact of the DEM and mesh size. • Gravity drainage for the Dunraven System is feasible if the capacity of the outlet is increased and the aforementioned ponding is deemed acceptable. [2] • Estimated cost range o Capital Cost: $2,300,000 o Operational Cost: Regular cleaning and pipe maintenance • Future Activities o Further calculations required to confirm necessary capacity of gravity outfall. o Confirm capacity of Eastport ditch is sufficient to prevent additional backwater effects on outlet.	• Constructing a pumping station would increase the capacity of the system to have a 100YR-HH capacity. The pumping station could either outlet into Lake Ontario or under the QEW into the Eastport Ditch. This outlet would not be impacted by backwater effects caused by high lake levels. o Capital Cost (Eastport Ditch Outlet): $3,000,000 o Capital Cost (Lake Ontario Outlet) [1]: $2,900,000 o Operational Cost: $15,000/year plus regular cleaning and pipe maintenance. • Future Activities o Further calculations required to confirm the capacity of a pumping station. o Environmental Assessment for pumping station.
Grafton	Not considered in this analysis		

Not feasible nor recommended
Feasible but not preferred
Preferred recommendation

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System	5YR-HH Single Outlet Gravity System	5YR-HH Triple Outlet Gravity System	100YR-HH Pumping Required
Lagoon	• Ponding occurs on private property owned privately and by COH. Ponding occurs on Clare Avenue, Lagoon Avenue and Arden Avenue with a maximum depth of 0.54m. • Single 0.6m gravity outlet is not sufficient for the Lagoon system. • The extent of flooding is significant enough that adding additional stormwater management features is not reasonable.	• Ponding occurs on the lower portion of Lagoon Avenue (maximum depth of 0.35m) and Arden Avenue (maximum depth of 0.30m). Additionally, ponding is present on four undeveloped parcel owned by COH (maximum depth of 0.23m) and two developed privately owned properties (maximum depth of 0.15m). • The COH owns several properties at the bottom of Clare Avenue, Lagoon Avenue and Arden Avenue. If this area is re-graded and converted into a stormwater management facility to provide relief from ponding on private property and the capacity of the outlet is increased, then gravity drainage for the Lagoon System is feasible. [2] • Estimated cost range o Capital Cost: $1,900,000 + potential property acquisition cost (1 undeveloped lot and 1 residential lot) o Operational Cost: Regular cleaning and pipe maintenance • Future Activities o Further calculations required to confirm the necessary capacity of gravity outfall and stormwater management facility. o Confirm capacity of Eastport ditch is sufficient to prevent additional backwater effects on outlet. o Re-grading of COH owned properties.	• Constructing a pumping station would increase the capacity of the system to have a 100YR-HH capacity. The pumping station could either outlet into Lake Ontario or under the QEW into the Eastport Ditch. This outlet would not be impacted by backwater effects caused by high lake levels. o Capital Cost (Eastport Ditch Outlet): $3,200,000 o Capital Cost (Lake Ontario Outlet): $3,400,000 o Operational Cost: $20,000/year plus regular cleaning and pipe maintenance • Future Activities o Further calculations required to confirm the capacity of a pumping station. o Environmental Assessment for pumping station.
Townhouse	• Ponding occurs on private property owned around the privately owned townhouse complex. However, since these are relatively new buildings, the ponding could be a result of the low quality DEM and not a deficiency in the Townhouse system. [2] • Future Activities o Confirm of current outlet location, size and condition.	No concerns about capacity in this system. [2]	No concerns about capacity in this system. [2]
Bayside	• Ponding occurs on private property owned privately and by COH. Ponding occurs on Towers Drive, Bayside Avenue and Wark Avenue with a maximum depth of 0.49m. • Single 0.6m gravity outlet is not sufficient for the Bayside system. • The extent of flooding is significant enough that adding additional stormwater management features is not reasonable.	• Ponding occurs on the lower portion of Towers Drive (maximum depth of 0.20m), Bayside Avenue (maximum depth of 0.18m) and Wark Avenue (maximum depth 0.23m). Additionally, ponding is present on three undeveloped parcel owned by COH on Bayside Avenue and Wark Avenue (maximum depth of 0.26m) and several privately owned properties on Towers Drive and Bayside Avenue (maximum depth of 0.20m). • The COH owns several properties at the bottom of Bayside Avenue and Wark Avenue. If this area is re-graded and converted into a stormwater management facility to provide relief from ponding on private property and the capacity of the outlet is increased then gravity drainage for this portion of Bayside system may be feasible. [2] However, COH does not own property on Towers Drive and would have to purchase land. • Estimated cost range o Capital Cost: $1,800,000 + property acquisition costs (2 undeveloped lots) o Operational Cost: Regular cleaning and pipe maintenance • Future Activities o Further calculations required to confirm the necessary capacity of gravity outfall and stormwater management facility. o Confirm capacity of Eastport ditch is sufficient to prevent additional backwater effects on outlet. o Purchasing of land at the bottom of Towers Drive. o Re-grading of COH owned properties.	• Constructing a pumping station would increase the capacity of the system to have a 100YR-HH capacity. The pumping station could either outlet into Lake Ontario or under the QEW into the Eastport Ditch. This outlet would not be impacted by backwater effects caused by high lake levels. o Capital Cost (Eastport Ditch Outlet): $4,300,000 o Capital Cost (Lake Ontario Outlet) [1]: $3,700,000 o Operational Cost: $25,000/year plus regular cleaning and pipe maintenance. • Future Activities o Further calculations required to confirm the capacity of a pumping station. o Environmental Assessment for pumping station.

Not feasible nor recommended
Feasible but not preferred
Preferred recommendation

System	5YR-HH Single Outlet Gravity System	5YR-HH Triple Outlet Gravity System	100YR-HH Pumping Required
Fletcher	• Ponding occurs on private property owned privately, by COH and by MTO. Ponding occurs on Kirk Road and Fletcher Avenue with a maximum depth of 0.38m. • Single 0.6m gravity outlet is not sufficient for the Fletcher system. • The Extent of flooding is significant enough that adding additional stormwater management features is not reasonable.	• Ponding occurs on Kirk Road (maximum depth of 0.15m), on an undeveloped parcel owned by MTO (maximum depth 0.07m) and on the edge of three parcels (maximum depth 0.15m). Ponding occurs on privately owned property and the ROW of Fletcher Avenue. • Gravity drainage for the Fletcher System is not feasible unless COH acquires several properties at the bottom of Kirk Road. [2] COH owns property southeast Fletcher Avenue that could be regraded to provide additional storage in this system. • Estimated cost range o Capital Cost: $2,400,000 + property acquisition costs (3-4 residential lots). o Operational Cost: Regular cleaning and pipe maintenance. • Future Activities o Further calculations required to confirm the necessary capacity of gravity outfall and stormwater management facility. o Purchasing of land at the bottom of Kirk Road. o Re-grading of COH owned properties.	• Constructing a pumping station would increase the capacity of the system to have a 100YR-HH capacity. The pumping station could either outlet into Lake Ontario or under the QEW into the Hamilton Harbour. This outlet would not be impacted by backwater effects caused by high lake levels. o Capital Cost (Hamilton Harbour Outlet): $3,200,000 o Capital Cost (Lake Ontario Outlet) [1]: $3,000,000 o Operational Cost: $20,000/year plus regular cleaning and pipe maintenance. • Future Activities o Further calculations required to confirm the capacity of a pumping station. o Environmental Assessment for pumping station.

[1]Costs for piping under roadway assumed to be done at same time as road works.
[2]Assuming the Eastport Ditch has sufficient capacity
All Costs rounded up to the nearest $100,000.

Not feasible nor recommended
Feasible but not preferred
Preferred recommendation

6.4 Model Errors

Differences in model results, such as variance between maximum water depths in 2D cells, can be attributed to model routing error. Model routing continuity error ranged from 1.4% to 5.5% across the different model scenarios. Industry standard recommends a routing error between 0% and 5%, however continuity errors below 10% are considered reasonable (Rossman, 2015). Thus the model may still exhibit some fluctuations in cell depths in the final results. These fluctuations were observed in the order of millimetres, which is acceptable for our purposes and scope.

7.0 Study Recommendations

The following tables represents a general summary of the various recommendations to address ponding within the Beaches Community. There are recommendations for future works, legislative changes, residential alterations and physical outlet recommendations. Sub-catchment system recommendations will need to be re-evaluated after the COH determines a level of service for the Beach Boulevard Community. In addition, sub-catchment recommendations will be subject to an Environmental Assessment and other regulatory requirements. The impact of dewatering on the capacity of the systems being designed should be verified as part of the design process.

TABLE 15: General recommendation for the entire Beach Boulevard Community

Category	Recommendations
General	• Confirm the capacity of the Eastport Ditch. • Continue to work with MTO, HPA and HCA to confirm existing size and conditions of outlets within the QEW right-of-way. • Work with MTO to construct a Cost Sharing Plan for the proposed recommendations.
Legislative	• Continue to transfer ownership of landlocked properties on the QEW side of the noise wall to MTO. • Educate the Committee of Adjustments and the general public as to why below-ground floors, basements and crawl spaces are prohibited in the Beach Boulevard Community. • Consider banning all forms of below ground structures and start a "basement filling" program. • Consider changing the language in the By-Laws to prevent the approval of basement structures unless the property owner can prove the structure will have no negative impact on the water system. • Update the minimum allowable ground floor elevation to 76.5 MASL (from 76 MASL) to account for the increase in allowable lake level by the IJC under Plan 2014. • Halt the sale of noted COH owned property sales until the recommendations of this study are available for review and accepted by the COH and the recommended EA is completed. • Work with the MTO to finalize a maintenance agreement for all stormwater ditches in the Beach Boulevard Community.
Lot Level	• Create an incentive program to encourage the installation of lot level stormwater management practices. • Install proper backwater valves to protect residents from the potential risk of system surcharging. • Install direct storm sewer connections for private property owners to convey the basement and dewatering pumping flows.
Infrastructure	• Continue to work with the MTO to conduct regular maintenance of catch basins, ditches and outlets. • Upgrade all stormwater pipes to handle the 5 year storm under high lake levels in parallel with other infrastructure works as they occur.

TABLE 16: Sub-catchment specific recommendations

Sub-catchment	Recommendation
Eastport	• A gravity system with the current outlet capacity is recommended. • The current outlet should be assessed to determine if a new outlet is required. • If a new outlet is required, the required size of the new outlet should be confirmed.
Hamilton Harbour	• A gravity system with an increased outlet capacity under the QEW is recommended. • Confirmation of the required size/quantity of additional pipes needed to meet the desired service level is required.
Dunraven	• A pumping station that outlets into either Lake Ontario or Hamilton Harbour is recommended. • An environmental assessment will need to be completed to determine the preferred configuration. • As part of the environmental assessment, the capacity of the pumping station should be confirmed. Additionally, the environmental assessment should determine if combining sub-catchments to minimize the number of required pumping stations is a feasible alternative.
Grafton	• No additional catchment specific recommendations.
Lagoon	• A pumping station that outlets into either Lake Ontario or Hamilton Harbour is recommended. • An environmental assessment will need to be completed to determine the preferred configuration. • As part of the environmental assessment, the capacity of the pumping station should be confirmed. Additionally, the environmental assessment should determine if combining sub-catchments to minimize the number of required pumping stations is a feasible alternative.
Townhouse	• Confirm flow path of discharge water from this catchment.
Bayside	• A pumping station that outlets into either Lake Ontario or Hamilton Harbour is recommended. • An environmental assessment will need to be completed to determine the preferred configuration. • As part of the environmental assessment, the capacity of the pumping station should be confirmed. Additionally, the environmental assessment should determine if combining sub-catchments to minimize the number of required pumping stations is a feasible alternative.
Fletcher	• A pumping station that outlets into either Lake Ontario or Hamilton Harbour is recommended. • An environmental assessment will need to be completed to determine the preferred configuration. • As part of the environmental assessment, the capacity of the pumping station should be confirmed. Additionally, the environmental assessment should determine if combining sub-catchments to minimize the number of required pumping stations is a feasible alternative.

The following are time estimates for the key infrastructure recommendations:

- Gravity Outlet Detailed Design: 3 – 6 months
- Environmental Assessment for Pumping Station: 8 – 24 months

- Pumping Station Detailed Design: 8 – 12 months

The purpose of this report was to determine the likely causes of ponding on the COH ROW within the Beaches Community, identify possible mitigation means, and recommend preferred solutions. Some of these recommendation could be implemented immediately, whereas others will require additional study, design, and public consultation. There are still activities that are required as part of advancing the recommendation, primarily an Environmental Assessment for the potential pumping stations, and confirmation on the level of service for design purposes. Further discussions and agreements will be required with the HPA and MTO for new infrastructure and the maintenance of existing infrastructure, including potential cost sharing.

8.0 Conclusions

The City of Hamilton has experienced flooding in the Beach Boulevard area dating back to 1943. The intent of the Beach Boulevard Community Stormwater Ponding Study is to investigate the cause of water ponding on the Rights of Way (ROW), and provide potential mitigation measures that the City of Hamilton (COH) could implement in order to minimize future flooding impacts. Some of the recommendations listed can be implemented by the City immediately (e.g., development of Maintenance Agreements with the MTO, property transfers, etc.). Sub-Catchment specific recommendations require more consideration and may take more time to implement. The installation of a new pumping station or new outlet would require confirmation existing conditions (e.g., outlet pipes under the QEW, Eastport Ditch outlet), and may be subject to an Environmental Assessment and/or other regulatory approvals/requirements. COH is required to confirm a level of service for the Beach Boulevard Community; other areas within the COH have a level of service of a 5 year storm. COH should work with the MTO to develop cost sharing agreements for this work, similar to that agreed on for the Grafton Pumping Station.

9.0 References

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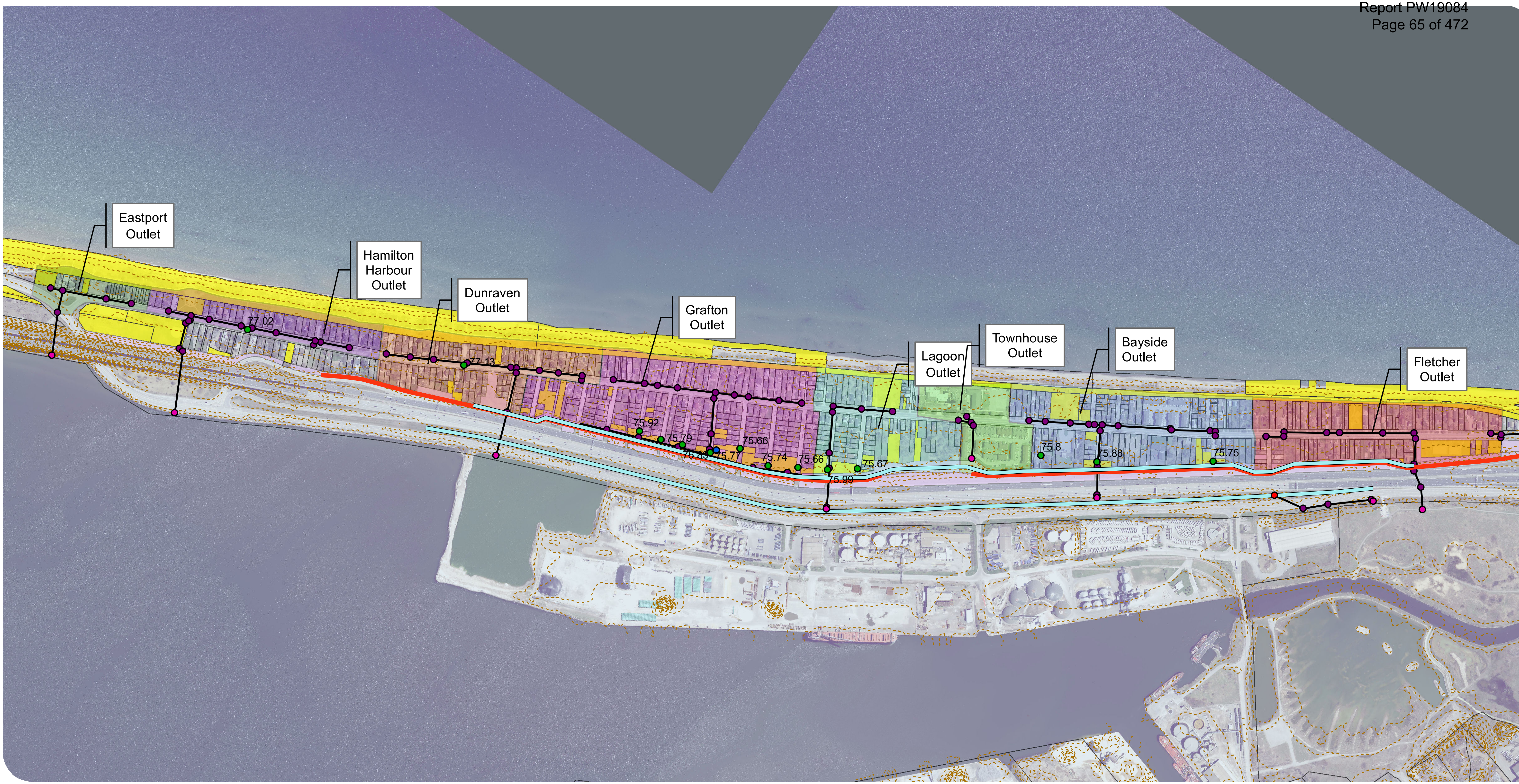
Figures



CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-1

CONTOUR	STORM SEWER INLET	LOW POINT (MASL)	CITY OWNED PROPERTY
STORM SEWER	STORM SEWER OUTLET	DRAINAGE DITCH	MTO OWNED PROPERTY
STORM SEWER MANHOLE	PUMPING STATION	MTO NOISE WALL	

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NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 180 360 720 Metres

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PROJECT: 17-5898 STATUS: DRAFT DATE: 02/04/19

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-2

CONTOUR	STORM SEWER INLET	LOW POINT (MASL)	CITY OWNED PROPERTY
STORM SEWER	STORM SEWER OUTLET	DRAINAGE DITCH	MTO OWNED PROPERTY
STORM SEWER MANHOLE	PUMPING STATION	MTO NOISE WALL	

DILLON CONSULTING

NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

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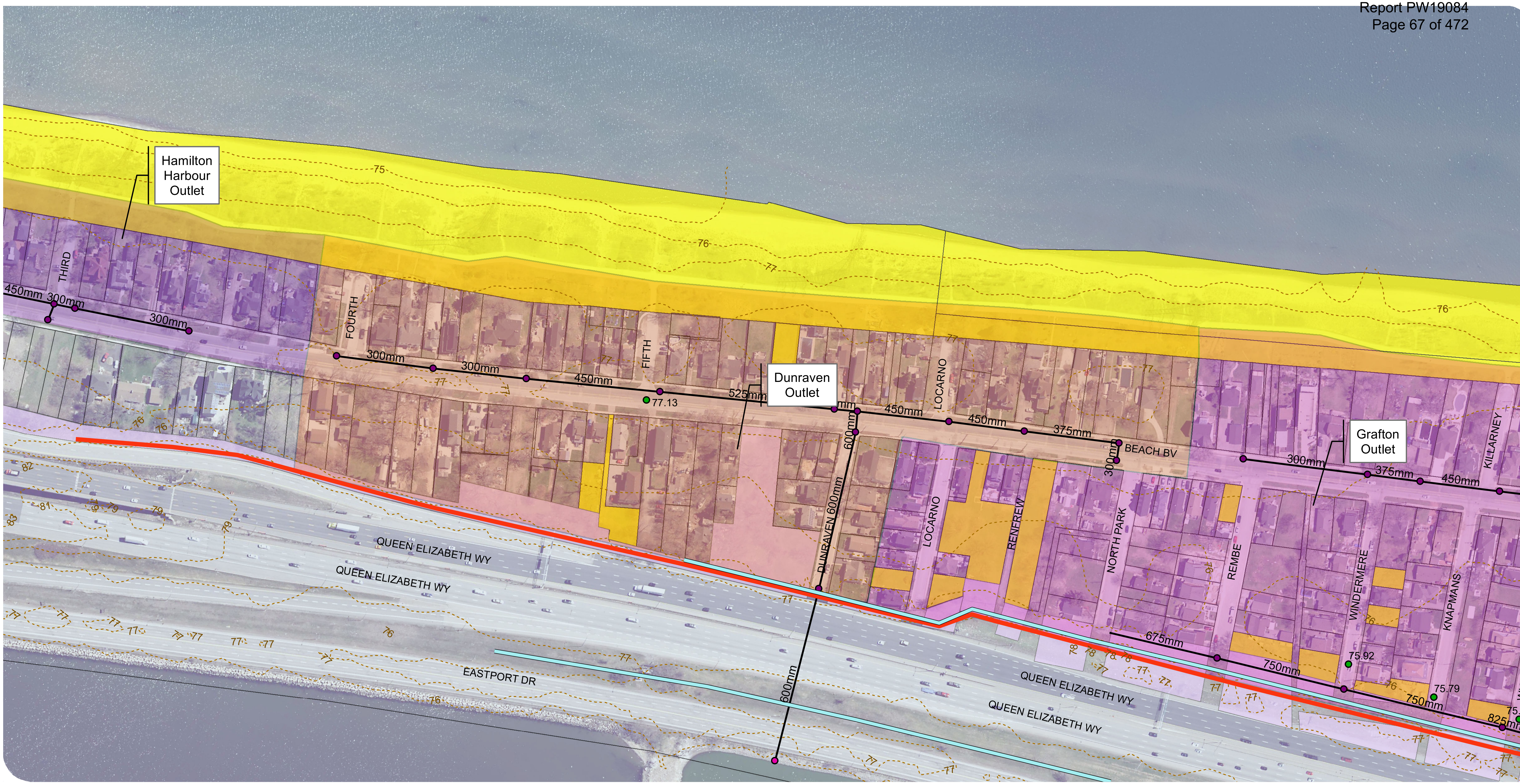

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-3

CONTOUR	STORM SEWER INLET	LOW POINT (MASL)	CITY OWNED PROPERTY
STORM SEWER	STORM SEWER OUTLET	DRAINAGE DITCH	MTO OWNED PROPERTY
STORM SEWER MANHOLE	PUMPING STATION	MTO NOISE WALL	

DILLON CONSULTING

NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

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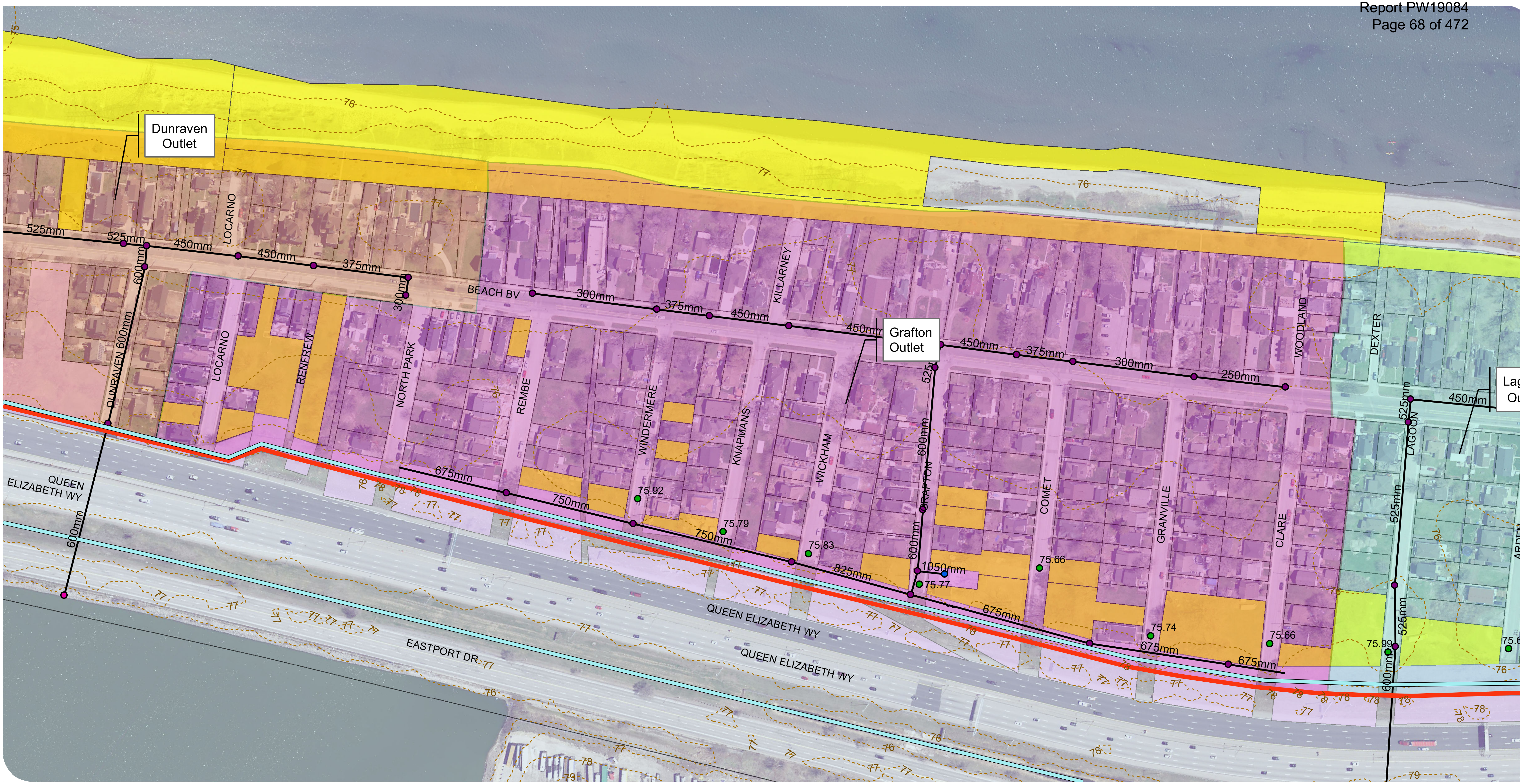

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-4

CONTOUR	STORM SEWER INLET	LOW POINT (MASL)	CITY OWNED PROPERTY
STORM SEWER	STORM SEWER OUTLET	DRAINAGE DITCH	MTO OWNED PROPERTY
STORM SEWER MANHOLE	PUMPING STATION	MTO NOISE WALL	

DILLON CONSULTING

NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 45 90 180 Metres

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PROJECT: 17-5898 STATUS: DRAFT DATE: 02/04/19

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-5

CONTOUR	STORM SEWER INLET	LOW POINT (MASL)	CITY OWNED PROPERTY
STORM SEWER	STORM SEWER OUTLET	DRAINAGE DITCH	MTO OWNED PROPERTY
STORM SEWER MANHOLE	PUMPING STATION	MTO NOISE WALL	

DILLON CONSULTING

NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 45 90 180 Metres

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PROJECT: 17-5898 STATUS: DRAFT DATE: 02/04/19

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-6

CONTOUR	STORM SEWER INLET	LOW POINT (MASL)	CITY OWNED PROPERTY
STORM SEWER	STORM SEWER OUTLET	DRAINAGE DITCH	MTO OWNED PROPERTY
STORM SEWER MANHOLE	PUMPING STATION	MTO NOISE WALL	

DILLON CONSULTING

NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 45 90 180 Metres

pw:\\pwintsrv.dillon.ca:Active_Prod\Documents\Projects\2017\175898 Beach Boulevard Flooding Study\2. Work\Analysis & Design\GIS\

PROJECT: 17-5898 STATUS: DRAFT DATE: 02/04/19

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-7

CONTOUR
STORM SEWER
STORM SEWER MANHOLE
STORM SEWER INLET
STORM SEWER OUTLET
PUMPING STATION
LOW POINT (MASL)
DRAINAGE DITCH
MTO NOISE WALL
CITY OWNED PROPERTY
MTO OWNED PROPERTY

DILLON CONSULTING

NOTES:
SOME CONTOURS WERE REMOVED FOR CLARITY

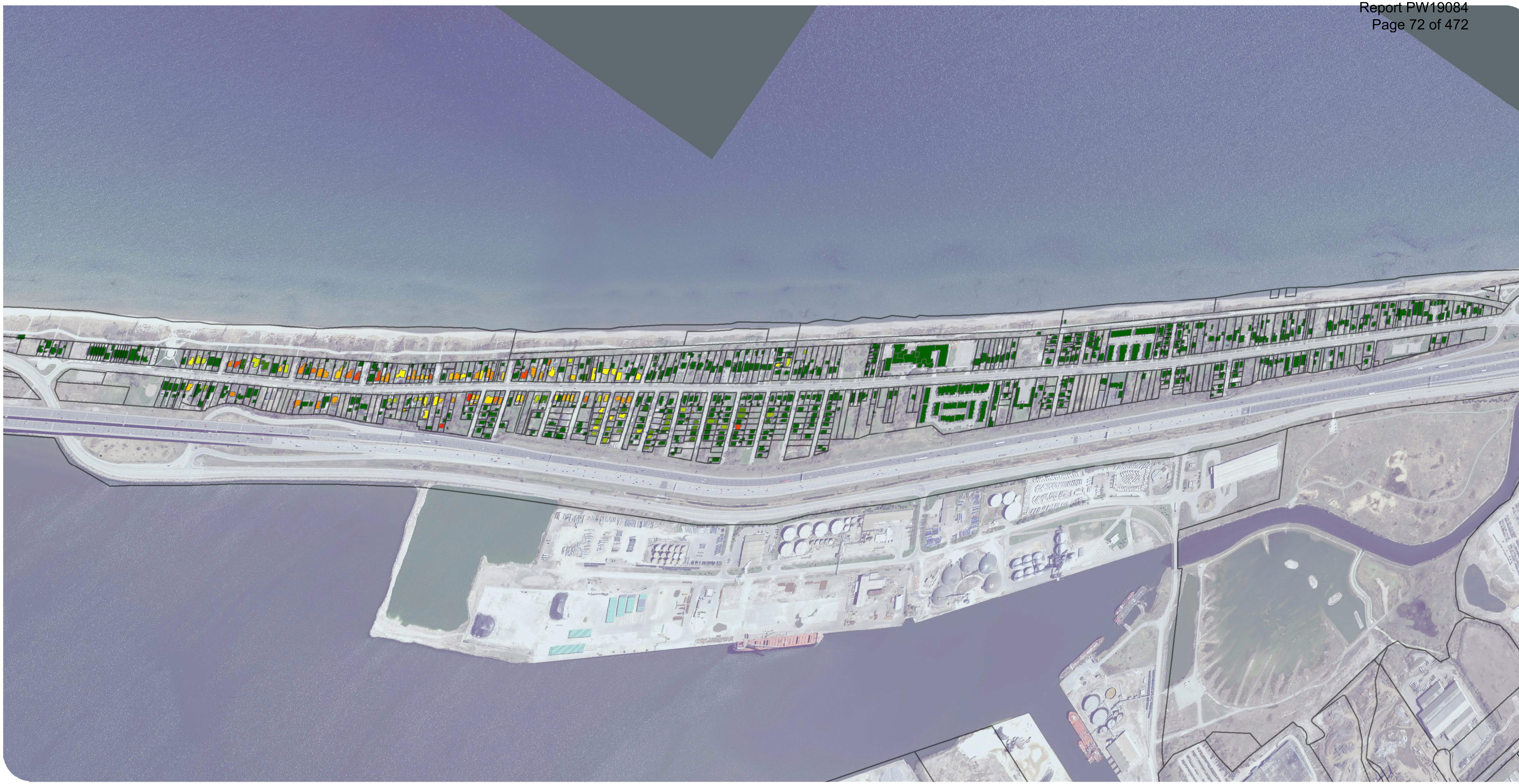
MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 45 90 180 Metres

pw:\\pwintsrv.dillon.ca:Active_Prod\Documents\Projects\2017\175898 Beach Boulevard Flooding Study\2. Work\Analysis & Design\GIS\

PROJECT: 17-5898 STATUS: DRAFT DATE: 02/04/19



CITY OF HAMILTON
BEACH BOULEVARD COMMUNITY
STORMWATER PONDING STUDY

BASEMENT INFORMATION
FIGURE 2- 1

BASEMENT DEPTH

MBGS (COUNT)

No Information (595)

0.2 (3)	0.6 (9)	0.9 (7)	1.2 (19)	1.5 (2)	1.8 (4)	3 (2)
0.4 (6)	0.7 (2)	1 (9)	1.3 (1)	1.6 (17)	1.9 (1)	
0.5 (4)	0.8 (7)	1.1 (2)	1.4 (18)	1.7 (7)	2 (5)	

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 200 400 800 Metres

pw:\\pwintsrv.dillon.ca:Active_Prod\Documents\Projects\2017\175898 Beach Boulevard Flooding Study\2. Work\Analysis & Design\GIS\

PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17

CITY OF HAMILTON
BEACH BOULEVARD COMMUNITY
STORMWATER PONDING STUDY

BASEMENT INFORMATION
FIGURE 2- 2

BASEMENT DEPTH

MBGS (COUNT)

No Information (348)

0.2 (3)	0.6 (9)	0.9 (7)	1.2 (19)	1.5 (2)	1.8 (4)	3 (2)
0.4 (6)	0.7 (2)	1 (9)	1.3 (1)	1.6 (17)	1.9 (1)	
0.5 (4)	0.8 (7)	1.1 (2)	1.4 (18)	1.7 (7)	2 (5)	

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 100 200 400 Metres

pw:\\pwintsrv.dillon.ca:Active_Prod\Documents\Projects\2017\175898 Beach Boulevard Flooding Study\2. Work\Analysis & Design\GIS\

PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17

Appendix A

International Joint Committee Plan Comparison

<table>
<tr><th>Level</th><th colspan="2">1958-D</th><th colspan="2">Plan 2014</th></tr>
<tr><td>Ice Formation Maximum Flow (m^3/s)</td><td>January - 6,230
1-14 Febuary - 6,800
14-28 Febuary - 7,360
March - 7,930</td><td>Page 32</td><td>6,230</td><td>I Limit
Page 60</td></tr>
<tr><td>Navigation Maximum Flow (m^3/s)</td><td>-</td><td>-</td><td>
<table>
<tr><th>Lake Ontario level (m, IGLD 1985)</th><th>L Limit Flow (m^3/s)</th></tr>
<tr><td colspan="2">For Seaway naigation season</td></tr>
<tr><td>≤74.22</td><td>5,950</td></tr>
<tr><td>> 74.22 and ≤ 74.34</td><td>5,950+1,333 (Lake Ontario level - 74.22)</td></tr>
<tr><td>> 74.34 and ≤ 74.54</td><td>6,111+9,100 (Lake Ontario level - 74.34)</td></tr>
<tr><td>> 74.54 and ≤ 74.70</td><td>7,930+2,625 (Lake Ontario level - 74.54)</td></tr>
<tr><td>> 74.70 and ≤ 75.13</td><td>8,350+1,000 (Lake Ontario level - 74.70)</td></tr>
<tr><td>> 75.13 and ≤ 75.44</td><td>8,780+3,645 (Lake Ontario level - 75.13</td></tr>
<tr><td>> 75.44 and ≤ 75.70</td><td>9,910</td></tr>
<tr><td>> 75.70 and ≤ 76.00</td><td>10,200</td></tr>
<tr><td>> 76.00</td><td>10,700</td></tr>
<tr><td colspan="2">For outside Seaway season</td></tr>
<tr><td>Any</td><td>11,500</td></tr>
</table>
</td><td>L Limit, Table B3
Page 61</td></tr>
<tr><td>Lake Ontario Minimum and Maximum Water Level (m)</td><td>Minimum: 74.00

Maximum : 75.23</td><td>Minimum:
Criteria (j)
Page 39
Maximum:
Criteria (h)
Page 39</td><td>
<table>
<tr><th></th><th colspan="2">Lake Ontario, Level IGLD</th></tr>
<tr><th>month</th><th>Minimum (m)</th><th>Maximum (m)</th></tr>
<tr><td>January</td><td>73.56</td><td>75.26</td></tr>
<tr><td>February</td><td>73.62</td><td>75.37</td></tr>
<tr><td>March</td><td>73.78</td><td>75.33</td></tr>
<tr><td>April</td><td>73.97</td><td>75.60</td></tr>
<tr><td>May</td><td>74.22</td><td>75.73</td></tr>
<tr><td>June</td><td>74.27</td><td>75.69</td></tr>
<tr><td>July</td><td>74.26</td><td>75.63</td></tr>
<tr><td>August</td><td>74.15</td><td>75.49</td></tr>
<tr><td>September</td><td>74.04</td><td>75.24</td></tr>
<tr><td>October</td><td>73.83</td><td>75.25</td></tr>
<tr><td>November</td><td>73.67</td><td>75.18</td></tr>
<tr><td>December</td><td>73.57</td><td>75.23</td></tr>
</table>
</td><td>Minimum:
Regulation H7
Page 53
Maximum:
Regulation Condition H4
Page 53</td></tr>
</table>

Appendix B

City of Hamilton Zoning Bylaw 99-169

Bill No. C-73 A

The Corporation of the City of Hamilton

BY-LAW NO. 99-169

To Amend:

Zoning By-law No. 6593

Respecting:

LANDS LOCATED EAST (LAKE SIDE) OF BEACH BOULEVARD,
IN THE BEACH NEIGHBOURHOOD ·

WHEREAS the Council of The Corporation of the City of Hamilton passed Zoning By-law No. 6593 on the 25th day of July 1950, which by-law was approved by the Ontario Municipal Board by Order dated the 7th day of December 1951, (File No. P.F.C. 3821);

AND WHEREAS this by-law is in conformity with the Official Plan of the Hamilton Planning Area, approved by the Minister under the Planning Act. on June 1, 1982.

NOW THEREFORE the Council of The Corporation of the City of Hamilton enacts as follows:

1. The "C11 (Urban Protected Residential, etc.} District, the "G" (Neighbourhood Shopping Centre, etc.) District, and the "H" (Community Shopping and Commercial, etc.) District provisions, as contained in Section 9, 13 and 14, respectively, of Zoning By.:.law No. 65931 applicable to the lands east (lake side) of Beach Boulevard, the extent and boundaries of which are shown on plans hereto annexed as Schedules "A·, "A-1" and aA-2", are amended to the extent only of the special requirement that, ·

(a) all buildings and structures, including accessory buildings, shall provide a side yard along each side lot line, of a width of at least
1.7 metres; and,

(b) notwithstanding clause (a), a side yard maybe reduced to a width of at least 1.5 metres, only where a common swale between the adjoining properties has been approved under a Lot Grading Agreement or approved under a Site Plan Control Agreement; and,

(c) notwithstanding clauses (a) and (b), Sections 18(3)(v)1 (viccc), and (vi)(e) shall not apply to side yards.

3. No building or structure shall be erected, altered, extended or enlarged, nor shall any building or structure or part thereof be used, nor shall any land be used, except in accordance with the "C", "G" and "H" District provisions, subject to the special requirements referred to in sections 1 and 2 of this by-law.

4. By-law No. 6593 is amended by adding this by-law to section 198 as Schedule S-1435.

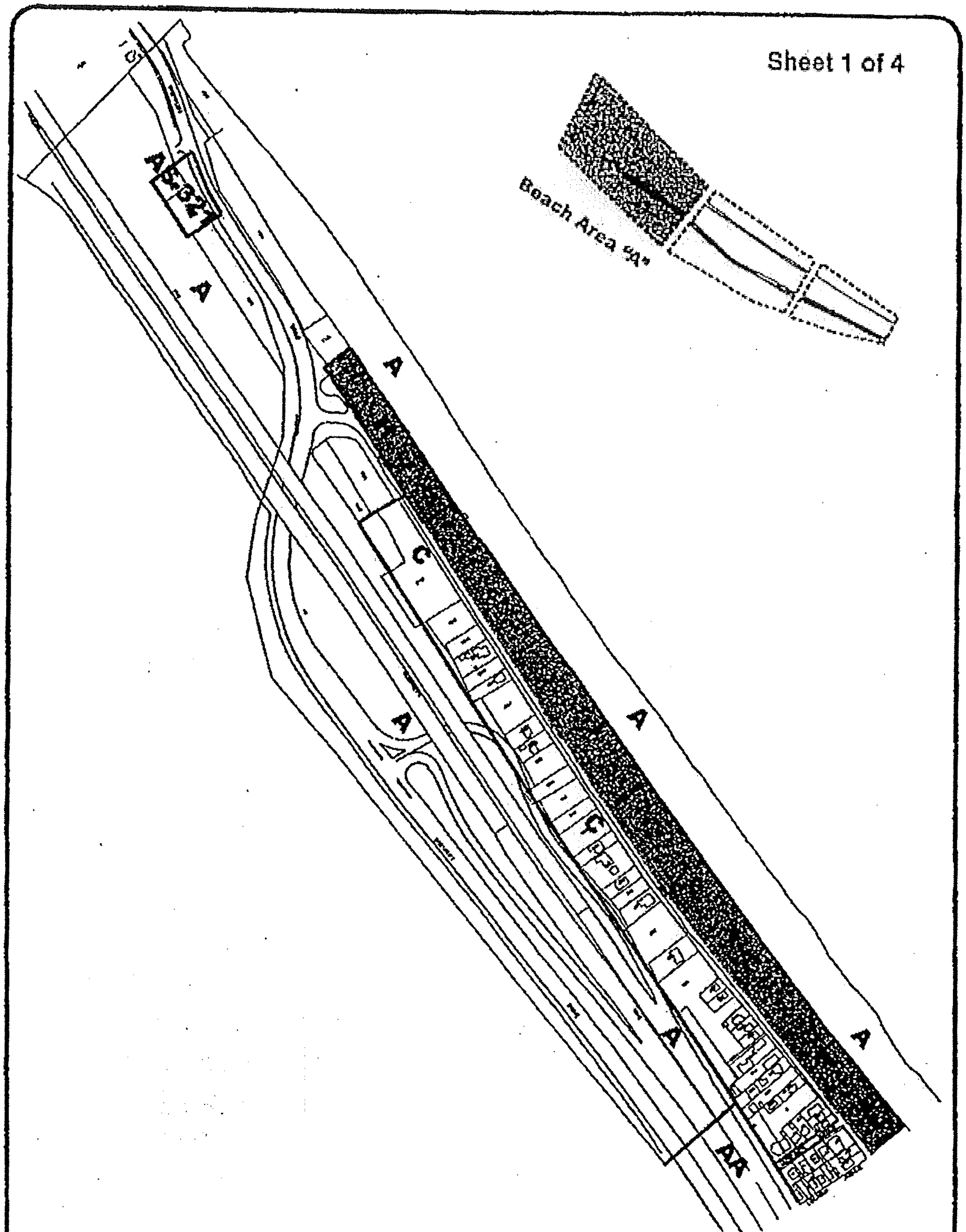
5. Sheets No. E-80b, E..SOC, E-80d, E..aOe, E-80f and E-80g of the District Maps are amended by marking the lands referred to in sections 1and2 of this by-law, S-1435.

6. The Municipal Clerk is hereby authorized and directed to proceed with the giving of notice of the passing of this by-law, in accordance with the Planning Act.

PASSED this 30th day of November AD.1999

MUNICIPAL CLERK MAYOR

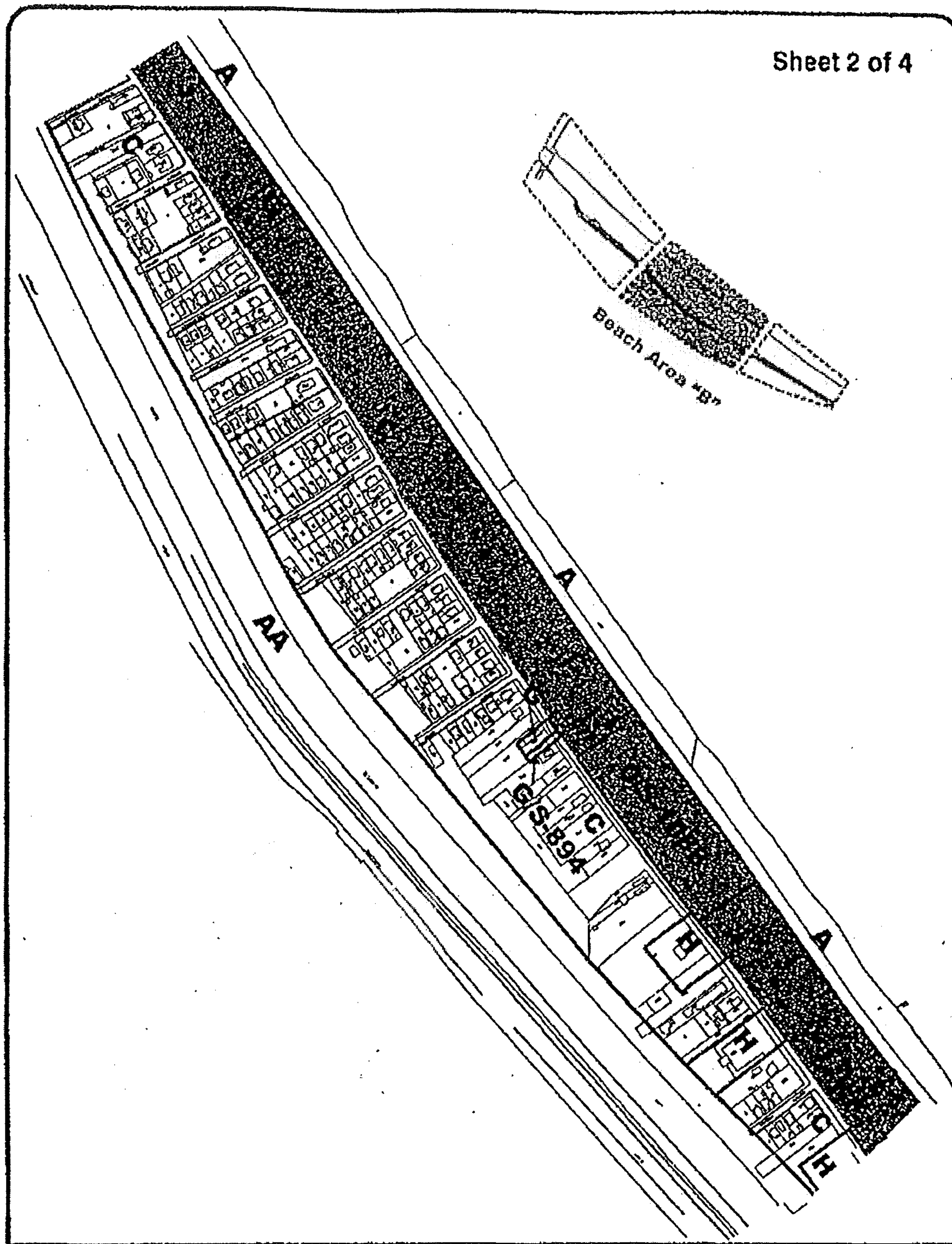
(1999) 23Ro R.P.D.C.(12A)-, November 30
City Initiative 98-D



This is Schedule "A" to By-Law No. 99-169....
Passed the ......30th...... day of ......November.............., 1999.

Clerk

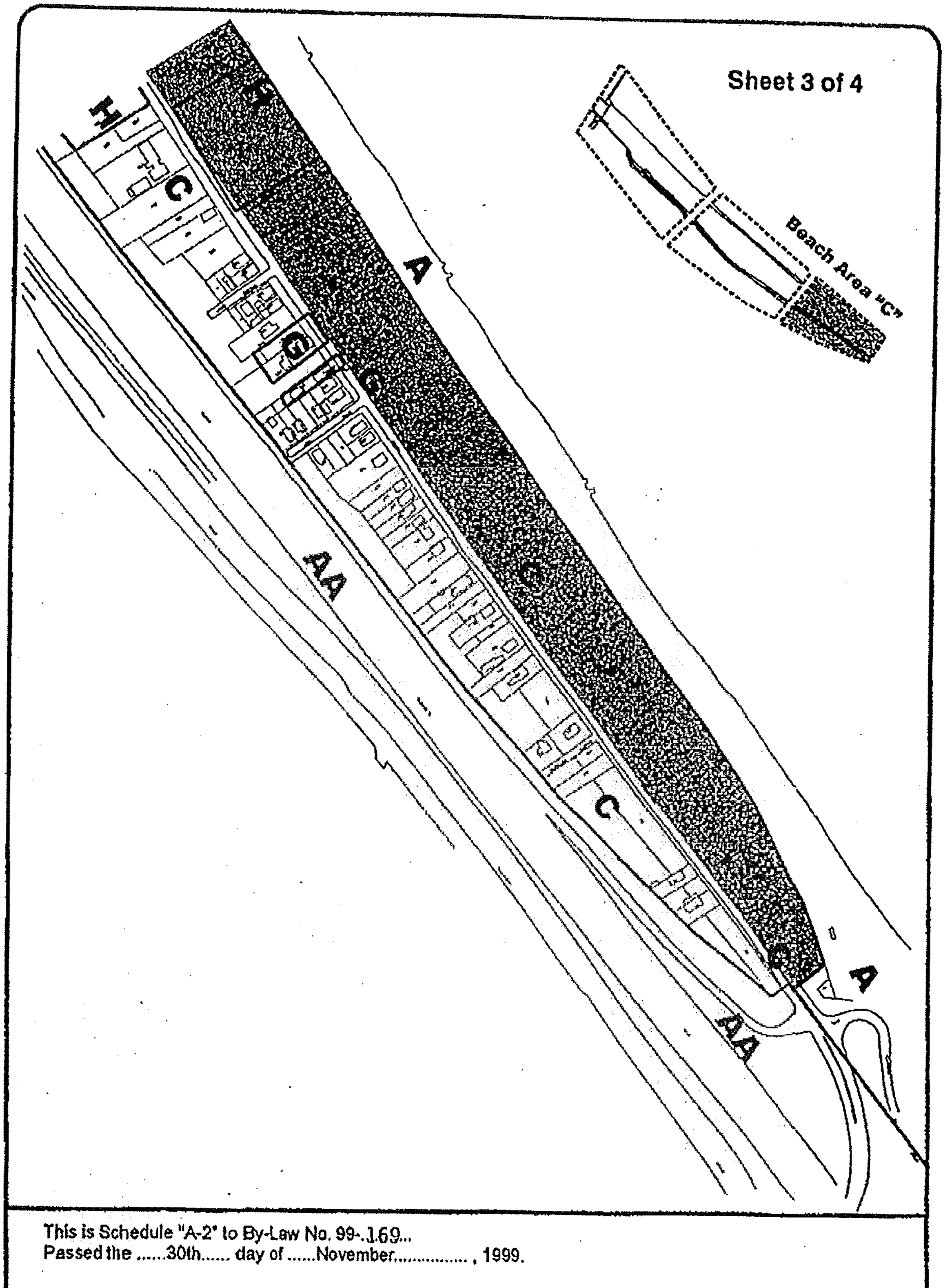
Mayor



This is Schedule "A-1" to By-Law No. 99-.169..
Passed the ......30th...... day of ......November................, 1999.

.... Clerk

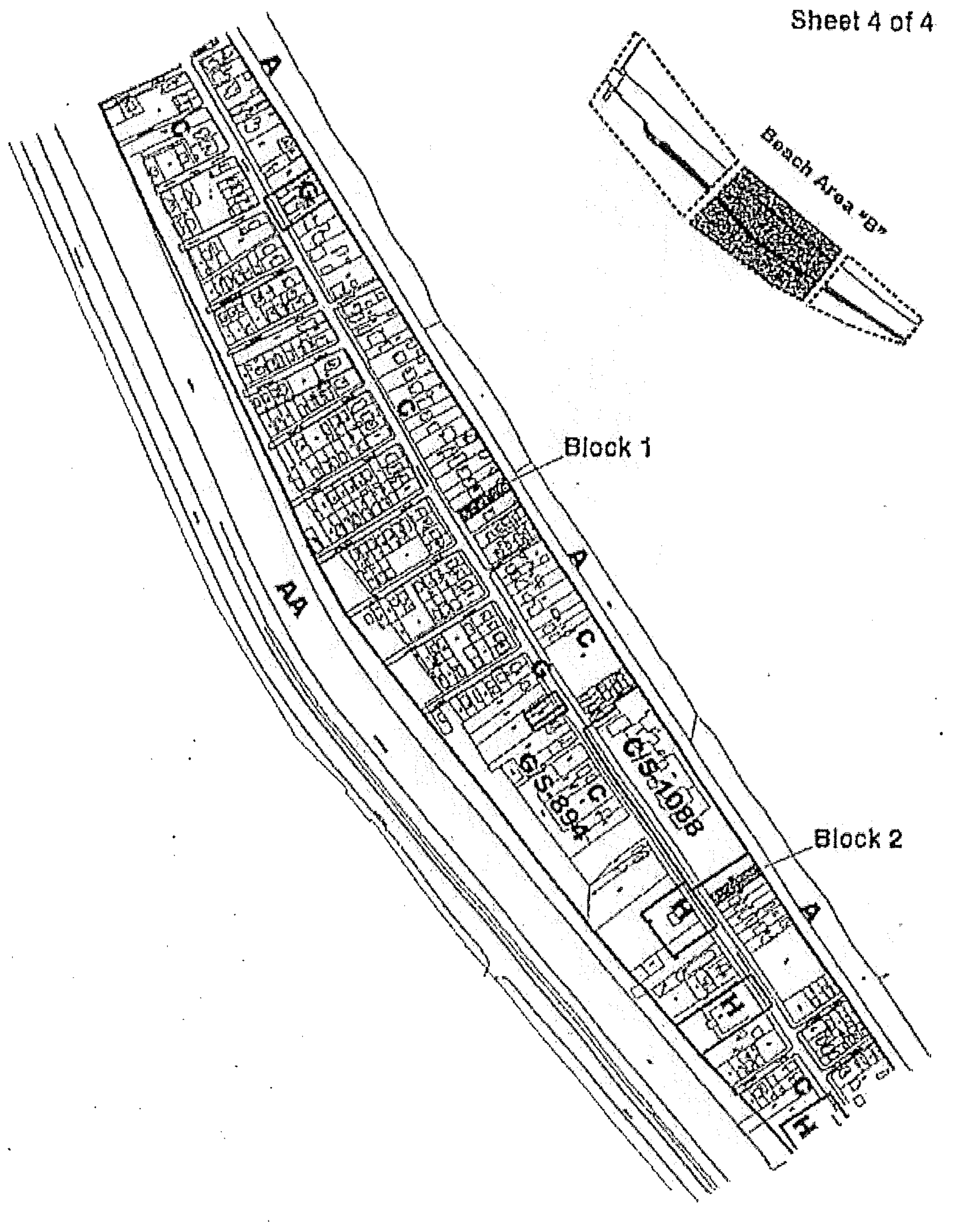
.... Mayor



This is Schedule "A-2" to By-Law No. 99-.169...
Passed the ......30th...... day of ......November................, 1999.

Clerk

Mayor



This is Schedule "A-3" to By-Law No. 99-169....
Passed the ......30th...... day of ......November................ , 1999.

Clerk

Mayor

The Corporation of the City of Hamilton

BY-LAW NO. 99- 170

To Amend:

Zoning By-law No. 6593 and
To Repeal Zoning By-law No. 98 281

Respecting:

LANDS LOCATED WEST (BAY SIDE) OF BEACH BOULEVARD, IN
THE BEACH NEIGHBOURHOOD

WHEREAS the Council of The Corporation of the City of Hamilton passed Zoning By-law No. 6593 on the 25th day of July 1950, which by law was approved by the Ontario Municipal Board by Order dated the 7th day of December 1951, (File No. P.F.C. 3821;

AND WHEREAS the Council of The Corporation of the City of Hamilton passed By-law No. 98-281 on the 10th day of November 1998 to establish special requirements under Section 198 of Zoning By-law No. 6593 for the ."C" District, in respect of lands located on the west side (bay side) of Beach Boulevard, in the Beach Neighbourhood, the extent and boundaries of which are shown on a plan thereto annexed as Schedule "A", which by-law came into force on the day it was passed in accordance with the Planning Act;·

AND WHEREAS the Council of The Corporation of the City of Hamilton, in adopting Section – of the 19th Report of the Planning and Development Committee at its meeting held on the 9th day of November 1999, recommended that Zoning By-law No. 6593 be amended as hereinafter provided and that Zoning By-law No. 98-281 be repealed in its entirety;

AND WHEREAS this by-law is in conformity .with the Official Plan of the Hamilton Planning Area, approved by the Minister under the Planning Act on June 1, 1982.

NOW THE FORE the Council of The Corporation of the City of Hamilton enacts as follows:

notwithstanding clause (a), a side yard maybe reduced to a width of at least 1.5 metres, only where a common swale between the adjoining properties has been approved under a lot Grading Agreement or approved under a Site Plan Control Agreement; and,

notwithstanding clauses (a) and (b), Sections 18(3)(v), (viccc), and (vi)(e) shall not apply to side yards; and,

(d) the minimum ground floor elevation of any building or any building addition shall be 76.0 metres above mean sea level, as defined by the Geodetic Survey Datum, except for any building addition less than 14 square metres in area and any accessory building or structure; and,

no basement or cellar shall be permitted for any building; and,

(f) any addition, less than 14 square metres in area, shall have a minimum floor elevation at or above the existing ground floor elevation of the building; and,

prior to the issuance of a building permit for every new building, a Lot Grading Agreement with the City of Hamilton shall be entered into and registered on title to the satisfaction of the Building Department Director, except for developments that require approval under the Site Plan Control By-law No. 79-275, as amended.

2. The °C" (Urban Protected Residential, etc.) District provisions, as contained in Section 9 of Zoning By-law No. 6593, applicable to the lands comprised in Blocks "1" and "2", the extent and boundaries of each Block are shown on a plan hereto annexed as Schedule "A-3", are amended to the extent only of the special requirement that,

No building or structure, except fences shall be located within 4.5 metres of the rear lot line:

(i) every fence, excluding the supporting posts must be at least .075m from the ground to the bottom of the fence, so as not to obstruct the natural flow of water.

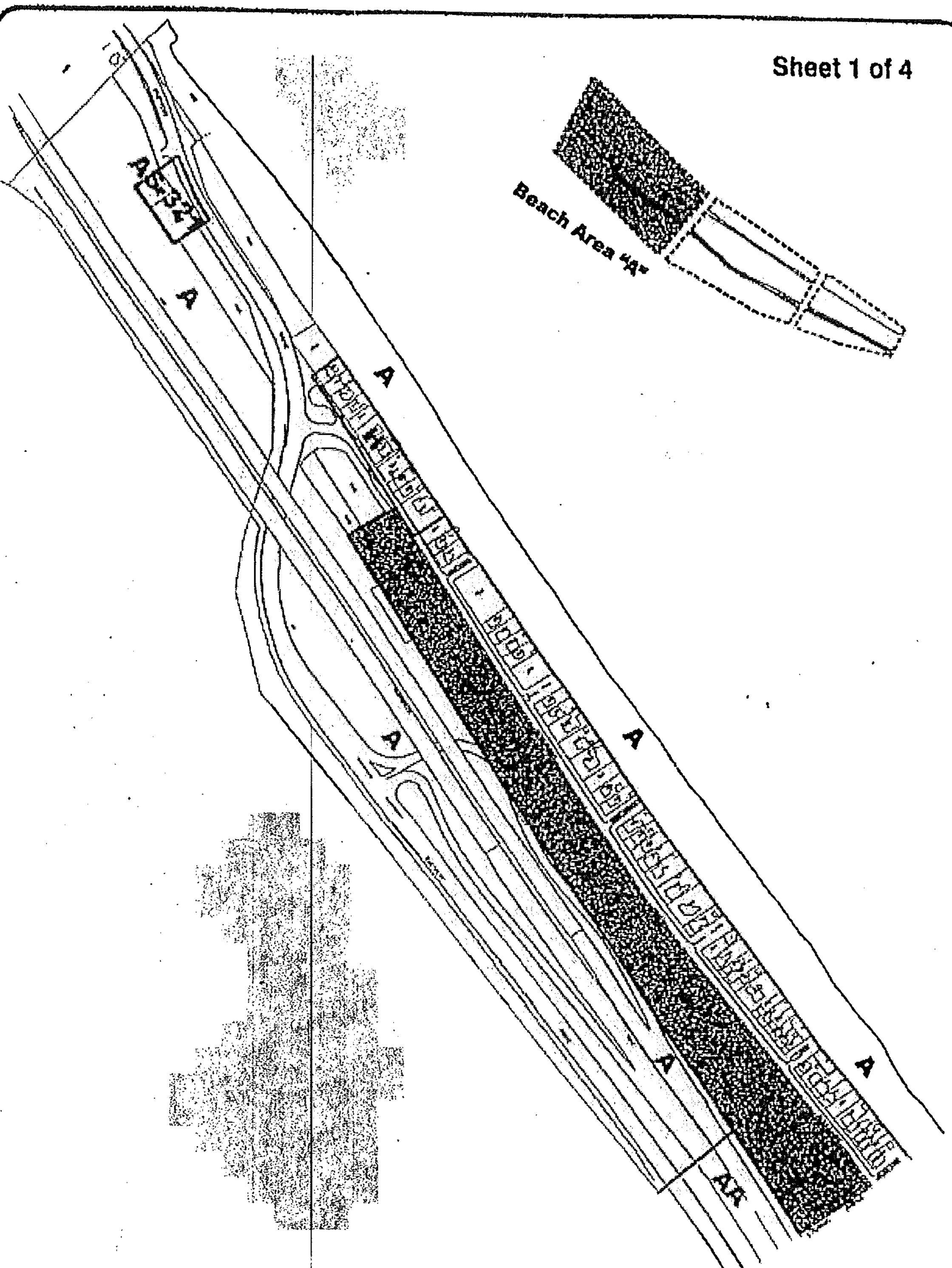
4. No building or structure shall be erected, altered, extended or enlarged, nor shall any building or structure or part thereof be used, nor shall any land be used, except in accordance with the "C, "G" and "H" District provisions, subject to the special requirements referred to in sections 1 and 2 of this by-law.

5. The Municipal Clerk is hereby authorized and directed to proceed with the giving of notice of the passing of this by-law, in accordance with the Planning *Act.*

PASSED this 30th day of November AD. 1999

MUNICIPAL CLERK MAYOR

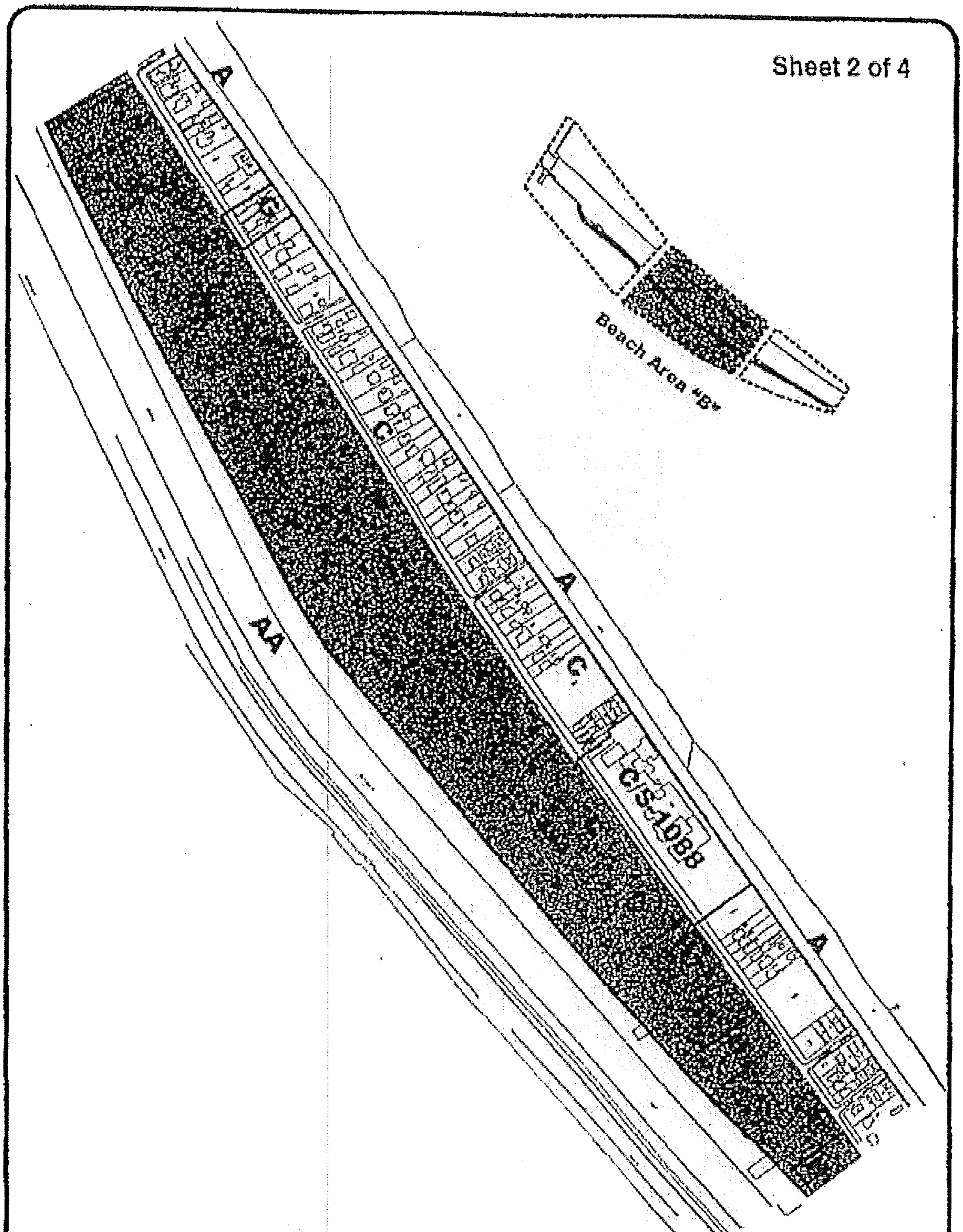
(1999) 23^{RD} R.P.D.C. (12A)-, November 30
City Initiative 98-D



This is Schedule "A" to By-Law No. 99-170...
Passed the ......30th...... day of .....November..............., 1999.

.... Clerk

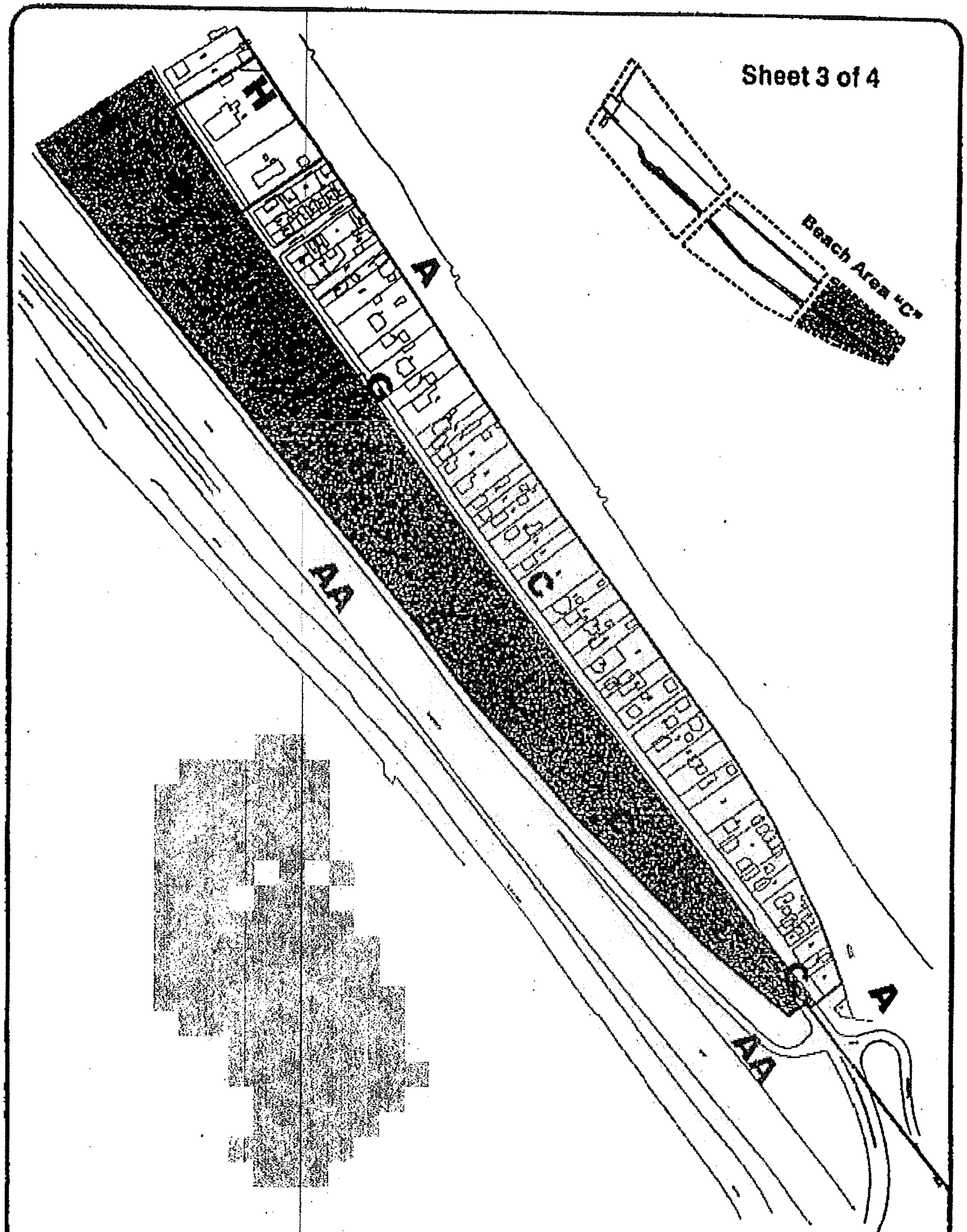
.... Mayor



This is Schedule "A-1" to By-Law No. 99-.170..
Passed the ......30th...... day of ......November............... , 1999.

Clerk

Mayor

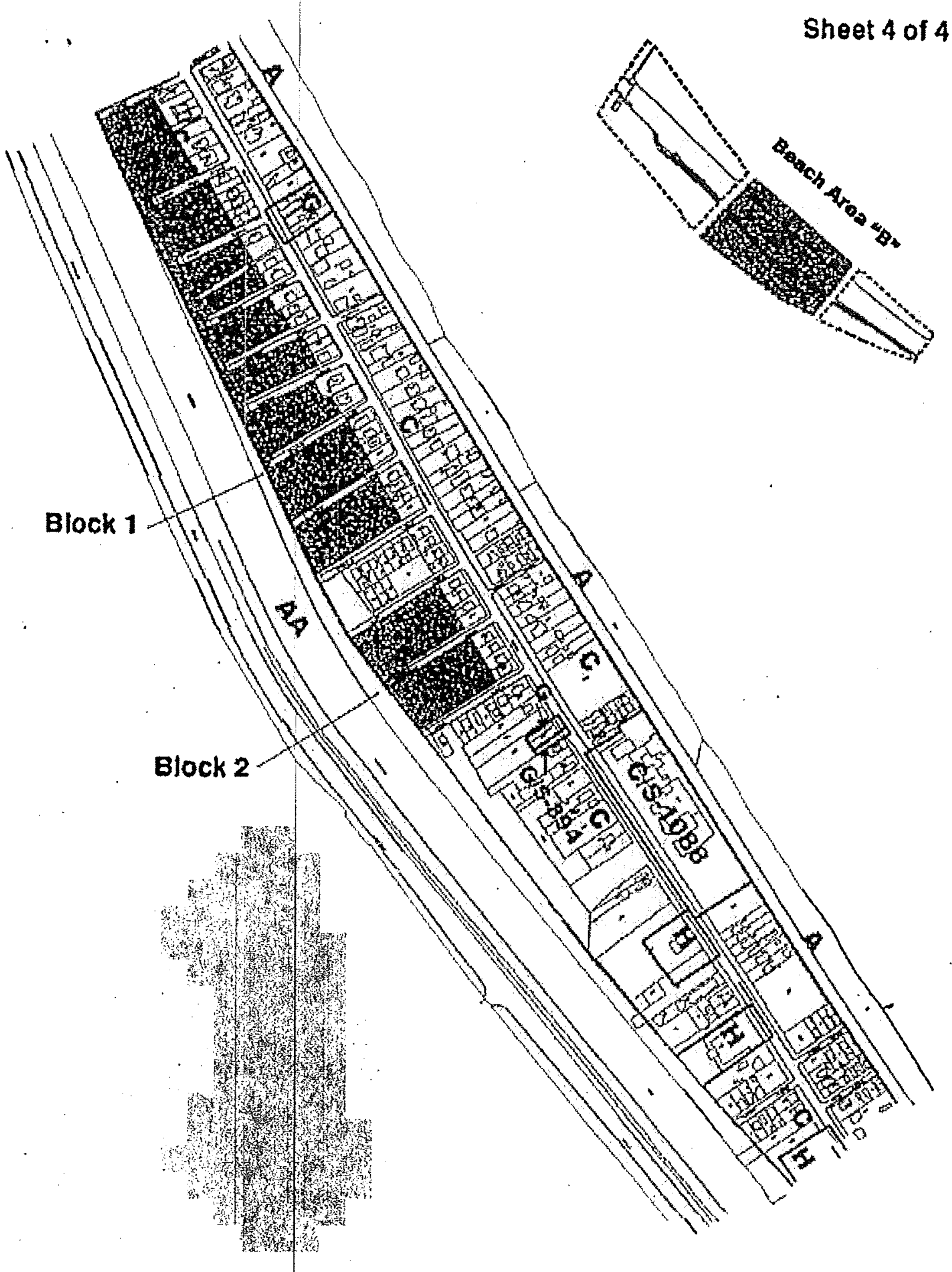


This Is Schedule "A-2" to By-Law No. 99-170....
Passed the ......30th...... day of ......November..............., 1999.

Clerk

Mayor

Sheet 4 of 4



This is Schedule "A-3" to By-Law No. 99-170..
Passed the ......30th...... day of ......November................, 1999.

....
Clerk

....
Mayor

Bill No. C- 051

The Corporation of the City of Hamilton

BY-LAW NO. 00- 136

To Amend:

Zoning By-law No. 6593
As Amended by Zoning By-laws No. 99-169 and 99-170

Respecting:

LANDS LOCATED AT
MUNICIPAL NOS. 869-1019 and 870-1064 BEACH BOULEVARD

WHEREAS the Council of The Corporation of the City of Hamilton passed Zoning By-law No. 6593 on the 25th day of July 1950, which by-law was approved by the Ontario Municipal Board by Order dated the 7th day of December 1951, (File No. P.F.C. 3821);

AND WHEREAS the Council of The Corporation of the City of Hamilton passed By-law No. 99-169 on the 30th day of November 1999 to establish special requirements under Section 19B of Zoning By-law No. 6593, for the "C", "G" and "H" Districts, in respect of the lands located east (Lake Side) of Beach Boulevard, in the Beach Neighbourhood, the extent and boundaries of which are shown on a plan thereto annexed as Schedule "A", which by-law came into force on the day it was passed in accordance with the Planning Act;

AND WHEREAS the Council of The Corporation of the City of Hamilton passed By-law No. 99-170 on the 30th day of November 1999 to establish special requirements under Section 19B of Zoning By-law No. 6593, for the "C", "G" and "H" Districts, in respect of the lands located west (Bay Side) of Beach Boulevard, in the Beach Neighbourhood, the extent and boundaries of which are shown on a plan thereto annexed as Schedule "A", which by-law came into force on the day it was passed in accordance with the Planning Act;

AND WHEREAS the Council of The Corporation of the City of Hamilton, in adopting Section 5 of Report Thirteen of the Planning and Development Committee at its meeting held on the 9th day of August 2000, recommended that Zoning By-law No. 6593, as amended by By-laws No. 99-169 and 99-170, be further amended as hereinafter provided;

AND WHEREAS this by-law is in conformity with the Official Plan of the Hamilton Planning Area, approved by the Minister under the Planning Act on June 1, 1982.

NOW THEREFORE the Council of The Corporation of the City of Hamilton enacts as follows:

1. The "C" (Urban Protected Residential, etc.) District provisions, as contained in Section 9 of Zoning By-law No. 6593, as amended by By-laws No. 99-169 and 99-170, applicable to the lands shown on a plan hereto annexed as Schedule "A" and forming part of this by-law, are further amended to the extent only of the special requirements that,

   (a) notwithstanding subsection 9. (2) of Zoning By-law No. 6593, no building shall exceed two storeys and no structure shall exceed 9.0 metres in height; and,

(b) notwithstanding Section 9. (3) (i) of Zoning By-law No. 6593, the maximum front yard depth for the dwelling shall not exceed 12.0 metres; and,

(c) for a dwelling with a carport or attached or detached garage, then the following provisions shall apply:

(i) notwithstanding any other provision of this by-law or Zoning By-law No. 6593, the front wall of the carport or garage shall be located a minimum of 1.5 metres behind the main wall of the dwelling and in every case have a front yard depth of not less than 7.5 metres; and,

(ii) Sections 18. (2) (i) and 18. (3) (iii) of Zoning By-law No. 6593 shall not apply.

2. No building or structure shall be erected, altered, extended or enlarged, nor shall any building or structure or part thereof be used, nor shall any land be used, except in accordance with the "C" District provisions, subject to the special requirements referred to in sections 1 and 2 of By-law No. 99-169, sections 1 and 2 of By-law No. 99-170 and section 1 of this by-law.

3. By-law No. 6593 is amended by adding this by-law to section 19B as Schedule S-1435a and S-1436a.

4. Sheets No. E-80e and E-80f of the District Maps are amended by marking the lands referred to in sections 1 and 2 of By-law No. 99-169, sections 1 and 2 of By-law No. 99-170 and further amended by section 1 of this by-law, S-1435a and S-1436a.

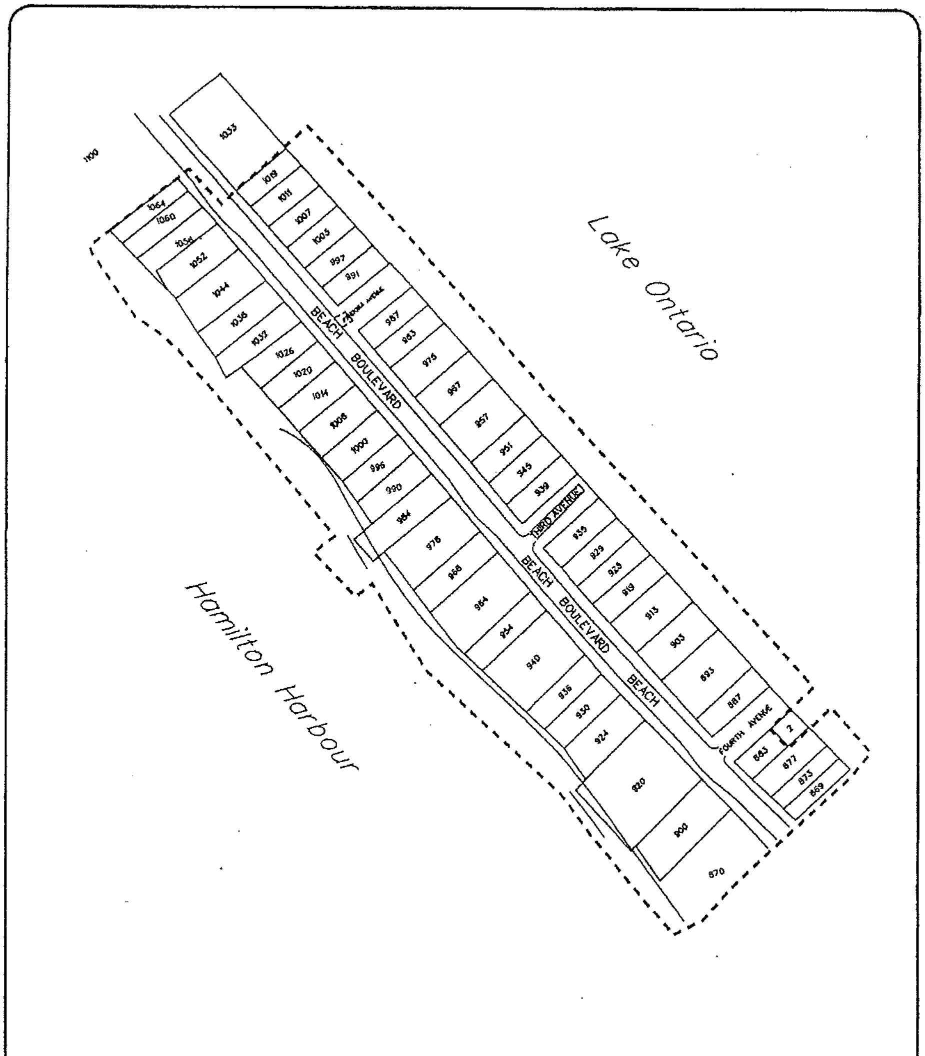
5. In all other respects, By-laws No. 99-169 and 99-170, are hereby confirmed, unchanged.

6. The Acting Municipal Clerk is hereby authorized and directed to proceed with the giving of notice of the passing of this by-law, in accordance with the Planning Act.

PASSED this 9th day of August A.D. 2000

ACTING MUNICIPAL CLERK MAYOR

(2000) 13 R.P.D.C. , August 9
City Initiative 00-D



This is Schedule "A" to By-Law No. 00 -136..........
Passed the ....9th... day of ..August...2000.

Clerk

Mayor

City of Hamilton

Schedule "A"

Map Forming Part of
By-Law No. 00- 136
to Amend By-Law No. 6593

Community Planning and Development Division

Legend

Modification to the "C" (Urban Protected Residential, etc) District regulations.

North	Scale	Reference File No.
	NOT TO SCALE	CI-00-D
	Date	Drawn By
	July, 2000	J.S

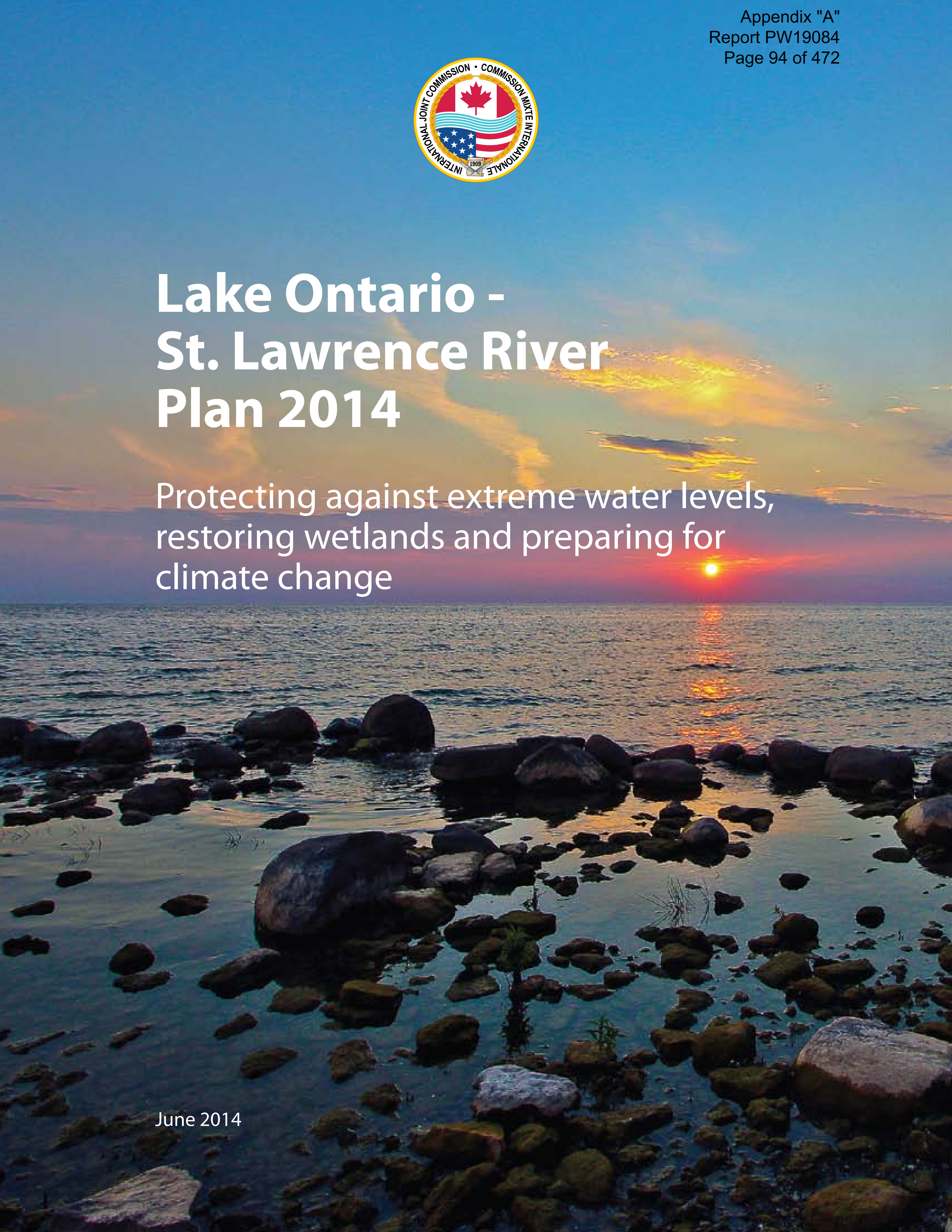
Appendix C

Plan 2014 – International Joint Commission

DILLON CONSULTING

Lake Ontario - St. Lawrence River Plan 2014

Protecting against extreme water levels, restoring wetlands and preparing for climate change



June 2014

A Report to the Governments of Canada and the United States by the International Joint Commission

For more information on regulation of Lake Ontario and St Lawrence River water levels or the International Joint Commission (IJC), please visit the IJC's website: www.ijc.org. Information also can be obtained by contacting any of the following IJC offices:

United States Section Office
2000 L Street, NW, Suite 615
Washington, DC 20440
Phone: 202-736-9000
Fax: 202-632-2006

Canadian Section Office
234 Laurier Avenue West
22nd Floor
Ottawa, ON K1P 6K6
Phone: 613-995-2984
Fax: 613-993-5583

Great Lakes Regional Office
100 Ouellette Avenue
8th Floor
Windsor, ON N9A 6T3
Phone: 519-257-6700
Fax: 519-257-6740

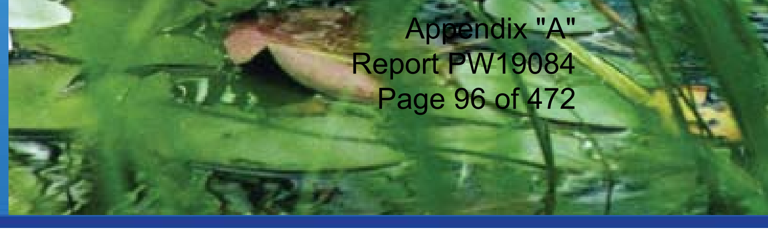
This report may be cited as:
International Joint Commission (2014). Lake Ontario St. Lawrence River Plan 2014: Protecting against extreme water levels, restoring wetlands and preparing for climate change.

ISBN: E95-2/18-2014E-PDF
978-1-100-24424-2

Cover: Istockphoto.com

@IJCsharedwaters

Facebook.com/internationaljointcommission



Preface

The Akwesasne people have lived in the territory that currently straddles the borders of Ontario, Quebec and New York for centuries. Although divided by an international border today, the Akwesasne live as one community, with some people in this nation residing just two miles downstream of the Moses-Saunders dam on Kawhno:ke, also known as Cornwall Island.

The Akwesasne live within sight of the Moses-Saunders Dam and in the 1950s they watched the dam be built across their western view. Perhaps they, more than any, appreciate the change to nature that was made, and they continue to press their concerns for the well-being and long-term health of the Lake Ontario and St. Lawrence River basins.

On July 19, 2013 during the International Joint Commission's Public Hearings on Plan 2014 that were held throughout communities within the basins, Henry Lickers, Environmental Science Officer and former member of the International Lake Ontario – St Lawrence River Study Board, honored Commissioners with an invocation that traditionally opens and closes his nation's meetings with governments and contains the teachings of how one is to conduct one's self in harmony with the natural world.

> *These words that come before all else are the ones that open everything, and we heard a little bit about the good mind and bringing your mind together to think about the problems. These are all of our problems. These are our issues and we feel responsible for them, whether it's my boating friends or my little minnow, we have a responsibility to them.*
>
> *And we say whenever we are gathered, one of us is chosen to do a greetings and thanks giving and I'd like you to think about the people of this world. There are many people that aren't as well off as we are and they live across this world and across this River. And I would say to you that my sons and daughters and your sons and daughters live in that water as well. So I ask you to bring together your minds and think about the peoples of this world, and can we agree that they are important to us?*
>
> *I ask you to think about the Mother Earth, for she continues to carry out her responsibility to us, never ceasing in her responsibility. We say that if you look at the colors of the soils of that world, in those colors of those soils you see the colors of every one of our skins and we know that she is our mother and that she will continue in her responsibility. So I ask you to bring together your minds and think about the Mother Earth, and can we agree that she is important to us?*
>
> *Today we have concentrated on the waters and the fishes of this world; they have been most important to our discussions and we know that they will continue to carry out their responsibilities. And they don't need anyone to teach them what their responsibilities to us are, but they continue to do this. So I ask you to bring together your minds and think about the waters and the aquatic life like our fishes, and can we agree that they are important to us?*
>
> *I know that we have spent a little time talking about the plants of this world, and the Haudenosaunee looked at the plants and we have a special relationship with them. We have three, called the Three Sisters: corn, beans and squash that have helped sustain our populations. But we also know that in those waters have been many medicine plants that can help us and it seems that the waters and the marshes and the wetlands seem to be those places where those medicine plants are. And then we talk about the trees. The trees that give so much to us and all of the things we see around us that are beneficial to make our lives a better place to live upon this world. So I ask you to bring together your minds and think about the plants of this world, and can we agree that they are important to us?*
>
> *We don't live here alone. We live here with many other species and this morning I rose and heard the crows crying in my backyard, waking me as usual. But we also have other animals; the four legged type. Some of them living in our own homes and we call them our pets but we treat them like they're our brothers and sisters. And so I would say to you that all of the animals and birds of this world deserve the same respect and deserve the same as our brothers and sisters. And so I ask you to bring together your minds and think about the animals and birds of this world, and can we agree that they are important to us?*

Today as we look outside we see the Four Great Winds getting ready to blow us a blustering night I think, and during that time we will hear the voices of our grandfathers. We call those the Thunderers, and they speak to us. But what they tell us is to be ever vigilant as we live upon this land for the land is changing and we must be ready for it. We must be the ones that help fulfill our responsibilities to the world around us. And so I ask you to bring together your minds and think about the Four Great Winds and those Thunderers, and can we agree that they are important to us?

This morning our elder brother the sun rose as he has done millennium after millennium, never ceasing in his responsibility to us and to all of creation. That we could carry out our responsibilities as such, this would truly be a wonderful thing. So I ask you to bring together your minds and think about our elder brother the sun, and can we agree that he is important to us?

This evening we'll see our grandmother moon as she turns her face to us every 28 days, and that 28-day cycle is the cycle of all female things in this world. And without that 28-day cycle it would truly be a lonely place. But she's also very powerful and she has the ability to move all of the waters of this world, even the waters of the first environment: the womb. And so I ask you to bring together your minds and think about grandmother moon and through her all female things upon this world, and can we agree that she is important to us?

In the evening we see the stars as they shine down upon us, and the Haudenosaunee say these are our aunties and uncles and they are still here with us looking down upon us. They guide us across the surface of this Earth and foretell of great events that will occur in our communities, but they too are carrying out their responsibilities to us. And so I ask you to bring together your minds and think about those stars, and can we agree that they are important to us?

Again we know that we don't exist here alone but we know that there's a spiritual world that surrounds us and that there are many spirits out there that can help us in our deliberations. The Haudenosaunee say that whenever our deliberations are so tough and that we really need to think about our answers and questions, that if we look deep into our souls those answers will come to us and lead us to peace and harmony upon this world. And so I ask you to bring together your minds and think about the spiritual world that surrounds us, and can we agree that they are important to us?

We know that there are many other teachers in this world and we sit here today and listen to our problems that we have, but we know that we have the knowledge that come to us down the corridors of time from elders and ancestors that have preceded us and each of us have those trusted elders that we have listened to in the past and hear their knowledge today and we will build on that knowledge that this will be a better place. And so I ask you to bring together your minds and think about those teachers of the world, and can we agree that they are important to us?

It has come that at this time we will cover our Council fire and as the Haudenosaunee would say "unbind that stout cord that bound us all in this place that we could talk about our responsibilities to the world. And I'll cut that cord now that we may each go our own separate way." But before we do that, the Haudenosaunee say we must never ask anything of the Creator, but on your behalf today I'll ask two things of the Creator: I'll ask that as you proceed from this place to your homes, your lodgings and your communities, that no impediment is placed in your way and that you arrive there safely. And the second thing I'll ask on your behalf is that when you arrive at your homes, your lodgings and your communities, that you see the happy smiling faces of your people and that no misfortune has befallen them while you've been here.

And so now those words have been said and our Council fire is closed but I call on you my friends one last time to bring together your finest thoughts and your finest thanksgiving and we'll pile them in a huge pile before us to send to the Creator of all things for the beauty that surrounds us. Ne onkwa'nikònra

International Joint Commission
Canada and United States

Commission mixte internationale
Canada et États-Unis

The United States of America and Canada are the applicants on the St. Lawrence Power Project as well as the Parties to the Boundary Waters Treaty. The International Joint Commission (the Commission) seeks the views and concurrence of the United States and Canada on the matter of amending the Order of Approval for the St. Lawrence Power Project (Docket No. 67 and 68). The Commission submits its conclusions on the matter of regulating Lake Ontario and St. Lawrence River levels and flows in a spirit consistent with the Boundary Waters Treaty.

The International Joint Commission, after 14 years of scientific study and public engagement, advances Plan 2014 as the preferred option for regulating Lake Ontario-St. Lawrence River water levels and flows. Scientific studies reveal that the Commission's 1956 Orders of Approval and regulation of the flows through the power project following Plan 1958D with deviations, have harmed ecosystem health primarily by substantially degrading 26,000 hectares (64,000 acres) of shoreline wetlands. After exhaustive consideration of alternative plans, the Commission concludes that Plan 2014 offers the best opportunity to reverse some of the harm while balancing upstream and downstream uses and minimizing possible increased damage to shoreline protection structures.

The Commission was created by a century-old treaty between the United States and Canada to help the two countries address challenging issues arising from managing their shared waters. The Commission has respectfully considered the diverse and often competing uses and interests affected by any regulation plan in reaching its conclusion that the current method of regulating the levels and flows of Lake Ontario and the St. Lawrence River needs to be modified. The Commission seeks the concurrence of the Parties on revising the Order to consider ecosystem health with respect to all other interests and uses of the Lake Ontario-St. Lawrence River system.

Plan 2014 is designed to provide for more natural variations of water levels of Lake Ontario and the St. Lawrence River that are needed to restore ecosystem health. It will continue to moderate extreme high and low levels, better maintain system-wide levels for navigation, frequently extend the recreational boating season and slightly increase hydropower production. More year-to-year variation in water levels improves coastal health. Thriving wetland habitats support highly valued recreational opportunities, filter polluted run-off, and provide nurseries for fisheries and wildlife. Ecosystem health was not considered in the 1950s when decisions were made to artificially compress the natural variability of levels of Lake Ontario.

Plan 2014 incorporates insights from more than 50 years of operational experience, significantly increased knowledge gained through the Commission's five-year landmark study, and additional analysis by U.S. and Canadian experts and important contributions from Quebec, Ontario and New York State, as well as from municipal governments, indigenous governments, and shipping, fishing, recreational, riparian, cultural, environmental and other interests that depend upon the St. Lawrence River and Lake Ontario.

The Commission acknowledges that erosion and storm damage are realities along the Lake Ontario shoreline. Varying degrees of erosion and damage to structures built close to the shoreline were present before the dam was built, are present under Plan 1958D with deviations (Plan 1958DD) and will exist under Plan 2014 or any other regulation plan. Due to local geology, as well as land use and development patterns, some south shore areas of Lake Ontario are uniquely vulnerable to occasional higher waters. In comparing Plan 2014 to Plan 1958DD, the Commission recognizes that costs to maintain hardened shoreline protection structures, such as shorewalls and revetments, may increase by a relatively small amount under Plan 2014.

However, before selecting Plan 2014, the Commission considered an exhaustive list of options in order to select the best possible plan to provide significant environmental restoration with overall economic benefits and the smallest increase in damage to any property, infrastructure, shipping or recreational interests.

Based on the science and consultations that guided the development of Plan 2014 – as well as on the principles and objectives of the recently reaffirmed Great Lakes Water Quality Agreement – the Commission recommends that governments and the Commission's Lake Ontario-St. Lawrence Board adopt an adaptive management strategy to foster a binational technical network, and support performance evaluation. The Board will provide regular public engagement opportunities through annual and special meetings, regular electronic updates, and timely responses to questions and comments received through its website or via social media.

Recognizing that modifications to Plan 1958DD have been the subject of discussion for several decades, the Commission believes Plan 2014 should be implemented soon after a timely review and concurrence by the Parties on the question of amending the Order of Approval. Once adopted, no significant changes would occur to Plan 2014 without a convenient opportunity for all interested parties to be heard and consultation with the governments. The accompanying report provides a brief historical overview, description of Plan 2014, responses to common concerns, alternatives considered and information on its public engagement process. Annexes provide further technical aspects of Plan 2014 regulation rules, governance, and an adaptive management program.

Plan 2014 represents the culmination of considerable work undertaken by all interests in the basin. Plan 2014 found widespread but not unanimous support throughout the basin. The Commission appreciates the more than $20 million financial investment by the Governments of Canada and the United States, which made possible the extensive scientific studies and public engagement that provide the foundation for Plan 2014. The Commission thanks the scores of Study Board and Public Advisory Group participants, hundreds of involved scientists and technical experts, its own staff and the thousands of people who have commented on the impacts of regulating levels and flows in Lake Ontario and the St. Lawrence River. On whole, the IJC is confident that Plan 2014 is the best management path for the human, plant, and animal communities and for the commercial interests that depend on Lake Ontario and the St. Lawrence River system in both Canada and the United States.

Lana Pollack
United States Chair

Gordon Walker
Interim Canadian Chair

Richard Moy
Commissioner

Benoît Bouchard
Commissioner

Dereth Glance
Commissioner

Executive Summary

This report to the Governments of Canada and the United States presents the conclusions of the International Joint Commission (IJC) investigation regarding needed changes to the 1952 and 1956 Orders of Approval for the St. Lawrence River Power Project.

After years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario, Plan 2014, should be implemented as soon as possible. A summary description of Plan 2014 is included in the main body of this report, with further technical details provided in the annexes.

The IJC finds that the regulation of water levels and flows in the St. Lawrence River in accordance with the 1952 and 1956 Orders of Approval has damaged ecosystems along the coast of Lake Ontario and upper St. Lawrence River over the last 50 years or more. The effects of the regulation of water flows and lake levels on ecosystems were not fully understood or considered when the existing Order of Approval and regulation plan were developed. However, robust coastal ecosystems are now recognized as essential in both countries, and the IJC finds that the effects on ecosystems should now be considered along with effects to other interestsand uses.

The IJC has reached these conclusions in consideration of the results from 14 years of study and extensive open public consultations with all interested parties. In 2000, the U.S. and Canadian governments agreed to provide about $20 million over five years for the IJC to conduct a thorough and comprehensive study to evaluate and recommend improvements to the regulation of Lake Ontario levels and outflows, including, among other issues, environmental concerns. This investment enabled the IJC to undertake scientific studies to understand and measure the effects of water levels and conduct extensive engagement with people from all interests in the formulation and evaluation of hundreds of potential alternative regulation plans.

Among the conclusions of its 2006 final report (IJC, 2006), the IJC's Lake Ontario-St. Lawrence River Study Board found that the compression of the range of water levels on Lake Ontario and the upper river has degraded coastal wetlands. It found that environmental conditions could be improved by changing the regulation plan, but not without tradeoffs that will reduce some existing economic benefits.

The IJC invited public comment and undertook a thorough review of the 2006 report and public comments. In 2008, the IJC invited comment on a proposed new Order of Approval and regulation plan, known as Plan 2007, based on one of the three options recommended by the Study Board. The IJC heard widespread opposition to Plan 2007 throughout the Lake Ontario–St. Lawrence River basin. In 2008, the IJC concluded that Plan 2007 was not viable, and sought the advice of governments on how to proceed.

In 2009, a new group was established with officials appointed by the two federal governments and the governments of New York, Ontario and Quebec to advise the IJC on the potential for a new regulation plan. Of the many regulation plans developed to date, the group determined that a plan that resulted in more natural flows and lake levels was preferable. It then worked to refine a regulation plan that the IJC developed into Plan 2014.

The IJC finds that Plan 2014 provides the best response to the range of issues that must be considered in regulating the water levels and flows of the Lake Ontario-St. Lawrence River system. Plan 2014 will mitigate much of the harm done by the existing regulation regime to the shoreline environment, while striving to maintain the benefits to other interests and users throughout the system. Plan 2014 will respect the order of precedence of uses specified in the *Boundary Waters Treaty of 1909*, while protecting interests that may be harmed by regulation.

Plan 2014 returns Lake Ontario levels to more natural variability, while continuing to moderate extreme low and high water levels

Figures Ex-1, Ex-2 and Ex-3 are examples of what are known as a "spaghetti graph". In these graphs, each year's water levels are shown as a separate line running from January to December. These three simulations of Lake Ontario levels were run using the historical water supply data for 1900-2000. The thick black dashed lines in each graph follow the minimum and maximum levels of Plan 1958DD for any year.

Under Plan 1958DD, the range of water levels is more compressed, particularly at the beginning of the year, when lower levels mean less productive wetlands.

By contrast, Plan 2014 represents a return to more natural level variability for Lake Ontario. It would relax the compressed Lake Ontario levels of Plan 1958-DD, but with the upper levels still substantially controlled to protect Lake Ontario riparians. The maximum level simulated under Plan 2014 is only 6 cm (a little more than 2 in) higher than the maximum level under Plan 1958DD.

The Natural Plan (referred to as Plan E in study documents) represents the release of Lake Ontario water through the existing flow control structures equivalent to what would occur with the unregulated river as it was circa 1953-1955 after removal of Gut Dam, but before any of the structures or channels approved in the 1952 and 1956 Orders were built, with minimal adjustments to reflect necessary ice management with the structures in place.

The reduction in high levels from Plan E to either Plan 2014 or Plan 1958DD represents the benefit provided to riparians along the Lake Ontario shoreline in terms of reduced damages to coastal shoreline protection structures and fewer flooded houses. In water supply conditions more extreme than historical conditions, Plan 2014 would operate under the same premise as Plan 1958DD: protecting riparians both upstream and downstream of the control structures.

Figure Ex-1

Lake Ontario Levels, Simulated for Plan 1958DD

(1 line for each of 101 years historical record)

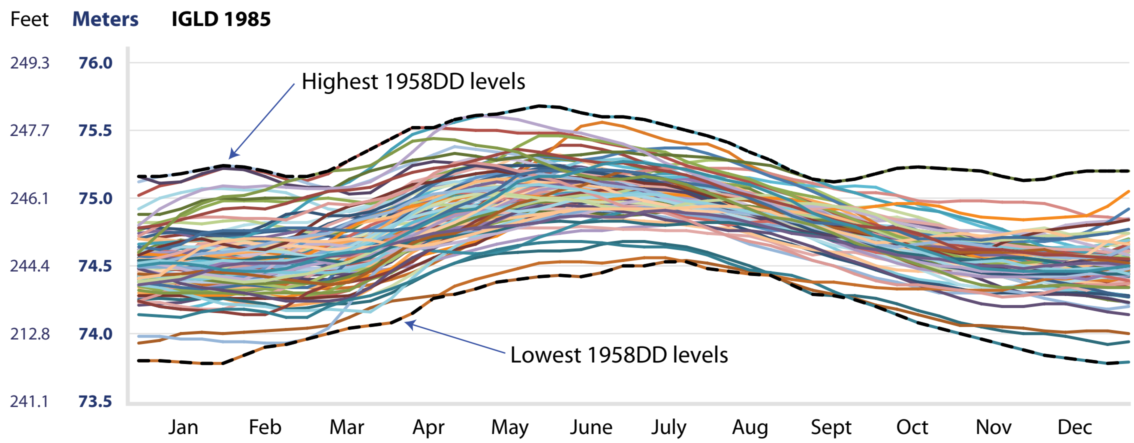


Figure Ex-2

Lake Ontario Levels, Simulated for Plan 2014

(1 line for each of 101 years historical record)

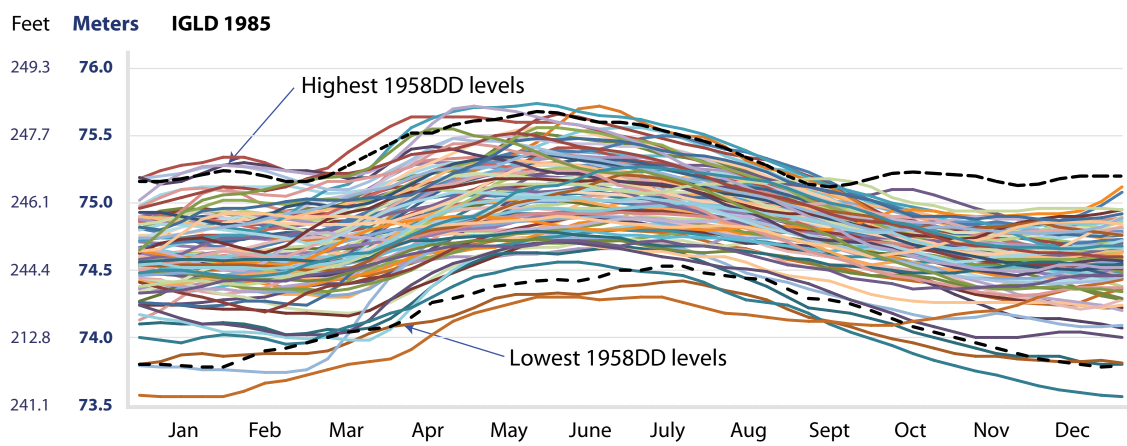
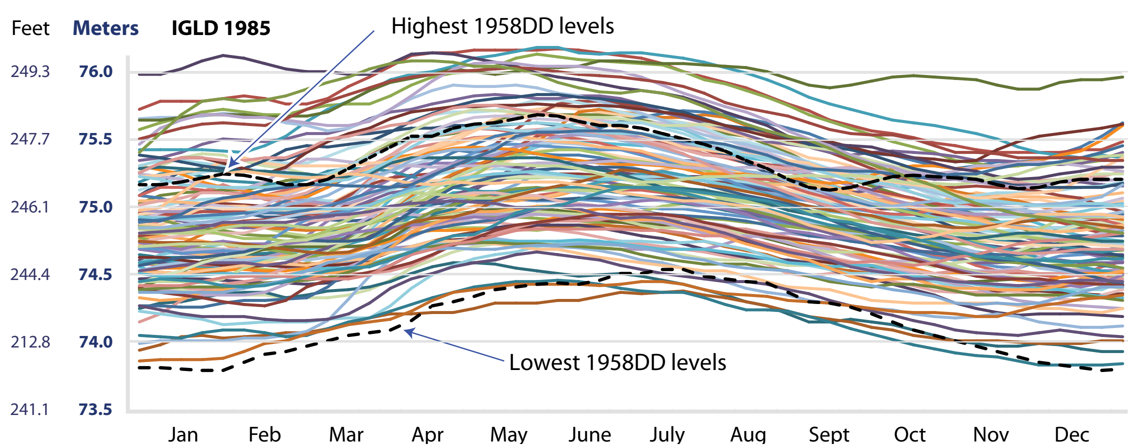


Figure Ex-3

Lake Ontario Levels, Simulated for No Regulation (Plan E)

(1 line for each of 101 years historical record)



Compared to the existing regulation plan for Lake Ontario and the St. Lawrence River, Plan 2014 will:

- provide essentially the same level of benefits to **domestic water uses**;
- provide essentially the same level of benefits for **navigation**;
- increase by a small amount the generation of **hydropower** at the Moses-Saunders dam and the Hydro-Quebec facilities on the St. Lawrence River;
- provide **riparians** (owners of shoreline property) on the upper and lower river essentially the same level of protection;
- result in a small reduction of benefits to **riparians** on Lake Ontario, in the form of increased costs of maintaining shoreline protection structures;
- work to restore the natural **environment** of Lake Ontario and the upper St. Lawrence River that support wetlands, birds, amphibians, fish, and mammals;
- have a mixed effect on **recreational boaters**; and,
- provide essentially the same benefits **downstream** of the dam as does the current regulation regime.

Some of the benefits now enjoyed by domestic water users, commercial navigation, hydropower producers and riparians on the St. Lawrence River are the result of ad hoc, discretionary decisions by the International St. Lawrence River Board of Control. Plan 2014 will make these benefits more assured and predictable, by removing the discretionary aspect of many of these decisions and formally making them part of the Plan's regulation rules.

Regulation of Lake Ontario outflows since 1960 has substantially compressed the range of Lake Ontario water levels compared to what would have occurred without regulation. Figures Ex-1 to Ex-3 illustrate this compression using what have come to be known as "spaghetti" graphs. These three graphs show 101 years of Lake Ontario water levels, with each year's level shown as a separate line running from January to December. These simulations were run using the historical water supply data for 1900-2000:

- Figure Ex-1 shows the compression of the range of lake levels resulting from the application of the current regulation regime (called Plan 1958-D with deviations, or Plan 1958DD);
- Figure Ex-2 shows the lake levels with Plan 2014 applied; and
- Figure Ex-3 shows what levels would be with no regulation except that minor amount necessary to control ice jam flooding.

The compression of lake levels shown in Ex-1 has benefitted property development along the Lake Ontario shore, but caused substantial harm to coastal ecosystems. To address that harm, Plan 2014 produces more natural water level cycles, while continuing to moderate extreme high and low water levels. The benefit provided to Lake Ontario shoreline property interests under either Plan 2014 or Plan 1958DD is clear when comparing Figure Ex-3 to either of the other two figures. The IJC's analysis found that without lake level regulation, property damage along the Lake Ontario shoreline would average more than $45 million[1] per year (IJC, 2006).

Plan 2014 is projected to have little effect on buildings compared to the current plan but likely will increase the costs of shore protection structures, such as sea walls and revetments. Plan 2014 will continue to provide significant benefits for riparians relative to what they would experience if there were no lake level regulation.

Plan 2014 will have little impact on buildings compared to the current plan, but is likely to increase the cost of shore protection.

[1] All economic values are expressed in $US 2005.

Despite a 10-year open and vigorous competition to design the ideal regulation plan, no plan has ever been developed that can help restore coastal ecosystems, maintain all the benefits to other interests and gain unanimous public support. After examining many alternative regulation plans, the IJC concludes that no regulation plan can meaningfully reduce the current risk of damage to some shoreline protection structures and some properties along the south shore of Lake Ontario. However, it may be possible to significantly reduce that risk through better coastal zone and floodplain management. The IJC acknowledges the domestic efforts to address coastal hazard risks and offers its support to these efforts as requested.

Plan 2014 should be implemented as soon as possible. In the near term, Plan 2014 will provide benefits to coastal ecosystems around Lake Ontario. Its more natural variation in levels and generally higher fall-through-spring water elevations will benefit wetlands, birds, fish, mammals, and amphibians. In most years, Plan 2014 will extend the boating season on Lake Ontario. Plan 2014 will slightly increase the production of hydropower. Overall, navigation will be held whole. Shippers will benefit from more consistent available drafts at different sections on the route from Montreal to Lake Ontario that will occur with Plan 2014, though tonnage transported per ship between Lake Ontario ports will be reduced in the driest years. Important opportunities to restore coastal wetlands arise with low and high water supply conditions that historically have occurred every few decades. If such an opportunity to expand meadow marsh is lost due to delayed implementation of Plan 2014, then the next opportunity may not arise for decades.

Since the IJC began regulating flows and water levels in the St. Lawrence River, much information and knowledge have been gained. Realizing that there is always more to learn, Plan 2014 performance will be tracked and evaluated. Applying an adaptive management framework, which includes ongoing monitoring and evaluation of plan performance, as well as continued public involvement, will allow for additional scientific knowledge to suggest opportunities to further improve and refine the plan over time. In this approach, both countries will continue to benefit from the investments made by the governments to develop an evaluation system for the regulation plans. Research over the last two decades has identified key areas, such as long-term weather forecasting, where improvements to information could further strengthen performance of the plan.

Adaptive management will provide insights and prompt recommendations, but once a new to the Order of Approval is approved and Plan 2014 is implemented, changes to the Order and regulation plan will occur only after considerable public consultation and the concurrence of the Governments of the United States and Canada.

The IJC concludes that Plan 2014 will provide the best possible balance between the multiple – and sometimes conflicting – uses and interests, including domestic and sanitary use, navigation, hydropower, and coastal development, while addressing environmental harm caused by past regulation and enhancing recreational boating opportunities in most years. The IJC has found widespread support for Plan 2014 with people around the basin, as well as strong opposition concentrated in Lake Ontario south shoreline property owners in New York. After thoroughly reviewing and considering thousands of comments from people throughout the Lake Ontario and St. Lawrence River watershed, the IJC believes that Plan 2014 is the best plan to maintain and improve Lake Ontario-St. Lawrence River water levels and flows for all uses and interests.

Despite an open and vigorous design competition to produce the ideal regulation plan, no plan has ever been developed that gained the support of all interests.

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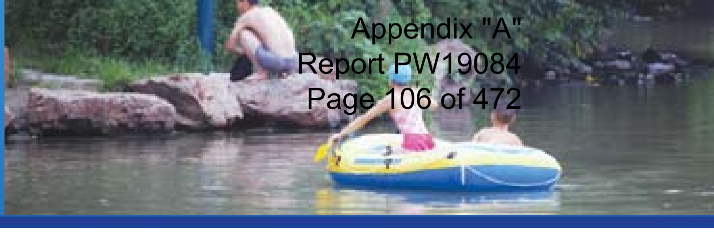

Annex

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1. Introduction

1.1 Purpose of the Report

This report to the Governments of Canada and the United States presents the conclusions of the International Joint Commission (IJC) investigation regarding needed changes to the 1952 and 1956 Orders of Approval regulating water levels and flows in Lake Ontario and the St. Lawrence River.

After more than 14 years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario, Plan 2014, should be implemented as soon as possible.

The report presents:

- an overview of the Lake Ontario-St. Lawrence River setting;
- a review of the history of the regulation of Lake Ontario and the St. Lawrence River since the 1950s;
- a review of the IJC's efforts to develop a new regulation plan and the role of public participation in this effort;
- a description of the rationale and key features of Plan 2014;
- a review of the expected effects of Plan 2014 on the uses and interests in the Lake Ontario-St. Lawrence River basin, including ecosystems; and,
- a discussion of the role that adaptive management can play in improving the outcomes of Lake Ontario-St. Lawrence River water level regulation.

The Annex provides technical details on the operations of Plan 2014, information on an adaptive management strategy, references, and a glossary.

1.2 Setting

Figure 1 shows a map of the Lake Ontario-St. Lawrence River system drainage basin. Lake Ontario has a water surface area of about 18,960 km^2 (7,340 mi^2). The lake's watershed is about 64,030 km^2 (24,720 mi^2) in size, though it receives water draining from the entire Great Lakes watershed, which covers more than 765,000 km^2 (more than 295,000 mi^2).

The St. Lawrence River at the northeast end of Lake Ontario is the natural outlet for the Great Lakes. Numerous rocky islands and reefs dominate the broad channel of the river for the first 80 km (about 50 mi) forming the section known as the Thousand Islands. The river then flows through the Galops channels, and into Lake St. Lawrence. Approximately 160 km (100 mi) downstream from Lake Ontario are the structures that are used to control the flow from Lake Ontario. The Moses-Saunders powerhouses use most of the flow and the roughly 24.5 m (80 ft) drop from Lake St. Lawrence into Lake St. Francis for hydroelectric generation. Additional water may be released through the gates of the nearby Long Sault Dam. From Lake St. Francis, the river flows through the Beauharnois Power and Navigation Canal and down the adjacent Coteau Rapids to Lake St. Louis, and then down the Lachine Rapids at Montreal. At Montreal, the St. Lawrence River is joined by its largest tributary, the Ottawa River, which drains a basin of about 146,300 km^2 (56,500 mi^2). From Montreal, the river flows through the St. Lawrence lowlands to Lake St. Pierre and finally to the Gulf of St. Lawrence.

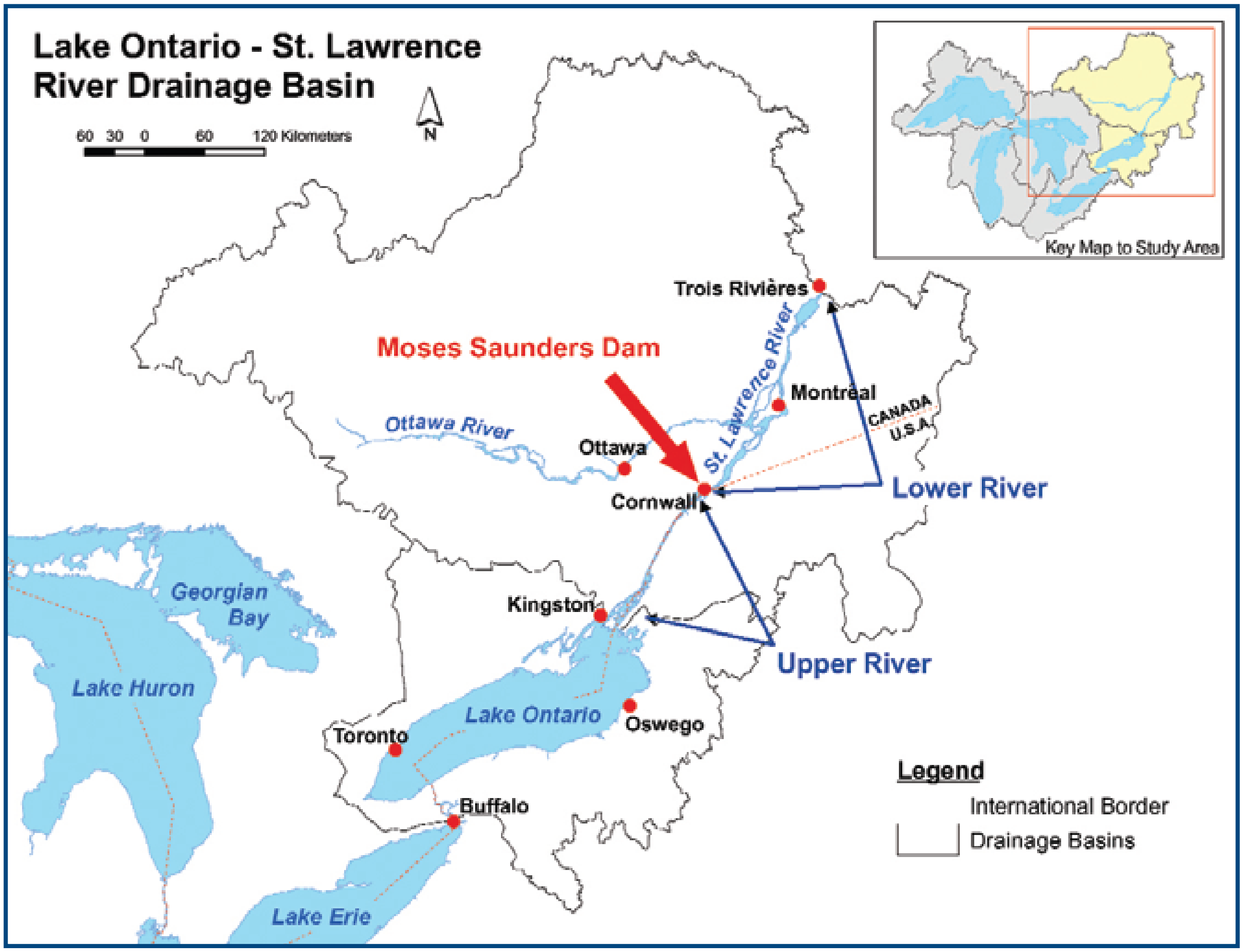
The St. Lawrence River and Seaway connects the Great Lakes to the Atlantic Ocean and provides navigation for lake and ocean-going vessels with drafts to up to 8.08 m (26.5 ft). Typically, the Seaway from Montreal to Lake Ontario is open from mid or late March until late December, depending in part on ice conditions in the river. The Montreal and downstream ports of the St. Lawrence River are open year-round and can accommodate larger, deeper-draft ships.

The net water supplies to Lake Ontario and the upper St. Lawrence River are made up primarily of inflow from Lake Erie (about 80% of the total), precipitation onto the lake's surface and runoff to the lake from streams that drain its watershed, minus evaporation from the lake's surface. Each of these components varies on timescales that range from seconds to seasons to decades (Figure 2). Within each year from 1860 to 2013, there re wet and dry periods. But decades-long trends are also visible – for example, the long decline to the 1940s, the high supplies of the 1950s before the dam was built, a relatively quick return to the very dry 1960s, followed by three decades of high levels. Scientists have tried to understand the driving factors behind these long-term cycles, but for now they are unpredictable.

The water level of Lake Ontario changes in response to the difference between the supply it receives and its outflow. The supply is uncontrolled, while the Moses-Saunders and Long Sault Dam on the St. Lawrence control the outflow. A change in outflow of 323 cubic meters per second (m^3/s) for a period of one week will cause a change of 1 centimeter (cm) in the Lake Ontario level, while a change in flow of this amount will cause a change in the level of Lake St. Lawrence of 16 cm and of Lake St. Louis of 10 cm.[2] The use of the dam to change the amount of water that would naturally flow from Lake Ontario into the St. Lawrence River provides some control over the impacts of water levels, but that control is very limited. There are physical limits to the amount of water that can be released. Larger releases may reduce Lake Ontario flooding but increase river flooding. Smaller releases can deepen water at Lake Ontario ports but reduce Seaway depths. A release that makes sense based on current supply conditions may or may not seem right in retrospect, but the ability to foresee water supply conditions even two months away is limited.

Figure 1

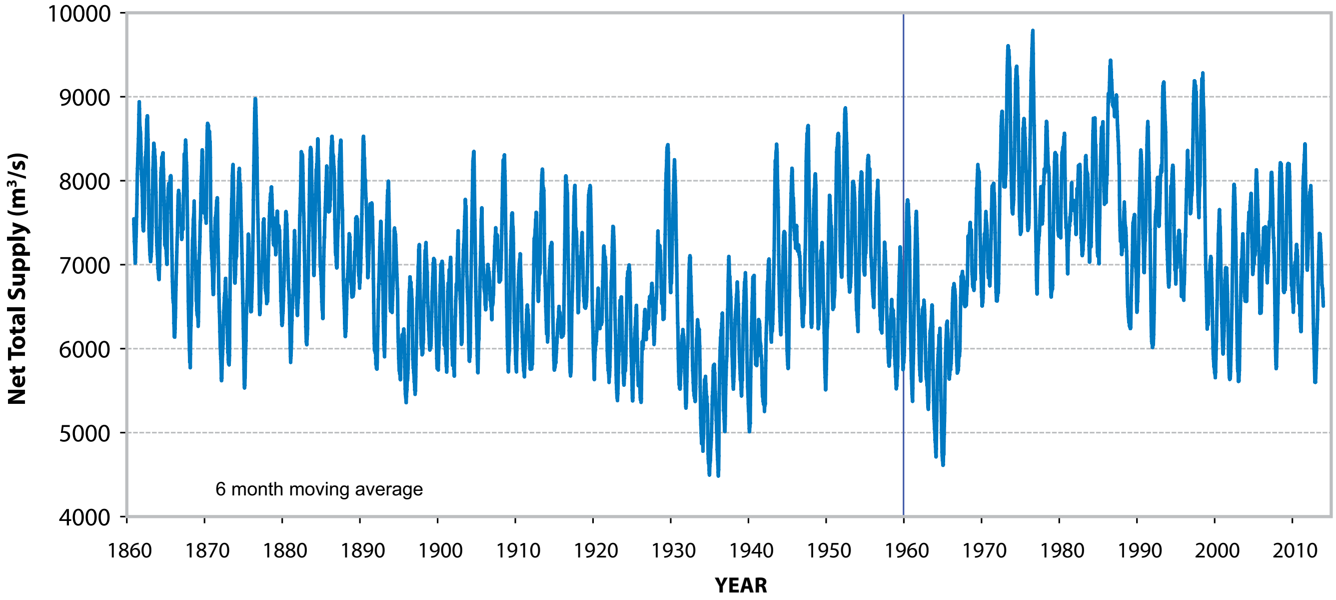
Lake Ontario-St. Lawrence River Drainage Basin



[2] In US customary units, about 29,000 cubic feet per second (cfs) for 1 week equates to a 1 inch change in the Lake Ontario level, while this change in flow of 29,000 cfs would change the level of Lake St. Lawrence by 16.5 inches and of Lake St. Louis by 10 inches.

Figure 2

Recorded Lake Ontario Net Total Supplies 1860-2013



Measurement Units Used in the Report

Metric units are presented first in this report, given that most of the collection, modeling and analysis of data undertaken in this study and previous studies used the metric system. The equivalent United States customary system units are provided, as well.

All water surface elevations are referenced to the International Great Lakes Datum, 1985 (IGLD 1985).

2. Regulating Water Levels and Flows of the Lake Ontario-St. Lawrence River System

This section presents a review of the history of the regulation of Lake Ontario and the St. Lawrence River since the 1950s. It describes the efforts of the IJC to develop a new regulation plan and provide interested parties with opportunities to comment on various proposed plans. Figure 3 presents a timeline of significant events in the history of Lake Ontario-St. Lawrence River regulation.[3]

2.1 History of the Project and Current Regulation Plan

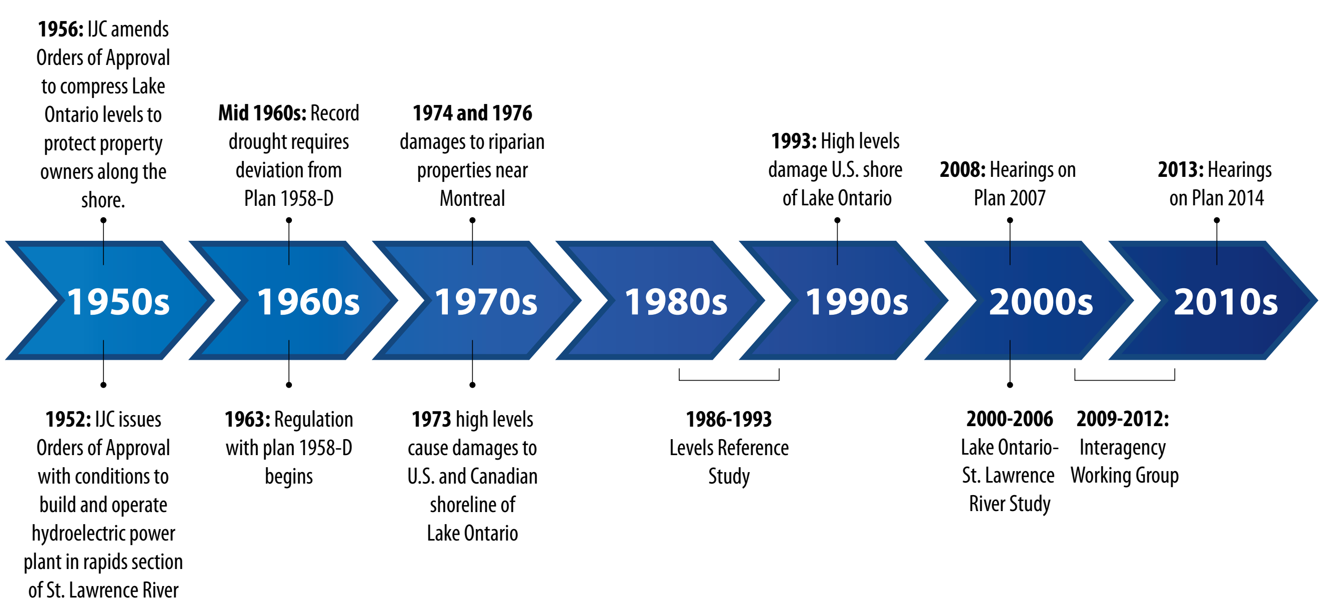
2.1.1 The 1952 Order of Approval

In accordance with the *Boundary Waters Treaty of 1909*, the Governments of Canada and the United States submitted an application to the IJC in June 1952 for approval to develop a hydroelectric power project in the International Rapids section of the St. Lawrence River (Figure 4). Operation of this project would determine the outflow from Lake Ontario and thus affect the water levels of the lake as well as the flows and levels of the St. Lawrence River from Lake Ontario downstream as far as Trois Rivières, QC. The design and operation of the hydropower dam would affect the design and operation of the St. Lawrence Seaway, then under construction. Under the terms of the Treaty, the hydropower use could not materially conflict with or restrain the navigation use.

The IJC considered the information received from the governments and from public hearings in 1952 on the application. On October 29, 1952, the IJC issued an Order of Approval adopting conditions for the construction and operation of the project presented by the governments. The Order established the International St. Lawrence River Board of Control (the Board of Control) to carry out the IJC's instructions and ensure that the provisions in the Order related to flows in the river were met.

Figure 3

Timeline of Significant Events, Lake Ontario-St. Lawrence River Regulation

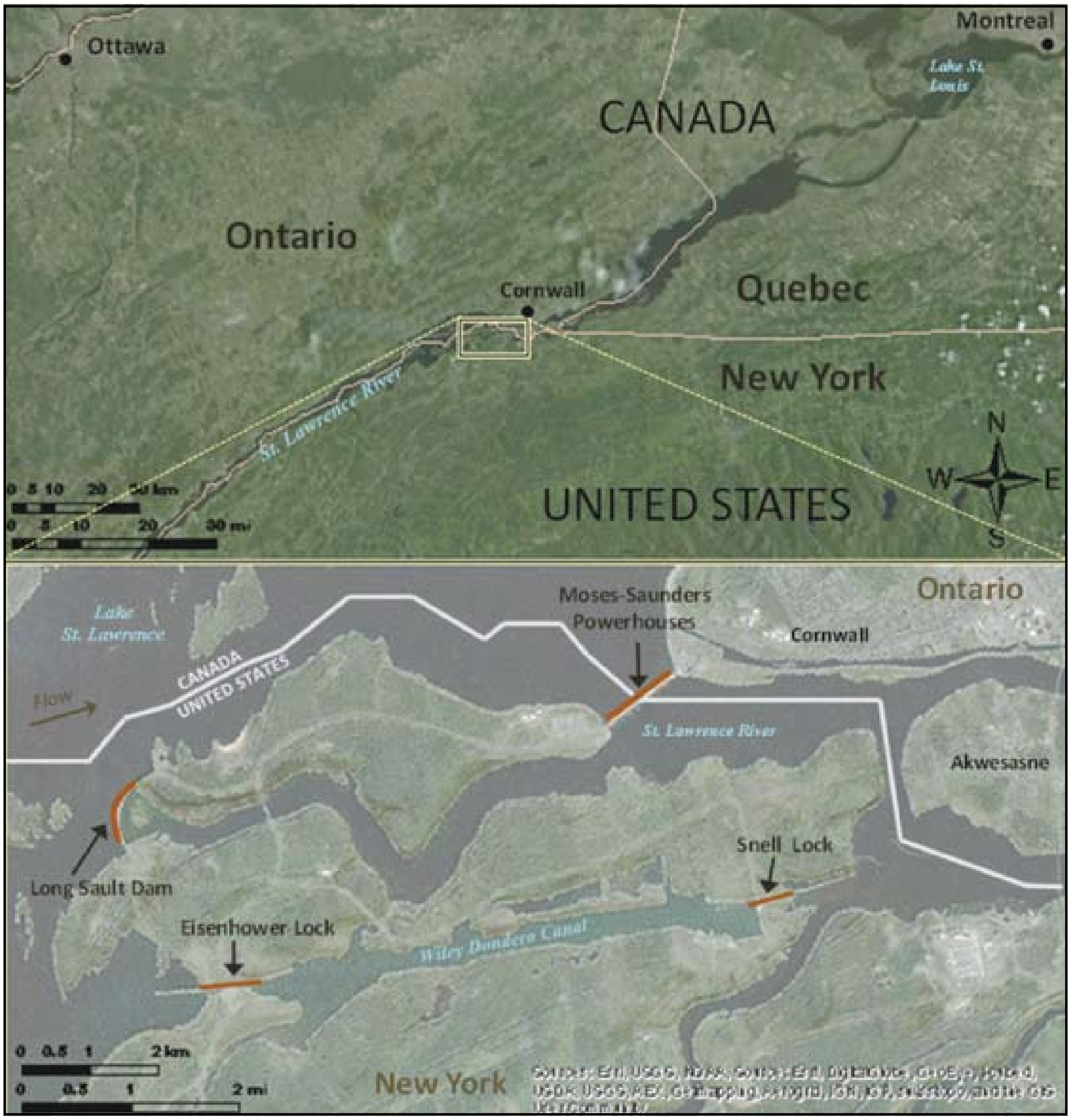


[3] This report focuses on the regulation of water levels and flows of Lake Ontario and the upper St. Lawrence River since the 1950s. However, the natural regime of the outlet from Lake Ontario into the St. Lawrence River was first changed in 1825 to facilitate navigation. By 1850, works in the St. Lawrence River provided a minimum channel depth of 2.7 m (9 ft) from the Atlantic Ocean to Lake Ontario. Between 1884 and 1905, a canal-building program undertaken by the Canadian government enabled ships with a 4.3 m (14 ft) draft to navigate from Montreal to Lake Superior. (Source: IJC,1976)

In 1952, following record floods in the early 1950s, the governments asked the IJC to determine, "having regard for all other interests", whether measures could be taken to regulate the level of Lake Ontario for the benefit of property owners on the shores of the lake, "having in mind the order of precedence to be observed in the uses of boundary waters as provided in Article VIII of the Boundary Waters Treaty of 1909" (IJC, 1952). The historical record up to that time showed that the range of Lake Ontario monthly average levels had been more than 1.8 m (6 ft). The IJC advised the governments that the project could be operated so that Lake Ontario could be regulated within a narrower 1.2 m (4 ft) target range of elevations from April through November for the benefit of shoreline property owners, provided that natural water supplies were no more extreme than those experienced in the past. As was the norm at the time, environmental interests were not considered in the analysis.. The IJC recommended 11 criteria for regulating Lake Ontario outflows and a regulation plan for setting the outflows in a manner that would meet the criteria. It also listed the benefits that the project and Order would provide to shoreline owners on Lake Ontario, to navigation on Lake Ontario and in the International Rapids section, and to power development in the International Rapids section.

Figure 4

Control Structures at Cornwall, ON and Massena, NY



2.1.2 The 1956 Order of Approval

In December 1955, the governments approved the provisions recommended by the IJC. After additional public hearings, the IJC amended its Order of Approval on July 2, 1956 to incorporate the design range of elevations for Lake Ontario, the 11 criteria, and a regulation plan. The project was to provide no less protection for navigation and riparian interests (shoreline property owners) downstream than with unregulated flows. The criteria addressed:

- regulated outflows from Lake Ontario and their effect on the minimum level of Montreal Harbour;
- winter outflows to permit power generation;
- outflows during the annual spring break-up in Montreal Harbour and during the annual flood discharge from the Ottawa River;
- minimum regulated outflows to secure the maximum dependable flow for power;
- limiting the maximum outflow to reduce the required channel excavation;
- reduction in the frequency of high Lake Ontario levels to benefit riparians; and,
- both maximum and minimum lake levels intended to benefit shoreline owners on Lake Ontario and navigation and other interests.

Several of these criteria are contingent on the water supplies to Lake Ontario being within the range of supplies experienced during the period of record (1860-1954), adjusted to account for the diversions into and out of the Great Lakes basin. The IJC recognized that not all of the criteria could be met when water supplies to Lake Ontario were more extreme than those experienced in the past. The 11th criterion, criterion k, specifies how Lake Ontario outflows should be regulated when water supplies are higher or lower than those experienced in the past.

The project includes many components. The principal structure used to regulate Lake Ontario outflows is the Moses-Saunders Power Dam that crosses the St. Lawrence River between Cornwall, Ontario, and Massena, New York (Figure 5). The nearby Long Sault Dam acts as a spillway when specified outflows from Lake Ontario exceed the capacity of the power dam. In addition, the river channel was enlarged in several locations to carry the higher flows needed to reduce maximum Lake Ontario levels and to facilitate navigation.

Initially, an evolving set of rules was used to determine how much water to release from Lake Ontario on a weekly basis, with each ruleset named Plan 1958 and a dashed letter suffix to denote the version. The IJC put Plan 1958-A into operation in April 1960. The IJC approved revised versions of

Figure 5

Moses-Saunders Dam

that plan that were made operational in January 1962 (Plan 1958-C) and October 1963 (Plan 1958-D). These refined plans were developed to better meet the criteria specified in the 1956 Order of Approval (IJC, 1963).

Plan 1958-D has remained in effect since 1963. Its rules use recent water supplies to the lake, lake levels, the time of year, Ottawa River flows, and various flow limits to determine the flow to be released for the coming week. These rules have been programmed to produce the specific weekly release for any given set of conditions.

2.1.3 Deviations from Plan 1958-D

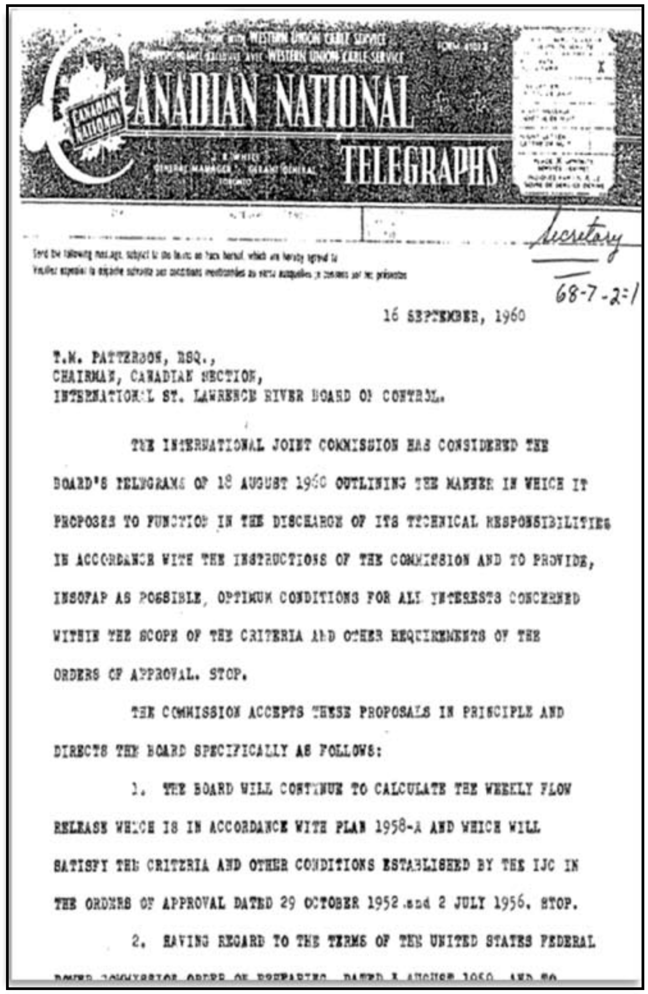
The regulation criteria, Plan 1958-D, and the project were designed for the hydrological conditions experienced from 1860 to 1954. For that reason, Plan 1958-D without deviations would not have performed well for riparians under the more extreme high water supply conditions experienced since that time. Without the deviations required by criterion k of the 1956 Order to deal with supplies more extreme than those experienced from 1860 to 1954, Plan 1958-D would have raised Lake Ontario levels to about 77.0 m (about 253 ft.). In spite of the major deviations from Plan 1958-D made in accordance with criterion k during these periods of extreme supplies, Lake Ontario levels have been outside the 1.2 m (4 ft.) target range specified in the 1956 Order for a total of 78 weeks since regulation began, with actual levels ranging about 0.3 m (1 ft) above and below the target range.

In a 1960 telegram to the Board of Control, the IJC granted authority to temporarily deviate from the regulation plan flow under emergency conditions and when ice formed and broke up during winter operations (Figure 6) (IJC, 1960).

In 1961, at the Board's request, the IJC granted "discretionary authority" for the Board to deviate temporarily from the plan to provide beneficial effects or relief from adverse effects to an interest, without causing appreciable adverse effects to any of the other interests. Given that the Lake Ontario outflow is quite often different from the Plan 1958-D outflow because of deviations, the current approach

Figure 6

Portion of 1960 IJC Telegram to the Board of Control


CANADIAN NATIONAL TELEGRAPHS

Secretary

68-7-2-1

16 SEPTEMBER, 1960

T.M. PATTERSON, ESQ.,
CHAIRMAN, CANADIAN SECTION,
INTERNATIONAL ST. LAWRENCE RIVER BOARD OF CONTROL.

THE INTERNATIONAL JOINT COMMISSION HAS CONSIDERED THE BOARD'S TELEGRAMS OF 18 AUGUST 1960 OUTLINING THE MANNER IN WHICH IT PROPOSES TO FUNCTION IN THE DISCHARGE OF ITS TECHNICAL RESPONSIBILITIES IN ACCORDANCE WITH THE INSTRUCTIONS OF THE COMMISSION AND TO PROVIDE, INSOFAR AS POSSIBLE, OPTIMUM CONDITIONS FOR ALL INTERESTS CONCERNED WITHIN THE SCOPE OF THE CRITERIA AND OTHER REQUIREMENTS OF THE ORDERS OF APPROVAL. STOP.

THE COMMISSION ACCEPTS THESE PROPOSALS IN PRINCIPLE AND DIRECTS THE BOARD SPECIFICALLY AS FOLLOWS:

1. THE BOARD WILL CONTINUE TO CALCULATE THE WEEKLY FLOW RELEASE WHICH IS IN ACCORDANCE WITH PLAN 1958-A AND WHICH WILL SATISFY THE CRITERIA AND OTHER CONDITIONS ESTABLISHED BY THE IJC IN THE ORDERS OF APPROVAL DATED 29 OCTOBER 1952 and 2 JULY 1956. STOP.

2. HAVING REGARD TO THE TERMS OF THE UNITED STATES FEDERAL

to regulation now is called "Plan 1958-D with deviations" or 1958DD.

2.2 Review of the Regulation Plan

2.2.1 Levels Reference Study

During the record high water levels of 1986 on the upper Great Lakes, the governments issued a reference[4] to the IJC to examine and report on methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes–St. Lawrence River basin (the Levels Reference Study). One of the specific requests in the reference was for

[4] A reference is a request from the governments for the IJC to study and recommend solutions to a transboundary issue. The word is derived from Article IX of the *Boundary Waters Treaty of 1909*, which stipulates that such issues "shall be referred from time to time to the International Joint Commission for examination and report, whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred."

the IJC to review and revise its earlier studies on lake level regulation.

The IJC 's Levels Reference Study Board report (IJC, 1993) recommended that the "Orders of Approval for the regulation of Lake Ontario be revised to better reflect the current needs of the users and interests of the system." Among other recommendations, the Board suggested that criteria should be added that consider the environmental interests on Lake Ontario and the St. Lawrence River.

2.2.2 Lake Ontario-St. Lawrence River Study

In April 1999, the IJC informed the Governments of Canada and the United States that it was becoming increasingly urgent to review the regulation of Lake Ontario levels and outflows in view of dissatisfaction on the part of some riparians and boaters, in light of environmental concerns, and because of the potential for climate change to affect lake levels (Figure 7). In response, the governments appropriated approximately $20 million for the IJC to undertake the five-year Lake Ontario-St. Lawrence River study (IJC, 2006).

The IJC appointed a binational Study Board to conduct the study (Figure 8). The Board was to assess the impacts of fluctuating water levels on the affected uses and interests and present the IJC with options for regulating the lake. Approximately 200 researchers and more than 20 organizations participated directly in the study.

The IJC also created an independent Public Interest Advisory Group (PIAG) as part of the Study (see section 2.3, below). The Study Board and PIAG interacted from the beginning to create a rigorous, thorough and transparent study. The U.S. and Canadian PIAG co-chairs were also Study Board members.

The analysis was carried out by technical work groups. Six of the groups were formed around the interest areas of navigation, municipal and industrial water use, hydropower, recreation, coastal impacts and the environment. Other groups managed climatological and hydrological research, common data needs such as Geographic Information System (GIS) of nearshore topography and bathymetry, data archiving and storage, and the formulation

Figure 7

Portion of IJC 1999 Letter to Governments


International Joint Commission

April 15, 1999

Honourable Lloyd Axworthy
Minister of Foreign Affairs
Department of Foreign Affairs and International Trade
125 Sussex Drive
Ottawa, ON K1A 0G2

Honorable Madeleine Albright
Secretary of State
Department of State
2201 C Street, NW
Washington, D.C. 20520

Dear Minister Axworthy and Secretary Albright:

It is becoming increasingly urgent to review the regulation of Lake Ontario in view of dissatisfaction, on the part of some interests, with the working of that system and in the light of environmental concerns and climate change issues. We would like to take this opportunity to provide some background information on this subject, inform you of recent

Figure 8

A Meeting of the Lake Ontario- St. Lawrence River Study Board

and evaluation of regulation plans. Each group was composed of experts and stakeholders[5].

In planning its work, the Study Board recognized that there are many possible effects that changes to the regulation of Lake Ontario outflows could have on the interests and uses. As not every possible effect could be studied and evaluated in detail, the Study Board chose to limit the extent of impact studies in all water sectors to those that best fit the study's purpose (that is, determining whether improvements can be made in flow regulation), budget, and timeline. The measures

[5] For a full list of participants in the Lake Ontario-St. Lawrence River Study, see IJC, 2006.

used to characterize the effects on each interest were consistent with widely-accepted planning and evaluation principles.

Economic performance indicators (for example, the value of additional hydropower energy produced) were approved by a separate advisory panel of four economic experts and based on scopes of work approved by the Study Board.

An binational team of environmental scientists worked with the Study Board to select the quantitative environmental "performance indicators" used in its evaluation (for example, an index of reproductive success for the Black Tern). Their selection was based on the sensitivity of the indicator to changes in water levels and flows, the significance and representativeness of the indicator, and the certainty in the research results.

Experts and members of the public worked with the Study Board to create a sound and transparent review and decision-making process. Together, they defined regulation plan objectives and then collaborated to create a computer evaluation model that measured how well alternative regulation plans met those objectives. The Study Board conducted six "practice" decisions using this collaboratively-built model starting in the second year of the five-year study to refine the decision framework and make sure that the research being done was sufficient for the decision. After each practice decision, the results were disseminated through the PIAG to the larger public and adjustments made to the research and models based on the feedback.

This collaborative framework supported a wide-ranging plan formulation and evaluation effort. Four plan formulation teams worked in friendly competition, each taking a different design approach. One team tried to improve the parameters in Plan 1958-D; another added rules to modify the pre-project or "natural" releases in order to moderate extreme levels; a third used "interest-satisfaction" curves; and a fourth used optimization models. The teams collaborated electronically, and then worked together in workshops to compare results and share lessons learned. Their intensive use of the evaluation model also provided an effective peer review of that model.

The design of the evaluation model allowed each plan formulator to evaluate new plan rules quickly, and that in turn permitted a much more thorough exploration of alternative regulation plans than would have been possible in traditional water resources studies. The legacy of the Study's comprehensive and collaborative approach is a framework that has been used since 2006 to formulate and evaluate hundreds of alternative regulation plans, including Plans 2007, Bv7 and 2014. In addition, the approach will be used in the future to support adaptive management.

Consideration of Climate Change and Variability

To ensure that the regulation plans developed in the study could perform under a wide range of water supply conditions, plans were tested with stochastically-generated water supplies[6] as well as the historical water supplies. The plans also were tested with four climate chan ge scenarios.

The historical supplies covered the period 1900-2000. The stochastic data provided the equivalent of another 495 water supply datasets, each set 101 years long. Some sequences had much wetter and some much drier periods than any experienced in the 20th century. All the economic evaluations shown in Table 2, in section 4, are based on the stochastic water supplies.

The four climate change supply sequences were based on the range of predictions from scenarios from the latest available two Global Circulation Models (Mortsch *et al*, 2005). The changes from base temperature, precipitation, humidity, wind speed and solar radiation for each of these four scenarios were used to adjust the historical recorded series of these climate properties.

To quantify the impact climate change might have for Lake Ontario interests, the evaluation model was run for each of these four different climate change scenarios using Plan 1958DD in all four evaluations. The warmest and driest of four scenarios was the most damaging. With this scenario, Lake

[6] Stochastic generation is a statistical method used in water resources studies for nearly 50 years to develop simulated water supply data that include conditions both wetter and drier than the historical data. The stochastic supplies are considered plausible because they have the same statistical properties as the historical supplies (e.g., the same average, standard deviation). The rules in Plan 1958-D (without deviations) were flawed because they were based on an analysis using recorded data from 1860-1954. Actual water supplies in the 1960s were lower than any in the 1860-1954 record, and supplies in the 1970s, 1980s and 1990s were wetter, requiring deviations from 1958-D.

Ontario levels and flows were generally lower than experienced with historical supplies, reducing hydropower benefits by more than $68 million a year, and recreational boating opportunities were reduced by almost $50 million a year (IJC, 2006). On the plus side, Lake Ontario shore protection damage was reduced slightly by about $1 million per year.

Alternative plans were also tested to determine their suitability under climate change and other extreme climate scenarios. These analyses showed that changes in climate could overcome the influence of regulation plans to protect stakeholders. For example, when tested using the driest portion of the stochastic water supplies, Lake Ontario levels dropped to 73.04 m (239.63 ft) under Plan 1958DD. This is 74 cm (2.5 ft) lower than the historical 1958DD minimum. By comparison, using the same water supplies but replacing Plan 1958DD with Plan 2014, the minimum Lake Ontario level simulated was 73.20 m (240.15 ft). This is clearly higher than the comparable 1958DD minimum, but still about .6 m (2 ft) below the historical levels. Similarly, when water supplies were extremely high, Plan 2014 and Plan 1958DD produce very high but very similar levels (76.62 m/251.4 ft for Plan 2014; 76.56 m/251.2 ft for Plan 1958DD).

Key Study Board Findings

The Study Board used the evaluation model to determine the limits of lake level regulation to address stakeholder concerns. The Study Board found that regulation has provided significant economic benefits to basin interests, particularly to riparians on Lake Ontario. The assessment of benefits to riparians included substantial information on the minimum level of risks under any regulation plan. The Board found that even if Lake Ontario were regulated solely for the benefit of Lake Ontario shoreline property owners, disregarding the interests of shoreline owners on the lower river, navigation and all other uses and interests, then Lake Ontario shoreline damages would be reduced by only about 5% from the levels produced by Plan 1958DD. Lake Ontario shoreline protection structures in particular were vulnerable, with many too low to avoid destruction no matter how the lake was regulated. In addition, erosion of the unprotected shoreline could not be slowed appreciably by regulation.

The Study Board also found that the compression of the range of Lake Ontario levels had resulted "… in a more narrowly defined transition zone within wetlands from submerged to upland plants, thus reducing the diversity of plant types along the shore and populations of animal species who feed on and live in the environments affected by the reduced water level ranges." Regulation also has caused dewatering drawdowns in the fall through early spring, to the detriment of some habitat. The Study Board noted that these degraded environmental conditions could be improved by changing the regulation plan, but not without tradeoffs that would reduce some existing economic benefits.

The evaluation of alternative plans showed that Lake Ontario shoreline protection structures in particular were vulnerable, with many too low to avoid destruction no matter how the lake was regulated.

The Study Board proposed three regulation plans (Plan A+, Plan B+, and Plan D+) that provided net economic and environmental improvements when compared to Plan 1958DD, but with varying trade-offs among the uses and interests on the lake and river. The Study Board found that, compared to the case without regulation, Plan 1958DD reduced the damages due to fluctuating water levels on Lake Ontario shoreline properties by about 60%, that "coastal damages occur regardless of the regulation plan", and that "the current Regulation Plan 1958-D with Deviations comes close to minimizing damages for Lake Ontario shoreline property owners."

2.2.3 Development of Plan 2007

Following the release of the Study Board's final report, the IJC invited public comment and subsequently undertook a thorough review of the report and public comments. The IJC then asked experts who had been associated with the Study to explore whether any of the three plans recommended by the Study Board could be refined to restore more of the environmental benefits while maintaining as much as possible the level of protection and benefits that other interests and uses enjoy under Plan 1958DD. This new work by the IJC resulted in additional candidate plans being developed.

In March 2008, the IJC invited comment on a proposed new Order of Approval and regulation plan, known as Plan 2007. The proposed new Order of Approval, among other things, made provision for the environment and recreational boating. The simulation models developed in the Lake Ontario–St. Lawrence River Study showed that the proposed regulation plan would have provided net economic improvements compared to Plan 1958DD and benefits to shoreline property owners comparable to those currently received under Plan 1958DD. The models also showed that Plan 2007 would have provided more environmental improvements than the existing Plan 1958DD. Nonetheless, at the public hearings held on the proposal in the summer of 2008, the IJC heard widespread opposition to Plan 2007 throughout the Lake Ontario-St. Lawrence River basin.

In September 2008, the IJC wrote the U.S. Department of State and the Canadian Department of Foreign Affairs and International Trade to inform them that the testimony at the hearings and the approximately 1,200 comments submitted outside the hearings showed serious divisions by political unit and little support for Plan 2007, but broad, strong interest in returning to more natural levels and flows.

The IJC informed the governments that "the Commission has determined that Plan 2007 is not a practical option for implementation and concludes that the regulation of water levels and flows should be based on a revised set of goals and objectives and criteria, specifically moving towards more natural flows to benefit the environment, while respecting other interests."

2.2.4 Development of Plan 2014

In October 2009, the IJC wrote to the governments of the United States, Canada, Quebec, New York and Ontario asking each government to nominate two senior officials to a Working Group to advise the IJC on its proposals on how to:

- manage water levels and flows in the Lake Ontario-St. Lawrence River system; and,
- better define and adequately protect all interests – economic, social and environmental– both upstream and downstream of the Moses-Saunders Dam, in compliance with the *Boundary Waters Treaty of 1909*.

After reviewing the range of regulation plans that had been developed to date, the Working Group agreed to investigate and further refine a set of release rules based on Plan B+, known as Bv7 (that is, the seventh version of the candidate B plan). The Working Group also considered a more detailed adaptive management strategy to respond to climate change, modifications to the plan's management oversight structure and policies on deviations from the plan.

All of the design and analysis done leading up to Plan 2007 and to Plan Bv7 used the same evaluation model and, with several minor improvements, the same performance indicators that the Lake Ontario-St. Lawrence River Study Board had developed with stakeholders. Using that system, the Working Group was able to evaluate about 60 variations on Plan Bv7 before recommending a version to the IJC.

In 2012, the IJC conducted public information sessions and invited comment on Plan Bv7. After further consultation with stakeholders, deliberation and refinement to the proposed regulation plan and the other components, the IJC then developed a formal proposal, known as Plan 2014. Plan 2014 included modifications to the rules of Bv7 to better balance Lake Ontario and river levels during low supply periods. Also, set of high and low lake levels were added to trigger special actions to better protect water intakes, navigation, boating and riparian interests.

Tables 1 and 2, presented in section 4, summarize a comparison of the environmental and economic performance of Plan 2014 and other regulation plans as measured using the performance indicators developed in the Lake Ontario-St. Lawrence River Study.

2.3 Public Participation in Plan Development

Throughout the studies into regulating Lake Ontario and the St. Lawrence River, the IJC has made extensive efforts to involve all interested parties in the formulation and evaluation of new regulation plans. These efforts have allowed the people whose lives would be affected by lake level regulation to help define the problem and the measures of success, help design new plans and communicate the results (Figure 9). The efforts during and after the Lake Ontario-St. Lawrence River Study were preceded by public outreach and involvement activities of the Board of Control.

Public Interest Advisory Group Role in the Lake Ontario-St. Lawrence River Study

Figure 10 shows the locations where the IJC hosted hearings, technical sessions and other public meetings during and after the Lake Ontario-St. Lawrence River Study.

During the work that led up to the 2006 report, the 20 members of PIAG worked with organizations and interests throughout the study area and conducted public participation activities on key issues to assist the Study Board in its deliberations. PIAG members acted as liaisons to each of the study science teams, suggesting performance metrics that were used in the coastal, environment and recreational boating technical work groups. PIAG members also reviewed the candidate plans and provided feedback into the Study Board's decision-making process.

In the executive summary of its final report, the PIAG reported that it could not find a consensus on a regulation plan (see text box). The inability of the PIAG as a group to endorse any of the candidate plans (regulation plans presented as options from the Study Board for the IJC) was the first, but not the last indication that no regulation plan can satisfy all interests.

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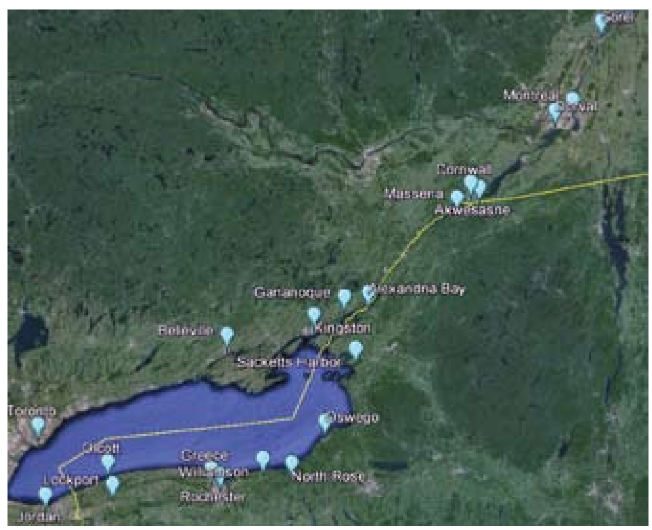
The inability of the Public Interest Advisory Group to endorse any of the candidate plans was the first, but not the last, indication that no regulation plan can satisfy all interests.

Figure 9

PIAG Members Participating in a Review of Performance Metrics during the Lake Ontario-St. Lawrence River Study

Figure 10

Location of Public Meetings on Lake Ontario Regulation, 2005-2013



In the summer of 2013, the IJC held hearings or technical sessions on Plan 2014 in Alexandria Bay, Cornwall, Jordan, Lockport, Montreal, Rochester, Williamson, and Oswego. There was widespread strong opposition to the plan in south shore communities, with a minority expressing support. Shipping industry representatives in Montreal supported the ecosystem goals so long as the order of precedence was maintained. There was strong, widespread support for Plan 2014 elsewhere around the lake and in communities along the river.

Executive Summary from Public Interest Advisory Group Final Report November 30, 2005

The International Lake Ontario - St. Lawrence River Study has been a trailblazer. The International Joint Commission (IJC) decided prior to the initiation of this Study to have the public represented at the "table" right from the start. The Public Interest Advisory Group (PIAG) had a separate mandate from the IJC, allowing it to act independently. We were an internal "peer review" group for the Study. To develop this "peer review" group, the IJC selected members of the public, in many cases, who were the toughest and most active critics of the International St. Lawrence River Board of Control's operations prior to the Study. Through this process, PIAG members met and learned from each other, gaining a better understanding of the system geographically and technically and of the various concerns of the regions. Consequently, the Study has now developed a cadre of lay-experts available to the International Joint Commission in the public interest.

Another facet of our mandate was to ensure effective communication between the public, which we represented, and the Study and its technical work groups. We provided input to Study decisions and communication and education to the public. We were there at the table for all Study Board discussions. The PIAG assisted the decision process, ensuring that the public input was considered and that the process remained transparent.

The Study Board kept an arms-length approach to our activities. We tested several innovative instruments of public outreach; the results of what worked and what did not work will be provided to the International St. Lawrence River Board of Control.

The two main lessons learned from the Study are:

We have to realize that the Study cannot satisfy the needs of all of the interests all of the time. This is indeed the case as the PIAG as a group does not favor any one candidate plan over another.

Communications cannot be an ad hoc procedure. The IJC must commit funds to ensure proper communications of the Board of Control by means of dedicated communication person(s) and budget to allow publication of meetings and other important communications, using techniques developed by PIAG during this Study and other valid methods of ensuring two-way communication.

(From: Lake Ontario-St. Lawrence River Study Public Interest Advisory Group, 2005)

Public Hearings on Plan 2014

In the summer of 2013, the IJC invited public comment and convened public hearings on the proposed Plan 2014. More than 5,500 comments were received, in total. This included 206 oral testimonies at the 12 hearings and public teleconferences, over 3,500 signatures on four different petitions, more than 700 post cards and form letters, and nearly 1,000 written website, email and unique letter responses. This latter group of responses ranged from short endorsements or rejections of Plan 2014 to formal responses from local governments, governmental departments and non-governmental organizations.

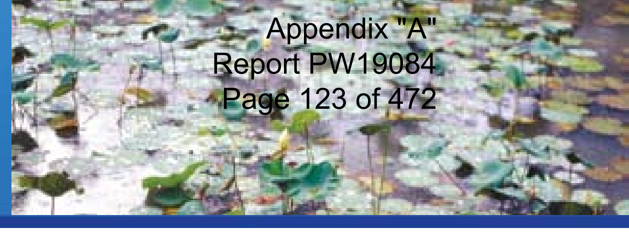
The response was polarized. Most south shore property owners in New York State who participated in the hearings and their local governments strongly opposed Plan 2014, though a few respondents from that area either supported Plan 2014 or supported the environmental objective but not Plan 2014 itself. *Save our Sodus*, a non-profit group, presented a petition with more than 400 comments that either opposed Plan 2014 or documented past flooding and erosion problems that had occurred under the current regulation rules. The concerns of these citizens were that the higher high water levels of Plan 2014 would cause more shoreline damage, and that the lower low levels would make boating more difficult.

The U.S. Department of Transportation raised concerns that the priority given to environmental objectives in Plan 2014 violated the Treaty, reflecting similar statements by several other respondents involved with commercial navigation on the seaway, including the St. Lawrence Seaway Management Corporation, the Canadian Shipowners Association and the Shipping Federation of Canada. The concern from commercial navigation was that Plan 2014 would create significantly lower levels on Lake Ontario in a few years out of a hundred, thus forcing ships to carry reduced loads.

Other than these groups, there was general, and often strong, support for Plan 2014. For example, the U.S. Environmental Protection Agency (USEPA) supported Plan 2014, writing that Plan 1958DD has significantly degraded Lake Ontario wetlands and vital fish and wildlife populations, and that Plan 2014 would increase the diversity and functioning of 26,000 ha (64,000 acres) of coastal wetlands. Conservation Ontario wrote to explain the significant economic value of wetlands and asserted that Plan 2014 would contribute to the economic, ecological and social well-being of the Lake Ontario and St. Lawrence River. The U.S. Department of the Interior wrote that Plan 2014 would best meet the stated goals and that it represented the most logical approach to bringing water level regulation into the 21st century. The City of Montreal supported Plan 2014, as well. The Nature Conservancy noted that selecting Plan 2014 would reverse decades of environmental harm, while rejecting it would not solve the coastal impact problems that would have to be confronted no matter the regulation plan. Audubon New York wrote to advise that Plan 2014 was central to the long-term success of the Great Lakes Restoration Initiative and the overall restoration of this important ecosystem. Ducks Unlimited commented that the IJC and other principal interests had done an outstanding job of balancing the needs and requirements of all the major parties, and encouraged the IJC to implement Plan 2014.

"Selecting Plan 2014 will reverse decades of environmental harm; rejecting Plan 2014 will not solve coastal damage problems."

- The Nature Conservancy



3. Regulation Plan 2014

After more than 14 years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario, Plan 2014, should be implemented as soon as possible.

Section 3 presents:

- the rationale for Plan 2014;
- a description of the key features of the plan; and,
- an overview of the role of the International Lake Ontario–St. Lawrence River Board in overseeing implementation of the plan.

3.1 Rationale

Based on the comprehensive Lake Ontario-St. Lawrence River Study, extensive consultations with governments and the public on two revised regulation plan proposals, and subsequent analysis and refinements, the IJC finds that Plan 2014 provides the best response to the range of issues that must be considered in regulating the flows through the Moses-Saunders Dam. These issues include the requirement of Article VIII of the Treaty to follow the order of precedence of water uses while providing "suitable and adequate protection" for interests that may be harmed by operation of the project.

Plan 2014 maintains the order of precedence while addressing the harm done by the 1956 Order and existing regulation rules to Lake Ontario coastal ecosystems. The IJC finds that the coastal and riverine ecosystems are an interest that existed but was not considered when the 1956 Order was developed. The design of Plan 2014 takes into consideration the more extreme water supplies experienced since 1954, the even more extreme supplies that may be experienced in the future, and other improvements in knowledge and analytical techniques.

Plan 2014 has been designed to satisfy the conditions and criteria specified in a revised Order of Approval for Lake Ontario-St. Lawrence River regulation. These conditions and criteria are listed in Annex A of this report.

Highlights of the Proposed Conditions and Criteria of an Order of Approval

Lake Ontario regulation plans must be consistent with the IJC Order of Approval governing the operation of the control structures. The IJC has concluded that some of the conditions and criteria in the 1952 and 1956 Orders of Approval for the St. Lawrence Power Project must be updated. Annex A lists the conditions and criteria to be included in a new Order of Approval that would govern Plan 2014 and subsequent plans.

The new conditions provide formal recognition of an established practice, which is that the IJC may issue directives to guide regulation of the discharge in addition to the criteria listed in this condition. The requirement that no less protection be provided for interests downstream than would have occurred under pre-project conditions carries over from the 1956 Order. The period of supplies used to evaluate plans is updated to 1900-2008, which encompasses more extreme high and low supply events than the 1860-1954 supply sequence upon which the criteria of the 1956 Order were based.

The criteria establish objectives and performance standards that Plan 2014 and any future regulation plans must meet when tested with the 1900-2008 supply sequence. The updated criteria recognize that:

- low levels at any time of year affect Port of Montreal navigation (the Port operates all year) as well as water intakes and other uses and interests, and that the frequency of low levels is of concern in addition to the minimum level;
- low levels affect water intakes as well as navigation and other uses and interests on Lake St. Louis;
- adequate levels for navigation in the Montreal to Lake Ontario section of the river need to be considered together for Seaway uses;
- releases above certain thresholds can cause currents that threaten safe navigation or reduce hydropower production if they are above the capacities of the hydropower plants;
- maintaining minimum flows as high as possible maintains a dependable amount of electricity generation;
- high levels can damage shoreline property and other uses and interests affected by flooding on Lake St. Louis and Lake St. Lawrence throughout the year;
- high levels can damage shoreline property and other uses and interests affected by flooding and erosion on Lake Ontario throughout the year, and that the seasonality of supplies to the lake, ice restrictions on winter flows and the fall storm season warrant maximum levels that vary through the year;
- when tested with the more extreme 1900-2008 supplies, no plan can maintain Lake Ontario levels within the range set in 1956;
- low levels can impact water intakes, shipping, boating and other uses and interests on Lake Ontario throughout the year, and that the seasonality of supplies to the lake warrant minimum levels that vary through the year;
- when Lake Ontario water levels reach or exceed extremely high levels, management of releases should provide all possible relief to the riparian owners upstream and downstream;
- when Lake Ontario levels reach or fall below extremely low levels, management of releases should provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream;
- deviations from the approved plan to provide all possible relief to interests are more clearly triggered by specific Lake Ontario levels, rather than "supplies outside the range of the past," which is more ambiguous;
- releases must be adjusted to avoid ice jam flooding whenever ice forms, to protect uses and interests upstream and downstream;
- water levels affect ecosystems and that releases must be managed to enhance wetland health whenever possible; and,
- releases must be managed to benefit recreational boating whenever possible.

In addition, current practices authorized in various letters are formally recognized in the Order for the first time. A new condition states that the IJC will issue directives to guide peaking and ponding operations and for deviations from the plan of regulation to address such matters as winter operations, emergencies and other special short-term situations. The installation of ice booms in the St. Lawrence River is also authorized subject to established conditions.

3.2 Key Features

This section summarizes the features of Plan 2014. For more technical information on the plan, see Annexes B and C.

3.2.1 A More Natural Hydrological Regime

The objective of Plan 2014 is to maintain beneficial uses for the key water-using interests while returning the Lake Ontario-St. Lawrence River system to a more natural hydrological regime, thereby helping to restore coastal and riverine ecosystems. This approach was first used during the Lake Ontario-St. Lawrence River Study to create Plans B and B+, and in 2012 to create Plan Bv7 (see Annex B for more details). Plan Bv7 included revisions made to Plan B+ by the IJC based on advice from the working group, public and stakeholder input. These revisions included additional rules to maintain navigation and flood reduction benefits on the St. Lawrence River below the control dam, rules to maintain navigation and boating benefits on Lake St. Lawrence, and adjustments to better balance Lake Ontario and St. Lawrence River levels below the dam.

Plan 2014 will use the releases prescribed by Plan Bv7 rules until Lake Ontario levels reach specified high or low trigger elevations. If levels reach the high trigger levels, then the Board will "provide all possible relief to the riparian owners upstream and downstream." If the levels reach the low triggers, then the Board will "provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream." This is the same logic the Board applies when it operates under criterion k of the existing 1956 Order.

Unlike the current plan, which is not based on the natural release, Plan 2014 rules start with the natural release, adjust it for supply conditions and then modify it when necessary to protect the various interests and the uses in the order of precedence of Article VIII of the Treaty.

In its natural state, without a dam regulating the release, the outflow from Lake Ontario is mainly a function of the lake level and, to a lesser degree, the resistance to flow in the river. Heavy vegetation or ice in the river channel can reduce the flow. If the lake rises, then the natural release increases. As lake levels change gradually, natural releases change gradually, as well.

Unlike the current plan, which is not based on the natural release, Plan 2014 rules start with the natural release and then modify it to protect the various interests and the uses in the order of precedence of Article VIII of the Treaty.

3.2.2 Adjusting for Changing Supplies

The eventual outcome of a water release decision cannot be fully known at the time it is made, because the outcome depends in part on future water supply conditions. Adjusting the release based on trends in the long-term supply and using supply forecasts, even though uncertain, improves release decisions. The release rules in Plan 2014 use an index of the long-term trend in supplies and a short-term statistical supply forecast to adjust the natural release. Although the releases in Plan 2014 tend to change less from week to week than with Plan 1958-D, this adjustment to the natural flow makes Plan 2014 respond to changing supplies more quickly than nature would to reduce the risk of coastal damage, unsafe navigation conditions, or other undesirable outcomes.

As in Plan 1958-D, flow limits are used in Plan 2014 to satisfy some of the criteria set out in the Order of Approval. This includes preventing river levels from falling too low or rising too high, facilitating stable river ice formation and providing acceptable navigation conditions and safe operating conditions for control structures. However, the Plan 2014 flow limits improve upon those in Plan 1958-D that were developed in the 1950s before the project started operation. The Plan 2014 limits incorporate the knowledge gained from more than 50 years of operational experience, including during times of extreme supplies outside the design range of Plan 1958-D.

3.2.3 Short-Term "River" Deviations

From time to time, the Board of Control has used the authority granted to it by the IJC to deviate from the releases specified by Plan 1958-D, first to avoid a temporary problem and then later to restore Lake Ontario levels to what they would have been without the deviation from the Plan specified flow. For example, ships entering the St. Lawrence River may encounter shallower conditions than expected based on forecasts of river levels used to load the ships in overseas ports.

The Board of Control occasionally has discharged more than the plan release for a day or two to increase river depths by up to several centimeters (a few inches) near Montreal, thus avoiding the need to re-direct the ship to another port or transfer cargo to lighten the ship. The larger releases lowered Lake Ontario by a fraction of a centimeter below the plan intent, so the Board then ordered a discharge less than the plan release to bring Lake Ontario back to its plan intended level. This practice was not foreseen in the 1956 Order but has developed under a policy approved by the IJC in 1961 to grant the Board of Control the authority to make discretionary deviations from the Plan specified release to provide benefits or relief to interests when they can be made without adverse impacts to others.

Under the proposed new order, these deviations for shipping and similar short-term "river" deviations would be specifically directed by the IJC and would continue in an identical manner under Plan 2014, except that the cumulative effect of these minor deviations would be limited to the equivalent of plus-or-minus 2 cm (nearly 1 inch) of water on Lake Ontario, unless there is a special approval by the IJC.

3.2.4 Less Frequent Need for Major Deviations from the Plan

Both Plans 1958-DD and 2014 include major deviations to moderate Lake Ontario levels from what they otherwise would be if the plan rules were followed as written. However, under Plan 2014, these major deviations would be less frequent and more clearly exercised. Criterion k of the 1956 Order requires that the release "provide all possible relief to the riparian owners upstream and downstream" when supplies exceed those experienced from 1860 to 1954, and to provide all possible relief to navigation and power interests when supplies are less than 1860-1954 supplies. The Board of Control advises the IJC when supplies are outside the 1860-1954 range, but it is the IJC that makes the determination that releases should be made according to this criterion, not the Board of Control.

Under criterion H14 of the proposed new Order, the same relief would be provided to riparian owners upstream and downstream when Lake Ontario levels hit high trigger levels. All possible relief to municipal water intakes, navigation and power purposes, upstream and downstream, would be provided when Lake Ontario reaches low trigger levels. Weekly Lake Ontario levels are expected to be at or above the higher trigger levels 2% of the time, and at or below the low trigger levels 5% of the time. The IJC directive to the Board on deviations from Plan 2014 is provided in Annex C.

Some future water supplies likely will be greater and some likely smaller than any on record. The supplies of the 1960s dipped lower and the supplies of the 1970s, 1980s and 1990s peaked higher than the 1860-1954 supplies that were used to design Plan 1958-D. The magnitude and frequency of these extreme supplies were estimated by hydrologists by using stochastic modeling. The high trigger levels are nearly as high as recorded highs on Lake Ontario, so they do not diminish coastal damages significantly based on 20th century supplies. However, in more extreme supply conditions, the sustained application of criteria k and H14 tends to make Plan 2014 and Plan 1958DD releases, levels and projected damages more similar.

The more natural, but still compressed, Lake Ontario levels of Plan 2014 are shown in comparison to those of Plan 1958DD and the Natural plan in Figures Ex-1 through Ex-3 of the Executive Summary.

3.3 International Lake Ontario–St. Lawrence River Board

The IJC establishes boards to ensure compliance with its Orders of Approval and to put its approved regulation plans into operation. Typically, the IJC appoints to its boards experienced water managers from government agencies on both sides of the border and other people with expertise on the water uses and an understanding of how local interests are affected by water regulation. These boards: direct the dam owners as to the amount of water they must release to comply with the regulation Orders; oversee the day-to-day regulation operations; maintain a liaison with stakeholders and the public; and report to the IJC on conditions and regulation actions.

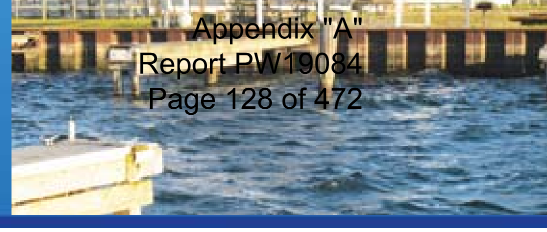
The IJC will transform the existing International St. Lawrence River Board of Control into the International Lake Ontario–St. Lawrence River Board to implement the Plan 2014 regulation plan and the directives stemming from the Order of Approval. This new Board would be responsible for making release decisions in accordance with the rules of the regulation plan (Annex B) and the directive on deviations (Annex C), and other duties assigned by IJC directives. The new Board will have at least 10 members, with an equal number from each country, including at least one Board member from each of the five federal, provincial and state jurisdictions. In addition, the IJC would appoint members to obtain a balance of expertise on the Board from across the Lake Ontario–St. Lawrence River basin, including First Nations and Tribes.

The IJC would appoint one member from each country to serve as co-chairs of the Board. Each of the co-chairs of the Board would appoint a Regulation Representative who would maintain a database of hydrological information for the Board, conduct the regulation plan calculations, make needed within-the-week flow adjustments, coordinate and keep account of flow deviations, and advise the Board on regulation operations.

The new Board would also: oversee the normal hourly and daily flow variations carried out by the hydropower entities according to the directive on peaking and ponding issued by the IJC; guide the development and implementation of an adaptive management plan; and promote outreach and engagement with the public and industry so that everyone interested in the regulation of the Lake Ontario-St. Lawrence River system can access the Board's information and has opportunities to express views regarding regulation. The Board will report at least semi-annually to the IJC.

Annex D addresses the governance of Plan 2014 in more detail.

4. Effects of Plan 2014 on the Uses and Interests



The *Boundary Waters Treaty of 1909* lists an order of precedence for the uses of boundary waters. It gives precedence to water uses for domestic and sanitary water purposes, uses for navigation, and for hydroelectric generation and irrigation. The Treaty also requires that the IJC ensure, as part of its approval of a project, that "suitable and adequate provision be made for the protection and indemnity of all interests" on either side of the boundary. The IJC respects the order of precedence of the listed uses while ensuring that all legitimate interests are protected.

Section 4 presents an overview of the projected effects of Plan 2014 on the uses and key interests served by the waters of Lake Ontario and the St. Lawrence River, compared to the effects under the existing Plan 1958DD. The uses and interests are:

- municipal and industrial water use;
- commercial navigation;
- hydropower generation;
- coastal development;
- ecosystems; and,
- recreational boating.

Tables 1 and 2 summarize the expected environmental and economic performance, respectively, of Plan 2014 relative to five other regulation plans, including the existing plan, Plan 1958DD. Performance estimates used in this section of the report are drawn from these tables.[7]

[7] Economic effects in Table 2 are expressed in U.S. dollars using the Canadian exchange rate of 0.833 of September 2005, reflecting the study timeframe. Updating costs and benefits to current dollars would entail consideration of changes in the exchange rate, energy and real estate prices, changes in the costs of operating ships, and more. However, updated costs would not change the conclusions of the analysis summarized in this section.

Table 1

Environmental Performance Indicators for Six Regulation Plans

Environmental Performance, Ratio to 1958DD, Historical water supplies	Regulation plans					
	Natural	1958DD	2007	B+	Bv7	2014
Lake Ontario						
Meadow marsh	1.56	1.00	1.22	1.44	1.46	1.41
Spawning habitat supply (Low Veg 18C)	0.88	1.00	0.93	0.95	0.96	0.96
Spawning habitat supply (High Veg 24C)	1.08	1.00	1.01	1.00	0.98	0.99
Spawning habitat supply (Low Veg 24C)	1.11	1.00	1.01	1.02	1.05	1.04
Northern Pike - YoY recruitment	1.03	1.00	1.02	1.00	0.98	0.99
Largemouth Bass - YoY recruitment	0.96	1.00	0.98	0.98	0.98	0.98
Least Bittern - reproductive index	1.13	1.00	0.93	1.04	1.12	1.11
Virginia Rail reproductive index	1.15	1.00	0.96	1.11	1.16	1.15
Black Tern reproductive index	1.16	1.00	0.97	1.12	1.19	1.16
Yellow Rail preferred breeding habitat	1.01	1.00	0.99	1.01	1.04	1.02
King Rail preferred breeding habitat	1.27	1.00	1.04	1.10	1.19	1.16
Upper River						
Spawning habitat supply - Low Veg 18C	1.04	1.00	1.01	1.01	1.02	1.01
Spawning habitat supply - High Veg 24C	1.02	1.00	1.02	1.01	1.00	1.01
Spawning habitat supply - Low Veg 24C	1.04	1.00	1.01	1.01	1.02	1.01
Northern Pike - YOY recruitment	1.06	1.00	1.00	1.03	1.03	1.03
Largemouth Bass - YOY recruitment	1.00	1.00	1.00	1.00	1.00	1.00
Northern Pike - YOY net productivity	2.07	1.00	1.01	1.46	1.39	1.39
Virginia Rail (RALI) - reproductive index	1.33	1.00	1.31	1.27	1.17	1.17
Muskrat house density,drowned river mouth wetlands	14.29	1.00	1.35	2.99	2.59	2.56
Lower River						
Golden Shiner - suitable feeding habitat area	1.01	1.00	1.02	1.00	See note	1.00
Wetlands fish - abundance index	0.97	1.00	0.81	0.90		1.00
Migratory wildfowl - habitat area	0.94	1.00	1.00	0.97		0.98
Least Bittern reproductive index	1.06	1.00	1.03	1.03		1.02
Virginia Rail reproductive index	1.04	1.00	0.96	1.05		1.03
Migratory wildfowl productivity	1.02	1.00	1.00	1.01		1.01
Black Tern reproductive index	1.01	1.00	0.95	0.97		1.01
Northern Pike reproductive area	1.01	1.00	0.97	1.03		1.01
Eastern Sand Darter reproductive area	1.00	1.00	1.03	0.99		1.00
Spiny Softshell Turtle reproductive habitat area	1.01	1.00	1.01	1.01		0.99
Bridle Shiner reproductive habitat area	0.97	1.00	1.06	0.92		0.95
Muskrat surviving houses	1.05	1.00	1.14	0.99		0.96
Shading indicates species at risk						

Note: Scores above 1.1 and below 0.9 are considered significantly different from Plan 1958DD results. Lower river results for Bv7 are not available; scores for a similar plan ranged from 0.94 (Muskrat) to 1.03 (Virginia Rail and Wetland fish abundance index)

Table 2

Average Annual Net Economic Benefits for Six Regulation Plans
(in $US million 2005)

Economic Benefits (Net Average Annual, using stochastic water supplies)	Natural	1958DD	2007	B+	Bv7	2014
Total	**-$20.80**	**$0.00**	**$3.55**	**$1.31**	**$1.61**	**$3.12**
Municipal and industrial water use	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
St. Lawrence River one time infrastructure costs	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Lake St. Louis water quality investments	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Commercial Navigation	**-$0.05**	**$0.00**	**-$0.29**	**-$1.24**	**-$0.02**	**$0.00**
Ontario	-$0.02	$0.00	$0.00	-$0.01	-$0.01	-$0.01
Seaway	-$0.02	$0.00	-$0.31	-$1.19	-$0.01	$0.00
Montreal	-$0.01	$0.00	$0.02	-$0.04	$0.00	$0.01
Hydropower	**$12.59**	**$0.00**	**$2.37**	**$6.08**	**$5.40**	**$5.26**
NYPA-OPG	$8.77	$0.00	$0.77	$3.85	$3.45	$3.41
Hydro-Quebec	$3.82	$0.00	$1.60	$2.22	$1.95	$1.85
Coastal	**-$29.88**	**$0.00**	**$0.16**	**-$2.78**	**-$3.17**	**-$2.23**
Ontario total	-$27.38	$0.00	$0.06	-$2.53	-$3.11	-$2.22
Shore protection maintenace	-$19.85	$0.00	$0.03	-$2.16	-$2.62	-$1.94
Erosion to unprotected developed parcels	-$0.58	$0.00	$0.01	-$0.17	-$0.17	-$0.16
Flooding	-$6.94	$0.00	$0.02	-$0.20	-$0.32	-$0.11
Upper St. Lawrence River flooding	-$2.00	$0.00	$0.01	-$0.04	-$0.07	-$0.01
Lower St. Lawrence River flooding	-$0.49	$0.00	$0.08	-$0.22	$0.00	$0.00
Recreational Boating	**-$3.46**	**$0.00**	**$1.32**	**-$0.74**	**-$0.60**	**$0.10**
Above dam	-$5.31	$0.00	-$0.15	-$1.42	-$1.33	-$0.68
Ontario	-$4.93	$0.00	-$0.27	-$1.18	-$1.11	-$0.57
Alexandria Bay	-$0.36	$0.00	$0.06	-$0.29	-$0.25	-$0.14
Ogdensburg	-$0.07	$0.00	$0.01	$0.00	-$0.02	-$0.01
Lake St. Lawrence	$0.05	$0.00	$0.05	$0.05	$0.04	$0.05
Below the dam	**$1.85**	**$0.00**	**$1.47**	**$0.68**	**$0.72**	**$0.78**
Lake St. Louis	$1.03	$0.00	$0.74	$0.49	$0.45	$0.48
Montreal	$0.64	$0.00	$0.55	$0.19	$0.20	$0.22
Lake St. Pierre	$0.18	$0.00	$0.18	$0.00	$0.07	$0.08

4.1 Municipal and Industrial Water Use

4.1.1 Overview of the Use[8]

Municipal and industrial water uses include public and private sector organizations using water for domestic, municipal and industrial purposes. This group includes owners/operators of municipal water and wastewater treatment facilities and large self-supplied industrial plants.

4.1.2 Effects of Plan 2014

The analysis concludes that there would be no change in the economic impacts on municipal and industrial water and wastewater use under Plan 2014. Regulation under Plan 2014 would continue to provide benefits to domestic water uses in the Lake Ontario-St. Lawrence River region. In its 2006 report, the Lake Ontario-St. Lawrence River Study Board concluded that domestic use on the St. Lawrence River would be affected by water levels regardless of the regulation plan. However, additional analysis undertaken for this study concludes that there would be no difference in those effects between Plans 2014 and 1958DD.

The Study Board's municipal and industrial water use studies[9] were based on the responses to questionnaires sent to 43 water treatment plants and 79 wastewater treatment plants in the basin. Shore well[10] and industrial users were also studied. Researchers and utility managers considered how low and high critical lake and river level elevations would affect domestic water uses.
The questionnaire responses were supplemented by telephone conversations and on-site visits in Quebec, New York and Ontario. Other issues, such as the impact of frazil ice at lower water surface elevations, were investigated, as well.

The Study Board identified two potential low water issues: whether water supply plants could draw water through the intake; and whether the quality of water drawn in at those levels would require additional treatment to avoid taste and odor problems. In general, evaluation of the ability to withdraw water was based on the minimum amount of water or "cover" that an operator would prefer to have above an intake structure. On Lake Ontario, water intakes are at least 3.6 m (12 ft) below chart datum (also known as low water datum), with large system intakes 12 to 18 m (40 to 60 ft) deep. St. Lawrence River water treatment plant operators reported taste and odor problems had occurred at low river stages, and researchers developed cost estimates for treatment based on operator experience.

The Study Board concluded that during long droughts, St. Lawrence River municipal water suppliers would need to undertake additional treatment because of taste and odor issues caused by the tendency for increased algal blooms at lower water elevations. However, the frequency and magnitude of this effect would be the same under Plan 2014 as under Plan 1958DD.

The Study Board also identified potential high water effects on water supply operations and wastewater treatment discharges. Flood damages to plant and shore protection structures were measured under the coastal sector in the Lake Ontario-St. Lawrence River Study. Wastewater treatment plant operators identified the high and low water elevations that would begin to affect or even interrupt the services they provided.

During and after the 2000-2006 Study, concerns were raised about the flooding of water supply and wastewater infrastructure on the Lake Ontario south shore. In all these cases, the facilities reported experiencing problems with the lake levels in recent decades under the current regulation plan. Following additional interviews and analysis, the Study Board concluded that, "municipal, industrial and domestic water-use facilities are generally not vulnerable to water level changes." For example, the Study Board reported that the Ginna Nuclear Generating Station planned to address design issues relating to the intake of water at low water levels that could occur with any regulation plan. However, the Monroe County potable water treatment plant in Greece on the south shore of Lake Ontario would

[8] Based on Lake Ontario-St. Lawrence River Study Municipal, Industrial and Domestic Water Uses Technical Work Group Report (IJC, 2006a).
[9] IJC, 2004
[10] A shore well is a well close to a lake in which the well water levels are directly influenced by lake levels.

experience problems even within the historical high water level range.

The Study Board also found that the Montreal water supply system could be at risk in the future if river levels fell below historical lows in conditions similar to those modeled with the driest climate change scenario.

During the IJC's 2013 public hearings on Plan 2014, representatives from the Village of Sodus Point, NY, reported that the main municipal sewer lift station was "at an elevation of 248 feet above sea level" and that higher Plan 2014 water levels would create a health and environmental hazard from some low-lying Wayne County septic systems (Figure 11). As noted earlier in this report, the IJC acknowledges that Lake Ontario levels would exceed this level slightly more often under Plan 2014 than under Plan 1958DD. However, Lake Ontario has risen above 75.59 m (248.0 ft) under Plan 1958DD in the 1970s and 1990s and will under any regulation plan with high water supplies to the lake. Parts of Wayne County, including septic tanks on Crescent Beach, will continue to be vulnerable to flooding and erosion under any regulation plan.

Regulation of Lake Ontario levels under either Plan 2014 or Plan 1958DD greatly reduces the frequency and depth of flooding in Sodus Point that would occur without regulation. The IJC recognizes that Lake Ontario's shoreline, particularly the south shore, is vulnerable to damage that can occur with any regulation plan due to extremely high supplies that have occurred a few times in the 20th century. The IJC supports collaborative attempts to reduce this vulnerability. Moreover, the IJC's extensive work with communities along the Lake Ontario-St. Lawrence River shoreline in Canada and the United States provides a unique opportunity to promote greater public and private collaboration to address this challenge.

4.2 Commercial Navigation

4.2.1 Overview of the Use[11]

Commercial navigation uses include domestic and international commercial ships transporting goods in the St. Lawrence and Lake Ontario system, including the St. Lawrence Seaway and the Port of Montreal. Ship traffic at the Port of Montreal includes ship transiting the Seaway and larger, deeper-draft ocean-going ships.

An estimated 70,000 jobs and nearly $4 billion in income and expenditures have been attributed to St. Lawrence River-Great Lakes commerce that transited the New York State waters (Martin Associates, 2011). The Port of Montreal handles more than 30 million tonnes of cargo annually and over 1 million TEUs (twenty-foot equivalent unit containers) (Port of Montreal, 2012).

The St. Lawrence River hydropower project was designed and built separately from the Seaway locks and channels but was to "be adaptable to the improvement of the International Rapids Section of the St. Lawrence River for navigation purposes" (IJC, 1952). The regulation of water levels and flows affects the water depths available on Lake Ontario and the St. Lawrence Seaway, which runs from Lake Ontario to Montreal. Lake Ontario outflow regulation also affects the levels at the Port of Montreal and those in the St. Lawrence ship channel as far downstream as Trois Rivières, QC.

4.2.2 Effects of Plan 2014

The IJC finds that, overall, Plan 2014 would provide about the same benefits as Plan 1958DD for commercial navigation in the Lake Ontario-St. Lawrence Seaway, as well as for ships using the Port of Montreal and lower St. Lawrence River.

Plan 2014 was developed and refined in collaboration with representatives of the navigation industry, including officials from the Canadian and U.S. St. Lawrence Seaway agencies and the Port of Montreal. The plan includes rules to support adequate levels for full-draft ships on the Seaway at all points in the navigation channel from Lake Ontario to Lake St. Louis. Formalized rules built into the plan mean that the Seaway would no longer have to rely on discretionary deviations by the Board of Control to provide adequate levels on Lake St. Lawrence and Lake St. Louis for shipping.

To address situations when water supplies are extremely low and threaten the plan's ability to maintain full depths throughout the system, the revised Orders would give authority to the

[11] Based on Lake Ontario-St. Lawrence River Study Commercial Navigation Technical Work Group Report (IJC, 2006b).

Board to deviate from the Bv7 release rules when Lake Ontario levels are at low trigger levels to provide relief to water intakes, navigation and hydropower in the system, consistent with the order of precedence of uses specified in the Treaty. In response to comments received during public consultations on Plan 2014, the IJC modified the draft directive to grant the Board the authority to deviate without first needing approval from the IJC (see Annex C).

The revised Order would establish the International Lake Ontario-St. Lawrence River Board, reporting to the IJC, to oversee daily operations and oversight of Lake Ontario-St. Lawrence River water levels and flows. In recognition that safe navigation depends on adequate water levels throughout the system, navigation expertise will be included on this Board.

Shipping Costs

The IJC's Lake Ontario-St. Lawrence River Study of the effects of regulation on commercial navigation was designed by experts from the Great Lakes-St. Lawrence Seaway Navigation community[12]. The Study measured the impact of available water depths and water velocities on shipping costs in the different reaches of the Lake Ontario and St. Lawrence River system. Table 2 lists the results using the Study's commercial navigation performance indicators.

The Commission finds that, overall, Plan 2014 will provide about the same benefits as Plan 1958DD for commercial navigation in the Lake Ontario-St. Lawrence Seaway as well as for ships using the Port of Montreal and lower St. Lawrence River.

Review of the navigation performance indicators after the Study found that the cost of light-loading[13] ships due to limited available depths downstream of Montreal had been underestimated, as only the effect on the ship travel cost on the St. Lawrence River had been included rather than the effect on travel costs on the entire ocean route. (A post-study analysis showed that correcting this error would not change plan rankings). Later, Seaway entities also questioned several of the assumptions in the Study's economic analysis of navigation, particularly those regarding costly ship stoppages due to unsafe velocities in the international section of the St. Lawrence River (St. Lawrence Seaway Management Corporation. 2008). They suggested that instead of an economic analysis, an analysis of water levels and flows resulting from the regulation plans would be more appropriate.

A full suite of water level and flow statistics defined by the Study Board's navigation work group is available for all regulation plans, including Plan 2014. This analysis indicates the frequency and magnitude of levels that require light-loading by ships on different routes and the frequency of flows greater than that considered safe by the Seaway. Although such statistics do not reveal the economic impact on navigation, the IJC did consider these statistics in its evaluation. This analysis shows that:

- the frequency of low levels on the St. Lawrence River at Montreal would be about the same under Plan 2014 as Plan 1958DD;
- Plan 2014 would increase the frequency of rare low levels Lake Ontario[14] that cause some ships that operate only on Lake Ontario to light-load; and,
- overall, there would be slightly fewer draft restrictions due to low levels for ships transiting the route from Lake Ontario to Montreal with Plan 2014 than with Plan 1958DD, which is the result of the rules built into Plan 2014 that better coordinate levels on the river with those on the lake.

[12] The Navigation Technical Working Group was led by representatives from the Canadian St. Lawrence Seaway Management Corporation, the U.S. Army Corps of Engineers, and the Shipping Federation of Canada. It also included members from the Port of Montreal, the Montreal Port Authority, Transport Quebec, the Canadian Coast Guard, and the U.S. St. Lawrence Seaway Development Corporation (IJC 2006).

[13] To light-load means to take on a load less than the ship capacity or less than a complete cargo, as the fully loaded ship would be too close to the channel bottom because of low water levels

[14] Analyses using the stochastic 50,000-year water supply set indicated that the frequency of quarter-month mean Lake Ontario levels below 74.27 m (the lake level required for full Seaway draft ships to transit without restrictions) during the nominal seaway season would increase from 1.8% to 3.3% of the time. The frequency of Lake Ontario levels below 74.00 m during the nominal seaway season would increase from 0.3% to 0.8% of the time.

Some navigation interests are concerned that lower Plan 2014 Lake Ontario levels, while very infrequent, could significantly impact commercial operations. Ships that do not leave Lake Ontario would have to carry reduced loads in those periods. However, most ships that traverse Lake Ontario are on their way to the St. Lawrence River or upper Great Lakes, and are loaded based on the minimum depth available along their entire route. The loading depths of ships that transit Lake Ontario and the upper Great Lakes may not be affected by lower Lake Ontario levels due to even shallower conditions on the upper lakes. The Lake Ontario-St. Lawrence River Study navigation analysis models did not consider the effect that water levels on the upper Great Lakes may have on shipping, but historical data demonstrate that Lakes Superior, Michigan and Huron are far more likely to determine ship loading than Lake Ontario levels under Plan 2014. Depths of water shown on Great Lakes navigation charts are referenced to one low water elevation called chart datum on each lake. Based on simulations using historical water supplies, Lake Ontario would be below chart datum during the seaway season 4% of the time under Plan 2014, while Lake Superior would be below chart datum 19% of the time and Lakes Michigan and Huron, 21% of the time. Thus, though Plan 2014 does not affect levels of any of the Great Lakes except Lake Ontario, water levels on the upper lakes should be taken into consideration when evaluating the effects of Lake Ontario regulation plans.

Other Benefits to Navigation Interests

The IJC concludes that Plan 2014 would offer benefits for navigation beyond providing adequate shipping depths. These additional benefits include the following:

- *Certainty of benefits that have previously been obtained through deviations at the discretion of the Board of Control*. Criterion H1 of the conditions to be included in a new Order of Approval (Annex A) would mandate limits on the occurrence of low levels at the Port of Montreal to rates similar to what has been achieved through past discretionary deviations from Plan 1958-D by the Board of Control. Criterion H2 would provide similar protection of levels on the Seaway at Lake St. Louis.
- *Clearer definition of the conditions required for long-term major deviations that help commercial navigation*. Criterion H14 would provide protection for navigation similar to criterion k of the current orders. The IJC changed the Directive on Deviations based on comments received during the 2013 Hearings on Plan 2014 so that the Board would no longer need to seek IJC approval to make these deviations. Under the current orders, the IJC has to approve criterion k deviations.
- *Greater ability to improve operations*. With an adaptive management framework in place, the performance of Plan 2014 for navigation would be monitored and suggested improvements tested.
- *Safer velocities*. More natural changes in flow from week to week and better maximum outflow rules would provide safer velocities for navigation in some circumstances.

In addition, minor deviations authorized now as part of Plan 1958DD to provide short-term assistance to commercial navigation would continue under Plan 2014. Deviations from the new regulation plan are expected to be much less frequent, because procedures to provide adequate river levels in the Seaway have been built into the new plan that were not in Plan 1958-D.

4.3 Hydropower

4.3.1 Overview of the Use[15]

Hydropower uses include: the two hydroelectric generating stations on the international section of the St. Lawrence River (the Robert-Moses station owned by the New York Power Authority and the Robert H Saunders station of Ontario Power Generation, which together form the Moses Saunders Dam); and the Beauharnois and Les Cedres stations of Hydro Quebec at the outlet of Lake St. Francis.

Combined, these power plants have an annual hydropower production of approximately

[15] Based on Lake Ontario-St. Lawrence River Study Hydroelectric Power Generation Technical Work Group Report (IJC, 2006c).

25 million MWh (13 million MWh at Moses-Saunders and 12 million MWh at Beauharnois-Les Cedres). The market value of this energy is approximately $1.5 billion U.S. a year at current market rates.[16] These hydroelectric plants produce enough energy to meet the needs of about two million homes.

4.3.2 Effects of Plan 2014

Under Plan 2014, the slightly higher and more natural fall through spring Lake Ontario levels that benefit coastal ecosystems also would slightly increase the head[17] and thus, energy production at the Moses-Saunders power plants. Plan 2014 also would slightly increase the amount and value of hydropower produced at the Hydro-Quebec plants. Although the higher Lake Ontario levels also would slightly reduce the head at the Niagara power plants, the net effect would be to increase the production of hydropower at all these plants by about 0.4%, or enough to supply the needs of about 8,000 homes.

In the Lake Ontario-St. Lawrence River Study, the economic experts panel advised the Study Board that the best metric to reflect societal impact in the energy sector was the increase in the value of hydropower energy caused by different regulation plans. Other societal metrics, such as the reduction in carbon emissions, were acknowledged but not evaluated in economic terms.

The Hydropower Technical Work Group of the Lake Ontario-St. Lawrence River Study helped design other metrics that were important to hydropower producers, termed the *stability* and *predictability* of flows. More stable releases change less from week to week, while more predictable releases change less from month to month. When possible, hydropower producers will take turbines out of production for maintenance only when the water release can be routed through other turbines that remain in service. A large, unexpected release increase may require spilling part of the release (that is, releasing the water but not running it through a turbine to create electricity). Plan 2014 would provide slightly more stable and predictable releases, thereby reducing the chance of energy losses during turbine maintenance.[18]

4.4 Coastal Development

4.4.1 Overview of the Interest[19]

Coastal development interests include individuals and organizations with a direct interest in the property along the shorelines of Lake Ontario and the St. Lawrence River (riparian property), particularly private property owners.

Approximately 60% of the Lake Ontario and St. Lawrence River shoreline is devoted to residential land use. In some of the developed counties, such as Monroe County, in New York on the southeast shore, the percentage of developed property is much higher, at almost 90% (Figures 11 and 12). The Lake Ontario-St. Lawrence River Study concluded that an estimated 25,000 privately owned riparian properties are located on Lake Ontario and the St. Lawrence River upstream of the Moses-Saunders Dam. More than 3,000 shoreline property parcels are located below elevation 76.2 m (250 ft) and could be at risk of flooding on Lake Ontario and the upper St. Lawrence River.

On the St. Lawrence River downstream of the Moses-Saunders dam, there are an estimated 5,770 single-family dwellings within the 100-year floodplain, with an estimated value of $380 million.

Shoreline protection structures are already present for a large percentage of riparian properties exposed to flooding and erosion hazards around the shores of Lake Ontario (Figure 13). Analysis undertaken as part of the Lake Ontario-St. Lawrence River Study found that approximately half of the developed shoreline length has been armoured with some sort of shorewall or revetment. In addition, shore protection measures have been added to about half of the total frontage on both the Canadian and American shores of the lower St. Lawrence River.

[16] Estimated price of $60 per MWh.

[17] The change in elevation between the water level upstream and downstream of the hydropower dam. Head, flow and turbine efficiency determine how much power is generated. All else being equal, greater head means more power generation.

[18] Flow into a turbine can be redirected to other turbines when it is necessary to perform maintenance or repair tasks, but only if the total flow is small enough to fit the capacity of the remaining turbines. When possible, turbine maintenance is scheduled for periods when releases are expected to be low. Plan 2014 releases do not change as much as 1958DD releases from week to week or even month to month.

[19] Based on Lake Ontario-St. Lawrence River Study Coastal Processes Technical Work Group Report (IJC, 2006d).

Figure 11

Crescent Beach, Wayne County, NY

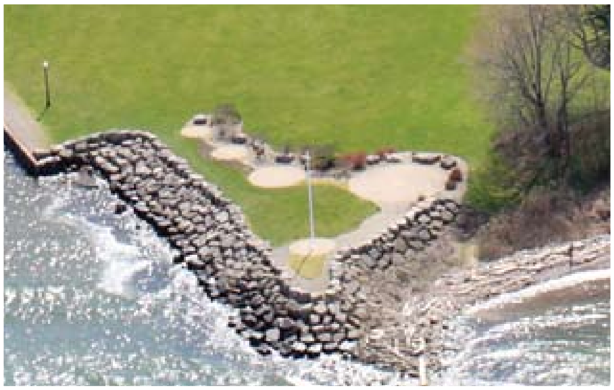
Figure 12

Monroe County, NY

These photographs, taken in March 2012, show two locations on the south shore of Lake Ontario when water levels are at 74.98 m (246.00 ft) IGLD 1985. This level is slightly above average for that time of the year, more typical of mid-summer levels, though 0.78 m (2.6 ft) below the maximum recorded level. Almost all the damage estimated by Lake Ontario coastal computer models is related to shore protection structures (either damage to existing structures or erosion that requires a new structure to protect a building). But there are some buildings that are vulnerable to flooding and storm damage, no matter the regulation plan.

Figure 13

Examples of Shore Protection, Lake Ontario



(source: U.S. Army Corps of Engineers)

4.4.2 Effects of Plan 2014

Over the past several decades, many property owners and their municipal and state elected representatives on the south shore on Lake Ontario in New York have expressed concern about coastal property damage from high lake levels. During public hearings on Plans 2007 and 2014, property owners spoke to the IJC about damage that has occurred in the past and additional damage that could result with a change in the regulation plan.

The damages, as identified in Table 3, suggest that Lake Ontario coastal development will be vulnerable, no matter the regulation plan. Both the gross and net damages in Table 3 show that these damages are mainly to shore protection structures, not homes. The vulnerable shore protection structures typically are revetments made of large rocks piled in a sloping cross-section on the graded bank of the shore, or vertical shore walls made of concrete or steel sheet-piles capped by a concrete or stone pad, or a combination of these structures.

The structures are meant to stop erosion of the bank by absorbing or reflecting the energy of coastal waves. The size of the rock, the steepness of the side slope and especially the elevation of the top of the structure are all important factors in the design of a revetment. A single major storm event with waves that rush over the top of such structures can cause significant erosion damage to the structure.

Computer simulations show that average annual damages to the Lake Ontario coastal development are expected to be somewhat larger under Plan 2014 than under Plan 1958DD. These long-term simulations are based on estimates of the damages under 1958DD and each alternative plan. For example, the average net increase in damage to all Lake Ontario shore protection structures for Plan 2014 is estimated at $1.94 million per year (the difference between estimated average annual damages of $15.48 million for Plan 1958DD and $17.43 million for Plan 2014).

The fact that Plan 2014 would cause more damage on average does not mean that continued regulation under Plan 1958DD would guarantee lower coastal damages. In some future circumstances, Plan 2014 could reduce damages compared to those under Plan 1958DD. The damages summarized in Table 3 are based on thousands of simulations of different water supply scenarios, each representing a different, possible sequence of water flowing into Lake Ontario. Of these, there are more scenarios in which Plan 2014 damages are greater than Plan 1958DD damages, but many in which Plan 1958DD is more damaging. The near-term future could include either type of water supply sequence.

Coastal damage will occur no matter the regulation plan

Most of the damage is to shore protection structures, not homes

More often than not, Plan 2014 would increase damages compared to Plan 1958DD

Table 3

Gross and Net Damage to Lake Ontario Coastal Development

(in $US millions 2005)

Expected Average Annual Lake Ontario Coastal Damages	1958DD	2014	Bv7	Natural
Damages	$18.15	$20.37	$21.26	$45.53
Shore Protection Maintenance	$15.48	$17.43	$18.11	$35.33
Erosion to Unprotected Developed Parcels	$2.50	$2.66	$2.67	$3.08
Flooding	$0.17	$0.28	$0.49	$7.11
% total damage attributed to shore protection structures	85%	86%	85%	78%
Net change from 1958DD damages	**$0.00**	**$2.22**	**$3.11**	**$27.38**
Net damages to shore protection structures		$1.94	$2.62	$19.85
% of changes attributes to shore protection structures		88%	84%	73%

Under either Plan 1958DD or Plan 2014, only about 1% of expected coastal damage is due to flooding of buildings; the rest is due to damage to existing shore protection (85-86%) and the costs of new shore protection because of erosion of unprotected developed parcels (13-14%). Five percent of the increase in coastal damages along Lake Ontario under Plan 2014 is due to increased flooding.

The Natural Plan (referred to as Plan E in Study documents) represents the release of Lake Ontario water through the existing flow control structures equivalent to what would occur with the river as it was circa 1953-1955 after removal of Gut Dam, but before any of the structures or channels approved in the 1952 and 1956 Orders were built, with minimal adjustments to reflect necessary ice management with the structures in place. Plan 2014 combines the release rules of Bv7 with deviations described in Annex C.

Tradeoffs in Managing the Natural and Developed Shore

There are challenges to balancing healthy coastal wetlands and property damage along the Lake Ontario shoreline. In its 2006 report, the Lake Ontario-St. Lawrence River Study Board found that Plan 1958DD came close to minimizing damages for Lake Ontario shoreline property owners but had reduced the diversity of plant types along the shore and populations of animal species that feed on and live in the environments affected by the reduced water level ranges.

The Study Board and Working Group produced a range of regulation plans that met the Treaty's requirements but that produced different levels of benefits among interests. No plan, however, could completely overcome this inherent conflict. Plans that restored a significant measure of coastal ecosystem health did so with more natural lake levels. More natural levels, by contrast, increased damages to vulnerable shoreline development. An alternative such as Plan 2007, which relaxed the compressed summer levels Lake Ontario while keeping autumn and winter levels unnaturally low, resulted in a slight reduction in coastal damages on average, but did little to reverse the harm to the environment.

In selecting a new regulation plan, the IJC chose to strike a balance between the two objectives. Plan 2014 produces a large improvement in coastal ecosystems in return for a small reduction in the benefits provided in the 1956 Order for those shoreline property owners who need to maintain shore protection to limit erosion and flooding.

Most south shore residents who testified in the 2013 hearings opposed Plan 2014. They argued that Plan 2014:

- would cause significant coastal damage;
- is based on past studies that underestimated impacts to south shore residents;
- is unfair because only the south shore would be hurt by Plan 2014;
- changed the rules for regulating Lake Ontario water levels after decades of long-term development decisions were made based on the previous regulation rules;
- damages should be mitigated if the plan were implemented; and,
- is based on flawed wetland science.

The IJC considered each of these concerns carefully before making its findings in support of Plan 2014.

Concern 1: Coastal Damage

Some south shore residents expressed concern that the new regulation plan would destroy coastal development and with it, the associated tax revenue, property values and tourism opportunities upon which shoreline counties depend.

This risk exists no matter the regulation plan. While models demonstrate that Plan 2014 is likely to increase coastal damage to shore protection structures on Lake Ontario by a relatively small margin, the same models also demonstrate that coastal damage could occur under either plan in the near future.

About 87% of the increase in expected damages to Lake Ontario coastal development under Plan 2014 would be to shore protection structures (Figure 14). This incremental damage could be avoided by designing such structures a few inches higher. Another 7% of the increase in cost would be due to new shore protection structures for currently unprotected developed properties. These structures would be built with either Plan 2014 or Plan 1958DD. But it is expected that they would be needed sooner with the higher frequency of higher levels under Plan 2014.

Figure 14

Increases in Lake Ontario Coastal Damage under Plan 2014, by Type

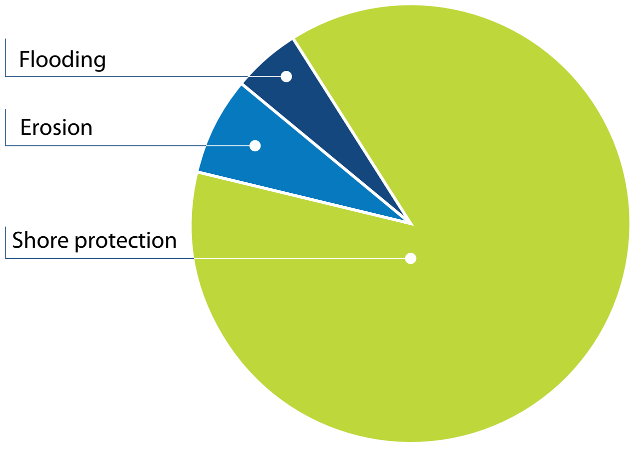
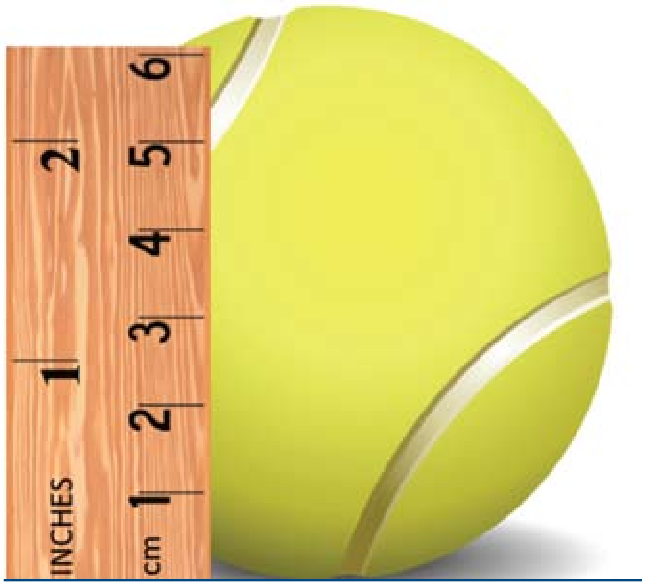


Figure 15

Comparing Maximum Triggering Levels of the Two Plans



Based on historical supplies, Plan 2014's projected maximum level would be 6 cm (2.4 in) higher than the maximum level under 1958DD. By way of comparison, a tennis ball is about 6.7 cm in diameter

The incremental increase from Plan 1958DD to Plan 2014 flooding damage to homes and other buildings is about 5%. Based on the best estimates available to the IJC, Plan 2014 would not change the floodplain delineation. Rather, the 5% increase in damages is based on the use of standard "depth damage" relationships that show the typical increase in damages with each additional centimeter (or inch) of flooding. The Plan 2014 maximum Lake Ontario level in the historical simulation, for example, is 6 cm (less than 3 inches) higher than the Plan 1958DD maximum level (Figure 15).

Water levels could be both higher and lower than any on record, regardless of the plan. With Plan 2014, if Lake Ontario water levels reach the high trigger levels, then releases from the dam would need to provide all possible relief to the riparian owners upstream and downstream. This is the same release requirement provided by criterion k of the 1956 Order. The proposed new Order would define a clear threshold for the relief to riparians, thus eliminating the need for IJC authorization.

The potential for record-breaking water supplies to cause serious damage to shoreline property was noted in testimony before the IJC. The risks of this level of damage are about the same under Plan 1958DD and Plan 2014. Because of the triggers, the more extreme the water supplies, the more Plan 2014 levels and releases would resemble Plan 1958DD levels and releases. At Lake Ontario levels of 76.0 m (249.34 ft) and higher, Plan 1958DD levels are higher than Plan 2014 levels 50% of the time.

Concern 2: Measurement of Effects

As noted, the Lake Ontario-St. Lawrence River Study Board had to limit studies in all categories, including coastal property damage, to those effects that were significant and useful in discerning differences between alternative regulation plans. An expert panel of economists advised the Study Board that measurement of secondary effects would have been practically impossible and, more importantly, unnecessary for plan ranking because the secondary effects moved proportionately with the major economic and environmental effects.

The Study Board accepted the expert opinion. The IJC endorses this finding.

Concern 3: Distribution of Effects

The negative net effects of Plan 2014 are all above the dam, because Plan 2014 is designed to reverse some of the environmental damage caused by compression of the range of Lake Ontario levels called for in the 1956 Order to reduce Lake Ontario coastal damage.

The compression of Lake Ontario levels since 1960 helped some riparians and hurt coastal ecosystems.

More natural levels hurt some shoreline protection structures and help coastal ecosystems.

Plan 2014 eliminates much of the environmental damage caused by past regulation while preserving most of the benefits to riparians.

As Table 3 shows, without water level regulation the damage to existing development on Lake Ontario and the St. Lawrence River would be more than $27 million per year higher on average than under the current regulation regime. Plan 2014 would eliminate much of the environmental damage caused by past regulation while preserving most of the benefits to shoreline property owners.

The meadow marsh performance indicator was used by the Study Board as an important indicator of how well a regulation plan produced diverse and robust wetland ecosystems. As shown in Tables 1 and 2, Plan 2014 would restore about 72% of the lost natural meadow marsh performance indicator[20] and a third of the lost natural northern pike young-of-year net productivity[21] at only about 8% of the Lake Ontario coastal damage expected in the natural unregulated system (Natural Plan/Plan E). Plan 2014 produces significant environmental gains while reducing the level of coastal damages caused by Plans B+ and Bv7. Wildlife biologists and coastal engineers worked together for years to achieve this result.

Concern 4: Past Siting and Design Decisions

During the 2013 hearings, the IJC heard testimony from some representatives of Lake Ontario's south shore that the IJC should not change the regulation plan because so many siting and design decisions had been made based on the lake levels expected with the 1956 Order.

Figure 16

Spaghetti Graphs of Plan 1958DD and Plan 2014. Lake Ontario Levels

Note: historical water supplies, spliced at mid-year to compare levels.

Plan 2014 increases the frequency of high lake elevations compared to 1958DD, but water levels under either plan will destroy shore protection designed for only the 1.22 m (4ft) range.

[20] The meadow marsh indicator is the ratio of the area of meadow marsh created by a plan after a long drought compared to the area produced by Plan 1958DD. The simulation of the Natural Plan (which is not, strictly speaking, a regulation plan, but rather refers to measures that are necessary in winter to avoid ice jams), produced a meadow marsh score of 1.56; Plan 2014 scores 1.41, a 41% increase in meadow marsh area. Damage to riparians was estimated in the Flood Erosion and Protection System (FEPS) model; three coastal damage indicators were used by the Study Board: flooding, erosion and shore protection damage, measured as the average annual change in damages or costs in each of the three sectors. The FEPS modeling indicated that the Natural Plan would on average cause $27.38 million more in damages along the Lake Ontario shore than Plan 1958DD, while Plan 2014 would cause $2.22 million. Comparing these two indicators, Plan 2014 gets 72% of the Natural Plan meadow marsh score for 8% of the E coastal damage cost.

[21] Young-of-year productivity is the amount of young fish (egg, fry, and juvenile, stages before sexual maturity) introduced into the system each year, measured in terms of the number and weight of the fish.

However, the IJC also heard testimony that development in this region typically has not been designed to withstand the actual levels experienced with the existing regulation plan, Plan 1958DD. Some testified that south shore development that flooded in the 1970s flooded again in the 1990s and will flood again at those same elevations. The IJC also heard testimony from south shore citizens during the hearings that shore protection structures are still being designed based on only a 1.22 m (4 ft) range in Lake Ontario levels. The "four-foot range" is a reference to the first part of a phrase in the 1956 Order to regulate Lake Ontario levels "*within a range of stage from elevation 74.15 meters (243.3 feet) (navigation season) to elevation 75.37 meters (247.3 feet), as nearly as may be*."

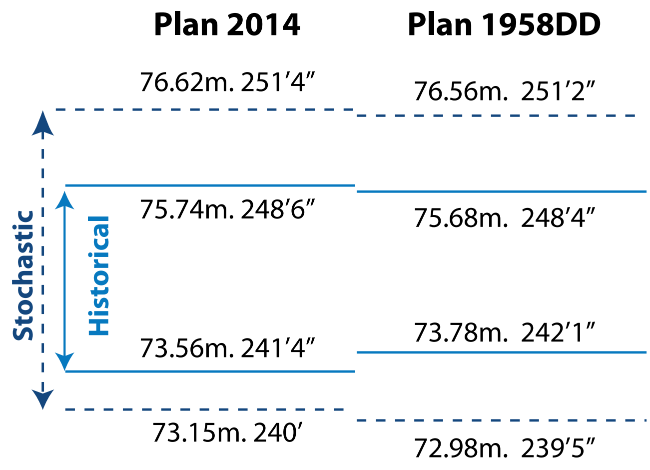
Note that the "nearly as may be" clause acknowledged even then that natural variation in water supplies could cause a wider range of levels. The criteria in the IJC's 1956 Order were clearly formulated on the knowledge that this range could not be guaranteed if supplies were more extreme than supplies of the past period of record (1860-1954). Water supplies to Lake Ontario in the 1970s, 1980s and 1990s were more extreme than those of the 1860-1954 period. As the split-screen spaghetti graph in Figure 16 shows, water levels under either plan will exceed the 1.22 m (4 ft) range even with historical supplies.

The fact that Lake Ontario levels will, despite the best efforts of the Board of Control under the existing 1956 Order, rise above and fall below the 1.22 m target range was demonstrated in the 1960s, 1970s and 1990s. Stochastic hydrology analysis developed by scientists during the Lake Ontario-St. Lawrence River Study suggests that it is possible that Lake Ontario levels under Plan 1958DD could rise above 76.5 m (251 ft) and fall below 73.0 m. (240 ft), a range of 3.5 m (11 ft) (Figure 17). These elevations were the most extreme reached in the simulation using the stochastic supplies. The damaging water elevations seen in 1952 (before regulation), 1973 and 1993 are not uncommon. As a result, some communities along the south shore will suffer coastal damages, again no matter the regulation plan.

As suggested by the stochastic supply analysis, it is likely that future water levels will again reach the high levels recorded in the 1970s and 1990s,

Figure 17

Lake Ontario Water Level Ranges, Plan 2014 and Plan 1958DD



The stochastic water supply data include much wetter and drier periods than have been recorded. Plan 2014 maximum Lake Ontario levels are 6 cm (2 in) higher than Plan 1958DD for the historical simulations, shown as solid lines in the figure above, as well as for the stochastic simulations, shown as dashed lines.

regardless of the regulation plan. The Lake Ontario-St. Lawrence River Study evaluation models verify this, showing that when the stochastic supplies are used as input to the plans, the average annual shore protection costs on Lake Ontario are $15.48 million under Plan 1958DD, and $17.43 under Plan 2014 (Table 3).

The projected effects of first-floor flooding of homes and other buildings and erosion to unprotected developed parcels are much smaller. Flooding damages under Plan 1958DD average $170,000 per year and $280,000 per year under Plan 2014. Study models do not indicate an increase in the number of homes flooded by Plan 2014 compared to Plan 1958DD.

Analysis using models developed for the Lake Ontario-St. Lawrence River Study suggests that Plan 2014 would not trigger a change in the floodplain delineation or in the base flood elevation. As noted, the difference in the maximum Lake Ontario levels of Plan 2014 and 1958DD in the historical water supply simulation is 6 cm (about 2.4 in). Given that floodplains are delineated at whole-foot increments, they are unlikely to be affected by such small increases in static levels.

Analysis by the Study Board suggests that Plan 2014 would not change the floodplain delineation or the base flood elevation, which is specified in whole-foot increments.

Study models do not indicate an increase in the number of first-floor flooding of homes under Plan 2014 compared to 1958DD.

The performance indicator used in the Study's evaluation model that accounts for the erosion of unprotected developed parcels of land measures the cost of future shore protection built when erosion brings the top of the shoreline within 10 m (33 ft) of the building to be protected. Plan 2014 would not change the number of these shoreline structures that eventually would be needed to protect their buildings, but typically would require homeowners to build the protection structures earlier, because the rate of erosion of the bank would be slightly higher. That is, the increase in average Plan 2014 erosion costs over Plan 1958DD costs represents the cost of building the same structure sooner. The two categories of damage relating to shore protection structures account for about 99% of the coastal damage under Plan 2014, with about 1% related to the flooding category.

Concern 5: Mitigation of Damages

The regulation of the outflows from Lake Ontario under the rules of Plan 2014 would continue to substantially reduce natural high levels and reduce the damages the south shore would experience without regulation of flows. As a result, Plan 2014 would benefit, not injure, south shore riparians relative to the unregulated condition.

The IJC's studies have underscored what other studies and past experience have shown: that future high Lake Ontario levels under any regulation plan, coupled with storms and wave action, can be expected to damage or threaten existing shore protection, water and wastewater systems and even some homes.

The IJC recognizes the complexity and difficulty of coastal zone and floodplain management, and the evolving and varied views evident in the responses to Hurricanes Hazel (1954), Katrina (2005) and Sandy (2013). However, the IJC believes that complex decisions to invest and manage coastal zones and floodplains should be based on the best available evidence of risk.

The level of risk accepted in the design of homes, structures and infrastructure systems is addressed by domestic regulations. The IJC can only inform those considerations with evidence from its own investigations. The IJC heard testimony and collected evidence in its own studies showing that damages or expense to avoid damages to shore protection structures and water and wastewater systems would occur under either Plan 1958DD or Plan 2014 more often than the common 1-in-100 years standard.

The IJC is considering the findings and recommendations from its International Great Lakes–St. Lawrence River Adaptive Management Task Team (IJC, 2013). The Task Team, led by experts from Environment Canada and the United States Army Corps of Engineers (USACE), investigated ways to adaptively manage the risks of and response to the impacts of low and high Great Lakes water levels, including those that cannot be managed through regulation of the levels of Lakes Superior and Ontario. The Task Team recommended that the negative impacts of very high and very low levels could be reduced if stakeholders and managers more effectively shared existing information on these risks to better support strategic decisions and investments.

Concern 6: Assessment of Damage to Wetlands

Some riparians who opposed Plan 2014 because of the effects on property on the south shore of Lake Ontario told the IJC that the environmental studies used as the basis for justifying Plan 2014 were flawed. The IJC reviewed the findings of the Lake Ontario-St. Lawrence River Study, the peer review commissioned by the IJC, and subsequent evidence and arguments on this subject before concluding that the evidence is overwhelming that current regulation rules damage the environment.

The Lake Ontario-St. Lawrence River Study Board sought out leading Great Lakes scientists to investigate and quantify the relationship between water levels and various aspects of coastal

Figure 18

Upper St. Lawrence River Wetland

(Photo: Doug Wilcox)

ecosystem health. The relationships were based on extensive field data and each study was required to validate the results.

As the Study used new data and methods, the IJC engaged the U.S. National Research Council and the Royal Society of Canada to conduct an independent peer review. The Study Board also conducted an extensive internal review process. The National Research Council review concluded that the breadth of the study was impressive, and commended the scale and inclusiveness of the studies and models (National Research Council, 2006). On the environmental studies, the reviewers concluded that "given the complexity of the LOSLR[22] system, binational interests, and the range of scientific and other information compiled, the undertaking of this comprehensive study is a major contribution by itself" and that the "identification and inclusion of performance indicators advance understanding of the Lake Ontario-St. Lawrence River system."

Concluding that there were few precedents for a study of this scale and that opportunities for improvement were to be expected, the peer reviewers raised three general criticisms:

- the level of empirical su pport varied among different studies (there were more data supporting some performance indicator algorithms than others);
- the level of integration among the models should be more dynamic, with feedback loops that would constitute a true systems model; and,
- ongoing monitoring and analysis are needed to provide a strong scientific basis for long-term decision making about water level and flow regulation in the Lake Ontario-St. Lawrence River basin.

The Study Board co-chairs and technical work group leads responded to the peer review (IJC, 2006e), concluding that none of the concerns raised by the reviewers challen ged the "appropriateness and sufficiency of the studies and models used to inform decisions related to regulation plan options." The co-chairs agreed with and addressed some of the peer review comments, but concluded that on other issues, such as lack of available documentation and the temporal resolution of the models, the peer review process should have allowed more communication between reviewers and study scientists. Study Board decisions were formulated after extensive debate among leading experts and in cooperation with the PIAG. The peer review process guaranteed the independence of peer reviewers, but as structured, that independence provided them with less information than study experts used in their decision making.

The peer review did raise questions about the wetlands study, and those questions were answered by the Study Board (IJC, 2006e). The wetlands study was published in a peer-reviewed journal after the Study Board finished its work (Wilcox and Xie, 2007), and, still later, the relationships between water levels and wetland plants were verified in a published study based on historical aerial photographs (Wilcox *et al*., 2008).

The IJC accepts the Study Board's response to the peer review and the scientific conclusions of the Lake Ontario-St. Lawrence River Study, including in particular, the Study Board findings on the relationships between Lake Ontario water levels and coastal ecosystems.

[22] Lake Ontario-St. Lawrence River

4.4.3 Prevention of Coastal Damage in the Province of Ontario

Modeling undertaken for the Lake Ontario-St. Lawrence River Study indicates that there would be coastal damage on the Canadian shore of Lake Ontario, particularly in the Niagara and Halton regional municipalities, under any regulation plan. However, the response from riparian interests along the Canadian shore of Lake Ontario has been markedly different. No concern was expressed in Ontario about Plan 2014 damage to coastal development during the 2013 hearings on Plan 2014. There was some concern expressed during the meetings in Ontario held by the PIAG in 2005, but in public meetings in the province from 2005 through 2013, the objective of more natural regulation received strong support.

The Ontario response can be attributed in part to a different history and institutional setting. In 1954, Hurricane Hazel caused about $1 billion ($Cdn 2013) dollars damage in the Toronto region, killing 81 people and leaving thousands homeless. After the hurricane, the provincial government amended the *Conservation Authorities Act* to enable an authority to acquire lands for recreation and conservation purposes and to regulate hazard lands for the safety of the community.[23]

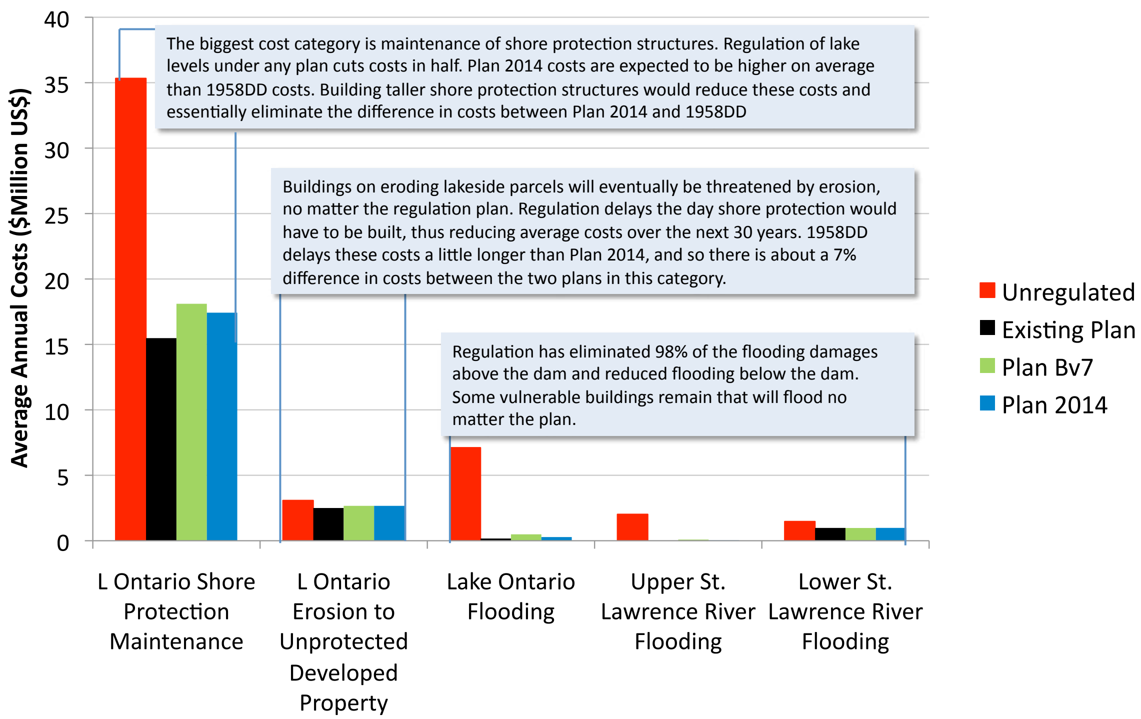
Along parts of the Ontario shore of Lake Ontario, local and regional governments are converting privately owned waterfront properties at risk of flooding or erosion to public space. For example, after the flooding of the 1970s, the City of Burlington, Halton Region and Conservation Halton began the Beach Property Acquisition Program with support from the Province of Ontario. After the purchase of 129 properties on a willing seller basis, less than 4% of the designated area remains under private ownership (City of Burlington *et al.*, 2011).

4.4.4 Summary

In summary, the IJC recognizes that there are challenges to balancing ecosystem protection interests and benefits to shore property development interests along the Lake Ontario shoreline. Each regulation plan involves a tradeoff among interests. Plans that restore a significant

Figure 19

Summary of Shoreline Protection, Erosion and Flooding Effects



[23] Environment Canada website, Hurricane Hazel Mitigation http://www.ec.gc.ca/ouragans-hurricanes/

measure of coastal ecosystem health do so with more natural lake levels. More natural levels, by contrast, could increase damages to shoreline development.

In selecting a new regulation plan, the IJC chose to strike a balance between the two objectives. Plan 2014 would produce a large improvement in coastal ecosystems in return for a small reduction in the benefits provided in the 1956 Order for those who live along the shore of Lake Ontario. The effects of Plan 2014 on shoreline property on the lake and river are summarized in Figure 19.

South shore residents who opposed Plan 2014 in the public hearings identified a range of concerns. The IJC considered each of these concerns carefully before making its findings in support of Plan 2014. Table 4 summarizes the IJC's response to the concerns.

The IJC finds that costs will have to be borne to maintain hardened shore structures along the shore of Lake Ontario regardless of the future regulation plan. Furthermore, the IJC finds that the benefits to wetlands are scientifically credible and that the evidence of harm by the current regulation plan is too great to ignore.

Table 4

Summary of the IJC's Response to Key Concerns Expressed by Residents of Lake Ontario's South Shore

Public Concern	IJC Response
1. Coastal Damage	Plan 2014 is not expected to change the floodplain delineation along Lake Ontario's shoreline Coastal damage will be experienced under either existing plan or Plan 2014 Most of this damage is to shoreline protection structures Most of the increase in damage to shore protection structures expected with Plan 2014 could be avoided by building these structures a few cm (inches) higher New shore protection structures will eventually be needed for currently unprotected developed properties under either plan, but likely would be needed sooner under Plan 2014
2. Measurement of Effects	IJC accepts the findings of the Study Board and its expert panel of economists that measurement of secondary effects is unnecessary for plan ranking, because secondary effects move proportionately with the major economic and environmental effects
3. Distribution of Effects	The compression of Lake Ontario levels under the existing plan helped some riparians and hurt coastal ecosystems Plan 2014 strikes a balance; it does not fully restore ecosystem health so that it can preserve most of the protection to riparians

Public Concern	IJC Response
4. Past Siting and Design Decisions	IJC heard testimony that many designs are not based on the current plan; some shore protection structures are being designed to accommodate only a 1.2 m (4 ft) range of water levels, even though the range of levels under Plan 1958DD has been about 1.8 m (6 ft) More than 90% of the impact to coastal property involves existing or new protection structures; as a result, some communities along the south shore will suffer coastal damages to existing development, no matter the regulation plan Plan 2014 is not expected to change the floodplain delineation that has guided home design along the Lake Ontario's shoreline
5. Mitigation of Damages	Future high Lake Ontario water levels under any regulation plan can be expected to damage or threaten existing shore protection, water and wastewater systems, and even some homes Meaningful reductions in the level of risk can only be realized through the design of homes, structures and infrastructure systems; while these are addressed by domestic regulations, the IJC can inform those considerations with evidence from its own investigations
6. Assessment of Damage to Wetlands	The IJC reviewed the findings of the Lake Ontario-St. Lawrence River Study, the peer review of that Study, and subsequent evidence and arguments on the subject of the integrity of the environmental science before concluding that the evidence is overwhelming that current regulation rules damage the environment

4.5 Ecosystems

4.5.1 Overview of the Interest[24]

The ecosystems interest includes the biological components of the natural environment of Lake Ontario and the St. Lawrence River, together with the ecological services that the natural environment provides to people who live and work in the region.

The biological communities of Lake Ontario and the St. Lawrence River have, by necessity, evolved to adapt to the natural range of water levels and water level changes that occur on time scales ranging from wind-driven seiches that can occur several times daily, to the seasonal cycle, to changes that occur over decades and longer.

The biological effects of water level fluctuations are greatest in shallow water, where even small changes in water levels can result in conversion of a standing water environment to an environment in which sediments are exposed to the air, or *vice versa*. The localized effects of this change in the environment are evident in the relatively immobile plant communities that occur in wetlands. In fact, the patterns of water level change are the driving force that determines the overall diversity and condition of wetland plant communities and the habitats they

[24] Based on Lake Ontario-St. Lawrence River Study Environmental Technical Work Group Report (IJC, 2006f).

provide for a multitude of invertebrates, amphibians, reptiles, fish, birds and mammals.

There are more than 80 species of plants and animals in the Lake Ontario-St. Lawrence coastal zone that are sensitive to water level fluctuations and that are being tracked as species of concern by the Natural Heritage Program in New York and the Natural Heritage Information Centre in Ontario. Of these species, 30 are officially designated by state, provincial or federal authorities as threatened or endangered. In the Quebec section of the lower St. Lawrence River, there are 13 special concern, vulnerable, threatened and/or endangered species affected by water levels.

The coastal wetland area within Lake Ontario and the St. Lawrence River is about 26,000 ha (64,000 acres) in size. These wetlands are made up of four basic types: submerged aquatic vegetation; emergent marsh; meadow marsh; and upland vegetation (trees/shrubs) (Wilcox, et al., 2005). More than 80% of the wetland area occurs in the eastern half of the Lake Ontario basin and Thousand Islands region.

Further down the river, the ecological value of Lake St. Pierre marshes has been recognized by their designation as a Ramsar wetland by an international compact. The lake is a UNESCO Biosphere Reserve and is included as a protected site under the Eastern Habitat Joint Venture. With more than 12,000 ha (30,000 acres) of swamps and marshes, Lake St. Pierre accounts for 80% of lower St. Lawrence River wetlands. The lake also supports a large population of nesting blue heron, a major staging area for migratory wildfowl and 167 species of nesting birds. Permanently submerged areas, wetlands and the spring floodplain are home to 13 amphibian and 79 fish species, many of which are sought by sport and commercial fisheries.

4.5.2 Effects of Plan 2014

The Lake Ontario-St. Lawrence River Study Board concluded that the:

> "…current regulation plan has reduced the range and occurrences of extreme Lake Ontario levels as intended under the existing Order of Approval. From an environmental perspective, this has resulted in a smaller transition zone within wetlands from submerged to upland plants, thus reducing the diversity of plant life along the shore and negatively impacting birds, fish and mammals that depend on those plants. Regulation has also caused dewatering drawdowns in the fall through early spring, to the detriment of some habitat." (IJC, 2006)

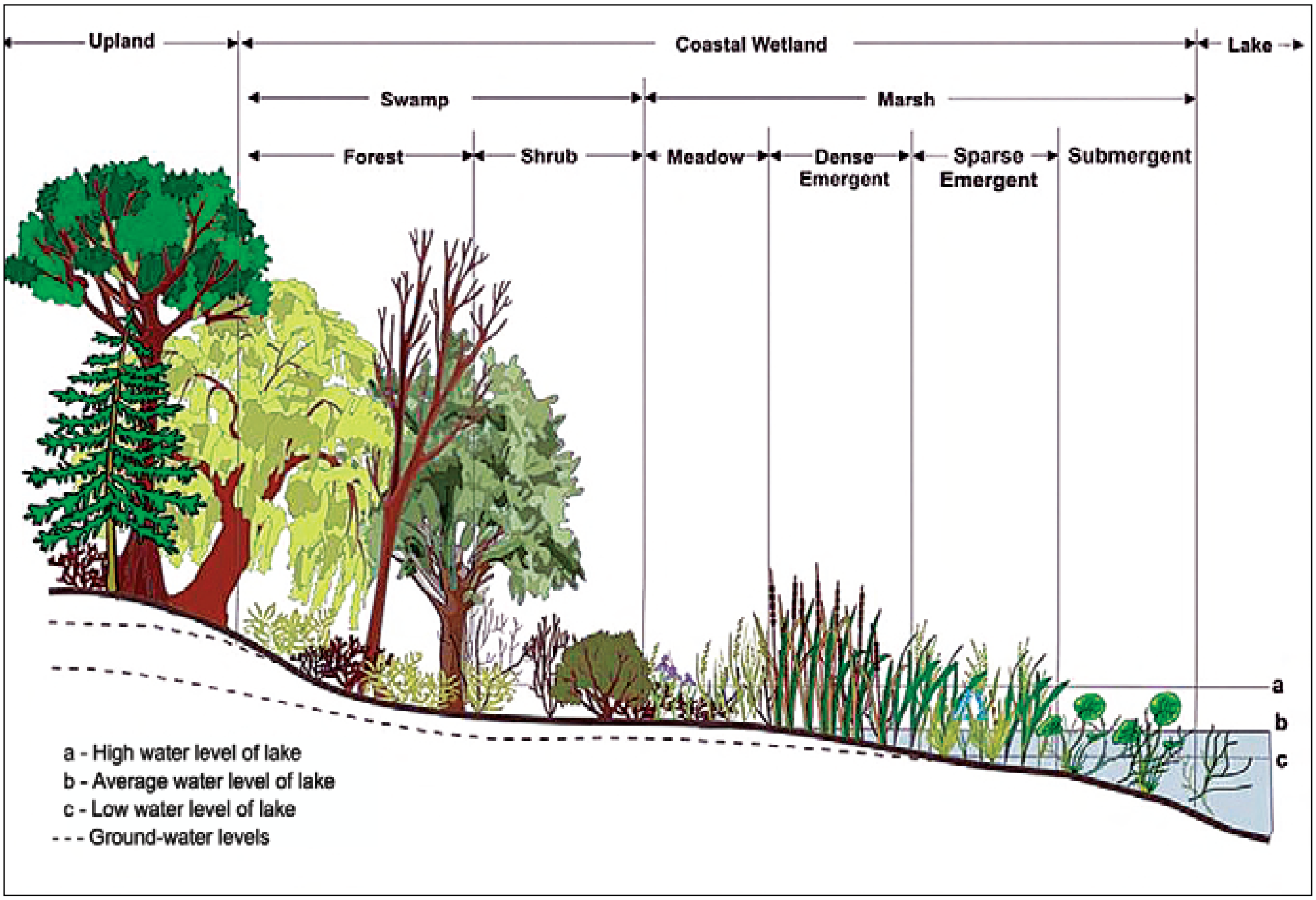
Comparing the variability of the 101 years of Lake Ontario water levels resulting with no regulation and with regulation under Plan 1958DD (shown in Figures Ex-1 and Ex-3 in the Executive Summary) demonstrates that regulation of Lake Ontario has restricted the natural fluctuations of its water levels, both in terms of reducing its extremes and year-to-year variability. These figures also show that Plan 1958DD typically has reduced the lake levels significantly in the winter compared to the natural levels.

Different plants have different watering requirements. The compression of the range of lake levels has allowed the trees and shrubs to grow closer to the water and cattails and other emergent plants that tolerate persistent flooding to expand their range up the shoreline, squeezing out meadow marsh plants in-between (see Figure 20). The strong correlations between plant types and flooding history were evident in the extensive sampling of wetlands at 32 sites around Lake Ontario during the Lake Ontario-St. Lawrence River Study. Study researchers carefully inventoried the kinds of plants growing at different elevations, and were then able to show strong relationships between the type of plants found on the shore and how recently the shore had been flooded at that elevation (Wilcox *et al*., 2005). They determined that upland plants dominated above elevations that had not been inundated in the past 30 years. As well, there was little meadow marsh vegetation at elevations that had been kept wet in the growing season for the last five years.

These results were consistent with the published water tolerances for upland and meadow marsh plants. Regulation plans could then be evaluated based on these evident relationships. Plan 2014 would allow both more frequent low and more frequent high Lake Ontario water levels that would

Figure 20

Compressing Natural Water Level Variability Reduces Plant and Animal Diversity
Source: Wilcox, 2012



expand the meadow marsh areas from time to time, creating a dynamic diversity in wetland plants and the animal life associated with them, while still controlling most of the high levels that can damage coastal development.

Plan 2014 also would help restore bird species such as the Black Tern, Least Bittern, and King Rail (Figure 21), which are listed as at-risk by either New York State or the Province of Ontario (DesGranges *et al*., 2005).

The health of muskrat and northern pike species is an indication of the health of the ecosystem more generally. The more natural fall-winter-spring drawdown of Lake Ontario levels with Plan 2014 would benefit the environment for muskrat overwintering survival and northern pike access to spawning habitat in the spring. Environmental scientists and organizations that responded during the IJC's 2013 public hearings supported these findings, though in some cases they expressed concern that the implementation of a new plan was taking years and that Plan 2014 ceded some of the environmental benefits attributed to Plans B+ and Bv7.

The U.S. Department of Interior, the USEPA, Conservation Ontario, and many environmental non-governmental organizations in New York, Ontario and Quebec that responded during the 2013 hearings supported Plan 2014 because of its environmental benefits. Many of these respondents noted the finding from IJC studies that past regulation of Lake Ontario levels has caused the loss of wetland plant diversity. Even some residents of Lake Ontario's south shore said during the 2013 hearings that they had personally observed this

Figure 21

Plan 2014 Would Help Several Species of At-risk Birds

Black Tern **Least Bittern** **King Rail**

Regulation of Lake Ontario levels since 1960 has greatly reduced the variability of water levels, and for over 50 years, that has affected natural life along the coastal zone of the lake. Plan 2014 would restore enough of the natural variability to make significant improvements to the environment while protecting most of the benefits to riparians along the Lake Ontario shorelines.

Ecosystem performance indicators associated with particular species, such as the three at-risk bird species shown here, often have broader significance because they are applicable to many species with the same habitat requirements.

impact over the decades they had lived there. In addition to confirming the scientific assessment of the relationship between water level patterns and wetland health, several thousand expressions of support for a regulation plan that addressed the environment were received by the IJC, documenting the public interest in ecosystem health.

The restoration of more natural water level regimes in Lake Ontario and the St. Lawrence River is not a traditional wetland restoration project, which typically includes harvesting and planting, physical transformations of the wetlands, or cleanup of pollutants. Nonetheless, as the USEPA noted, "Plan 2014 will increase the diversity and functioning of 64,000 acres of coastal wetlands by allowing hydrologic conditions to support native wetland plant seed germination and growth" (USEPA, 2013).

Focusing on scale alone, there are few wetland restoration projects in the history of such projects in North America that have affected as large an area. By comparison, the Everglades Restoration is much larger, costing billions of dollars and affecting millions of acres, but is considered the largest ecosystem restoration project in the world. Napa Sonoma Marsh Restoration project in California, when completed, is expected to restore as many as 10,000 acres at a cost of $55 million (2004 U.S. dollars) USACE, 2004). The Emiquon Floodplain Restoration on the Illinois River, near Peoria, Illinois, will restore about 5,400 acres at a cost of over $13 million (USACE, 2014).

Ecosystem Effects of Plan 2014 on the Lower St. Lawrence River

As shown in Table 1, there are no significant differences to ecosystems on the lower river among the various regulation plans. The relationship between releases from the Moses-Saunders dam and each lower river ecosystem performance indicator is different. Factors such as mean water depth or levels, mean current velocity and water level decrease over certain parts of the year are important drivers of many of these indicators. However, the changes from the Plan 1958DD release patterns to Plan 2014 patterns were not enough to make a significant difference to the lower river ecosystem given the defined sensitivity of the indicators to changes in those parameters. Variability of the flows from the Ottawa River and other tributaries dampen the effects of the release patterns at the Moses-Saunders dam. The spaghetti graphs of Lake St. Louis in Figure 22 (for Plan 1958DD) and Figure 23 (for Plan 2014) show how little the river levels change between the two plans. River levels downstream of Lake St. Louis are even less affected by the change in plans.

To conclude, the IJC finds that:

- robust coastal ecosystems are in the interests of both countries;
- the existing regulation plan has harmed and continues to harm those ecosystems; and,
- Plan 2014 would address much, though not all, of this damage over time.

The IJC, therefore, believes that Plan 2014 should be implemented as quickly as possible.

Figure 22

Lake St. Louis Levels, Plan 1958DD, Historical Supplies

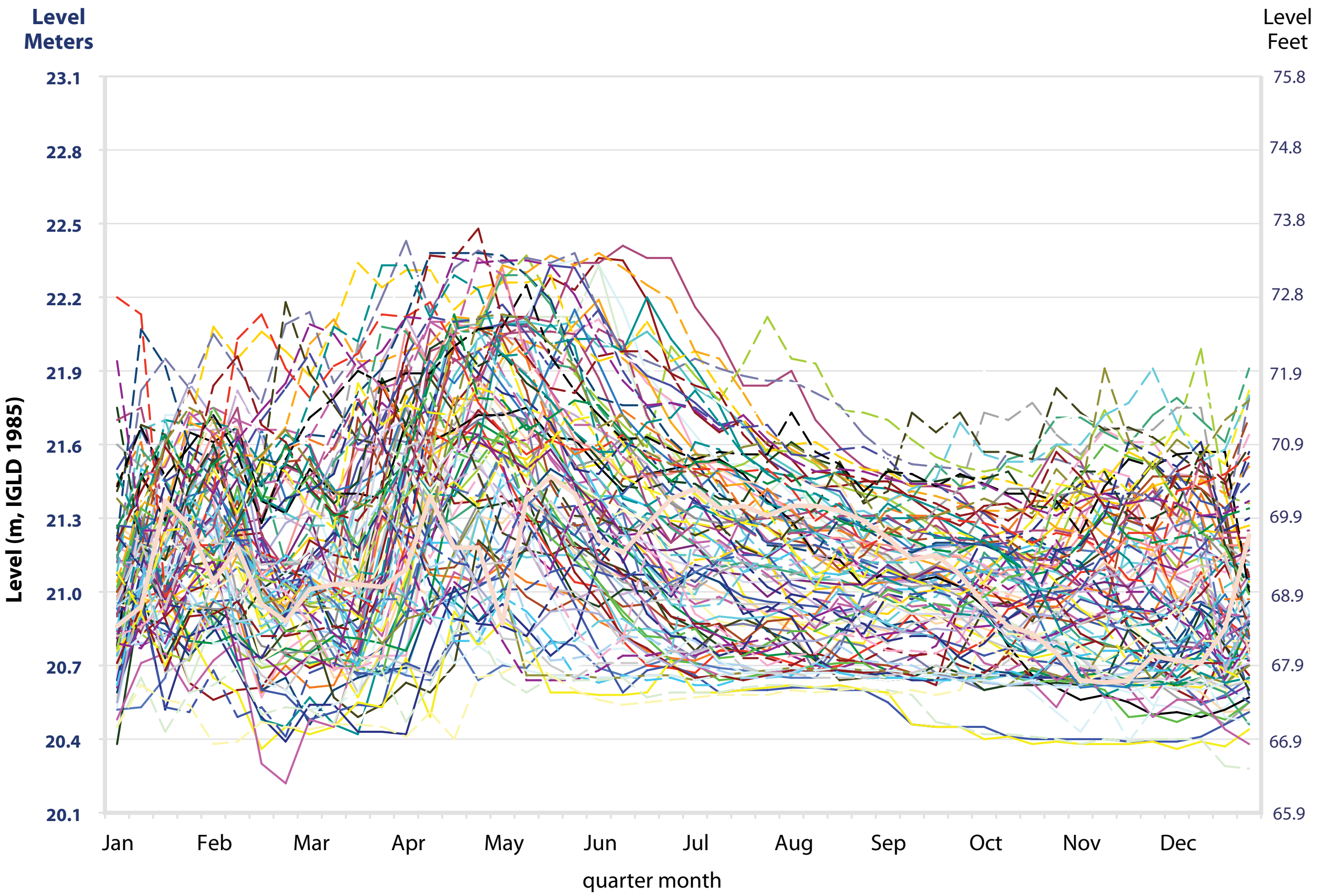
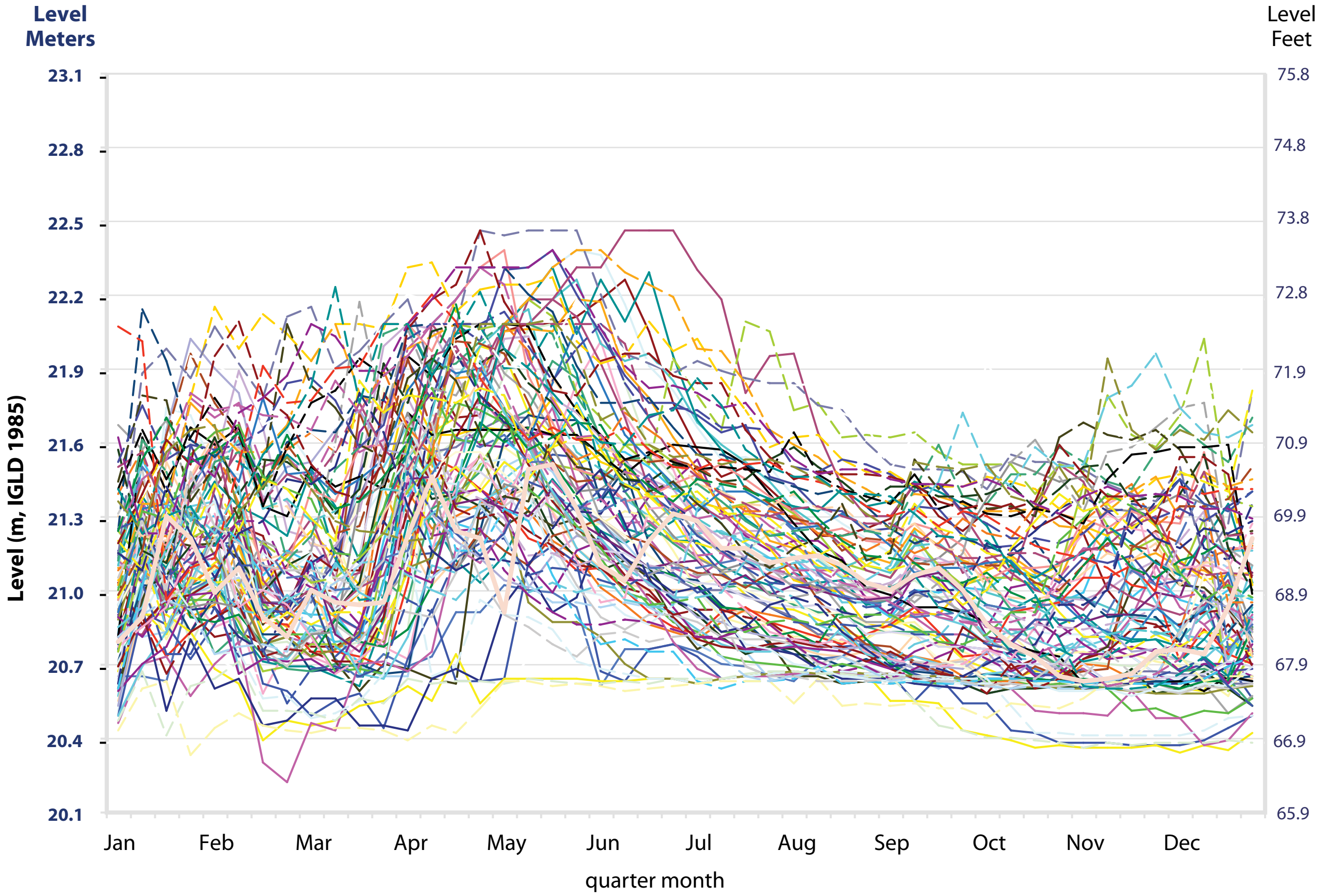


Figure 23

Lake St. Louis Levels, Plan 2014, Historical Supplies



4.6 Recreational Boating

4.6.1 Overview of the Interest[25]

The recreational boating interest includes pleasure boating and fishing, marinas and the commercial cruise ship industry. Lake Ontario and the St. Lawrence River support a large recreational boating and sport fishing industry. Analysis undertaken for the IJC's Lake Ontario-St. Lawrence River Study found that recreational boaters in the U.S. and Canada spent an estimated $430 million on boating-related trips taken on Lake Ontario and the St. Lawrence River in 2002.

4.6.2 Effects of Plan 2014

Compared to Plan 1958DD, Plan 2014 would reduce average recreational boating benefits on Lake Ontario and the river upstream of Ogdensburg, NY and increase them on Lake St. Lawrence and the river below the dam (see summary in Table 2). However, Plan 2014 did receive some support from many boaters upstream of Ogdensburg. Field studies and statements during public meetings and hearings suggest that there are two reasons for this upstream support.

Firstly, in most years, upstream boaters would prefer Plan 2014 because of the higher water levels later in the autumn, which would extend their boating season. The tradeoff is that there also would be summers in which Lake Ontario levels were noticeably and more naturally lower, which allows the re-establishment of meadow marsh vegetation at lower shore elevations. Those low lake level summers would be relatively rare. In terms of economic impacts, the adverse effects of the bad

[25] Based on Lake Ontario-St. Lawrence River Study Recreational Boating and Tourism Technical Work Group Report (IJC, 2006g).

summers would be slightly greater than the benefits enjoyed in the good summers and fall, largely because there are more boaters in the summer.

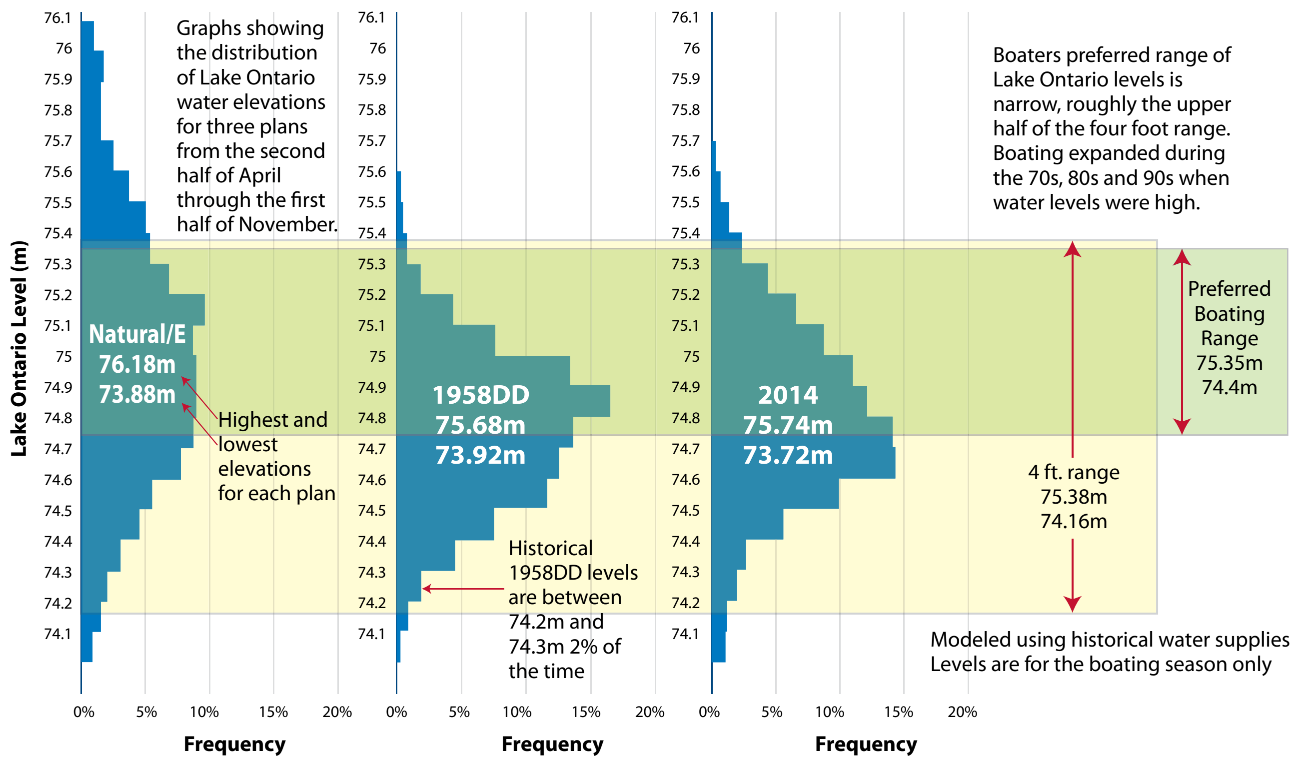
Secondly, it is important to note that despite the negative impacts, many upstream boaters will not be affected during the low summers. The negative economic impacts result in part from the fact that some docks are so shallow that they are unusable even when Lake Ontario is at average water levels. In fact, the range of lake levels with no impact on boaters is significantly narrower than the four-foot range referenced by south shore (Figure 24). Boaters who participated in plan formulation and evaluation exercises asked plan formulators to minimize the frequency, severity and duration of water levels on Lake Ontario below 74.74 m (245.2 ft) or above 75.35 m (247.2 ft) from April 15th through to October 15th. Under Plan 1958DD, levels are outside this range more than 30% of the time. However, many boaters have dockage better suited to a wide range of water levels and would not be as affected by the occasional low summer levels caused by Plan 2014.

4.7 Protection of Other Benefits to the Interests

Some benefits to interests are provided in an *ad hoc* manner now under Plan 1958DD. However, the balance among interests would be more assured and predictable under Plan 2014 than under Plan 1958DD. The performance estimates in this report for Plan 1958DD are modeled in part on the judgments that the Board of Control has applied when it deviated from the prescriptive rules of Plan 1958-D. However, changes in the membership of the Board could result in different judgments.

Figure 24

Preferred Lake Ontario Water Level Ranges of Recreational Boating Interests



This graph shows the frequency of water levels in 10 cm (4 in) bands for three regulation plans using the historical water supplies. The 1.22 m (4 ft) range of the 1956 Order and the range of levels preferred by boaters are superimposed. The preferred range was provided by boaters and verified in a study of dock depths and the drafts of registered boats undertaken for the Study Board (Connelly et al., 2005). The most common depths under Plan 1958DD are within the preferred boating range, though 1958DD levels are below the range about 20% of the time. The most common 2014 depths straddle the lower edge of the range boaters prefer. Not all boats are kept in shallow docks.

Plan 2014 received some support from boaters because it generally provides greater Lake Ontario and upper river depths in the fall, extending the boating season.

The Board of Control sometimes must address inherent potential for conflict. For example:

- in times of high supply, releases to reduce high Lake Ontario levels could cause flood damages downstream, especially during the spring freshet when flows from the Ottawa River and other downstream tributaries are also high; and,
- in times of low supply, increased releases to maintain adequate downstream levels for water intakes and ships using the Seaway or the Port of Montreal could adversely affect levels for boating and navigation above the dam.

By some estimates, about half of the weekly releases include deviations made by the Board of Control. As a result, these deviations are a key part of the performance of Plan 1958DD. For example, based on simulations using the historical supplies, the maximum Lake Ontario level under Plan 1958-D (no deviations) would be 77.07 m (252.85 ft). Modeled deviations from the rules of 1958-D reduce that to 75.68 m (248.29 ft). If a future Board negotiated deviations differently or future IJC Commissioners made different determinations about whether to invoke criterion k, then future results could vary considerably under the existing Order and plan.

By contrast, the results from Plan 2014 would be inherently more predictable. Plan rules were designed around a longer supply record with a much wider range of supplies than those used in the 1950s to design Plan 1958-D. Consequently, the written rules can be used much more frequently, perhaps in more than 90% of future decisions. Under Plan 2014, the maximum level of Lake Ontario using the historical supplies would be the same with or without deviations.

Table 2 indicates, that on the whole, Plan 2014 would maintain the balance struck under the 1956 Order and 1958DD. Effects on municipal and industrial water intakes are the same under both plans (that is, $0 net difference). There is a slight shift in recreational boating benefits from above to below the dam, primarily because of the modeled tradeoff between typically higher autumn and the occasional low summer levels induced by Plan 2014, which would create, on average, about 5% less recreational opportunities above the dam and 5% more below the dam. Overall, impacts to navigation are neutral.

Under the existing plan, if Lake Ontario levels get very high or very low and the IJC wants to trigger a major deviation so as to provide relief to affected interests, then it first must determine, on the advice of its Board of Control, whether the current supplies fall outside the range of past supplies. Under the Order for Plan 2014, no action by the IJC would be needed for the Board to act. When Lake Ontario levels hit the high-trigger levels, the Board would deviate from the Plan as needed to protect riparians upstream and downstream, and when the Lake levels hit the low triggers, the Board would deviate to protect municipal water intakes, navigation and hydropower production.

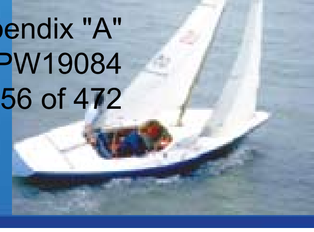
4.8 Summary of Effects of Plan 2014 on the Uses and Interests

Table 5 presents a summary of the effects of Plan 2014, compared to the current Plan 1958DD, on each of the uses and interests.

Table 5

Summary of Effects of Plan 2014 on the Uses and Interests

Uses/Interests	Effects of Plan 2014
Municipal and Industrial Water Use	Overall, no difference in economic effects between the two plans With low water levels: • no net effect on Lake Ontario water treatment plants • no change in frequency and magnitude of effects on St. Lawrence River municipal water suppliers during long droughts With high water levels: • most water supply and treatment plants not vulnerable • septic tanks in some rural New York state areas along the lake's shoreline would continue to be vulnerable to flooding and erosion under any regulation plan
Commercial Navigation	Overall, no difference in economic effects between the two plans No change in frequency of low levels on the St. Lawrence River at Montreal Lower levels several months per century would force some ships (mainly those that operate only on Lake Ontario) to carry lighter loads Slightly fewer draft restrictions due to low levels for ships transiting the route from Lake Ontario to Montreal Allows for safer currents Provides greater predictability/certainty of benefits Provides flexibility to improve operations on an ongoing basis
Hydropower Generation	Increases hydropower energy generation slightly Provides slightly more stable and predictable releases, allowing for more effective scheduling of maintenance
Coastal Development	Provides riparians on the upper and lower river essentially the same level of protection Results in a small reduction of benefits to riparians on Lake Ontario in the form of increased costs of maintaining shoreline protection structures No change in risks of serious damage to shoreline property from water levels outside historical levels
Ecosystems	Helps restores ecosystem diversity and function of coastal wetlands along Lake Ontario due to more natural water level regimes and cycles
Recreational Boating	Recreational Boating



5. The Role of Adaptive Management

Adaptive management is an ongoing planning process that can improve actions through long-term monitoring, modeling and assessment – "a learning by doing" approach that compares actual and predicted results. Through adaptive management, decisions can be reviewed and adjusted as new information and knowledge become available or as conditions change.

The 2012 Protocol amending the Canada-United States *Great Lakes Water Quality Agreement* (Governments of Canada and the United States, 2012) noted the role of adaptive management. The Protocol confirmed adaptive management as a guiding principle and approach for the Parties in working towards the goals of the Agreement. The Parties also committed to using adaptive management "as a framework for organizing science to provide and monitor the effectiveness of science-based management options."

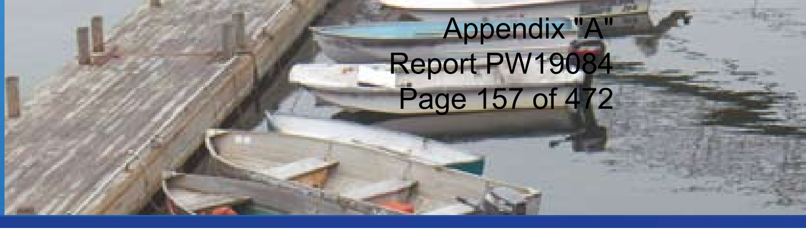
The IJC concludes that adaptive management is a cost-effective way to improve the outcomes of Lake Ontario-St. Lawrence River level regulation. Adaptive management can provide an objective measure of how well a plan is meeting its goals, replacing the current ad hoc approach to regulation plan improvement. It can focus basin research on the issues of particular importance to the interests.

The Lake Ontario-St. Lawrence River Study Board designed the research and modeling approach of that study to facilitate adaptation of new information. For example:

- quantitative analyses were done to identify the issues where advances in knowledge, such as better long-term weather forecasting, would likely improve outcomes from Lake Ontario regulation;
- research was explicitly designed and organized to address the objectives for regulation developed by the Study Board in consultation with the public;
- the evaluation models used by the Study Board were designed to be both comprehensive and easy to use and adapt; and,
- research and models were saved so as to be more easily accessible to future users.

There were concerns raised during the 2013 public hearings on Plan 2014 that adaptive management could lead to changes in the regulation plan that were not considered and reviewed by stakeholders. The IJC appreciates these concerns but confirms that this will not be the case. While adaptive management is expected to more effectively produce suggestions for changes in the regulation plan, the process for implementing a revision to the plan would not change. The IJC intends to maintain its extensive consultations with the federal governments as Parties to the Treaty, with the state of New York and provinces of Ontario and Quebec, and with industry, shoreline stakeholders, and the public at large. Proposed changes to the regulation rules in Plan 2014 would be widely publicized and any significant changes would require a public review process, as is the case now.

Annex E provides more details on the role of adaptive management as an important tool for improving the outcomes of Lake Ontario-St. Lawrence River regulation.



6. Summary

After more than 14 years of intensive analysis and extensive consultation with governments, experts, Lake Ontario and St. Lawrence River interests, and the public, the IJC concludes that a new approach to regulating the flows and levels of the St. Lawrence River and Lake Ontario is needed.

The IJC finds that the regulation of water levels and flows in the St. Lawrence River in accordance with the 1952 and 1956 Orders of Approval has damaged ecosystems along the shores of Lake Ontario and St. Lawrence River over the last 50 years. Under likely future water level and climate conditions, further damage to coastal ecosystems and shoreline property can be expected.

The IJC acknowledges that the effects of the regulation of water flows and lake levels on ecosystems were not fully understood in the development of the existing Order of Approval and regulation plan. However, the IJC finds that these effects should now be considered.

The IJC must act on this finding, and is therefore seeking the concurrence of the Governments of the United States and Canada that Plan 2014 be implemented as soon as possible.

Plan 2014 would respect the order of precedence of uses specified in the Boundary Waters Treaty of 1909, while protecting interests that may be harmed by regulation.

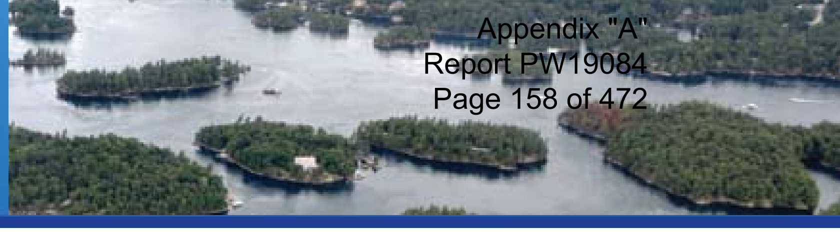
Compared to the existing regulation plan for Lake Ontario and the St. Lawrence River, Plan 2014 would:

- provide essentially the same level of benefits to domestic water uses;
- provide essentially the same level of benefits to navigation;
- increase, by a small amount, the generation of hydropower at the Moses-Saunders dam and the Hydro-Quebec facilities on the St. Lawrence River;
- provide riparians on the upper and lower river essentially the same level of protection;
- result in a small reduction of benefits to riparians on Lake Ontario, in the form of increased costs of maintaining shoreline protection structures;
- work to restore the natural environment of Lake Ontario and the St. Lawrence River that supports wetlands, birds, amphibians, fish, and small mammals;
- have a mixed effect on recreational boating interests; and,
- provide essentially the same benefits downstream of the dam as does the current regulation regime.

In addition, some of the benefits now enjoyed by domestic water, navigation, hydropower and riparians on the St. Lawrence River are the result of ad hoc, discretionary decisions by the International St. Lawrence River Board of Control. Plan 2014 would make these benefits more assured and predictable, by removing the discretionary aspect of many of these decisions and formally making them part of the Plan's regulation rules.

The implementation of Plan 2014 would produce a substantial improvement in coastal ecosystem health while preserving most of the benefits currently enjoyed by riparians along the shoreline of Lake Ontario. The IJC does not control coastal property management, but will support, when requested, efforts to reduce the vulnerability of coastal structures. In this regard, adaptive management can play a helpful role.

Annex A



Proposed Regulation Conditions Adaptive

International Joint Commission Order of Approval for Lake Ontario – St. Lawrence River

Note: All elevations use the 1985 International Great Lakes Datum and metric system of measurement.

A1. Regulation conditions

A. All interests on either side of the International Boundary which are injured by reason of the construction, maintenance and operation of the works shall be given suitable and adequate protection and indemnity in accordance with the laws in Canada or the Constitution and laws in the United States respectively, and in accordance with the requirements of Article VIII of the Treaty.

B. The works shall be so planned, located, constructed, maintained and operated as not to conflict with or restrain uses of the waters of the St. Lawrence River for purposes given preference over uses of water for power purposes by the Treaty, namely, uses for domestic and sanitary purposes and uses for navigation, including the service of canals for the purpose of navigation, and shall be so planned, located, constructed, maintained and operated as to give effect to the provisions of this Order.

C. The works shall be constructed, maintained and operated in such manner as to safeguard the rights and lawful interests of other engaged or to be engaged in the development of power in the St. Lawrence River below the International Rapids Section.

D. The works shall be so designed, constructed, maintained and operated as to safeguard so far as possible the rights of all interests affected by the levels of the St. Lawrence River upstream from the Iroquois regulatory structure and by the levels of Lake Ontario and the lower Niagara River; and any change in levels resulting from the works which injuriously affects such rights shall be subject to the requirements of paragraph A relating to protection and indemnification.

E. The hydro-electric plants approved by this Order shall not be subjected to operating rules and procedures more rigorous than are necessary to comply with the provisions of the foregoing paragraphs B, C and D.

F. Before Ontario Power Generation or any successor make any changes to any part of the works, it shall submit to the Government of Canada, and before the New York Power Authority makes any changes to any part of the works, it shall submit to the Government of the United States, for approval in writing, detailed plans and specifications of that part of the works located in their respective countries and details of the program of construction thereof or such details of such plans and specifications or programs of construction relating thereto as the respective governments may require. Following the approval of any plan, specification or program, if Ontario Power Generation or the New York Power Authority wishes to make any change therein, it shall first submit the changed plan, specification or program for approval in a like manner

G. A Board to be known as the International Lake Ontario-St. Lawrence River Board (hereinafter referred to as the "Board") consisting of an equal number of members from Canada and the United States, shall be established by the Commission. The Board shall include but is not limited to at least one member each nominated by the State of New York, the Province of Quebec, the Province of Ontario, and the United States and Canadian federal governments. The duties of the Board shall be to execute the instructions of the Commission as issued from time to time with respect to this Order. The duties of the Board shall be to ensure that the provisions of the Order relating to water levels and the regulation of the discharge of water from Lake Ontario and the flow of water through the International Rapids Section as herein set out are complied with, and Ontario Power Generation and the New York Power Authority shall duly observe any direction given them by the Board for the purpose of ensuring such compliance. The Board shall report to the Commission at such times as the Commission may determine. In the event of any disagreement among the members of the Board which they are unable to resolve, the matter shall be referred by them to the Commission. The Board may, at any time, make representations to the Commission in regard to any matter affecting or arising out of the terms of the Order with respect to water levels and the regulation of discharges and flows.

H. The discharge of water from Lake Ontario and the flow of water through the International Rapids Section shall be regulated to meet the requirements of conditions B, C, and D hereof and shall be regulated within a range of levels as specified in the below listed criteria, as nearly as may be, and following the Commission's directive(s). The project works shall be operated in such a manner as to provide no less protection for navigation and riparian interests downstream than would have occurred under pre-project conditions and with the 1900 to 2008 adjusted supplies and conditions specified in the basis of comparison. The Commission will indicate in an appropriate fashion, as the occasion may require, the inter-relationship of the criteria, the range of elevations and the other requirements.

H1. The regulated outflow from Lake Ontario shall be such as not to increase the frequency of low levels or reduce the minimum level of Montreal Harbour below those listed in the table below which would have occurred with the 1900 to 2008 adjusted supplies and conditions (hereinafter called the "supplies of the past as adjusted") that are defined in the document "Basis of Comparison Conditions for Lake Ontario – St. Lawrence River Regulation".

Montreal Jetty #1 Level IGLD		
meters	**feet**	**Number of quarter-months in 1900-2008 below level**
5.55	18.21	811
5.50	18.21	679
5.40	17.72	366
5.30	17.39	153
5.20	17.06	83
5.10	16.73	45
5.00	16.40	15
4.90	16.08	1
4.80	15.75	1
4.70	15.42	minimum

H2. The regulated outflow from Lake Ontario shall be such as not to increase the frequency of low levels or reduce the minimum level of Lake St. Louis below those listed in the table below which would have occurred with the supplies of the past as adjusted.

Lake St. Louis at Pointe Claire Level IGLD		
meters	**feet**	**Number of quarter-months in 1900-2008 below level**
20.70	67.01	735
20.60	67.58	161
20.50	67.26	87
20.40	66.93	21
20.30	66.6	2
20.20	66.27	1
20.10	65.94	0
20.10	65.94	minimum

H3. The regulated outflow from Lake Ontario shall be such that the frequencies of occurrence of high water levels on Lake St. Louis as measured at the Pointe Claire gauge are not greater than those listed below with supplies of the past as adjusted.

Lake St. Louis at Pointe Claire Level IGLD		
Meters	**Feet**	**Number of quarter-months in 1900-2008 above level**
22.50	73.82	0
22.40	73.49	9
22.33	73.26	15
22.20	72.83	51
22.10	72.51	97
22.00	72.18	221
22.48	73.75	maximum

H4. The regulated monthly mean level of Lake Ontario shall not exceed the following elevations (IGLD85) in the corresponding months with the supplies of the past as adjusted.

Lake Ontario Level IGLD		
month	**(m)**	**(ft)**
January	75.26	246.92
February	75.37	247.28
March	75.33	247.15
April	75.60	248.03
May	75.73	248.46
June	75.69	248.33
July	75.63	248.13
August	75.49	247.67
September	75.24	246.85
October	75.25	246.88
November	75.18	246.65
December	75.23	246.82

H5. The regulated winter outflows from Lake Ontario shall be maintained so that the difficulties of river ice management for winter power operation are minimized in the International Rapids Section of the St. Lawrence River and the outlet of Lake St. Francis.

H6. Under regulation, the frequency of occurrences of monthly mean elevations of approximately 75.07 meters (m), 246.3 feet (ft) IGLD 1985 and higher on Lake Ontario shall not be greater than would have occurred with supplies of the past as adjusted and with pre-project conditions.

H7. The regulated monthly mean water levels of Lake Ontario, with supplies of the past as adjusted shall not be less than the following elevations (IGLD 1985) in the corresponding months.

Lake Ontario Level IGLD		
month	**(m)**	**(ft)**
January	73.56	241.34
February	73.62	241.54
March	73.78	242.06
April	73.97	242.68
May	74.22	243.50
June	74.27	243.67
July	74.26	243.64
August	74.15	243.27
September	74.04	242.91
October	73.83	242.22
November	73.67	241.70
December	73.57	241.37

H8. Consistent with other requirements, the outflow from Lake Ontario shall be regulated so as to maintain adequate levels for navigation in the Montreal to Lake Ontario section of the St. Lawrence River.

H9. Consistent with other requirements, the maximum regulated outflow from Lake Ontario shall be maintained as low as possible to maintain safe velocities for Seaway navigation and to minimize spill at the hydropower facilities in the St. Lawrence River.

H10. Consistent with other requirements, the minimum regulated monthly outflow from Lake Ontario shall be such as to secure the maximum dependable flow for power.

H11. Consistent with other requirements, the levels of Lake Ontario shall be regulated for the benefit of property owners on the shores of Lake Ontario in the United States and Canada so as to reduce extremes of stage which have occurred under pre-project conditions and supplies of the past as adjusted on Lake Ontario.

H12. Consistent with other requirements, the outflow from Lake Ontario shall be regulated so as to enhance biodiversity and the resiliency of wetlands on Lake Ontario and on the St. Lawrence River.

H13. Consistent with other requirements, the outflow from Lake Ontario shall be regulated so as to benefit recreational boating on Lake Ontario and on the St. Lawrence River.

H14. In the event that Lake Ontario water levels reach or exceed extremely high levels, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream. In the event that Lake Ontario levels reach or fall below extremely low levels the works in the International Rapids Section shall be operated to provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream. The high and low water levels at which this provision applies will be established by a Commission directive to the Board.

The Commission shall approve a plan of regulation, and associated operational guides and issue directives for the discharge of water from Lake Ontario and its flow through the International Rapids Section of the St Lawrence River that satisfy the criteria and conditions of this Order with criterion "H14" governing principles of relief, should extreme levels be experienced. The flow of water through the International Rapids Section of the St Lawrence River in any period shall equal the discharge of water from Lake Ontario as determined for that period.

The Commission's directives to the Board shall make provision for peaking and ponding operations and for deviations from the plan of regulation to address such matters as winter operations, emergencies and other special short-term situations.

Subject to the requirements of conditions B, C and D hereof, and of the range of levels, and criteria, above written, the Board, after obtaining the approval of the Commission, may temporarily modify or change the restrictions as to the discharge of water from Lake Ontario and the flow of water through the International Rapids Section for the purpose of determining what modifications or changes in the plan of regulation may be advisable. The Board shall report to the Commission the results of such experiments, together with its recommendations as to any changes or modifications in the plan of regulation. When the plan of regulation has been improved so as best to meet the requirements of all interests, within the range of levels and criteria above defined, the Commission will recommend to the two governments that it be implemented and, if the two governments thereafter agrees, such plan of regulation shall be given effect as if contained in this Order. Should there be a change to the approved regulation plan, then the Commission will consult with governments as appropriate.

I. The works shall be operated so that the forebay water level at the power houses does not exceed a maximum instantaneous elevation of 74.48 m (244.36 feet).

J. Ontario Power Generation and the New York Power Authority, and any successor entities, shall maintain and supply for the information of the Board accurate records relating to water levels and the discharge of water through the works and the regulation of the flow of water through the International Rapids Section as the Board may determine to be suitable and necessary, and shall install and maintain such gauges, carry out such measurements, and perform such other services as the Board may deem necessary for these purposes.

K. The installation, maintenance, operation and removal of the ice booms in the St. Lawrence River by Ontario Power Generation and the New York Power Authority, and any successor entities, are subject t o the following:

1. Any significant modifications in the design or location of the booms shall require the approval of the Commission;
2. The placement and removal of ice booms shall be timed so as not to interfere with the requirements of navigation; and
3. The St. Lawrence Seaway Management Corporation and the St. Lawrence Seaway Development Corporation, and any successor entities, shall be kept informed of all such operations.

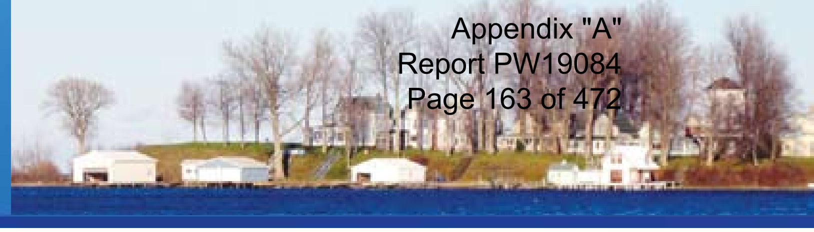
L. The Board shall report to the Commission as of 31 December each year on the effect, if any, of the operation of the down-stream hydro-electric power plants and related structures on the tail-water elevations at the hydro-electric power plants approved by this Order.

No later than 15 years after the effective date of this Order,and periodically thereafter, the Commission will conduct a review of the results of regulation under this Order. This review will be to assess the extent to which the results predicted by the research and models used to develop any approved regulation plan occurred as expected, consistent with the adaptive management plan. The review will be based upon the information available at the time of the review and may provide the basis for possible changes to the regulation of water levels and flows.

A2. Definitions:

1. St. Lawrence River – the section of the St. Lawrence River that is affected by flow regulation, which stretches from Lake Ontario to the outlet of Lake St. Pierre.
2. International Rapids Section - the section of the St. Lawrence River that prior to the project was characterized by series of rapids from Ogdensburg, NY- Prescott, ON to Cornwall, ON – Massena, NY.
3. Pre-project conditions – the hydraulic channel characteristics that existed in the Galops Rapids Section of the St. Lawrence River as of March 1955 that formed the control section for Lake Ontario outflows prior to the project. This is defined by a stage-discharge capacity relationship for this condition that also accounts for the effects of glacial isostatic adjustment.

Annex B



Lake Ontario – St. Lawrence Plan 2014

Lake Ontario - St. Lawrence Plan 2014 is the combination of the mechanistic release rules labeled "Bv7" together with discretionary decisions made by the International Lake Ontario - St. Lawrence River Board to deviate from the flows specified by the release rules Bv7 according to the Directive on Operational Adjustments, Deviations and Extreme Conditions. In that regard, Bv7 is analogous to Plan 1958-D. Each is a set of functions that can be programmed to produce a release based on established categories of input conditions such as current water levels. The following is a technical description of the Bv7 algorithm or release rules.

B1. Technical Description of Plan Bv7 Release Rules

B1.1 Objectives

The objective of the Bv7 release rules is to return the Lake Ontario-St. Lawrence River System to a more natural hydrological regime, while limiting impacts to other interests. Bv7 rules build on the B+ rules developed during the International Lake Ontario - St. Lawrence River Study. Bv7 differs from B+ in that it includes additional rules to maintain navigation and flood reduction benefits on the lower St. Lawrence River (Lake St. Louis to Lake St. Pierre) and adjustments to the B+ rules to balance Lake Ontario and lower river levels. Bv7 maintains most of the benefits of the current regulation regime because the range of levels and flows that Bv7 produces are closer to the current regulation regime than to unregulated conditions.

B1.2 Goals

The goals of the rules are to:

- Maintain more natural seasonal level and flow hydrographs on the lake and river;
- Provide stable lak e releases;
- Maintain benefits to coastal interests as much as possible while enhancing environmental conditions;
- Maintain benefits to recreational boating as much as possible while enhancing environmental conditions;
- Obtain inter-annual highs and lows required for healthy vegetation habitats;
- Enhance diversity, productivity, and sustainability of species sensitive to water level fluctuations;
- Provide flood and low water protection to the lower St. Lawrence River comparable to Plan 1958-D with Deviations; and,
- Maintain benefits as much as possible for municipal water intakes, commercial navigation and hydropower interests while taking other interests into account.

Bv7 uses short-term forecasts and a longer-term index of water supplies in conjunction with the pre-project stage-discharge relationship to determine lake releases. Rules are included to reduce the risk of flooding on the lake and river. Flow limits are applied to prevent river flows from falling too low, facilitate stable river ice formation, provide acceptable navigation conditions, provide safe operating conditions for control structures, and ensure controlled week-to-week changes in flows.

B2. Approach

B2.1 Rule Curves

Lake releases are primarily a function of a sliding rule curve based on the pre-project stage-discharge relationship adjusted to recent long-term supply conditions. The open-water pre-project stage-discharge relationship, in units of cubic meters per second (m^3/s) is:

$$\text{Pre-project release} = 555.823(\text{Lake Ontario level} - 0.035 - 69.474)^{1.5}$$

In the equation above, the 0.035 meter term adjusts the Lake Ontario level (referenced to IGLD 1985) for differential crustal movement fixed to the year 2010[26]. The pre-project relationship is that from Caldwell and Fay (2002), but here the ice retardation effect is not considered.

The flow computed with this equation is then adjusted depending on the recent supply conditions. As water supplies trend above normal, lake releases are increased. As supplies trend below normal, lake releases are decreased.

For supplies above normal (the index is greater than or equal to 7,011 m^3/s), the lake release is determined by:

Table B1.
Bv7 Rule Curve Parameter Values based on Historical Supplies

Climate	A_NTS_{max}	A_NTS_{avg}	A_NTS_{min}
Historical (1900-2000)	8552 m^3/s	7011 m^3/s	5717 m^3/s

The rule curve parameters should be updated periodically to account for climate change.

$$outflow_t = preproject\ release + \left[\frac{F\_NTS - A\_NTS_{avg}}{A\_NTS_{max} - A\_NTS_{avg}}\right]^{P_1} x(C_1)$$

For supplies below normal (the index is less than 7,011 m^3/s), the lake release is determined by:

$$outflow_t = preproject\ release - \left[\frac{A\_NTS_{avg} - F\_NTS}{A\_NTS_{avg} - A\_NTS_{min}}\right]^{P_2} x(C_2)$$

In the equation above, ***F_NTS*** is a supply index based on the net total supply for the past 52 weeks (48 quarter-months), and ***A_NTS*** represents the maximum, minimum and average statistics of the annual net total supply series. The constants C_1 and C_2 determine the rate of flow adjustment to the pre-project release. C_1 is further dependent on the long-term trend in supplies. If the categorical long-term trend indicator is 1 (demonstrating above normal supplies; that is, when the current supply value exceeds 7,237 m^3/s) and the confidence indicator is 3 (indicating high confidence in extreme supplies; that is, when the current supply value exceeds 7,426 m3/s), then C_1 is set to 2,600 m^3/s, otherwise it is equal to 2,200 m^3/s. The value of C_2 is 600 m^3/s. The exponents P1 and P2 serve to accelerate or decelerate the rate of flow adjustment. The values of P_1 and P_2 are 0.9 and 1.0, respectively.

The flow is further reduced by 200 m3/s if the 52 week (48 quarter-month) running lake level mean is less than or equal to 74.6 m IGLD 1985.

Variability of releases from one week (or quarter-month) to the next is smoothed by taking the average of short-term forecasts[27] of releases four weeks (or quarter-months) into the future:

$$outflow = \frac{\sum_{t=1}^{t=4} outflow_t}{4}$$

This averaging also has the impact of accelerating releases during periods of rising lake levels (typically spring), and decelerating releases during periods of falling lake levels (typically fall). Sensitivity analysis indicated that forecasts four quarter-months into the future were optimal.

Bv7 also has a rule to reduce the risk of Lake Ontario and St. Lawrence River flooding in the following spring and summer. If the level of Lake Ontario is relatively high, then it adds to the rule curve flow to reduce the level of Lake Ontario in the fall. It lowers otherwise high Lake Ontario by the onset of winter, thus preparing for spring and making temporary lake storage available for reduced flows during the Ottawa River freshet. It also provides

[26] The year 2010 was selected by the ILOSLRS Plan Formulation and Evaluation Group to compare what pre-project conditions would be near the completion of the Study. The year should be fixed as otherwise there would be a gradual increase in the lake level due to the continual adjustment for glacial isostatic uplift of the lake's outlet.

[27] See Lee (2004) for the derivation of the forecast algorithms

some benefit (relative to the Natural Plan) to the lower river muskrats by reducing winter den flooding. The rule strives to lower Lake Ontario to 74.8 m by January 1 whenever Lake Ontario level is above 74.8 m at the beginning of September. The rule curve flow is linearly increased by the amount needed to eliminate the storage on the lake above 74.8 m over the remaining time before January 1. A check is made to ensure that the adjusted flow for the first week of September does not exceed that of the last week in August to prevent falling levels affecting Lake St. Lawrence recreational boaters through the Labor Day weekend. The adjusted flow is constrained by the L Limits.

B2.2 Flow Limits

Several flow limits, adapted from previous plan development, are used in Bv7. If the rule curve flow (described above) falls outside of these limits, then the lowest of the maxima, or the minimum limit, as applicable, constrains the rule curve flow.

- J Limit – maximum change in flow from one week (or quarter-month) to the next unless another limit takes precedence. Flows are permitted to increase or decrease by up to 700 m^3/s. If the lake is above 75.2 m, and ice is not forming, then the flow may increase by up to 1,420 m^3/s from one week (or quarter-month) to the next.
- M Limit – minimum limit flows t o balance low levels of Lake Ontario and Lake St. Louis primarily for Seaway navigation interests. This limit uses a one week (or quarter-month) forecast of Ottawa River and local tributary flows to estimate the inflows to Lake St. Louis, other than those from Lake Ontario. In actual operation, the flow will be adjusted from day-to-day to maintain the level of Lake St. Louis above the applicable level determined by the Lake Ontario stage.
- I Limit – maximum flows for ice formation and stability.[28] During ice cover formation, either downstream on the Beauharnois Canal or on the critical portions of the International Section, the maximum flow is 6,230 m^3/s. Once a complete ice cover has formed on the key sections of the river, the winter flow constraint prevents the river level at Long Sault from falling lower than 71.8 m. (Note the J limit also applies.) This limit may apply in the non-Seaway season whether ice is present or not. This flow limit is calculated using the stage-fall discharge equation for Kingston-Long Sault, which includes an ice roughness parameter that must be forecast for the coming period. This limit prevents low levels that might impact municipal water intakes on Lake St. Lawrence, and also acts to limit the shear stress on the ice cover and maintain stability of the ice cover. The I limit also limits the maximum flow with an ice cover present in the Beauharnois and/or international channels to no more than 9,430 m^3/s.
- L Limit – maximum flows to maintain adequate levels and safe velocities for navigation in the International Section of the river (navigation season) and the overall maximum flow limit (non-navigation season). Maximum releases are limited to 10,700 m^3/s if the Lake Ontario level should rise above 76.0 m during the navigation season and 11,500 m^3/s during the non-navigation season.

[28] Managing flows during ice formation on the Beauharnois Canal and upstream is paramount, since a restriction caused by a build-up of rough ice in the Beauharnois Canal or upper river can constrain outflows the remainder of the winter which may, in some cases, exacerbate high Lake Ontario levels. During ice formation, operation of the Iroquois Dam must be done in consideration of ice conditions on Lake St. Lawrence.

Table B2.
M Limits as used in Plan Bv7.

Lake Ontario level (m, IGLD 1985)	Total Flow from Lake St. Louis (m^3/s)	Approximate Corresponding Lake St. Louis level at Pointe Claire (m IGLD 1985)
> 74.2	6,800	20.64
> 74.1 and ≤ 74.2	6,500	20.54
> 74.0 and ≤ 74.1	6,200	20.43
> 73.6 and ≤ 74.0	6,100	20.39
≤ 73.6	Minimum of 5,770 or pre-project flow	20.27 or less

Table B3.
L Limits as used in Plan Bv7.

Lake Ontario level (m, IGLD 1985)	L Limit Flow (m^3/s)
For Seaway navigation season (i.e. quarter-months 13-47):	
≤ 74.22	5,950
> 74.22 and ≤ 74.34	5,950+1,333 (Lake Ontario level – 74.22)
> 74.34 and ≤ 74.54	6,111+9,100 (Lake Ontario level – 74.34)
> 74.54 and ≤ 74.70	7,930+2,625 (Lake Ontario level – 74.54)
> 74.70 and ≤ 75.13	8,350+1,000 (Lake Ontario level – 74.70)
> 75.13 and ≤ 75.44	8,780+3,645 (Lake Ontario level – 75.13)
> 75.44 and ≤ 75.70	9,910
> 75.70 and ≤ 76.00	10,200
> 76.00	10,700
For outside Seaway season (i.e. quarter-months 48-12) all levels	
Any	11,500

Table B4.
Lake St. Louis (Pointe Claire) levels corresponding to Lake Ontario levels for limiting lower St. Lawrence River flooding damages (F limits).

Lake Ontario level (m, IGLD 1985)	Pte. Claire level (m, IGLD 1985)
< 75.3	22.10
≥ 75.3 and < 75.37	22.20
≥ 75.37 and < 75.5	22.33
≥ 75.5 and < 75.6	22.40
≥ 75.6	22.48

An additional rule limits the maximum flow in the Seaway season to prevent the weekly mean level of Lake St. Lawrence at Long Sault Dam from falling below 72.60 m. To deal with very low levels, if the Lake Ontario level is below chart datum (74.20 m) then the level of Lake St. Lawrence at Long Sault Dam in this rule is allowed to be equally below the 72.60 m level.

A final check ensures that the L Limit does not exceed the actual channel hydraulic capacity (in m^3/s) defined as (Lee *et al.*, 1994):

$$\text{channel capacity} = 747.2(\text{Lake Ontario level} - 69.10)^{1.47}$$

- F limit – the maximum flow to limit flooding on Lake St. Louis and near Montreal in consideration of Lake Ontario level. It is a multi-tier rule that attempts to balance upstream and downstream flooding damages by keeping the level of Lake St. Louis below a given stage for a corresponding Lake Ontario level as follows:

This limit uses a one week (or quarter-month) forecast of the Ottawa River and local tributary inflows and the following relationship between Lake St. Louis outflows and levels at Pointe Claire:

$$Pte.\ Claire\ level = 16.57 + \left[\left(R_{Pt.Claire} \times Q_{L.St.Louis} / 604.0\right)^{0.58}\right]$$

In this equation, ***R*** is the roughness factor and ***Q*** (in m^3/s) is the total flow from Lake St. Louis. In operation the flow will be adjusted from day to day to maintain the level of Lake St. Louis below the applicable level determined by the Lake Ontario stage.

B3. Application

Bv7 uses imperfect forecasts of Lake Ontario total supplies, Ottawa River and local tributary flows, ice formation and ice roughness. The water supply forecasts are based on time-series analysis of the historical data as described in Lee (2004). Overall, the statistical forecasts were found to have similar error to those in use operationally. Because the operational methods generally rely upon hydrometeorological data not available for either the historical time series or the stochastic time series, actual forecasts could not be used. However, it was envisioned that operationally, the best available real-time forecasts would be used. In addition, because week-ahead forecasts will generally be imperfect, it is expected that in actual operations the flows will be adjusted within the week[29] taking into account the actual ice and downstream inflow conditions to achieve the intent of the Bv7 rules and limits.

B3.1 Procedure

1. For each of the next four weeks (quarter-months), calculate the Lake Ontario annual net total supply index, forecast the weekly (quarter-monthly) Lake Erie inflow and Lake Ontario net basin supply, Ottawa River and local tributary flows to Lake St. Louis, and ice roughness.
2. For each of the next four weeks (quarter-months), sequentially route the supplies and determine forecasts of lake outflows using the sliding rule curve.
3. Average the next four weeks (quarter-months) forecast releases to determine the next period's release.
4. If the current time period is within September through December inclusive, and Lake Ontario was at or above 74.8 m on September 1 (end of quarter-month 32), then increase the basic rule curve by the amount needed to achieve 74.8 m by January 1, not exceeding the flow in the week before Labor Day (quarter-month 32) in the flow in the Labor Day week (quarter-month 33).
5. Apply the M, L, I, J and F limits. If the plan flow is outside of the maximum of the minimum limits and the minimum of the maximum limits, the appropriate limit becomes the plan flow.

B4. Simulation of Bv7 with 1900-2008 Hydrology and Ice Conditions

The tables on the following pages are based only on the Bv7 release rules, not the deviations in Plan 2014. The tables show how often under Bv7 water levels will be above a range of levels for Lake Ontario, Lake St. Lawrence, Lake Louis and Montreal Harbour, and how often releases from the Moses-Saunders dam will be above certain flows. The tables are based on a simulation of Bv7 on a quarter-monthly time step and with the 1900-2008 dataset of supplies and inflows, ice conditions, channel roughness factors,

[29] See **Annex C** for more on operational adjustments

and related conditions. This 109-year simulation includes 436 quarter-months for each calendar month, 5,232 quarter-months in all. For example, in Table B-5, Lake Ontario never rises above 75.80 meters, but rises above 75.70 meters six times in May and three times in June.

The tables are:

- Table B 5 Bv7 Historical Lake Ontario Levels
- Table B 6 Bv7 Historical Lake Ontario Outflows
- Table B 7 Bv7 Historical Lake St Lawrence at Long Sault Dam Levels
- Table B 8 Bv7 Historical Lake St. Louis Levels
- Table B 9 Bv7 Historical Montreal Harbour at Jetty 1 Levels

Table B5.
Bv7 Historical Lake Ontario Levels

Lake Ontario
Quarter-monthly mean levels
Number of Occurences Above Level Shown ... 1900-2008 supplies simulation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Months
Level (m IGLD 1985)													
75.8	0	0	0	0	0	0	0	0	0	0	0	0	0
75.7	0	0	0	0	6	3	0	0	0	0	0	0	9
75.6	0	0	0	6	10	12	6	0	0	0	0	0	34
75.5	0	0	0	12	23	27	13	2	0	0	0	0	77
75.4	0	0	1	24	43	52	30	9	0	0	0	0	159
75.3	2	6	3	39	90	91	61	18	1	0	0	0	311
75.2	12	15	19	70	143	146	107	46	6	4	1	4	573
75.1	17	28	33	115	183	204	176	99	26	4	4	5	894
75.0	32	50	68	166	241	269	245	179	69	11	4	7	1341
74.9	63	79	115	216	296	322	312	251	136	34	17	23	1864
74.8	121	138	166	274	340	357	357	312	230	116	66	76	2553
74.7	163	185	226	339	381	397	389	368	306	230	143	135	3262
74.6	209	223	266	371	410	420	412	402	361	310	257	215	3856
74.5	306	295	335	397	418	420	419	410	394	351	321	312	4378
74.4	360	366	379	410	426	428	426	417	410	392	363	364	4741
74.3	390	390	396	418	428	429	432	421	413	408	391	388	4904
74.2	407	405	401	425	434	436	435	427	418	412	411	408	5019
74.1	415	409	411	428	436	436	436	436	423	418	420	414	5082
74.0	420	419	420	434	436	436	436	436	434	424	421	422	5138
73.9	424	424	427	435	436	436	436	436	436	429	424	424	5167
73.8	424	425	432	436	436	436	436	436	436	434	428	424	5183
73.7	431	432	436	436	436	436	436	436	436	436	433	430	5214
73.6	432	435	436	436	436	436	436	436	436	436	436	432	5223
73.5	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	75.31	75.39	75.46	75.7	75.75	75.72	75.65	75.59	75.36	75.26	75.22	75.25	75.75
Minimum Level	73.55	73.56	73.72	73.84	74.16	74.24	74.2	74.12	73.96	73.76	73.61	73.55	73.55

Table B6.

Bv7 Historical Lake Ontario Outflows

Lake Ontario Quarter-monthly mean Outflows Number of Occurences Above Flow Shown ... 1900-2008 supplies simulation													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**All Months**
Flow (m^3/s)													
10400	0	0	0	0	0	0	0	0	0	0	0	0	0
10200	0	0	0	0	0	0	0	0	0	0	0	0	0
10000	0	0	0	0	4	1	0	0	0	0	0	0	5
9800	2	0	2	5	14	15	5	1	0	0	0	0	44
9600	2	0	2	8	18	21	10	1	0	0	0	0	62
9400	2	0	6	9	22	24	16	3	0	0	0	0	82
9200	2	1	10	9	27	26	21	6	0	2	0	0	104
9000	2	5	15	12	37	37	25	10	1	4	1	3	152
8800	2	5	19	18	40	53	33	15	8	4	2	4	203
8600	2	7	24	31	61	70	61	32	24	8	4	7	331
8400	2	10	34	42	75	93	80	52	45	20	20	27	500
8200	5	24	48	66	104	115	95	65	59	30	29	29	669
8000	11	36	61	92	123	137	114	86	79	49	46	42	876
7800	13	48	76	114	147	165	135	108	110	69	59	52	1096
7600	26	63	97	130	175	192	172	132	139	86	73	67	1352
7400	33	76	121	168	201	220	207	165	164	114	91	84	1644
7200	38	97	149	212	244	259	250	216	199	136	115	100	2015
7000	50	128	178	246	292	299	290	260	238	178	147	114	2420
6800	99	174	211	284	326	340	322	297	262	212	179	146	2852
6600	123	224	256	325	356	365	360	333	286	251	225	177	3281
6400	151	265	305	358	390	387	376	374	347	312	279	216	3760
6200	322	338	349	386	401	407	414	415	403	376	348	331	4490
6000	373	375	394	399	408	419	428	432	420	405	382	381	4816
5800	398	401	409	404	421	429	434	434	427	412	400	403	4972
5600	416	416	415	412	425	432	436	436	434	427	414	413	5076
5400	424	422	421	421	431	435	436	436	435	431	423	425	5140
5200	429	429	427	429	433	436	436	436	436	432	430	434	5187
5000	434	435	431	431	435	436	436	436	436	432	435	435	5212
4800	435	436	433	434	436	436	436	436	436	435	436	435	5224
4600	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Flow	9910	9290	9910	9910	10200	10200	9910	9880	9150	9220	9060	9180	10200
Minimum Flow	4620	4910	4650	4780	4870	5250	5640	5760	5290	4800	4980	4780	4620

Table B7.

Bv7 Historical Lake St. Lawrence at Long Sault Dam Levels

Lake St. Lawrence at Long Sault Dam
Quarter-monthly mean levels
Number of Occurences Above Level Shown ... 1900-2008 supplies simulation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Months
Level (m IGLD 1985)													
74.4	0	0	0	0	0	0	0	0	0	0	0	0	0
74.3	4	0	0	0	0	0	0	0	0	0	0	0	4
74.2	6	0	0	0	0	0	0	0	0	0	0	1	7
74.1	8	0	0	0	0	0	0	0	0	0	0	2	10
74.0	13	1	0	0	0	0	0	0	0	0	0	5	19
73.9	21	2	0	3	1	4	6	1	0	0	0	10	48
73.8	30	6	6	67	139	130	95	52	7	0	2	19	553
73.7	44	10	18	138	208	209	190	141	28	13	15	33	1047
73.6	60	11	46	212	277	280	255	210	94	82	57	63	1647
73.5	90	14	76	278	336	314	287	259	177	155	138	134	2258
73.4	114	20	110	323	373	353	318	300	223	211	203	195	2743
73.3	136	29	132	369	397	386	346	331	270	267	257	242	3162
73.2	156	41	156	392	418	409	382	351	314	301	292	285	3497
73.1	186	65	188	414	428	422	409	374	341	336	328	323	3814
73.0	208	88	216	431	431	432	423	399	368	362	359	350	4067
72.9	221	114	242	433	432	434	429	412	393	388	381	374	4253
72.8	241	152	264	434	433	436	433	427	415	404	400	391	4430
72.7	261	180	292	434	435	436	435	433	426	416	417	410	4575
72.6	275	212	312	436	436	436	436	436	436	435	428	425	4703
72.5	299	228	331	436	436	436	436	436	436	436	433	432	4775
72.4	320	257	349	436	436	436	436	436	436	436	435	434	4847
72.3	339	276	359	436	436	436	436	436	436	436	436	434	4896
72.2	351	291	373	436	436	436	436	436	436	436	436	436	4939
72.1	359	307	382	436	436	436	436	436	436	436	436	436	4972
72.0	370	323	392	436	436	436	436	436	436	436	436	436	5009
71.9	376	336	402	436	436	436	436	436	436	436	436	436	5038
71.8	401	380	424	436	436	436	436	436	436	436	436	436	5129
71.7	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	74.35	74.09	73.88	73.92	73.92	73.93	73.93	73.91	73.86	73.74	73.81	74.29	74.35
Minimum Level	71.74	71.71	71.72	72.66	72.66	72.84	72.69	72.66	72.63	72.6	72.39	72.22	71.71

Table B8.
Bv7 Historical Lake St. Louis Levels

Lake St. Louis at Pointe Claire Quarter-monthly mean levels Number of Occurences Above Level Shown ... 1900-2008 simulation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Months
Level (m IGLD 1985)													
22.5	0	0	0	0	0	0	0	0	0	0	0	0	0
22.4	0	0	0	3	4	2	0	0	0	0	0	0	9
22.3	0	0	0	10	17	6	0	0	0	0	0	0	33
22.2	0	0	0	14	26	11	0	0	0	0	0	0	51
22.1	1	4	5	27	45	15	0	0	0	0	0	0	97
22.0	3	8	15	80	85	26	2	0	0	0	0	2	221
21.9	7	14	25	107	101	45	7	0	0	1	4	5	316
21.8	13	20	39	131	123	58	19	4	0	1	6	10	424
21.7	23	35	57	162	155	77	30	8	1	3	10	18	579
21.6	43	63	72	200	196	101	44	17	8	7	22	28	801
21.5	68	96	96	237	240	145	79	30	22	23	34	40	1110
21.4	93	128	134	276	279	188	114	63	51	41	52	63	1482
21.3	133	157	156	311	318	229	152	91	77	73	91	86	1874
21.2	175	193	179	337	347	268	187	128	110	90	124	106	2244
21.1	234	240	222	366	375	308	241	167	148	125	157	144	2727
21.0	279	280	262	394	397	344	288	226	190	165	183	183	3191
20.9	347	337	298	405	409	380	326	271	241	203	211	223	3651
20.8	385	369	335	413	419	404	366	318	277	245	249	263	4043
20.7	405	406	384	421	426	415	393	369	329	301	295	321	4465
20.6	423	419	412	428	436	436	436	430	418	412	408	402	5060
20.5	431	427	423	432	436	436	436	436	426	421	419	417	5140
20.4	435	433	436	436	436	436	436	436	436	430	421	427	5198
20.3	436	434	436	436	436	436	436	436	436	436	436	435	5229
20.2	436	436	436	436	436	436	436	436	436	436	436	435	5231
20.1	436	436	436	436	436	436	436	436	436	436	436	435	5231
20.0	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	22.16	22.17	22.2	22.48	22.48	22.48	22.04	21.86	21.74	21.94	21.98	22.08	22.48
Minimum Level	20.35	20.21	20.41	20.41	20.63	20.61	20.62	20.55	20.42	20.38	20.38	20.1	20.1

Table B9.

Bv7 Historical Montreal Harbour at Jetty 1 Levels

Montreal Harbour at Jetty #1 Quarter-monthly mean levels Number of Occurences Above Level Shown ... 1900-2008 supplies simulation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All Months
Level (m IGLD 1985)													
9.2	0	0	0	0	0	0	0	0	0	0	0	0	0
9.0	1	1	0	0	0	0	0	0	0	0	0	0	2
8.8	1	1	0	2	1	1	0	0	0	0	0	0	6
8.6	1	3	0	3	9	2	0	0	0	0	0	0	18
8.4	1	5	0	7	22	5	0	0	0	0	0	0	40
8.2	1	5	3	18	40	7	0	0	0	0	0	0	74
8.0	2	5	5	53	66	12	0	0	0	0	0	0	143
7.8	2	7	11	84	85	21	0	0	0	0	0	0	210
7.6	3	15	23	115	103	27	3	0	0	0	0	2	291
7.4	5	22	32	157	132	38	6	0	0	0	6	5	403
7.2	14	32	63	199	181	60	11	3	0	1	7	8	579
7.0	32	51	88	240	224	85	34	13	3	6	15	23	814
6.8	60	86	119	286	273	124	58	23	8	21	27	37	1122
6.6	96	144	152	321	328	185	106	43	37	43	67	65	1587
6.4	139	182	189	350	356	239	155	88	70	75	112	94	2049
6.2	183	224	239	382	375	291	201	144	114	107	144	130	2534
6.0	262	295	287	399	402	343	271	198	174	148	179	185	3143
5.9	300	327	306	410	411	362	296	237	205	176	195	206	3431
5.8	336	352	333	415	419	381	322	272	234	196	214	225	3699
5.7	368	373	361	420	423	396	352	305	267	235	236	252	3988
5.6	384	397	381	427	431	410	380	336	289	267	272	286	4260
5.5	404	414	402	428	434	422	393	373	321	309	316	316	4532
5.4	413	420	417	430	436	426	420	411	392	365	355	359	4844
5.3	427	430	428	432	436	433	434	430	416	406	396	397	5065
5.2	432	433	434	435	436	436	436	435	426	421	412	410	5146
5.1	436	434	435	435	436	436	436	436	431	423	420	426	5184
5.0	436	436	436	436	436	436	436	436	436	430	431	431	5216
4.9	436	436	436	436	436	436	436	436	436	436	436	434	5230
4.8	436	436	436	436	436	436	436	436	436	436	436	435	5231
4.7	436	436	436	436	436	436	436	436	436	436	436	435	5231
4.6	436	436	436	436	436	436	436	436	436	436	436	436	5232
Maximum Level	9.08	9.17	8.34	8.96	8.94	8.9	7.73	7.26	7.19	7.4	7.5	7.69	9.17
Minimum Level	5.11	5.03	5.03	5.06	5.43	5.27	5.21	5.2	5.01	4.94	4.91	4.7	4.7

B5. References

Caldwell, R. and Fay, D.(2002). Lake Ontario Pre-project Outlet Hydraulic Relationship Final Report. Hydrology and Hydraulics Technical Work Group, International Joint Commission Lake Ontario-St. Lawrence River Study.

Lee, D. (2004). Deterministic Forecasts for Lake Ontario Plan Formulation. Plan Formulation and Evaluation Group, International Joint Commission Lake Ontario-St. Lawrence River Study.

Lee, D.H., Quinn, F.H., Sparks, D. and Rassam, J.C. (1994). Simulation of Maximum Lake Ontario Outflows. Journal of Great Lakes Research 20(3) 569-582.

Directive to the International Lake Ontario - St. Lawrence River Board on Operational Adjustments, Deviations and Extreme Conditions

This directive was created in conjunction with the proposed revised Order of Approval. It provides specific protocols and guidance to the International Lake Ontario-St. Lawrence River Board for implementing a regulation plan approved by the Commission, particularly as they relate to making operational adjustments, deviating from that plan, and managing extreme conditions. This directive updates and replaces all past directives on these topics to the former International St. Lawrence River Board of Control, including letters from the International Joint Commission (the Commission) dated May 5, 1961 and October 18, 1963 that vested the Board with limited authority to deviate from the approved regulation plan.

Plan 2014 is the combination of the mechanistic release rules labeled "Bv7" (described in Annex B) together with discretionary decisions made by the International Lake Ontario - St. Lawrence River Board to deviate from the flows specified by the rules of Bv7 according to this directive on deviations. In that regard, Bv7 is analogous to Plan 1958-D; each is a set of release rules that solves algorithms to produce an unambiguous release amount each week.

Under the revised Order of Approval, the International Lake Ontario – St. Lawrence River Board is responsible for ensuring compliance with the Order pertaining to the regulation of the St. Lawrence River and Lake Ontario and any requirements outlined in directives from the Commission. This includes setting weekly discharges for the St. Lawrence River through the flow control structures of the Moses-Saunders hydro-electric plant located at Cornwall-Massena according to the regulation plan approved by the Commission. Bv7 release rules are designed to handle a broader range of water supply situations than the previous release rules (Plan 1958-D). In most instances, it will be important to release flows as determined by the release rules in order to realize its expected benefits. Therefore, the Commission anticipates fewer, more limited instances where flow releases would differ from those of the release rules than was the case with 1958-D.

The following sections of this Annex describe and differentiate between operational adjustments, minor, major, and emergency deviations. The Annex also explains when and how the Board can adjust and deviate from the outflows prescribed by the regulation plan. If the Board cannot establish consensus regarding deviations from plan outflows, then the issue shall be raised immediately to the Commission through the Commission's Engineering Advisors located in Washington, DC and Ottawa, ON. In such cases, the Board must reach consensus on an interim outflow in consideration of the particular circumstances at the time and that is consistent with the Treaty, while the Commission makes a decision.

C1. Operational Adjustments due to Inaccurate Forecasts

The rules and logic of the regulation plan determine the flow to be released for the coming week based on observed and forecasted hydrologic and ice conditions. As forecasts of conditions have some uncertainty, there will be occasions when the actual within-the-week conditions experienced differ significantly from the forecasted conditions used to calculate the regulation plan flow. Due to inaccurate forecasts, in some cases adjustments to the flows determined by the regulation plan at the beginning of the regulation week will be required later in the week in order to maintain the intent of the plan. The Board will consider these flow adjustments as within-plan operations and not as deviations from the plan.

The rules and logic of the plan provide protection against extreme high and low levels downstream in balance with Lake Ontario levels. The Board shall oversee operational adjustments to successfully manage rapidly varying flood and low flows coming from the Ottawa River in accordance with the rules set out in the regulation plan, unless conditions require minor or major deviations as defined below. The plan also includes rules, based on decades of operational experience, to form and manage the ice cover in the river reaches of importance upstream of the Moses-Saunders and Beauharnois hydro-electric plants. The Board shall also continue flow changes as needed for ice management in these river reaches consistent with the intent of the plan. Ottawa River discharges and ice conditions can change significantly from day-to-day, and the week-ahead forecasts of Ottawa River flows and ice conditions used for regulation calculations are subject to rapid variations due to changing weather conditions. Therefore, short-term within-the-week flow adjustments will be made when needed to avoid flooding near Montreal consistent with the intent of the plan when the Ottawa River flow is very high and changing rapidly. Such adjustments will also be made when required to maintain St. Lawrence River levels above the minimums specified in the plan when inflows to the river are varying. As ice conditions can vary quickly due to changing weather conditions, it is anticipated that adjustments will also be necessary for the formation of a smooth ice cover to prevent ice jams in the International Rapids Section of the St. Lawrence River and the Beauharnois Canal. Within-the-week flow adjustments may also be required to address other unexpected within-the--week changes in river conditions. These flow adjustments are consistent with and accounted for in the design of the regulation plan, which was developed with the assumption that the flows during the Ottawa River freshet, droughts and the ice formation would be adjusted in practice within the week as they have been with Plan 1958DD. Therefore, no future offsetting adjustments are needed to compensate for within-the-week flow adjustments due to uncertainties in forecasts of Ottawa River flows, ice conditions, or other weather-related circumstances that are made to maintain the intent of the Plan.

The Board may direct its Regulation Representatives to be responsible for monitoring conditions, making operational flow adjustments and tracking their use. Tracking records will be used to replicate plan results, as needed for subsequent plan reviews.

C2. Minor Deviations for the St. Lawrence River

To respond to short-term needs on the St. Lawrence River, the Commission will allow the Board to make minor discretionary deviations from the approved regulation plan that have no appreciable effect on Lake Ontario levels. Minor deviations are made to provide beneficial effects or relief from adverse effects to an interest when this can be done without appreciable adverse effects to other interests, and consistent with the requirements of the Order of Approval. Unlike flow adjustments made to maintain the intent of the plan, minor deviations from the plan require accounting and flow restoration.

Minor deviations, while not necessarily limited to only these situations, could include those to address contingencies such as:

- short-term flow capacity limitations due to hydropower unit maintenance;
- assistance to commercial vessels on the river due to unanticipated low water levels;
- assistance, when appropriate, with recreational boat haul-out on Lake St. Lawrence or Lake St. Louis at the beginning or at the end of the boating season; and,
- unexpected ice problems on the river downstream of Montreal.

These deviations will affect levels on Lake St. Lawrence and the St. Lawrence River downstream to Montreal, but due to the relatively small volume of water involved, such deviations would have a very minor effect on Lake Ontario levels and the river upstream of Cardinal, ON. The intention is for minor flow deviations to be restored by equivalent offsetting deviations from the plan flow as soon as conditions permit to avoid or minimize cumulative impacts on the Lake Ontario level and avoid changing the balance of benefits under the approved regulation plan. Some discretion will be left to the Board as to whether conditions permit the restoration of the volume of water released or held back by these deviations. However, the Board shall not allow the cumulative effect of these minor deviations to cause the Lake Ontario level to vary by more than +/- 2 cm from that which would have occurred had the releases prescribed by the approved plan been strictly followed. The intent is to accommodate, where possible, those needs of the river interests that are difficult to foresee and build into the plan, while being consistent with the intent of the regulation plan and Order of Approval.

The Board will provide post-action reports to the Commission of these minor deviations from plan flows as part of normal semi-annual reporting requirements. However, if circumstances are such that minor deviations cause the Lake Ontario level to vary more than +/- 2 cm from the level resulting from the approved plan (*i.e.*, potentially having a significant impact on Lake Ontario levels), then the Board shall advise the Commission in advance as soon as the potential need for the longer-term deviation is known. If there is a need for a longer-term deviation, the Board must provide a flow restoration plan and obtain approval from the Commission, or obtain a waiver from the Commission not requiring flow restoration. It is intended that such a waiver be rarely used so as to avoid changing the balance of benefits associated with the approved regulation plan.

The Board may direct its Regulation Representatives to approve minor deviations from plan flow, within parameters set by the Board.

C3. Major Deviations

Major deviations are significant departures from the approved regulation plan that are made in response to extreme high or low levels of Lake Ontario in accordance with criterion H14 of the revised Order of Approval:

> In the event that Lake Ontario water levels reach or exceed extremely high levels, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream. In the event that Lake Ontario levels reach or fall below extremely low levels, the works in the International Rapids Section shall be operated to provide all possible relief to municipal water intakes, navigation and power purposes, upstream and downstream. The high and low water levels at which this provision applies will be established by a Commission directive to the Board.

Major deviations are expected to significantly alter the level of Lake Ontario compared to the level that would occur by following the approved regulation plan. Although the approved regulation plan was developed to perform under a wide range of hydrological conditions and with the experience gained in four decades of regulation operations, extreme high or low Lake Ontario water levels could require major deviations from the plan. Extreme high and low Lake Ontario levels to trigger major deviations are set out in Table C-1 of this report based on quarter-month levels through the year. If the Board expects that lake levels will be outside the range defined by the trigger levels, then based on analysis using the technical expertise at its disposal, the Board will inform the Commission that it expects to make a major deviation from the plan once the trigger level is reached to moderate the extreme levels. The Board is authorized to use its discretion to set flows in such conditions and deviate from the approved plan to provide balanced relief to the degree possible, upstream and downstream, in accordance with criterion H14 and the Treaty. For example, if the lake level is above the high trigger, then the Board could decide to increase the flow to the maximum specified by the limits used in the approved regulation plan if the plan flow is not already at this maximum, or it could apply the maximum flow limits used in Plan 1958DD, or it could release another flow consistent with criterion H14. While major deviations take downstream interests into account, they are not triggered by downstream levels, as the Bv7 release rules are designed to prevent extreme levels downstream, provided that Lake Ontario levels are not at extremes.

The Commission emphasizes that for the objectives of the approved regulation plan to be met, the regulation plan needs to be followed until water levels reach any of the defined triggers. The Board shall keep the Commission informed of the difference between the Lake Ontario level and the defined trigger levels. The Board will provide regular reports on implementation of the major deviation to the Commission. As the extreme event ends, the Board shall develop for Commission approval a strategy to return to plan flows and recommendations as to whether or not equivalent offsetting deviations from the plan flow should be made, as appropriate on a case-by-case basis.

The effectiveness of major deviations initiated with the trigger levels defined in Table C-1 will be assessed as part of the adaptive management process through follow-up monitoring and modeling. The trigger levels or implementation of major deviations could be modified by the Commission through future directives if warranted.

C4. Emergency Deviations

Emergency situations are considered to be those that threaten the physical integrity of the water management system and that may lead to a loss of the ability to control the flows in the system, or unusual life-threatening situations. Examples could include the failure of a lock gate, flooding of the hydropower control works, failure of a spillway gate, dike failure, a regional power outage, or other such active or imminent incidents. Such incidents arise only on extremely rare occasions. In such cases, immediate action is required and the Board is directed to authorize the Regulation Representatives to direct and approve, on the Board's behalf, emergency flow changes as required. The Regulation Representatives will report any such emergency actions as soon as possible to the Board and immediately thereafter the Board will report such actions to the Commission.

The Board will determine the need to make subsequent equivalent offsetting deviations from the plan flow, as appropriate, on a case-by-case basis.

Table C1.
Lake Ontario Trigger Levels for Major Deviations

Quarter months		High trigger (m./ft.)		Low trigger (m./ft.)	
1	1-Jan	75.03	246.16	74.13	243.21
2		75.07	246.29	74.13	243.21
3		75.1	246.39	74.13	243.21
4		75.13	246.49	74.12	243.18
5	1-Feb	75.14	246.52	74.12	243.18
6		75.14	246.52	74.12	243.18
7		75.13	246.49	74.11	243.14
8		75.14	246.52	74.11	243.14
9	1-Mar	75.16	246.59	74.13	243.21
10		75.18	246.65	74.15	243.27
11		75.22	246.78	74.19	243.41
12		75.27	246.95	74.25	243.6
13	1-Apr	75.33	247.15	74.33	243.86
14		75.4	247.38	74.4	244.09
15		75.45	247.54	74.46	244.29
16		75.5	247.7	74.51	244.46
17	1-May	75.53	247.8	74.55	244.59
18		75.56	247.9	74.58	244.69
19		75.6	248.03	74.61	244.78
20		75.62	248.1	74.62	244.82
21	1-Jun	75.63	248.13	74.64	244.88
22		75.62	248.1	74.65	244.91
23		75.6	248.03	74.65	244.91
24		75.59	248	74.65	244.91
25	1-Jul	75.57	247.93	74.65	244.91
26		75.54	247.83	74.64	244.88
27		75.5	247.7	74.63	244.85
28		75.47	247.6	74.61	244.78
29	1-Aug	75.43	247.47	74.59	244.72
30		75.39	247.34	74.56	244.62
31		75.34	247.18	74.53	244.52
32		75.3	247.05	74.5	244.42
33	1-Sep	75.26	246.92	74.46	244.29
34		75.2	246.72	74.42	244.16
35		75.15	246.56	74.39	244.06
36		75.1	246.39	74.35	243.93
37	1-Oct	75.06	246.26	74.31	243.8
38		75.01	246.1	74.27	243.67
39		74.97	245.96	74.24	243.57
40		74.95	245.9	74.2	243.44
41	1-Nov	74.94	245.87	74.18	243.37
42		74.92	245.8	74.17	243.34
43		74.91	245.77	74.16	243.31
44		74.92	245.8	74.16	243.31
45	1-Dec	74.93	245.83	74.15	243.27
46		74.93	245.83	74.15	243.27
47		74.95	245.9	74.14	243.24
48		75	246.06	74.13	243.21

Directive to the International Lake Ontario - St. Lawrence River Board

This directive updates and replaces the November 16, 1953 directive that created the International St. Lawrence River Board of Control. This directive creates and directs the International Lake Ontario-St. Lawrence River Board as a new Board, with any further direction to the new Board to be issued by the International Joint Commission (the Commission) from this date forward.

D1. Function and Composition of the Board

The International Lake Ontario-St. Lawrence River Board (Board) is responsible for ensuring compliance with the Order of Approval pertaining to the regulation of flows and levels of the St. Lawrence River and Lake Ontario, the regulation plan approved by the Commission and any requirements or duties outlined in directives from the Commission.

The Board shall perform duties specifically assigned to it in the Order of Approval as well as those assigned to it by the Commission directives. Under the Order, the Board has duties related to flow regulation and responsibilities related to adaptive management, communications and public involvement. To carry out these duties, the Board shall meet at least twice a year, hold teleconferences as needed, and provide semi-annual reports to the Commission. It will also hold at least two meetings with the public annually.

The Board shall have an equal number of members from each country. The Commission shall determine the number of members (normally a minimum of 10) and shall normally appoint each member for a three-year term. Members may serve for more than one term. Members shall act in their personal and professional capacity, and not as representatives of their countries, agencies or institutions. They are to seek decisions by consensus according to the tradition of the Commission.

Within this binational balance, at least one Board member will be from each of the five jurisdictions – federal, provincial and state. The jurisdictions may nominate members to serve on the Board. The Commission will review nominees, in consultation with the respective nominating federal, state or provincial jurisdiction, to ensure that all Board members are suited to fulfilling the new and continuing responsibilities of the Board. The expertise of potential Board members, their ability to act impartially and effectively with good judgment, their commitment to work towards Board consensus, engage appropriately with the public and reach decisions quickly when necessary will be key considerations for the Commission in the appointment of candidates to the Board. The Commission will appoint the nominees if it finds them suitable. If the Commission determines a nominee is not suitable, it will request the nominating jurisdiction to make an additional nomination (or nominations) until the Commission determines the nominee is suitable. In addition to members nominated by the jurisdictions, the Commission itself may appoint members to obtain an appropriate balance of expertise and geographic representation on the Board. The Commission shall appoint one member from each country to serve as co-chairs of the Board. Each co-chair is to appoint a Secretary, who, under the general supervision of the chair(s), shall carry out such duties as are assigned by the chairs or the Board as a whole. Upon request to the Commission, either co-chair may appoint an alternate member to act as Chair when they are not available to the Board.

The co-chairs of the Board, through the assistance of the Board secretaries, shall be responsible for maintaining proper liaison between the Board and the Commission, among the Board members and between the Board and its sub-groups. Chairs shall ensure that all members of the Board are informed of all instructions, inquiries, and authorizations received from the Commission and also of activities undertaken by or on behalf of the Board, progress made, and any developments affecting such progress.

In order to provide prompt action which may be necessary under winter operations or emergency conditions, each of the co-chairs of the Board shall appoint a Regulation Representative who is authorized by the Board to act on its behalf in such situations. Among other duties, the Regulation Representatives shall maintain a database of hydrological information for the Board, conduct the regulation plan calculations, make needed within-the-week flow adjustments, coordinate and keep account of flow deviations, and advise the Board on regulation operations.

The Board shall appoint an Operations Advisory Group (OAG) composed of representatives from the operating entities and shall keep the Commission informed of OAG membership. The Board and the Regulation Representatives may consult with OAG members individually or collectively as the occasion requires.

D2. Flow Regulation

The Board shall set flows from Lake Ontario into the St. Lawrence River through the Moses-Saunders Dam and Long Sault Dam in accordance with the Order of Approval, normally as specified by the approved weekly flow regulation plan and directives from the Commission. It shall also approve the gate setting at the Iroquois Dam in consideration of Lake St. Lawrence levels and ice management, which may be delegated to the Regulation Representatives for prompt action.

The Board shall oversee the normal flow variations carried out by the hydropower entities according to the directive on peaking and ponding issued by the Commission. The Board shall also supervise the Regulation Representatives in their conduct of within-the-week flow adjustments and shall direct minor and major flow deviations when required, consistent with the Commission's directive and Order of Approval.

Following the regulation plan will be important over the long-term to ensure that the expected objectives for system regulation are achieved.

D3. Adaptive Management

The Board will take part in an adaptive management plan designed to verify that the effects of the new regulation plan over time are as anticipated, react to the influence of changing conditions such as climate change, and adapt or improve the implementation of the regulation plan as required. The Board may also use the information acquired through the adaptive management strategy to propose to the Commission modifications to the plan should it learn over time that conditions (climatic, socio-economic or environmental) have changed enough such that the plan is no longer meeting its intended objectives or improvements to the plan could realize increased benefits.

D4. Communications and Public Involvement

The Board is directed to have a communications committee. The aim of the communications committee is to ensure that everyone interested in the regulation of the Lake Ontario-St. Lawrence River system is informed and has opportunities to express personal views regarding regulation. The communications committee will ensure that the Board is proactive in acquiring knowledge about stakeholder needs and perspectives on an ongoing basis and in providing them with regular information about Board decisions and the issues before the Board. The Commission encourages the Board to take advantage of multiple means, including modern technology and alternative communications fora, to better inform and receive input from stakeholders and the public within the framework of the Commission's communication strategy. The Board may collaborate with other Commission boards, governmental and quasi-governmental organizations to effectively strengthen information delivery and involve the public.

The Commission (through its public information officers) shall be informed, in advance, of plans for any public meetings or public involvement in the Board deliberations. The Board shall report in a timely manner to the Commission on these meetings, including representations made to the Board.

The Board shall provide the text of media releases and other public information materials to the Secretaries of the Commission for review by the Commission's Public Information Officers, prior to their release in English and French.

Reports, including semi-annual reports, and correspondence of the Board shall normally remain privileged and be available only to the Commission and to members of the Board and its committees (including appropriate individuals who support these entities with respect to Lake Ontario-St. Lawrence River activities) until their release has been authorized by the Commission. Board members and committees shall maintain files in accordance with the Commission policy on segregation of documents. All Board members shall be provided with these policy documents at the time of their appointment to the Board.

The Board shall provide minutes of Board meetings to the Commission within 45 days of the close of the meeting in keeping with the Commission's April 2002 Policy Concerning Public Access to Minutes of Meetings. The minutes will subsequently be put on the Commission's website.

To facilitate communication between the Board and the relevant federal, state and provincial jurisdictions of the Lake Ontario–St. Lawrence River system, the Commission shall request from these jurisdictions the name of an appropriate contact person and provide these names to the Board. The Board should note that its communications with the jurisdictions are only with respect to the carrying out of the functions of the Board, as set out in the Order of Approval and associated directives. It will remain the role of the Commission to engage all the jurisdictions (federal, state, provincial), as appropriate in the consideration of any changes to the regulation plan or directives to the Board. Any issues raised by the jurisdictions with the Board in these respects should be redirected to the Commission.

D5. Other Aspects

According to need and on an ad-hoc basis, the Board may establish any other committees and working groups as may be required to discharge its responsibilities effectively. The Commission shall be kept informed of the duties and composition of any committee or working group. Commissioners and relevant Commission staff are invited to any meetings of the Board and any committees the Board may establish. Unless other arrangements are made, members of the Board, committees, or working groups will make their own arrangements for reimbursement of necessary expenditures. The Commission should also be informed of the Board's plans and progress and of any developments or cost impediments, actual or anticipated, that are likely to affect carrying out the Board's responsibilities.

If, in the opinion of the Board or of any member, any instruction, directive, or authorization received from the Commission lacks clarity or precision, then the matter shall be referred promptly to the Commission for appropriate action. In the event of any unresolved disagreement among the members of the Board, the Board shall refer the matter forthwith to the Commission for decision.

Adaptive Management Strategy

The International Joint Commission (IJC) is working with the governments in the basin to develop adaptive management as an important tool for improving management of the Lake Ontario-St. Lawrence River regulation plan. An adaptive management strategy will enable the IJC to take advantage of future scientific and management advances, to ensure that the effects of regulation are those that have been calculated by the model used to develop the regulation plan, and to adjust for possible long-term changes in the amount of water entering the system (net basin supplies). The IJC does not have the resources or capacity to undertake adaptive management alone, but will work with jurisdictions and stakeholder groups that have capacity for monitoring various effects of regulation to identify the most important monitoring needs. The IJC will act on the results, as appropriate, using its standard procedures of reviews, consultations and hearings, if necessary, to make adjustments or changes. The benefits of an adaptive management strategy would apply to any regulation plan. Given that the adaptive management components will be funded and managed collaboratively by different governments and stakeholders, the list of components will gradually be built up and evolve over time. The IJC has worked with funding sources and interest groups to establish a framework for a Lake Ontario-St. Lawrence River adaptive management strategy based on the key monitoring priorities and estimated costs. The aspects of regulation that are incorporated into or affected by adaptive management include the regulation rules, the directive on deviations from those rules, and governance procedures.

E1. The Adaptive Management Process

Adaptive management is a process for improving decisions that cycles through these steps:

- estimate the impacts of a decision using best available models, but identify areas of uncertainty in those model predictions;
- make a decision that produces an appropriate balance of estimated impacts;
- monitor indicators of the impacts of the decision related to the key areas of uncertainty and compare them to what the models predicted;
- change the models if necessary based on monitoring evidence; and,
- change the decision if warranted based on the revised models.

There are two main areas of uncertainty in evaluating the performance of regulation rules for the Lake Ontario-St. Lawrence River system:

1. Will future water supplies be different from those used to test the rules?
2. Will the impacts of levels and flows be different from the modeled impacts used in designing the rules?

The adaptive management strategy will address the water supply and impact uncertainties and will support periodic evaluations to determine if new evidence can be used to develop improved regulation rules. Review of the regulation rules may occur at any time monitoring evidence suggests that it is warranted, but the first review is to take place within 15 years of the implementation of the adaptive management program.

E1.1. The Adaptive Management Committee

The International Lake Ontario-St. Lawrence River Board will oversee an Adaptive Management Committee (Committee) made up of technical experts who will coordinate the monitoring, research and modeling needed to carry out the adaptive management strategy. The Committee members will be appointed by the IJC with the advice of its boards. They will report to the Board on their work and present periodically their assessment of the monitoring results. The Board may use information developed by the Committee to propose modifications of the regulation rules to the IJC. The Committee will work with the

Board to provide for public input to the adaptive management process. Changes to the regulation plan, as always, will require approval of the Commissioners.

E2. Water Supply Research and Monitoring

The outcomes of regulation rules will depend on the water supplies that occur in the coming years, so there is a potential to improve the rules if more is known about future climate. The adaptive management strategy identifies three areas in which reduced uncertainty could improve regulation rules; forecasting, triggers and climate research.

E2.1 Forecasting

Two categories of forecast in particular hold promise for better regulation, and will have the highest priority for adaptive management research.

1. Better forecasts of supplies could help further reduce flooding along the shores of Lake Ontario and the St. Lawrence River caused by extremely wet winters and severe ice conditions that limit the winter outflow. If it were possible to improve the six-to-eight month forecasts of the amount of water entering Lake Ontario during the coming winter and early spring, then the regulation rules could be adjusted in the fall and winter depending on the risk of unusually wet conditions in the coming months. This could reduce property damage along the Lake Ontario coast while still improving ecosystem health.
2. Integrated Lake Ontario-Ottawa River forecasts. Independent forecasting systems exist or are under development for Lake Ontario supplies as well as Ottawa River flows, but there is no joint probabilistic forecast of Lake Ontario supplies and Ottawa River flow. An integrated Lake Ontario and Ottawa River ensemble forecasting system would support better short-term (2-4 week) water level forecasts, which could, for example, help the shipping industry forecast the available water draft for ships arriving at the Port of Montreal.

E2.2 Refined Deviation Triggers

The Proposal for Lake Ontario – St-Lawrence River regulation includes authority for the Board to deviate from the regulation rules when Lake Ontario levels reach trigger levels. Currently these triggers are set using statistics based on the historical record. There are high triggers for each quarter-month of the year which represent levels that are expected to be exceeded 2% of the time; the low triggers are levels that Lake Ontario is expected to be below 5% of the time. Adjusting releases at these triggers improves economic benefits without significant impact to the ecosystem, but further research might produce even better economic and environmental results using a different mix of trigger levels.

E2.3 Creation of a Coordinated Lake Ontario-St. Lawrence River Climate Change Model

Water supply datasets for the lake and river are needed to simulate the effects of climate change with different regulation rules. Datasets that reflect many different possible future climates for Lake Ontario have been developed, but there are not as many for the river. Given that the impact of climate change on lake and river levels is uncertain, it is important to test regulation rules using a wide array of supplies. Developing river datasets is more difficult because the flow from the major tributary to the St. Lawrence – the Ottawa River – is affected by the operation of a number of reservoirs in its basin. This adds a significant amount of work compared to what is necessary for estimating lake supplies because in addition to modeling rainfall, evaporation and runoff, the operating policies for these reservoirs on the Ottawa River have to be determined and simulated to estimate the inflows to the St. Lawrence River. It is also necessary to have a coordinated model to properly simulate the coincidence of high and low supplies to Lake Ontario with high and low flows from the Ottawa River basin. The development of a coordinated climate model for these two regions would help assure that regulation rules will work well under different possible future climate conditions.

E2.4. Environmental Impact Research and Monitoring

The Shared Vision Model of the Lake Ontario-St. Lawrence River system combines all of the performance models and the data used to design and evaluate the proposed regulation rules. The Integrated Ecological Response Model (IERM) portion of the Shared Vision Model demonstrates that the proposed rules will help wetland vegetation, bird communities, northern pike and muskrat (the muskrat is important because it is an indicator for the general health of a riparian ecosystem). Performance indicators for these elements of the Lake Ontario and St. Lawrence River environment played a critical role in plan selection because they were sensitive to water level changes and representative of a broader ecosystem response. The monitoring design for these four indicators will seek to isolate water level changes from other stressors and drivers that could influence the performance indicator's response. Efforts have already been initiated to establish mid- and long-term monitoring protocols. The Integrated Ecological Response Model predicts that the proposed regulation rules will not make a significant difference in the lower St. Lawrence River environment relative to the current regulation rules. However, there will be an effort to integrate existing monitoring data requirements to ensure that the proposed regulation rules do not result in unexpected negative environmental impacts on the lower St. Lawrence River.

E3. Economic Impact Research and Monitoring

The Flood and Erosion Prediction System (FEPS) portion of the Shared Vision Model indicates that the rules will increase maintenance costs to existing shore protection structures on Lake Ontario. However, those estimates rely heavily on the assumptions made by coastal engineers when the model was developed. The Lake Ontario-St. Lawrence River Study Board recognized the uncertainty in this assumption and suggested that measurements of the actual elevations of the top of structures be made.

Surveys of some of these structures already have been made and indicate considerable variability in the height of these shore protection structures, with many structures being higher than previously assumed for these locations. The higher the shore protection height, the less likely they are to be overtopped. Given that, this limited survey suggests some shore protection structures in the surveyed areas would be less sensitive to the changes in water levels brought about by the proposed regulation rules than is currently estimated by FEPS.

Although FEPS shows very little change in flooding with the proposed regulation rules, work has also been initiated to assess the use of a different model - the Flood Tool - to estimate the sensitivity of shoreline flooding impacts with a broader range of storm surge and wave conditions. Under the adaptive management strategy, measurements of shore protection in more areas would be taken and the use of the Flood Tool evaluated for a number of sites. The results of these activities will support continued improvements to the Flood and Erosion Prediction System and a refined assessment of potential effects along the Lake Ontario shoreline.

While refinements to the Flood and Erosion Prediction System have the highest priority among the economic indicators, the Adaptive Management Strategy will also address updates to model the impacts to recreational boating, hydropower, and navigation as funding becomes available.

Models of recreational boating requirements and use in the Shared Vision Model predict that the proposed regulation rules will tend to provide deeper water in the fall on Lake Ontario and the river compared to the current rules, but less depth on the lake and River during those years that experience the driest summers. On balance, the models predict slightly negative boating impacts above Lake St. Lawrence, because the estimated boating activity in summer months is much higher than in fall. Future boat ownership and use could change these assumptions. Adaptive management could include a targeted survey of boat ownership and use patterns throughout the boating season.

The proposed regulation rules produce about the same loading conditions for commercial navigation on average as the current rules, but the proposed rules are expected to provide a modest increase in the value of hydropower produced at both the Moses-Saunders and Beauharnois plants. The Study Board recognized that there was less uncertainty in the models used to evaluate these sectors and that hydropower and shipping agencies already gather much of the data needed for tracking performance. The adaptive management strategy assumes data for these sectors will continue to be available in the future for regulation rule evaluations, but updates to the model may be needed.

E4. Periodic Assessments of the Regulation Rules

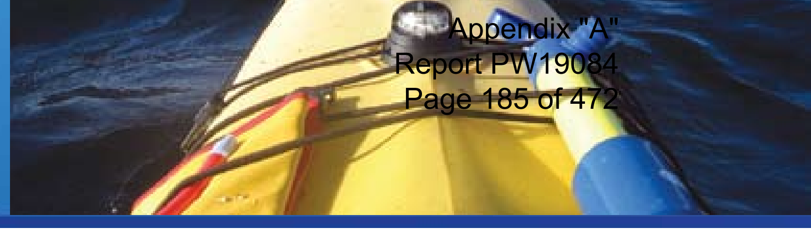
Over time, the evidence collected from the water supply and impact research and monitoring may suggest there is need to develop an improved set of regulation rules. The adaptive management strategy calls for the maintenance of the tools and expertise developed during the Lake Ontario-St. Lawrence River Study to facilitate the formulation and evaluation of regulation rules in the future.

The tools include: the Shared Vision Model; the Integrated Ecological Response Model for Lake Ontario and the St. Lawrence River; the Integrated Ecological Response Model for the lower St. Lawrence River; the Flood and Erosion Prediction System; a subsequent flood impact analysis tool developed for Lake Ontario to more closely assess local flooding and wave surge impacts; and information management systems to make the latest research and best data readily available. The Shared Vision Model has already been re-designed for use in adaptive management. The adaptive management strategy calls for periodic model exercises and training to maintain agency familiarity with the tools needed to evaluate plans.

E5. Summary

The IJC always has strived to improve its regulation rules over time; adaptive management is a more structured, science-based and effective way of doing it because:

- data collection is more purposeful and better coordinated, increasing the chances that the data needed to inform regulation decisions will be available;
- on-going evaluation of the rules should be easier because the tools and knowledge needed to assess performance are maintained on a continuing basis, with a relatively small, steady effort; and,
- decisions are more transparent because the community of experts, decision makers and stakeholders that helped build the models used in adaptive management will be sustained in the outreach efforts of the new International Lake Ontario – St. Lawrence Board.



Annex F

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Note: All International Joint Commission-related reports and publications, as well as full text of the *Boundary Waters Treaty of 1909 and the 2012 Protocol to the Great Lakes Water Quality Agreement*, are available through the website of the IJC: www.ijc.org

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Annex G

Glossary

ADAPTIVE MANAGEMENT – A planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modeling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change.

BASIN; WATERSHED – The region or area of which the surface waters and groundwater ultimately drain into a particular course or body of water.

BASIN (LAKE ONTARIO – ST. LAWRENCE RIVER) – The surface area contributing runoff to Lake Ontario and the St. Lawrence River downstream to Trois Rivières, QC.

***BOUNDARY WATERS TREATY OF 1909* –** The agreement between the United States and Canada that established principles and mechanisms for the resolution of disputes related to boundary waters shared by the two countries. The International Joint Commission was created as a result of this treaty.

CHART DATUM – The water level used to calculate the water depths that are shown on "navigation charts" and are a reference point for harbor and channel dredging. Also known as Low Water Datum.

CLIMATE – The prevalent weather conditions of a given region (temperature, precipitation, wind speed, atmospheric pressure, etc.) observed throughout the year and averaged over a number of years.

CLIMATE CHANGE – A change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

COAST – The land or zone adjoining a large body of water.

COASTAL EROSION – The wearing away of a shoreline as a result of the action of water current, wind and waves.

COSMOS MODEL – Name of the erosion prediction numerical model used in the 2006 Lake Ontario-St. Lawrence River Study.

DEVITATIONS – Temporary changes to a regulation plan to provide beneficial effects or relief from adverse effects to an interest, without causing appreciable adverse effects to any of the other interests.

DIRECTIVE –.An IJC instruction to a new or existing Study Board specifying the study's terms of reference, including tasks and responsibilities.

DRAINAGE BASIN – The area that contributes runoff to a stream, river, or lake.

ECOSYSTEM – A biological community in interaction with its physical environment, and including the transfer and circulation of matter and energy.

ENVIRONMENT – Air, land or water; plant and animal life including humans; and the social, economic, cultural, physical, biological and other conditions that may act on an organism or community to influence its development or existence.

EROSION – The wearing away of land surfaces through the action of rainfall, running water, wind, waves and water current. Erosion results naturally from weather or runoff, but human activity such as the clearing of land for farming, logging, construction or road building can intensify the process.

FLOOD AND EROSION PROTECTION SYSTEM (FEPS) – A series of numerical models including COSMOS that compile and evaluate shoreline data to compute flood and erosion damages.

FLOODING – The inundation of low-lying areas by water.

FLOODPLAIN – The lowlands surrounding a watercourse (river or stream) or a standing body of water (lake), which are subject to flooding.

FRAZIL ICE – Stream ice with the consistency of slush, formed when small ice crystals develop in supercooled stream water as air temperatures drop below freezing. These ice crystals join and are pressed together by newer crystals as they form.

FRESHET – The sudden overflow or rise in level of a stream as a result of heavy rains or snowmelt.

HABITAT – The particular environment or place where a plant or an animal naturally lives and grows.

HYDROELECTRIC POWER – Electrical energy produced by the action of moving water.

ICE JAM – An accumulation of river ice, in any form which obstructs the normal river flow.

INTERESTS – In the context of the report, the groups or sectors served by the waters of Lake Ontario and the St. Lawrence River, including municipal and industrial water uses, commercial navigation, hydroelectric power generation, coastal development, ecosystems, and recreational boating. Under the Boundary Waters Treaty of 1909, the interests of domestic and sanitary water uses, navigation and hydroelectric generation and irrigation are given order of precedence in water uses in the development of regulation plans.

INTERNATIONAL JOINT COMMISSION (IJC) – International independent agency formed in 1909 by the United States and Canada under the *Boundary Waters Treaty* to prevent and resolve boundary waters disputes between the two countries. The IJC makes decisions on applications for projects such as dams in boundary waters, issues Orders of Approval and regulates the operations of many of those projects. It also has a permanent reference under the Great Lakes Water Quality Agreement to help the two national governments restore and maintain the chemical, physical, and biological integrity of those waters.

INTERNATIONAL LAKE ONTARIO - ST. LAWRENCE RIVER STUDY – A study, sponsored by the IJC and completed in 2006, to examine the effects of water level and flow variations on all users and interest groups and to determine if better regulation is possible at the existing installations controlling Lake Ontario outflows.

INTERNATIONAL REACH – The portion of the St. Lawrence River that is between Lake Ontario and the Moses-Saunders Dam.

INTERNATIONAL ST. LAWRENCE RIVER BOARD OF CONTROL – Board established by the International Joint Commission in its 1952 Order of Approval. Its main duty is to ensure that outflows from Lake Ontario meet the requirements of the Commission's Order. The Board also develops regulation plans and conducts special studies as requested by the Commission.

LIGHT LOAD – A load less than the ship capacity, required when a fully loaded ship would be too close to the channel bottom because of low water levels.

LOWER ST. LAWRENCE RIVER – The portion of the St. Lawrence River downstream of the Moses-Saunders Dam is called the lower St. Lawrence in this Study. It includes Lake St. Francis, Lake St. Louis, Montreal Harbour, Lake St. Pierre and the portions of the River connecting these lakes as far downstream as Trois Rivieres, QC.

MARINA – A private or publicly-owned facility allowing recreational watercraft access to water, and offering mooring and related services.

MARSH – An area of low, wet land, characterized by shallow, stagnant water and plant life dominated by grasses and cattails.

MEASURE, STRUCTURAL – Any measure that requires some form of construction. Commonly includes control works and shore protection devices.

MODEL, COMPUTER – A series of equations and mathematical terms based on physical laws and statistical theories that simulate natural processes.

MONTHLY MEAN WATER LEVEL – The arithmetic average of all past observations (of water levels or flows) for that month.

ORDERS OF APPROVAL – In ruling upon applications for approval of projects affecting boundary or transboundary waters, such as dams and hydroelectric power stations, the IJC can regulate the terms and conditions of such projects through Orders of Approval to maintain specific targets with respect to water levels and flows in the lakes and connecting channels.

PEAKING – The variation of hourly water flows above and below the daily average flow (for instance, midday flow higher than evening and night flows), primarily due to hydroelectric generating operations during which water is stocked during periods of off-peak demand in order to increase hydroelectric power generation at peak periods.

PERFORMANCE INDICATOR – A measure of economic, social or environmental health. In the context of the Study, performance indicators relate to impacts of different water levels in Lake Ontario and the St. Lawrence River.

PLAN FORMULATION METHOD – A particular way of searching for a better regulation plan; mathematical optimization based on economic benefits, for example.

PONDING – The variation of daily water flows above and below the weekly average flow (for instance, average weekday flow higher than average weekend flow), primarily due to hydroelectric generating operations.

PUBLIC INTEREST ADVISORY GROUP (PIAG) – The group of volunteers from the United States and Canada that worked to ensure effective communication between the public and the 2006 International Lake Ontario-St. Lawrence River Study Board.

REFERENCE – A request from government for the IJC to study and recommend solutions to transboundary issue. The word is derived from Article IX of 1909 *Boundary Waters Treaty*, which stipulates that such issues "shall be referred from time to time to the International Joint Commission for examination and report, whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred."

REGULATION PLANS – In the context of the report, the control of waterflows through regulatory structures to meet the needs of various water-using interests in a basin. These plans have incorporated the specific objectives established in the IJC's Orders of Approval, established monthly outflow levels, and allocated flows to various water-using interests, such as hydroelectric generation.

REGULATORY STRUCTURES – Adjustable structures, such as a gated dam, that can be raised or lowered to adjust water levels and flows both upstream and downstream.

REVETMENT – A natural (e.g., grass, aquatic plants) or artificial (*e.g.,* concrete, stone, asphalt, earth, sand bag) covering to protect an embankment or other structure from erosion.

RIPARIAN – Of, relating to or found along a shoreline.

RIPARIANS – Persons residing on the banks of a body of water. Typically associated with private owners of shoreline property.

SHORE WELL – A well close to a lake in which the well water levels are directly influenced by lake levels.

SHORELINE – Intersection of a specified plane of water with the shore.

STAKEHOLDER – An individual, group, or institution with an interest or concern, either economic, societal or environmental, that is affected by fluctuating water levels or by measures proposed to respond to fluctuating water levels within the Lake Ontario–St. Lawrence River Basin.

STOCHASTIC – Random. A stochastic process is one whose behavior is non-deterministic, in that a system's subsequent state is determined both by the process's predictable actions and by a random element.

STOCHASTIC SUPPLIES – Simulated sequences of water supply conditions that reflect climate variability.

UPPER ST. LAWRENCE RIVER – The portion of the St. Lawrence River upstream of the Moses-Saunders Dam is called the upper St. Lawrence River. It includes the entire river from Kingston/Cape Vincent to the power dam and locks at Cornwall-Massena, including Lake St. Lawrence.

WATER LEVEL – The elevation of the surface of the water of a lake or at a particular site on the river. The elevation is measured with respect to average sea level.

WATER SUPPLY – Water reaching the Great Lakes as a direct result of precipitation, less evaporation from land and lake surfaces.

WATERFOWL – Birds that are ecologically dependant on wetlands for their food, shelter and reproduction.

WAVE – An oscillatory movement in a body of water which results in an alternate rise and fall of the surfaces.

WAVE CREST – The highest part of a wave.

WETLANDS – An area characterized by wet soil and high biologically productivity, providing an important habitat for waterfowl, amphibians, reptiles and mammals.








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Appendix D

2017 Aerial Photos Showing Ponding Water

(Taken June 8, 2017)

DILLON CONSULTING

Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142219

Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142200

Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142200

Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142156

Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142146

Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142142

Appendix E

1-D Excel Model Outputs

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	100
Location	Mount Hope
a	2317.4
b	11
c	0.836

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	181.81	9.96	9.96	22.51	32.47	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	15.90%	0.70	0.73		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	181.81	25.72	25.72	58.16	83.88	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	100.79%	0.75	1.39	0.38	450	$ 101.30	$ 6,365.67
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.39	172.33	42.38	68.10	145.95	214.06	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	104.85%	0.94	1.90	0.535	600	$ 148.70	$ 16,012.41
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.29	160.97	98.17	176.22	352.78	529.00	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	157.30%	1.19	0.77	0.71	750	$ 300.50	$ 16,439.30
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.06	156.84	17.06	193.28	377.02	570.30	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	169.58%	1.19	1.49	0.73	750	$ 300.50	$ 31,960.44
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	181.81	39.49	39.49	89.29	128.78	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	280.55%	0.65	1.43	0.44	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	181.81	72.72	72.72	164.43	237.16	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	516.64%	0.65	1.83	0.555	600	$ 148.70	$ 10,591.62
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	169.56	73.67	146.39	308.70	455.08	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	991.40%	0.65	0.34	0.705	750	$ 300.50	$ 3,958.53
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	181.81	8.88	8.88	20.08	28.95	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	63.08%	0.69	0.25		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	167.49	10.96	166.23	346.25	512.47	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	378.66%	0.85	1.93	0.74	750	$ 300.50	$ 29,605.65
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	156.65	83.26	249.48	486.06	735.54	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	360.30%	0.94	1.06	0.845	900	$ 418.20	$ 25,086.02
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	151.33	54.68	304.16	572.43	876.59	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	260.65%	1.19	0.38	0.855	900	$ 418.20	$ 11,357.30
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	149.51	23.10	327.26	608.51	935.76	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	278.25%	1.19	1.12	0.875	900	$ 418.20	$ 33,556.37
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	144.41	70.96	398.22	715.20	1113.42	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	331.07%	1.19	0.64	0.935	975	$ 458.80	$ 20,851.76
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	141.69	85.57	523.28	922.10	1445.38	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	429.78%	1.19	0.15	1.03	1050	$ 525.50	$ 5,733.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	141.05	1.01	524.28	919.72	1444.00	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	429.37%	1.19	0.06	1.03	1050	$ 525.50	$ 2,102.36
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	140.82	0.00	524.28	918.21	1442.49	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	428.92%	1.19	0.13	1.03	1050	$ 525.50	$ 4,780.70
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	140.30	0.00	524.28	914.79	1439.07	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	524.07%	0.97	1.10	1.11	1200	$ 658.60	$ 42,176.21
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	135.95	0.00	524.28	886.44	1410.72	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	419.47%	1.19	0.15	1.02	1050	$ 525.50	$ 5,621.94
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	135.38	0.00	524.28	882.72	1407.00	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	418.37%	1.19	2.13	1.02	1050	$ 525.50	$ 80,020.15
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	181.81	26.03	26.03	58.86	84.89	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	184.94%	0.65	1.53	0.375	450	$ 101.30	$ 6,045.86
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	171.42	57.18	83.21	177.40	260.61	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	567.74%	0.65	1.47	0.575	600	$ 148.70	$ 8,538.81
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	162.58	51.39	134.60	272.16	406.76	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	300.55%	0.85	1.62	0.675	750	$ 300.50	$ 24,790.52
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	153.96	85.82	220.42	422.06	642.47	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	314.71%	0.94	1.90	0.805	825	$ 348.60	$ 37,468.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	145.03	102.86	323.28	583.09	906.37	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	443.98%	0.94	0.25	0.915	975	$ 458.80	$ 6,515.74
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	181.81	27.68	27.68	62.58	90.26	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	108.44%	0.75	1.30	0.385	450	$ 101.30	$ 5,932.94
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.30	172.94	52.53	80.21	172.51	252.71	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	186.73%	0.85	0.91	0.565	600	$ 148.70	$ 6,939.85
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.21	167.23	52.54	132.75	276.09	408.84	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	302.08%	0.85	1.11	0.68	750	$ 300.50	$ 16,975.38
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	143.93	51.97	508.01	909.34	1417.34	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	421.44%	1.19	0.18	1.025	1050	$ 525.50	$ 6,807.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	143.15	9.91	517.91	922.03	1439.94	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	428.16%	1.19	1.38	1.03	1050	$ 525.50	$ 51,889.96
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	137.48	77.67	595.58	1018.33	1613.91	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	479.89%	1.19	1.53	1.075	1200	$ 658.60	$ 71,780.96
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	181.81	51.30	51.30	116.01	167.31	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	364.49%	0.65	1.97	0.485	525	$ 110.50	$ 8,481.96
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	168.68	84.55	135.85	285.00	420.85	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	505.66%	0.75	0.72	0.685	750	$ 300.50	$ 9,815.09
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	164.37	35.20	171.06	349.68	520.74	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	384.77%	0.85	0.96	0.745	750	$ 300.50	$ 14,752.34
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	159.00	56.65	227.70	450.26	677.96	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	500.94%	0.85	1.84	0.82	825	$ 348.60	$ 32,665.47
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	181.81	161.46	161.46	365.09	526.55	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1865.30%	0.58	1.63	0.745	750	$ 300.50	$ 16,949.09
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	170.77	84.04	245.50	521.40	766.90	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1670.70%	0.65	1.93	0.86	900	$ 418.20	$ 31,372.17
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	159.50	47.86	293.36	581.95	875.32	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	1051.71%	0.75	0.77	0.9	975	$ 458.80	$ 15,972.32
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	155.44	0.00	293.36	567.13	860.49	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	635.81%	0.85	0.92	0.895	900	$ 418.20	$ 19,646.58
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	149.73	107.38	628.45	1170.29	1798.74	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	881.10%	0.94	0.25	1.18	1200	$ 658.60	$ 9,464.83
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	148.54	18.65	647.10	1195.44	1842.54	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	547.87%	1.19	1.23	1.13	1200	$ 658.60	$ 57,646.85
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	143.08	68.94	716.04	1274.13	1990.17	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	591.77%	1.19	0.53	1.16	1200	$ 658.60	$ 24,954.70
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	181.81	314.61	314.61	711.38	1025.99	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	168.26%	1.38	0.97	0.905	975	$ 458.80	$ 36,705.39
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	175.10	86.33	400.94	873.14	1274.08	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	208.95%	1.38	1.21	0.985	1050	$ 525.50	$ 52,606.19
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	167.44	164.77	565.71	1178.01	1743.73	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	221.79%	1.47	0.86	1.105	1200	$ 658.60	$ 49,807.51
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	181.81	128.60	128.60	290.78	419.38	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	91.09%	1.47	0.98		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	10.98	175.02	262.16	390.76	850.57	1241.33	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	269.61%	1.29	1.49	0.975	1050	$ 525.50	$ 60,442.57
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	162.43	0.00	956.47	1932.16	2888.63	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	193.13%	1.73	0.15	1.335	1350	$ 847.00	$ 12,811.65
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	140.85	42.79	1715.30	3004.64	4719.94	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	315.57%	1.73	0.16	1.605	1650	$ 1,240.60	$ 20,795.66
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	181.81	51.15	51.15	115.67	166.82	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	123.26%	0.85	1.50	0.485	525	$ 110.50	$ 8,470.50
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.50	171.61	69.55	120.70	257.61	378.31	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	279.53%	0.85	1.37	0.66	675	$ 227.90	$ 15,989.75
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.88	163.32	74.65	195.35	396.78	592.14	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	290.05%	0.94	0.25	0.78	825	$ 348.60	$ 4,939.64
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.13	161.90	0.00	195.35	393.34	588.69	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	288.36%	0.94	1.78	0.775	825	$ 348.60	$ 35,028.43
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.90	152.57	79.36	274.71	521.24	795.96	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	389.89%	0.94	0.66	0.87	900	$ 418.20	$ 15,684.19
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.56	149.38	452.17	726.88	1350.37	2077.25	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	617.66%	1.19	1.34	1.18	1200	$ 658.60	$ 62,957.34
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	181.81	104.60	104.60	236.52	341.12	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	743.13%	0.65	0.81	0.635	675	$ 227.90	$ 7,164.02
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	181.81	76.86	76.86	173.80	250.66	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	185.21%	0.85	0.35	0.565	600	$ 148.70	$ 2,668.33
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	176.17	0.00	181.46	397.59	579.05	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	283.64%	0.94	0.16	0.775	825	$ 348.60	$ 3,090.05
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	175.12	248.42	429.88	936.25	1366.13	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	669.19%	0.94	1.43	1.065	1200	$ 658.60	$ 53,417.01
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	181.81	115.34	115.34	260.81	376.16	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	451.96%	0.75	0.87	0.66	675	$ 227.90	$ 8,963.30
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	175.75	39.35	154.69	338.12	492.82	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	364.14%	0.85	1.21	0.725	750	$ 300.50	$ 18,520.71
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	168.03	71.52	226.21	472.72	698.94	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	516.44%	0.85	0.89	0.83	900	$ 418.20	$ 19,085.31
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	162.77	40.10	266.31	539.12	805.43	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	394.53%	0.94	0.24	0.875	900	$ 418.20	$ 5,610.76
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	161.44	12.49	278.80	559.78	838.59	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	410.78%	0.94	0.34	0.885	900	$ 418.20	$ 7,989.65
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	181.81	109.83	109.83	248.34	358.16	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	264.64%	0.85	0.25	0.645	675	$ 227.90	$ 2,856.08
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	180.06	19.43	129.25	289.44	418.69	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	309.37%	0.85	1.85	0.685	750	$ 300.50	$ 28,441.49
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	167.89	60.65	189.90	396.53	586.44	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	174.37%	1.19	0.06	0.735	750	$ 300.50	$ 1,201.29
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	167.55	117.06	306.96	639.66	946.62	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	281.48%	1.19	1.80	0.88	900	$ 418.20	$ 53,774.23
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	157.38	80.12	387.09	757.65	1144.73	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	340.38%	1.19	0.55	0.945	975	$ 458.80	$ 17,881.44
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	154.56	33.78	699.67	1344.91	2044.59	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	607.95%	1.19	0.22	1.175	1200	$ 658.60	$ 10,201.65
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	153.47	0.00	699.67	1335.42	2035.09	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	605.13%	1.19	1.23	1.17	1200	$ 658.60	$ 58,042.30
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	147.57	469.73	1169.41	2146.15	3315.56	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	985.87%	1.19	0.96	1.405	1500	$ 1,036.00	$ 71,225.29
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	143.30	0.00	1169.41	2084.06	3253.47	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	967.41%	1.19	0.10	1.395	1500	$ 1,036.00	$ 7,547.54
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	181.81	52.48	52.48	118.66	171.13	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	372.81%	0.65	1.13	0.49	525	$ 110.50	$ 4,855.63
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	174.03	0.00	52.48	113.58	166.05	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	361.75%	0.65	0.27	0.485	525	$ 110.50	$ 1,176.59
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	172.26	29.97	82.45	176.63	259.08	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	126.91%	0.94	1.85	0.57	600	$ 148.70	$ 15,540.00
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.25	161.22	114.85	197.30	395.59	592.88	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	290.42%	0.94	0.54	0.78	825	$ 348.60	$ 10,703.56
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.79	158.26	30.39	227.69	448.15	675.84	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	200.96%	1.19	1.49	0.775	825	$ 348.60	$ 37,156.30
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.28	150.71	106.87	334.55	627.06	961.62	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	285.93%	1.19	1.07	0.885	900	$ 418.20	$ 31,922.91
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.35	145.77	218.85	553.41	1003.25	1556.66	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	462.87%	1.19	0.20	1.06	1200	$ 658.60	$ 9,329.66
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.55	144.89	0.00	553.41	997.20	1550.61	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	461.07%	1.19	0.87	1.06	1200	$ 658.60	$ 41,056.29
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.43	141.16	116.88	670.29	1176.71	1847.00	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	549.20%	1.19	0.24	1.13	1200	$ 658.60	$ 11,303.27
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.67	140.16	0.00	670.29	1168.45	1838.74	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	546.74%	1.19	0.60	1.13	1200	$ 658.60	$ 28,145.96
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.27	137.76	0.00	670.29	1148.43	1818.72	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	540.79%	1.19	0.77	1.125	1200	$ 658.60	$ 36,336.22

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	0	0	0	0	0	0	0	0
450	63	56	118	0	0	0	0	0
525	31	0	0	77	77	0	0	55
600	108	71	104	0	0	18	0	105
675	0	0	0	86	70	31	52	0
750	161	112	139	138	0	0	160	0
825	0	0	107	94	115	9	0	137
900	0	167	0	122	38	0	207	76
975	0	45	14	115	0	0	39	0
1050	0	187	112	215	0	0	0	0
1200	0	64	109	215	96	81	104	192
1350	0	0	0	15	0	0	0	0
1500	0	0	0	0	0	0	76	0
1650	0	0	0	17	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions	
Min Slope	0.3 %
Lake Level	75.5 m
Total Basement Q	1.54 m^3/s
Minimum Tc	10 min
Min. dia.	0.3 m

Design Storm	
Frequency	100
Location	Mount Hope
a	2317.4
b	11
c	0.836

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	181.81	2.54	2.54	22.51	25.05	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	12.27%	0.65	0.79		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	181.81	6.56	6.56	58.16	64.73	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	77.77%	0.84	1.25		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.25	173.26	10.82	17.38	146.74	164.12	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	80.39%	1.06	1.70		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.94	162.94	25.05	44.97	357.09	402.07	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	119.55%	1.19	0.77	0.64	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.71	158.70	4.35	49.33	381.48	430.81	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	128.10%	1.19	1.49	0.655	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	181.81	10.08	10.08	89.29	99.37	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	216.48%	0.65	1.43	0.4	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	181.81	18.56	18.56	164.43	182.99	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	398.65%	0.65	1.83	0.505	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	169.56	18.80	37.36	308.70	346.05	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	753.88%	0.65	0.34	0.635	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	181.81	2.27	2.27	20.08	22.34	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	48.67%	0.65	0.27		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	167.49	2.80	42.42	346.25	388.67	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	287.18%	0.85	1.93	0.665	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	156.65	21.25	63.67	486.06	549.73	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	269.28%	0.94	1.06	0.76	825	$ 348.60	$ 20,911.02
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	151.33	13.95	77.62	572.43	650.05	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	193.29%	1.19	0.38	0.765	825	$ 348.60	$ 9,467.13
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	149.51	5.89	83.52	608.51	692.02	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	205.77%	1.19	1.12	0.785	825	$ 348.60	$ 27,971.66
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	144.41	18.11	101.62	715.20	816.83	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	242.88%	1.19	0.64	0.835	900	$ 418.20	$ 19,006.56
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	141.69	21.84	133.54	922.10	1055.64	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	313.89%	1.19	0.15	0.915	975	$ 458.80	$ 5,006.02
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	141.05	0.26	133.80	919.72	1053.52	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	313.26%	1.19	0.06	0.915	975	$ 458.80	$ 1,835.51
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	140.82	0.00	133.80	918.21	1052.01	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	312.81%	1.19	0.13	0.915	975	$ 458.80	$ 4,173.90
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	140.30	0.00	133.80	914.79	1048.59	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	381.87%	0.97	1.10	0.985	1050	$ 525.50	$ 33,652.60
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	135.95	0.00	133.80	886.44	1020.23	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	303.36%	1.19	0.15	0.905	975	$ 458.80	$ 4,908.37
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	135.38	0.00	133.80	882.72	1016.51	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	302.26%	1.19	2.13	0.905	975	$ 458.80	$ 69,863.45
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	181.81	6.64	6.64	58.86	65.50	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	142.70%	0.65	1.53	0.345	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	171.42	14.59	21.24	177.40	198.63	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	432.72%	0.65	1.47	0.52	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	162.58	13.11	34.35	272.16	306.51	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	226.47%	0.85	1.62	0.61	675	$ 227.90	$ 18,801.19
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	153.96	21.90	56.25	422.06	478.31	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	234.29%	0.94	1.90	0.72	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	145.03	26.25	82.50	583.09	665.59	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	326.03%	0.94	0.25	0.815	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	181.81	7.06	7.06	62.58	69.64	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	83.68%	0.85	1.15		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.15	173.90	13.41	20.47	173.47	193.93	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	143.30%	0.85	0.91	0.515	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.06	168.12	13.41	33.88	277.56	311.44	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	230.12%	0.85	1.11	0.615	675	$ 227.90	$ 12,874.17
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	143.93	13.26	129.64	909.34	1038.98	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	308.94%	1.19	0.18	0.91	975	$ 458.80	$ 5,943.45
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	143.15	2.53	132.17	922.03	1054.20	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	313.46%	1.19	1.38	0.915	975	$ 458.80	$ 45,303.74
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	137.48	19.82	151.99	1018.33	1170.32	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	347.99%	1.19	1.53	0.955	975	$ 458.80	$ 50,004.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	181.81	13.09	13.09	116.01	129.10	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	281.25%	0.65	1.97	0.44	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	168.68	21.58	34.67	285.00	319.67	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	384.09%	0.75	0.72	0.62	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	164.37	8.98	43.65	349.68	393.33	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	290.63%	0.85	0.96	0.67	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	159.00	14.46	58.11	450.26	508.37	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	375.63%	0.85	1.84	0.735	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	181.81	41.20	41.20	365.09	406.30	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1439.30%	0.58	1.63	0.675	750	$ 300.50	$ 16,949.09
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	170.77	21.45	62.65	521.40	584.05	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1272.36%	0.65	1.93	0.775	825	$ 348.60	$ 26,150.98
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	159.50	12.21	74.87	581.95	656.82	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	789.18%	0.75	0.77	0.81	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	155.44	0.00	74.87	567.13	641.99	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	474.36%	0.85	0.92	0.805	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	149.73	27.40	160.38	1170.29	1330.67	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	651.82%	0.94	0.25	1.055	1200	$ 658.60	$ 9,464.83
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	148.54	4.76	165.14	1195.44	1360.58	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	404.56%	1.19	1.23	1.01	1050	$ 525.50	$ 45,996.69
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	143.08	17.59	182.73	1274.13	1456.86	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	433.19%	1.19	0.53	1.035	1050	$ 525.50	$ 19,911.47
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	181.81	80.29	80.29	711.38	791.67	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	129.83%	1.38	0.97	0.825	900	$ 418.20	$ 33,457.27
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	175.10	22.03	102.32	873.14	975.46	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	159.97%	1.38	1.21	0.89	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	167.44	42.05	144.37	1178.01	1322.38	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	168.19%	1.47	0.86	0.995	1050	$ 525.50	$ 39,741.65
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	181.81	32.82	32.82	290.78	323.60	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	70.29%	1.41	1.02		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.02	174.76	66.90	99.72	849.29	949.01	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	206.12%	1.29	1.49	0.88	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	162.43	0.00	244.09	1932.16	2176.25	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	145.50%	1.73	0.15	1.2	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	140.85	10.92	437.74	3004.64	3442.38	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	230.15%	1.73	0.16	1.425	1500	$ 1,036.00	$ 17,366.04
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	181.81	13.05	13.05	115.67	128.72	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	95.11%	0.97	1.32	0.455	525	$ 110.50	$ 8,470.50
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.32	172.80	17.75	30.80	259.39	290.19	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	214.42%	0.85	1.37	0.595	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.69	164.38	19.05	49.85	399.36	449.22	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	220.05%	0.94	0.25	0.705	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.94	162.94	0.00	49.85	395.87	445.72	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	218.33%	0.94	1.78	0.7	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.72	153.48	20.25	70.11	524.37	594.47	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	291.20%	0.94	0.66	0.78	825	$ 348.60	$ 13,073.91
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.38	150.25	115.39	185.50	1358.25	1543.75	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	459.03%	1.19	1.34	1.055	1200	$ 658.60	$ 62,957.34
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	181.81	26.69	26.69	236.52	263.21	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	573.41%	0.65	0.81	0.575	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	181.81	19.62	19.62	173.80	193.41	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	142.91%	0.85	0.35	0.515	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	176.17	0.00	46.31	397.59	443.90	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	217.44%	0.94	0.16	0.7	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	175.12	63.40	109.70	936.25	1045.96	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	512.35%	0.94	1.43	0.965	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	181.81	29.44	29.44	260.81	290.25	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	348.74%	0.75	0.87	0.595	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	175.75	10.04	39.48	338.12	377.60	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	279.00%	0.85	1.21	0.66	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	168.03	18.25	57.73	472.72	530.45	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	391.95%	0.85	0.89	0.75	825	$ 348.60	$ 15,908.99
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	162.77	10.23	67.96	539.12	607.08	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	297.37%	0.94	0.24	0.785	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	161.44	3.19	71.15	559.78	630.93	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	309.06%	0.94	0.34	0.8	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	181.81	28.03	28.03	248.34	276.36	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	204.20%	0.85	0.25	0.585	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	180.06	4.96	32.99	289.44	322.42	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	238.23%	0.85	1.85	0.62	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	167.89	15.48	48.46	396.53	444.99	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	132.32%	1.19	0.06	0.665	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	167.55	29.87	78.34	639.66	718.00	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	213.49%	1.19	1.80	0.795	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	157.38	20.45	98.78	757.65	856.43	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	254.66%	1.19	0.55	0.85	900	$ 418.20	$ 16,299.08
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	154.56	8.62	178.56	1344.91	1523.47	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	453.00%	1.19	0.22	1.05	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	153.47	0.00	178.56	1335.42	1513.97	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	450.17%	1.19	1.23	1.05	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	147.57	119.87	298.43	2146.15	2444.58	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	726.89%	1.19	0.96	1.255	1350	$ 847.00	$ 58,231.49
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	143.30	0.00	298.43	2084.06	2382.49	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	708.43%	1.19	0.10	1.245	1350	$ 847.00	$ 6,170.63
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	181.81	13.39	13.39	118.66	132.05	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	287.66%	0.65	1.13	0.445	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	174.03	0.00	13.39	113.58	126.97	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	276.60%	0.65	0.27	0.44	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	172.26	7.65	21.04	176.63	197.67	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	96.83%	1.07	1.62	0.53	600	$ 148.70	$ 15,540.00
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.02	162.48	29.31	50.35	398.68	449.03	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	219.96%	0.94	0.54	0.705	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	159.47	7.76	58.11	451.58	509.69	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	151.55%	1.19	1.49	0.7	750	$ 300.50	$ 32,029.46
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.06	151.80	27.27	85.38	631.59	716.97	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	213.19%	1.19	1.07	0.795	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.13	146.78	55.85	141.23	1010.21	1151.43	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	342.38%	1.19	0.20	0.945	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	145.88	0.00	141.23	1004.07	1145.30	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	340.55%	1.19	0.87	0.945	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.20	142.10	29.83	171.06	1184.56	1355.62	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	403.09%	1.19	0.24	1.005	1050	$ 525.50	$ 9,018.93
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.44	141.09	0.00	171.06	1176.18	1347.24	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	400.60%	1.19	0.60	1.005	1050	$ 525.50	$ 22,457.79
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.04	138.66	0.00	171.06	1155.87	1326.93	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	394.56%	1.19	0.77	1	1050	$ 525.50	$ 28,992.84

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	0	0	0	55
525	138	71	104	0	77	18	0	0
600	0	0	0	0	70	31	52	105
675	161	112	139	168	0	0	160	0
750	0	0	107	150	115	9	0	137
825	0	167	14	157	38	0	207	76
900	0	45	0	295	0	0	39	0
975	0	187	221	0	0	81	0	77
1050	0	64	0	201	0	0	104	115
1200	0	0	0	29	96	0	0	0
1350	0	0	0	0	0	0	76	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	100
Location	Mount Hope
a	2317.4
b	11
c	0.836

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	181.81	0.66	0.66	22.51	23.17	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	11.35%	0.64	0.81		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	181.81	1.70	1.70	58.16	59.86	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	71.92%	0.83	1.26		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.26	173.14	2.80	4.50	146.64	151.14	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	74.03%	1.04	1.72		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.99	162.69	6.48	11.64	356.56	368.20	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	109.48%	1.19	0.77	0.62	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.75	158.47	1.13	12.76	380.93	393.69	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	117.06%	1.19	1.49	0.635	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	181.81	2.61	2.61	89.29	91.90	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	200.20%	0.65	1.43	0.39	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	181.81	4.80	4.80	164.43	169.24	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	368.68%	0.65	1.83	0.49	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	169.56	4.86	9.67	308.70	318.36	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	693.55%	0.65	0.34	0.62	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	181.81	0.59	0.59	20.08	20.66	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	45.01%	0.64	0.27		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	167.49	0.72	10.98	346.25	357.22	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	263.95%	0.85	1.93	0.645	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	156.65	5.50	16.47	486.06	502.53	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	246.16%	0.94	1.06	0.735	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	151.33	3.61	20.08	572.43	592.52	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	176.18%	1.19	0.38	0.74	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	149.51	1.52	21.61	608.51	630.12	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	187.36%	1.19	1.12	0.755	825	$ 348.60	$ 27,971.66
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	144.41	4.69	26.29	715.20	741.50	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	220.48%	1.19	0.64	0.805	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	141.69	5.65	34.55	922.10	956.65	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	284.46%	1.19	0.15	0.885	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	141.05	0.07	34.62	919.72	954.34	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	283.77%	1.19	0.06	0.885	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	140.82	0.00	34.62	918.21	952.83	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	283.32%	1.19	0.13	0.88	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	140.30	0.00	34.62	914.79	949.41	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	345.75%	0.97	1.10	0.95	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	135.95	0.00	34.62	886.44	921.05	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	273.87%	1.19	0.15	0.87	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	135.38	0.00	34.62	882.72	917.33	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	272.77%	1.19	2.13	0.87	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	181.81	1.72	1.72	58.86	60.58	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	131.97%	0.65	1.53	0.335	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	171.42	3.78	5.49	177.40	182.89	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	398.43%	0.65	1.47	0.5	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	162.58	3.39	8.89	272.16	281.04	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	207.66%	0.85	1.62	0.59	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	153.96	5.67	14.55	422.06	436.61	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	213.87%	0.94	1.90	0.695	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	145.03	6.79	21.35	583.09	604.43	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	296.08%	0.94	0.25	0.785	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	181.81	1.83	1.83	62.58	64.41	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	77.39%	0.84	1.16		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.16	173.81	3.47	5.30	173.37	178.67	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	132.02%	0.85	0.91	0.5	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	168.03	3.47	8.77	277.42	286.18	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	211.46%	0.85	1.11	0.595	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	143.93	3.43	33.54	909.34	942.88	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	280.36%	1.19	0.18	0.88	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	143.15	0.65	34.20	922.03	956.23	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	284.33%	1.19	1.38	0.885	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	137.48	5.13	39.32	1018.33	1057.66	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	314.49%	1.19	1.53	0.915	975	$ 458.80	$ 50,004.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	181.81	3.39	3.39	116.01	119.40	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	260.10%	0.65	1.97	0.43	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	168.68	5.58	8.97	285.00	293.97	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	353.21%	0.75	0.72	0.6	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	164.37	2.32	11.29	349.68	360.98	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	266.72%	0.85	0.96	0.65	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	159.00	3.74	15.03	450.26	465.29	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	343.80%	0.85	1.84	0.71	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	181.81	10.66	10.66	365.09	375.75	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1331.10%	0.58	1.63	0.655	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	170.77	5.55	16.21	521.40	537.61	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1171.19%	0.65	1.93	0.75	825	$ 348.60	$ 26,150.98
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	159.50	3.16	19.37	581.95	601.32	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	722.50%	0.75	0.77	0.785	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	155.44	0.00	19.37	567.13	586.50	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	433.36%	0.85	0.92	0.775	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	149.73	7.09	41.50	1170.29	1211.79	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	593.58%	0.94	0.25	1.02	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	148.54	1.23	42.73	1195.44	1238.17	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	368.17%	1.19	1.23	0.975	1050	$ 525.50	$ 45,996.69
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	143.08	4.55	47.28	1274.13	1321.41	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	392.92%	1.19	0.53	0.995	1050	$ 525.50	$ 19,911.47
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	181.81	20.77	20.77	711.38	732.16	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	120.07%	1.38	0.97	0.8	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	175.10	5.70	26.47	873.14	899.61	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	147.53%	1.38	1.21	0.865	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	167.44	10.88	37.35	1178.01	1215.37	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	154.58%	1.47	0.86	0.965	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	181.81	8.49	8.49	290.78	299.28	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	65.00%	1.39	1.03		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.03	174.65	17.31	25.80	848.75	874.55	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	189.95%	1.29	1.49	0.855	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	162.43	0.00	63.15	1932.16	1995.31	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	133.41%	1.73	0.15	1.165	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	140.85	2.83	113.26	3004.64	3117.90	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	208.46%	1.73	0.16	1.375	1500	$ 1,036.00	$ 17,366.04
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	181.81	3.38	3.38	115.67	119.05	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	87.96%	0.97	1.32		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.32	172.76	4.59	7.97	259.34	267.31	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	197.51%	0.85	1.37	0.58	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.70	164.35	4.93	12.90	399.29	412.19	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	201.91%	0.94	0.25	0.68	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.95	162.91	0.00	12.90	395.80	408.69	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	200.20%	0.94	1.78	0.68	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.72	153.45	5.24	18.14	524.28	542.41	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	265.70%	0.94	0.66	0.755	825	$ 348.60	$ 13,073.91
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.39	150.22	29.86	47.99	1358.02	1406.02	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	418.07%	1.19	1.34	1.02	1050	$ 525.50	$ 50,233.96
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	181.81	6.91	6.91	236.52	243.42	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	530.30%	0.65	0.81	0.56	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	181.81	5.08	5.08	173.80	178.87	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	132.17%	0.85	0.35	0.5	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	176.17	0.00	11.98	397.59	409.57	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	200.62%	0.94	0.16	0.68	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	175.12	16.40	28.38	936.25	964.64	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	472.52%	0.94	1.43	0.935	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	181.81	7.62	7.62	260.81	268.43	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	322.52%	0.75	0.87	0.58	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	175.75	2.60	10.21	338.12	348.34	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	257.38%	0.85	1.21	0.64	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	168.03	4.72	14.94	472.72	487.66	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	360.33%	0.85	0.89	0.725	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	162.77	2.65	17.58	539.12	556.70	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	272.69%	0.94	0.24	0.76	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	161.44	0.82	18.41	559.78	578.19	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	283.22%	0.94	0.34	0.77	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	181.81	7.25	7.25	248.34	255.59	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	188.85%	0.85	0.25	0.57	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	180.06	1.28	8.53	289.44	297.97	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	220.17%	0.85	1.85	0.605	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	167.89	4.00	12.54	396.53	409.07	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	121.64%	1.19	0.06	0.645	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	167.55	7.73	20.27	639.66	659.93	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	196.23%	1.19	1.80	0.77	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	157.38	5.29	25.56	757.65	783.20	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	232.88%	1.19	0.55	0.82	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	154.56	2.23	46.20	1344.91	1391.11	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	413.64%	1.19	0.22	1.015	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	153.47	0.00	46.20	1335.42	1381.62	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	410.82%	1.19	1.23	1.015	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	147.57	31.02	77.21	2146.15	2223.36	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	661.11%	1.19	0.96	1.21	1350	$ 847.00	$ 58,231.49
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	143.30	0.00	77.21	2084.06	2161.28	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	642.65%	1.19	0.10	1.2	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	181.81	3.46	3.46	118.66	122.12	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	266.04%	0.65	1.13	0.43	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	174.03	0.00	3.46	113.58	117.04	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	254.98%	0.65	0.27	0.425	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	172.26	1.98	5.44	176.63	182.07	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	89.19%	1.07	1.62		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.03	162.46	7.58	13.03	398.64	411.67	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	201.65%	0.94	0.54	0.68	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	159.46	2.01	15.03	451.54	466.57	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	138.73%	1.19	1.49	0.675	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.06	151.78	7.06	22.09	631.53	653.62	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	194.35%	1.19	1.07	0.765	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.13	146.76	14.45	36.54	1010.12	1046.66	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	311.22%	1.19	0.20	0.915	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	145.87	0.00	36.54	1003.98	1040.52	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	309.40%	1.19	0.87	0.91	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.20	142.09	7.72	44.26	1184.46	1228.72	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	365.36%	1.19	0.24	0.97	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.44	141.08	0.00	44.26	1176.08	1220.34	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	362.86%	1.19	0.60	0.97	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.04	138.64	0.00	44.26	1155.78	1200.03	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	356.83%	1.19	0.77	0.96	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	0	139	0	70	31	52	0
675	161	112	0	224	0	0	160	107
750	0	87	107	94	115	9	46	31
825	0	126	14	237	38	0	200	76
900	0	187	112	215	0	0	0	0
975	0	64	109	76	0	81	0	192
1050	0	0	0	140	96	0	104	0
1200	0	0	0	15	0	0	7	0
1350	0	0	0	0	0	0	69	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	100
Location	Mount Hope
a	2317.4
b	11
c	0.836

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	181.81	0.22	0.22	22.51	22.73	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	11.13%	0.63	0.81		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	181.81	0.56	0.56	58.16	58.72	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	70.55%	0.83	1.27		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.27	173.11	0.92	1.48	146.62	148.10	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	72.55%	1.04	1.73		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.00	162.63	2.14	3.84	356.42	360.26	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	107.12%	1.19	0.77	0.615	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.76	158.41	0.37	4.21	380.78	384.99	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	114.48%	1.19	1.49	0.63	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	181.81	0.86	0.86	89.29	90.15	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	196.40%	0.65	1.43	0.385	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	181.81	1.58	1.58	164.43	166.02	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	361.67%	0.65	1.83	0.485	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	169.56	1.60	3.19	308.70	311.88	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	679.44%	0.65	0.34	0.615	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	181.81	0.19	0.19	20.08	20.27	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	44.16%	0.64	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	167.49	0.24	3.62	346.25	349.87	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	258.52%	0.85	1.93	0.64	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	156.65	1.81	5.43	486.06	491.49	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	240.75%	0.94	1.06	0.725	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	151.33	1.19	6.62	572.43	579.06	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	172.18%	1.19	0.38	0.73	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	149.51	0.50	7.13	608.51	615.63	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	183.06%	1.19	1.12	0.75	825	$ 348.60	$ 27,971.66
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	144.41	1.55	8.67	715.20	723.87	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	215.24%	1.19	0.64	0.795	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	141.69	1.86	11.40	922.10	933.50	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	277.57%	1.19	0.15	0.875	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	141.05	0.02	11.42	919.72	931.14	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	276.87%	1.19	0.06	0.875	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	140.82	0.00	11.42	918.21	929.63	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	276.42%	1.19	0.13	0.875	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	140.30	0.00	11.42	914.79	926.21	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	337.30%	0.97	1.10	0.94	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	135.95	0.00	11.42	886.44	897.85	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	266.97%	1.19	0.15	0.865	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	135.38	0.00	11.42	882.72	894.13	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	265.87%	1.19	2.13	0.86	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	181.81	0.57	0.57	58.86	59.43	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	129.47%	0.65	1.53	0.33	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	171.42	1.25	1.81	177.40	179.21	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	390.41%	0.65	1.47	0.5	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	162.58	1.12	2.93	272.16	275.09	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	203.26%	0.85	1.62	0.585	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	153.96	1.87	4.80	422.06	426.86	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	209.09%	0.94	1.90	0.69	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	145.03	2.24	7.04	583.09	590.13	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	289.07%	0.94	0.25	0.78	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	181.81	0.60	0.60	62.58	63.18	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	75.92%	0.84	1.17		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.17	173.78	1.14	1.75	173.35	175.09	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	129.37%	0.85	0.91	0.495	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	168.01	1.14	2.89	277.38	280.27	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	207.09%	0.85	1.11	0.59	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	143.93	1.13	11.06	909.34	920.40	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	273.68%	1.19	0.18	0.87	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	143.15	0.22	11.28	922.03	933.31	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	277.52%	1.19	1.38	0.875	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	137.48	1.69	12.97	1018.33	1031.30	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	306.65%	1.19	1.53	0.91	975	$ 458.80	$ 50,004.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	181.81	1.12	1.12	116.01	117.13	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	255.16%	0.65	1.97	0.425	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	168.68	1.84	2.96	285.00	287.96	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	345.99%	0.75	0.72	0.595	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	164.37	0.77	3.73	349.68	353.41	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	261.13%	0.85	0.96	0.645	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	159.00	1.23	4.96	450.26	455.22	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	336.36%	0.85	1.84	0.705	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	181.81	3.52	3.52	365.09	368.61	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1305.79%	0.58	1.63	0.655	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	170.77	1.83	5.35	521.40	526.75	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1147.52%	0.65	1.93	0.745	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	159.50	1.04	6.39	581.95	588.34	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	706.90%	0.75	0.77	0.775	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	155.44	0.00	6.39	567.13	573.51	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	423.76%	0.85	0.92	0.77	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	149.73	2.34	13.69	1170.29	1183.98	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	579.96%	0.94	0.25	1.01	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	148.54	0.41	14.09	1195.44	1209.53	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	359.65%	1.19	1.23	0.965	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	143.08	1.50	15.59	1274.13	1289.73	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	383.50%	1.19	0.53	0.99	1050	$ 525.50	$ 19,911.47
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	181.81	6.85	6.85	711.38	718.24	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	117.79%	1.38	0.97	0.795	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	175.10	1.88	8.73	873.14	881.87	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	144.62%	1.38	1.21	0.855	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	167.44	3.59	12.32	1178.01	1190.33	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	151.40%	1.47	0.86	0.96	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	181.81	2.80	2.80	290.78	293.58	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	63.77%	1.38	1.04		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.04	174.62	5.71	8.51	848.61	857.12	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	186.17%	1.29	1.49	0.85	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	162.43	0.00	20.83	1932.16	1952.99	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	130.58%	1.73	0.15	1.155	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	140.85	0.93	37.35	3004.64	3041.99	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	203.39%	1.73	0.16	1.36	1500	$ 1,036.00	$ 17,366.04
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	181.81	1.11	1.11	115.67	116.78	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	86.29%	0.96	1.33		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.33	172.75	1.51	2.63	259.31	261.94	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	193.55%	0.85	1.37	0.575	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.70	164.33	1.63	4.25	399.25	403.50	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	197.65%	0.94	0.25	0.675	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.95	162.89	0.00	4.25	395.76	400.01	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	195.94%	0.94	1.78	0.675	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.73	153.44	1.73	5.98	524.23	530.21	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	259.72%	0.94	0.66	0.75	825	$ 348.60	$ 13,073.91
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.39	150.21	9.85	15.83	1357.90	1373.73	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	408.47%	1.19	1.34	1.01	1050	$ 525.50	$ 50,233.96
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	181.81	2.28	2.28	236.52	238.80	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	520.22%	0.65	0.81	0.555	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	181.81	1.67	1.67	173.80	175.47	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	129.66%	0.85	0.35	0.495	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	176.17	0.00	3.95	397.59	401.54	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	196.69%	0.94	0.16	0.675	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	175.12	5.41	9.36	936.25	945.61	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	463.20%	0.94	1.43	0.93	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	181.81	2.51	2.51	260.81	263.32	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	316.39%	0.75	0.87	0.575	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	175.75	0.86	3.37	338.12	341.49	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	252.32%	0.85	1.21	0.635	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	168.03	1.56	4.93	472.72	477.65	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	352.93%	0.85	0.89	0.72	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	162.77	0.87	5.80	539.12	544.92	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	266.92%	0.94	0.24	0.755	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	161.44	0.27	6.07	559.78	565.85	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	277.18%	0.94	0.34	0.765	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	181.81	2.39	2.39	248.34	250.73	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	185.26%	0.85	0.25	0.565	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	180.06	0.42	2.81	289.44	292.25	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	215.94%	0.85	1.85	0.6	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	167.89	1.32	4.14	396.53	400.67	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	119.14%	1.19	0.06	0.64	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	167.55	2.55	6.68	639.66	646.35	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	192.19%	1.19	1.80	0.765	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	157.38	1.74	8.43	757.65	766.08	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	227.79%	1.19	0.55	0.815	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	154.56	0.74	15.24	1344.91	1360.15	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	404.44%	1.19	0.22	1.01	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	153.47	0.00	15.24	1335.42	1350.65	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	401.61%	1.19	1.23	1.005	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	147.57	10.23	25.47	2146.15	2171.62	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	645.72%	1.19	0.96	1.2	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	143.30	0.00	25.47	2084.06	2109.53	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	627.26%	1.19	0.10	1.19	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	181.81	1.14	1.14	118.66	119.80	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	260.98%	0.65	1.13	0.43	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	174.03	0.00	1.14	113.58	114.72	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	249.92%	0.65	0.27	0.42	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	172.26	0.65	1.80	176.63	178.43	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	87.40%	1.07	1.63		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.03	162.45	2.50	4.30	398.60	402.90	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	197.36%	0.94	0.54	0.675	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	159.44	0.66	4.96	451.49	456.45	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	135.72%	1.19	1.49	0.67	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.07	151.77	2.33	7.29	631.47	638.75	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	189.93%	1.19	1.07	0.76	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.13	146.75	4.77	12.05	1010.02	1022.07	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	303.91%	1.19	0.20	0.905	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	145.86	0.00	12.05	1003.88	1015.93	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	302.08%	1.19	0.87	0.905	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.21	142.07	2.55	14.60	1184.35	1198.94	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	356.50%	1.19	0.24	0.96	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.45	141.07	0.00	14.60	1175.97	1190.57	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	354.01%	1.19	0.60	0.96	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.05	138.63	0.00	14.60	1155.67	1170.27	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	347.97%	1.19	0.77	0.955	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	0	139	33	70	31	52	0
675	161	112	0	191	0	0	160	107
750	0	87	107	169	115	9	46	31
825	0	126	14	162	38	0	200	76
900	0	187	112	215	0	0	0	0
975	0	64	109	163	0	81	0	192
1050	0	0	0	52	96	0	104	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74	m
Total Basement Q	0.00	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	100
Location	Mount Hope
a	2317.4
b	11
c	0.836

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	181.81	0.00	0.00	22.51	22.51	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	11.03%	0.63	0.81		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	181.81	0.00	0.00	58.16	58.16	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	69.88%	0.82	1.27		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.27	173.10	0.00	0.00	146.60	146.60	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	71.81%	1.04	1.73		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.00	162.59	0.00	0.00	356.35	356.35	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	105.96%	1.19	0.77	0.61	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.77	158.38	0.00	0.00	380.71	380.71	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	113.20%	1.19	1.49	0.625	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	181.81	0.00	0.00	89.29	89.29	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	194.52%	0.65	1.43	0.385	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	181.81	0.00	0.00	164.43	164.43	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	358.22%	0.65	1.83	0.485	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	169.56	0.00	0.00	308.70	308.70	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	672.50%	0.65	0.34	0.61	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	181.81	0.00	0.00	20.08	20.08	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	43.73%	0.64	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	167.49	0.00	0.00	346.25	346.25	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	255.84%	0.85	1.93	0.64	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	156.65	0.00	0.00	486.06	486.06	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	238.09%	0.94	1.06	0.725	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	151.33	0.00	0.00	572.43	572.43	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	170.21%	1.19	0.38	0.73	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	149.51	0.00	0.00	608.51	608.51	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	180.94%	1.19	1.12	0.745	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	144.41	0.00	0.00	715.20	715.20	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	212.66%	1.19	0.64	0.795	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	141.69	0.00	0.00	922.10	922.10	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	274.18%	1.19	0.15	0.87	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	141.05	0.00	0.00	919.72	919.72	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	273.48%	1.19	0.06	0.87	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	140.82	0.00	0.00	918.21	918.21	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	273.03%	1.19	0.13	0.87	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	140.30	0.00	0.00	914.79	914.79	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	333.14%	0.97	1.10	0.935	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	135.95	0.00	0.00	886.44	886.44	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	263.58%	1.19	0.15	0.86	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	135.38	0.00	0.00	882.72	882.72	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	262.47%	1.19	2.13	0.855	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	181.81	0.00	0.00	58.86	58.86	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	128.23%	0.65	1.53	0.33	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	171.42	0.00	0.00	177.40	177.40	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	386.46%	0.65	1.47	0.495	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	162.58	0.00	0.00	272.16	272.16	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	201.09%	0.85	1.62	0.585	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	153.96	0.00	0.00	422.06	422.06	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	206.74%	0.94	1.90	0.685	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	145.03	0.00	0.00	583.09	583.09	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	285.62%	0.94	0.25	0.775	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	181.81	0.00	0.00	62.58	62.58	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	75.19%	0.84	1.17		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.17	173.77	0.00	0.00	173.33	173.33	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	128.07%	0.85	0.91	0.49	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	168.00	0.00	0.00	277.36	277.36	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	204.94%	0.85	1.11	0.585	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	143.93	0.00	0.00	909.34	909.34	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	270.39%	1.19	0.18	0.865	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	143.15	0.00	0.00	922.03	922.03	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	274.16%	1.19	1.38	0.87	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	137.48	0.00	0.00	1018.33	1018.33	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	302.80%	1.19	1.53	0.905	975	$ 458.80	$ 50,004.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	181.81	0.00	0.00	116.01	116.01	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	252.72%	0.65	1.97	0.425	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	168.68	0.00	0.00	285.00	285.00	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	342.43%	0.75	0.72	0.595	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	164.37	0.00	0.00	349.68	349.68	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	258.38%	0.85	0.96	0.64	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	159.00	0.00	0.00	450.26	450.26	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	332.69%	0.85	1.84	0.705	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	181.81	0.00	0.00	365.09	365.09	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1293.33%	0.58	1.63	0.65	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	170.77	0.00	0.00	521.40	521.40	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1135.87%	0.65	1.93	0.745	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	159.50	0.00	0.00	581.95	581.95	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	699.23%	0.75	0.77	0.775	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	155.44	0.00	0.00	567.13	567.13	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	419.04%	0.85	0.92	0.765	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	149.73	0.00	0.00	1170.29	1170.29	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	573.26%	0.94	0.25	1.005	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	148.54	0.00	0.00	1195.44	1195.44	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	355.46%	1.19	1.23	0.96	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	143.08	0.00	0.00	1274.13	1274.13	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	378.86%	1.19	0.53	0.985	1050	$ 525.50	$ 19,911.47
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	181.81	0.00	0.00	711.38	711.38	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	116.66%	1.38	0.97	0.79	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	175.10	0.00	0.00	873.14	873.14	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	143.19%	1.38	1.21	0.855	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	167.44	0.00	0.00	1178.01	1178.01	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	149.83%	1.47	0.86	0.955	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	181.81	0.00	0.00	290.78	290.78	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	63.16%	1.38	1.04		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.04	174.61	0.00	0.00	848.54	848.54	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	184.30%	1.29	1.49	0.845	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	162.43	0.00	0.00	1932.16	1932.16	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	129.18%	1.73	0.15	1.15	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	140.85	0.00	0.00	3004.64	3004.64	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	200.89%	1.73	0.16	1.355	1500	$ 1,036.00	$ 17,366.04
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	181.81	0.00	0.00	115.67	115.67	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	85.47%	0.96	1.33		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.33	172.74	0.00	0.00	259.30	259.30	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	191.59%	0.85	1.37	0.57	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.70	164.32	0.00	0.00	399.23	399.23	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	195.56%	0.94	0.25	0.67	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.95	162.89	0.00	0.00	395.73	395.73	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	193.85%	0.94	1.78	0.67	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.73	153.43	0.00	0.00	524.20	524.20	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	256.78%	0.94	0.66	0.745	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.39	150.20	0.00	0.00	1357.84	1357.84	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	403.75%	1.19	1.34	1.005	1050	$ 525.50	$ 50,233.96
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	181.81	0.00	0.00	236.52	236.52	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	515.25%	0.65	0.81	0.555	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	181.81	0.00	0.00	173.80	173.80	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	128.42%	0.85	0.35	0.495	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	176.17	0.00	0.00	397.59	397.59	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	194.75%	0.94	0.16	0.67	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	175.12	0.00	0.00	936.25	936.25	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	458.62%	0.94	1.43	0.925	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	181.81	0.00	0.00	260.81	260.81	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	313.37%	0.75	0.87	0.575	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	175.75	0.00	0.00	338.12	338.12	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	249.83%	0.85	1.21	0.63	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	168.03	0.00	0.00	472.72	472.72	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	349.29%	0.85	0.89	0.715	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	162.77	0.00	0.00	539.12	539.12	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	264.08%	0.94	0.24	0.75	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	161.44	0.00	0.00	559.78	559.78	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	274.21%	0.94	0.34	0.765	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	181.81	0.00	0.00	248.34	248.34	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	183.49%	0.85	0.25	0.565	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	180.06	0.00	0.00	289.44	289.44	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	213.86%	0.85	1.85	0.595	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	167.89	0.00	0.00	396.53	396.53	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	117.91%	1.19	0.06	0.635	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	167.55	0.00	0.00	639.66	639.66	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	190.20%	1.19	1.80	0.76	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	157.38	0.00	0.00	757.65	757.65	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	225.28%	1.19	0.55	0.81	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	154.56	0.00	0.00	1344.91	1344.91	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	399.90%	1.19	0.22	1.005	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	153.47	0.00	0.00	1335.42	1335.42	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	397.08%	1.19	1.23	1	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	147.57	0.00	0.00	2146.15	2146.15	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	638.15%	1.19	0.96	1.195	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	143.30	0.00	0.00	2084.06	2084.06	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	619.69%	1.19	0.10	1.18	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	181.81	0.00	0.00	118.66	118.66	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	258.49%	0.65	1.13	0.43	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	174.03	0.00	0.00	113.58	113.58	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	247.43%	0.65	0.27	0.42	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	172.26	0.00	0.00	176.63	176.63	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	86.52%	1.07	1.63		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.03	162.44	0.00	0.00	398.57	398.57	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	195.24%	0.94	0.54	0.67	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	159.43	0.00	0.00	451.46	451.46	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	134.24%	1.19	1.49	0.665	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.07	151.76	0.00	0.00	631.43	631.43	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	187.75%	1.19	1.07	0.755	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.14	146.74	0.00	0.00	1009.96	1009.96	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	300.31%	1.19	0.20	0.9	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	145.85	0.00	0.00	1003.83	1003.83	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	298.48%	1.19	0.87	0.9	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.21	142.06	0.00	0.00	1184.28	1184.28	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	352.14%	1.19	0.24	0.955	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.45	141.06	0.00	0.00	1175.91	1175.91	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	349.65%	1.19	0.60	0.955	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.05	138.62	0.00	0.00	1155.61	1155.61	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	343.62%	1.19	0.77	0.95	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	0	139	33	70	31	147	0
675	161	112	0	191	115	9	66	137
750	0	167	107	169	38	0	46	0
825	0	45	14	162	0	0	200	76
900	0	187	112	215	0	0	0	0
975	0	64	109	163	0	81	0	192
1050	0	0	0	52	96	0	104	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	50
Location	Mount Hope
a	1954.8
b	10
c	0.826

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	164.61	9.96	9.96	20.38	30.34	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	14.86%	0.69	0.75		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	164.61	25.72	25.72	52.66	78.38	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	94.17%	0.86	1.22		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.22	156.76	42.38	68.10	132.77	200.87	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	98.39%	1.07	1.67	0.53	600	$ 148.70	$ 16,012.41
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.89	147.22	98.17	176.22	322.66	498.88	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	148.34%	1.19	0.77	0.695	750	$ 300.50	$ 16,439.30
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.66	143.27	17.06	193.28	344.40	537.68	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	159.88%	1.19	1.49	0.71	750	$ 300.50	$ 31,960.44
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	164.61	39.49	39.49	80.84	120.33	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	262.14%	0.65	1.43	0.43	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	164.61	72.72	72.72	148.87	221.60	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	482.75%	0.65	1.83	0.54	600	$ 148.70	$ 10,591.62
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	153.14	73.67	146.39	278.80	425.18	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	926.26%	0.65	0.34	0.69	750	$ 300.50	$ 3,958.53
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	164.61	8.88	8.88	18.18	27.05	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	58.94%	0.68	0.26		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	151.20	10.96	166.23	312.58	478.81	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	353.79%	0.85	1.93	0.72	750	$ 300.50	$ 29,605.65
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	141.13	83.26	249.48	437.90	687.38	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	336.71%	0.94	1.06	0.825	900	$ 418.20	$ 25,086.02
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	136.20	54.68	304.16	515.21	819.37	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	243.64%	1.19	0.38	0.835	900	$ 418.20	$ 11,357.30
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	134.52	23.10	327.26	547.50	874.76	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	260.11%	1.19	1.12	0.855	900	$ 418.20	$ 33,556.37
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	129.82	70.96	398.22	642.92	1041.14	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	309.58%	1.19	0.64	0.91	975	$ 458.80	$ 20,851.76
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	127.31	85.57	523.28	828.52	1351.80	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	401.95%	1.19	0.15	1.005	1050	$ 525.50	$ 5,733.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	126.72	1.01	524.28	826.29	1350.58	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	401.59%	1.19	0.06	1.005	1050	$ 525.50	$ 2,102.36
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	126.51	0.00	524.28	824.90	1349.18	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	401.18%	1.19	0.13	1.005	1050	$ 525.50	$ 4,780.70
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	126.03	0.00	524.28	821.76	1346.04	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	490.19%	0.97	1.10	1.085	1200	$ 658.60	$ 42,176.21
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	122.03	0.00	524.28	795.71	1319.99	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	392.49%	1.19	0.15	0.995	1050	$ 525.50	$ 5,621.94
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	121.51	0.00	524.28	792.29	1316.58	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	391.48%	1.19	2.13	0.995	1050	$ 525.50	$ 80,020.15
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	164.61	26.03	26.03	53.29	79.32	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	172.81%	0.65	1.53	0.37	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	154.87	57.18	83.21	160.27	243.48	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	530.43%	0.65	1.47	0.56	600	$ 148.70	$ 8,538.81
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	146.63	51.39	134.60	245.46	380.06	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	280.83%	0.85	1.62	0.66	675	$ 227.90	$ 18,801.19
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	138.64	85.82	220.42	380.05	600.47	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	294.13%	0.94	1.90	0.785	825	$ 348.60	$ 37,468.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	130.38	102.86	323.28	524.22	847.50	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	415.14%	0.94	0.25	0.89	900	$ 418.20	$ 5,939.15
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	164.61	27.68	27.68	56.66	84.33	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	101.33%	0.75	1.30	0.38	450	$ 101.30	$ 5,932.94
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.30	156.29	52.53	80.21	155.90	236.11	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	174.46%	0.85	0.91	0.555	600	$ 148.70	$ 6,939.85
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.21	150.96	52.54	132.75	249.23	381.98	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	282.24%	0.85	1.11	0.66	675	$ 227.90	$ 12,874.17
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	129.37	51.97	508.01	817.37	1325.37	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	394.09%	1.19	0.18	1	1050	$ 525.50	$ 6,807.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	128.65	9.91	517.91	828.67	1346.58	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	400.40%	1.19	1.38	1.005	1050	$ 525.50	$ 51,889.96
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	123.44	77.67	595.58	914.34	1509.91	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	448.97%	1.19	1.53	1.05	1050	$ 525.50	$ 57,274.36
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	164.61	51.30	51.30	105.03	156.34	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	340.58%	0.65	1.97	0.475	525	$ 110.50	$ 8,481.96
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	152.32	84.55	135.85	257.35	393.20	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	472.44%	0.75	0.72	0.67	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	148.30	35.20	171.06	315.49	486.55	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	359.51%	0.85	0.96	0.725	750	$ 300.50	$ 14,752.34
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	143.30	56.65	227.70	405.82	633.53	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	468.11%	0.85	1.84	0.8	825	$ 348.60	$ 32,665.47
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	164.61	161.46	161.46	330.54	492.00	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1742.91%	0.58	1.63	0.725	750	$ 300.50	$ 16,949.09
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	154.27	84.04	245.50	471.01	716.51	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1560.92%	0.65	1.93	0.835	900	$ 418.20	$ 31,372.17
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	143.78	47.86	293.36	524.57	817.93	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	982.76%	0.75	0.77	0.88	900	$ 418.20	$ 14,558.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	140.01	0.00	293.36	510.82	804.18	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	594.20%	0.85	0.92	0.875	900	$ 418.20	$ 19,646.58
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	134.73	107.38	628.45	1053.01	1681.46	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	823.65%	0.94	0.25	1.15	1200	$ 658.60	$ 9,464.83
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	133.63	18.65	647.10	1075.41	1722.51	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	512.18%	1.19	1.23	1.1	1200	$ 658.60	$ 57,646.85
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	128.59	68.94	716.04	1145.10	1861.14	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	553.40%	1.19	0.53	1.135	1200	$ 658.60	$ 24,954.70
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	164.61	314.61	314.61	644.07	958.67	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	157.22%	1.38	0.97	0.885	900	$ 418.20	$ 33,457.27
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	158.32	86.33	400.94	789.44	1190.38	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	195.22%	1.38	1.21	0.96	975	$ 458.80	$ 45,929.06
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	151.15	164.77	565.71	1063.47	1629.18	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	207.22%	1.47	0.86	1.08	1200	$ 658.60	$ 49,807.51
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	164.61	128.60	128.60	263.27	391.87	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	85.11%	1.46	0.98		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	10.98	158.20	262.16	390.76	768.82	1159.57	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	251.86%	1.29	1.49	0.95	975	$ 458.80	$ 52,770.80
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	146.49	0.00	956.47	1742.60	2699.07	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	180.46%	1.73	0.15	1.305	1350	$ 847.00	$ 12,811.65
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	126.53	42.79	1715.30	2699.32	4414.63	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	295.16%	1.73	0.16	1.565	1650	$ 1,240.60	$ 20,795.66
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	164.61	51.15	51.15	104.72	155.88	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	115.18%	0.85	1.50	0.475	525	$ 110.50	$ 8,470.50
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.50	155.05	69.55	120.70	232.76	353.46	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	261.17%	0.85	1.37	0.645	675	$ 227.90	$ 15,989.75
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.88	147.32	74.65	195.35	357.92	553.27	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	271.01%	0.94	0.25	0.76	825	$ 348.60	$ 4,939.64
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.13	146.00	0.00	195.35	354.71	550.06	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	269.44%	0.94	1.78	0.76	825	$ 348.60	$ 35,028.43
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.90	137.35	79.36	274.71	469.25	743.96	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	364.42%	0.94	0.66	0.85	900	$ 418.20	$ 15,684.19
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.56	134.40	452.17	726.88	1214.96	1941.84	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	577.40%	1.19	1.34	1.15	1200	$ 658.60	$ 62,957.34
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	164.61	104.60	104.60	214.14	318.74	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	694.37%	0.65	0.81	0.62	675	$ 227.90	$ 7,164.02
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	164.61	76.86	76.86	157.35	234.21	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	173.06%	0.85	0.35	0.55	600	$ 148.70	$ 2,668.33
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	159.32	0.00	181.46	359.55	541.01	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	265.01%	0.94	0.16	0.755	825	$ 348.60	$ 3,090.05
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	158.33	248.42	429.88	846.50	1276.38	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	625.22%	0.94	1.43	1.04	1050	$ 525.50	$ 42,621.68
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	164.61	115.34	115.34	236.13	351.48	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	422.30%	0.75	0.87	0.64	675	$ 227.90	$ 8,963.30
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	158.92	39.35	154.69	305.75	460.44	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	340.22%	0.85	1.21	0.71	750	$ 300.50	$ 18,520.71
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	151.71	71.52	226.21	426.81	653.02	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	482.51%	0.85	0.89	0.81	825	$ 348.60	$ 15,908.99
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	146.81	40.10	266.31	486.26	752.57	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	368.64%	0.94	0.24	0.85	900	$ 418.20	$ 5,610.76
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	145.57	12.49	278.80	504.77	783.58	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	383.83%	0.94	0.34	0.865	900	$ 418.20	$ 7,989.65
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	164.61	109.83	109.83	224.84	334.66	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	247.28%	0.85	0.25	0.63	675	$ 227.90	$ 2,856.08
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	162.96	19.43	129.25	261.95	391.21	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	289.06%	0.85	1.85	0.665	675	$ 227.90	$ 21,570.10
65	Bayside	Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	151.58	60.65	189.90	358.01	547.91	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	162.92%	1.19	0.06	0.715	750	$ 300.50	$ 1,201.29
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	151.27	117.06	306.96	577.48	884.44	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	262.99%	1.19	1.80	0.86	900	$ 418.20	$ 53,774.23
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	141.81	80.12	387.09	682.67	1069.76	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	318.09%	1.19	0.55	0.92	975	$ 458.80	$ 17,881.44
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	139.19	33.78	699.67	1211.18	1910.86	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	568.19%	1.19	0.22	1.145	1200	$ 658.60	$ 10,201.65
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	138.18	0.00	699.67	1202.39	1902.07	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	565.57%	1.19	1.23	1.145	1200	$ 658.60	$ 58,042.30
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	132.73	469.73	1169.41	1930.32	3099.73	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	921.69%	1.19	0.96	1.37	1500	$ 1,036.00	$ 71,225.29
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	128.79	0.00	1169.41	1873.08	3042.48	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	904.67%	1.19	0.10	1.36	1500	$ 1,036.00	$ 7,547.54
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	164.61	52.48	52.48	107.43	159.90	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	348.35%	0.65	1.13	0.48	525	$ 110.50	$ 4,855.63
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	157.32	0.00	52.48	102.67	155.14	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	337.98%	0.65	0.27	0.475	525	$ 110.50	$ 1,176.59
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	155.65	29.97	82.45	159.61	242.06	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	118.57%	0.94	1.85	0.56	600	$ 148.70	$ 15,540.00
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.25	145.37	114.85	197.30	356.70	553.99	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	271.37%	0.94	0.54	0.76	825	$ 348.60	$ 10,703.56
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.79	142.62	30.39	227.69	403.87	631.55	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	187.79%	1.19	1.49	0.755	825	$ 348.60	$ 37,156.30
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.28	135.63	106.87	334.55	564.32	898.87	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	267.28%	1.19	1.07	0.865	900	$ 418.20	$ 31,922.91
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.35	131.06	218.85	553.41	902.07	1455.48	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	432.78%	1.19	0.20	1.035	1050	$ 525.50	$ 7,444.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.55	130.26	0.00	553.41	896.50	1449.90	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	431.12%	1.19	0.87	1.03	1050	$ 525.50	$ 32,759.00
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.43	126.82	116.88	670.29	1057.20	1727.49	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	513.66%	1.19	0.24	1.1	1200	$ 658.60	$ 11,303.27
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.67	125.91	0.00	670.29	1049.60	1719.89	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	511.40%	1.19	0.60	1.1	1200	$ 658.60	$ 28,145.96
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.27	123.70	0.00	670.29	1031.20	1701.49	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	505.93%	1.19	0.77	1.095	1200	$ 658.60	$ 36,336.22

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	60	0	0	0	0	0
450	0	56	59	0	0	0	0	0
525	31	0	0	77	77	0	0	55
600	108	71	104	0	0	18	0	105
675	0	0	139	119	70	31	147	0
750	161	112	0	105	0	0	66	0
825	0	0	107	94	115	9	46	137
900	0	167	14	237	38	0	161	76
975	0	45	0	215	0	0	39	0
1050	0	187	221	0	0	81	0	77
1200	0	64	0	215	96	0	104	115
1350	0	0	0	15	0	0	0	0
1500	0	0	0	0	0	0	76	0
1650	0	0	0	17	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75.5	m
Total Basement Q	1.54	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	50
Location	Mount Hope
a	1954.8
b	10
c	0.826

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9 m/s			
Max. Velocity =	3.65 m/s			

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	164.61	2.54	2.54	20.38	22.92	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	11.23%	0.63	0.81		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	164.61	6.56	6.56	52.66	59.22	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	71.16%	0.83	1.27		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.27	156.47	10.82	17.38	132.52	149.90	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	73.43%	1.04	1.72		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.99	146.71	25.05	44.97	321.53	366.51	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	108.98%	1.19	0.77	0.615	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.76	142.79	4.35	49.33	343.24	392.56	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	116.73%	1.19	1.49	0.635	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	164.61	10.08	10.08	80.84	90.92	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	198.07%	0.65	1.43	0.385	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	164.61	18.56	18.56	148.87	167.43	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	364.75%	0.65	1.83	0.485	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	153.14	18.80	37.36	278.80	316.15	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	688.74%	0.65	0.34	0.615	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	164.61	2.27	2.27	18.18	20.44	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	44.53%	0.64	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	151.20	2.80	42.42	312.58	355.01	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	262.31%	0.85	1.93	0.645	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	141.13	21.25	63.67	437.90	501.56	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	245.69%	0.94	1.06	0.73	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	136.20	13.95	77.62	515.21	592.83	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	176.28%	1.19	0.38	0.74	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	134.52	5.89	83.52	547.50	631.02	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	187.63%	1.19	1.12	0.755	825	$ 348.60	$ 27,971.66
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	129.82	18.11	101.62	642.92	744.55	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	221.39%	1.19	0.64	0.805	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	127.31	21.84	133.54	828.52	962.06	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	286.07%	1.19	0.15	0.885	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	126.72	0.26	133.80	826.29	960.09	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	285.48%	1.19	0.06	0.885	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	126.51	0.00	133.80	824.90	958.70	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	285.07%	1.19	0.13	0.885	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	126.03	0.00	133.80	821.76	955.55	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	347.99%	0.97	1.10	0.955	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	122.03	0.00	133.80	795.71	929.50	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	276.38%	1.19	0.15	0.875	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	121.51	0.00	133.80	792.29	926.09	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	275.37%	1.19	2.13	0.875	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	164.61	6.64	6.64	53.29	59.93	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	130.57%	0.65	1.53	0.33	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	154.87	14.59	21.24	160.27	181.51	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	395.42%	0.65	1.47	0.5	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	146.63	13.11	34.35	245.46	279.81	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	206.75%	0.85	1.62	0.59	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	138.64	21.90	56.25	380.05	436.30	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	213.72%	0.94	1.90	0.695	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	130.38	26.25	82.50	524.22	606.72	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	297.20%	0.94	0.25	0.785	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	164.61	7.06	7.06	56.66	63.72	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	76.56%	0.84	1.16		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.16	157.09	13.41	20.47	156.70	177.17	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	130.91%	0.85	0.91	0.495	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	151.70	13.41	33.88	250.45	284.33	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	210.09%	0.85	1.11	0.59	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	129.37	13.26	129.64	817.37	947.01	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	281.59%	1.19	0.18	0.88	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	128.65	2.53	132.17	828.67	960.84	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	285.70%	1.19	1.38	0.885	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	123.44	19.82	151.99	914.34	1066.33	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	317.07%	1.19	1.53	0.92	975	$ 458.80	$ 50,004.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	164.61	13.09	13.09	105.03	118.12	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	257.33%	0.65	1.97	0.425	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	152.32	21.58	34.67	257.35	292.02	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	350.87%	0.75	0.72	0.6	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	148.30	8.98	43.65	315.49	359.15	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	265.37%	0.85	0.96	0.645	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	143.30	14.46	58.11	405.82	463.93	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	342.80%	0.85	1.84	0.71	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	164.61	41.20	41.20	330.54	371.75	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1316.91%	0.58	1.63	0.655	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	154.27	21.45	62.65	471.01	533.66	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1162.58%	0.65	1.93	0.75	825	$ 348.60	$ 26,150.98
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	143.78	12.21	74.87	524.57	599.43	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	720.23%	0.75	0.77	0.785	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	140.01	0.00	74.87	510.82	585.68	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	432.76%	0.85	0.92	0.775	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	134.73	27.40	160.38	1053.01	1213.38	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	594.37%	0.94	0.25	1.02	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	133.63	4.76	165.14	1075.41	1240.55	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	368.87%	1.19	1.23	0.975	1050	$ 525.50	$ 45,996.69
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	128.59	17.59	182.73	1145.10	1327.83	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	394.83%	1.19	0.53	1	1050	$ 525.50	$ 19,911.47
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	164.61	80.29	80.29	644.07	724.35	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	118.79%	1.38	0.97	0.795	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	158.32	22.03	102.32	789.44	891.76	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	146.25%	1.38	1.21	0.86	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	151.15	42.05	144.37	1063.47	1207.84	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	153.63%	1.47	0.86	0.965	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	164.61	32.82	32.82	263.27	296.09	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	64.31%	1.38	1.04		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.04	157.88	66.90	99.72	767.24	866.96	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	188.30%	1.29	1.49	0.85	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	146.49	0.00	244.09	1742.60	1986.69	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	132.83%	1.73	0.15	1.16	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	126.53	10.92	437.74	2699.32	3137.07	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	209.74%	1.73	0.16	1.38	1500	$ 1,036.00	$ 17,366.04
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	164.61	13.05	13.05	104.72	117.78	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	87.02%	0.97	1.32		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.32	156.12	17.75	30.80	234.36	265.16	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	195.92%	0.85	1.37	0.575	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.70	148.27	19.05	49.85	360.23	410.08	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	200.88%	0.94	0.25	0.68	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.95	146.93	0.00	49.85	356.98	406.83	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	199.28%	0.94	1.78	0.675	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.72	138.16	20.25	70.11	472.03	542.13	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	265.56%	0.94	0.66	0.755	825	$ 348.60	$ 13,073.91
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.39	135.17	115.39	185.50	1221.97	1407.47	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	418.51%	1.19	1.34	1.02	1050	$ 525.50	$ 50,233.96
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	164.61	26.69	26.69	214.14	240.83	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	524.65%	0.65	0.81	0.555	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	164.61	19.62	19.62	157.35	176.97	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	130.76%	0.85	0.35	0.495	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	159.32	0.00	46.31	359.55	405.86	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	198.81%	0.94	0.16	0.675	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	158.33	63.40	109.70	846.50	956.21	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	468.39%	0.94	1.43	0.93	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	164.61	29.44	29.44	236.13	265.57	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	319.08%	0.75	0.87	0.575	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	158.92	10.04	39.48	305.75	345.22	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	255.08%	0.85	1.21	0.635	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	151.71	18.25	57.73	426.81	484.54	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	358.02%	0.85	0.89	0.725	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	146.81	10.23	67.96	486.26	554.22	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	271.48%	0.94	0.24	0.76	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	145.57	3.19	71.15	504.77	575.92	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	282.11%	0.94	0.34	0.77	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	164.61	28.03	28.03	224.84	252.86	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	186.84%	0.85	0.25	0.565	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	162.96	4.96	32.99	261.95	294.94	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	217.93%	0.85	1.85	0.6	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	151.58	15.48	48.46	358.01	406.47	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	120.86%	1.19	0.06	0.64	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	151.27	29.87	78.34	577.48	655.81	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	195.00%	1.19	1.80	0.765	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	141.81	20.45	98.78	682.67	781.45	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	232.36%	1.19	0.55	0.82	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	139.19	8.62	178.56	1211.18	1389.74	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	413.23%	1.19	0.22	1.015	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	138.18	0.00	178.56	1202.39	1380.95	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	410.62%	1.19	1.23	1.015	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	132.73	119.87	298.43	1930.32	2228.75	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	662.71%	1.19	0.96	1.215	1350	$ 847.00	$ 58,231.49
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	128.79	0.00	298.43	1873.08	2171.51	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	645.69%	1.19	0.10	1.2	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	164.61	13.39	13.39	107.43	120.82	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	263.20%	0.65	1.13	0.43	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	157.32	0.00	13.39	102.67	116.06	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	252.84%	0.65	0.27	0.425	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	155.65	7.65	21.04	159.61	180.65	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	88.49%	1.07	1.63		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.03	146.52	29.31	50.35	359.52	409.87	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	200.77%	0.94	0.54	0.68	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	143.73	7.76	58.11	406.99	465.10	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	138.30%	1.19	1.49	0.675	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.06	136.62	27.27	85.38	568.43	653.81	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	194.41%	1.19	1.07	0.765	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.13	131.98	55.85	141.23	908.37	1049.60	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	312.10%	1.19	0.20	0.915	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	131.16	0.00	141.23	902.71	1043.94	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	310.41%	1.19	0.87	0.915	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.20	127.67	29.83	171.06	1064.29	1235.35	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	367.33%	1.19	0.24	0.97	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.45	126.75	0.00	171.06	1056.58	1227.64	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	365.03%	1.19	0.60	0.97	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.04	124.51	0.00	171.06	1037.91	1208.97	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	359.48%	1.19	0.77	0.965	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	0	139	0	70	31	52	0
675	161	112	0	224	0	0	160	107
750	0	87	107	94	115	9	46	31
825	0	126	14	237	38	0	200	76
900	0	187	112	215	0	0	0	0
975	0	64	109	76	0	81	0	192
1050	0	0	0	140	96	0	104	0
1200	0	0	0	15	0	0	7	0
1350	0	0	0	0	0	0	69	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	50
Location	Mount Hope
a	1954.8
b	10
c	0.826

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	164.61	0.66	0.66	20.38	21.04	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	10.31%	0.62	0.83		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	164.61	1.70	1.70	52.66	54.36	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	65.31%	0.81	1.29		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.29	156.33	2.80	4.50	132.40	136.90	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	67.06%	1.02	1.76		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.05	146.42	6.48	11.64	320.91	332.54	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	98.88%	1.35	0.68	0.605	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.72	142.97	1.13	12.76	343.68	356.44	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	105.99%	1.19	1.49	0.61	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	164.61	2.61	2.61	80.84	83.45	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	181.80%	0.65	1.43	0.375	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	164.61	4.80	4.80	148.87	153.68	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	334.78%	0.65	1.83	0.47	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	153.14	4.86	9.67	278.80	288.46	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	628.41%	0.65	0.34	0.595	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	164.61	0.59	0.59	18.18	18.76	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	40.87%	0.63	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	151.20	0.72	10.98	312.58	323.56	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	239.08%	0.85	1.93	0.62	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	141.13	5.50	16.47	437.90	454.37	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	222.57%	0.94	1.06	0.705	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	136.20	3.61	20.08	515.21	535.29	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	159.17%	1.19	0.38	0.71	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	134.52	1.52	21.61	547.50	569.11	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	169.22%	1.19	1.12	0.73	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	129.82	4.69	26.29	642.92	669.22	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	198.99%	1.19	0.64	0.775	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	127.31	5.65	34.55	828.52	863.07	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	256.63%	1.19	0.15	0.85	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	126.72	0.07	34.62	826.29	860.91	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	255.99%	1.19	0.06	0.85	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	126.51	0.00	34.62	824.90	859.52	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	255.58%	1.19	0.13	0.85	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	126.03	0.00	34.62	821.76	856.37	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	311.87%	0.97	1.10	0.915	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	122.03	0.00	34.62	795.71	830.33	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	246.89%	1.19	0.15	0.84	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	121.51	0.00	34.62	792.29	826.91	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	245.88%	1.19	2.13	0.835	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	164.61	1.72	1.72	53.29	55.01	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	119.84%	0.65	1.53	0.32	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	154.87	3.78	5.49	160.27	165.77	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	361.13%	0.65	1.47	0.485	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	146.63	3.39	8.89	245.46	254.35	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	187.94%	0.85	1.62	0.57	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	138.64	5.67	14.55	380.05	394.60	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	193.29%	0.94	1.90	0.67	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	130.38	6.79	21.35	524.22	545.56	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	267.24%	0.94	0.25	0.755	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	164.61	1.83	1.83	56.66	58.49	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	70.27%	0.82	1.18		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.18	156.97	3.47	5.30	156.58	161.88	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	119.61%	0.85	0.91	0.48	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.10	151.59	3.47	8.77	250.27	259.04	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	191.40%	0.85	1.11	0.57	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	129.37	3.43	33.54	817.37	850.91	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	253.01%	1.19	0.18	0.845	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	128.65	0.65	34.20	828.67	862.86	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	256.57%	1.19	1.38	0.85	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	123.44	5.13	39.32	914.34	953.66	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	283.57%	1.19	1.53	0.885	900	$ 418.20	$ 45,579.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	164.61	3.39	3.39	105.03	108.42	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	236.19%	0.65	1.97	0.415	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	152.32	5.58	8.97	257.35	266.32	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	319.99%	0.75	0.72	0.58	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	148.30	2.32	11.29	315.49	326.79	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	241.46%	0.85	0.96	0.625	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	143.30	3.74	15.03	405.82	420.86	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	310.97%	0.85	1.84	0.685	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	164.61	10.66	10.66	330.54	341.20	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1208.71%	0.58	1.63	0.635	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	154.27	5.55	16.21	471.01	487.22	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1061.41%	0.65	1.93	0.725	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	143.78	3.16	19.37	524.57	543.94	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	653.55%	0.75	0.77	0.755	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	140.01	0.00	19.37	510.82	530.19	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	391.75%	0.85	0.92	0.75	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	134.73	7.09	41.50	1053.01	1094.50	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	536.13%	0.94	0.25	0.98	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	133.63	1.23	42.73	1075.41	1118.13	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	332.47%	1.19	1.23	0.935	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	128.59	4.55	47.28	1145.10	1192.38	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	354.55%	1.19	0.53	0.96	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	164.61	20.77	20.77	644.07	664.84	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	109.03%	1.38	0.97	0.77	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	158.32	5.70	26.47	789.44	815.91	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	133.81%	1.38	1.21	0.835	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	151.15	10.88	37.35	1063.47	1100.82	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	140.01%	1.47	0.86	0.93	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	164.61	8.49	8.49	263.27	271.76	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	59.03%	1.36	1.06		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.06	157.75	17.31	25.80	766.64	792.44	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	172.12%	1.29	1.49	0.825	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	146.49	0.00	63.15	1742.60	1805.76	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	120.73%	1.73	0.15	1.12	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	126.53	2.83	113.26	2699.32	2812.58	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	188.05%	1.73	0.16	1.325	1350	$ 847.00	$ 14,197.91
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	164.61	3.38	3.38	104.72	108.10	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	79.87%	0.95	1.34		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.34	156.02	4.59	7.97	234.21	242.18	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	178.94%	0.85	1.37	0.56	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.71	148.18	4.93	12.90	360.02	372.92	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	182.67%	0.94	0.25	0.655	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.96	146.85	0.00	12.90	356.77	369.67	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	181.08%	0.94	1.78	0.655	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.74	138.09	5.24	18.14	471.77	489.91	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	239.98%	0.94	0.66	0.725	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.40	135.10	29.86	47.99	1221.34	1269.33	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	377.43%	1.19	1.34	0.98	1050	$ 525.50	$ 50,233.96
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	164.61	6.91	6.91	214.14	221.04	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	481.54%	0.65	0.81	0.54	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	164.61	5.08	5.08	157.35	162.43	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	120.02%	0.85	0.35	0.48	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	159.32	0.00	11.98	359.55	371.53	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	181.99%	0.94	0.16	0.655	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	158.33	16.40	28.38	846.50	874.89	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	428.56%	0.94	1.43	0.9	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	164.61	7.62	7.62	236.13	243.75	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	292.87%	0.75	0.87	0.56	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	158.92	2.60	10.21	305.75	315.96	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	233.46%	0.85	1.21	0.615	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	151.71	4.72	14.94	426.81	441.74	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	326.40%	0.85	0.89	0.7	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	146.81	2.65	17.58	486.26	503.84	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	246.80%	0.94	0.24	0.735	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	145.57	0.82	18.41	504.77	523.18	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	256.28%	0.94	0.34	0.745	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	164.61	7.25	7.25	224.84	232.09	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	171.49%	0.85	0.25	0.55	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	162.96	1.28	8.53	261.95	270.49	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	199.86%	0.85	1.85	0.58	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	151.58	4.00	12.54	358.01	370.55	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	110.18%	1.19	0.06	0.62	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	151.27	7.73	20.27	577.48	597.74	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	177.74%	1.19	1.80	0.74	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	141.81	5.29	25.56	682.67	708.23	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	210.59%	1.19	0.55	0.79	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	139.19	2.23	46.20	1211.18	1257.38	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	373.88%	1.19	0.22	0.98	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	138.18	0.00	46.20	1202.39	1248.59	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	371.26%	1.19	1.23	0.975	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	132.73	31.02	77.21	1930.32	2007.53	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	596.93%	1.19	0.96	1.165	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	128.79	0.00	77.21	1873.08	1950.29	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	579.91%	1.19	0.10	1.155	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	164.61	3.46	3.46	107.43	110.89	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	241.58%	0.65	1.13	0.415	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	157.32	0.00	3.46	102.67	106.13	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	231.21%	0.65	0.27	0.41	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	155.65	1.98	5.44	159.61	165.05	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	80.85%	1.06	1.65		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.05	146.42	7.58	13.03	359.27	372.30	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	182.37%	0.94	0.54	0.655	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.59	143.63	2.01	15.03	406.72	421.75	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	125.41%	1.19	1.49	0.65	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.08	136.53	7.06	22.09	568.07	590.16	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	175.48%	1.19	1.07	0.74	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.15	131.90	14.45	36.54	907.82	944.36	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	280.80%	1.19	0.20	0.88	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.35	131.08	0.00	36.54	902.17	938.71	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	279.12%	1.19	0.87	0.875	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.22	127.60	7.72	44.26	1063.67	1107.92	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	329.44%	1.19	0.24	0.935	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.46	126.67	0.00	44.26	1055.97	1100.23	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	327.15%	1.19	0.60	0.93	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.06	124.43	0.00	44.26	1037.32	1081.58	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	321.60%	1.19	0.77	0.925	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	13	139	33	70	31	147	0
675	161	99	107	191	115	9	66	137
750	0	167	0	169	38	0	207	76
825	0	45	14	162	0	0	39	0
900	0	187	221	215	0	0	0	77
975	0	64	0	201	0	81	0	115
1050	0	0	0	14	96	0	104	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	50
Location	Mount Hope
a	1954.8
b	10
c	0.826

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
Pipe Information					**Hydrology Flow Calculations**											**Hydraulic Calculations**										**Design Calculations**			
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	164.61	0.22	0.22	20.38	20.60	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	10.09%	0.61	0.83		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	164.61	0.56	0.56	52.66	53.22	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	63.94%	0.81	1.30		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.30	156.29	0.92	1.48	132.37	133.86	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	65.57%	1.02	1.76		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.06	146.35	2.14	3.84	320.74	324.58	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	96.51%	1.35	0.67	0.605	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.73	142.91	0.37	4.21	343.53	347.74	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	103.40%	1.19	1.49	0.605	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	164.61	0.86	0.86	80.84	81.70	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	177.99%	0.65	1.43	0.37	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	164.61	1.58	1.58	148.87	150.46	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	327.77%	0.65	1.83	0.465	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	153.14	1.60	3.19	278.80	281.98	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	614.30%	0.65	0.34	0.59	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	164.61	0.19	0.19	18.18	18.37	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	40.02%	0.62	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	151.20	0.24	3.62	312.58	316.20	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	233.64%	0.85	1.93	0.615	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	141.13	1.81	5.43	437.90	443.33	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	217.16%	0.94	1.06	0.7	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	136.20	1.19	6.62	515.21	521.83	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	155.17%	1.19	0.38	0.705	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	134.52	0.50	7.13	547.50	554.63	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	164.92%	1.19	1.12	0.72	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	129.82	1.55	8.67	642.92	651.59	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	193.75%	1.19	0.64	0.765	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	127.31	1.86	11.40	828.52	839.92	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	249.75%	1.19	0.15	0.84	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	126.72	0.02	11.42	826.29	837.71	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	249.09%	1.19	0.06	0.84	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	126.51	0.00	11.42	824.90	836.32	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	248.68%	1.19	0.13	0.84	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	126.03	0.00	11.42	821.76	833.17	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	303.42%	0.97	1.10	0.905	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	122.03	0.00	11.42	795.71	807.12	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	240.00%	1.19	0.15	0.83	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	121.51	0.00	11.42	792.29	803.71	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	238.98%	1.19	2.13	0.83	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	164.61	0.57	0.57	53.29	53.86	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	117.33%	0.65	1.53	0.32	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	154.87	1.25	1.81	160.27	162.09	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	353.11%	0.65	1.47	0.48	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	146.63	1.12	2.93	245.46	248.39	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	183.54%	0.85	1.62	0.565	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	138.64	1.87	4.80	380.05	384.85	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	188.51%	0.94	1.90	0.665	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	130.38	2.24	7.04	524.22	531.26	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	260.23%	0.94	0.25	0.75	825	$ 348.60	$ 4,950.71
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	164.61	0.60	0.60	56.66	57.26	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	68.80%	0.82	1.19		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.19	156.94	1.14	1.75	156.55	158.30	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	116.96%	0.85	0.91	0.475	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.10	151.56	1.14	2.89	250.22	253.11	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	187.02%	0.85	1.11	0.565	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	129.37	1.13	11.06	817.37	828.43	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	246.33%	1.19	0.18	0.835	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	128.65	0.22	11.28	828.67	839.95	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	249.75%	1.19	1.38	0.84	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	123.44	1.69	12.97	914.34	927.30	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	275.73%	1.19	1.53	0.875	900	$ 418.20	$ 45,579.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	164.61	1.12	1.12	105.03	106.15	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	231.24%	0.65	1.97	0.41	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	152.32	1.84	2.96	257.35	260.31	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	312.77%	0.75	0.72	0.575	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	148.30	0.77	3.73	315.49	319.22	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	235.87%	0.85	0.96	0.62	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	143.30	1.23	4.96	405.82	410.78	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	303.52%	0.85	1.84	0.68	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	164.61	3.52	3.52	330.54	334.06	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1183.40%	0.58	1.63	0.63	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	154.27	1.83	5.35	471.01	476.36	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1037.74%	0.65	1.93	0.72	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	143.78	1.04	6.39	524.57	530.96	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	637.96%	0.75	0.77	0.75	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	140.01	0.00	6.39	510.82	517.21	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	382.16%	0.85	0.92	0.74	750	$ 300.50	$ 14,117.17
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	134.73	2.34	13.69	1053.01	1066.69	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	522.51%	0.94	0.25	0.97	975	$ 458.80	$ 6,593.48
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	133.63	0.41	14.09	1075.41	1089.50	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	323.96%	1.19	1.23	0.93	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	128.59	1.50	15.59	1145.10	1160.69	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	345.13%	1.19	0.53	0.95	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	164.61	6.85	6.85	644.07	650.92	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	106.75%	1.38	0.97	0.765	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	158.32	1.88	8.73	789.44	798.17	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	130.90%	1.38	1.21	0.825	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	151.15	3.59	12.32	1063.47	1075.79	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	136.83%	1.47	0.86	0.925	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	164.61	2.80	2.80	263.27	266.07	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	57.79%	1.35	1.06		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.06	157.72	5.71	8.51	766.48	774.99	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	168.33%	1.29	1.49	0.815	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	146.49	0.00	20.83	1742.60	1763.43	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	117.90%	1.73	0.15	1.11	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	126.53	0.93	37.35	2699.32	2736.68	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	182.97%	1.73	0.16	1.31	1350	$ 847.00	$ 14,197.91
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	164.61	1.11	1.11	104.72	105.84	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	78.20%	0.95	1.34		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.34	155.99	1.51	2.63	234.17	236.80	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	174.97%	0.85	1.37	0.555	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.72	148.16	1.63	4.25	359.96	364.21	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	178.41%	0.94	0.25	0.65	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.97	146.82	0.00	4.25	356.71	360.97	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	176.82%	0.94	1.78	0.65	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.75	138.06	1.73	5.98	471.70	477.68	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	233.99%	0.94	0.66	0.72	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.41	135.08	9.85	15.83	1221.15	1236.98	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	367.81%	1.19	1.34	0.975	1050	$ 525.50	$ 50,233.96
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	164.61	2.28	2.28	214.14	216.41	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	471.46%	0.65	0.81	0.535	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	164.61	1.67	1.67	157.35	159.03	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	117.50%	0.85	0.35	0.475	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	159.32	0.00	3.95	359.55	363.50	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	178.06%	0.94	0.16	0.65	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	158.33	5.41	9.36	846.50	855.86	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	419.24%	0.94	1.43	0.895	900	$ 418.20	$ 33,918.91
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	164.61	2.51	2.51	236.13	238.64	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	286.73%	0.75	0.87	0.555	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	158.92	0.86	3.37	305.75	309.12	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	228.40%	0.85	1.21	0.61	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	151.71	1.56	4.93	426.81	431.73	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	319.00%	0.85	0.89	0.69	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	146.81	0.87	5.80	486.26	492.06	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	241.03%	0.94	0.24	0.725	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	145.57	0.27	6.07	504.77	510.84	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	250.23%	0.94	0.34	0.735	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	164.61	2.39	2.39	224.84	227.23	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	167.90%	0.85	0.25	0.545	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	162.96	0.42	2.81	261.95	264.77	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	195.63%	0.85	1.85	0.575	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	151.58	1.32	4.14	358.01	362.14	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	107.68%	1.19	0.06	0.615	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	151.27	2.55	6.68	577.48	584.16	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	173.70%	1.19	1.80	0.735	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	141.81	1.74	8.43	682.67	691.10	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	205.50%	1.19	0.55	0.785	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	139.19	0.74	15.24	1211.18	1226.42	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	364.67%	1.19	0.22	0.97	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	138.18	0.00	15.24	1202.39	1217.63	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	362.06%	1.19	1.23	0.965	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	132.73	10.23	25.47	1930.32	1955.79	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	581.55%	1.19	0.96	1.155	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	128.79	0.00	25.47	1873.08	1898.54	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	564.53%	1.19	0.10	1.14	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	164.61	1.14	1.14	107.43	108.57	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	236.52%	0.65	1.13	0.415	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	157.32	0.00	1.14	102.67	103.81	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	226.15%	0.65	0.27	0.405	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	155.65	0.65	1.80	159.61	161.40	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	79.06%	1.05	1.65		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.05	146.39	2.50	4.30	359.20	363.49	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	178.05%	0.94	0.54	0.65	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.59	143.60	0.66	4.96	406.63	411.59	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	122.39%	1.19	1.49	0.645	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.09	136.50	2.33	7.29	567.96	575.24	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	171.05%	1.19	1.07	0.73	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.16	131.88	4.77	12.05	907.65	919.70	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	273.47%	1.19	0.20	0.87	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.36	131.05	0.00	12.05	902.00	914.05	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	271.79%	1.19	0.87	0.87	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.23	127.57	2.55	14.60	1063.48	1078.07	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	320.56%	1.19	0.24	0.925	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.47	126.65	0.00	14.60	1055.78	1070.38	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	318.27%	1.19	0.60	0.92	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.07	124.41	0.00	14.60	1037.14	1051.74	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	312.73%	1.19	0.77	0.915	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	0	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	13	139	33	70	31	147	0
675	161	99	107	191	115	9	66	137
750	0	167	0	216	38	0	207	76
825	0	45	14	230	0	0	39	0
900	0	187	221	100	0	81	0	77
975	0	64	0	215	0	0	104	115
1050	0	0	0	0	96	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions	
Min Slope	0.3 %
Lake Level	74 m
Total Basement Q	0.00 m^3/s
Minimum Tc	10 min
Min. dia.	0.3 m

Design Storm	
Frequency	50
Location	Mount Hope
a	1954.8
b	10
c	0.826

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	164.61	0.00	0.00	20.38	20.38	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	9.98%	0.61	0.84		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	164.61	0.00	0.00	52.66	52.66	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	63.27%	0.81	1.30		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.30	156.27	0.00	0.00	132.36	132.36	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	64.83%	1.01	1.77		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.07	146.31	0.00	0.00	320.66	320.66	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	95.35%	1.36	0.67	0.605	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.74	142.88	0.00	0.00	343.45	343.45	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	102.12%	1.19	1.49	0.605	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	164.61	0.00	0.00	80.84	80.84	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	176.12%	0.65	1.43	0.37	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	164.61	0.00	0.00	148.87	148.87	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	324.32%	0.65	1.83	0.465	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	153.14	0.00	0.00	278.80	278.80	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	607.36%	0.65	0.34	0.59	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	164.61	0.00	0.00	18.18	18.18	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	39.60%	0.62	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	151.20	0.00	0.00	312.58	312.58	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	230.97%	0.85	1.93	0.615	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	141.13	0.00	0.00	437.90	437.90	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	214.50%	0.94	1.06	0.695	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	136.20	0.00	0.00	515.21	515.21	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	153.20%	1.19	0.38	0.7	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	134.52	0.00	0.00	547.50	547.50	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	162.80%	1.19	1.12	0.715	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	129.82	0.00	0.00	642.92	642.92	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	191.17%	1.19	0.64	0.76	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	127.31	0.00	0.00	828.52	828.52	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	246.36%	1.19	0.15	0.835	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	126.72	0.00	0.00	826.29	826.29	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	245.70%	1.19	0.06	0.835	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	126.51	0.00	0.00	824.90	824.90	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	245.28%	1.19	0.13	0.835	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	126.03	0.00	0.00	821.76	821.76	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	299.26%	0.97	1.10	0.9	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	122.03	0.00	0.00	795.71	795.71	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	236.60%	1.19	0.15	0.825	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	121.51	0.00	0.00	792.29	792.29	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	235.59%	1.19	2.13	0.825	900	$ 418.20	$ 63,681.11
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	164.61	0.00	0.00	53.29	53.29	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	116.10%	0.65	1.53	0.315	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	154.87	0.00	0.00	160.27	160.27	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	349.16%	0.65	1.47	0.48	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	146.63	0.00	0.00	245.46	245.46	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	181.37%	0.85	1.62	0.56	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	138.64	0.00	0.00	380.05	380.05	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	186.16%	0.94	1.90	0.66	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	130.38	0.00	0.00	524.22	524.22	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	256.78%	0.94	0.25	0.745	750	$ 300.50	$ 4,267.61
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	164.61	0.00	0.00	56.66	56.66	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	68.08%	0.82	1.19		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.19	156.93	0.00	0.00	156.53	156.53	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	115.66%	0.85	0.91	0.475	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.11	151.55	0.00	0.00	250.20	250.20	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	184.87%	0.85	1.11	0.565	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	129.37	0.00	0.00	817.37	817.37	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	243.04%	1.19	0.18	0.835	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	128.65	0.00	0.00	828.67	828.67	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	246.40%	1.19	1.38	0.835	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	123.44	0.00	0.00	914.34	914.34	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	271.87%	1.19	1.53	0.87	900	$ 418.20	$ 45,579.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	164.61	0.00	0.00	105.03	105.03	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	228.81%	0.65	1.97	0.41	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	152.32	0.00	0.00	257.35	257.35	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	309.21%	0.75	0.72	0.57	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	148.30	0.00	0.00	315.49	315.49	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	233.11%	0.85	0.96	0.615	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	143.30	0.00	0.00	405.82	405.82	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	299.86%	0.85	1.84	0.675	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	164.61	0.00	0.00	330.54	330.54	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1170.94%	0.58	1.63	0.625	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	154.27	0.00	0.00	471.01	471.01	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1026.10%	0.65	1.93	0.715	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	143.78	0.00	0.00	524.57	524.57	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	630.28%	0.75	0.77	0.745	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	140.01	0.00	0.00	510.82	510.82	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	377.44%	0.85	0.92	0.735	750	$ 300.50	$ 14,117.17
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	134.73	0.00	0.00	1053.01	1053.01	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	515.81%	0.94	0.25	0.965	975	$ 458.80	$ 6,593.48
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	133.63	0.00	0.00	1075.41	1075.41	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	319.77%	1.19	1.23	0.925	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	128.59	0.00	0.00	1145.10	1145.10	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	340.49%	1.19	0.53	0.945	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	164.61	0.00	0.00	644.07	644.07	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	105.62%	1.38	0.97	0.76	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	158.32	0.00	0.00	789.44	789.44	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	129.47%	1.38	1.21	0.82	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	151.15	0.00	0.00	1063.47	1063.47	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	135.26%	1.47	0.86	0.92	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	164.61	0.00	0.00	263.27	263.27	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	57.18%	1.35	1.07		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.07	157.70	0.00	0.00	766.40	766.40	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	166.46%	1.29	1.49	0.815	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	146.49	0.00	0.00	1742.60	1742.60	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	116.51%	1.73	0.15	1.105	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	126.53	0.00	0.00	2699.32	2699.32	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	180.47%	1.73	0.16	1.305	1350	$ 847.00	$ 14,197.91
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	164.61	0.00	0.00	104.72	104.72	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	77.38%	0.95	1.35		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.35	155.98	0.00	0.00	234.15	234.15	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	173.01%	0.85	1.37	0.55	600	$ 148.70	$ 10,432.98
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.72	148.15	0.00	0.00	359.93	359.93	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	176.31%	0.94	0.25	0.645	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.97	146.81	0.00	0.00	356.68	356.68	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	174.72%	0.94	1.78	0.645	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.75	138.05	0.00	0.00	471.66	471.66	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	231.04%	0.94	0.66	0.715	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.41	135.07	0.00	0.00	1221.05	1221.05	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	363.08%	1.19	1.34	0.97	975	$ 458.80	$ 43,857.92
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	164.61	0.00	0.00	214.14	214.14	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	466.50%	0.65	0.81	0.535	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	164.61	0.00	0.00	157.35	157.35	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	116.27%	0.85	0.35	0.475	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	159.32	0.00	0.00	359.55	359.55	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	176.12%	0.94	0.16	0.645	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	158.33	0.00	0.00	846.50	846.50	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	414.65%	0.94	1.43	0.89	900	$ 418.20	$ 33,918.91
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	164.61	0.00	0.00	236.13	236.13	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	283.72%	0.75	0.87	0.555	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	158.92	0.00	0.00	305.75	305.75	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	225.91%	0.85	1.21	0.61	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	151.71	0.00	0.00	426.81	426.81	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	315.36%	0.85	0.89	0.69	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	146.81	0.00	0.00	486.26	486.26	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	238.19%	0.94	0.24	0.725	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	145.57	0.00	0.00	504.77	504.77	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	247.26%	0.94	0.34	0.735	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	164.61	0.00	0.00	224.84	224.84	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	166.13%	0.85	0.25	0.545	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	162.96	0.00	0.00	261.95	261.95	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	193.55%	0.85	1.85	0.575	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	151.58	0.00	0.00	358.01	358.01	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	106.45%	1.19	0.06	0.61	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	151.27	0.00	0.00	577.48	577.48	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	171.71%	1.19	1.80	0.73	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	141.81	0.00	0.00	682.67	682.67	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	202.99%	1.19	0.55	0.78	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	139.19	0.00	0.00	1211.18	1211.18	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	360.14%	1.19	0.22	0.965	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	138.18	0.00	0.00	1202.39	1202.39	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	357.53%	1.19	1.23	0.965	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	132.73	0.00	0.00	1930.32	1930.32	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	573.97%	1.19	0.96	1.15	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	128.79	0.00	0.00	1873.08	1873.08	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	556.95%	1.19	0.10	1.135	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	164.61	0.00	0.00	107.43	107.43	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	234.03%	0.65	1.13	0.41	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	157.32	0.00	0.00	102.67	102.67	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	223.66%	0.65	0.27	0.405	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	155.65	0.00	0.00	159.61	159.61	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	78.18%	1.05	1.65		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.06	146.37	0.00	0.00	359.16	359.16	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	175.93%	0.94	0.54	0.645	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.60	143.59	0.00	0.00	406.59	406.59	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	120.90%	1.19	1.49	0.64	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.09	136.49	0.00	0.00	567.90	567.90	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	168.86%	1.19	1.07	0.725	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.16	131.86	0.00	0.00	907.56	907.56	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	269.86%	1.19	0.20	0.865	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.36	131.04	0.00	0.00	901.91	901.91	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	268.18%	1.19	0.87	0.865	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.23	127.56	0.00	0.00	1063.37	1063.37	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	316.19%	1.19	0.24	0.92	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.47	126.64	0.00	0.00	1055.68	1055.68	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	313.90%	1.19	0.60	0.915	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.07	124.40	0.00	0.00	1037.04	1037.04	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	308.36%	1.19	0.77	0.91	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	0	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	13	139	33	70	31	147	0
675	161	99	107	191	115	9	66	137
750	0	167	14	251	38	0	207	76
825	0	45	0	295	0	0	39	0
900	0	187	221	0	0	81	0	77
975	0	64	0	215	96	0	104	115
1050	0	0	0	0	0	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	25
Location	Mount Hope
a	1719.5
b	10
c	0.823

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	146.10	9.96	9.96	18.09	28.04	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	13.74%	0.67	0.76		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	146.10	25.72	25.72	46.74	72.46	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	87.06%	0.85	1.23		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.23	139.12	42.38	68.10	117.83	185.93	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	91.08%	1.07	1.67		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.90	130.71	98.17	176.22	286.47	462.69	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	137.58%	1.19	0.77	0.675	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.66	127.21	17.06	193.28	305.80	499.08	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	148.40%	1.19	1.49	0.695	750	$ 300.50	$ 31,960.44
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	146.10	39.49	39.49	71.75	111.24	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	242.34%	0.65	1.43	0.415	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	146.10	72.72	72.72	132.14	204.86	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	446.28%	0.65	1.83	0.525	600	$ 148.70	$ 10,591.62
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	135.95	73.67	146.39	247.52	393.90	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	858.12%	0.65	0.34	0.67	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	146.10	8.88	8.88	16.13	25.01	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	54.49%	0.67	0.26		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	134.25	10.96	166.23	277.53	443.75	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	327.88%	0.85	1.93	0.7	750	$ 300.50	$ 29,605.65
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	125.33	83.26	249.48	388.88	638.37	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	312.70%	0.94	1.06	0.8	825	$ 348.60	$ 20,911.02
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	120.97	54.68	304.16	457.60	761.76	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	226.51%	1.19	0.38	0.81	825	$ 348.60	$ 9,467.13
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	119.48	23.10	327.26	486.30	813.56	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	241.91%	1.19	1.12	0.83	900	$ 418.20	$ 33,556.37
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	115.32	70.96	398.22	571.13	969.35	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	288.23%	1.19	0.64	0.89	900	$ 418.20	$ 19,006.56
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	113.10	85.57	523.28	736.06	1259.34	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	374.46%	1.19	0.15	0.98	1050	$ 525.50	$ 5,733.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	112.58	1.01	524.28	734.09	1258.37	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	374.17%	1.19	0.06	0.98	1050	$ 525.50	$ 2,102.36
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	112.39	0.00	524.28	732.86	1257.14	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	373.81%	1.19	0.13	0.98	1050	$ 525.50	$ 4,780.70
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	111.97	0.00	524.28	730.08	1254.36	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	456.80%	0.97	1.10	1.055	1200	$ 658.60	$ 42,176.21
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	108.43	0.00	524.28	707.01	1231.30	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	366.12%	1.19	0.15	0.97	975	$ 458.80	$ 4,908.37
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	107.97	0.00	524.28	703.99	1228.28	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	365.22%	1.19	2.13	0.97	975	$ 458.80	$ 69,863.45
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	146.10	26.03	26.03	47.30	73.33	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	159.75%	0.65	1.53	0.355	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	137.49	57.18	83.21	142.29	225.50	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	491.24%	0.65	1.47	0.545	600	$ 148.70	$ 8,538.81
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	130.20	51.39	134.60	217.96	352.56	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	260.50%	0.85	1.62	0.64	675	$ 227.90	$ 18,801.19
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	123.13	85.82	220.42	337.53	557.95	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	273.31%	0.94	1.90	0.76	825	$ 348.60	$ 37,468.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	115.82	102.86	323.28	465.67	788.95	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	386.46%	0.94	0.25	0.865	900	$ 418.20	$ 5,939.15
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	146.10	27.68	27.68	50.29	77.96	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	93.68%	0.86	1.14		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.14	139.61	52.53	80.21	139.26	219.46	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	162.16%	0.85	0.91	0.54	600	$ 148.70	$ 6,939.85
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.05	134.83	52.54	132.75	222.59	355.34	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	262.56%	0.85	1.11	0.645	675	$ 227.90	$ 12,874.17
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	114.93	51.97	508.01	726.11	1234.11	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	366.96%	1.19	0.18	0.97	975	$ 458.80	$ 5,943.45
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	114.29	9.91	517.91	736.16	1254.07	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	372.89%	1.19	1.38	0.98	1050	$ 525.50	$ 51,889.96
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	109.68	77.67	595.58	812.39	1407.96	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	418.65%	1.19	1.53	1.02	1050	$ 525.50	$ 57,274.36
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	146.10	51.30	51.30	93.22	144.53	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	314.85%	0.65	1.97	0.46	525	$ 110.50	$ 8,481.96
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	135.23	84.55	135.85	228.48	364.33	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	437.76%	0.75	0.72	0.65	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	131.68	35.20	171.06	280.13	451.18	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	333.38%	0.85	0.96	0.705	750	$ 300.50	$ 14,752.34
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	127.26	56.65	227.70	360.38	588.08	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	434.53%	0.85	1.84	0.775	825	$ 348.60	$ 32,665.47
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	146.10	161.46	161.46	293.38	454.84	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1611.27%	0.58	1.63	0.705	750	$ 300.50	$ 16,949.09
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	136.95	84.04	245.50	418.15	663.66	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1445.78%	0.65	1.93	0.815	825	$ 348.60	$ 26,150.98
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	127.67	47.86	293.36	465.82	759.19	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	912.18%	0.75	0.77	0.855	900	$ 418.20	$ 14,558.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	124.34	0.00	293.36	453.65	747.02	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	551.97%	0.85	0.92	0.85	900	$ 418.20	$ 19,646.58
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	119.67	107.38	628.45	935.30	1563.75	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	765.99%	0.94	0.25	1.12	1200	$ 658.60	$ 9,464.83
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	118.69	18.65	647.10	955.22	1602.32	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	476.44%	1.19	1.23	1.07	1200	$ 658.60	$ 57,646.85
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	114.23	68.94	716.04	1017.27	1733.31	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	515.39%	1.19	0.53	1.105	1200	$ 658.60	$ 24,954.70
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	146.10	314.61	314.61	571.65	886.26	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	145.34%	1.38	0.97	0.86	900	$ 418.20	$ 33,457.27
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	140.54	86.33	400.94	700.78	1101.72	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	180.68%	1.38	1.21	0.93	975	$ 458.80	$ 45,929.06
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	134.20	164.77	565.71	944.20	1509.91	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	192.05%	1.47	0.86	1.05	1050	$ 525.50	$ 39,741.65
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	146.10	128.60	128.60	233.67	362.27	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	78.68%	1.44	1.00		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.00	140.37	262.16	390.76	682.16	1072.92	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	233.04%	1.29	1.49	0.92	975	$ 458.80	$ 52,770.80
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	130.08	0.00	956.47	1547.34	2503.81	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	167.40%	1.73	0.15	1.265	1350	$ 847.00	$ 12,811.65
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	112.41	42.79	1715.30	2398.13	4113.43	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	275.02%	1.73	0.16	1.525	1650	$ 1,240.60	$ 20,795.66
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	146.10	51.15	51.15	92.95	144.10	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	106.48%	0.85	1.50	0.46	525	$ 110.50	$ 8,470.50
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.50	137.65	69.55	120.70	206.63	327.33	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	241.86%	0.85	1.37	0.625	675	$ 227.90	$ 15,989.75
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.88	130.81	74.65	195.35	317.81	513.16	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	251.37%	0.94	0.25	0.74	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.13	129.64	0.00	195.35	314.97	510.32	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	249.98%	0.94	1.78	0.735	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.90	121.98	79.36	274.71	416.76	691.47	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	338.71%	0.94	0.66	0.825	900	$ 418.20	$ 15,684.19
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.56	119.38	452.17	726.88	1079.16	1806.03	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	537.02%	1.19	1.34	1.12	1200	$ 658.60	$ 62,957.34
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	146.10	104.60	104.60	190.06	294.66	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	641.92%	0.65	0.81	0.6	675	$ 227.90	$ 7,164.02
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	146.10	76.86	76.86	139.66	216.52	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	159.99%	0.85	0.35	0.535	600	$ 148.70	$ 2,668.33
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	141.42	0.00	181.46	319.16	500.63	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	245.23%	0.94	0.16	0.73	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	140.55	248.42	429.88	751.44	1181.32	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	578.66%	0.94	1.43	1.01	1050	$ 525.50	$ 42,621.68
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	146.10	115.34	115.34	209.58	324.93	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	390.41%	0.75	0.87	0.625	675	$ 227.90	$ 8,963.30
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	141.07	39.35	154.69	271.41	426.10	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	314.84%	0.85	1.21	0.69	750	$ 300.50	$ 18,520.71
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	134.69	71.52	226.21	378.93	605.15	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	447.14%	0.85	0.89	0.785	825	$ 348.60	$ 15,908.99
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	130.36	40.10	266.31	431.77	698.08	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	341.95%	0.94	0.24	0.83	900	$ 418.20	$ 5,610.76
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	129.27	12.49	278.80	448.22	727.02	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	356.13%	0.94	0.34	0.84	900	$ 418.20	$ 7,989.65
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	146.10	109.83	109.83	199.56	309.38	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	228.60%	0.85	0.25	0.61	675	$ 227.90	$ 2,856.08
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	144.64	19.43	129.25	232.51	361.76	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	267.30%	0.85	1.85	0.65	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	134.58	60.65	189.90	317.85	507.76	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	150.98%	1.19	0.06	0.695	750	$ 300.50	$ 1,201.29
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	134.30	117.06	306.96	512.71	819.67	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	243.73%	1.19	1.80	0.835	900	$ 418.20	$ 53,774.23
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	125.93	80.12	387.09	606.24	993.33	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	295.36%	1.19	0.55	0.895	900	$ 418.20	$ 16,299.08
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	123.62	33.78	699.67	1075.67	1775.34	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	527.89%	1.19	0.22	1.115	1200	$ 658.60	$ 10,201.65
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	122.72	0.00	699.67	1067.89	1767.56	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	525.58%	1.19	1.23	1.11	1200	$ 658.60	$ 58,042.30
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	117.90	469.73	1169.41	1714.64	2884.04	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	857.56%	1.19	0.96	1.335	1350	$ 847.00	$ 58,231.49
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	114.41	0.00	1169.41	1663.97	2833.38	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	842.50%	1.19	0.10	1.325	1350	$ 847.00	$ 6,170.63
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	146.10	52.48	52.48	95.35	147.82	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	322.04%	0.65	1.13	0.465	525	$ 110.50	$ 4,855.63
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	139.65	0.00	52.48	91.14	143.62	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	312.87%	0.65	0.27	0.46	525	$ 110.50	$ 1,176.59
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	138.18	29.97	82.45	141.69	224.14	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	109.79%	0.94	1.85	0.54	600	$ 148.70	$ 15,540.00
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.25	129.08	114.85	197.30	316.74	514.03	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	251.79%	0.94	0.54	0.74	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.79	126.65	30.39	227.69	358.65	586.33	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	174.34%	1.19	1.49	0.735	750	$ 300.50	$ 32,029.46
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.28	120.46	106.87	334.55	501.22	835.78	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	248.52%	1.19	1.07	0.84	900	$ 418.20	$ 31,922.91
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.35	116.43	218.85	553.41	801.31	1354.72	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	402.82%	1.19	0.20	1.005	1050	$ 525.50	$ 7,444.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.55	115.71	0.00	553.41	796.38	1349.79	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	401.36%	1.19	0.87	1.005	1050	$ 525.50	$ 32,759.00
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.43	112.67	116.88	670.29	939.22	1609.52	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	478.58%	1.19	0.24	1.075	1200	$ 658.60	$ 11,303.27
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.67	111.86	0.00	670.29	932.50	1602.79	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	476.58%	1.19	0.60	1.07	1200	$ 658.60	$ 28,145.96
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.27	109.91	0.00	670.29	916.21	1586.50	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	471.74%	1.19	0.77	1.07	1200	$ 658.60	$ 36,336.22

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	0	0	0	0	0
525	138	0	0	77	77	0	0	55
600	0	71	104	0	0	18	0	105
675	55	13	139	119	70	31	147	0
750	106	99	0	105	115	9	66	137
825	0	87	107	169	0	0	46	0
900	0	126	14	162	38	0	200	76
975	0	163	13	215	0	0	0	0
1050	0	24	208	76	0	81	0	77
1200	0	64	0	140	96	0	104	115
1350	0	0	0	15	0	0	76	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	17	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		Design Storm		Other Hydraulic Restrictions	
Min Slope	0.3 %	Frequency	25	Mannings n =	0.015 dia. < 0.6 m
Lake Level	75.5 m	Location	Mount Hope		0.013 dia. => 0.6 m
Total Basement Q	1.54 m^3/s	a	1719.5	Min.Velocity =	0.9 m/s
Minimum Tc	10 min	b	10	Max. Velocity =	3.65 m/s
Min. dia.	0.3 m	c	0.823		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	146.10	2.54	2.54	18.09	20.63	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	10.11%	0.61	0.83		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	146.10	6.56	6.56	46.74	53.30	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	64.04%	0.81	1.29		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.29	138.75	10.82	17.38	117.51	134.89	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	66.08%	1.02	1.76		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.06	129.97	25.05	44.97	284.84	329.81	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	98.07%	1.35	0.67	0.605	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.73	126.92	4.35	49.33	305.09	354.41	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	105.38%	1.19	1.49	0.61	675	$ 227.90	$ 24,238.88
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	146.10	10.08	10.08	71.75	81.83	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	178.27%	0.65	1.43	0.37	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	146.10	18.56	18.56	132.14	150.69	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	328.29%	0.65	1.83	0.465	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	135.95	18.80	37.36	247.52	284.87	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	620.60%	0.65	0.34	0.595	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	146.10	2.27	2.27	16.13	18.40	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	40.08%	0.62	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	134.25	2.80	42.42	277.53	319.95	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	236.41%	0.85	1.93	0.62	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	125.33	21.25	63.67	388.88	452.55	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	221.68%	0.94	1.06	0.705	750	$ 300.50	$ 18,025.71
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	120.97	13.95	77.62	457.60	535.22	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	159.15%	1.19	0.38	0.71	750	$ 300.50	$ 8,160.85
12	Hamilton Harbour	Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	119.48	5.89	83.52	486.30	569.82	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	169.43%	1.19	1.12	0.73	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	115.32	18.11	101.62	571.13	672.76	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	200.04%	1.19	0.64	0.775	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	113.10	21.84	133.54	736.06	869.60	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	258.57%	1.19	0.15	0.855	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	112.58	0.26	133.80	734.09	867.89	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	258.06%	1.19	0.06	0.85	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	112.39	0.00	133.80	732.86	866.66	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	257.70%	1.19	0.13	0.85	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	111.97	0.00	133.80	730.08	863.87	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	314.60%	0.97	1.10	0.92	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	108.43	0.00	133.80	707.01	840.81	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	250.01%	1.19	0.15	0.84	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	107.97	0.00	133.80	703.99	837.79	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	249.11%	1.19	2.13	0.84	900	$ 418.20	$ 63,681.11
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	146.10	6.64	6.64	47.30	53.94	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	117.52%	0.65	1.53	0.32	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	137.49	14.59	21.24	142.29	163.52	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	356.23%	0.65	1.47	0.48	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	130.20	13.11	34.35	217.96	252.31	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	186.43%	0.85	1.62	0.565	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	123.13	21.90	56.25	337.53	393.78	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	192.89%	0.94	1.90	0.67	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	115.82	26.25	82.50	465.67	548.17	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	268.52%	0.94	0.25	0.755	825	$ 348.60	$ 4,950.71
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	146.10	7.06	7.06	50.29	57.35	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	68.91%	0.82	1.19		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.19	139.32	13.41	20.47	138.97	159.44	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	117.81%	0.85	0.91	0.475	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.10	134.56	13.41	33.88	222.16	256.04	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	189.18%	0.85	1.11	0.57	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	114.93	13.26	129.64	726.11	855.75	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	254.45%	1.19	0.18	0.85	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	114.29	2.53	132.17	736.16	868.33	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	258.19%	1.19	1.38	0.85	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	109.68	19.82	151.99	812.39	964.38	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	286.75%	1.19	1.53	0.885	900	$ 418.20	$ 45,579.71
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	146.10	13.09	13.09	93.22	106.31	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	231.61%	0.65	1.97	0.41	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	135.23	21.58	34.67	228.48	263.15	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	316.18%	0.75	0.72	0.575	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	131.68	8.98	43.65	280.13	323.78	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	239.24%	0.85	0.96	0.62	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	127.26	14.46	58.11	360.38	418.49	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	309.22%	0.85	1.84	0.685	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	146.10	41.20	41.20	293.38	334.58	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1185.26%	0.58	1.63	0.63	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	136.95	21.45	62.65	418.15	480.81	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1047.44%	0.65	1.93	0.72	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	127.67	12.21	74.87	465.82	540.69	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	649.65%	0.75	0.77	0.755	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	124.34	0.00	74.87	453.65	528.52	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	390.52%	0.85	0.92	0.745	750	$ 300.50	$ 14,117.17
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	119.67	27.40	160.38	935.30	1095.68	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	536.71%	0.94	0.25	0.98	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	118.69	4.76	165.14	955.22	1120.36	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	333.14%	1.19	1.23	0.935	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	114.23	17.59	182.73	1017.27	1200.00	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	356.82%	1.19	0.53	0.96	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	146.10	80.29	80.29	571.65	651.94	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	106.92%	1.38	0.97	0.765	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	140.54	22.03	102.32	700.78	803.10	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	131.71%	1.38	1.21	0.83	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	134.20	42.05	144.37	944.20	1088.57	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	138.46%	1.47	0.86	0.925	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	146.10	32.82	32.82	233.67	266.49	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	57.88%	1.35	1.06		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.06	140.01	66.90	99.72	680.42	780.14	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	169.45%	1.29	1.49	0.82	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	130.08	0.00	244.09	1547.34	1791.43	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	119.77%	1.73	0.15	1.115	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	112.41	10.92	437.74	2398.13	2835.87	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	189.60%	1.73	0.16	1.325	1350	$ 847.00	$ 14,197.91
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	146.10	13.05	13.05	92.95	106.00	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	78.32%	0.95	1.34		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.34	138.49	17.75	30.80	207.88	238.69	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	176.36%	0.85	1.37	0.555	600	$ 148.70	$ 10,432.98
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.72	131.55	19.05	49.85	319.61	369.47	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	180.98%	0.94	0.25	0.655	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.97	130.37	0.00	49.85	316.74	366.60	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	179.57%	0.94	1.78	0.65	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.74	122.62	20.25	70.11	418.94	489.05	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	239.56%	0.94	0.66	0.725	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.41	119.98	115.39	185.50	1084.65	1270.14	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	377.67%	1.19	1.34	0.98	1050	$ 525.50	$ 50,233.96
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	146.10	26.69	26.69	190.06	216.75	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	472.20%	0.65	0.81	0.535	600	$ 148.70	$ 4,674.37
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	146.10	19.62	19.62	139.66	159.28	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	117.69%	0.85	0.35	0.475	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	141.42	0.00	46.31	319.16	365.47	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	179.02%	0.94	0.16	0.65	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	140.55	63.40	109.70	751.44	861.14	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	421.82%	0.94	1.43	0.895	900	$ 418.20	$ 33,918.91
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	146.10	29.44	29.44	209.58	239.02	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	287.19%	0.75	0.87	0.555	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	141.07	10.04	39.48	271.41	310.88	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	229.71%	0.85	1.21	0.61	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	134.69	18.25	57.73	378.93	436.66	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	322.65%	0.85	0.89	0.695	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	130.36	10.23	67.96	431.77	499.73	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	244.79%	0.94	0.24	0.73	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	129.27	3.19	71.15	448.22	519.37	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	254.41%	0.94	0.34	0.74	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	146.10	28.03	28.03	199.56	227.59	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	168.16%	0.85	0.25	0.545	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	144.64	4.96	32.99	232.51	265.50	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	196.17%	0.85	1.85	0.575	600	$ 148.70	$ 14,074.04
65	Bayside	Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	134.58	15.48	48.46	317.85	366.31	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	108.92%	1.19	0.06	0.615	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	134.30	29.87	78.34	512.71	591.05	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	175.75%	1.19	1.80	0.74	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	125.93	20.45	98.78	606.24	705.03	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	209.64%	1.19	0.55	0.79	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	123.62	8.62	178.56	1075.67	1254.22	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	372.94%	1.19	0.22	0.98	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	122.72	0.00	178.56	1067.89	1246.44	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	370.63%	1.19	1.23	0.975	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	117.90	119.87	298.43	1714.64	2013.07	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	598.58%	1.19	0.96	1.165	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	114.41	0.00	298.43	1663.97	1962.40	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	583.51%	1.19	0.10	1.155	1200	$ 658.60	$ 4,798.08
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	146.10	13.39	13.39	95.35	108.74	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	236.89%	0.65	1.13	0.415	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	139.65	0.00	13.39	91.14	104.53	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	227.72%	0.65	0.27	0.41	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	138.18	7.65	21.04	141.69	162.73	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	79.71%	1.06	1.65		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.05	129.99	29.31	50.35	318.97	369.32	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	180.91%	0.94	0.54	0.655	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.59	127.53	7.76	58.11	361.12	419.23	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	124.66%	1.19	1.49	0.65	675	$ 227.90	$ 24,291.23
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.09	121.25	27.27	85.38	504.48	589.86	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	175.39%	1.19	1.07	0.74	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.16	117.15	55.85	141.23	806.31	947.54	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	281.75%	1.19	0.20	0.88	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.35	116.42	0.00	141.23	801.31	942.53	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	280.26%	1.19	0.87	0.88	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.23	113.34	29.83	171.06	944.85	1115.90	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	331.81%	1.19	0.24	0.935	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.47	112.52	0.00	171.06	938.03	1109.09	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	329.78%	1.19	0.60	0.935	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.07	110.54	0.00	171.06	921.53	1092.59	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	324.88%	1.19	0.77	0.93	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	0	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	13	139	33	70	31	147	0
675	161	99	107	191	115	9	66	137
750	0	167	0	216	38	0	207	76
825	0	45	14	230	0	0	39	0
900	0	187	221	100	0	81	0	77
975	0	64	0	201	0	0	0	115
1050	0	0	0	14	96	0	104	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	25
Location	Mount Hope
a	1719.5
b	10
c	0.823

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/S)	Total Flow (L/S)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	146.10	0.66	0.66	18.09	18.75	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	9.18%	0.60	0.86		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	146.10	1.70	1.70	46.74	48.44	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	58.20%	0.79	1.32		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.32	138.60	2.80	4.50	117.39	121.88	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	59.70%	1.00	1.80		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.12	129.65	6.48	11.64	284.14	295.78	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	87.95%	1.35	0.68		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.80	126.61	1.13	12.76	304.36	317.12	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	94.29%	1.36	1.31		600	$ 148.70	$ 15,815.36
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	146.10	2.61	2.61	71.75	74.36	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	162.00%	0.65	1.43	0.36	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	146.10	4.80	4.80	132.14	136.94	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	298.32%	0.65	1.83	0.45	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	135.95	4.86	9.67	247.52	257.18	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	560.27%	0.65	0.34	0.57	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	146.10	0.59	0.59	16.13	16.72	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	36.42%	0.61	0.29		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	134.25	0.72	10.98	277.53	288.50	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	213.17%	0.85	1.93	0.595	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	125.33	5.50	16.47	388.88	405.35	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	198.56%	0.94	1.06	0.675	750	$ 300.50	$ 18,025.71
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	120.97	3.61	20.08	457.60	477.68	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	142.04%	1.19	0.38	0.68	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	119.48	1.52	21.61	486.30	507.91	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	151.03%	1.19	1.12	0.695	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	115.32	4.69	26.29	571.13	597.42	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	177.64%	1.19	0.64	0.74	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	113.10	5.65	34.55	736.06	770.61	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	229.14%	1.19	0.15	0.815	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	112.58	0.07	34.62	734.09	768.71	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	228.57%	1.19	0.06	0.815	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	112.39	0.00	34.62	732.86	767.48	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	228.21%	1.19	0.13	0.815	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	111.97	0.00	34.62	730.08	764.69	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	278.48%	0.97	1.10	0.875	900	$ 418.20	$ 26,781.19
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	108.43	0.00	34.62	707.01	741.63	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	220.52%	1.19	0.15	0.805	825	$ 348.60	$ 3,729.42
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	107.97	0.00	34.62	703.99	738.61	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	219.62%	1.19	2.13	0.8	825	$ 348.60	$ 53,082.82
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	146.10	1.72	1.72	47.30	49.02	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	106.79%	0.65	1.53	0.31	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	137.49	3.78	5.49	142.29	147.78	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	321.94%	0.65	1.47	0.465	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	130.20	3.39	8.89	217.96	226.84	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	167.61%	0.85	1.62	0.545	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	123.13	5.67	14.55	337.53	352.08	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	172.47%	0.94	1.90	0.64	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	115.82	6.79	21.35	465.67	487.02	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	238.56%	0.94	0.25	0.725	750	$ 300.50	$ 4,267.61
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	146.10	1.83	1.83	50.29	52.12	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	62.62%	0.80	1.21		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.21	139.19	3.47	5.30	138.84	144.14	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	106.50%	0.85	0.91	0.46	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.13	134.44	3.47	8.77	221.96	230.72	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	170.48%	0.85	1.11	0.55	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	114.93	3.43	33.54	726.11	759.65	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	225.88%	1.19	0.18	0.81	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	114.29	0.65	34.20	736.16	770.36	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	229.06%	1.19	1.38	0.815	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	109.68	5.13	39.32	812.39	851.71	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	253.25%	1.19	1.53	0.845	900	$ 418.20	$ 45,579.71
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	146.10	3.39	3.39	93.22	96.61	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	210.46%	0.65	1.97	0.395	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	135.23	5.58	8.97	228.48	237.45	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	285.30%	0.75	0.72	0.555	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	131.68	2.32	11.29	280.13	291.42	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	215.33%	0.85	0.96	0.6	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	127.26	3.74	15.03	360.38	375.41	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	277.39%	0.85	1.84	0.655	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	146.10	10.66	10.66	293.38	304.04	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1077.06%	0.58	1.63	0.605	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	136.95	5.55	16.21	418.15	434.36	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	946.26%	0.65	1.93	0.695	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	127.67	3.16	19.37	465.82	485.19	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	582.97%	0.75	0.77	0.725	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	124.34	0.00	19.37	453.65	473.02	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	349.51%	0.85	0.92	0.715	750	$ 300.50	$ 14,117.17
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	119.67	7.09	41.50	935.30	976.79	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	478.47%	0.94	0.25	0.94	975	$ 458.80	$ 6,593.48
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	118.69	1.23	42.73	955.22	997.95	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	296.74%	1.19	1.23	0.9	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	114.23	4.55	47.28	1017.27	1064.55	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	316.54%	1.19	0.53	0.92	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	146.10	20.77	20.77	571.65	592.43	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	97.16%	1.57	0.85	0.755	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.85	141.19	5.70	26.47	704.03	730.50	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	119.80%	1.38	1.21	0.8	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.06	134.79	10.88	37.35	948.33	985.69	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	125.37%	1.47	0.86	0.895	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	146.10	8.49	8.49	233.67	242.16	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	52.60%	1.32	1.09		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.09	139.88	17.31	25.80	679.77	705.57	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	153.25%	1.29	1.49	0.79	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.91	130.63	0.00	63.15	1553.87	1617.02	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	108.11%	1.73	0.15	1.075	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	112.41	2.83	113.26	2398.13	2511.39	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	167.91%	1.73	0.16	1.27	1350	$ 847.00	$ 14,197.91
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	146.10	3.38	3.38	92.95	96.33	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	71.17%	0.93	1.37		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.37	138.36	4.59	7.97	207.69	215.66	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	159.35%	0.85	1.37	0.535	600	$ 148.70	$ 10,432.98
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.74	131.44	4.93	12.90	319.34	332.23	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	162.74%	0.94	0.25	0.63	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.99	130.26	0.00	12.90	316.47	329.37	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	161.34%	0.94	1.78	0.625	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.77	122.52	5.24	18.14	418.60	436.74	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	213.93%	0.94	0.66	0.695	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.43	119.89	29.86	47.99	1083.80	1131.79	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	336.54%	1.19	1.34	0.94	975	$ 458.80	$ 43,857.92
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	146.10	6.91	6.91	190.06	196.97	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	429.09%	0.65	0.81	0.515	525	$ 110.50	$ 3,473.56
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	146.10	5.08	5.08	139.66	144.74	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	106.94%	0.85	0.35	0.46	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	141.42	0.00	11.98	319.16	331.15	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	162.21%	0.94	0.16	0.625	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	140.55	16.40	28.38	751.44	779.82	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	381.99%	0.94	1.43	0.865	900	$ 418.20	$ 33,918.91
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	146.10	7.62	7.62	209.58	217.20	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	260.97%	0.75	0.87	0.535	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	141.07	2.60	10.21	271.41	281.62	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	208.09%	0.85	1.21	0.59	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	134.69	4.72	14.94	378.93	393.87	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	291.03%	0.85	0.89	0.67	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	130.36	2.65	17.58	431.77	449.35	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	220.11%	0.94	0.24	0.705	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	129.27	0.82	18.41	448.22	466.63	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	228.57%	0.94	0.34	0.715	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	146.10	7.25	7.25	199.56	206.81	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	152.81%	0.85	0.25	0.525	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	144.64	1.28	8.53	232.51	241.04	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	178.11%	0.85	1.85	0.555	600	$ 148.70	$ 14,074.04
65	Bayside	Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	134.58	4.00	12.54	317.85	330.39	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	98.24%	1.35	0.05	0.605	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	134.33	7.73	20.27	512.84	533.11	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	158.52%	1.19	1.80	0.71	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	125.96	5.29	25.56	606.38	631.94	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	187.91%	1.19	0.55	0.755	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	123.64	2.23	46.20	1075.91	1122.11	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	333.66%	1.19	0.22	0.94	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	122.75	0.00	46.20	1068.13	1114.33	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	331.34%	1.19	1.23	0.935	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	117.92	31.02	77.21	1715.00	1792.22	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	532.91%	1.19	0.96	1.12	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	114.44	0.00	77.21	1664.31	1741.53	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	517.84%	1.19	0.10	1.105	1200	$ 658.60	$ 4,798.08
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	146.10	3.46	3.46	95.35	98.81	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	215.27%	0.65	1.13	0.4	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	139.65	0.00	3.46	91.14	94.60	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	206.10%	0.65	0.27	0.395	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	138.18	1.98	5.44	141.69	147.14	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	72.07%	1.04	1.68		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.08	129.85	7.58	13.03	318.63	331.66	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	162.46%	0.94	0.54	0.625	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.62	127.39	2.01	15.03	360.74	375.78	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	111.74%	1.19	1.49	0.625	675	$ 227.90	$ 24,291.23
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.12	121.13	7.06	22.09	503.98	526.07	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	156.42%	1.19	1.07	0.705	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.19	117.04	14.45	36.54	805.54	842.08	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	250.39%	1.19	0.20	0.845	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.38	116.31	0.00	36.54	800.55	837.09	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	248.91%	1.19	0.87	0.84	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.26	113.24	7.72	44.26	943.98	988.24	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	293.85%	1.19	0.24	0.895	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.50	112.42	0.00	44.26	937.18	981.44	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	291.83%	1.19	0.60	0.89	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.10	110.45	0.00	44.26	920.71	964.97	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	286.93%	1.19	0.77	0.885	900	$ 418.20	$ 23,072.90

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	0	0	77	77	0	0	55
525	138	71	104	0	0	49	13	105
600	161	112	139	33	70	0	196	0
675	0	0	107	285	115	9	50	137
750	0	213	14	157	38	0	161	76
825	0	187	112	295	0	0	39	0
900	0	64	109	76	0	81	0	192
975	0	0	0	140	96	0	104	0
1050	0	0	0	0	0	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	25
Location	Mount Hope
a	1719.5
b	10
c	0.823

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9 m/s			
Max. Velocity =	3.65 m/s			

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	146.10	0.22	0.22	18.09	18.31	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	8.97%	0.59	0.86		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	146.10	0.56	0.56	46.74	47.30	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	56.83%	0.79	1.33		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.33	138.56	0.92	1.48	117.35	118.84	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	58.21%	0.99	1.81		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.14	129.57	2.14	3.84	283.96	287.80	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	85.58%	1.35	0.68		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.82	126.53	0.37	4.21	304.15	308.36	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	91.69%	1.35	1.31		600	$ 148.70	$ 15,815.36
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	146.10	0.86	0.86	71.75	72.61	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	158.19%	0.65	1.43	0.355	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	146.10	1.58	1.58	132.14	133.72	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	291.31%	0.65	1.83	0.445	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	135.95	1.60	3.19	247.52	250.70	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	546.16%	0.65	0.34	0.565	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	146.10	0.19	0.19	16.13	16.33	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	35.57%	0.60	0.29		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	134.25	0.24	3.62	277.53	281.15	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	207.74%	0.85	1.93	0.59	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	125.33	1.81	5.43	388.88	394.31	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	193.15%	0.94	1.06	0.67	675	$ 227.90	$ 13,670.74
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	120.97	1.19	6.62	457.60	464.22	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	138.04%	1.19	0.38	0.675	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	119.48	0.50	7.13	486.30	493.43	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	146.72%	1.19	1.12	0.69	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	115.32	1.55	8.67	571.13	579.80	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	172.40%	1.19	0.64	0.735	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	113.10	1.86	11.40	736.06	747.45	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	222.25%	1.19	0.15	0.805	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	112.58	0.02	11.42	734.09	745.51	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	221.67%	1.19	0.06	0.805	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	112.39	0.00	11.42	732.86	744.28	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	221.31%	1.19	0.13	0.805	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	111.97	0.00	11.42	730.08	741.49	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	270.03%	0.97	1.10	0.865	900	$ 418.20	$ 26,781.19
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	108.43	0.00	11.42	707.01	718.43	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	213.62%	1.19	0.15	0.795	825	$ 348.60	$ 3,729.42
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	107.97	0.00	11.42	703.99	715.41	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	212.72%	1.19	2.13	0.795	825	$ 348.60	$ 53,082.82
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	146.10	0.57	0.57	47.30	47.87	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	104.28%	0.65	1.53	0.305	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	137.49	1.25	1.81	142.29	144.10	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	313.92%	0.65	1.47	0.46	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	130.20	1.12	2.93	217.96	220.89	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	163.21%	0.85	1.62	0.54	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	123.13	1.87	4.80	337.53	342.33	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	167.69%	0.94	1.90	0.635	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	115.82	2.24	7.04	465.67	472.71	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	231.55%	0.94	0.25	0.715	750	$ 300.50	$ 4,267.61
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	146.10	0.60	0.60	50.29	50.89	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	61.15%	0.80	1.22		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.22	139.16	1.14	1.75	138.81	140.55	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	103.85%	0.85	0.91	0.455	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.13	134.41	1.14	2.89	221.90	224.79	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	166.10%	0.85	1.11	0.545	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	114.93	1.13	11.06	726.11	737.17	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	219.19%	1.19	0.18	0.8	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	114.29	0.22	11.28	736.16	747.44	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	222.25%	1.19	1.38	0.805	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	109.68	1.69	12.97	812.39	825.36	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	245.42%	1.19	1.53	0.835	900	$ 418.20	$ 45,579.71
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	146.10	1.12	1.12	93.22	94.34	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	205.52%	0.65	1.97	0.395	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	135.23	1.84	2.96	228.48	231.44	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	278.08%	0.75	0.72	0.55	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	131.68	0.77	3.73	280.13	283.85	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	209.74%	0.85	0.96	0.59	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	127.26	1.23	4.96	360.38	365.34	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	269.94%	0.85	1.84	0.65	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	146.10	3.52	3.52	293.38	296.90	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1051.75%	0.58	1.63	0.6	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	136.95	1.83	5.35	418.15	423.50	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	922.60%	0.65	1.93	0.685	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	127.67	1.04	6.39	465.82	472.21	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	567.37%	0.75	0.77	0.715	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	124.34	0.00	6.39	453.65	460.04	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	339.92%	0.85	0.92	0.71	750	$ 300.50	$ 14,117.17
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	119.67	2.34	13.69	935.30	948.98	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	464.85%	0.94	0.25	0.93	975	$ 458.80	$ 6,593.48
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	118.69	0.41	14.09	955.22	969.31	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	288.22%	1.19	1.23	0.89	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	114.23	1.50	15.59	1017.27	1032.86	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	307.12%	1.19	0.53	0.91	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	146.10	6.85	6.85	571.65	578.50	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	94.87%	1.57	0.85		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.85	141.20	1.88	8.73	704.06	712.79	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	116.90%	1.38	1.21	0.79	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.06	134.80	3.59	12.32	948.37	960.69	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	122.19%	1.47	0.86	0.885	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	146.10	2.80	2.80	233.67	236.47	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	51.36%	1.31	1.09		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.09	139.84	5.71	8.51	679.61	688.12	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	149.46%	1.29	1.49	0.78	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.91	130.63	0.00	20.83	1553.93	1574.76	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	105.29%	1.73	0.15	1.065	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	112.41	0.93	37.35	2398.13	2435.48	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	162.83%	1.73	0.16	1.255	1350	$ 847.00	$ 14,197.91
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	146.10	1.11	1.11	92.95	94.06	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	69.50%	0.93	1.37		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.37	138.32	1.51	2.63	207.64	210.27	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	155.36%	0.85	1.37	0.53	600	$ 148.70	$ 10,432.98
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.75	131.41	1.63	4.25	319.26	323.51	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	158.47%	0.94	0.25	0.62	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.00	130.23	0.00	4.25	316.40	320.65	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	157.07%	0.94	1.78	0.62	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.78	122.50	1.73	5.98	418.51	424.50	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	207.94%	0.94	0.66	0.69	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.44	119.86	9.85	15.83	1083.57	1099.40	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	326.90%	1.19	1.34	0.93	975	$ 458.80	$ 43,857.92
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	146.10	2.28	2.28	190.06	192.34	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	419.01%	0.65	0.81	0.51	525	$ 110.50	$ 3,473.56
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	146.10	1.67	1.67	139.66	141.33	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	104.43%	0.85	0.35	0.455	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	141.42	0.00	3.95	319.16	323.12	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	158.28%	0.94	0.16	0.62	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	140.55	5.41	9.36	751.44	760.80	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	372.67%	0.94	1.43	0.855	900	$ 418.20	$ 33,918.91
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	146.10	2.51	2.51	209.58	212.10	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	254.84%	0.75	0.87	0.53	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	141.07	0.86	3.37	271.41	274.78	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	203.03%	0.85	1.21	0.585	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	134.69	1.56	4.93	378.93	383.86	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	283.63%	0.85	0.89	0.665	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	130.36	0.87	5.80	431.77	437.57	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	214.34%	0.94	0.24	0.695	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	129.27	0.27	6.07	448.22	454.29	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	222.53%	0.94	0.34	0.705	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	146.10	2.39	2.39	199.56	201.95	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	149.22%	0.85	0.25	0.52	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	144.64	0.42	2.81	232.51	235.32	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	173.88%	0.85	1.85	0.55	600	$ 148.70	$ 14,074.04
65	Bayside	Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	134.58	1.32	4.14	317.85	321.99	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	95.74%	1.36	0.05	0.605	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	134.33	2.55	6.68	512.84	519.52	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	154.48%	1.19	1.80	0.705	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	125.96	1.74	8.43	606.39	614.82	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	182.81%	1.19	0.55	0.75	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	123.64	0.74	15.24	1075.92	1091.15	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	324.45%	1.19	0.22	0.93	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	122.75	0.00	15.24	1068.13	1083.37	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	322.14%	1.19	1.23	0.925	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	117.92	10.23	25.47	1715.01	1740.47	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	517.52%	1.19	0.96	1.105	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	114.44	0.00	25.47	1664.32	1689.79	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	502.45%	1.19	0.10	1.095	1200	$ 658.60	$ 4,798.08
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	146.10	1.14	1.14	95.35	96.49	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	210.21%	0.65	1.13	0.395	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	139.65	0.00	1.14	91.14	92.28	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	201.04%	0.65	0.27	0.39	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	138.18	0.65	1.80	141.69	143.49	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	70.29%	1.03	1.69		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.09	129.82	2.50	4.30	318.53	322.83	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	158.14%	0.94	0.54	0.62	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.63	127.36	0.66	4.96	360.64	365.59	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	108.71%	1.19	1.49	0.615	675	$ 227.90	$ 24,291.23
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.12	121.09	2.33	7.29	503.84	511.13	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	151.98%	1.19	1.07	0.7	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.19	117.01	4.77	12.05	805.33	817.38	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	243.04%	1.19	0.20	0.835	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.39	116.28	0.00	12.05	800.34	812.39	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	241.56%	1.19	0.87	0.83	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.27	113.21	2.55	14.60	943.74	958.34	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	284.96%	1.19	0.24	0.885	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.51	112.39	0.00	14.60	936.95	951.54	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	282.94%	1.19	0.60	0.88	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.11	110.42	0.00	14.60	920.49	935.08	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	278.04%	1.19	0.77	0.875	900	$ 418.20	$ 23,072.90

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	71	0	77	77	0	0	55
525	138	0	104	0	0	49	13	105
600	161	112	139	82	70	0	196	0
675	0	87	107	236	115	9	50	137
750	0	126	14	237	38	0	161	76
825	0	187	112	215	0	0	39	0
900	0	64	109	163	0	81	0	192
975	0	0	0	52	96	0	104	0
1050	0	0	0	0	0	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions	
Min Slope	0.3 %
Lake Level	74 m
Total Basement Q	0.00 m^3/s
Minimum Tc	10 min
Min. dia.	0.3 m

Design Storm	
Frequency	25
Location	Mount Hope
a	1719.5
b	10
c	0.823

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	146.10	0.00	0.00	18.09	18.09	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	8.86%	0.59	0.87		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	146.10	0.00	0.00	46.74	46.74	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	56.16%	0.78	1.33		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.33	138.54	0.00	0.00	117.34	117.34	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	57.48%	0.99	1.82		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.15	129.52	0.00	0.00	283.87	283.87	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	84.41%	1.34	0.68		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.83	126.48	0.00	0.00	304.04	304.04	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	90.41%	1.35	1.31		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	146.10	0.00	0.00	71.75	71.75	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	156.31%	0.65	1.43	0.355	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	146.10	0.00	0.00	132.14	132.14	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	287.86%	0.65	1.83	0.445	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	135.95	0.00	0.00	247.52	247.52	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	539.21%	0.65	0.34	0.56	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	146.10	0.00	0.00	16.13	16.13	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	35.14%	0.60	0.29		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	134.25	0.00	0.00	277.53	277.53	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	205.06%	0.85	1.93	0.585	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	125.33	0.00	0.00	388.88	388.88	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	190.49%	0.94	1.06	0.665	675	$ 227.90	$ 13,670.74
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	120.97	0.00	0.00	457.60	457.60	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	136.07%	1.19	0.38	0.67	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	119.48	0.00	0.00	486.30	486.30	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	144.60%	1.19	1.12	0.685	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	115.32	0.00	0.00	571.13	571.13	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	169.82%	1.19	0.64	0.73	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	113.10	0.00	0.00	736.06	736.06	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	218.86%	1.19	0.15	0.8	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	112.58	0.00	0.00	734.09	734.09	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	218.28%	1.19	0.06	0.8	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	112.39	0.00	0.00	732.86	732.86	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	217.91%	1.19	0.13	0.8	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	111.97	0.00	0.00	730.08	730.08	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	265.87%	0.97	1.10	0.86	900	$ 418.20	$ 26,781.19
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	108.43	0.00	0.00	707.01	707.01	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	210.23%	1.19	0.15	0.79	825	$ 348.60	$ 3,729.42
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	107.97	0.00	0.00	703.99	703.99	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	209.33%	1.19	2.13	0.79	825	$ 348.60	$ 53,082.82
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	146.10	0.00	0.00	47.30	47.30	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	103.04%	0.65	1.53	0.305	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	137.49	0.00	0.00	142.29	142.29	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	309.97%	0.65	1.47	0.46	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	130.20	0.00	0.00	217.96	217.96	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	161.05%	0.85	1.62	0.535	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	123.13	0.00	0.00	337.53	337.53	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	165.34%	0.94	1.90	0.63	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	115.82	0.00	0.00	465.67	465.67	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	228.11%	0.94	0.25	0.71	750	$ 300.50	$ 4,267.61
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	146.10	0.00	0.00	50.29	50.29	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	60.42%	0.80	1.22		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.22	139.14	0.00	0.00	138.79	138.79	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	102.55%	0.85	0.91	0.455	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.14	134.39	0.00	0.00	221.88	221.88	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	163.94%	0.85	1.11	0.54	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	114.93	0.00	0.00	726.11	726.11	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	215.91%	1.19	0.18	0.795	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	114.29	0.00	0.00	736.16	736.16	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	218.89%	1.19	1.38	0.8	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	109.68	0.00	0.00	812.39	812.39	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	241.56%	1.19	1.53	0.83	900	$ 418.20	$ 45,579.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	146.10	0.00	0.00	93.22	93.22	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	203.08%	0.65	1.97	0.39	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	135.23	0.00	0.00	228.48	228.48	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	274.53%	0.75	0.72	0.545	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	131.68	0.00	0.00	280.13	280.13	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	206.98%	0.85	0.96	0.59	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	127.26	0.00	0.00	360.38	360.38	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	266.28%	0.85	1.84	0.645	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	146.10	0.00	0.00	293.38	293.38	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1039.29%	0.58	1.63	0.6	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	136.95	0.00	0.00	418.15	418.15	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	910.95%	0.65	1.93	0.685	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	127.67	0.00	0.00	465.82	465.82	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	559.69%	0.75	0.77	0.71	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	124.34	0.00	0.00	453.65	453.65	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	335.20%	0.85	0.92	0.705	750	$ 300.50	$ 14,117.17
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	119.67	0.00	0.00	935.30	935.30	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	458.15%	0.94	0.25	0.925	975	$ 458.80	$ 6,593.48
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	118.69	0.00	0.00	955.22	955.22	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	284.03%	1.19	1.23	0.885	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	114.23	0.00	0.00	1017.27	1017.27	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	302.48%	1.19	0.53	0.905	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	146.10	0.00	0.00	571.65	571.65	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	93.75%	1.57	0.85		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.85	141.20	0.00	0.00	704.06	704.06	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	115.46%	1.38	1.21	0.79	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.06	134.80	0.00	0.00	948.37	948.37	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	120.62%	1.47	0.86	0.88	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	146.10	0.00	0.00	233.67	233.67	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	50.75%	1.31	1.10		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.10	139.83	0.00	0.00	679.52	679.52	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	147.59%	1.29	1.49	0.78	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.91	130.63	0.00	0.00	1553.93	1553.93	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	103.89%	1.73	0.15	1.06	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	112.41	0.00	0.00	2398.13	2398.13	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	160.34%	1.73	0.16	1.245	1350	$ 847.00	$ 14,197.91
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	146.10	0.00	0.00	92.95	92.95	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	68.68%	0.93	1.38		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.38	138.30	0.00	0.00	207.61	207.61	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	153.40%	0.85	1.37	0.525	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.75	131.39	0.00	0.00	319.22	319.22	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	156.37%	0.94	0.25	0.62	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.00	130.21	0.00	0.00	316.36	316.36	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	154.97%	0.94	1.78	0.615	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.78	122.48	0.00	0.00	418.47	418.47	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	204.98%	0.94	0.66	0.685	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.44	119.85	0.00	0.00	1083.45	1083.45	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	322.16%	1.19	1.34	0.925	975	$ 458.80	$ 43,857.92
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	146.10	0.00	0.00	190.06	190.06	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	414.05%	0.65	0.81	0.51	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	146.10	0.00	0.00	139.66	139.66	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	103.19%	0.85	0.35	0.455	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	141.42	0.00	0.00	319.16	319.16	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	156.34%	0.94	0.16	0.62	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	140.55	0.00	0.00	751.44	751.44	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	368.09%	0.94	1.43	0.85	900	$ 418.20	$ 33,918.91
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	146.10	0.00	0.00	209.58	209.58	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	251.82%	0.75	0.87	0.53	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	141.07	0.00	0.00	271.41	271.41	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	200.54%	0.85	1.21	0.58	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	134.69	0.00	0.00	378.93	378.93	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	279.99%	0.85	0.89	0.66	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	130.36	0.00	0.00	431.77	431.77	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	211.50%	0.94	0.24	0.69	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	129.27	0.00	0.00	448.22	448.22	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	219.56%	0.94	0.34	0.7	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	146.10	0.00	0.00	199.56	199.56	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	147.45%	0.85	0.25	0.52	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	144.64	0.00	0.00	232.51	232.51	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	171.80%	0.85	1.85	0.55	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	134.58	0.00	0.00	317.85	317.85	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	94.51%	1.36	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	134.33	0.00	0.00	512.84	512.84	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	152.49%	1.19	1.80	0.7	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	125.96	0.00	0.00	606.39	606.39	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	180.31%	1.19	0.55	0.745	750	$ 300.50	$ 11,711.80
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	123.64	0.00	0.00	1075.92	1075.92	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	319.92%	1.19	0.22	0.925	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	122.75	0.00	0.00	1068.13	1068.13	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	317.61%	1.19	1.23	0.92	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	117.92	0.00	0.00	1715.01	1715.01	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	509.95%	1.19	0.96	1.1	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	114.44	0.00	0.00	1664.32	1664.32	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	494.88%	1.19	0.10	1.085	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	146.10	0.00	0.00	95.35	95.35	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	207.72%	0.65	1.13	0.395	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	139.65	0.00	0.00	91.14	91.14	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	198.55%	0.65	0.27	0.39	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	138.18	0.00	0.00	141.69	141.69	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	69.41%	1.03	1.69		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.09	129.80	0.00	0.00	318.49	318.49	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	156.01%	0.94	0.54	0.62	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.64	127.34	0.00	0.00	360.58	360.58	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	107.22%	1.19	1.49	0.615	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.13	121.08	0.00	0.00	503.77	503.77	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	149.79%	1.19	1.07	0.695	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.20	116.99	0.00	0.00	805.22	805.22	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	239.43%	1.19	0.20	0.83	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.40	116.27	0.00	0.00	800.23	800.23	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	237.95%	1.19	0.87	0.825	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.27	113.19	0.00	0.00	943.62	943.62	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	280.58%	1.19	0.24	0.88	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.51	112.38	0.00	0.00	936.83	936.83	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	278.56%	1.19	0.60	0.875	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.11	110.41	0.00	0.00	920.37	920.37	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	273.67%	1.19	0.77	0.87	900	$ 418.20	$ 23,072.90

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	71	0	77	77	0	0	55
525	138	0	104	0	70	49	13	105
600	161	112	139	82	0	0	200	0
675	0	87	107	236	115	9	46	137
750	0	126	14	237	38	0	200	76
825	0	187	112	215	0	0	0	0
900	0	64	109	163	0	81	0	192
975	0	0	0	52	96	0	104	0
1050	0	0	0	0	0	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	10
Location	Mount Hope
a	1343.7
b	9
c	0.814

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/S)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	122.29	9.96	9.96	15.14	25.10	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	12.29%	0.65	0.79		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	122.29	25.72	25.72	39.12	64.84	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	77.91%	0.84	1.25		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.25	116.13	42.38	68.10	98.36	166.46	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	81.54%	1.06	1.69		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.94	108.78	98.17	176.22	238.41	414.63	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	123.29%	1.19	0.77	0.645	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.70	105.78	17.06	193.28	254.29	447.57	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	133.08%	1.19	1.49	0.665	675	$ 227.90	$ 24,238.88
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	122.29	39.49	39.49	60.06	99.55	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	216.87%	0.65	1.43	0.4	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	122.29	72.72	72.72	110.60	183.32	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	399.37%	0.65	1.83	0.505	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	113.48	73.67	146.39	206.60	352.99	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	768.99%	0.65	0.34	0.64	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	122.29	8.88	8.88	13.50	22.38	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	48.76%	0.65	0.27		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	112.00	10.96	166.23	231.54	397.77	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	293.91%	0.85	1.93	0.67	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	104.32	83.26	249.48	323.70	573.18	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	280.77%	0.94	1.06	0.77	825	$ 348.60	$ 20,911.02
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	100.58	54.68	304.16	380.48	684.64	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	203.58%	1.19	0.38	0.78	825	$ 348.60	$ 9,467.13
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	99.31	23.10	327.26	404.20	731.45	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	217.50%	1.19	1.12	0.8	825	$ 348.60	$ 27,971.66
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	95.75	70.96	398.22	474.22	872.44	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	259.42%	1.19	0.64	0.855	900	$ 418.20	$ 19,006.56
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	93.86	85.57	523.28	610.85	1134.12	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	337.23%	1.19	0.15	0.94	975	$ 458.80	$ 5,006.02
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	93.42	1.01	524.28	609.14	1133.42	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	337.02%	1.19	0.06	0.94	975	$ 458.80	$ 1,835.51
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	93.26	0.00	524.28	608.09	1132.37	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	336.71%	1.19	0.13	0.94	975	$ 458.80	$ 4,173.90
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	92.90	0.00	524.28	605.72	1130.00	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	411.52%	0.97	1.10	1.015	1050	$ 525.50	$ 33,652.60
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	89.89	0.00	524.28	586.11	1110.39	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	330.17%	1.19	0.15	0.935	975	$ 458.80	$ 4,908.37
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	89.49	0.00	524.28	583.54	1107.82	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	329.41%	1.19	2.13	0.935	975	$ 458.80	$ 69,863.45
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	122.29	26.03	26.03	39.59	65.62	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	142.96%	0.65	1.53	0.345	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	114.81	57.18	83.21	118.82	202.03	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	440.11%	0.65	1.47	0.52	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	108.51	51.39	134.60	181.65	316.25	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	233.68%	0.85	1.62	0.615	675	$ 227.90	$ 18,801.19
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	102.43	85.82	220.42	280.80	501.22	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	245.52%	0.94	1.90	0.73	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	96.18	102.86	323.28	386.71	709.99	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	347.78%	0.94	0.25	0.835	900	$ 418.20	$ 5,939.15
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	122.29	27.68	27.68	42.09	69.77	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	83.83%	0.85	1.15		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.15	116.59	52.53	80.21	116.30	196.50	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	145.20%	0.85	0.91	0.515	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.06	112.46	52.54	132.75	185.66	318.41	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	235.27%	0.85	1.11	0.62	675	$ 227.90	$ 12,874.17
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	95.42	51.97	508.01	602.85	1110.85	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	330.31%	1.19	0.18	0.935	975	$ 458.80	$ 5,943.45
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	94.87	9.91	517.91	611.10	1129.01	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	335.71%	1.19	1.38	0.94	975	$ 458.80	$ 45,303.74
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	90.95	77.67	595.58	673.65	1269.23	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	377.40%	1.19	1.53	0.98	1050	$ 525.50	$ 57,274.36
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	122.29	51.30	51.30	78.03	129.33	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	281.75%	0.65	1.97	0.44	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	112.85	84.55	135.85	190.68	326.53	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	392.33%	0.75	0.72	0.625	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	109.79	35.20	171.06	233.56	404.61	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	298.96%	0.85	0.96	0.675	750	$ 300.50	$ 14,752.34
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	105.98	56.65	227.70	300.12	527.82	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	390.00%	0.85	1.84	0.745	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	122.29	161.46	161.46	245.57	407.03	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1441.90%	0.58	1.63	0.675	750	$ 300.50	$ 16,949.09
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	114.35	84.04	245.50	349.13	594.63	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1295.40%	0.65	1.93	0.78	825	$ 348.60	$ 26,150.98
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	106.34	47.86	293.36	387.97	681.34	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	818.64%	0.75	0.77	0.82	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	103.47	0.00	293.36	377.52	670.88	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	495.71%	0.85	0.92	0.815	825	$ 348.60	$ 16,376.85
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	99.47	107.38	628.45	777.42	1405.87	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	688.65%	0.94	0.25	1.075	1200	$ 658.60	$ 9,464.83
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	98.63	18.65	647.10	793.79	1440.89	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	428.44%	1.19	1.23	1.03	1050	$ 525.50	$ 45,996.69
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	94.83	68.94	716.04	844.44	1560.48	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	464.00%	1.19	0.53	1.06	1200	$ 658.60	$ 24,954.70
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	122.29	314.61	314.61	478.49	793.10	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	130.07%	1.38	0.97	0.825	900	$ 418.20	$ 33,457.27
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	117.45	86.33	400.94	585.67	986.61	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	161.80%	1.38	1.21	0.895	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	111.97	164.77	565.71	787.75	1353.46	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	172.15%	1.47	0.86	1.005	1050	$ 525.50	$ 39,741.65
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	122.29	128.60	128.60	195.59	324.19	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	70.41%	1.41	1.02		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.02	117.21	262.16	390.76	569.60	960.36	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	208.59%	1.29	1.49	0.885	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	108.41	0.00	956.47	1289.55	2246.02	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	150.17%	1.73	0.15	1.215	1350	$ 847.00	$ 12,811.65
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	93.28	42.79	1715.30	1989.85	3705.16	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	247.72%	1.73	0.16	1.465	1500	$ 1,036.00	$ 17,366.04
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	122.29	51.15	51.15	77.80	128.95	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	95.28%	0.97	1.32	0.455	525	$ 110.50	$ 8,470.50
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.32	115.80	69.55	120.70	173.83	294.53	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	217.62%	0.85	1.37	0.6	675	$ 227.90	$ 15,989.75
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.69	109.79	74.65	195.35	266.74	462.09	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	226.35%	0.94	0.25	0.71	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.94	108.77	0.00	195.35	264.26	459.61	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	225.14%	0.94	1.78	0.71	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.72	102.09	79.36	274.71	348.80	623.51	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	305.42%	0.94	0.66	0.795	825	$ 348.60	$ 13,073.91
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.38	99.83	452.17	726.88	902.44	1629.32	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	484.47%	1.19	1.34	1.08	1200	$ 658.60	$ 62,957.34
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	122.29	104.60	104.60	159.09	263.69	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	574.44%	0.65	0.81	0.575	600	$ 148.70	$ 4,674.37
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	122.29	76.86	76.86	116.90	193.76	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	143.17%	0.85	0.35	0.515	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	118.22	0.00	181.46	266.80	448.26	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	219.58%	0.94	0.16	0.7	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	117.47	248.42	429.88	628.01	1057.89	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	518.20%	0.94	1.43	0.97	975	$ 458.80	$ 37,211.85
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	122.29	115.34	115.34	175.43	290.77	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	349.37%	0.75	0.87	0.595	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	117.92	39.35	154.69	226.86	381.55	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	281.93%	0.85	1.21	0.66	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	112.39	71.52	226.21	316.19	542.40	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	400.78%	0.85	0.89	0.755	825	$ 348.60	$ 15,908.99
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	108.65	40.10	266.31	359.86	626.17	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	306.73%	0.94	0.24	0.795	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	107.71	12.49	278.80	373.47	652.27	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	319.51%	0.94	0.34	0.81	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	122.29	109.83	109.83	167.04	276.86	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	204.57%	0.85	0.25	0.585	600	$ 148.70	$ 1,863.53
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	121.02	19.43	129.25	194.54	323.79	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	239.25%	0.85	1.85	0.62	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	112.29	60.65	189.90	265.21	455.12	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	135.33%	1.19	0.06	0.67	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	112.05	117.06	306.96	427.77	734.73	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	218.47%	1.19	1.80	0.8	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	104.84	80.12	387.09	504.70	891.79	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	265.17%	1.19	0.55	0.86	900	$ 418.20	$ 16,299.08
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	102.85	33.78	699.67	894.98	1594.65	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	474.16%	1.19	0.22	1.07	1200	$ 658.60	$ 10,201.65
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	102.08	0.00	699.67	888.30	1587.98	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	472.18%	1.19	1.23	1.07	1200	$ 658.60	$ 58,042.30
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	97.95	469.73	1169.41	1424.59	2594.00	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	771.32%	1.19	0.96	1.285	1350	$ 847.00	$ 58,231.49
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	94.98	0.00	1169.41	1381.34	2550.74	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	758.45%	1.19	0.10	1.275	1350	$ 847.00	$ 6,170.63
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	122.29	52.48	52.48	79.81	132.29	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	288.18%	0.65	1.13	0.445	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	116.68	0.00	52.48	76.15	128.63	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	280.21%	0.65	0.27	0.44	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	115.41	29.97	82.45	118.34	200.79	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	98.36%	1.07	1.63	0.53	600	$ 148.70	$ 15,540.00
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.03	108.43	114.85	197.30	266.06	463.36	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	226.97%	0.94	0.54	0.71	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	106.30	30.39	227.69	301.02	528.71	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	157.21%	1.19	1.49	0.71	750	$ 300.50	$ 32,029.46
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.06	100.90	106.87	334.55	419.83	754.38	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	224.31%	1.19	1.07	0.81	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.13	97.39	218.85	553.41	670.31	1223.71	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	363.87%	1.19	0.20	0.97	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	96.77	0.00	553.41	666.03	1219.44	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	362.60%	1.19	0.87	0.97	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.20	94.14	116.88	670.29	784.74	1455.03	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	432.65%	1.19	0.24	1.035	1050	$ 525.50	$ 9,018.93
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.44	93.44	0.00	670.29	778.92	1449.22	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	430.92%	1.19	0.60	1.03	1050	$ 525.50	$ 22,457.79
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.04	91.75	0.00	670.29	764.86	1435.15	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	426.74%	1.19	0.77	1.03	1050	$ 525.50	$ 28,992.84

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	0	0	0	55
525	138	71	104	0	77	18	0	0
600	0	0	0	0	0	31	52	105
675	161	112	139	119	70	0	160	0
750	0	0	107	199	115	9	0	137
825	0	167	0	157	38	0	207	76
900	0	45	14	295	0	0	39	0
975	0	187	112	0	0	81	0	77
1050	0	64	109	163	0	0	0	115
1200	0	0	0	52	96	0	104	0
1350	0	0	0	15	0	0	76	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75.5	m
Total Basement Q	1.54	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	10
Location	Mount Hope
a	1343.7
b	9
c	0.814

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	122.29	2.54	2.54	15.14	17.68	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	8.66%	0.59	0.87		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	122.29	6.56	6.56	39.12	45.68	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	54.89%	0.78	1.34		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.34	115.69	10.82	17.38	97.98	115.36	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	56.51%	0.98	1.82		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.17	107.87	25.05	44.97	236.42	281.39	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	83.67%	1.34	0.68		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.85	105.26	4.35	49.33	253.01	302.34	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	89.90%	1.35	1.31		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	122.29	10.08	10.08	60.06	70.14	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	152.79%	0.65	1.43	0.35	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	122.29	18.56	18.56	110.60	129.16	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	281.38%	0.65	1.83	0.44	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	113.48	18.80	37.36	206.60	243.96	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	531.47%	0.65	0.34	0.56	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	122.29	2.27	2.27	13.50	15.77	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	34.35%	0.60	0.29		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	112.00	2.80	42.42	231.54	273.97	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	202.43%	0.85	1.93	0.585	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	104.32	21.25	63.67	323.70	387.37	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	189.75%	0.94	1.06	0.665	675	$ 227.90	$ 13,670.74
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	100.58	13.95	77.62	380.48	458.10	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	136.22%	1.19	0.38	0.67	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	99.31	5.89	83.52	404.20	487.71	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	145.02%	1.19	1.12	0.685	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	95.75	18.11	101.62	474.22	575.85	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	171.23%	1.19	0.64	0.73	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	93.86	21.84	133.54	610.85	744.39	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	221.34%	1.19	0.15	0.805	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	93.42	0.26	133.80	609.14	742.93	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	220.91%	1.19	0.06	0.805	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	93.26	0.00	133.80	608.09	741.89	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	220.60%	1.19	0.13	0.805	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	92.90	0.00	133.80	605.72	739.52	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	269.31%	0.97	1.10	0.865	900	$ 418.20	$ 26,781.19
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	89.89	0.00	133.80	586.11	719.90	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	214.06%	1.19	0.15	0.795	825	$ 348.60	$ 3,729.42
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	89.49	0.00	133.80	583.54	717.34	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	213.30%	1.19	2.13	0.795	825	$ 348.60	$ 53,082.82
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	122.29	6.64	6.64	39.59	46.23	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	100.72%	0.65	1.53	0.305	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	114.81	14.59	21.24	118.82	140.05	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	305.10%	0.65	1.47	0.455	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	108.51	13.11	34.35	181.65	216.00	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	159.60%	0.85	1.62	0.535	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	102.43	21.90	56.25	280.80	337.05	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	165.10%	0.94	1.90	0.63	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	96.18	26.25	82.50	386.71	469.21	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	229.84%	0.94	0.25	0.715	750	$ 300.50	$ 4,267.61
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	122.29	7.06	7.06	42.09	49.16	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	59.06%	0.79	1.23		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.23	116.21	13.41	20.47	115.92	136.39	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	100.77%	0.85	0.91	0.455	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.14	112.10	13.41	33.88	185.08	218.95	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	161.78%	0.85	1.11	0.535	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	95.42	13.26	129.64	602.85	732.49	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	217.80%	1.19	0.18	0.8	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	94.87	2.53	132.17	611.10	743.27	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	221.01%	1.19	1.38	0.805	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	90.95	19.82	151.99	673.65	825.64	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	245.50%	1.19	1.53	0.835	900	$ 418.20	$ 45,579.71
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	122.29	13.09	13.09	78.03	91.12	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	198.51%	0.65	1.97	0.385	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	112.85	21.58	34.67	190.68	225.35	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	270.76%	0.75	0.72	0.545	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	109.79	8.98	43.65	233.56	277.21	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	204.83%	0.85	0.96	0.585	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	105.98	14.46	58.11	300.12	358.23	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	264.69%	0.85	1.84	0.645	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	122.29	41.20	41.20	245.57	286.77	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1015.89%	0.58	1.63	0.595	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	114.35	21.45	62.65	349.13	411.78	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	897.06%	0.65	1.93	0.68	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	106.34	12.21	74.87	387.97	462.84	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	556.11%	0.75	0.77	0.71	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	103.47	0.00	74.87	377.52	452.38	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	334.26%	0.85	0.92	0.705	750	$ 300.50	$ 14,117.17
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	99.47	27.40	160.38	777.42	937.80	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	459.37%	0.94	0.25	0.925	975	$ 458.80	$ 6,593.48
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	98.63	4.76	165.14	793.79	958.93	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	285.13%	1.19	1.23	0.885	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	94.83	17.59	182.73	844.44	1027.18	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	305.43%	1.19	0.53	0.905	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	122.29	80.29	80.29	478.49	558.78	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	91.64%	1.57	0.85		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.85	118.02	22.03	102.32	588.50	690.82	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	113.29%	1.38	1.21	0.78	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.06	112.48	42.05	144.37	791.34	935.71	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	119.01%	1.47	0.86	0.875	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	122.29	32.82	32.82	195.59	228.41	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	49.61%	1.30	1.10		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.10	116.81	66.90	99.72	567.65	667.37	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	144.95%	1.29	1.49	0.77	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.91	108.88	0.00	244.09	1295.20	1539.29	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	102.92%	1.73	0.15	1.055	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	93.28	10.92	437.74	1989.85	2427.60	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	162.31%	1.73	0.16	1.25	1350	$ 847.00	$ 14,197.91
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	122.29	13.05	13.05	77.80	90.85	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	67.13%	0.92	1.38		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.38	115.49	17.75	30.80	173.36	204.16	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	150.85%	0.85	1.37	0.525	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.76	109.51	19.05	49.85	266.07	315.92	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	154.75%	0.94	0.25	0.615	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.01	108.50	0.00	49.85	263.60	313.45	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	153.54%	0.94	1.78	0.615	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.79	101.86	20.25	70.11	347.99	418.10	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	204.80%	0.94	0.66	0.685	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.45	99.60	115.39	185.50	900.41	1085.91	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	322.89%	1.19	1.34	0.925	975	$ 458.80	$ 43,857.92
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	122.29	26.69	26.69	159.09	185.78	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	404.72%	0.65	0.81	0.505	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	122.29	19.62	19.62	116.90	136.52	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	100.87%	0.85	0.35	0.455	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	118.22	0.00	46.31	266.80	313.11	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	153.37%	0.94	0.16	0.615	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	117.47	63.40	109.70	628.01	737.71	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	361.36%	0.94	1.43	0.845	900	$ 418.20	$ 33,918.91
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	122.29	29.44	29.44	175.43	204.86	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	246.15%	0.75	0.87	0.525	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	117.92	10.04	39.48	226.86	266.34	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	196.79%	0.85	1.21	0.58	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	112.39	18.25	57.73	316.19	373.92	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	276.29%	0.85	0.89	0.655	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	108.65	10.23	67.96	359.86	427.82	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	209.57%	0.94	0.24	0.69	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	107.71	3.19	71.15	373.47	444.62	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	217.79%	0.94	0.34	0.7	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	122.29	28.03	28.03	167.04	195.06	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	144.13%	0.85	0.25	0.515	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	121.02	4.96	32.99	194.54	227.52	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	168.12%	0.85	1.85	0.545	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	112.29	15.48	48.46	265.21	313.68	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	93.27%	1.36	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	112.08	29.87	78.34	427.88	506.22	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	150.52%	1.19	1.80	0.695	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	104.86	20.45	98.78	504.83	603.61	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	179.48%	1.19	0.55	0.745	750	$ 300.50	$ 11,711.80
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	102.88	8.62	178.56	895.19	1073.74	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	319.27%	1.19	0.22	0.925	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	102.11	0.00	178.56	888.51	1067.07	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	317.29%	1.19	1.23	0.92	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	97.97	119.87	298.43	1424.91	1723.34	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	512.43%	1.19	0.96	1.1	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	95.00	0.00	298.43	1381.64	1680.07	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	499.56%	1.19	0.10	1.09	1200	$ 658.60	$ 4,798.08
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	122.29	13.39	13.39	79.81	93.20	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	203.04%	0.65	1.13	0.39	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	116.68	0.00	13.39	76.15	89.54	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	195.07%	0.65	0.27	0.385	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	115.41	7.65	21.04	118.34	139.38	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	68.28%	1.03	1.70		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.10	108.14	29.31	50.35	265.35	315.70	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	154.64%	0.94	0.54	0.615	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.64	106.03	7.76	58.11	300.23	358.34	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	106.55%	1.19	1.49	0.61	675	$ 227.90	$ 24,291.23
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.13	100.65	27.27	85.38	418.80	504.18	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	149.92%	1.19	1.07	0.695	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.20	97.16	55.85	141.23	668.74	809.97	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	240.84%	1.19	0.20	0.83	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.40	96.54	0.00	141.23	664.48	805.71	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	239.58%	1.19	0.87	0.83	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.28	93.92	29.83	171.06	782.98	954.03	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	283.68%	1.19	0.24	0.885	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.52	93.23	0.00	171.06	777.19	948.25	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	281.96%	1.19	0.60	0.88	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.12	91.55	0.00	171.06	763.19	934.25	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	277.80%	1.19	0.77	0.875	900	$ 418.20	$ 23,072.90

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	71	0	77	77	0	0	55
525	138	0	104	0	70	49	13	105
600	161	112	139	138	0	0	200	0
675	0	87	107	180	115	9	46	137
750	0	126	14	237	38	0	200	76
825	0	187	112	215	0	0	0	0
900	0	64	109	163	0	81	0	192
975	0	0	0	52	96	0	104	0
1050	0	0	0	0	0	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	10
Location	Mount Hope
a	1343.7
b	9
c	0.814

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	122.29	0.66	0.66	15.14	15.80	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	7.74%	0.57	0.90		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	122.29	1.70	1.70	39.12	40.82	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	49.04%	0.76	1.38		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.38	115.51	2.80	4.50	97.83	102.33	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	50.13%	0.96	1.88		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.26	107.52	6.48	11.64	235.63	247.27	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	73.52%	1.31	0.69		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.95	104.86	1.13	12.76	252.07	264.83	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	78.75%	1.33	1.33		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	122.29	2.61	2.61	60.06	62.67	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	136.52%	0.65	1.43	0.335	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	122.29	4.80	4.80	110.60	115.40	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	251.41%	0.65	1.83	0.425	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	113.48	4.86	9.67	206.60	216.27	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	471.14%	0.65	0.34	0.535	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	122.29	0.59	0.59	13.50	14.09	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	30.69%	0.58	0.30		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	112.00	0.72	10.98	231.54	242.52	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	179.20%	0.85	1.93	0.56	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	104.32	5.50	16.47	323.70	340.17	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	166.63%	0.94	1.06	0.635	675	$ 227.90	$ 13,670.74
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	100.58	3.61	20.08	380.48	400.56	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	119.11%	1.19	0.38	0.64	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	99.31	1.52	21.61	404.20	425.80	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	126.61%	1.19	1.12	0.655	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	95.75	4.69	26.29	474.22	500.52	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	148.83%	1.19	0.64	0.695	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	93.86	5.65	34.55	610.85	645.40	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	191.91%	1.19	0.15	0.765	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	93.42	0.07	34.62	609.14	643.75	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	191.42%	1.19	0.06	0.76	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	93.26	0.00	34.62	608.09	642.71	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	191.11%	1.19	0.13	0.76	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	92.90	0.00	34.62	605.72	640.34	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	233.19%	0.97	1.10	0.82	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	89.89	0.00	34.62	586.11	620.72	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	184.57%	1.19	0.15	0.75	825	$ 348.60	$ 3,729.42
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	89.49	0.00	34.62	583.54	618.16	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	183.81%	1.19	2.13	0.75	825	$ 348.60	$ 53,082.82
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	122.29	1.72	1.72	39.59	41.31	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	89.99%	0.74	1.35		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.35	115.66	3.78	5.49	119.70	125.19	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	272.73%	0.65	1.47	0.435	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.82	109.26	3.39	8.89	182.91	191.79	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	141.72%	0.85	1.62	0.51	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.44	103.09	5.67	14.55	282.60	297.16	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	145.56%	0.94	1.90	0.6	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.34	96.75	6.79	21.35	389.01	410.35	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	201.01%	0.94	0.25	0.68	750	$ 300.50	$ 4,267.61
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	122.29	1.83	1.83	42.09	43.92	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	52.77%	0.77	1.26		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.26	116.05	3.47	5.30	115.76	121.06	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	89.45%	0.97	0.80		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.07	112.44	3.47	8.77	185.63	194.39	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	143.64%	0.85	1.11	0.515	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.59	95.98	3.43	33.54	606.40	639.94	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	190.28%	1.19	0.18	0.76	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.77	95.43	0.65	34.20	614.68	648.87	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	192.94%	1.19	1.38	0.765	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.15	91.45	5.13	39.32	677.39	716.72	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	213.11%	1.19	1.53	0.795	825	$ 348.60	$ 37,993.99
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	122.29	3.39	3.39	78.03	81.42	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	177.37%	0.65	1.97	0.37	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	112.85	5.58	8.97	190.68	199.65	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	239.88%	0.75	0.72	0.52	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	109.79	2.32	11.29	233.56	244.85	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	180.92%	0.85	0.96	0.56	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	105.98	3.74	15.03	300.12	315.15	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	232.86%	0.85	1.84	0.615	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	122.29	10.66	10.66	245.57	256.23	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	907.69%	0.58	1.63	0.57	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	114.35	5.55	16.21	349.13	365.34	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	795.89%	0.65	1.93	0.65	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	106.34	3.16	19.37	387.97	407.34	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	489.43%	0.75	0.77	0.68	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	103.47	0.00	19.37	377.52	396.89	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	293.26%	0.85	0.92	0.67	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	99.47	7.09	41.50	777.42	818.91	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	401.14%	0.94	0.25	0.88	900	$ 418.20	$ 6,010.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	98.63	1.23	42.73	793.79	836.52	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	248.74%	1.19	1.23	0.84	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	94.83	4.55	47.28	844.44	891.72	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	265.15%	1.19	0.53	0.86	900	$ 418.20	$ 15,845.82
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	122.29	20.77	20.77	478.49	499.27	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	81.88%	1.55	0.86		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.86	117.97	5.70	26.47	588.24	614.72	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	100.81%	1.38	1.21	0.755	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.07	112.43	10.88	37.35	791.01	828.37	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	105.36%	1.47	0.86	0.835	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	122.29	8.49	8.49	195.59	204.08	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	44.33%	1.26	1.13		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.13	116.66	17.31	25.80	566.93	592.73	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	128.74%	1.29	1.49	0.74	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.92	108.84	0.00	63.15	1294.69	1357.84	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	90.78%	1.97	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	93.28	2.83	113.26	1989.85	2103.11	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	140.61%	1.73	0.16	1.185	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	122.29	3.38	3.38	77.80	81.18	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	59.98%	0.90	1.42		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.42	115.33	4.59	7.97	173.12	181.09	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	133.80%	0.85	1.37	0.5	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.79	109.37	4.93	12.90	265.72	278.62	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	136.48%	0.94	0.25	0.59	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.04	108.36	0.00	12.90	263.26	276.16	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	135.27%	0.94	1.78	0.585	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.82	101.74	5.24	18.14	347.58	365.72	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	179.14%	0.94	0.66	0.65	675	$ 227.90	$ 8,547.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.48	99.49	29.86	47.99	899.37	947.36	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	281.70%	1.19	1.34	0.88	900	$ 418.20	$ 39,976.86
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	122.29	6.91	6.91	159.09	165.99	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	361.62%	0.65	0.81	0.485	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	122.29	5.08	5.08	116.90	121.98	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	90.13%	0.97	0.31		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	118.22	0.00	11.98	266.80	278.78	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	136.56%	0.94	0.16	0.59	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	117.47	16.40	28.38	628.01	656.39	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	321.53%	0.94	1.43	0.81	825	$ 348.60	$ 28,273.87
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	122.29	7.62	7.62	175.43	183.04	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	219.93%	0.75	0.87	0.505	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	117.92	2.60	10.21	226.86	237.07	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	175.17%	0.85	1.21	0.555	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	112.39	4.72	14.94	316.19	331.13	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	244.67%	0.85	0.89	0.625	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	108.65	2.65	17.58	359.86	377.45	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	184.89%	0.94	0.24	0.66	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	107.71	0.82	18.41	373.47	391.88	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	191.96%	0.94	0.34	0.67	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	122.29	7.25	7.25	167.04	174.29	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	128.78%	0.85	0.25	0.495	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	121.02	1.28	8.53	194.54	203.07	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	150.05%	0.85	1.85	0.52	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	112.29	4.00	12.54	265.21	277.75	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	82.59%	1.34	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	112.08	7.73	20.27	427.87	448.14	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	133.25%	1.19	1.80	0.665	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	104.86	5.29	25.56	504.82	530.37	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	157.70%	1.19	0.55	0.71	750	$ 300.50	$ 11,711.80
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	102.87	2.23	46.20	895.17	941.37	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	279.91%	1.19	0.22	0.88	900	$ 418.20	$ 6,477.88
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	102.11	0.00	46.20	888.50	934.69	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	277.93%	1.19	1.23	0.875	900	$ 418.20	$ 36,855.89
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	97.97	31.02	77.21	1424.88	1502.09	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	446.64%	1.19	0.96	1.045	1050	$ 525.50	$ 36,128.27
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	95.00	0.00	77.21	1381.61	1458.82	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	433.78%	1.19	0.10	1.035	1050	$ 525.50	$ 3,828.41
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	122.29	3.46	3.46	79.81	83.28	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	181.41%	0.65	1.13	0.375	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	116.68	0.00	3.46	76.15	79.62	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	173.44%	0.65	0.27	0.37	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	115.41	1.98	5.44	118.34	123.78	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	60.64%	1.00	1.74		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.14	107.96	7.58	13.03	264.92	277.94	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	136.15%	0.94	0.54	0.585	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.69	105.86	2.01	15.03	299.76	314.79	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	93.60%	1.36	1.31		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.00	101.13	7.06	22.09	420.77	442.86	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	131.68%	1.19	1.07	0.665	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.07	97.60	14.45	36.54	671.75	708.29	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	210.61%	1.19	0.20	0.79	825	$ 348.60	$ 4,938.23
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.26	96.98	0.00	36.54	667.45	703.99	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	209.33%	1.19	0.87	0.79	825	$ 348.60	$ 21,731.28
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.14	94.33	7.72	44.26	786.36	830.62	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	246.98%	1.19	0.24	0.84	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.38	93.63	0.00	44.26	780.52	824.78	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	245.25%	1.19	0.60	0.835	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	17.98	91.93	0.00	44.26	766.39	810.65	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	241.04%	1.19	0.77	0.83	900	$ 418.20	$ 23,072.90

Pipe Sizes	Length (m)							
(mm)	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	11
450	0	71	104	0	77	18	0	44
525	138	0	139	33	70	31	147	105
600	161	112	0	105	115	9	66	137
675	0	167	107	302	38	0	207	76
750	0	45	14	230	0	0	39	0
825	0	251	221	100	0	81	0	77
900	0	0	0	215	96	0	104	115
975	0	0	0	0	0	0	0	0
1050	0	0	0	15	0	0	76	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	10
Location	Mount Hope
a	1343.7
b	9
c	0.814

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/S)	Total Flow (L/S)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	122.29	0.22	0.22	15.14	15.36	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	7.52%	0.56	0.91		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	122.29	0.56	0.56	39.12	39.68	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	47.68%	0.75	1.39		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.39	115.47	0.92	1.48	97.80	99.28	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	48.63%	0.95	1.89		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.28	107.42	2.14	3.84	235.43	239.27	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	71.15%	1.30	0.70		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.98	104.76	0.37	4.21	251.81	256.02	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	76.13%	1.32	1.34		600	$ 148.70	$ 15,815.36
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	122.29	0.86	0.86	60.06	60.92	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	132.71%	0.65	1.43	0.335	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	122.29	1.58	1.58	110.60	112.19	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	244.40%	0.65	1.83	0.42	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	113.48	1.60	3.19	206.60	209.79	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	457.03%	0.65	0.34	0.53	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	122.29	0.19	0.19	13.50	13.70	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	29.84%	0.57	0.31		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	112.00	0.24	3.62	231.54	235.16	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	173.76%	0.85	1.93	0.55	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	104.32	1.81	5.43	323.70	329.13	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	161.22%	0.94	1.06	0.625	675	$ 227.90	$ 13,670.74
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	100.58	1.19	6.62	380.48	387.10	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	115.10%	1.19	0.38	0.63	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	99.31	0.50	7.13	404.20	411.32	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	122.31%	1.19	1.12	0.645	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	95.75	1.55	8.67	474.22	482.90	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	143.59%	1.19	0.64	0.685	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	93.86	1.86	11.40	610.85	622.24	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	185.02%	1.19	0.15	0.75	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	93.42	0.02	11.42	609.14	620.55	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	184.52%	1.19	0.06	0.75	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	93.26	0.00	11.42	608.09	619.51	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	184.21%	1.19	0.13	0.75	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	92.90	0.00	11.42	605.72	617.14	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	224.74%	0.97	1.10	0.81	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	89.89	0.00	11.42	586.11	597.52	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	177.67%	1.19	0.15	0.74	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	89.49	0.00	11.42	583.54	594.96	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	176.91%	1.19	2.13	0.74	750	$ 300.50	$ 45,758.43
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	122.29	0.57	0.57	39.59	40.16	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	87.49%	0.74	1.35		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.35	115.65	1.25	1.81	119.68	121.49	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	264.67%	0.65	1.47	0.43	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.82	109.25	1.12	2.93	182.88	185.81	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	137.30%	0.85	1.62	0.505	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.44	103.08	1.87	4.80	282.57	287.37	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	140.77%	0.94	1.90	0.595	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.34	96.74	2.24	7.04	388.96	396.00	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	193.98%	0.94	0.25	0.67	675	$ 227.90	$ 3,236.57
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	122.29	0.60	0.60	42.09	42.70	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	51.30%	0.77	1.27		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.27	116.01	1.14	1.75	115.72	117.47	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	86.80%	0.96	0.81		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	112.39	1.14	2.89	185.55	188.44	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	139.24%	0.85	1.11	0.51	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.59	95.97	1.13	11.06	606.33	617.39	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	183.58%	1.19	0.18	0.75	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.77	95.42	0.22	11.28	614.61	625.89	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	186.11%	1.19	1.38	0.755	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.16	91.44	1.69	12.97	677.32	690.29	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	205.26%	1.19	1.53	0.78	825	$ 348.60	$ 37,993.99
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	122.29	1.12	1.12	78.03	79.15	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	172.42%	0.65	1.97	0.37	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	112.85	1.84	2.96	190.68	193.63	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	232.66%	0.75	0.72	0.515	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	109.79	0.77	3.73	233.56	237.28	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	175.33%	0.85	0.96	0.555	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	105.98	1.23	4.96	300.12	305.08	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	225.42%	0.85	1.84	0.61	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	122.29	3.52	3.52	245.57	249.08	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	882.38%	0.58	1.63	0.565	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	114.35	1.83	5.35	349.13	354.47	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	772.22%	0.65	1.93	0.645	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	106.34	1.04	6.39	387.97	394.36	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	473.83%	0.75	0.77	0.67	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	103.47	0.00	6.39	377.52	383.91	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	283.66%	0.85	0.92	0.665	675	$ 227.90	$ 10,706.50
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	99.47	2.34	13.69	777.42	791.10	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	387.52%	0.94	0.25	0.87	900	$ 418.20	$ 6,010.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	98.63	0.41	14.09	793.79	807.88	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	240.22%	1.19	1.23	0.83	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	94.83	1.50	15.59	844.44	860.04	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	255.73%	1.19	0.53	0.85	900	$ 418.20	$ 15,845.82
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	122.29	6.85	6.85	478.49	485.34	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	79.60%	1.55	0.86		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.86	117.95	1.88	8.73	588.15	596.88	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	97.89%	1.57	1.06	0.755	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	11.93	113.05	3.59	12.32	795.39	807.71	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	102.73%	1.47	0.86	0.83	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	122.29	2.80	2.80	195.59	198.39	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	43.09%	1.26	1.14		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.14	116.62	5.71	8.51	566.74	575.25	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	124.94%	1.29	1.49	0.73	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.78	109.42	0.00	20.83	1301.56	1322.39	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	88.41%	1.96	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	93.28	0.93	37.35	1989.85	2027.21	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	135.54%	1.73	0.16	1.17	1200	$ 658.60	$ 11,039.84
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	122.29	1.11	1.11	77.80	78.91	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	58.31%	0.89	1.43		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.43	115.28	1.51	2.63	173.05	175.68	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	129.81%	0.85	1.37	0.495	525	$ 110.50	$ 7,752.82
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.80	109.33	1.63	4.25	265.63	269.88	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	132.20%	0.94	0.25	0.58	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.05	108.32	0.00	4.25	263.17	267.42	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	131.00%	0.94	1.78	0.58	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.83	101.70	1.73	5.98	347.47	353.45	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	173.14%	0.94	0.66	0.645	675	$ 227.90	$ 8,547.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.49	99.46	9.85	15.83	899.09	914.92	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	272.05%	1.19	1.34	0.87	900	$ 418.20	$ 39,976.86
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	122.29	2.28	2.28	159.09	161.37	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	351.53%	0.65	0.81	0.48	525	$ 110.50	$ 3,473.56
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	122.29	1.67	1.67	116.90	118.57	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	87.61%	0.97	0.31		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	118.22	0.00	3.95	266.80	270.75	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	132.63%	0.94	0.16	0.58	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	117.47	5.41	9.36	628.01	637.37	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	312.21%	0.94	1.43	0.8	825	$ 348.60	$ 28,273.87
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	122.29	2.51	2.51	175.43	177.94	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	213.80%	0.75	0.87	0.495	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	117.92	0.86	3.37	226.86	230.23	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	170.11%	0.85	1.21	0.545	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	112.39	1.56	4.93	316.19	321.12	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	237.27%	0.85	0.89	0.62	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	108.65	0.87	5.80	359.86	365.66	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	179.12%	0.94	0.24	0.65	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	107.71	0.27	6.07	373.47	379.54	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	185.91%	0.94	0.34	0.66	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	122.29	2.39	2.39	167.04	169.43	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	125.19%	0.85	0.25	0.49	525	$ 110.50	$ 1,384.81
64	Bayside	Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	121.02	0.42	2.81	194.54	197.35	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	145.82%	0.85	1.85	0.515	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	112.29	1.32	4.14	265.21	269.35	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	80.09%	1.33	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	112.08	2.55	6.68	427.87	434.55	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	129.21%	1.19	1.80	0.66	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	104.86	1.74	8.43	504.81	513.24	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	152.61%	1.19	0.55	0.7	750	$ 300.50	$ 11,711.80
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	102.87	0.74	15.24	895.16	910.40	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	270.70%	1.19	0.22	0.865	900	$ 418.20	$ 6,477.88
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	102.11	0.00	15.24	888.49	903.72	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	268.72%	1.19	1.23	0.865	900	$ 418.20	$ 36,855.89
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	97.97	10.23	25.47	1424.87	1450.34	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	431.25%	1.19	0.96	1.03	1050	$ 525.50	$ 36,128.27
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	95.00	0.00	25.47	1381.60	1407.07	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	418.39%	1.19	0.10	1.02	1050	$ 525.50	$ 3,828.41
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	122.29	1.14	1.14	79.81	80.95	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	176.36%	0.65	1.13	0.37	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	116.68	0.00	1.14	76.15	77.29	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	168.38%	0.65	0.27	0.365	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	115.41	0.65	1.80	118.34	120.14	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	58.85%	0.99	1.75		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.15	107.92	2.50	4.30	264.80	269.10	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	131.81%	0.94	0.54	0.58	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.70	105.81	0.66	4.96	299.63	304.58	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	90.57%	1.35	1.31		600	$ 148.70	$ 15,849.52
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.01	101.08	2.33	7.29	420.57	427.86	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	127.22%	1.19	1.07	0.655	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.08	97.56	4.77	12.05	671.45	683.50	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	203.24%	1.19	0.20	0.78	825	$ 348.60	$ 4,938.23
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.28	96.93	0.00	12.05	667.15	679.21	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	201.96%	1.19	0.87	0.775	825	$ 348.60	$ 21,731.28
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.15	94.29	2.55	14.60	786.02	800.62	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	238.06%	1.19	0.24	0.825	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.39	93.59	0.00	14.60	780.19	794.78	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	236.33%	1.19	0.60	0.825	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	17.99	91.90	0.00	14.60	766.07	780.66	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	232.13%	1.19	0.77	0.82	825	$ 348.60	$ 19,232.93

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	18	0	0
525	138	0	139	33	70	31	147	105
600	161	112	107	105	115	9	66	137
675	0	167	14	337	38	0	207	76
750	0	208	0	195	0	0	39	0
825	0	88	221	100	0	81	0	132
900	0	0	0	215	96	0	104	60
975	0	0	0	0	0	0	0	0
1050	0	0	0	15	0	0	76	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74	m
Total Basement Q	0.00	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	10
Location	Mount Hope
a	1343.7
b	9
c	0.814

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	122.29	0.00	0.00	15.14	15.14	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	7.42%	0.56	0.91		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	122.29	0.00	0.00	39.12	39.12	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	47.00%	0.75	1.39		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.39	115.45	0.00	0.00	97.78	97.78	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	47.90%	0.95	1.90		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.29	107.37	0.00	0.00	235.32	235.32	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	69.97%	1.30	0.70		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.99	104.70	0.00	0.00	251.68	251.68	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	74.84%	1.32	1.35		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	122.29	0.00	0.00	60.06	60.06	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	130.84%	0.65	1.43	0.33	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	122.29	0.00	0.00	110.60	110.60	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	240.95%	0.65	1.83	0.415	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	113.48	0.00	0.00	206.60	206.60	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	450.08%	0.65	0.34	0.525	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	122.29	0.00	0.00	13.50	13.50	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	29.42%	0.57	0.31		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	112.00	0.00	0.00	231.54	231.54	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	171.09%	0.85	1.93	0.55	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	104.32	0.00	0.00	323.70	323.70	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	158.56%	0.94	1.06	0.62	675	$ 227.90	$ 13,670.74
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	100.58	0.00	0.00	380.48	380.48	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	113.13%	1.19	0.38	0.625	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	99.31	0.00	0.00	404.20	404.20	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	120.19%	1.19	1.12	0.64	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	95.75	0.00	0.00	474.22	474.22	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	141.01%	1.19	0.64	0.68	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	93.86	0.00	0.00	610.85	610.85	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	181.63%	1.19	0.15	0.745	750	$ 300.50	$ 3,278.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	93.42	0.00	0.00	609.14	609.14	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	181.12%	1.19	0.06	0.745	750	$ 300.50	$ 1,202.20
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	93.26	0.00	0.00	608.09	608.09	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	180.81%	1.19	0.13	0.745	750	$ 300.50	$ 2,733.78
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	92.90	0.00	0.00	605.72	605.72	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	220.59%	0.97	1.10	0.805	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	89.89	0.00	0.00	586.11	586.11	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	174.28%	1.19	0.15	0.735	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	89.49	0.00	0.00	583.54	583.54	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	173.51%	1.19	2.13	0.735	750	$ 300.50	$ 45,758.43
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	122.29	0.00	0.00	39.59	39.59	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	86.25%	0.74	1.35		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.35	115.64	0.00	0.00	119.67	119.67	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	260.70%	0.65	1.47	0.43	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.83	109.24	0.00	0.00	182.87	182.87	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	135.12%	0.85	1.62	0.5	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.44	103.07	0.00	0.00	282.55	282.55	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	138.40%	0.94	1.90	0.59	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.34	96.74	0.00	0.00	388.94	388.94	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	190.52%	0.94	0.25	0.665	675	$ 227.90	$ 3,236.57
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	122.29	0.00	0.00	42.09	42.09	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	50.58%	0.77	1.28		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.28	115.99	0.00	0.00	115.70	115.70	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	85.49%	0.96	0.81		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	112.36	0.00	0.00	185.51	185.51	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	137.07%	0.85	1.11	0.505	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.59	95.96	0.00	0.00	606.29	606.29	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	180.28%	1.19	0.18	0.745	750	$ 300.50	$ 3,892.78
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.77	95.41	0.00	0.00	614.57	614.57	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	182.74%	1.19	1.38	0.75	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.16	91.44	0.00	0.00	677.28	677.28	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	201.39%	1.19	1.53	0.775	825	$ 348.60	$ 37,993.99
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	122.29	0.00	0.00	78.03	78.03	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	169.99%	0.65	1.97	0.365	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	112.85	0.00	0.00	190.68	190.68	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	229.10%	0.75	0.72	0.51	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	109.79	0.00	0.00	233.56	233.56	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	172.57%	0.85	0.96	0.55	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	105.98	0.00	0.00	300.12	300.12	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	221.76%	0.85	1.84	0.605	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	122.29	0.00	0.00	245.57	245.57	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	869.92%	0.58	1.63	0.56	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	114.35	0.00	0.00	349.13	349.13	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	760.57%	0.65	1.93	0.64	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	106.34	0.00	0.00	387.97	387.97	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	466.16%	0.75	0.77	0.665	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	103.47	0.00	0.00	377.52	377.52	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	278.94%	0.85	0.92	0.66	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	99.47	0.00	0.00	777.42	777.42	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	380.81%	0.94	0.25	0.865	900	$ 418.20	$ 6,010.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	98.63	0.00	0.00	793.79	793.79	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	236.03%	1.19	1.23	0.825	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	94.83	0.00	0.00	844.44	844.44	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	251.09%	1.19	0.53	0.845	900	$ 418.20	$ 15,845.82
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	122.29	0.00	0.00	478.49	478.49	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	78.47%	1.54	0.86		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.86	117.94	0.00	0.00	588.10	588.10	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	96.45%	1.57	1.06	0.755	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	11.93	113.05	0.00	0.00	795.37	795.37	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	101.16%	1.47	0.86	0.83	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	122.29	0.00	0.00	195.59	195.59	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	42.48%	1.25	1.15		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.15	116.60	0.00	0.00	566.64	566.64	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	123.07%	1.29	1.49	0.725	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.78	109.42	0.00	0.00	1301.54	1301.54	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	87.02%	1.96	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	93.28	0.00	0.00	1989.85	1989.85	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	133.04%	1.73	0.16	1.16	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	122.29	0.00	0.00	77.80	77.80	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	57.49%	0.89	1.43		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.43	115.26	0.00	0.00	173.02	173.02	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	127.84%	0.85	1.37	0.49	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.81	109.31	0.00	0.00	265.58	265.58	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	130.09%	0.94	0.25	0.575	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.06	108.30	0.00	0.00	263.12	263.12	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	128.89%	0.94	1.78	0.575	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.83	101.69	0.00	0.00	347.42	347.42	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	170.18%	0.94	0.66	0.64	675	$ 227.90	$ 8,547.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.50	99.44	0.00	0.00	898.95	898.95	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	267.30%	1.19	1.34	0.865	900	$ 418.20	$ 39,976.86
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	122.29	0.00	0.00	159.09	159.09	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	346.57%	0.65	0.81	0.475	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	122.29	0.00	0.00	116.90	116.90	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	86.38%	0.96	0.31		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	118.22	0.00	0.00	266.80	266.80	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	130.69%	0.94	0.16	0.58	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	117.47	0.00	0.00	628.01	628.01	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	307.62%	0.94	1.43	0.795	825	$ 348.60	$ 28,273.87
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	122.29	0.00	0.00	175.43	175.43	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	210.78%	0.75	0.87	0.495	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	117.92	0.00	0.00	226.86	226.86	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	167.62%	0.85	1.21	0.545	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	112.39	0.00	0.00	316.19	316.19	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	233.63%	0.85	0.89	0.615	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	108.65	0.00	0.00	359.86	359.86	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	176.28%	0.94	0.24	0.645	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	107.71	0.00	0.00	373.47	373.47	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	182.94%	0.94	0.34	0.655	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	122.29	0.00	0.00	167.04	167.04	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	123.42%	0.85	0.25	0.485	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	121.02	0.00	0.00	194.54	194.54	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	143.74%	0.85	1.85	0.515	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	112.29	0.00	0.00	265.21	265.21	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	78.86%	1.33	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	112.08	0.00	0.00	427.87	427.87	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	127.22%	1.19	1.80	0.655	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	104.86	0.00	0.00	504.81	504.81	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	150.10%	1.19	0.55	0.695	750	$ 300.50	$ 11,711.80
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	102.87	0.00	0.00	895.16	895.16	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	266.17%	1.19	0.22	0.86	900	$ 418.20	$ 6,477.88
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	102.10	0.00	0.00	888.48	888.48	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	264.19%	1.19	1.23	0.86	900	$ 418.20	$ 36,855.89
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	97.97	0.00	0.00	1424.86	1424.86	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	423.68%	1.19	0.96	1.025	1050	$ 525.50	$ 36,128.27
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	95.00	0.00	0.00	1381.59	1381.59	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	410.81%	1.19	0.10	1.015	1050	$ 525.50	$ 3,828.41
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	122.29	0.00	0.00	79.81	79.81	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	173.87%	0.65	1.13	0.37	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	116.68	0.00	0.00	76.15	76.15	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	165.89%	0.65	0.27	0.36	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	115.41	0.00	0.00	118.34	118.34	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	57.97%	0.99	1.76		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.16	107.89	0.00	0.00	264.74	264.74	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	129.68%	0.94	0.54	0.575	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.70	105.79	0.00	0.00	299.56	299.56	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	89.07%	1.35	1.31		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.02	101.05	0.00	0.00	420.46	420.46	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	125.02%	1.19	1.07	0.65	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.09	97.53	0.00	0.00	671.28	671.28	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	199.60%	1.19	0.20	0.775	825	$ 348.60	$ 4,938.23
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.29	96.91	0.00	0.00	666.98	666.98	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	198.33%	1.19	0.87	0.77	825	$ 348.60	$ 21,731.28
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.16	94.27	0.00	0.00	785.83	785.83	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	233.66%	1.19	0.24	0.82	825	$ 348.60	$ 5,982.87
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.40	93.57	0.00	0.00	780.00	780.00	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	231.93%	1.19	0.60	0.82	825	$ 348.60	$ 14,897.78
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.00	91.87	0.00	0.00	765.88	765.88	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	227.73%	1.19	0.77	0.815	825	$ 348.60	$ 19,232.93

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	18	0	0
525	138	0	139	33	70	31	147	105
600	161	112	107	105	115	9	66	137
675	0	167	14	337	38	0	207	76
750	0	232	13	195	0	0	39	0
825	0	64	208	100	0	81	0	192
900	0	0	0	215	96	0	104	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	15	0	0	76	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	5
Location	Mount Hope
a	1049.5
b	8
c	0.803

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	103.04	9.96	9.96	12.76	22.71	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	11.13%	0.63	0.81		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	103.04	25.72	25.72	32.96	58.68	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	70.51%	0.83	1.27		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.27	97.55	42.38	68.10	82.62	150.72	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	73.83%	1.04	1.72		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	12.99	91.07	98.17	176.22	199.60	375.82	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	111.75%	1.19	0.77	0.625	675	$ 227.90	$ 12,467.61
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.76	88.49	17.06	193.28	212.71	405.99	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	120.72%	1.19	1.49	0.64	675	$ 227.90	$ 24,238.88
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	103.04	39.49	39.49	50.60	90.09	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	196.27%	0.65	1.43	0.385	450	$ 101.30	$ 5,646.16
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	103.04	72.72	72.72	93.19	165.91	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	361.44%	0.65	1.83	0.485	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	95.34	73.67	146.39	173.57	319.96	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	697.03%	0.65	0.34	0.62	675	$ 227.90	$ 3,002.16
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	103.04	8.88	8.88	11.38	20.26	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	44.13%	0.64	0.28		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	94.05	10.96	166.23	194.44	360.66	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	266.49%	0.85	1.93	0.645	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	87.40	83.26	249.48	271.18	520.66	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	255.04%	0.94	1.06	0.745	750	$ 300.50	$ 18,025.71
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	84.17	54.68	304.16	318.40	622.56	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	185.12%	1.19	0.38	0.755	825	$ 348.60	$ 9,467.13
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	83.08	23.10	327.26	338.12	665.38	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	197.85%	1.19	1.12	0.77	825	$ 348.60	$ 27,971.66
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	80.02	70.96	398.22	396.30	794.52	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	236.25%	1.19	0.64	0.825	900	$ 418.20	$ 19,006.56
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	78.40	85.57	523.28	510.21	1033.49	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	307.30%	1.19	0.15	0.91	975	$ 458.80	$ 5,006.02
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	78.02	1.01	524.28	508.72	1033.01	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	307.16%	1.19	0.06	0.91	975	$ 458.80	$ 1,835.51
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	77.88	0.00	524.28	507.83	1032.11	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	306.89%	1.19	0.13	0.91	975	$ 458.80	$ 4,173.90
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	77.57	0.00	524.28	505.80	1030.08	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	375.13%	0.97	1.10	0.98	1050	$ 525.50	$ 33,652.60
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	75.00	0.00	524.28	489.03	1013.31	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	301.31%	1.19	0.15	0.905	975	$ 458.80	$ 4,908.37
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	74.66	0.00	524.28	486.84	1011.12	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	300.65%	1.19	2.13	0.9	975	$ 458.80	$ 69,863.45
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	103.04	26.03	26.03	33.36	59.39	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	129.38%	0.65	1.53	0.33	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	96.50	57.18	83.21	99.86	183.07	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	398.82%	0.65	1.47	0.505	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	91.02	51.39	134.60	152.37	286.97	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	212.04%	0.85	1.62	0.595	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	85.76	85.82	220.42	235.11	455.53	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	223.14%	0.94	1.90	0.705	750	$ 300.50	$ 32,298.17
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	80.39	102.86	323.28	323.20	646.49	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	316.68%	0.94	0.25	0.805	825	$ 348.60	$ 4,950.71
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	103.04	27.68	27.68	35.47	63.14	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	75.87%	0.84	1.17		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.17	97.97	52.53	80.21	97.73	177.93	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	131.47%	0.85	0.91	0.495	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	94.38	52.54	132.75	155.81	288.56	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	213.21%	0.85	1.11	0.595	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	79.73	51.97	508.01	503.75	1011.75	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	300.84%	1.19	0.18	0.9	975	$ 458.80	$ 5,943.45
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	79.27	9.91	517.91	510.57	1028.48	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	305.81%	1.19	1.38	0.91	975	$ 458.80	$ 45,303.74
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	75.90	77.67	595.58	562.23	1157.81	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	344.27%	1.19	1.53	0.95	975	$ 458.80	$ 50,004.71
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	103.04	51.30	51.30	65.75	117.05	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	254.99%	0.65	1.97	0.425	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	94.79	84.55	135.85	160.16	296.01	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	355.67%	0.75	0.72	0.6	675	$ 227.90	$ 7,443.79
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	92.13	35.20	171.06	195.99	367.04	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	271.21%	0.85	0.96	0.65	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	88.83	56.65	227.70	251.55	479.25	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	354.12%	0.85	1.84	0.72	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	103.04	161.46	161.46	206.91	368.37	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1304.94%	0.58	1.63	0.655	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	96.09	84.04	245.50	293.39	538.89	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	1173.98%	0.65	1.93	0.75	825	$ 348.60	$ 26,150.98
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	89.14	47.86	293.36	325.22	618.59	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	743.24%	0.75	0.77	0.79	825	$ 348.60	$ 12,135.90
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	86.66	0.00	293.36	316.19	609.55	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	450.39%	0.85	0.92	0.79	825	$ 348.60	$ 16,376.85
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	83.21	107.38	628.45	650.36	1278.81	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	626.41%	0.94	0.25	1.04	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	82.49	18.65	647.10	663.90	1311.00	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	389.82%	1.19	1.23	0.995	1050	$ 525.50	$ 45,996.69
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	79.22	68.94	716.04	705.51	1421.55	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	422.69%	1.19	0.53	1.025	1050	$ 525.50	$ 19,911.47
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	103.04	314.61	314.61	403.16	717.77	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	117.71%	1.38	0.97	0.795	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	98.80	86.33	400.94	492.67	893.61	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	146.55%	1.38	1.21	0.86	900	$ 418.20	$ 41,864.72
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.17	94.02	164.77	565.71	661.49	1227.20	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	156.09%	1.47	0.86	0.97	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	103.04	128.60	128.60	164.79	293.39	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	63.72%	1.38	1.04		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.04	98.50	262.16	390.76	478.68	869.43	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	188.84%	1.29	1.49	0.855	900	$ 418.20	$ 48,101.02
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	13.03	90.93	0.00	956.47	1081.66	2038.13	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	136.27%	1.73	0.15	1.175	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	77.90	42.79	1715.30	1661.77	3377.08	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	225.79%	1.73	0.16	1.415	1500	$ 1,036.00	$ 17,366.04
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	103.04	51.15	51.15	65.55	116.71	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	86.23%	0.96	1.33		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.33	97.32	69.55	120.70	146.10	266.80	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	197.13%	0.85	1.37	0.58	600	$ 148.70	$ 10,432.98
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.70	92.10	74.65	195.35	223.76	419.11	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	205.30%	0.94	0.25	0.685	750	$ 300.50	$ 4,258.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.95	91.22	0.00	195.35	221.61	416.96	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	204.25%	0.94	1.78	0.685	750	$ 300.50	$ 30,195.19
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.73	85.45	79.36	274.71	291.93	566.64	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	277.57%	0.94	0.66	0.765	825	$ 348.60	$ 13,073.91
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.39	83.50	452.17	726.88	754.82	1481.70	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	440.58%	1.19	1.34	1.04	1050	$ 525.50	$ 50,233.96
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	103.04	104.60	104.60	134.04	238.64	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	519.88%	0.65	0.81	0.555	600	$ 148.70	$ 4,674.37
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	103.04	76.86	76.86	98.50	175.36	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	129.57%	0.85	0.35	0.495	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	99.47	0.00	181.46	224.49	405.95	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	198.85%	0.94	0.16	0.675	750	$ 300.50	$ 2,663.68
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	98.81	248.42	429.88	528.29	958.16	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	469.35%	0.94	1.43	0.935	975	$ 458.80	$ 37,211.85
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	103.04	115.34	115.34	147.81	263.15	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	316.18%	0.75	0.87	0.575	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	99.21	39.35	154.69	190.86	345.56	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	255.33%	0.85	1.21	0.635	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	94.39	71.52	226.21	265.55	491.76	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	363.36%	0.85	0.89	0.725	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	91.14	40.10	266.31	301.87	568.18	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	278.32%	0.94	0.24	0.765	825	$ 348.60	$ 4,676.97
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	90.32	12.49	278.80	313.19	592.00	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	289.99%	0.94	0.34	0.78	825	$ 348.60	$ 6,659.95
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	103.04	109.83	109.83	140.74	250.56	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	185.14%	0.85	0.25	0.565	600	$ 148.70	$ 1,863.53
64	Bayside	Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	101.92	19.43	129.25	163.84	293.09	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	216.56%	0.85	1.85	0.6	675	$ 227.90	$ 21,570.10
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	94.30	60.65	189.90	222.73	412.63	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	122.69%	1.19	0.06	0.645	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	94.09	117.06	306.96	359.22	666.18	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	198.09%	1.19	1.80	0.77	825	$ 348.60	$ 44,824.72
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	87.84	80.12	387.09	422.88	809.97	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	240.84%	1.19	0.55	0.83	900	$ 418.20	$ 16,299.08
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	86.13	33.78	699.67	749.44	1449.11	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	430.89%	1.19	0.22	1.03	1050	$ 525.50	$ 8,139.94
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	85.46	0.00	699.67	743.68	1443.36	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	429.18%	1.19	1.23	1.03	1050	$ 525.50	$ 46,312.22
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	81.91	469.73	1169.41	1191.24	2360.65	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	701.93%	1.19	0.96	1.24	1350	$ 847.00	$ 58,231.49
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	79.36	0.00	1169.41	1154.12	2323.53	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	690.89%	1.19	0.10	1.23	1350	$ 847.00	$ 6,170.63
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	103.04	52.48	52.48	67.25	119.72	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	260.81%	0.65	1.13	0.43	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	98.13	0.00	52.48	64.04	116.52	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	253.83%	0.65	0.27	0.425	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	97.02	29.97	82.45	99.48	181.93	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	89.12%	1.07	1.62		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.03	90.95	114.85	197.30	223.17	420.47	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	205.96%	0.94	0.54	0.685	750	$ 300.50	$ 9,226.68
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.57	89.11	30.39	227.69	252.33	480.02	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	142.73%	1.19	1.49	0.685	750	$ 300.50	$ 32,029.46
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.06	84.45	106.87	334.55	351.36	685.91	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	203.95%	1.19	1.07	0.78	825	$ 348.60	$ 26,610.06
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.13	81.43	218.85	553.41	560.43	1113.84	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	331.20%	1.19	0.20	0.935	975	$ 458.80	$ 6,499.31
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.33	80.89	0.00	553.41	556.76	1110.16	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	330.10%	1.19	0.87	0.935	975	$ 458.80	$ 28,601.01
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.20	78.63	116.88	670.29	655.51	1325.80	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	394.22%	1.19	0.24	1	1050	$ 525.50	$ 9,018.93
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.44	78.04	0.00	670.29	650.53	1320.82	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	392.74%	1.19	0.60	0.995	1050	$ 525.50	$ 22,457.79
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.04	76.59	0.00	670.29	638.49	1308.79	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	389.16%	1.19	0.77	0.995	1050	$ 525.50	$ 28,992.84

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	0	118	0	0	0	0	0
450	0	56	0	77	77	0	0	55
525	138	71	104	0	0	18	0	105
600	0	0	139	0	70	31	52	0
675	161	112	0	224	0	0	160	0
750	0	60	107	94	115	9	46	137
825	0	107	14	237	38	0	161	76
900	0	45	0	215	0	0	39	0
975	0	187	221	76	0	81	0	77
1050	0	64	0	140	96	0	104	115
1200	0	0	0	15	0	0	0	0
1350	0	0	0	0	0	0	76	0
1500	0	0	0	17	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75.5	m
Total Basement Q	1.54	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	5
Location	Mount Hope
a	1049.5
b	8
c	0.803

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	103.04	2.54	2.54	12.76	15.30	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	7.49%	0.56	0.91		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	103.04	6.56	6.56	32.96	39.53	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	47.49%	0.75	1.39		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.39	97.06	10.82	17.38	82.21	99.59	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	48.78%	0.95	1.89		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.28	90.08	25.05	44.97	197.42	242.39	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	72.07%	1.31	0.70		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.98	87.78	4.35	49.33	211.00	260.32	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	77.41%	1.33	1.34		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	103.04	10.08	10.08	50.60	60.68	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	132.20%	0.65	1.43	0.335	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	103.04	18.56	18.56	93.19	111.75	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	243.44%	0.65	1.83	0.42	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	95.34	18.80	37.36	173.57	210.93	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	459.51%	0.65	0.34	0.53	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	103.04	2.27	2.27	11.38	13.64	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	29.72%	0.57	0.31		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	94.05	2.80	42.42	194.44	236.86	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	175.01%	0.85	1.93	0.555	600	$ 148.70	$ 14,650.12
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	87.40	21.25	63.67	271.18	334.85	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	164.02%	0.94	1.06	0.63	675	$ 227.90	$ 13,670.74
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	84.17	13.95	77.62	318.40	396.02	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	117.76%	1.19	0.38	0.635	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	83.08	5.89	83.52	338.12	421.64	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	125.37%	1.19	1.12	0.65	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	80.02	18.11	101.62	396.30	497.93	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	148.06%	1.19	0.64	0.69	750	$ 300.50	$ 13,657.27
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	78.40	21.84	133.54	510.21	643.75	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	191.42%	1.19	0.15	0.76	825	$ 348.60	$ 3,803.61
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	78.02	0.26	133.80	508.72	642.52	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	191.05%	1.19	0.06	0.76	825	$ 348.60	$ 1,394.64
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	77.88	0.00	133.80	507.83	641.62	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	190.78%	1.19	0.13	0.76	825	$ 348.60	$ 3,171.36
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	77.57	0.00	133.80	505.80	639.59	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	232.92%	0.97	1.10	0.82	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	75.00	0.00	133.80	489.03	622.83	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	185.20%	1.19	0.15	0.755	825	$ 348.60	$ 3,729.42
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	74.66	0.00	133.80	486.84	620.64	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	184.54%	1.19	2.13	0.75	825	$ 348.60	$ 53,082.82
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	103.04	6.64	6.64	33.36	40.00	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	87.14%	0.74	1.35		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.35	97.22	14.59	21.24	100.61	121.85	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	265.45%	0.65	1.47	0.43	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.82	91.66	13.11	34.35	153.44	187.79	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	138.75%	0.85	1.62	0.505	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.44	86.32	21.90	56.25	236.63	292.88	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	143.47%	0.94	1.90	0.6	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.34	80.87	26.25	82.50	325.14	407.64	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	199.68%	0.94	0.25	0.68	750	$ 300.50	$ 4,267.61
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	103.04	7.06	7.06	35.47	42.53	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	51.10%	0.77	1.27		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.27	97.54	13.41	20.47	97.30	117.76	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	87.01%	0.97	0.81		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.08	94.38	13.41	33.88	155.82	189.70	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	140.17%	0.85	1.11	0.51	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.59	80.20	13.26	129.64	506.73	636.37	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	189.22%	1.19	0.18	0.76	825	$ 348.60	$ 4,515.88
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.77	79.73	2.53	132.17	513.56	645.73	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	192.01%	1.19	1.38	0.765	825	$ 348.60	$ 34,422.15
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.16	76.33	19.82	151.99	565.36	717.35	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	213.30%	1.19	1.53	0.795	825	$ 348.60	$ 37,993.99
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	103.04	13.09	13.09	65.75	78.84	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	171.75%	0.65	1.97	0.365	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	94.79	21.58	34.67	160.16	194.83	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	234.09%	0.75	0.72	0.515	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	92.13	8.98	43.65	195.99	239.64	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	177.07%	0.85	0.96	0.555	600	$ 148.70	$ 7,300.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	88.83	14.46	58.11	251.55	309.66	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	228.80%	0.85	1.84	0.61	675	$ 227.90	$ 21,355.31
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	103.04	41.20	41.20	206.91	248.11	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	878.93%	0.58	1.63	0.565	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	96.09	21.45	62.65	293.39	356.04	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	775.64%	0.65	1.93	0.645	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	89.14	12.21	74.87	325.22	400.09	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	480.71%	0.75	0.77	0.675	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	86.66	0.00	74.87	316.19	391.05	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	288.94%	0.85	0.92	0.665	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	83.21	27.40	160.38	650.36	810.74	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	397.13%	0.94	0.25	0.875	900	$ 418.20	$ 6,010.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	82.49	4.76	165.14	663.90	829.04	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	246.51%	1.19	1.23	0.84	900	$ 418.20	$ 36,604.79
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	79.22	17.59	182.73	705.51	888.24	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	264.12%	1.19	0.53	0.86	900	$ 418.20	$ 15,845.82
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	103.04	80.29	80.29	403.16	483.45	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	79.28%	1.54	0.86		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.86	99.23	22.03	102.32	494.83	597.14	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	97.93%	1.57	1.06	0.755	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	11.93	94.96	42.05	144.37	668.12	812.49	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	103.34%	1.47	0.86	0.83	900	$ 418.20	$ 31,626.94
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	103.04	32.82	32.82	164.79	197.61	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	42.92%	1.25	1.14		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.14	98.07	66.90	99.72	476.59	576.31	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	125.17%	1.29	1.49	0.73	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.78	91.80	0.00	244.09	1092.05	1336.14	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	89.33%	1.96	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	77.90	10.92	437.74	1661.77	2099.52	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	140.37%	1.73	0.16	1.185	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	103.04	13.05	13.05	65.55	78.61	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	58.08%	0.89	1.43		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.43	96.90	17.75	30.80	145.46	176.27	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	130.24%	0.85	1.37	0.495	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.80	91.73	19.05	49.85	222.86	272.71	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	133.59%	0.94	0.25	0.585	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.05	90.85	0.00	49.85	220.73	270.58	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	132.54%	0.94	1.78	0.58	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.83	85.13	20.25	70.11	290.86	360.96	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	176.81%	0.94	0.66	0.65	675	$ 227.90	$ 8,547.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.49	83.20	115.39	185.50	752.11	937.61	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	278.80%	1.19	1.34	0.875	900	$ 418.20	$ 39,976.86
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	103.04	26.69	26.69	134.04	160.73	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	350.16%	0.65	0.81	0.48	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	103.04	19.62	19.62	98.50	118.11	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	87.27%	0.97	0.31		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	99.47	0.00	46.31	224.49	270.80	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	132.65%	0.94	0.16	0.58	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	98.81	63.40	109.70	528.29	637.99	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	312.51%	0.94	1.43	0.8	825	$ 348.60	$ 28,273.87
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	103.04	29.44	29.44	147.81	177.24	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	212.96%	0.75	0.87	0.495	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	99.21	10.04	39.48	190.86	230.34	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	170.20%	0.85	1.21	0.55	600	$ 148.70	$ 9,164.83
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	94.39	18.25	57.73	265.55	323.28	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	238.87%	0.85	0.89	0.62	675	$ 227.90	$ 10,400.63
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	91.14	10.23	67.96	301.87	369.83	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	181.16%	0.94	0.24	0.655	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	90.32	3.19	71.15	313.19	384.34	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	188.27%	0.94	0.34	0.665	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	103.04	28.03	28.03	140.74	168.77	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	124.70%	0.85	0.25	0.49	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	101.92	4.96	32.99	163.84	196.83	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	145.43%	0.85	1.85	0.515	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	94.30	15.48	48.46	222.73	271.19	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	80.64%	1.33	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	94.12	29.87	78.34	359.30	437.64	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	130.13%	1.19	1.80	0.66	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	87.86	20.45	98.78	422.97	521.76	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	155.14%	1.19	0.55	0.705	750	$ 300.50	$ 11,711.80
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	86.14	8.62	178.56	749.60	928.16	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	275.98%	1.19	0.22	0.875	900	$ 418.20	$ 6,477.88
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.71	85.48	0.00	178.56	743.85	922.40	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	274.27%	1.19	1.23	0.87	900	$ 418.20	$ 36,855.89
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	81.92	119.87	298.43	1191.49	1489.92	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	443.02%	1.19	0.96	1.045	1050	$ 525.50	$ 36,128.27
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	79.37	0.00	298.43	1154.35	1452.78	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	431.98%	1.19	0.10	1.035	1050	$ 525.50	$ 3,828.41
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	103.04	13.39	13.39	67.25	80.64	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	175.67%	0.65	1.13	0.37	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	98.13	0.00	13.39	64.04	77.43	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	168.69%	0.65	0.27	0.365	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	97.02	7.65	21.04	99.48	120.52	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	59.04%	0.99	1.75		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.15	90.51	29.31	50.35	222.09	272.44	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	133.45%	0.94	0.54	0.585	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.70	88.69	7.76	58.11	251.14	309.24	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	91.95%	1.36	1.31		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.01	84.61	27.27	85.38	352.03	437.41	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	130.06%	1.19	1.07	0.66	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.08	81.58	55.85	141.23	561.45	702.68	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	208.94%	1.19	0.20	0.785	825	$ 348.60	$ 4,938.23
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.28	81.04	0.00	141.23	557.76	698.99	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	207.84%	1.19	0.87	0.785	825	$ 348.60	$ 21,731.28
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.15	78.77	29.83	171.06	656.66	827.72	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	246.12%	1.19	0.24	0.835	900	$ 418.20	$ 7,177.39
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.39	78.17	0.00	171.06	651.66	822.72	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	244.63%	1.19	0.60	0.835	900	$ 418.20	$ 17,872.21
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	17.99	76.72	0.00	171.06	639.57	810.63	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	241.04%	1.19	0.77	0.83	900	$ 418.20	$ 23,072.90

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	18	0	0
525	138	0	139	33	70	31	147	105
600	161	112	0	105	115	9	66	137
675	0	167	107	302	38	0	207	76
750	0	45	14	230	0	0	39	0
825	0	251	221	100	0	81	0	77
900	0	0	0	215	96	0	104	115
975	0	0	0	0	0	0	0	0
1050	0	0	0	15	0	0	76	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	5
Location	Mount Hope
a	1049.5
b	8
c	0.803

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	103.04	0.66	0.66	12.76	13.41	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	6.57%	0.54	0.95		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	103.04	1.70	1.70	32.96	34.66	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	41.64%	0.73	1.44		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.44	96.88	2.80	4.50	82.05	86.55	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	42.39%	0.92	1.96		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.40	89.69	6.48	11.64	196.56	208.20	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	61.91%	1.27	0.72		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.12	87.34	1.13	12.76	209.94	222.70	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	66.22%	1.29	1.38		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	103.04	2.61	2.61	50.60	53.21	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	115.92%	0.65	1.43	0.315	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	103.04	4.80	4.80	93.19	97.99	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	213.47%	0.65	1.83	0.4	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	95.34	4.86	9.67	173.57	183.24	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	399.18%	0.65	0.34	0.505	525	$ 110.50	$ 1,455.63
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	103.04	0.59	0.59	11.38	11.96	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	26.06%	0.55	0.32		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	94.05	0.72	10.98	194.44	205.41	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	151.78%	0.85	1.93	0.525	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	87.40	5.50	16.47	271.18	287.65	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	140.90%	0.94	1.06	0.595	600	$ 148.70	$ 8,919.87
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	84.17	3.61	20.08	318.40	338.48	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	100.65%	1.19	0.38	0.605	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	83.08	1.52	21.61	338.12	359.73	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	106.96%	1.19	1.12	0.615	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	80.02	4.69	26.29	396.30	422.60	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	125.66%	1.19	0.64	0.65	675	$ 227.90	$ 10,357.71
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	78.40	5.65	34.55	510.21	544.76	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	161.98%	1.19	0.15	0.715	750	$ 300.50	$ 3,278.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	78.02	0.07	34.62	508.72	543.34	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	161.56%	1.19	0.06	0.715	750	$ 300.50	$ 1,202.20
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	77.88	0.00	34.62	507.83	542.44	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	161.29%	1.19	0.13	0.715	750	$ 300.50	$ 2,733.78
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	77.57	0.00	34.62	505.80	540.41	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	196.80%	0.97	1.10	0.77	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	75.00	0.00	34.62	489.03	523.65	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	155.71%	1.19	0.15	0.705	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	74.66	0.00	34.62	486.84	521.46	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	155.05%	1.19	2.13	0.705	750	$ 300.50	$ 45,758.43
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	103.04	1.72	1.72	33.36	35.08	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	76.42%	0.72	1.38		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.38	97.11	3.78	5.49	100.50	106.00	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	230.91%	0.65	1.47	0.41	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.85	91.56	3.39	8.89	153.28	162.16	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	119.82%	0.85	1.62	0.48	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.47	86.24	5.67	14.55	236.40	250.96	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	122.93%	0.94	1.90	0.565	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.37	80.80	6.79	21.35	324.85	346.19	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	169.58%	0.94	0.25	0.64	675	$ 227.90	$ 3,236.57
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	103.04	1.83	1.83	35.47	37.29	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	44.81%	0.74	1.31		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.31	97.37	3.47	5.30	97.12	102.42	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	75.68%	0.94	0.82		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.14	94.16	3.47	8.77	155.45	164.22	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	121.34%	0.85	1.11	0.485	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.62	80.13	3.43	33.54	506.28	539.82	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	160.51%	1.19	0.18	0.715	750	$ 300.50	$ 3,892.78
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.80	79.66	0.65	34.20	513.12	547.31	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	162.74%	1.19	1.38	0.715	750	$ 300.50	$ 29,672.56
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.18	76.26	5.13	39.32	564.89	604.22	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	179.66%	1.19	1.53	0.745	750	$ 300.50	$ 32,751.56
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	103.04	3.39	3.39	65.75	69.13	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	150.61%	0.65	1.97	0.35	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	94.79	5.58	8.97	160.16	169.13	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	203.21%	0.75	0.72	0.49	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	92.13	2.32	11.29	195.99	207.28	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	153.16%	0.85	0.96	0.525	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	88.83	3.74	15.03	251.55	266.58	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	196.98%	0.85	1.84	0.58	600	$ 148.70	$ 13,933.89
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	103.04	10.66	10.66	206.91	217.57	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	770.73%	0.58	1.63	0.535	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	96.09	5.55	16.21	293.39	309.60	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	674.47%	0.65	1.93	0.61	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	89.14	3.16	19.37	325.22	344.59	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	414.03%	0.75	0.77	0.635	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	86.66	0.00	19.37	316.19	335.56	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	247.94%	0.85	0.92	0.63	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	83.21	7.09	41.50	650.36	691.85	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	338.90%	0.94	0.25	0.825	900	$ 418.20	$ 6,010.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	82.49	1.23	42.73	663.90	706.63	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	210.11%	1.19	1.23	0.79	825	$ 348.60	$ 30,512.74
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	79.22	4.55	47.28	705.51	752.79	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	223.84%	1.19	0.53	0.81	825	$ 348.60	$ 13,208.64
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	103.04	20.77	20.77	403.16	423.93	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	69.52%	1.51	0.88		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.88	99.14	5.70	26.47	494.37	520.85	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	85.42%	1.56	1.07		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	11.95	94.86	10.88	37.35	667.39	704.75	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	89.64%	1.67	0.75		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	103.04	8.49	8.49	164.79	173.29	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	37.64%	1.21	1.18		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.18	97.91	17.31	25.80	475.80	501.60	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	108.95%	1.29	1.49	0.695	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.71	92.08	0.00	63.15	1095.29	1158.45	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	77.45%	1.93	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	77.90	2.83	113.26	1661.77	1775.03	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	118.68%	1.73	0.16	1.115	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	103.04	3.38	3.38	65.55	68.93	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	50.93%	0.87	1.48		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.48	96.72	4.59	7.97	145.19	153.16	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	113.17%	0.85	1.37	0.47	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.85	91.57	4.93	12.90	222.47	235.37	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	115.29%	0.94	0.25	0.55	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.10	90.69	0.00	12.90	220.34	233.24	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	114.25%	0.94	1.78	0.55	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.88	85.00	5.24	18.14	290.39	308.53	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	151.13%	0.94	0.66	0.61	675	$ 227.90	$ 8,547.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.54	83.07	29.86	47.99	750.94	798.94	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	237.56%	1.19	1.34	0.825	900	$ 418.20	$ 39,976.86
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	103.04	6.91	6.91	134.04	140.95	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	307.05%	0.65	0.81	0.455	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	103.04	5.08	5.08	98.50	103.57	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	76.53%	0.95	0.32		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	99.47	0.00	11.98	224.49	236.47	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	115.83%	0.94	0.16	0.555	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	98.81	16.40	28.38	528.29	556.67	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	272.68%	0.94	1.43	0.76	825	$ 348.60	$ 28,273.87
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	103.04	7.62	7.62	147.81	155.43	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	186.75%	0.75	0.87	0.475	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	99.21	2.60	10.21	190.86	201.08	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	148.57%	0.85	1.21	0.52	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	94.39	4.72	14.94	265.55	280.48	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	207.25%	0.85	0.89	0.59	600	$ 148.70	$ 6,786.19
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	91.14	2.65	17.58	301.87	319.45	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	156.48%	0.94	0.24	0.62	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	90.32	0.82	18.41	313.19	331.60	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	162.43%	0.94	0.34	0.625	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	103.04	7.25	7.25	140.74	147.99	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	109.35%	0.85	0.25	0.465	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	101.92	1.28	8.53	163.84	172.38	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	127.37%	0.85	1.85	0.49	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	94.30	4.00	12.54	222.73	235.27	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	69.96%	1.30	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	94.11	7.73	20.27	359.28	379.55	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	112.86%	1.19	1.80	0.625	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	87.86	5.29	25.56	422.95	448.51	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	133.36%	1.19	0.55	0.665	675	$ 227.90	$ 8,882.26
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	86.14	2.23	46.20	749.57	795.77	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	236.62%	1.19	0.22	0.825	900	$ 418.20	$ 6,477.88
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	85.48	0.00	46.20	743.81	790.01	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	234.91%	1.19	1.23	0.825	900	$ 418.20	$ 36,855.89
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	81.92	31.02	77.21	1191.44	1268.65	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	377.23%	1.19	0.96	0.98	1050	$ 525.50	$ 36,128.27
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	79.37	0.00	77.21	1154.30	1231.51	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	366.19%	1.19	0.10	0.97	975	$ 458.80	$ 3,342.48
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	103.04	3.46	3.46	67.25	70.71	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	154.04%	0.65	1.13	0.355	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	98.13	0.00	3.46	64.04	67.51	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	147.06%	0.65	0.27	0.345	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	97.02	1.98	5.44	99.48	104.93	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	51.40%	0.96	1.81		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.21	90.31	7.58	13.03	221.60	234.62	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	114.93%	0.94	0.54	0.55	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.75	88.50	2.01	15.03	250.59	265.63	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	78.98%	1.33	1.34		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.09	84.36	7.06	22.09	351.01	373.10	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	110.94%	1.19	1.07	0.62	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.16	81.35	14.45	36.54	559.90	596.44	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	177.35%	1.19	0.20	0.74	750	$ 300.50	$ 4,256.85
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.36	80.82	0.00	36.54	556.24	592.78	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	176.26%	1.19	0.87	0.74	750	$ 300.50	$ 18,732.79
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.23	78.56	7.72	44.26	654.92	699.18	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	207.90%	1.19	0.24	0.785	825	$ 348.60	$ 5,982.87
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.47	77.97	0.00	44.26	649.95	694.21	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	206.42%	1.19	0.60	0.785	825	$ 348.60	$ 14,897.78
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.07	76.53	0.00	44.26	637.94	682.20	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	202.85%	1.19	0.77	0.78	825	$ 348.60	$ 19,232.93

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	18	0	0
525	138	112	139	82	70	31	208	105
600	161	60	107	150	115	9	50	137
675	0	153	14	243	38	0	200	76
750	0	187	221	295	0	0	0	77
825	0	64	0	201	0	81	0	115
900	0	0	0	14	96	0	104	0
975	0	0	0	0	0	0	7	0
1050	0	0	0	15	0	0	69	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	5
Location	Mount Hope
a	1049.5
b	8
c	0.803

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/S)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	103.04	0.22	0.22	12.76	12.97	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	6.36%	0.54	0.96		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	103.04	0.56	0.56	32.96	33.52	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	40.28%	0.72	1.45		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.45	96.83	0.92	1.48	82.01	83.49	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	40.90%	0.91	1.98		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.43	89.58	2.14	3.84	196.33	200.17	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	59.52%	1.26	0.73		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.15	87.22	0.37	4.21	209.66	213.87	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	63.59%	1.27	1.39		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	103.04	0.86	0.86	50.60	51.46	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	112.11%	0.65	1.43	0.315	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	103.04	1.58	1.58	93.19	94.77	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	206.46%	0.65	1.83	0.395	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	95.34	1.60	3.19	173.57	176.76	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	385.07%	0.65	0.34	0.495	525	$ 110.50	$ 1,455.63
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	103.04	0.19	0.19	11.38	11.57	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	25.21%	0.55	0.32		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	94.05	0.24	3.62	194.44	198.06	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	146.34%	0.85	1.93	0.52	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	87.40	1.81	5.43	271.18	276.61	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	135.50%	0.94	1.06	0.585	600	$ 148.70	$ 8,919.87
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	84.17	1.19	6.62	318.40	325.02	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	96.64%	1.35	0.33	0.605	675	$ 227.90	$ 6,189.21
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.49	83.21	0.50	7.13	338.66	345.78	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	102.82%	1.19	1.12	0.605	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.61	80.14	1.55	8.67	396.90	405.58	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	120.60%	1.19	0.64	0.64	675	$ 227.90	$ 10,357.71
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.25	78.51	1.86	11.40	510.97	522.36	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	155.32%	1.19	0.15	0.705	750	$ 300.50	$ 3,278.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.40	78.13	0.02	11.42	509.47	520.89	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	154.88%	1.19	0.06	0.705	750	$ 300.50	$ 1,202.20
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.46	78.00	0.00	11.42	508.57	519.99	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	154.62%	1.19	0.13	0.705	750	$ 300.50	$ 2,733.78
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.59	77.68	0.00	11.42	506.53	517.95	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	188.62%	0.97	1.10	0.76	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.69	75.11	0.00	11.42	489.72	501.13	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	149.01%	1.19	0.15	0.695	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.84	74.77	0.00	11.42	487.52	498.93	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	148.36%	1.19	2.13	0.695	750	$ 300.50	$ 45,758.43
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	103.04	0.57	0.57	33.36	33.93	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	73.91%	0.72	1.39		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.39	97.08	1.25	1.81	100.47	102.28	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	222.81%	0.65	1.47	0.405	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.86	91.53	1.12	2.93	153.23	156.16	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	115.38%	0.85	1.62	0.475	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.48	86.21	1.87	4.80	236.33	241.13	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	118.12%	0.94	1.90	0.555	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.37	80.77	2.24	7.04	324.76	331.80	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	162.53%	0.94	0.25	0.63	675	$ 227.90	$ 3,236.57
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	103.04	0.60	0.60	35.47	36.07	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	43.34%	0.74	1.33		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.33	97.32	1.14	1.75	97.08	98.83	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	73.02%	0.94	0.83		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.15	94.10	1.14	2.89	155.35	158.24	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	116.92%	0.85	1.11	0.475	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.63	80.11	1.13	11.06	506.14	517.20	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	153.79%	1.19	0.18	0.7	750	$ 300.50	$ 3,892.78
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.81	79.64	0.22	11.28	512.98	524.25	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	155.89%	1.19	1.38	0.705	750	$ 300.50	$ 29,672.56
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.19	76.24	1.69	12.97	564.75	577.72	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	171.78%	1.19	1.53	0.73	750	$ 300.50	$ 32,751.56
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	103.04	1.12	1.12	65.75	66.86	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	145.66%	0.65	1.97	0.345	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	94.79	1.84	2.96	160.16	163.12	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	195.99%	0.75	0.72	0.48	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	92.13	0.77	3.73	195.99	199.71	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	147.57%	0.85	0.96	0.52	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	88.83	1.23	4.96	251.55	256.51	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	189.53%	0.85	1.84	0.57	600	$ 148.70	$ 13,933.89
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	103.04	3.52	3.52	206.91	210.42	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	745.42%	0.58	1.63	0.53	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	96.09	1.83	5.35	293.39	298.74	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	650.80%	0.65	1.93	0.605	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	89.14	1.04	6.39	325.22	331.61	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	398.44%	0.75	0.77	0.625	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	86.66	0.00	6.39	316.19	322.57	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	238.35%	0.85	0.92	0.62	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	83.21	2.34	13.69	650.36	664.05	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	325.28%	0.94	0.25	0.815	825	$ 348.60	$ 5,009.78
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	82.49	0.41	14.09	663.90	677.99	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	201.60%	1.19	1.23	0.775	825	$ 348.60	$ 30,512.74
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	79.22	1.50	15.59	705.51	721.10	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	214.42%	1.19	0.53	0.795	825	$ 348.60	$ 13,208.64
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	103.04	6.85	6.85	403.16	410.01	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	67.24%	1.50	0.89		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.89	99.12	1.88	8.73	494.25	502.98	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	82.49%	1.55	1.07		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	11.96	94.82	3.59	12.32	667.09	679.41	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	86.41%	1.67	0.76		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	103.04	2.80	2.80	164.79	167.60	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	36.40%	1.20	1.19		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.19	97.86	5.71	8.51	475.59	484.10	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	105.15%	1.29	1.49	0.685	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.72	92.03	0.00	20.83	1094.70	1115.53	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	74.58%	1.91	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	77.90	0.93	37.35	1661.77	1699.13	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	113.60%	1.73	0.16	1.095	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	103.04	1.11	1.11	65.55	66.67	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	49.26%	0.86	1.49		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.49	96.67	1.51	2.63	145.12	147.75	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	109.17%	0.85	1.37	0.465	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.86	91.52	1.63	4.25	222.36	226.62	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	111.01%	0.94	0.25	0.545	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.11	90.65	0.00	4.25	220.24	224.50	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	109.97%	0.94	1.78	0.54	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.89	84.96	1.73	5.98	290.27	296.25	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	145.12%	0.94	0.66	0.6	675	$ 227.90	$ 8,547.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.55	83.03	9.85	15.83	750.63	766.46	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	227.90%	1.19	1.34	0.815	825	$ 348.60	$ 33,323.61
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	103.04	2.28	2.28	134.04	136.32	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	296.97%	0.65	0.81	0.45	525	$ 110.50	$ 3,473.56
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	103.04	1.67	1.67	98.50	100.17	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	74.01%	0.94	0.32		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	99.47	0.00	3.95	224.49	228.44	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	111.90%	0.94	0.16	0.545	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	98.81	5.41	9.36	528.29	537.65	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	263.36%	0.94	1.43	0.75	825	$ 348.60	$ 28,273.87
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	103.04	2.51	2.51	147.81	150.32	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	180.61%	0.75	0.87	0.465	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	99.21	0.86	3.37	190.86	194.23	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	143.52%	0.85	1.21	0.515	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	94.39	1.56	4.93	265.55	270.47	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	199.85%	0.85	0.89	0.58	600	$ 148.70	$ 6,786.19
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	91.14	0.87	5.80	301.87	307.67	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	150.71%	0.94	0.24	0.61	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	90.32	0.27	6.07	313.19	319.26	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	156.39%	0.94	0.34	0.62	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	103.04	2.39	2.39	140.74	143.13	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	105.76%	0.85	0.25	0.46	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	101.92	0.42	2.81	163.84	166.66	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	123.14%	0.85	1.85	0.485	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	94.30	1.32	4.14	222.73	226.86	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	67.46%	1.29	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	94.11	2.55	6.68	359.28	365.96	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	108.82%	1.19	1.80	0.615	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	87.86	1.74	8.43	422.95	431.38	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	128.27%	1.19	0.55	0.655	675	$ 227.90	$ 8,882.26
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	86.14	0.74	15.24	749.56	764.79	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	227.41%	1.19	0.22	0.815	825	$ 348.60	$ 5,399.78
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	85.48	0.00	15.24	743.80	759.04	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	225.70%	1.19	1.23	0.81	825	$ 348.60	$ 30,722.06
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	81.92	10.23	25.47	1191.42	1216.89	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	361.84%	1.19	0.96	0.965	975	$ 458.80	$ 31,542.63
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	79.37	0.00	25.47	1154.28	1179.75	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	350.79%	1.19	0.10	0.955	975	$ 458.80	$ 3,342.48
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	103.04	1.14	1.14	67.25	68.39	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	148.98%	0.65	1.13	0.35	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	98.13	0.00	1.14	64.04	65.19	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	142.01%	0.65	0.27	0.34	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	97.02	0.65	1.80	99.48	101.28	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	49.61%	0.95	1.83		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.23	90.26	2.50	4.30	221.46	225.76	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	110.59%	0.94	0.54	0.545	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.77	88.44	0.66	4.96	250.45	255.41	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	75.94%	1.32	1.34		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.12	84.29	2.33	7.29	350.71	358.00	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	106.45%	1.19	1.07	0.61	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.18	81.28	4.77	12.05	559.44	571.49	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	169.93%	1.19	0.20	0.73	750	$ 300.50	$ 4,256.85
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.38	80.75	0.00	12.05	555.78	567.83	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	168.84%	1.19	0.87	0.725	750	$ 300.50	$ 18,732.79
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.26	78.50	2.55	14.60	654.40	669.00	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	198.92%	1.19	0.24	0.775	825	$ 348.60	$ 5,982.87
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.50	77.91	0.00	14.60	649.44	664.04	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	197.45%	1.19	0.60	0.77	825	$ 348.60	$ 14,897.78
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.10	76.47	0.00	14.60	637.45	652.04	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	193.88%	1.19	0.77	0.765	825	$ 348.60	$ 19,232.93

Pipe Sizes	Length (m)							
(mm)	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	18	0	0
525	138	112	139	82	70	31	208	105
600	161	60	107	150	115	9	50	137
675	0	153	14	243	38	0	200	76
750	0	187	221	295	0	0	0	77
825	0	64	0	215	96	81	104	115
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	76	0
1050	0	0	0	15	0	0	0	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74	m
Total Basement Q	0.00	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	5
Location	Mount Hope
a	1049.5
b	8
c	0.803

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	103.04	0.00	0.00	12.76	12.76	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	6.25%	0.53	0.96		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	103.04	0.00	0.00	32.96	32.96	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	39.60%	0.72	1.46		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.46	96.80	0.00	0.00	81.99	81.99	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	40.16%	0.90	1.99		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.44	89.53	0.00	0.00	196.22	196.22	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	58.34%	1.25	0.73		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.17	87.16	0.00	0.00	209.51	209.51	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	62.30%	1.27	1.40		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	103.04	0.00	0.00	50.60	50.60	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	110.24%	0.65	1.43	0.31	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	103.04	0.00	0.00	93.19	93.19	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	203.01%	0.65	1.83	0.39	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	95.34	0.00	0.00	173.57	173.57	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	378.12%	0.65	0.34	0.495	525	$ 110.50	$ 1,455.63
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	103.04	0.00	0.00	11.38	11.38	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	24.79%	0.55	0.32		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	94.05	0.00	0.00	194.44	194.44	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	143.67%	0.85	1.93	0.515	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	87.40	0.00	0.00	271.18	271.18	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	132.83%	0.94	1.06	0.58	600	$ 148.70	$ 8,919.87
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	84.17	0.00	0.00	318.40	318.40	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	94.67%	1.36	0.33		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.49	83.21	0.00	0.00	338.66	338.66	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	100.70%	1.19	1.12	0.605	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.61	80.14	0.00	0.00	396.91	396.91	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	118.02%	1.19	0.64	0.635	675	$ 227.90	$ 10,357.71
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.25	78.52	0.00	0.00	510.97	510.97	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	151.94%	1.19	0.15	0.7	750	$ 300.50	$ 3,278.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.40	78.14	0.00	0.00	509.48	509.48	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	151.49%	1.19	0.06	0.7	750	$ 300.50	$ 1,202.20
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.46	78.00	0.00	0.00	508.57	508.57	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	151.22%	1.19	0.13	0.7	750	$ 300.50	$ 2,733.78
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.59	77.69	0.00	0.00	506.54	506.54	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	184.47%	0.97	1.10	0.75	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.69	75.11	0.00	0.00	489.72	489.72	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	145.62%	1.19	0.15	0.69	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.84	74.77	0.00	0.00	487.52	487.52	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	144.96%	1.19	2.13	0.685	750	$ 300.50	$ 45,758.43
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	103.04	0.00	0.00	33.36	33.36	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	72.67%	0.72	1.39		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.39	97.06	0.00	0.00	100.45	100.45	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	218.82%	0.65	1.47	0.4	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.86	91.52	0.00	0.00	153.20	153.20	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	113.20%	0.85	1.62	0.47	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.48	86.20	0.00	0.00	236.29	236.29	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	115.75%	0.94	1.90	0.555	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.38	80.76	0.00	0.00	324.71	324.71	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	159.06%	0.94	0.25	0.62	675	$ 227.90	$ 3,236.57
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	103.04	0.00	0.00	35.47	35.47	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	42.61%	0.73	1.33		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.33	97.30	0.00	0.00	97.06	97.06	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	71.71%	0.94	0.83		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.16	94.06	0.00	0.00	155.30	155.30	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	114.75%	0.85	1.11	0.475	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.63	80.10	0.00	0.00	506.07	506.07	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	150.48%	1.19	0.18	0.695	750	$ 300.50	$ 3,892.78
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.81	79.63	0.00	0.00	512.90	512.90	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	152.51%	1.19	1.38	0.7	750	$ 300.50	$ 29,672.56
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.20	76.23	0.00	0.00	564.67	564.67	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	167.90%	1.19	1.53	0.725	750	$ 300.50	$ 32,751.56
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	103.04	0.00	0.00	65.75	65.75	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	143.23%	0.65	1.97	0.345	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	94.79	0.00	0.00	160.16	160.16	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	192.44%	0.75	0.72	0.48	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	92.13	0.00	0.00	195.99	195.99	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	144.81%	0.85	0.96	0.515	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	88.83	0.00	0.00	251.55	251.55	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	185.87%	0.85	1.84	0.565	600	$ 148.70	$ 13,933.89
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	103.04	0.00	0.00	206.91	206.91	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	732.96%	0.58	1.63	0.525	600	$ 148.70	$ 8,387.12
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	96.09	0.00	0.00	293.39	293.39	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	639.15%	0.65	1.93	0.6	675	$ 227.90	$ 17,096.41
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	89.14	0.00	0.00	325.22	325.22	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	390.76%	0.75	0.77	0.625	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	86.66	0.00	0.00	316.19	316.19	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	233.63%	0.85	0.92	0.615	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	83.21	0.00	0.00	650.36	650.36	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	318.57%	0.94	0.25	0.805	825	$ 348.60	$ 5,009.78
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	82.49	0.00	0.00	663.90	663.90	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	197.41%	1.19	1.23	0.77	825	$ 348.60	$ 30,512.74
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	79.22	0.00	0.00	705.51	705.51	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	209.78%	1.19	0.53	0.79	825	$ 348.60	$ 13,208.64
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	103.04	0.00	0.00	403.16	403.16	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	66.12%	1.49	0.89		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.89	99.11	0.00	0.00	494.18	494.18	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	81.04%	1.55	1.08		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	11.97	94.79	0.00	0.00	666.93	666.93	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	84.83%	1.66	0.76		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	103.04	0.00	0.00	164.79	164.79	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	35.79%	1.20	1.20		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.20	97.84	0.00	0.00	475.48	475.48	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	103.27%	1.29	1.49	0.68	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.73	92.00	0.00	0.00	1094.37	1094.37	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	73.17%	1.91	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	77.90	0.00	0.00	1661.77	1661.77	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	111.10%	1.73	0.16	1.085	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	103.04	0.00	0.00	65.55	65.55	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	48.44%	0.86	1.49		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.49	96.65	0.00	0.00	145.08	145.08	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	107.20%	0.85	1.37	0.46	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.87	91.50	0.00	0.00	222.31	222.31	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	108.90%	0.94	0.25	0.54	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.12	90.63	0.00	0.00	220.19	220.19	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	107.86%	0.94	1.78	0.54	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.89	84.94	0.00	0.00	290.20	290.20	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	142.15%	0.94	0.66	0.595	600	$ 148.70	$ 5,576.85
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.56	83.02	0.00	0.00	750.47	750.47	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	223.15%	1.19	1.34	0.805	825	$ 348.60	$ 33,323.61
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	103.04	0.00	0.00	134.04	134.04	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	292.01%	0.65	0.81	0.445	450	$ 101.30	$ 3,184.36
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	103.04	0.00	0.00	98.50	98.50	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	72.78%	0.94	0.32		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	99.47	0.00	0.00	224.49	224.49	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	109.97%	0.94	0.16	0.54	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	98.81	0.00	0.00	528.29	528.29	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	258.78%	0.94	1.43	0.745	750	$ 300.50	$ 24,372.63
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	103.04	0.00	0.00	147.81	147.81	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	177.60%	0.75	0.87	0.465	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	99.21	0.00	0.00	190.86	190.86	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	141.03%	0.85	1.21	0.51	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	94.39	0.00	0.00	265.55	265.55	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	196.21%	0.85	0.89	0.575	600	$ 148.70	$ 6,786.19
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	91.14	0.00	0.00	301.87	301.87	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	147.87%	0.94	0.24	0.605	675	$ 227.90	$ 3,057.61
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	90.32	0.00	0.00	313.19	313.19	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	153.41%	0.94	0.34	0.615	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	103.04	0.00	0.00	140.74	140.74	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	103.99%	0.85	0.25	0.455	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	101.92	0.00	0.00	163.84	163.84	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	121.06%	0.85	1.85	0.48	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	94.30	0.00	0.00	222.73	222.73	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	66.23%	1.29	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.15	94.11	0.00	0.00	359.28	359.28	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	106.83%	1.19	1.80	0.615	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.95	87.85	0.00	0.00	422.95	422.95	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	125.76%	1.19	0.55	0.65	675	$ 227.90	$ 8,882.26
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	86.14	0.00	0.00	749.55	749.55	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	222.88%	1.19	0.22	0.805	825	$ 348.60	$ 5,399.78
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	85.48	0.00	0.00	743.80	743.80	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	221.16%	1.19	1.23	0.805	825	$ 348.60	$ 30,722.06
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.95	81.92	0.00	0.00	1191.41	1191.41	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	354.26%	1.19	0.96	0.96	975	$ 458.80	$ 31,542.63
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.91	79.37	0.00	0.00	1154.28	1154.28	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	343.22%	1.19	0.10	0.95	975	$ 458.80	$ 3,342.48
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	103.04	0.00	0.00	67.25	67.25	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	146.49%	0.65	1.13	0.345	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	98.13	0.00	0.00	64.04	64.04	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	139.52%	0.65	0.27	0.34	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	97.02	0.00	0.00	99.48	99.48	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	48.73%	0.95	1.84		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.24	90.23	0.00	0.00	221.40	221.40	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	108.45%	0.94	0.54	0.54	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.78	88.42	0.00	0.00	250.37	250.37	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	74.45%	1.32	1.35		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.13	84.25	0.00	0.00	350.55	350.55	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	104.24%	1.19	1.07	0.605	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.20	81.25	0.00	0.00	559.20	559.20	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	166.28%	1.19	0.20	0.725	750	$ 300.50	$ 4,256.85
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.40	80.72	0.00	0.00	555.54	555.54	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	165.19%	1.19	0.87	0.72	750	$ 300.50	$ 18,732.79
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.27	78.47	0.00	0.00	654.13	654.13	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	194.50%	1.19	0.24	0.765	825	$ 348.60	$ 5,982.87
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.51	77.87	0.00	0.00	649.18	649.18	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	193.03%	1.19	0.60	0.765	825	$ 348.60	$ 14,897.78
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.11	76.44	0.00	0.00	637.19	637.19	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	189.47%	1.19	0.77	0.76	825	$ 348.60	$ 19,232.93

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	49	0	0
525	138	112	139	82	70	0	208	105
600	161	87	107	150	152	9	50	137
675	0	126	14	243	0	0	200	76
750	0	187	221	295	0	81	0	77
825	0	64	0	215	96	0	104	115
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	76	0
1050	0	0	0	15	0	0	0	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	2
Location	Mount Hope
a	646
b	6
c	0.781

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9 m/s			
Max. Velocity =	3.65 m/s			

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	74.10	9.96	9.96	9.17	19.13	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	9.37%	0.60	0.85		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	74.10	25.72	25.72	23.70	49.43	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	59.39%	0.80	1.32		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.32	69.66	42.38	68.10	59.00	127.10	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	62.26%	1.01	1.78		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.10	64.52	98.17	176.22	141.41	317.63	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	94.45%	1.36	0.67		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	13.77	62.80	17.06	193.28	150.97	344.25	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	102.36%	1.19	1.49	0.605	675	$ 227.90	$ 24,238.88
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	74.10	39.49	39.49	36.39	75.88	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	165.31%	0.65	1.43	0.36	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	74.10	72.72	72.72	67.02	139.74	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	304.42%	0.65	1.83	0.455	525	$ 110.50	$ 7,870.70
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	68.10	73.67	146.39	123.97	270.36	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	588.98%	0.65	0.34	0.58	600	$ 148.70	$ 1,958.85
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	74.10	8.88	8.88	8.18	17.06	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	37.17%	0.61	0.29		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	67.10	10.96	166.23	138.72	304.95	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	225.32%	0.85	1.93	0.61	675	$ 227.90	$ 22,453.00
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	62.02	83.26	249.48	192.42	441.91	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	216.47%	0.94	1.06	0.7	750	$ 300.50	$ 18,025.71
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	59.58	54.68	304.16	225.36	529.52	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	157.45%	1.19	0.38	0.71	750	$ 300.50	$ 8,160.85
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.54	58.75	23.10	327.26	239.12	566.38	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	168.41%	1.19	1.12	0.725	750	$ 300.50	$ 24,112.12
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.66	56.46	70.96	398.22	279.63	677.85	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	201.56%	1.19	0.64	0.775	825	$ 348.60	$ 15,843.34
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.30	55.25	85.57	523.28	359.59	882.86	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	262.52%	1.19	0.15	0.86	900	$ 418.20	$ 4,563.03
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.45	54.97	1.01	524.28	358.44	882.72	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	262.48%	1.19	0.06	0.855	900	$ 418.20	$ 1,673.08
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.51	54.87	0.00	524.28	357.77	882.06	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	262.28%	1.19	0.13	0.855	900	$ 418.20	$ 3,804.55
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.63	54.64	0.00	524.28	356.27	880.55	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	320.67%	0.97	1.10	0.925	975	$ 458.80	$ 29,381.18
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.73	52.73	0.00	524.28	343.84	868.12	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	258.13%	1.19	0.15	0.85	900	$ 418.20	$ 4,474.02
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.88	52.48	0.00	524.28	342.22	866.51	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	257.65%	1.19	2.13	0.85	900	$ 418.20	$ 63,681.11
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	74.10	26.03	26.03	23.99	50.02	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	108.97%	0.65	1.53	0.31	375	$ 98.30	$ 5,866.81
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.53	68.99	57.18	83.21	71.40	154.61	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	336.82%	0.65	1.47	0.47	525	$ 110.50	$ 6,345.25
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.01	64.78	51.39	134.60	108.44	243.04	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	179.58%	0.85	1.62	0.56	600	$ 148.70	$ 12,267.39
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.62	60.78	85.82	220.42	166.61	387.03	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	189.59%	0.94	1.90	0.665	675	$ 227.90	$ 24,495.02
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.52	56.74	102.86	323.28	228.12	551.40	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	270.10%	0.94	0.25	0.76	825	$ 348.60	$ 4,950.71
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	74.10	27.68	27.68	25.51	53.18	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	63.90%	0.81	1.21		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.21	70.01	52.53	80.21	69.83	150.04	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	110.86%	0.85	0.91	0.465	525	$ 110.50	$ 5,157.05
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.12	67.23	52.54	132.75	111.00	243.75	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	180.10%	0.85	1.11	0.56	600	$ 148.70	$ 8,400.13
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.77	56.25	51.97	508.01	355.37	863.38	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	256.72%	1.19	0.18	0.85	900	$ 418.20	$ 5,417.51
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.95	55.90	9.91	517.91	360.06	877.97	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	261.06%	1.19	1.38	0.855	900	$ 418.20	$ 41,294.73
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.34	53.40	77.67	595.58	395.55	991.13	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	294.71%	1.19	1.53	0.895	900	$ 418.20	$ 45,579.71
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	74.10	51.30	51.30	47.28	98.58	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	214.77%	0.65	1.97	0.4	450	$ 101.30	$ 7,775.77
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	67.68	84.55	135.85	114.34	250.19	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	300.61%	0.75	0.72	0.565	600	$ 148.70	$ 4,856.92
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	65.62	35.20	171.06	139.61	310.66	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	229.55%	0.85	0.96	0.61	675	$ 227.90	$ 11,188.21
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	63.10	56.65	227.70	178.70	406.40	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	300.29%	0.85	1.84	0.675	750	$ 300.50	$ 28,158.27
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	74.10	161.46	161.46	148.80	310.26	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	1099.08%	0.58	1.63	0.61	675	$ 227.90	$ 12,854.23
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	68.68	84.04	245.50	209.69	455.19	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	991.64%	0.65	1.93	0.705	750	$ 300.50	$ 22,542.65
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	63.34	47.86	293.36	231.09	524.46	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	630.15%	0.75	0.77	0.745	750	$ 300.50	$ 10,461.38
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	61.46	0.00	293.36	224.23	517.60	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	382.45%	0.85	0.92	0.74	750	$ 300.50	$ 14,117.17
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	58.85	107.38	628.45	459.99	1088.44	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	533.16%	0.94	0.25	0.98	1050	$ 525.50	$ 7,552.03
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	58.32	18.65	647.10	469.31	1116.41	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	331.96%	1.19	1.23	0.935	975	$ 458.80	$ 40,158.48
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	55.87	68.94	716.04	497.52	1213.56	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	360.85%	1.19	0.53	0.965	975	$ 458.80	$ 17,384.17
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	74.10	314.61	314.61	289.93	604.54	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	99.14%	1.57	0.85	0.755	825	$ 348.60	$ 27,889.06
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.85	71.16	86.33	400.94	354.83	755.77	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	123.94%	1.38	1.21	0.81	825	$ 348.60	$ 34,897.27
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.06	67.41	164.77	565.71	474.28	1039.99	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	132.28%	1.47	0.86	0.91	975	$ 458.80	$ 34,697.37
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	74.10	128.60	128.60	118.51	247.11	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	53.67%	1.33	1.08		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.08	70.41	262.16	390.76	342.18	732.94	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	159.19%	1.29	1.49	0.8	825	$ 348.60	$ 40,095.68
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.92	65.01	0.00	956.47	773.37	1729.84	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	115.66%	1.73	0.15	1.105	1200	$ 658.60	$ 9,961.92
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	54.88	42.79	1715.30	1170.76	2886.07	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	192.96%	1.73	0.16	1.335	1350	$ 847.00	$ 14,197.91
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	74.10	51.15	51.15	47.14	98.29	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	72.63%	0.94	1.36		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.36	69.52	69.55	120.70	104.35	225.05	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	166.29%	0.85	1.37	0.545	600	$ 148.70	$ 10,432.98
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.74	65.50	74.65	195.35	159.14	354.49	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	173.64%	0.94	0.25	0.645	675	$ 227.90	$ 3,229.33
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.99	64.83	0.00	195.35	157.50	352.85	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	172.84%	0.94	1.78	0.64	675	$ 227.90	$ 22,900.11
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.76	60.45	79.36	274.71	206.54	481.25	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	235.74%	0.94	0.66	0.72	750	$ 300.50	$ 11,269.97
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.43	58.99	452.17	726.88	533.25	1260.13	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	374.70%	1.19	1.34	0.98	1050	$ 525.50	$ 50,233.96
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	74.10	104.60	104.60	96.39	200.99	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	437.87%	0.65	0.81	0.52	525	$ 110.50	$ 3,473.56
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	74.10	76.86	76.86	70.83	147.70	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	109.13%	0.85	0.35	0.465	525	$ 110.50	$ 1,982.86
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	71.31	0.00	181.46	160.92	342.39	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	167.72%	0.94	0.16	0.635	675	$ 227.90	$ 2,020.14
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	70.79	248.42	429.88	378.47	808.35	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	395.96%	0.94	1.43	0.875	900	$ 418.20	$ 33,918.91
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	74.10	115.34	115.34	106.30	221.64	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	266.30%	0.75	0.87	0.54	600	$ 148.70	$ 5,848.37
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	71.10	39.35	154.69	136.79	291.48	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	215.37%	0.85	1.21	0.6	675	$ 227.90	$ 14,046.16
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	67.36	71.52	226.21	189.51	415.73	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	307.18%	0.85	0.89	0.685	750	$ 300.50	$ 13,713.86
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	64.87	40.10	266.31	214.85	481.16	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	235.69%	0.94	0.24	0.72	750	$ 300.50	$ 4,031.64
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	64.24	12.49	278.80	222.76	501.57	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	245.69%	0.94	0.34	0.73	750	$ 300.50	$ 5,741.01
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	74.10	109.83	109.83	101.21	211.04	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	155.93%	0.85	0.25	0.53	600	$ 148.70	$ 1,863.53
64	Bayside	Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.25	73.22	19.43	129.25	117.71	246.96	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	182.48%	0.85	1.85	0.56	600	$ 148.70	$ 14,074.04
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.10	67.30	60.65	189.90	158.94	348.85	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	103.73%	1.19	0.06	0.605	675	$ 227.90	$ 911.06
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.16	67.14	117.06	306.96	256.30	563.26	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	167.48%	1.19	1.80	0.725	750	$ 300.50	$ 38,639.78
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.96	62.35	80.12	387.09	300.18	687.26	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	204.36%	1.19	0.55	0.78	825	$ 348.60	$ 13,586.46
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.50	61.05	33.78	699.67	531.26	1230.93	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	366.01%	1.19	0.22	0.97	975	$ 458.80	$ 7,106.77
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.72	60.55	0.00	699.67	526.91	1226.58	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	364.72%	1.19	1.23	0.97	975	$ 458.80	$ 40,433.97
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.96	57.88	469.73	1169.41	841.72	2011.13	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	598.00%	1.19	0.96	1.165	1200	$ 658.60	$ 45,278.94
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.92	55.97	0.00	1169.41	813.96	1983.37	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	589.75%	1.19	0.10	1.16	1200	$ 658.60	$ 4,798.08
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	74.10	52.48	52.48	48.36	100.83	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	219.67%	0.65	1.13	0.4	450	$ 101.30	$ 4,451.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	70.26	0.00	52.48	45.85	98.33	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	214.21%	0.65	0.27	0.4	450	$ 101.30	$ 1,078.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	69.40	29.97	82.45	71.16	153.61	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	75.24%	1.05	1.67		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.07	64.62	114.85	197.30	158.55	355.85	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	174.31%	0.94	0.54	0.645	675	$ 227.90	$ 6,997.54
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.61	63.22	30.39	227.69	179.01	406.69	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	120.93%	1.19	1.49	0.64	675	$ 227.90	$ 24,291.23
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.10	59.69	106.87	334.55	248.37	582.92	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	173.33%	1.19	1.07	0.735	750	$ 300.50	$ 22,938.39
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.17	57.43	218.85	553.41	395.28	948.69	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	282.09%	1.19	0.20	0.88	900	$ 418.20	$ 5,924.18
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.37	57.03	0.00	553.41	392.54	945.95	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	281.28%	1.19	0.87	0.88	900	$ 418.20	$ 26,070.06
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.24	55.35	116.88	670.29	461.44	1131.73	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	336.52%	1.19	0.24	0.94	975	$ 458.80	$ 7,874.19
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.48	54.91	0.00	670.29	457.74	1128.03	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	335.42%	1.19	0.60	0.94	975	$ 458.80	$ 19,607.29
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.08	53.84	0.00	670.29	448.83	1119.12	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	332.77%	1.19	0.77	0.935	975	$ 458.80	$ 25,312.88

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	0	0	0	0	0	0
375	63	56	118	0	0	0	0	0
450	0	0	0	77	77	0	0	55
525	138	71	104	0	0	49	0	105
600	55	13	139	33	70	0	147	0
675	106	99	107	191	115	9	66	137
750	0	167	0	251	38	0	207	76
825	0	45	14	295	0	0	39	0
900	0	187	221	0	0	81	0	77
975	0	64	0	201	0	0	104	115
1050	0	0	0	14	96	0	0	0
1200	0	0	0	15	0	0	76	0
1350	0	0	0	17	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75.5	m
Total Basement Q	1.54	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	2
Location	Mount Hope
a	646
b	6
c	0.781

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	74.10	2.54	2.54	9.17	11.71	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	5.74%	0.52	0.98		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	74.10	6.56	6.56	23.70	30.27	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	36.37%	0.70	1.49		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.49	69.12	10.82	17.38	58.55	75.92	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	37.19%	0.89	2.03		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.52	63.45	25.05	44.97	139.06	184.03	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	54.72%	1.23	0.74		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.26	61.63	4.35	49.33	148.15	197.48	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	58.72%	1.25	1.42		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	74.10	10.08	10.08	36.39	46.47	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	101.23%	0.65	1.43	0.305	375	$ 98.30	$ 5,478.95
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	74.10	18.56	18.56	67.02	85.58	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	186.43%	0.65	1.83	0.38	450	$ 101.30	$ 7,215.41
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	68.10	18.80	37.36	123.97	161.33	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	351.46%	0.65	0.34	0.48	525	$ 110.50	$ 1,455.63
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	74.10	2.27	2.27	8.18	10.45	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	22.76%	0.53	0.33		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	67.10	2.80	42.42	138.72	181.15	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	133.85%	0.85	1.93	0.5	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	62.02	21.25	63.67	192.42	256.09	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	125.44%	0.94	1.06	0.57	600	$ 148.70	$ 8,919.87
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	59.58	13.95	77.62	225.36	302.98	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	90.09%	1.35	0.33		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.49	58.85	5.89	83.52	239.52	323.04	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	96.05%	1.36	0.99	0.605	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.48	56.82	18.11	101.62	281.42	383.04	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	113.90%	1.19	0.64	0.63	675	$ 227.90	$ 10,357.71
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.11	55.60	21.84	133.54	361.82	495.36	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	147.29%	1.19	0.15	0.69	750	$ 300.50	$ 3,278.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.27	55.31	0.26	133.80	360.65	494.45	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	147.02%	1.19	0.06	0.69	750	$ 300.50	$ 1,202.20
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.32	55.21	0.00	133.80	359.97	493.77	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	146.82%	1.19	0.13	0.69	750	$ 300.50	$ 2,733.78
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.45	54.97	0.00	133.80	358.44	492.24	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	179.26%	0.97	1.10	0.745	750	$ 300.50	$ 19,243.78
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.55	53.04	0.00	133.80	345.85	479.65	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	142.62%	1.19	0.15	0.685	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.70	52.79	0.00	133.80	344.21	478.00	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	142.13%	1.19	2.13	0.68	750	$ 300.50	$ 45,758.43
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	74.10	6.64	6.64	23.99	30.63	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	66.73%	0.70	1.41		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.41	69.36	14.59	21.24	71.77	93.01	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	202.62%	0.65	1.47	0.39	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.89	65.09	13.11	34.35	108.96	143.31	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	105.89%	0.85	1.62	0.46	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.50	61.05	21.90	56.25	167.36	223.61	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	109.53%	0.94	1.90	0.54	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.40	56.97	26.25	82.50	229.05	311.55	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	152.61%	0.94	0.25	0.615	675	$ 227.90	$ 3,236.57
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	74.10	7.06	7.06	25.51	32.57	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	39.13%	0.72	1.36		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.36	69.52	13.41	20.47	69.35	89.82	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	66.36%	0.92	0.85		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.21	66.99	13.41	33.88	110.60	144.47	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	106.75%	0.85	1.11	0.46	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.65	56.47	13.26	129.64	356.81	486.45	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	144.64%	1.19	0.18	0.685	750	$ 300.50	$ 3,892.78
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.84	56.12	2.53	132.17	361.50	493.67	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	146.79%	1.19	1.38	0.69	750	$ 300.50	$ 29,672.56
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.22	53.60	19.82	151.99	397.05	549.04	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	163.25%	1.19	1.53	0.72	750	$ 300.50	$ 32,751.56
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	74.10	13.09	13.09	47.28	60.37	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	131.52%	0.65	1.97	0.33	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	67.68	21.58	34.67	114.34	149.01	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	179.04%	0.75	0.72	0.465	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	65.62	8.98	43.65	139.61	183.26	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	135.41%	0.85	0.96	0.505	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	63.10	14.46	58.11	178.70	236.81	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	174.98%	0.85	1.84	0.555	600	$ 148.70	$ 13,933.89
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	74.10	41.20	41.20	148.80	190.00	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	673.07%	0.58	1.63	0.51	525	$ 110.50	$ 6,232.53
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	68.68	21.45	62.65	209.69	272.34	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	593.30%	0.65	1.93	0.585	600	$ 148.70	$ 11,155.05
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	63.34	12.21	74.87	231.09	305.96	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	367.62%	0.75	0.77	0.61	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	61.46	0.00	74.87	224.23	299.10	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	221.00%	0.85	0.92	0.605	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	58.85	27.40	160.38	459.99	620.37	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	303.88%	0.94	0.25	0.795	825	$ 348.60	$ 5,009.78
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	58.32	4.76	165.14	469.31	634.45	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	188.65%	1.19	1.23	0.76	825	$ 348.60	$ 30,512.74
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	55.87	17.59	182.73	497.52	680.26	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	202.27%	1.19	0.53	0.78	825	$ 348.60	$ 13,208.64
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	74.10	80.29	80.29	289.93	370.22	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	60.71%	1.46	0.91		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.91	70.96	22.03	102.32	353.85	456.17	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	74.81%	1.53	1.09		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.00	67.58	42.05	144.37	475.48	619.85	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	78.84%	1.64	0.77		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	74.10	32.82	32.82	118.51	151.33	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	32.87%	1.17	1.23		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.23	69.95	66.90	99.72	339.93	439.65	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	95.49%	1.47	1.31	0.68	750	$ 300.50	$ 34,563.26
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.77	65.42	0.00	244.09	778.15	1022.24	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	68.35%	1.88	0.13		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	54.88	10.92	437.74	1170.76	1608.51	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	107.54%	1.73	0.16	1.075	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	74.10	13.05	13.05	47.14	60.20	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	44.48%	0.84	1.53		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.53	69.01	17.75	30.80	103.59	134.39	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	99.30%	0.97	1.21	0.455	525	$ 110.50	$ 7,752.82
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.74	65.50	19.05	49.85	159.13	208.99	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	102.37%	0.94	0.25	0.53	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	12.99	64.82	0.00	49.85	157.49	207.34	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	101.57%	0.94	1.78	0.53	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.76	60.45	20.25	70.11	206.53	276.64	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	135.51%	0.94	0.66	0.585	600	$ 148.70	$ 5,576.85
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.43	58.99	115.39	185.50	533.24	718.73	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	213.71%	1.19	1.34	0.795	825	$ 348.60	$ 33,323.61
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	74.10	26.69	26.69	96.39	123.09	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	268.15%	0.65	0.81	0.435	450	$ 101.30	$ 3,184.36
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	74.10	19.62	19.62	70.83	90.45	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	66.83%	0.92	0.32		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	71.31	0.00	46.31	160.92	207.23	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	101.51%	0.94	0.16	0.53	600	$ 148.70	$ 1,318.10
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	70.79	63.40	109.70	378.47	488.18	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	239.13%	0.94	1.43	0.725	750	$ 300.50	$ 24,372.63
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	74.10	29.44	29.44	106.30	135.73	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	163.08%	0.75	0.87	0.45	525	$ 110.50	$ 4,345.96
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	71.10	10.04	39.48	136.79	176.26	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	130.24%	0.85	1.21	0.495	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	67.36	18.25	57.73	189.51	247.24	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	182.69%	0.85	0.89	0.56	600	$ 148.70	$ 6,786.19
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	64.87	10.23	67.96	214.85	282.82	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	138.54%	0.94	0.24	0.59	600	$ 148.70	$ 1,995.03
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	64.24	3.19	71.15	222.76	293.91	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	143.97%	0.94	0.34	0.6	675	$ 227.90	$ 4,354.00
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	74.10	28.03	28.03	101.21	129.24	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	95.49%	0.97	0.22	0.455	525	$ 110.50	$ 1,384.81
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.22	73.33	4.96	32.99	117.88	150.86	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	111.47%	0.85	1.85	0.47	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.07	67.39	15.48	48.46	159.15	207.61	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	61.73%	1.27	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.12	67.23	29.87	78.34	256.67	335.01	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	99.61%	1.35	1.59	0.605	675	$ 227.90	$ 29,304.51
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.71	62.96	20.45	98.78	303.09	401.87	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	119.50%	1.19	0.55	0.64	675	$ 227.90	$ 8,882.26
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.26	61.63	8.62	178.56	536.27	714.83	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	212.55%	1.19	0.22	0.79	825	$ 348.60	$ 5,399.78
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.47	61.12	0.00	178.56	531.83	710.39	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	211.23%	1.19	1.23	0.79	825	$ 348.60	$ 30,722.06
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.71	58.39	119.87	298.43	849.14	1147.57	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	341.23%	1.19	0.96	0.945	975	$ 458.80	$ 31,542.63
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.67	56.44	0.00	298.43	820.83	1119.26	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	332.81%	1.19	0.10	0.935	975	$ 458.80	$ 3,342.48
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	74.10	13.39	13.39	48.36	61.75	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	134.52%	0.65	1.13	0.335	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	70.26	0.00	13.39	45.85	59.25	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	129.07%	0.65	0.27	0.33	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	69.40	7.65	21.04	71.16	92.20	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	45.16%	0.93	1.87		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.27	64.08	29.31	50.35	157.23	207.58	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	101.68%	0.94	0.54	0.53	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.81	62.70	7.76	58.11	177.56	235.66	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	70.07%	1.30	1.37		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.18	59.52	27.27	85.38	247.67	333.04	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	99.03%	1.35	0.94	0.605	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.12	57.53	55.85	141.23	395.99	537.21	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	159.74%	1.19	0.20	0.71	750	$ 300.50	$ 4,256.85
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.32	57.13	0.00	141.23	393.23	534.46	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	158.92%	1.19	0.87	0.71	750	$ 300.50	$ 18,732.79
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.19	55.45	29.83	171.06	462.22	633.28	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	188.30%	1.19	0.24	0.755	825	$ 348.60	$ 5,982.87
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.43	55.00	0.00	171.06	458.51	629.57	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	187.20%	1.19	0.60	0.755	825	$ 348.60	$ 14,897.78
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.03	53.93	0.00	171.06	449.56	620.62	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	184.54%	1.19	0.77	0.75	825	$ 348.60	$ 19,232.93

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	11	60	0	0	0	0	0
375	63	56	59	77	0	0	0	55
450	0	71	104	0	77	49	0	0
525	138	112	139	138	70	0	208	105
600	161	87	107	169	152	9	63	137
675	0	126	14	168	0	0	187	76
750	0	251	221	295	0	81	0	77
825	0	0	0	215	96	0	104	115
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	76	0
1050	0	0	0	15	0	0	0	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	2
Location	Mount Hope
a	646
b	6
c	0.781

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	74.10	0.66	0.66	9.17	9.83	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	4.82%	0.49	1.04		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	74.10	1.70	1.70	23.70	25.40	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	30.52%	0.67	1.56		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.56	68.90	2.80	4.50	58.36	62.86	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	30.79%	0.84	2.13		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.69	63.01	6.48	11.64	138.09	149.72	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	44.52%	1.17	0.78		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.47	61.13	1.13	12.76	146.94	159.70	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	47.49%	1.19	1.49		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	74.10	2.61	2.61	36.39	39.00	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	84.96%	0.73	1.27		300	$ 79.70	$ 4,442.24
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	74.10	4.80	4.80	67.02	71.82	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	156.46%	0.65	1.83	0.355	375	$ 98.30	$ 7,001.72
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	68.10	4.86	9.67	123.97	133.64	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	291.13%	0.65	0.34	0.445	450	$ 101.30	$ 1,334.44
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	74.10	0.59	0.59	8.18	8.77	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	19.10%	0.51	0.35		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	67.10	0.72	10.98	138.72	149.70	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	110.61%	0.85	1.93	0.465	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	62.02	5.50	16.47	192.42	208.90	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	102.33%	0.94	1.06	0.53	600	$ 148.70	$ 8,919.87
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	59.58	3.61	20.08	225.36	245.45	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	72.98%	1.31	0.35		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.50	58.83	1.52	21.61	239.43	261.04	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	77.62%	1.33	1.01		600	$ 148.70	$ 11,931.69
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.51	56.76	4.69	26.29	281.10	307.40	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	91.40%	1.35	0.56		600	$ 148.70	$ 6,758.19
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.07	55.68	5.65	34.55	362.37	396.93	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	118.02%	1.19	0.15	0.635	675	$ 227.90	$ 2,486.64
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.22	55.40	0.07	34.62	361.20	395.82	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	117.70%	1.19	0.06	0.635	675	$ 227.90	$ 911.76
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.28	55.29	0.00	34.62	360.52	395.14	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	117.49%	1.19	0.13	0.635	675	$ 227.90	$ 2,073.30
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.40	55.06	0.00	34.62	358.99	393.61	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	143.34%	0.97	1.10	0.685	750	$ 300.50	$ 19,243.78
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.50	53.12	0.00	34.62	346.35	380.97	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	113.28%	1.19	0.15	0.625	675	$ 227.90	$ 2,438.14
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.65	52.87	0.00	34.62	344.70	379.32	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	112.79%	1.19	2.13	0.625	675	$ 227.90	$ 34,703.31
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	74.10	1.72	1.72	23.99	25.71	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	56.01%	0.68	1.47		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.47	69.18	3.78	5.49	71.59	77.09	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	167.93%	0.65	1.47	0.365	375	$ 98.30	$ 5,644.69
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.95	64.94	3.39	8.89	108.71	117.60	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	86.89%	0.96	1.43		450	$ 101.30	$ 8,357.00
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.37	61.36	5.67	14.55	168.22	182.77	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	89.53%	1.07	1.67		525	$ 110.50	$ 11,876.70
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.04	57.70	6.79	21.35	231.99	253.33	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	124.09%	0.94	0.25	0.565	600	$ 148.70	$ 2,111.79
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	74.10	1.83	1.83	25.51	27.33	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	32.84%	0.68	1.43		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.43	69.32	3.47	5.30	69.15	74.44	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	55.00%	0.88	0.88		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.31	66.70	3.47	8.77	110.12	118.88	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	87.84%	0.97	0.97		450	$ 101.30	$ 5,722.48
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.29	57.19	3.43	33.54	361.34	394.88	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	117.42%	1.19	0.18	0.635	675	$ 227.90	$ 2,952.29
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.47	56.83	0.65	34.20	366.06	400.25	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	119.01%	1.19	1.38	0.64	675	$ 227.90	$ 22,503.75
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	17.86	54.24	5.13	39.32	401.76	441.08	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	131.15%	1.19	1.53	0.66	675	$ 227.90	$ 24,838.87
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	74.10	3.39	3.39	47.28	50.67	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	110.38%	0.65	1.97	0.31	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	67.68	5.58	8.97	114.34	123.31	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	148.16%	0.75	0.72	0.435	450	$ 101.30	$ 3,308.71
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	65.62	2.32	11.29	139.61	150.90	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	111.50%	0.85	0.96	0.47	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	63.10	3.74	15.03	178.70	193.74	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	143.15%	0.85	1.84	0.515	525	$ 110.50	$ 10,354.37
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	74.10	10.66	10.66	148.80	159.46	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	564.87%	0.58	1.63	0.475	525	$ 110.50	$ 6,232.53
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	68.68	5.55	16.21	209.69	225.90	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	492.13%	0.65	1.93	0.545	600	$ 148.70	$ 11,155.05
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	63.34	3.16	19.37	231.09	250.47	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	300.94%	0.75	0.77	0.565	600	$ 148.70	$ 5,176.73
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	61.46	0.00	19.37	224.23	243.60	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	179.99%	0.85	0.92	0.56	600	$ 148.70	$ 6,985.77
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	58.85	7.09	41.50	459.99	501.48	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	245.65%	0.94	0.25	0.73	750	$ 300.50	$ 4,318.53
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	58.32	1.23	42.73	469.31	512.04	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	152.25%	1.19	1.23	0.7	750	$ 300.50	$ 26,302.58
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	55.87	4.55	47.28	497.52	544.80	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	162.00%	1.19	0.53	0.715	750	$ 300.50	$ 11,386.10
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	74.10	20.77	20.77	289.93	310.70	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	50.95%	1.40	0.95		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.95	70.84	5.70	26.47	353.23	379.70	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	62.27%	1.47	1.13		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.08	67.35	10.88	37.35	473.82	511.17	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	65.02%	1.58	0.80		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	74.10	8.49	8.49	118.51	127.00	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	27.58%	1.11	1.29		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.29	69.76	17.31	25.80	339.01	364.81	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	79.24%	1.44	1.33		675	$ 227.90	$ 26,212.87
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.88	65.12	0.00	63.15	774.61	837.76	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	56.01%	1.80	0.14		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	54.88	2.83	113.26	1170.76	1284.02	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	85.85%	1.96	0.14		1050	$ 525.50	$ 8,808.74
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	74.10	3.38	3.38	47.14	50.52	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	37.33%	0.80	1.60		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.60	68.79	4.59	7.97	103.27	111.23	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	82.19%	0.96	1.22		450	$ 101.30	$ 7,107.34
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.82	65.28	4.93	12.90	158.60	171.50	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	84.01%	1.06	0.22		525	$ 110.50	$ 1,565.78
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.04	64.69	0.00	12.90	157.16	170.06	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	83.30%	1.06	1.57		525	$ 110.50	$ 11,103.39
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.61	60.79	5.24	18.14	207.70	225.84	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	110.63%	0.94	0.66	0.545	600	$ 148.70	$ 5,576.85
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.28	59.31	29.86	47.99	536.16	584.16	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	173.70%	1.19	1.34	0.735	750	$ 300.50	$ 28,725.60
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	74.10	6.91	6.91	96.39	103.30	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	225.04%	0.65	0.81	0.405	450	$ 101.30	$ 3,184.36
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	74.10	5.08	5.08	70.83	75.91	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	56.09%	0.89	0.34		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	71.31	0.00	11.98	160.92	172.91	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	84.70%	1.07	0.14		525	$ 110.50	$ 979.49
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.95	70.85	16.40	28.38	378.79	407.17	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	199.45%	0.94	1.43	0.675	750	$ 300.50	$ 24,372.63
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	74.10	7.62	7.62	106.30	113.91	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	136.87%	0.75	0.87	0.42	450	$ 101.30	$ 3,984.13
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	71.10	2.60	10.21	136.79	147.00	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	108.62%	0.85	1.21	0.465	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	67.36	4.72	14.94	189.51	204.45	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	151.07%	0.85	0.89	0.525	525	$ 110.50	$ 5,042.87
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	64.87	2.65	17.58	214.85	232.44	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	113.86%	0.94	0.24	0.55	600	$ 148.70	$ 1,995.03
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	64.24	0.82	18.41	222.76	241.17	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	118.14%	0.94	0.34	0.555	600	$ 148.70	$ 2,840.89
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	74.10	7.25	7.25	101.21	108.46	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	80.14%	0.95	0.22		450	$ 101.30	$ 1,269.51
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.22	73.32	1.28	8.53	117.86	126.39	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	93.39%	0.97	1.63		450	$ 101.30	$ 9,587.76
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	11.85	68.04	4.00	12.54	160.71	173.25	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	51.51%	1.21	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	11.90	67.88	7.73	20.27	259.15	279.42	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	83.08%	1.34	1.60		600	$ 148.70	$ 19,120.58
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.50	63.50	5.29	25.56	305.68	331.24	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	98.49%	1.35	0.48	0.605	675	$ 227.90	$ 8,882.26
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	13.98	62.30	2.23	46.20	542.11	588.31	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	174.93%	1.19	0.22	0.735	750	$ 300.50	$ 4,654.72
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.20	61.78	0.00	46.20	537.56	583.76	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	173.58%	1.19	1.23	0.735	750	$ 300.50	$ 26,483.01
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.43	58.98	31.02	77.21	857.76	934.97	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	278.01%	1.19	0.96	0.875	900	$ 418.20	$ 28,751.37
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.39	56.99	0.00	77.21	828.80	906.02	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	269.40%	1.19	0.10	0.865	900	$ 418.20	$ 3,046.70
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	74.10	3.46	3.46	48.36	51.82	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	112.90%	0.65	1.13	0.315	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	70.26	0.00	3.46	45.85	49.32	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	107.44%	0.65	0.27	0.31	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	69.40	1.98	5.44	71.16	76.60	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	37.52%	0.89	1.96		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.36	63.84	7.58	13.03	156.65	169.68	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	83.12%	1.06	0.48		525	$ 110.50	$ 3,392.84
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.84	62.63	2.01	15.03	177.35	192.38	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	57.20%	1.24	1.43		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.27	59.32	7.06	22.09	246.82	268.91	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	79.96%	1.33	0.95		600	$ 148.70	$ 11,350.88
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.23	57.32	14.45	36.54	394.53	431.07	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	128.18%	1.19	0.20	0.655	675	$ 227.90	$ 3,228.41
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.43	56.93	0.00	36.54	391.80	428.34	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	127.37%	1.19	0.87	0.655	675	$ 227.90	$ 14,207.00
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.30	55.25	7.72	44.26	460.60	504.85	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	150.12%	1.19	0.24	0.695	750	$ 300.50	$ 5,157.35
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.54	54.81	0.00	44.26	456.92	501.17	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	149.02%	1.19	0.60	0.695	750	$ 300.50	$ 12,842.18
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.14	53.75	0.00	44.26	448.04	492.30	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	146.38%	1.19	0.77	0.69	750	$ 300.50	$ 16,579.16

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	66	60	0	0	0	0	0
375	63	71	116	77	0	0	0	55
450	0	13	186	33	147	49	147	0
525	138	99	107	199	115	9	107	135
600	161	213	14	157	38	0	165	183
675	0	187	221	201	0	0	39	77
750	0	64	0	320	96	81	104	115
825	0	0	0	76	0	0	0	0
900	0	0	0	0	0	0	76	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	32	0	0	0	0
1200	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	2
Location	Mount Hope
a	646
b	6
c	0.781

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	74.10	0.22	0.22	9.17	9.39	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	4.60%	0.49	1.05		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	74.10	0.56	0.56	23.70	24.26	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	29.15%	0.66	1.58		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.58	68.84	0.92	1.48	58.31	59.79	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	29.29%	0.83	2.16		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.74	62.89	2.14	3.84	137.82	141.66	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	42.12%	1.15	0.79		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.53	60.99	0.37	4.21	146.60	150.81	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	44.84%	1.17	1.51		600	$ 148.70	$ 15,815.36
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	74.10	0.86	0.86	36.39	37.25	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	81.15%	0.73	1.27		300	$ 79.70	$ 4,442.24
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	74.10	1.58	1.58	67.02	68.60	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	149.45%	0.65	1.83	0.35	375	$ 98.30	$ 7,001.72
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	68.10	1.60	3.19	123.97	127.16	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	277.02%	0.65	0.34	0.44	450	$ 101.30	$ 1,334.44
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	74.10	0.19	0.19	8.18	8.38	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	18.25%	0.50	0.35		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	67.10	0.24	3.62	138.72	142.34	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	105.18%	0.85	1.93	0.46	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	62.02	1.81	5.43	192.42	197.86	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	96.92%	1.07	0.93	0.53	600	$ 148.70	$ 8,919.87
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.03	59.86	1.19	6.62	226.44	233.07	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	69.30%	1.30	0.35		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.38	59.10	0.50	7.13	240.53	247.65	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	73.64%	1.31	1.02		600	$ 148.70	$ 11,931.69
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.39	56.99	1.55	8.67	282.24	290.91	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	86.50%	1.35	0.56		600	$ 148.70	$ 6,758.19
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	16.96	55.90	1.86	11.40	363.77	375.16	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	111.55%	1.19	0.15	0.625	675	$ 227.90	$ 2,486.64
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.11	55.61	0.02	11.42	362.58	374.00	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	111.21%	1.19	0.06	0.62	675	$ 227.90	$ 911.76
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.16	55.50	0.00	11.42	361.90	373.31	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	111.00%	1.19	0.13	0.62	675	$ 227.90	$ 2,073.30
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.29	55.26	0.00	11.42	360.35	371.77	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	135.39%	0.97	1.10	0.67	675	$ 227.90	$ 14,594.53
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.39	53.31	0.00	11.42	347.60	359.02	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	106.75%	1.19	0.15	0.615	675	$ 227.90	$ 2,438.14
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.54	53.06	0.00	11.42	345.94	357.36	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	106.26%	1.19	2.13	0.61	675	$ 227.90	$ 34,703.31
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	74.10	0.57	0.57	23.99	24.56	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	53.50%	0.67	1.49		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.49	69.13	1.25	1.81	71.54	73.35	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	159.80%	0.65	1.47	0.355	375	$ 98.30	$ 5,644.69
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.96	64.90	1.12	2.93	108.64	111.57	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	82.44%	0.96	1.43		450	$ 101.30	$ 8,357.00
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.40	61.30	1.87	4.80	168.05	172.85	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	84.67%	1.07	1.68		525	$ 110.50	$ 11,876.70
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.08	57.63	2.24	7.04	231.69	238.73	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	116.94%	0.94	0.25	0.555	600	$ 148.70	$ 2,111.79
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	74.10	0.60	0.60	25.51	26.11	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	31.37%	0.68	1.44		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.44	69.26	1.14	1.75	69.09	70.84	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	52.34%	0.87	0.89		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.34	66.62	1.14	2.89	109.98	112.87	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	83.40%	0.96	0.98		450	$ 101.30	$ 5,722.48
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.33	57.12	1.13	11.06	360.88	371.94	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	110.59%	1.19	0.18	0.62	675	$ 227.90	$ 2,952.29
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.51	56.76	0.22	11.28	365.59	376.87	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	112.06%	1.19	1.38	0.625	675	$ 227.90	$ 22,503.75
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	17.89	54.18	1.69	12.97	401.28	414.25	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	123.18%	1.19	1.53	0.645	675	$ 227.90	$ 24,838.87
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	74.10	1.12	1.12	47.28	48.40	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	105.43%	0.65	1.97	0.305	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	67.68	1.84	2.96	114.34	117.30	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	140.94%	0.75	0.72	0.425	450	$ 101.30	$ 3,308.71
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	65.62	0.77	3.73	139.61	143.33	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	105.91%	0.85	0.96	0.46	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	63.10	1.23	4.96	178.70	183.66	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	135.70%	0.85	1.84	0.505	525	$ 110.50	$ 10,354.37
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	74.10	3.52	3.52	148.80	152.31	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	539.56%	0.58	1.63	0.47	525	$ 110.50	$ 6,232.53
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	68.68	1.83	5.35	209.69	215.04	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	468.46%	0.65	1.93	0.535	600	$ 148.70	$ 11,155.05
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	63.34	1.04	6.39	231.09	237.48	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	285.34%	0.75	0.77	0.555	600	$ 148.70	$ 5,176.73
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	61.46	0.00	6.39	224.23	230.62	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	170.40%	0.85	0.92	0.55	600	$ 148.70	$ 6,985.77
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	58.85	2.34	13.69	459.99	473.67	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	232.03%	0.94	0.25	0.715	750	$ 300.50	$ 4,318.53
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	58.32	0.41	14.09	469.31	483.40	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	143.74%	1.19	1.23	0.685	750	$ 300.50	$ 26,302.58
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	55.87	1.50	15.59	497.52	513.12	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	152.57%	1.19	0.53	0.7	750	$ 300.50	$ 11,386.10
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	74.10	6.85	6.85	289.93	296.78	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	48.67%	1.39	0.96		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.96	70.80	1.88	8.73	353.05	361.78	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	59.33%	1.46	1.15		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.11	67.28	3.59	12.32	473.35	485.67	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	61.77%	1.57	0.80		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	74.10	2.80	2.80	118.51	121.31	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	26.35%	1.10	1.30		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.30	69.71	5.71	8.51	338.76	347.27	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	75.43%	1.43	1.34		675	$ 227.90	$ 26,212.87
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.91	65.03	0.00	20.83	773.57	794.40	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	53.11%	1.78	0.14		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	54.88	0.93	37.35	1170.76	1208.12	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	80.77%	1.94	0.14		1050	$ 525.50	$ 8,808.74
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	74.10	1.11	1.11	47.14	48.26	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	35.66%	0.79	1.62		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.62	68.73	1.51	2.63	103.18	105.80	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	78.18%	0.95	1.23		450	$ 101.30	$ 7,107.34
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.85	65.20	1.63	4.25	158.41	162.66	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	79.68%	1.06	0.22		525	$ 110.50	$ 1,565.78
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.07	64.60	0.00	4.25	156.96	161.21	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	78.97%	1.05	1.59		525	$ 110.50	$ 11,103.39
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.66	60.69	1.73	5.98	207.36	213.34	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	104.50%	0.94	0.66	0.53	600	$ 148.70	$ 5,576.85
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.32	59.21	9.85	15.83	535.29	551.12	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	163.87%	1.19	1.34	0.72	750	$ 300.50	$ 28,725.60
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	74.10	2.28	2.28	96.39	98.67	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	214.96%	0.65	0.81	0.4	450	$ 101.30	$ 3,184.36
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	74.10	1.67	1.67	70.83	72.51	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	53.57%	0.88	0.34		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	71.31	0.00	3.95	160.92	164.88	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	80.76%	1.06	0.14		525	$ 110.50	$ 979.49
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.95	70.85	5.41	9.36	378.77	388.13	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	190.12%	0.94	1.43	0.665	675	$ 227.90	$ 18,484.27
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	74.10	2.51	2.51	106.30	108.81	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	130.73%	0.75	0.87	0.415	450	$ 101.30	$ 3,984.13
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	71.10	0.86	3.37	136.79	140.15	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	103.56%	0.85	1.21	0.455	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	67.36	1.56	4.93	189.51	194.44	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	143.67%	0.85	0.89	0.515	525	$ 110.50	$ 5,042.87
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	64.87	0.87	5.80	214.85	220.65	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	108.09%	0.94	0.24	0.54	600	$ 148.70	$ 1,995.03
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	64.24	0.27	6.07	222.76	228.83	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	112.09%	0.94	0.34	0.545	600	$ 148.70	$ 2,840.89
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	74.10	2.39	2.39	101.21	103.60	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	76.55%	0.95	0.22		450	$ 101.30	$ 1,269.51
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.22	73.31	0.42	2.81	117.85	120.66	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	89.16%	0.97	1.63		450	$ 101.30	$ 9,587.76
65	Bayside	Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	11.85	68.03	1.32	4.14	160.67	164.80	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	49.00%	1.20	0.06		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	11.91	67.86	2.55	6.68	259.07	265.76	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	79.02%	1.33	1.61		600	$ 148.70	$ 19,120.58
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.52	63.45	1.74	8.43	305.44	313.87	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	93.33%	1.36	0.48		600	$ 148.70	$ 5,795.49
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.00	62.26	0.74	15.24	541.74	556.97	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	165.61%	1.19	0.22	0.72	750	$ 300.50	$ 4,654.72
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.21	61.73	0.00	15.24	537.19	552.43	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	164.26%	1.19	1.23	0.72	750	$ 300.50	$ 26,483.01
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.45	58.94	10.23	25.47	857.20	882.67	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	262.46%	1.19	0.96	0.855	900	$ 418.20	$ 28,751.37
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.41	56.95	0.00	25.47	828.29	853.75	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	253.86%	1.19	0.10	0.845	900	$ 418.20	$ 3,046.70
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	74.10	1.14	1.14	48.36	49.50	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	107.84%	0.65	1.13	0.31	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	70.26	0.00	1.14	45.85	47.00	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	102.38%	0.65	0.27	0.305	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	69.40	0.65	1.80	71.16	72.96	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	35.74%	0.88	1.99		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.39	63.78	2.50	4.30	156.49	160.79	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	78.76%	1.05	0.49		525	$ 110.50	$ 3,392.84
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.87	62.56	0.66	4.96	177.14	182.10	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	54.15%	1.23	1.45		600	$ 148.70	$ 15,849.52
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.32	59.22	2.33	7.29	246.39	253.67	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	75.43%	1.32	0.96		600	$ 148.70	$ 11,350.88
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.28	57.21	4.77	12.05	393.73	405.78	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	120.66%	1.19	0.20	0.64	675	$ 227.90	$ 3,228.41
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.48	56.81	0.00	12.05	391.01	403.06	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	119.85%	1.19	0.87	0.64	675	$ 227.90	$ 14,207.00
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.36	55.15	2.55	14.60	459.70	474.30	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	141.03%	1.19	0.24	0.68	750	$ 300.50	$ 5,157.35
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.60	54.71	0.00	14.60	456.04	470.64	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	139.94%	1.19	0.60	0.68	750	$ 300.50	$ 12,842.18
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.20	53.65	0.00	14.60	447.20	461.80	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	137.31%	1.19	0.77	0.675	675	$ 227.90	$ 12,573.68

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	66	60	0	0	0	0	0
375	63	71	116	77	0	0	0	55
450	0	13	186	33	147	49	147	0
525	138	99	107	199	115	9	107	135
600	161	213	14	157	38	0	204	183
675	0	251	221	201	0	81	0	132
750	0	0	0	320	96	0	104	60
825	0	0	0	76	0	0	0	0
900	0	0	0	0	0	0	76	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	32	0	0	0	0
1200	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74	m
Total Basement Q	0.00	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	2
Location	Mount Hope
a	646
b	6
c	0.781

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9 m/s			
Max. Velocity =	3.65 m/s			

Pipe Information					Hydrology Flow Calculations										
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	74.10	0.00	0.00	9.17	9.17
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	74.10	0.00	0.00	23.70	23.70
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.59	68.81	0.00	0.00	58.28	58.28
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.77	62.82	0.00	0.00	137.68	137.68
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.56	60.91	0.00	0.00	146.43	146.43
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	74.10	0.00	0.00	36.39	36.39
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	74.10	0.00	0.00	67.02	67.02
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	68.10	0.00	0.00	123.97	123.97
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	74.10	0.00	0.00	8.18	8.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	67.10	0.00	0.00	138.72	138.72
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	62.02	0.00	0.00	192.42	192.42
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.03	59.86	0.00	0.00	226.45	226.45
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.38	59.10	0.00	0.00	240.52	240.52
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.40	56.98	0.00	0.00	282.17	282.17
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	16.96	55.88	0.00	0.00	363.66	363.66
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.12	55.59	0.00	0.00	362.47	362.47
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.17	55.49	0.00	0.00	361.79	361.79
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.30	55.25	0.00	0.00	360.24	360.24
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.40	53.29	0.00	0.00	347.50	347.50
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.55	53.04	0.00	0.00	345.85	345.85
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	74.10	0.00	0.00	23.99	23.99
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.50	69.10	0.00	0.00	71.51	71.51
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.97	64.87	0.00	0.00	108.60	108.60
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.41	61.27	0.00	0.00	167.95	167.95
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.10	57.58	0.00	0.00	231.52	231.52
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	74.10	0.00	0.00	25.51	25.51
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.45	69.24	0.00	0.00	69.06	69.06
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.35	66.58	0.00	0.00	109.91	109.91
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.35	57.08	0.00	0.00	360.61	360.61
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.53	56.72	0.00	0.00	365.33	365.33
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	17.91	54.14	0.00	0.00	401.00	401.00
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	74.10	0.00	0.00	47.28	47.28
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	67.68	0.00	0.00	114.34	114.34
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	65.62	0.00	0.00	139.61	139.61
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	63.10	0.00	0.00	178.70	178.70
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	74.10	0.00	0.00	148.80	148.80
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	68.68	0.00	0.00	209.69	209.69
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	63.34	0.00	0.00	231.09	231.09
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	61.46	0.00	0.00	224.23	224.23
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	58.85	0.00	0.00	459.99	459.99
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	58.32	0.00	0.00	469.31	469.31
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	55.87	0.00	0.00	497.52	497.52
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	74.10	0.00	0.00	289.93	289.93
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.97	70.78	0.00	0.00	352.96	352.96
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.12	67.24	0.00	0.00	473.10	473.10
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	74.10	0.00	0.00	118.51	118.51
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.31	69.68	0.00	0.00	338.63	338.63
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.93	64.99	0.00	0.00	773.03	773.03
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	54.88	0.00	0.00	1170.76	1170.76
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	74.10	0.00	0.00	47.14	47.14
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.63	68.70	0.00	0.00	103.13	103.13
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.86	65.16	0.00	0.00	158.31	158.31
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.09	64.56	0.00	0.00	156.85	156.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.68	60.64	0.00	0.00	207.17	207.17
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.35	59.16	0.00	0.00	534.82	534.82
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	74.10	0.00	0.00	96.39	96.39
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	74.10	0.00	0.00	70.83	70.83
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	71.31	0.00	0.00	160.92	160.92
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.95	70.85	0.00	0.00	378.76	378.76
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	74.10	0.00	0.00	106.30	106.30
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	71.10	0.00	0.00	136.79	136.79
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	67.36	0.00	0.00	189.51	189.51
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	64.87	0.00	0.00	214.85	214.85
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	64.24	0.00	0.00	222.76	222.76
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	74.10	0.00	0.00	101.21	101.21
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.22	73.31	0.00	0.00	117.84	117.84
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	11.86	68.01	0.00	0.00	160.63	160.63
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	11.91	67.85	0.00	0.00	259.01	259.01
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.53	63.42	0.00	0.00	305.29	305.29
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.01	62.23	0.00	0.00	541.46	541.46
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.23	61.70	0.00	0.00	536.92	536.92
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.46	58.91	0.00	0.00	856.80	856.80
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.42	56.93	0.00	0.00	827.92	827.92
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	74.10	0.00	0.00	48.36	48.36
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	70.26	0.00	0.00	45.85	45.85
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.37	69.50	0.00	0.00	71.26	71.26
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.37	63.83	0.00	0.00	156.61	156.61
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.86	62.60	0.00	0.00	177.26	177.26
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.31	59.23	0.00	0.00	246.46	246.46
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.28	57.21	0.00	0.00	393.76	393.76
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.48	56.82	0.00	0.00	391.05	391.05
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.35	55.15	0.00	0.00	459.74	459.74
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.59	54.71	0.00	0.00	456.08	456.08
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.19	53.65	0.00	0.00	447.24	447.24

	Hydraulic Calculations										Design Calculations			
Area No.	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	4.49%	0.48	1.06		525	$ 110.50	$ 3,393.95
1	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	28.48%	0.66	1.59		375	$ 98.30	$ 6,177.15
2	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	28.55%	0.82	2.18		525	$ 110.50	$ 11,898.93
3	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	40.94%	1.15	0.80		600	$ 148.70	$ 8,134.85
4	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	43.54%	1.16	1.52		600	$ 148.70	$ 15,815.36
5	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	79.28%	0.73	1.28		300	$ 79.70	$ 4,442.24
6	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	146.00%	0.65	1.83	0.345	375	$ 98.30	$ 7,001.72
7	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	270.08%	0.65	0.34	0.435	450	$ 101.30	$ 1,334.44
8	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	17.82%	0.50	0.35		300	$ 79.70	$ 841.18
9	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	102.50%	0.85	1.93	0.455	525	$ 110.50	$ 10,886.60
10	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	94.26%	1.08	0.93		525	$ 110.50	$ 6,628.42
11	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	67.33%	1.29	0.35		600	$ 148.70	$ 4,038.33
12	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	71.52%	1.31	1.02		600	$ 148.70	$ 11,931.69
13	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	83.90%	1.34	0.56		600	$ 148.70	$ 6,758.19
14	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	108.13%	1.19	0.15	0.615	675	$ 227.90	$ 2,486.64
15	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	107.78%	1.19	0.06	0.615	675	$ 227.90	$ 911.76
-	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	107.58%	1.19	0.13	0.615	675	$ 227.90	$ 2,073.30
-	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	131.19%	0.97	1.10	0.66	675	$ 227.90	$ 14,594.53
-	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	103.33%	1.19	0.15	0.605	675	$ 227.90	$ 2,438.14
-	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	102.84%	1.19	2.13	0.605	675	$ 227.90	$ 34,703.31
16	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	52.26%	0.66	1.50		300	$ 79.70	$ 4,756.71
17	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	155.79%	0.65	1.47	0.355	375	$ 98.30	$ 5,644.69
18	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	80.24%	0.95	1.44		450	$ 101.30	$ 8,357.00
19	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	82.27%	1.06	1.69		525	$ 110.50	$ 11,876.70
20	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	113.41%	0.94	0.25	0.55	600	$ 148.70	$ 2,111.79
22	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	30.64%	0.67	1.45		375	$ 98.30	$ 5,757.24
23	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	51.03%	0.87	0.90		450	$ 101.30	$ 4,727.69
24	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	81.22%	0.96	0.98		450	$ 101.30	$ 5,722.48
25	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	107.23%	1.19	0.18	0.615	675	$ 227.90	$ 2,952.29
26	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	108.63%	1.19	1.38	0.615	675	$ 227.90	$ 22,503.75
27	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	119.24%	1.19	1.53	0.64	675	$ 227.90	$ 24,838.87
28	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	103.00%	0.65	1.97	0.305	375	$ 98.30	$ 7,545.49
29	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	137.38%	0.75	0.72	0.42	450	$ 101.30	$ 3,308.71
30	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	103.15%	0.85	0.96	0.455	525	$ 110.50	$ 5,424.74
31	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	132.04%	0.85	1.84	0.5	525	$ 110.50	$ 10,354.37
50	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	527.11%	0.58	1.63	0.465	525	$ 110.50	$ 6,232.53
34	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	456.81%	0.65	1.93	0.53	600	$ 148.70	$ 11,155.05
35	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	277.66%	0.75	0.77	0.55	600	$ 148.70	$ 5,176.73
-	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	165.68%	0.85	0.92	0.54	600	$ 148.70	$ 6,985.77
36	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	225.32%	0.94	0.25	0.71	750	$ 300.50	$ 4,318.53
37	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	139.55%	1.19	1.23	0.675	675	$ 227.90	$ 19,947.95
38	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	147.94%	1.19	0.53	0.69	750	$ 300.50	$ 11,386.10
40	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	47.55%	1.38	0.97		750	$ 300.50	$ 24,040.91
41	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	57.88%	1.45	1.15		750	$ 300.50	$ 30,082.13
42	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	60.17%	1.56	0.81		825	$ 348.60	$ 26,363.35
44	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	25.74%	1.09	1.31		675	$ 227.90	$ 19,599.38
45	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	73.55%	1.42	1.35		675	$ 227.90	$ 26,212.87
-	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	51.68%	1.76	0.14		1050	$ 525.50	$ 7,948.67
47	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	78.28%	1.93	0.14		1050	$ 525.50	$ 8,808.74
48	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	34.83%	0.79	1.63		450	$ 101.30	$ 7,765.27
49	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	76.20%	0.95	1.24		450	$ 101.30	$ 7,107.34
83	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	77.55%	1.05	0.22		525	$ 110.50	$ 1,565.78
-	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	76.83%	1.05	1.60		525	$ 110.50	$ 11,103.39
51	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	101.48%	0.94	0.66	0.53	600	$ 148.70	$ 5,576.85
52	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	159.03%	1.19	1.34	0.71	750	$ 300.50	$ 28,725.60
53	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	210.00%	0.65	0.81	0.395	450	$ 101.30	$ 3,184.36
54	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	52.34%	0.87	0.34		450	$ 101.30	$ 1,817.77
-	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	78.83%	1.05	0.14		525	$ 110.50	$ 979.49
56	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	185.53%	0.94	1.43	0.66	675	$ 227.90	$ 18,484.27
57	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	127.72%	0.75	0.87	0.41	450	$ 101.30	$ 3,984.13
58	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	101.07%	0.85	1.21	0.455	525	$ 110.50	$ 6,810.45
59	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	140.03%	0.85	0.89	0.51	525	$ 110.50	$ 5,042.87
60	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	105.24%	0.94	0.24	0.535	600	$ 148.70	$ 1,995.03
61	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	109.12%	0.94	0.34	0.54	600	$ 148.70	$ 2,840.89
63	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	74.78%	0.94	0.22		450	$ 101.30	$ 1,269.51
64	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	87.07%	0.97	1.63		450	$ 101.30	$ 9,587.76
65	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	47.76%	1.19	0.06		600	$ 148.70	$ 594.45
66	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	77.02%	1.32	1.62		600	$ 148.70	$ 19,120.58
67	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	90.78%	1.35	0.48		600	$ 148.70	$ 5,795.49
68	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	161.00%	1.19	0.22	0.715	750	$ 300.50	$ 4,654.72
-	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	159.65%	1.19	1.23	0.71	750	$ 300.50	$ 26,483.01
70	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	254.77%	1.19	0.96	0.85	900	$ 418.20	$ 28,751.37
-	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	246.18%	1.19	0.10	0.835	900	$ 418.20	$ 3,046.70
72	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	105.35%	0.65	1.13	0.305	375	$ 98.30	$ 4,319.53
-	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	99.89%	0.74	0.24	0.305	375	$ 98.30	$ 1,046.68
74	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	34.91%	0.87	2.00		525	$ 110.50	$ 11,547.88
75	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	76.72%	1.05	0.49		525	$ 110.50	$ 3,392.84
76	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	52.71%	1.22	1.46		600	$ 148.70	$ 15,849.52
77	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	73.28%	1.31	0.97		600	$ 148.70	$ 11,350.88
78	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	117.08%	1.19	0.20	0.635	675	$ 227.90	$ 3,228.41
-	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	116.28%	1.19	0.87	0.635	675	$ 227.90	$ 14,207.00
80	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	136.70%	1.19	0.24	0.67	675	$ 227.90	$ 3,911.35
-	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	135.61%	1.19	0.60	0.67	675	$ 227.90	$ 9,739.54
-	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	132.99%	1.19	0.77	0.665	675	$ 227.90	$ 12,573.68

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	66	60	0	0	0	0	0
375	63	71	116	77	0	0	0	55
450	0	13	186	33	147	49	147	0
525	138	159	107	199	115	9	107	135
600	161	153	14	157	38	0	204	183
675	0	251	221	289	0	81	0	192
750	0	0	0	232	96	0	104	0
825	0	0	0	76	0	0	0	0
900	0	0	0	0	0	0	76	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	32	0	0	0	0
1200	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	76	m
Total Basement Q	6.02	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	0
Location	Mount Hope
a	0
b	0
c	0

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9 m/s			
Max. Velocity =	3.65 m/s			

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	0.00	9.96	9.96	0.00	9.96	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	4.88%	0.50	1.03		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	0.00	25.72	25.72	0.00	25.72	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	30.91%	0.67	1.56		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	11.56	0.00	42.38	68.10	0.00	68.10	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	33.36%	0.86	2.09		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	13.64	0.00	98.17	176.22	0.00	176.22	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	52.40%	1.22	0.75		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	14.39	0.00	17.06	193.28	0.00	193.28	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	57.47%	1.25	1.42		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	0.00	39.49	39.49	0.00	39.49	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	86.03%	0.74	1.26		300	$ 79.70	$ 4,442.24
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	0.00	72.72	72.72	0.00	72.72	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	158.42%	0.65	1.83	0.355	375	$ 98.30	$ 7,001.72
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.83	0.00	73.67	146.39	0.00	146.39	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	318.90%	0.65	0.34	0.46	525	$ 110.50	$ 1,455.63
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	0.00	8.88	8.88	0.00	8.88	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	19.34%	0.51	0.35		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.17	0.00	10.96	166.23	0.00	166.23	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	122.82%	0.85	1.93	0.485	525	$ 110.50	$ 10,886.60
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.10	0.00	83.26	249.48	0.00	249.48	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	122.21%	0.94	1.06	0.565	600	$ 148.70	$ 8,919.87
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.16	0.00	54.68	304.16	0.00	304.16	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	90.44%	1.35	0.33		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	15.49	0.00	23.10	327.26	0.00	327.26	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	97.31%	1.35	0.99	0.605	675	$ 227.90	$ 18,286.70
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	16.48	0.00	70.96	398.22	0.00	398.22	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	118.41%	1.19	0.64	0.635	675	$ 227.90	$ 10,357.71
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	17.11	0.00	85.57	523.28	0.00	523.28	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	155.59%	1.19	0.15	0.705	750	$ 300.50	$ 3,278.79
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	17.27	0.00	1.01	524.28	0.00	524.28	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	155.89%	1.19	0.06	0.705	750	$ 300.50	$ 1,202.20
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	17.32	0.00	0.00	524.28	0.00	524.28	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	155.89%	1.19	0.13	0.705	750	$ 300.50	$ 2,733.78
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	17.45	0.00	0.00	524.28	0.00	524.28	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	190.93%	0.97	1.10	0.76	825	$ 348.60	$ 22,324.06
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	18.55	0.00	0.00	524.28	0.00	524.28	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	155.89%	1.19	0.15	0.705	750	$ 300.50	$ 3,214.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	18.70	0.00	0.00	524.28	0.00	524.28	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	155.89%	1.19	2.13	0.705	750	$ 300.50	$ 45,758.43
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	0.00	26.03	26.03	0.00	26.03	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	56.71%	0.68	1.47		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	11.47	0.00	57.18	83.21	0.00	83.21	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	181.27%	0.65	1.47	0.375	450	$ 101.30	$ 5,816.96
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	12.94	0.00	51.39	134.60	0.00	134.60	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	99.46%	0.96	1.43	0.455	525	$ 110.50	$ 9,115.98
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	14.37	0.00	85.82	220.42	0.00	220.42	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	107.97%	0.94	1.90	0.54	600	$ 148.70	$ 15,982.49
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	16.27	0.00	102.86	323.28	0.00	323.28	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	158.36%	0.94	0.25	0.62	675	$ 227.90	$ 3,236.57
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	0.00	27.68	27.68	0.00	27.68	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	33.25%	0.69	1.42		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	11.42	0.00	52.53	80.21	0.00	80.21	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	59.26%	0.90	0.87		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	12.29	0.00	52.54	132.75	0.00	132.75	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	98.09%	0.97	0.97	0.455	525	$ 110.50	$ 6,242.20
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	16.52	0.00	51.97	508.01	0.00	508.01	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	151.05%	1.19	0.18	0.695	750	$ 300.50	$ 3,892.78
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	16.70	0.00	9.91	517.91	0.00	517.91	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	154.00%	1.19	1.38	0.705	750	$ 300.50	$ 29,672.56
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	18.08	0.00	77.67	595.58	0.00	595.58	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	177.09%	1.19	1.53	0.74	750	$ 300.50	$ 32,751.56
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	0.00	51.30	51.30	0.00	51.30	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	111.77%	0.65	1.97	0.315	375	$ 98.30	$ 7,545.49
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	11.97	0.00	84.55	135.85	0.00	135.85	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	163.23%	0.75	0.72	0.45	525	$ 110.50	$ 3,609.21
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	12.69	0.00	35.20	171.06	0.00	171.06	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	126.39%	0.85	0.96	0.49	525	$ 110.50	$ 5,424.74
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	13.65	0.00	56.65	227.70	0.00	227.70	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	168.25%	0.85	1.84	0.545	600	$ 148.70	$ 13,933.89
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	0.00	161.46	161.46	0.00	161.46	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	571.97%	0.58	1.63	0.48	525	$ 110.50	$ 6,232.53
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	0.00	84.04	245.50	0.00	245.50	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	534.83%	0.65	1.93	0.56	600	$ 148.70	$ 11,155.05
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	0.00	47.86	293.36	0.00	293.36	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	352.48%	0.75	0.77	0.6	675	$ 227.90	$ 7,933.94
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.33	0.00	0.00	293.36	0.00	293.36	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	216.76%	0.85	0.92	0.6	675	$ 227.90	$ 10,706.50
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.49	0.00	107.38	628.45	0.00	628.45	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	307.84%	0.94	0.25	0.795	825	$ 348.60	$ 5,009.78
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	15.74	0.00	18.65	647.10	0.00	647.10	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	192.41%	1.19	1.23	0.765	825	$ 348.60	$ 30,512.74
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	16.97	0.00	68.94	716.04	0.00	716.04	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	212.91%	1.19	0.53	0.795	825	$ 348.60	$ 13,208.64
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	0.00	314.61	314.61	0.00	314.61	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	51.59%	1.41	0.95		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	10.95	0.00	86.33	400.94	0.00	400.94	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	65.75%	1.49	1.12		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.07	0.00	164.77	565.71	0.00	565.71	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	71.95%	1.62	0.78		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	0.00	128.60	128.60	0.00	128.60	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	27.93%	1.12	1.28		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.28	0.00	262.16	390.76	0.00	390.76	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	84.87%	1.45	1.32		675	$ 227.90	$ 26,212.87
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	12.85	0.00	0.00	956.47	0.00	956.47	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	63.95%	1.85	0.14		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.50	0.00	42.79	1715.30	0.00	1715.30	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	114.68%	1.73	0.16	1.1	1200	$ 658.60	$ 11,039.84
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	0.00	51.15	51.15	0.00	51.15	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	37.80%	0.80	1.59		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	11.59	0.00	69.55	120.70	0.00	120.70	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	89.18%	0.97	1.21		450	$ 101.30	$ 7,107.34
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	12.80	0.00	74.65	195.35	0.00	195.35	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	95.69%	1.07	0.22	0.53	600	$ 148.70	$ 2,107.07
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	13.02	0.00	0.00	195.35	0.00	195.35	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	95.69%	1.07	1.56	0.53	600	$ 148.70	$ 14,941.85
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	14.58	0.00	79.36	274.71	0.00	274.71	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	134.57%	0.94	0.66	0.585	600	$ 148.70	$ 5,576.85
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	15.24	0.00	452.17	726.88	0.00	726.88	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	216.13%	1.19	1.34	0.795	825	$ 348.60	$ 33,323.61
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	0.00	104.60	104.60	0.00	104.60	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	227.87%	0.65	0.81	0.41	450	$ 101.30	$ 3,184.36
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	0.00	76.86	76.86	0.00	76.86	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	56.79%	0.89	0.34		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.81	0.00	0.00	181.46	0.00	181.46	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	88.89%	1.07	0.14		525	$ 110.50	$ 979.49
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.94	0.00	248.42	429.88	0.00	429.88	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	210.57%	0.94	1.43	0.69	750	$ 300.50	$ 24,372.63
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	0.00	115.34	115.34	0.00	115.34	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	138.59%	0.75	0.87	0.425	450	$ 101.30	$ 3,984.13
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.87	0.00	39.35	154.69	0.00	154.69	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	114.30%	0.85	1.21	0.47	525	$ 110.50	$ 6,810.45
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.08	0.00	71.52	226.21	0.00	226.21	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	167.15%	0.85	0.89	0.545	600	$ 148.70	$ 6,786.19
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	12.97	0.00	40.10	266.31	0.00	266.31	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	130.45%	0.94	0.24	0.58	600	$ 148.70	$ 1,995.03
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.21	0.00	12.49	278.80	0.00	278.80	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	136.57%	0.94	0.34	0.59	600	$ 148.70	$ 2,840.89
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	0.00	109.83	109.83	0.00	109.83	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	81.15%	0.96	0.22		450	$ 101.30	$ 1,269.51
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.22	0.00	19.43	129.25	0.00	129.25	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	95.50%	0.97	1.63	0.455	525	$ 110.50	$ 10,458.52
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	11.84	0.00	60.65	189.90	0.00	189.90	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	56.47%	1.24	0.05		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	11.90	0.00	117.06	306.96	0.00	306.96	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	91.27%	1.35	1.58		600	$ 148.70	$ 19,120.58
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	13.48	0.00	80.12	387.09	0.00	387.09	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	115.10%	1.19	0.55	0.63	675	$ 227.90	$ 8,882.26
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	14.03	0.00	33.78	699.67	0.00	699.67	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	208.05%	1.19	0.22	0.785	825	$ 348.60	$ 5,399.78
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	14.24	0.00	0.00	699.67	0.00	699.67	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	208.05%	1.19	1.23	0.785	825	$ 348.60	$ 30,722.06
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	15.48	0.00	469.73	1169.41	0.00	1169.41	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	347.72%	1.19	0.96	0.955	975	$ 458.80	$ 31,542.63
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	16.44	0.00	0.00	1169.41	0.00	1169.41	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	347.72%	1.19	0.10	0.955	975	$ 458.80	$ 3,342.48
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	0.00	52.48	52.48	0.00	52.48	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	114.32%	0.65	1.13	0.315	375	$ 98.30	$ 4,319.53
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.13	0.00	0.00	52.48	0.00	52.48	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	114.32%	0.65	0.27	0.315	375	$ 98.30	$ 1,046.68
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.40	0.00	29.97	82.45	0.00	82.45	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	40.39%	0.90	1.92		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	13.33	0.00	114.85	197.30	0.00	197.30	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	96.64%	1.07	0.48	0.53	600	$ 148.70	$ 4,565.75
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	13.80	0.00	30.39	227.69	0.00	227.69	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	67.70%	1.29	1.38		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	15.18	0.00	106.87	334.55	0.00	334.55	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	99.48%	1.35	0.94	0.605	675	$ 227.90	$ 17,396.53
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	16.12	0.00	218.85	553.41	0.00	553.41	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	164.55%	1.19	0.20	0.72	750	$ 300.50	$ 4,256.85
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	16.32	0.00	0.00	553.41	0.00	553.41	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	164.55%	1.19	0.87	0.72	750	$ 300.50	$ 18,732.79
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	17.19	0.00	116.88	670.29	0.00	670.29	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	199.31%	1.19	0.24	0.775	825	$ 348.60	$ 5,982.87
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	17.43	0.00	0.00	670.29	0.00	670.29	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	199.31%	1.19	0.60	0.775	825	$ 348.60	$ 14,897.78
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	18.03	0.00	0.00	670.29	0.00	670.29	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	199.31%	1.19	0.77	0.775	825	$ 348.60	$ 19,232.93

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	66	60	0	0	0	0	0
375	63	71	59	77	0	0	0	55
450	0	0	104	0	147	49	52	0
525	138	112	139	138	0	9	156	105
600	161	87	107	169	152	0	211	137
675	0	126	14	283	0	0	39	76
750	0	187	221	180	0	81	0	77
825	0	64	0	215	96	0	104	115
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	76	0
1050	0	0	0	15	0	0	0	0
1200	0	0	0	17	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75.5	m
Total Basement Q	1.54	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	0
Location	Mount Hope
a	0
b	0
c	0

Other Hydraulic Restrictions			
Mannings n =	0.015	dia. <	0.6 m
	0.013	dia. =>	0.6 m
Min.Velocity =	0.9 m/s		
Max. Velocity =	3.65 m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	0.00	2.54	2.54	0.00	2.54	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	1.24%	0.33	1.56		525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	0.00	6.56	6.56	0.00	6.56	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	7.89%	0.46	2.29		375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	12.29	0.00	10.82	17.38	0.00	17.38	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	8.51%	0.58	3.07		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	15.37	0.00	25.05	44.97	0.00	44.97	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	13.37%	0.84	1.09		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	16.45	0.00	4.35	49.33	0.00	49.33	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	14.67%	0.86	2.05		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	0.00	10.08	10.08	0.00	10.08	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	21.95%	0.53	1.76		300	$ 79.70	$ 4,442.24
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	0.00	18.56	18.56	0.00	18.56	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	40.43%	0.62	1.90		300	$ 79.70	$ 5,676.88
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	11.90	0.00	18.80	37.36	0.00	37.36	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	81.38%	0.73	0.30		300	$ 79.70	$ 1,049.90
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	0.00	2.27	2.27	0.00	2.27	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	4.94%	0.34	0.51		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	12.21	0.00	2.80	42.42	0.00	42.42	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	31.34%	0.76	2.15		450	$ 101.30	$ 9,980.21
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	14.36	0.00	21.25	63.67	0.00	63.67	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	31.19%	0.84	1.18		525	$ 110.50	$ 6,628.42
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	15.54	0.00	13.95	77.62	0.00	77.62	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	23.08%	0.98	0.46		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	16.00	0.00	5.89	83.52	0.00	83.52	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	24.83%	1.00	1.34		600	$ 148.70	$ 11,931.69
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	17.34	0.00	18.11	101.62	0.00	101.62	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	30.22%	1.06	0.72		600	$ 148.70	$ 6,758.19
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	18.05	0.00	21.84	133.54	0.00	133.54	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	39.71%	1.14	0.16		600	$ 148.70	$ 1,622.48
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	18.21	0.00	0.26	133.80	0.00	133.80	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	39.78%	1.14	0.06		600	$ 148.70	$ 594.90
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	18.27	0.00	0.00	133.80	0.00	133.80	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	39.78%	1.14	0.13		600	$ 148.70	$ 1,352.79
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	18.41	0.00	0.00	133.80	0.00	133.80	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	48.73%	0.98	1.09		600	$ 148.70	$ 9,522.63
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	19.50	0.00	0.00	133.80	0.00	133.80	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	39.78%	1.14	0.16		600	$ 148.70	$ 1,590.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	19.65	0.00	0.00	133.80	0.00	133.80	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	39.78%	1.14	2.23		600	$ 148.70	$ 22,643.19
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	0.00	6.64	6.64	0.00	6.64	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	14.47%	0.47	2.12		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	12.12	0.00	14.59	21.24	0.00	21.24	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	46.26%	0.65	1.48		300	$ 79.70	$ 4,576.62
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	13.60	0.00	13.11	34.35	0.00	34.35	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	25.38%	0.72	1.91		450	$ 101.30	$ 8,357.00
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	15.51	0.00	21.90	56.25	0.00	56.25	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	27.55%	0.82	2.19		525	$ 110.50	$ 11,876.70
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	17.70	0.00	26.25	82.50	0.00	82.50	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	40.41%	0.91	0.26		525	$ 110.50	$ 1,569.29
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	0.00	7.06	7.06	0.00	7.06	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	8.49%	0.47	2.09		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	12.09	0.00	13.41	20.47	0.00	20.47	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	15.12%	0.62	1.25		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	13.34	0.00	13.41	33.88	0.00	33.88	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	25.03%	0.72	1.31		450	$ 101.30	$ 5,722.48
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	17.97	0.00	13.26	129.64	0.00	129.64	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	38.55%	1.13	0.19		600	$ 148.70	$ 1,926.31
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	18.16	0.00	2.53	132.17	0.00	132.17	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	39.30%	1.13	1.45		600	$ 148.70	$ 14,683.23
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	19.61	0.00	19.82	151.99	0.00	151.99	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	45.19%	1.17	1.55		600	$ 148.70	$ 16,206.85
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	0.00	13.09	13.09	0.00	13.09	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	28.52%	0.57	2.25		300	$ 79.70	$ 6,117.76
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	12.25	0.00	21.58	34.67	0.00	34.67	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	41.66%	0.73	0.75		375	$ 98.30	$ 3,210.73
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	13.00	0.00	8.98	43.65	0.00	43.65	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	32.25%	0.77	1.06		450	$ 101.30	$ 4,973.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	14.06	0.00	14.46	58.11	0.00	58.11	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	42.94%	0.83	1.88		450	$ 101.30	$ 9,492.29
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	0.00	41.20	41.20	0.00	41.20	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	145.97%	0.58	1.63	0.29	300	$ 79.70	$ 4,495.31
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.63	0.00	21.45	62.65	0.00	62.65	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	136.49%	0.65	1.93	0.335	375	$ 98.30	$ 7,374.19
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.56	0.00	12.21	74.87	0.00	74.87	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	89.95%	0.86	0.68		375	$ 98.30	$ 3,422.14
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.24	0.00	0.00	74.87	0.00	74.87	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	55.32%	0.88	0.89		450	$ 101.30	$ 4,758.96
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	15.95	0.00	27.40	160.38	0.00	160.38	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	78.56%	1.05	0.23		525	$ 110.50	$ 1,588.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	16.17	0.00	4.76	165.14	0.00	165.14	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	49.10%	1.20	1.22		600	$ 148.70	$ 13,015.62
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	17.39	0.00	17.59	182.73	0.00	182.73	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	54.33%	1.23	0.51		600	$ 148.70	$ 5,634.32
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	0.00	80.29	80.29	0.00	80.29	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	13.17%	0.97	1.37		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	11.37	0.00	22.03	102.32	0.00	102.32	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	16.78%	1.04	1.60		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	12.98	0.00	42.05	144.37	0.00	144.37	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	18.36%	1.14	1.11		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	0.00	32.82	32.82	0.00	32.82	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	7.13%	0.76	1.90		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	11.90	0.00	66.90	99.72	0.00	99.72	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	21.66%	1.04	1.84		675	$ 227.90	$ 26,212.87
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	14.09	0.00	0.00	244.09	0.00	244.09	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	16.32%	1.29	0.20		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	17.90	0.00	10.92	437.74	0.00	437.74	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	29.27%	1.52	0.18		1050	$ 525.50	$ 8,808.74
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	0.00	13.05	13.05	0.00	13.05	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	9.65%	0.55	2.34		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	12.34	0.00	17.75	30.80	0.00	30.80	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	22.76%	0.70	1.67		450	$ 101.30	$ 7,107.34
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	14.01	0.00	19.05	49.85	0.00	49.85	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	24.42%	0.79	0.30		525	$ 110.50	$ 1,565.78
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	14.31	0.00	0.00	49.85	0.00	49.85	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	24.42%	0.79	2.12		525	$ 110.50	$ 11,103.39
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	16.43	0.00	20.25	70.11	0.00	70.11	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	34.34%	0.87	0.72		525	$ 110.50	$ 4,144.20
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	17.15	0.00	115.39	185.50	0.00	185.50	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	55.16%	1.23	1.29		600	$ 148.70	$ 14,214.63
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	0.00	26.69	26.69	0.00	26.69	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	58.15%	0.68	0.77		300	$ 79.70	$ 2,505.36
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	0.00	19.62	19.62	0.00	19.62	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	14.49%	0.62	0.49		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	10.77	0.00	0.00	46.31	0.00	46.31	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	22.68%	0.77	0.19		525	$ 110.50	$ 979.49
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	10.96	0.00	63.40	109.70	0.00	109.70	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	53.74%	0.97	1.39		525	$ 110.50	$ 8,962.31
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	0.00	29.44	29.44	0.00	29.44	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	35.37%	0.70	0.94		375	$ 98.30	$ 3,866.14
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	10.94	0.00	10.04	39.48	0.00	39.48	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	29.17%	0.75	1.37		450	$ 101.30	$ 6,243.42
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	12.31	0.00	18.25	57.73	0.00	57.73	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	42.66%	0.83	0.92		450	$ 101.30	$ 4,623.01
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	13.23	0.00	10.23	67.96	0.00	67.96	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	33.29%	0.86	0.26		525	$ 110.50	$ 1,482.52
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	13.49	0.00	3.19	71.15	0.00	71.15	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	34.85%	0.87	0.37		525	$ 110.50	$ 2,111.09
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	0.00	28.03	28.03	0.00	28.03	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	20.71%	0.68	0.31		450	$ 101.30	$ 1,269.51
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.31	0.00	4.96	32.99	0.00	32.99	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	24.37%	0.71	2.21		450	$ 101.30	$ 9,587.76
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	12.52	0.00	15.48	48.46	0.00	48.46	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	14.41%	0.86	0.08		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	12.60	0.00	29.87	78.34	0.00	78.34	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	23.29%	0.98	2.18		600	$ 148.70	$ 19,120.58
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	14.78	0.00	20.45	98.78	0.00	98.78	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	29.37%	1.05	0.62		600	$ 148.70	$ 5,795.49
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	15.40	0.00	8.62	178.56	0.00	178.56	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	53.09%	1.22	0.21		600	$ 148.70	$ 2,303.35
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	15.61	0.00	0.00	178.56	0.00	178.56	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	53.09%	1.22	1.20		600	$ 148.70	$ 13,104.91
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	16.81	0.00	119.87	298.43	0.00	298.43	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	88.74%	1.35	0.85		600	$ 148.70	$ 10,223.17
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	17.66	0.00	0.00	298.43	0.00	298.43	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	88.74%	1.35	0.09		600	$ 148.70	$ 1,083.32
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	0.00	13.39	13.39	0.00	13.39	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	29.17%	0.57	1.28		300	$ 79.70	$ 3,502.20
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.28	0.00	0.00	13.39	0.00	13.39	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	29.17%	0.57	0.31		300	$ 79.70	$ 848.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	11.59	0.00	7.65	21.04	0.00	21.04	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	10.31%	0.62	2.82		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	14.41	0.00	29.31	50.35	0.00	50.35	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	24.66%	0.79	0.65		525	$ 110.50	$ 3,392.84
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	15.06	0.00	7.76	58.11	0.00	58.11	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	17.28%	0.90	1.97		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	17.02	0.00	27.27	85.38	0.00	85.38	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	25.39%	1.01	1.26		600	$ 148.70	$ 11,350.88
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	18.29	0.00	55.85	141.23	0.00	141.23	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	41.99%	1.15	0.20		600	$ 148.70	$ 2,106.47
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	18.49	0.00	0.00	141.23	0.00	141.23	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	41.99%	1.15	0.90		600	$ 148.70	$ 9,269.77
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	19.39	0.00	29.83	171.06	0.00	171.06	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	50.86%	1.21	0.24		600	$ 148.70	$ 2,552.07
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	19.63	0.00	0.00	171.06	0.00	171.06	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	50.86%	1.21	0.59		600	$ 148.70	$ 6,354.85
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	20.22	0.00	0.00	171.06	0.00	171.06	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	50.86%	1.21	0.76		600	$ 148.70	$ 8,204.06

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	151	117	133	0	31	0	55
375	63	0	59	142	0	0	39	0
450	0	99	186	190	147	18	214	0
525	138	60	122	14	152	90	33	135
600	161	404	221	125	96	0	351	374
675	0	0	0	201	0	0	0	0
750	0	0	0	180	0	0	0	0
825	0	0	0	76	0	0	0	0
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	32	0	0	0	0
1200	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
Manhole	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	75	m
Total Basement Q	0.40	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	0
Location	Mount Hope
a	0
b	0
c	0

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0		Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	0.00	0.66	0.66	0.00	0.66	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	0.32%	-1.00			525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	0.00	1.70	1.70	0.00	1.70	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	2.04%	0.30	3.43		375	$ 98.30	$ 6,177.15
2	Eastport	Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	13.43	0.00	2.80	4.50	0.00	4.50	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	2.20%	0.39	4.59		525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	#VALUE!	#VALUE!	6.48	11.64	0.00	11.64	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	3.46%	0.56	1.62		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	#VALUE!	#VALUE!	1.13	12.76	0.00	12.76	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	3.79%	0.58	3.06		600	$ 148.70	$ 15,815.36
5		Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	0.00	2.61	2.61	0.00	2.61	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	5.68%	0.36	2.60		300	$ 79.70	$ 4,442.24
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	0.00	4.80	4.80	0.00	4.80	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	10.46%	0.43	2.78		300	$ 79.70	$ 5,676.88
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	12.78	0.00	4.86	9.67	0.00	9.67	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	21.06%	0.52	0.42		300	$ 79.70	$ 1,049.90
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	0.00	0.59	0.59	0.00	0.59	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	1.28%	0.23	0.77		300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	13.20	0.00	0.72	10.98	0.00	10.98	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	8.11%	0.52	3.16		450	$ 101.30	$ 9,980.21
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	16.36	0.00	5.50	16.47	0.00	16.47	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	8.07%	0.58	1.74		525	$ 110.50	$ 6,628.42
11	Hamilton Harbour	Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	18.10	0.00	3.61	20.08	0.00	20.08	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	5.97%	0.66	0.68		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	18.78	0.00	1.52	21.61	0.00	21.61	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	6.43%	0.68	1.97		600	$ 148.70	$ 11,931.69
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	20.75	0.00	4.69	26.29	0.00	26.29	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	7.82%	0.72	1.05		600	$ 148.70	$ 6,758.19
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	21.81	0.00	5.65	34.55	0.00	34.55	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	10.27%	0.78	0.23		600	$ 148.70	$ 1,622.48
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	22.04	0.00	0.07	34.62	0.00	34.62	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	10.29%	0.78	0.09		600	$ 148.70	$ 594.90
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	22.13	0.00	0.00	34.62	0.00	34.62	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	10.29%	0.78	0.19		600	$ 148.70	$ 1,352.79
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	22.32	0.00	0.00	34.62	0.00	34.62	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	12.61%	0.67	1.58		600	$ 148.70	$ 9,522.63
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	23.91	0.00	0.00	34.62	0.00	34.62	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	10.29%	0.78	0.23		600	$ 148.70	$ 1,590.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	24.13	0.00	0.00	34.62	0.00	34.62	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	10.29%	0.78	3.26		600	$ 148.70	$ 22,643.19
16		Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	0.00	1.72	1.72	0.00	1.72	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	3.74%	0.32	3.15		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	13.15	0.00	3.78	5.49	0.00	5.49	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	11.97%	0.44	2.15		300	$ 79.70	$ 4,576.62
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	15.31	0.00	3.39	8.89	0.00	8.89	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	6.57%	0.49	2.82		450	$ 101.30	$ 8,357.00
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	18.13	0.00	5.67	14.55	0.00	14.55	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	7.13%	0.55	3.23		525	$ 110.50	$ 11,876.70
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	21.36	0.00	6.79	21.35	0.00	21.35	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	10.46%	0.62	0.38		525	$ 110.50	$ 1,569.29
22	Dunraven	Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	0.00	1.83	1.83	0.00	1.83	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	2.20%	0.31	3.13		375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	13.13	0.00	3.47	5.30	0.00	5.30	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	3.91%	0.42	1.86		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	14.99	0.00	3.47	8.77	0.00	8.77	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	6.48%	0.49	1.94		450	$ 101.30	$ 5,722.48
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	21.74	0.00	3.43	33.54	0.00	33.54	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	9.97%	0.77	0.28		600	$ 148.70	$ 1,926.31
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	22.02	0.00	0.65	34.20	0.00	34.20	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	10.17%	0.78	2.12		600	$ 148.70	$ 14,683.23
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	24.14	0.00	5.13	39.32	0.00	39.32	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	11.69%	0.81	2.25		600	$ 148.70	$ 16,206.85
28		Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	0.00	3.39	3.39	0.00	3.39	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	7.38%	0.39	3.32		300	$ 79.70	$ 6,117.76
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	13.32	0.00	5.58	8.97	0.00	8.97	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	10.78%	0.50	1.09		375	$ 98.30	$ 3,210.73
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	14.41	0.00	2.32	11.29	0.00	11.29	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	8.35%	0.52	1.56		450	$ 101.30	$ 4,973.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	15.97	0.00	3.74	15.03	0.00	15.03	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	11.11%	0.57	2.74		450	$ 101.30	$ 9,492.29
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	0.00	10.66	10.66	0.00	10.66	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	37.77%	0.54	1.73		250	$ 70.00	$ 3,948.21
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	11.73	0.00	5.55	16.21	0.00	16.21	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	35.31%	0.60	2.08		300	$ 79.70	$ 5,978.87
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	13.81	0.00	3.16	19.37	0.00	19.37	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	23.27%	0.62	0.93		375	$ 98.30	$ 3,422.14
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	14.74	0.00	0.00	19.37	0.00	19.37	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	14.31%	0.61	1.28		450	$ 101.30	$ 4,758.96
36	Grafton	Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	18.71	0.00	7.09	41.50	0.00	41.50	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	20.33%	0.75	0.32		525	$ 110.50	$ 1,588.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	19.03	0.00	1.23	42.73	0.00	42.73	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	12.70%	0.83	1.76		600	$ 148.70	$ 13,015.62
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	20.79	0.00	4.55	47.28	0.00	47.28	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	14.06%	0.85	0.74		600	$ 148.70	$ 5,634.32
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	0.00	20.77	20.77	0.00	20.77	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	3.41%	0.65	2.05		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	12.05	0.00	5.70	26.47	0.00	26.47	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	4.34%	0.70	2.38		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	14.43	0.00	10.88	37.35	0.00	37.35	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	4.75%	0.77	1.64		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	0.00	8.49	8.49	0.00	8.49	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	1.84%	0.50	2.84		675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	12.84	0.00	17.31	25.80	0.00	25.80	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	5.60%	0.70	2.72		675	$ 227.90	$ 26,212.87
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	16.07	0.00	0.00	63.15	0.00	63.15	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	4.22%	0.87	0.29		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	21.53	0.00	2.83	113.26	0.00	113.26	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	7.57%	1.03	0.27		1050	$ 525.50	$ 8,808.74
48		Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	0.00	3.38	3.38	0.00	3.38	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	2.50%	0.37	3.49		450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	13.49	0.00	4.59	7.97	0.00	7.97	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	5.89%	0.47	2.47		450	$ 101.30	$ 7,107.34
83	Lagoon	Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	15.97	0.00	4.93	12.90	0.00	12.90	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	6.32%	0.54	0.44		525	$ 110.50	$ 1,565.78
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	16.41	0.00	0.00	12.90	0.00	12.90	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	6.32%	0.54	3.13		525	$ 110.50	$ 11,103.39
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	19.54	0.00	5.24	18.14	0.00	18.14	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	8.89%	0.59	1.06		525	$ 110.50	$ 4,144.20
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	20.59	0.00	29.86	47.99	0.00	47.99	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	14.27%	0.86	1.86		600	$ 148.70	$ 14,214.63
53		Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	0.00	6.91	6.91	0.00	6.91	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	15.05%	0.47	1.10		300	$ 79.70	$ 2,505.36
54	Townhouse	Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	0.00	5.08	5.08	0.00	5.08	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	3.75%	0.41	0.72		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	11.10	0.00	0.00	11.98	0.00	11.98	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	5.87%	0.52	0.28		525	$ 110.50	$ 979.49
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	11.39	0.00	16.40	28.38	0.00	28.38	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	13.90%	0.67	2.01		525	$ 110.50	$ 8,962.31
57		Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	0.00	7.62	7.62	0.00	7.62	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	9.15%	0.48	1.38		375	$ 98.30	$ 3,866.14
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	11.38	0.00	2.60	10.21	0.00	10.21	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	7.55%	0.51	2.02		450	$ 101.30	$ 6,243.42
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	13.39	0.00	4.72	14.94	0.00	14.94	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	11.04%	0.57	1.34		450	$ 101.30	$ 4,623.01
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	14.73	0.00	2.65	17.58	0.00	17.58	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	8.61%	0.59	0.38		525	$ 110.50	$ 1,482.52
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	15.11	0.00	0.82	18.41	0.00	18.41	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	9.02%	0.59	0.54		525	$ 110.50	$ 2,111.09
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	0.00	7.25	7.25	0.00	7.25	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	5.36%	0.46	0.45		450	$ 101.30	$ 1,269.51
64	Bayside	Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.45	0.00	1.28	8.53	0.00	8.53	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	6.31%	0.48	3.27		450	$ 101.30	$ 9,587.76
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	13.72	0.00	4.00	12.54	0.00	12.54	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	3.73%	0.58	0.12		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	13.84	0.00	7.73	20.27	0.00	20.27	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	6.03%	0.67	3.22		600	$ 148.70	$ 19,120.58
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	17.06	0.00	5.29	25.56	0.00	25.56	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	7.60%	0.71	0.91		600	$ 148.70	$ 5,795.49
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	17.97	0.00	2.23	46.20	0.00	46.20	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	13.74%	0.85	0.30		600	$ 148.70	$ 2,303.35
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	18.28	0.00	0.00	46.20	0.00	46.20	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	13.74%	0.85	1.73		600	$ 148.70	$ 13,104.91
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	20.01	0.00	31.02	77.21	0.00	77.21	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	22.96%	0.98	1.17		600	$ 148.70	$ 10,223.17
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	21.18	0.00	0.00	77.21	0.00	77.21	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	22.96%	0.98	0.12		600	$ 148.70	$ 1,083.32
72		Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	0.00	3.46	3.46	0.00	3.46	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	7.55%	0.39	1.89		300	$ 79.70	$ 3,502.20
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	11.89	0.00	0.00	3.46	0.00	3.46	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	7.55%	0.39	0.46		300	$ 79.70	$ 848.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	12.34	0.00	1.98	5.44	0.00	5.44	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	2.67%	0.41	4.21		525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	16.55	0.00	7.58	13.03	0.00	13.03	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	6.38%	0.54	0.95		525	$ 110.50	$ 3,392.84
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	17.51	0.00	2.01	15.03	0.00	15.03	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	4.47%	0.61	2.92		600	$ 148.70	$ 15,849.52
77	Fletcher	Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	20.43	0.00	7.06	22.09	0.00	22.09	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	6.57%	0.68	1.86		600	$ 148.70	$ 11,350.88
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	22.29	0.00	14.45	36.54	0.00	36.54	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	10.87%	0.79	0.30		600	$ 148.70	$ 2,106.47
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	22.59	0.00	0.00	36.54	0.00	36.54	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	10.87%	0.79	1.31		600	$ 148.70	$ 9,269.77
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	23.90	0.00	7.72	44.26	0.00	44.26	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	13.16%	0.84	0.34		600	$ 148.70	$ 2,552.07
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	24.24	0.00	0.00	44.26	0.00	44.26	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	13.16%	0.84	0.85		600	$ 148.70	$ 6,354.85
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	25.10	0.00	0.00	44.26	0.00	44.26	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	13.16%	0.84	1.10		600	$ 148.70	$ 8,204.06

Pipe Sizes (mm)	Length (m) Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhouse	Bayside	Fletcher
300	0	151	117	152	0	31	0	55
375	63	0	59	67	0	0	39	0
450	0	99	186	190	147	18	214	0
525	138	60	122	14	152	90	33	135
600	161	404	221	125	96	0	351	374
675	0	0	0	201	0	0	0	0
750	0	0	0	180	0	0	0	0
825	0	0	0	76	0	0	0	0
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	32	0	0	0	0
1200	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Dillon Consulting Limited
Breithaupt
Kitchener, ON

CITY OF HAMILTON
STORM SEWER DESIGN

Project: Beach Boulevard Community Stormwater Ponding Study
Design by: ARC
Date: December 2017

Hydraulic Conditions		
Min Slope	0.3	%
Lake Level	74.5	m
Total Basement Q	0.13	m^3/s
Minimum Tc	10	min
Min. dia.	0.3	m

Design Storm	
Frequency	0
Location	Mount Hope
a	0
b	0
c	0

Other Hydraulic Restrictions				
Mannings n =	0.015	dia. <	0.6	m
	0.013	dia. =>	0.6	m
Min.Velocity =	0.9	m/s		
Max. Velocity =	3.65	m/s		

Pipe Information					Hydrology Flow Calculations											Hydraulic Calculations										Design Calculations			
Area No.	System Name	Street Name	From MH No.	To MH No.	Area (ha)	Total Area (ha)	C Value	Area x C	Cumm. A x C	Cumm. Tc	I (mm/hr)	Pumping Flow (L/S)	Cumm Pumping Flow (L/S)	Total Storm Flow (L/s)	Total Flow (L/s)	D (m)	Pipe Slope m/m	n	Length (m)	A Full m^2	Q Full (L/s)	V Full (m/s)	% Flow Capacity	Actual Velocity (m/s)	Time of Flow (min)	Pipe Sizes (m)	Pipe Sizes (mm)	Unit Cost	Cost
0	Eastport	Beach	HZ07B001	HZ07B002	0.09	0.09	0.50	0.04	0.04	10.00	0.00	0.22	0.22	0.00	0.22	0.525	0.00300	0.015	30.71	0.22	204.15	0.94	0.11%	-1.00			525	$ 110.50	$ 3,393.95
1		Beach	HZ06B007	HZ06B008	0.23	0.23	0.50	0.12	0.12	10.00	0.00	0.56	0.56	0.00	0.56	0.375	0.00300	0.015	62.84	0.11	83.23	0.75	0.67%	-1.00			375	$ 98.30	$ 6,177.15
2		Beach	HZ06B008	HZ07B002	0.38	0.61	0.50	0.19	0.30	#VALUE!	#VALUE!	0.92	1.48	0.00	1.48	0.525	0.00300	0.015	107.68	0.22	204.15	0.94	0.73%	-1.00			525	$ 110.50	$ 11,898.93
3		Eastport	HZ07B002	HZ07B004	0.88	1.58	0.50	0.44	0.79	#VALUE!	#VALUE!	2.14	3.84	0.00	3.84	0.600	0.00300	0.013	54.71	0.28	336.31	1.19	1.14%	0.40	2.26		600	$ 148.70	$ 8,134.85
4		Eastport	HZ07B004	HZ07OF01	0.15	1.73	0.50	0.08	0.87	#VALUE!	#VALUE!	0.37	4.21	0.00	4.21	0.600	0.00300	0.013	106.36	0.28	336.31	1.19	1.25%	0.42	4.27		600	$ 148.70	$ 15,815.36
5	Hamilton Harbour	Beach	HZ06B006	HZ06B005	0.35	0.35	0.50	0.18	0.18	10.00	0.00	0.86	0.86	0.00	0.86	0.300	0.00300	0.015	55.74	0.07	45.90	0.65	1.87%	0.26	3.63		300	$ 79.70	$ 4,442.24
6		Beach	HZ05B005	HZ05B006	0.65	0.65	0.50	0.33	0.33	10.00	0.00	1.58	1.58	0.00	1.58	0.300	0.00300	0.015	71.23	0.07	45.90	0.65	3.45%	0.31	3.86		300	$ 79.70	$ 5,676.88
7		Beach	HZ05B006	HZ05B008	0.66	1.31	0.50	0.33	0.66	13.86	0.00	1.60	3.19	0.00	3.19	0.300	0.00300	0.015	13.17	0.07	45.90	0.65	6.94%	0.38	0.58		300	$ 79.70	$ 1,049.90
8		Beach	HZ05B007	HZ05B008	0.08	0.08	0.50	0.04	0.04	10.00	0.00	0.19	0.19	0.00	0.19	0.300	0.00300	0.015	10.55	0.07	45.90	0.65	0.42%	-1.00			300	$ 79.70	$ 841.18
9		Beach	HZ05B008	HZ06B001	0.10	1.49	0.50	0.05	0.74	#VALUE!	#VALUE!	0.24	3.62	0.00	3.62	0.450	0.00300	0.015	98.52	0.16	135.34	0.85	2.67%	0.37	4.39		450	$ 101.30	$ 9,980.21
10		Beach	HZ06B001	HZ06B002	0.75	2.23	0.50	0.37	1.12	#VALUE!	#VALUE!	1.81	5.43	0.00	5.43	0.525	0.00300	0.015	59.99	0.22	204.15	0.94	2.66%	0.41	2.42		525	$ 110.50	$ 6,628.42
11		Beach	HZ06B002	HZ06B003	0.49	2.72	0.50	0.24	1.36	#VALUE!	#VALUE!	1.19	6.62	0.00	6.62	0.600	0.00300	0.013	27.16	0.28	336.31	1.19	1.97%	0.48	0.95		600	$ 148.70	$ 4,038.33
12		Beach	HZ06B003	HZ06B004	0.21	2.93	0.50	0.10	1.47	#VALUE!	#VALUE!	0.50	7.13	0.00	7.13	0.600	0.00300	0.013	80.24	0.28	336.31	1.19	2.12%	0.49	2.75		600	$ 148.70	$ 11,931.69
13		Beach	HZ06B004	HZ06B005	0.64	3.57	0.50	0.32	1.78	#VALUE!	#VALUE!	1.55	8.67	0.00	8.67	0.600	0.00300	0.013	45.45	0.28	336.31	1.19	2.58%	0.52	1.47		600	$ 148.70	$ 6,758.19
14		-	HZ06B005	HZ06B009	0.77	4.69	0.50	0.38	2.34	#VALUE!	#VALUE!	1.86	11.40	0.00	11.40	0.600	0.00300	0.013	10.91	0.28	336.31	1.19	3.39%	0.56	0.32		600	$ 148.70	$ 1,622.48
15		-	HZ06B009	HZ06B012	0.01	4.69	0.50	0.00	2.35	#VALUE!	#VALUE!	0.02	11.42	0.00	11.42	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	3.39%	0.56	0.12		600	$ 148.70	$ 594.90
-		-	HZ06B012	HZ06B010	0.00	4.69	0.50	0.00	2.35	#VALUE!	#VALUE!	0.00	11.42	0.00	11.42	0.600	0.00300	0.013	9.10	0.28	336.31	1.19	3.39%	0.56	0.27		600	$ 148.70	$ 1,352.79
-		-	HZ06B010	HZ06B014	0.00	4.69	0.50	0.00	2.35	#VALUE!	#VALUE!	0.00	11.42	0.00	11.42	0.600	0.00200	0.013	64.04	0.28	274.59	0.97	4.16%	0.49	2.19		600	$ 148.70	$ 9,522.63
-		-	HZ06B014	HZ06B016	0.00	4.69	0.50	0.00	2.35	#VALUE!	#VALUE!	0.00	11.42	0.00	11.42	0.600	0.00300	0.013	10.70	0.28	336.31	1.19	3.39%	0.56	0.32		600	$ 148.70	$ 1,590.83
-		-	HZ06B016	HZ06OF01	0.00	4.69	0.50	0.00	2.35	#VALUE!	#VALUE!	0.00	11.42	0.00	11.42	0.600	0.00300	0.013	152.27	0.28	336.31	1.19	3.39%	0.56	4.52		600	$ 148.70	$ 22,643.19
16	Dunraven	Beach	HZ05B004	HZ05B003	0.23	0.23	0.50	0.12	0.12	10.00	0.00	0.57	0.57	0.00	0.57	0.300	0.00300	0.015	59.68	0.07	45.90	0.65	1.23%	0.23	4.41		300	$ 79.70	$ 4,756.71
17		Beach	HZ05B003	HZ05B002	0.51	0.75	0.50	0.26	0.37	14.41	0.00	1.25	1.81	0.00	1.81	0.300	0.00300	0.015	57.42	0.07	45.90	0.65	3.95%	0.32	2.99		300	$ 79.70	$ 4,576.62
18		Beach	HZ05B002	HZ05B001	0.46	1.21	0.50	0.23	0.60	17.39	0.00	1.12	2.93	0.00	2.93	0.450	0.00300	0.015	82.50	0.16	135.34	0.85	2.17%	0.35	3.92		450	$ 101.30	$ 8,357.00
19		Beach	HZ05B001	HZ04B010	0.77	1.97	0.50	0.38	0.99	21.31	0.00	1.87	4.80	0.00	4.80	0.525	0.00300	0.015	107.48	0.22	204.15	0.94	2.35%	0.40	4.50		525	$ 110.50	$ 11,876.70
20		Beach	HZ04B010	HZ04B009	0.92	2.89	0.50	0.46	1.45	25.81	0.00	2.24	7.04	0.00	7.04	0.525	0.00300	0.015	14.20	0.22	204.15	0.94	3.45%	0.45	0.53		525	$ 110.50	$ 1,569.29
22		Beach	HZ04B006	HZ04B007	0.25	0.25	0.50	0.12	0.12	10.00	0.00	0.60	0.60	0.00	0.60	0.375	0.00300	0.015	58.57	0.11	83.23	0.75	0.72%	-1.00			375	$ 98.30	$ 5,757.24
23		Beach	HZ04B007	HZ04B008	0.47	0.72	0.50	0.24	0.36	#VALUE!	#VALUE!	1.14	1.75	0.00	1.75	0.450	0.00300	0.015	46.67	0.16	135.34	0.85	1.29%	0.30	2.59		450	$ 101.30	$ 4,727.69
24		Beach	HZ04B008	HZ04B009	0.47	1.19	0.50	0.24	0.59	#VALUE!	#VALUE!	1.14	2.89	0.00	2.89	0.450	0.00300	0.015	56.49	0.16	135.34	0.85	2.14%	0.35	2.70		450	$ 101.30	$ 5,722.48
25		Beach	HZ04B009	HZ04B011	0.47	4.55	0.50	0.23	2.27	#VALUE!	#VALUE!	1.13	11.06	0.00	11.06	0.600	0.00300	0.013	12.95	0.28	336.31	1.19	3.29%	0.56	0.39		600	$ 148.70	$ 1,926.31
26		Dunraven	HZ04B011	HZ04B012	0.09	4.64	0.50	0.04	2.32	#VALUE!	#VALUE!	0.22	11.28	0.00	11.28	0.600	0.00300	0.013	98.74	0.28	336.31	1.19	3.35%	0.56	2.94		600	$ 148.70	$ 14,683.23
27		Dunraven	HZ04B012	HZ04B12	0.70	5.33	0.50	0.35	2.67	#VALUE!	#VALUE!	1.69	12.97	0.00	12.97	0.600	0.00300	0.013	108.99	0.28	336.31	1.19	3.86%	0.58	3.12		600	$ 148.70	$ 16,206.85
28	Grafton	Beach/Rembe	HZ04B004	HZ04B003	0.46	0.46	0.50	0.23	0.23	10.00	0.00	1.12	1.12	0.00	1.12	0.300	0.00300	0.015	76.76	0.07	45.90	0.65	2.43%	0.28	4.62		300	$ 79.70	$ 6,117.76
29		Beach/Windmere	HZ04B003	HZ04B002	0.76	1.22	0.50	0.38	0.61	14.62	0.00	1.84	2.96	0.00	2.96	0.375	0.00300	0.015	32.66	0.11	83.23	0.75	3.55%	0.36	1.51		375	$ 98.30	$ 3,210.73
30		Beach	HZ04B002	HZ04B001	0.32	1.53	0.50	0.16	0.77	16.13	0.00	0.77	3.73	0.00	3.73	0.450	0.00300	0.015	49.09	0.16	135.34	0.85	2.75%	0.38	2.17		450	$ 101.30	$ 4,973.08
31		Beach/Killarney	HZ04B001	HZ03B012	0.51	2.04	0.50	0.25	1.02	18.30	0.00	1.23	4.96	0.00	4.96	0.450	0.00300	0.015	93.70	0.16	135.34	0.85	3.66%	0.41	3.80		450	$ 101.30	$ 9,492.29
50		Beach/Woodland	HZ03B008	HZ03B009	1.45	1.45	0.50	0.72	0.72	10.00	0.00	3.52	3.52	0.00	3.52	0.250	0.00300	0.015	56.40	0.05	28.23	0.58	12.46%	0.40	2.36		250	$ 70.00	$ 3,948.21
34		Beach/Granville	HZ03B009	HZ03B010	0.75	2.20	0.50	0.38	1.10	12.36	0.00	1.83	5.35	0.00	5.35	0.300	0.00300	0.015	75.02	0.07	45.90	0.65	11.65%	0.44	2.84		300	$ 79.70	$ 5,978.87
35		Beach/Comet	HZ03B010	HZ03B011	0.43	2.63	0.50	0.21	1.31	15.20	0.00	1.04	6.39	0.00	6.39	0.375	0.00300	0.015	34.81	0.11	83.23	0.75	7.68%	0.45	1.28		375	$ 98.30	$ 3,422.14
-		-	HZ03B011	HZ03B012	0.00	2.63	0.50	0.00	1.31	16.48	0.00	0.00	6.39	0.00	6.39	0.450	0.00300	0.015	46.98	0.16	135.34	0.85	4.72%	0.44	1.77		450	$ 101.30	$ 4,758.96
36		Beach/Grafton	HZ03B012	HZ03B013	0.96	5.63	0.50	0.48	2.81	22.10	0.00	2.34	13.69	0.00	13.69	0.525	0.00300	0.015	14.37	0.22	204.15	0.94	6.70%	0.54	0.44		525	$ 110.50	$ 1,588.01
37		Beach/Grafton	HZ03B013	HZ03B014	0.17	5.79	0.50	0.08	2.90	22.54	0.00	0.41	14.09	0.00	14.09	0.600	0.00300	0.013	87.53	0.28	336.31	1.19	4.19%	0.60	2.44		600	$ 148.70	$ 13,015.62
38		Grafton	HZ03B014	HZ03B015	0.62	6.41	0.50	0.31	3.21	24.98	0.00	1.50	15.59	0.00	15.59	0.600	0.00300	0.013	37.89	0.28	336.31	1.19	4.64%	0.62	1.03		600	$ 148.70	$ 5,634.32
40		Rembe	HZ04B014	HZ04B016	2.82	2.82	0.50	1.41	1.41	10.00	0.00	6.85	6.85	0.00	6.85	0.750	0.00300	0.013	80.00	0.44	609.77	1.38	1.12%	0.47	2.86		750	$ 300.50	$ 24,040.91
41		Windermere	HZ04B016	HZ04B018	0.77	3.59	0.50	0.39	1.79	12.86	0.00	1.88	8.73	0.00	8.73	0.750	0.00300	0.013	100.11	0.44	609.77	1.38	1.43%	0.50	3.32		750	$ 300.50	$ 30,082.13
42		Wickham	HZ04B018	HZ03B016	1.48	5.07	0.50	0.74	2.53	16.18	0.00	3.59	12.32	0.00	12.32	0.825	0.00300	0.013	75.63	0.53	786.22	1.47	1.57%	0.55	2.29		825	$ 348.60	$ 26,363.35
44		Clare	HZ03B020	HZ03B018	1.15	1.15	0.50	0.58	0.58	10.00	0.00	2.80	2.80	0.00	2.80	0.675	0.00300	0.013	86.00	0.36	460.41	1.29	0.61%	-1.00			675	$ 227.90	$ 19,599.38
45		Comet/Granville	HZ03B018	HZ03B016	2.35	3.50	0.50	1.17	1.75	#VALUE!	#VALUE!	5.71	8.51	0.00	8.51	0.675	0.00300	0.013	115.02	0.36	460.41	1.29	1.85%	0.51	3.79		675	$ 227.90	$ 26,212.87
-		-	HZ03B016	HZ03B015	0.00	8.56	0.50	0.00	4.28	#VALUE!	#VALUE!	0.00	20.83	0.00	20.83	1.050	0.00300	0.013	15.13	0.87	1495.68	1.73	1.39%	0.62	0.40		1050	$ 525.50	$ 7,948.67
47		Grafton	HZ03B015	HZ03PS08	0.38	15.36	0.50	0.19	7.68	#VALUE!	#VALUE!	0.93	37.35	0.00	37.35	1.050	0.00300	0.013	16.76	0.87	1495.68	1.73	2.50%	0.74	0.38		1050	$ 525.50	$ 8,808.74
48	Lagoon	Sierra	HZ03B001	HZ03B002	0.46	0.46	0.50	0.23	0.23	10.00	0.00	1.11	1.11	0.00	1.11	0.450	0.00300	0.015	76.66	0.16	135.34	0.85	0.82%	-1.00			450	$ 101.30	$ 7,765.27
49		Beach/Arden	HZ03B002	HZ03B003	0.62	1.08	0.50	0.31	0.54	#VALUE!	#VALUE!	1.51	2.63	0.00	2.63	0.450	0.00300	0.015	70.16	0.16	135.34	0.85	1.94%	0.34	3.45		450	$ 101.30	$ 7,107.34
83		Beach/Lagoon	HZ03B003	HZ03B004	0.67	1.75	0.50	0.33	0.87	#VALUE!	#VALUE!	1.63	4.25	0.00	4.25	0.525	0.00300	0.015	14.17	0.22	204.15	0.94	2.08%	0.38	0.61		525	$ 110.50	$ 1,565.78
-		-	HZ03B004	HZ03B005	0.00	1.75	0.50	0.00	0.87	#VALUE!	#VALUE!	0.00	4.25	0.00	4.25	0.525	0.00300	0.015	100.48	0.22	204.15	0.94	2.08%	0.38	4.36		525	$ 110.50	$ 11,103.39
51		Lagoon	HZ03B005	HZ03B006	0.71	2.46	0.50	0.36	1.23	#VALUE!	#VALUE!	1.73	5.98	0.00	5.98	0.525	0.00300	0.015	37.50	0.22	204.15	0.94	2.93%	0.43	1.47		525	$ 110.50	$ 4,144.20
52		Lagoon/Arden	HZ03B006	HZ03B007	4.05	6.51	0.50	2.02	3.25	#VALUE!	#VALUE!	9.85	15.83	0.00	15.83	0.600	0.00300	0.013	95.59	0.28	336.31	1.19	4.71%	0.62	2.58		600	$ 148.70	$ 14,214.63
53	Townhouse	Beach	HZ02B015	HZ02B011	0.94	0.94	0.50	0.47	0.47	10.00	0.00	2.28	2.28	0.00	2.28	0.300	0.00300	0.015	31.43	0.07	45.90	0.65	4.96%	0.34	1.53		300	$ 79.70	$ 2,505.36
54		Beach	HZ02B010	HZ02B011	0.69	0.69	0.50	0.34	0.34	10.00	0.00	1.67	1.67	0.00	1.67	0.450	0.00300	0.015	17.94	0.16	135.34	0.85	1.24%	0.30	1.01		450	$ 101.30	$ 1,817.77
-		-	HZ02B011	HZ02B013	0.00	1.62	0.50	0.00	0.81	11.53	0.00	0.00	3.95	0.00	3.95	0.525	0.00300	0.015	8.86	0.22	204.15	0.94	1.94%	0.38	0.39		525	$ 110.50	$ 979.49
56		Beach/Townhouses	HZ02B013	HZ02OF03	2.22	3.85	0.50	1.11	1.92	11.92	0.00	5.41	9.36	0.00	9.36	0.525	0.00300	0.015	81.11	0.22	204.15	0.94	4.59%	0.49	2.78		525	$ 110.50	$ 8,962.31
57	Bayside	Beach/Tower	HZ02B009	HZ02B008	1.03	1.03	0.50	0.52	0.52	10.00	0.00	2.51	2.51	0.00	2.51	0.375	0.00300	0.015	39.33	0.11	83.23	0.75	3.02%	0.34	1.91		375	$ 98.30	$ 3,866.14
58		Beach/Tower	HZ02B008	HZ02B007	0.35	1.39	0.50	0.18	0.69	11.91	0.00	0.86	3.37	0.00	3.37	0.450	0.00300	0.015	61.63	0.16	135.34	0.85	2.49%	0.37	2.81		450	$ 101.30	$ 6,243.42
59		Beach	HZ02B007	HZ02B006	0.64	2.03	0.50	0.32	1.01	14.72	0.00	1.56	4.93	0.00	4.93	0.450	0.00300	0.015	45.64	0.16	135.34	0.85	3.64%	0.41	1.86		450	$ 101.30	$ 4,623.01
60		Beach/Lakeside	HZ02B006	HZ02B005	0.36	2.38	0.50	0.18	1.19	16.58	0.00	0.87	5.80	0.00	5.80	0.525	0.00300	0.015	13.42	0.22	204.15	0.94	2.84%	0.42	0.53		525	$ 110.50	$ 1,482.52
61		Lakeside	HZ02B005	HZ02B004	0.11	2.50	0.50	0.06	1.25	17.11	0.00	0.27	6.07	0.00	6.07	0.525	0.00300	0.015	19.10	0.22	204.15	0.94	2.97%	0.43	0.74		525	$ 110.50	$ 2,111.09
63		Beach/Wark	HZ01B005	HZ01B030	0.98	0.98	0.50	0.49	0.49	10.00	0.00	2.39	2.39	0.00	2.39	0.450	0.00300	0.015	12.53	0.16	135.34	0.85	1.77%	0.33	0.63		450	$ 101.30	$ 1,269.51
64		Beach/Wark	HZ01B030	HZ01B006	0.17	1.16	0.50	0.09	0.58	10.63	0.00	0.42	2.81	0.00	2.81	0.450	0.00300	0.015	94.65	0.16	135.34	0.85	2.08%	0.35	4.55		450	$ 101.30	$ 9,587.76
65		Beach/Mareve	HZ01B006	HZ01B007	0.54	1.70	0.50	0.27	0.85	15.19	0.00	1.32	4.14	0.00	4.14	0.600	0.00300	0.013	4.00	0.28	336.31	1.19	1.23%	0.41	0.16		600	$ 148.70	$ 594.45
66		Beach/Townhouses	HZ01B007	HZ01B008	1.05	2.75	0.50	0.52	1.37	15.35	0.00	2.55	6.68	0.00	6.68	0.600	0.00300	0.013	128.58	0.28	336.31	1.19	1.99%	0.48	4.49		600	$ 148.70	$ 19,120.58
67		Beach/Fitch	HZ01B008	HZ02B004	0.72	3.47	0.50	0.36	1.73	19.84	0.00	1.74	8.43	0.00	8.43	0.600	0.00300	0.013	38.97	0.28	336.31	1.19	2.51%	0.51	1.27		600	$ 148.70	$ 5,795.49
68		Beach/Bayside	HZ02B004	HZ02B003	0.30	6.26	0.50	0.15	3.13	21.10	0.00	0.74	15.24	0.00	15.24	0.600	0.00300	0.013	15.49	0.28	336.31	1.19	4.53%	0.61	0.42		600	$ 148.70	$ 2,303.35
-		-	HZ02B003	HZ02B002	0.00	6.26	0.50	0.00	3.13	21.53	0.00	0.00	15.24	0.00	15.24	0.600	0.00300	0.013	88.13	0.28	336.31	1.19	4.53%	0.61	2.40		600	$ 148.70	$ 13,104.91
70		Bayside	HZ02B002	HZ02B001	4.21	10.47	0.50	2.10	5.24	23.93	0.00	10.23	25.47	0.00	25.47	0.600	0.00300	0.013	68.75	0.28	336.31	1.19	7.57%	0.71	1.61		600	$ 148.70	$ 10,223.17
-		-	HZ02B001	HZ02OF02	0.00	10.47	0.50	0.00	5.24	25.54	0.00	0.00	25.47	0.00	25.47	0.600	0.00300	0.013	7.29	0.28	336.31	1.19	7.57%	0.71	0.17		600	$ 148.70	$ 1,083.32
72	Fletcher	Beach/Kirk	HZ01B003	HZ01B002	0.47	0.47	0.50	0.23	0.23	10.00	0.00	1.14	1.14	0.00	1.14	0.300	0.00300	0.015	43.94	0.07	45.90	0.65	2.49%	0.28	2.62		300	$ 79.70	$ 3,502.20
-		-	HZ01B002	HZ01B001	0.00	0.47	0.50	0.00	0.23	12.62	0.00	0.00	1.14	0.00	1.14	0.300	0.00300	0.015	10.65	0.07	45.90	0.65	2.49%	0.28	0.64		300	$ 79.70	$ 848.63
74		Beach	HZ01B001	HP02B007	0.27	0.74	0.50	0.13	0.37	13.26	0.00	0.65	1.80	0.00	1.80	0.525	0.00300	0.015	104.51	0.22	204.15	0.94	0.88%	-1.00			525	$ 110.50	$ 11,547.88
75		Beach	HP02B007	HP02B006	1.03	1.77	0.50	0.51	0.88	#VALUE!	#VALUE!	2.50	4.30	0.00	4.30	0.525	0.00300	0.015	30.70	0.22	204.15	0.94	2.10%	0.39	1.33		525	$ 110.50	$ 3,392.84
76		Beach	HP02B006	HP02B005	0.27	2.04	0.50	0.14	1.02	#VALUE!	#VALUE!	0.66	4.96	0.00	4.96	0.600	0.00300	0.013	106.59	0.28	336.31	1.19	1.47%	0.44	4.07		600	$ 148.70	$ 15,849.52
77		Beach	HP02B005	HP02B004	0.96	3.00	0.50	0.48	1.50	#VALUE!	#VALUE!	2.33	7.29	0.00	7.29	0.600	0.00300	0.013	76.33	0.28	336.31	1.19	2.17%	0.49	2.60		600	$ 148.70	$ 11,350.88
78		Beach/Fletcher	HP02B004	HP02B008	1.96	4.96	0.50	0.98	2.48	#VALUE!	#VALUE!	4.77	12.05	0.00	12.05	0.600	0.00300	0.013	14.17	0.28	336.31	1.19	3.58%	0.57	0.41		600	$ 148.70	$ 2,106.47
-		-	HP02B008	HP02B009	0.00	4.96	0.50	0.00	2.48	#VALUE!	#VALUE!	0.00	12.05	0.00	12.05	0.600	0.00300	0.013	62.34	0.28	336.31	1.19	3.58%	0.57	1.82		600	$ 148.70	$ 9,269.77
80		Fletcher	HP02B009	HP02B010	1.05	6.00	0.50	0.52	3.00	#VALUE!	#VALUE!	2.55	14.60	0.00	14.60	0.600	0.00300	0.013	17.16	0.28	336.31	1.19	4.34%	0.60	0.47		600	$ 148.70	$ 2,552.07
-		-	HP02B010	HP02B011	0.00	6.00	0.50	0.00	3.00	#VALUE!	#VALUE!	0.00	14.60	0.00	14.60	0.600	0.00300	0.013	42.74	0.28	336.31	1.19	4.34%	0.60	1.18		600	$ 148.70	$ 6,354.85
-		-	HP02B011	HP02OF01	0.00	6.00	0.50	0.00	3.00	#VALUE!	#VALUE!	0.00	14.60	0.00	14.60	0.600	0.00300	0.013	55.17	0.28	336.31	1.19	4.34%	0.60	1.52		600	$ 148.70	$ 8,204.06

Pipe Sizes (mm)	Length (m)							
	Eastport	Hamilton Harbour	Dunraven	Grafton	Lagoon	Townhous	Bayside	Fletcher
300	0	151	117	152	0	31	0	55
375	63	0	59	67	0	0	39	0
450	0	99	186	190	147	18	214	0
525	138	60	122	14	152	90	33	135
600	161	404	221	125	96	0	351	374
675	0	0	0	201	0	0	0	0
750	0	0	0	180	0	0	0	0
825	0	0	0	76	0	0	0	0
900	0	0	0	0	0	0	0	0
975	0	0	0	0	0	0	0	0
1050	0	0	0	32	0	0	0	0
1200	0	0	0	0	0	0	0	0
1350	0	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0	0
1650	0	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
2100	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0
2400	0	0	0	0	0	0	0	0
2550	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
MHs	5	15	11	18	7	4	14	11

Appendix F

Storage Calculations

	Eastport	Hamilton Harbour	Dunraven	Lagoon	Townhouses	Bayside	Fletcher
Lake Level	76	76	76	76	76	76	76
100yr Storage	141	454	506	563	268	952	567
Lowest road elevation	76	77	77	76	76	76	77
Storage pond bottom elevation	75	75	75	75	75	75	75
Max depth of the storage pond	0.6	1.6	1.7	0.6	0.6	0.5	1.5
Area of City owned Properties (m^2)	567	728	1,052	1,619		567	5,544
Storm water pond Calc							
Slope X:1	5	5	5	5	5	5	5
Top Length (m)	27	31	32	91	62	113	35
Top Width	21	31	32	21	16	35	30
Base Length (m)	21	14	15	85	56	108	20
Base Width (m)	15	15	15	15	10	15	15
Required Area (m^2)	561	957	1,030	1,903	989	3,935	1,060

Appendix G

Detailed Costing

Storm 5YR
Lake Level 74

Size	Each	Multiplier	Eastport Amount	Eastport Cost	Hamilton Harbour Amount	Hamilton Harbour Cost	Dunraven Amount	Dunraven Cost	Grafton Amount	Grafton Cost	Lagoon Amount	Lagoon Cost	Townhouse Amount	Townhouse Cost	Bayside Amount	Bayside Cost	Fletcher Amount	Fletcher Cost
300	79.7	2.5	0	$ -	11	$ 2,103	60	$ 11,892	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -
375	98.3	2.57	63	$ 15,875	56	$ 14,081	59	$ 14,796	77	$ 19,392	0	$ -	0	$ -	0	$ -	55	$ 13,791
450	101.3	2.64	0	$ -	71	$ 19,049	104	$ 27,838	0	$ -	77	$ 20,500	49	$ 13,206	0	$ -	0	$ -
525	110.5	2.71	138	$ 41,444	112	$ 33,447	139	$ 41,621	82	$ 24,482	70	$ 21,010	0	$ -	208	$ 62,329	105	$ 31,295
600	148.7	2.78	161	$ 66,582	87	$ 36,024	107	$ 44,431	150	$ 62,052	152	$ 62,900	9	$ 3,664	50	$ 20,518	137	$ 56,754
675	227.9	2.85	0	$ -	126	$ 81,637	14	$ 9,224	243	$ 157,708	0	$ -	0	$ -	200	$ 129,955	76	$ 49,580
750	300.5	2.92	0	$ -	187	$ 164,069	221	$ 193,645	295	$ 258,964	0	$ -	81	$ 71,168	0	$ -	77	$ 67,130
825	348.6	2.99	0	$ -	64	$ 66,749	0	$ -	215	$ 224,533	96	$ 99,638	0	$ -	104	$ 108,004	115	$ 119,940
900	418.2	3.06	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -
975	458.8	3.13	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	76	$ 109,190	0	$ -
1050	525.5	3.2	0	$ -	0	$ -	0	$ -	15	$ 25,436	0	$ -	0	$ -	0	$ -	0	$ -
1200	658.6	3.27	0	$ -	0	$ -	0	$ -	17	$ 36,100	0	$ -	0	$ -	0	$ -	0	$ -
1350	847	3.34	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -
1500	1036	3.41	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -
1650	1240.6	3.48	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -
Manhole	6500	-	5	$ 32,500	15	$ 97,500	11	$ 71,500	18	$ 117,000	7	$ 45,500	4	$ 26,000	14	$ 91,000	11	$ 71,500
				$ 156,401		$ 514,658		$ 414,947		$ 925,667		$ 249,548		$ 114,038		$ 520,998		$ 409,990

TOTAL $ 3,306,246

Appendix H

Planning Memo

DILLON CONSULTING

MEMO

TO: Angela Doyle, City of Hamilton
FROM: Paddy Kennedy and Zahra Jaffer
cc: Denis Viens
DATE: January 19, 2018
SUBJECT: Planning Review of Beach Strip Flooding Study – Draft Memo
OUR FILE: File #17-5898

The purpose of the following memo is to provide a summary of the planning considerations for the Beach Strip Flooding Study. The Flooding Study is being undertaken by the City to understand the potential opportunities for addressing flooding issues in the Beaches area. The planning review consisted of the following elements:

1. Review of the local context;
2. Review of the local planning policies;
3. Review of Zoning By-Law;
4. Review of historical building permit data; and,
5. Summary of findings and recommendations.

A summary of the findings for each of the above components is provided below.

Local Context

The Study Area is approximately 211 hectares in size, extending approximately 4.3km along a narrow strip of waterfront land in the north-west limits of the City (see Figure 1). The Study Area is bounded by the Hamilton Harbour to the west and Lake Ontario to the east, and is bisected by the QEW. The Study Area east of the QEW is populated with a mix of low-rise residential dwellings, parks and open space uses. A range of industrial uses are located to the west of the QEW within the Study Area. For purposes of this review for the Beaches Flooding Study, only the lands east of the QEW were focused on.

FIGURE 1 STUDY AREA

Policy Framework Review

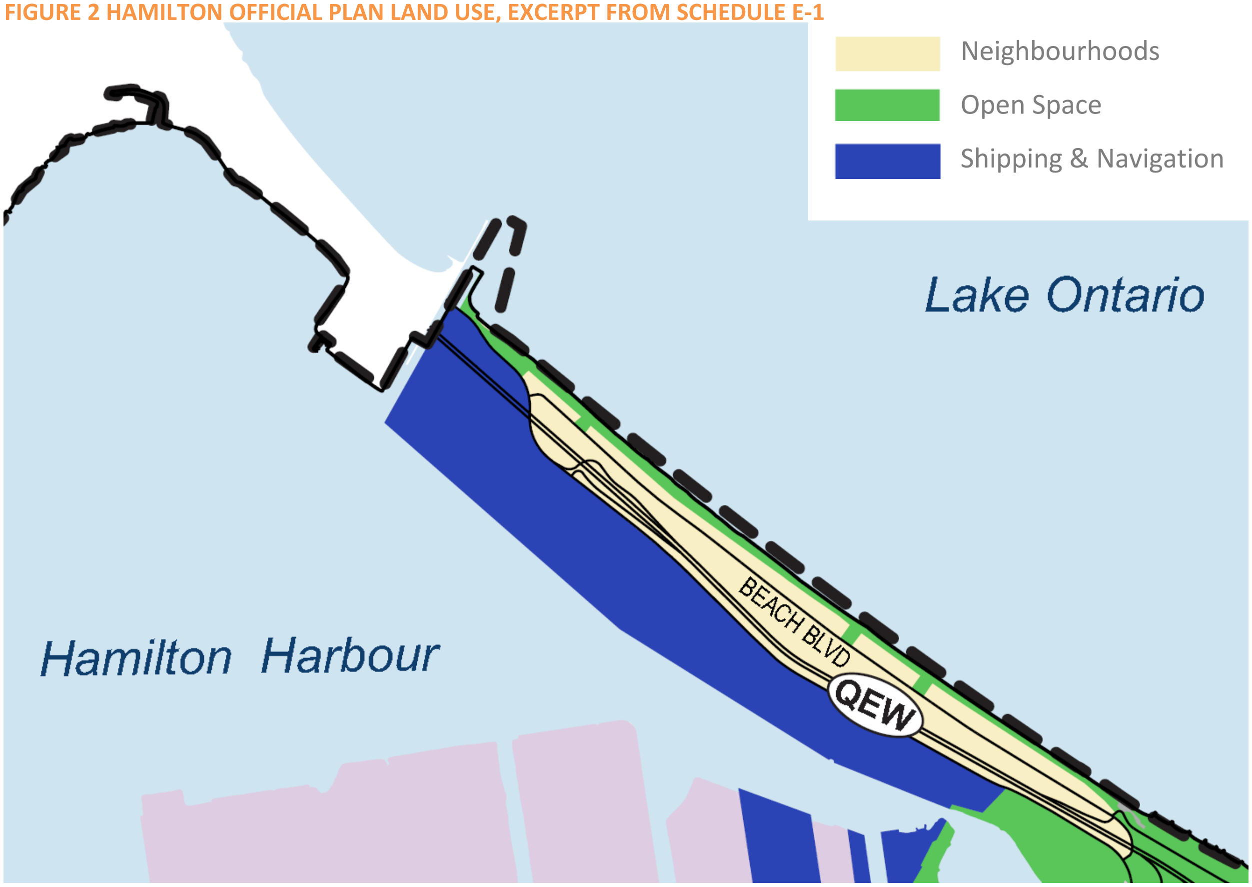
Lands within the Study Area east of the QEW are designated in the City's Official Plan as Neighbourhoods, with some Open Space lands designated along the waterfront (see Figure 2 on the following page, showing excerpt from Schedule E-1 of the Official Plan). The uses permitted under the Neighbourhoods designation include residential as well as a range of supporting amenity services, institutional uses, and a range of commercial uses. The lands west of the QEW have the Official Plan designation of Shipping and Navigation.

Lands within the Study Area are subject to Special Policy Area designation UH-2 (Map H-6 of the Official Plan), for which the following policies apply, as quoted in the Official Plan:

a. "The City shall ensure that appropriate shoreline protection measures as may be prescribed by the province and will be taken to mitigate flooding, erosion and pollution.

b. Recreational-oriented and water-related commercial uses, such as theme parks, amusement parks, boating facilities, interpretive centres, craft centres, etc., shall be permitted, in addition to those uses set out in Section C.3.3 - Open Space of Volume 1. This policy does not purport to prohibit or otherwise regulate the Hamilton Port Authority from using their lands for bona fide shipping and navigation purposes."

FIGURE 2 HAMILTON OFFICIAL PLAN LAND USE, EXCERPT FROM SCHEDULE E-1



Some portions along the shoreline of the Study Area also fall within Hamilton Conservation Authority's Regulated Areas, meaning that some forms of development within the Regulated Areas are subject to Conservation Authority approval.

Zoning By-Law Review

The City of Hamilton Zoning By-Law is currently undergoing an update. The existing City of Hamilton Zoning By-Law No. 6593 was referred to for purposes of this review. The following key points are noted:

- Most lands in the Study Area east of the QEW are zoned as "Urban Protected Residential", which allows for single family residential uses as well as some community services such as retirement homes, nurseries, etc.
  - The maximum permitted height is 11 metres
  - Front Yards are restricted to 6 metres in depth
  - Sideyard 1.2 metres
  - Rear yard 7.5 metres
  - There is a minimum lot width of 12 metres
- Zoning By-Law amendment 99-170 was passed in 1999 which includes regulations which restrict basement developments on the east side of Beach Boulevard. The amendment was enacted to implement the findings of the City's Beach Master Drainage Study (1999), and included:
  - Requirements for a minimum side yard for all structures of 1.7 metres (reduced to 1.5 metres if a common swale is present)
  - Prohibition on basements
  - Minimum ground floor elevation for all buildings of 76.0 metres above mean sea level.

The Zoning By-law is one of the main tools for limiting the development of basements in the Study Area, thereby limiting the potential vulnerability to flooding risks.

Building Permit Data Review

Building Permit data for the Study Area was requested from the City covering the period from 2009-2017, with a focus on lands east of the QEW. The data received was processed through GIS (see Figure 3-1 attached for a summary) and in Excel format. Figures 3-2 to 3-7 break down the Study Area to allow for clearer understanding of the information. Properties with a blue outline indicate a permit issued within this time frame; the colour of the building footprint indicates the depth of basement. A number of the properties where a permit was issued appear to have basements, although the depth is not known. These properties represent instances where the City may undertake further investigation to determine if appropriate compliance is in place with respect to limiting the construction of basements in the Study Area.

The following points are noted as a result of the data review:

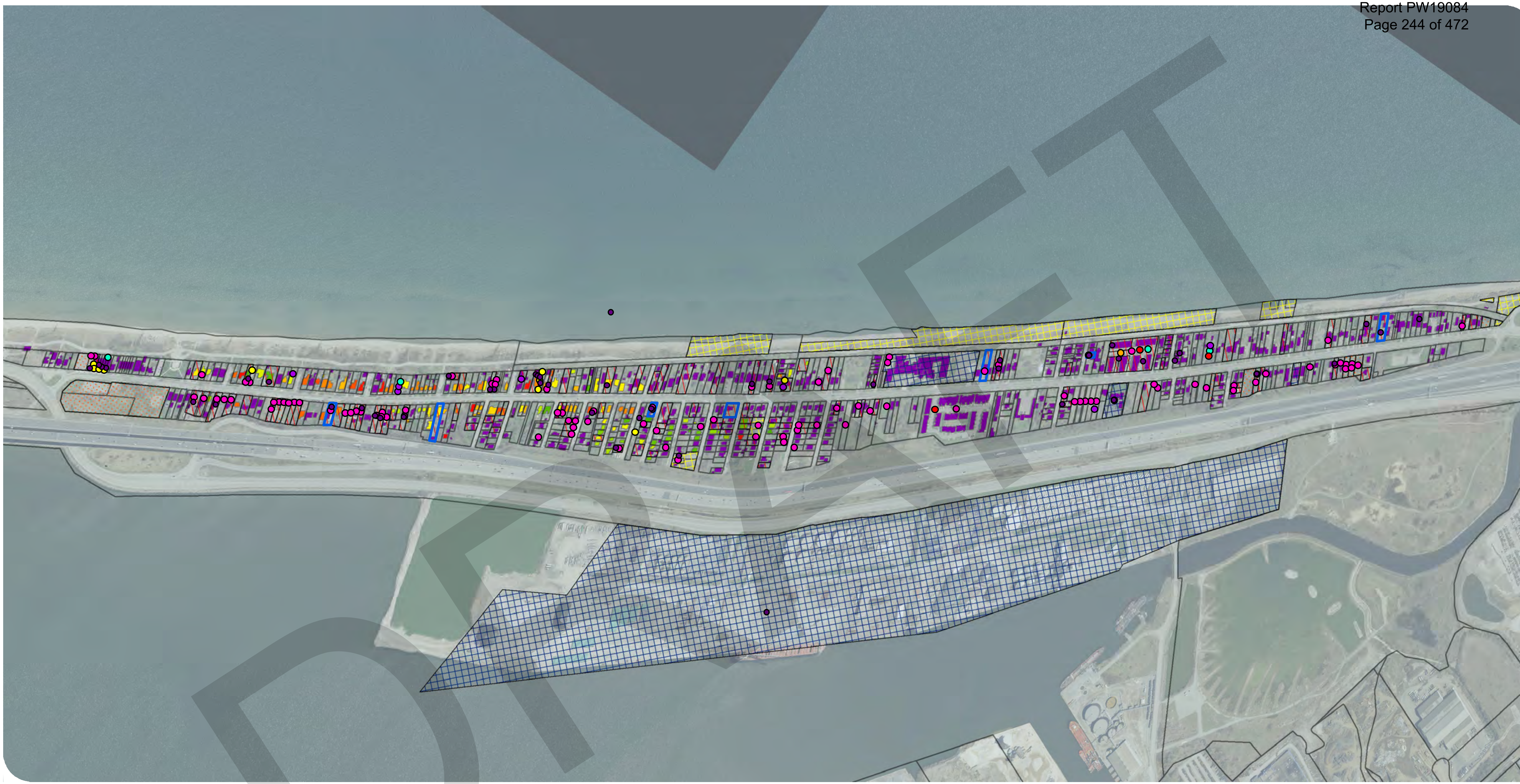
- Of the large number of Building Permits issued over the past 10 years since 2007, approximately 32% represent new construction, with an additional 13% being additions and 15% alterations. It would appear that approximately 50% of parcels in the beach strip have received a Building Permit for some variety of activity over the past 10 years.
- A total of approximately 90 units were added in the Study Area between 2009 and 2017.

- A total of approximately $36.8M in development was permitted between 2009-2017, across 204 permits issued that had an associated cost of project construction. The highest development cost was $6.7M for the Grafton Pumping Station (2012).
- 8 Building Permits were issued for a new basement within the Study Area. The Development Applications data received from the City for the same time period did not show any applications for Zoning By-Law amendments related specifically to basements within the time period.

Summary

The City's Official Plan includes a Special Policy (UH-2) identifying the potential for additional development risks related to shoreline erosion and flooding resulting from Lake-based storm events. The Zoning By-law features a specific regulation prohibiting new basements for certain lands on the east side of Beaches Boulevard (By-Law 99-170). While there has been a continuous level of development in the Study Area over the last decade, there have only been a handful of new basements have been constructed. It does not appear as though additional major planning policies or regulations could be implemented to resolve or address issues related to increased basement flooding in the Study Area. The City could consider the following minor adjustments:

- Updating Special Policy Area designation UH-2 to reference the potential risks related to basement flooding so as to align with the language/restrictions in the Zoning By-law.
- Reviewing the geographic limits of the Amendment 99-170 to ensure that all properties which could be vulnerable to basement flooding are covered by the basement prohibition regulation (which appears to be the case, but should be confirmed).



CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 1

BASEMENT DEPTH
MBGS (COUNT)
No Information (594)
0.2 (3)
0.4 (6)
0.5 (4)
0.6 (9)
0.7 (2)
0.8 (7)
0.9 (7)
1 (9)
1.1 (2)
1.2 (19)
1.3 (1)
1.4 (18)
1.5 (2)
1.6 (17)
1.7 (7)
1.8 (4)
1.9 (1)
2 (5)
3 (2)

Builing Permits (10 Years)
Type
Commercial (5)
Institutional (12)
Residential (185)
Utilities (17)
Vacant Lands (15)
Building Permits for Basements (8)

Development Applicatons (10 Years)
File Type
Condominium (3)
Formal Consultation (7)
Land Division (10)
Official Plan Amendment (1)
Site Plan (100)
Zoning Amendment (4)

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 205 410 820 Metres

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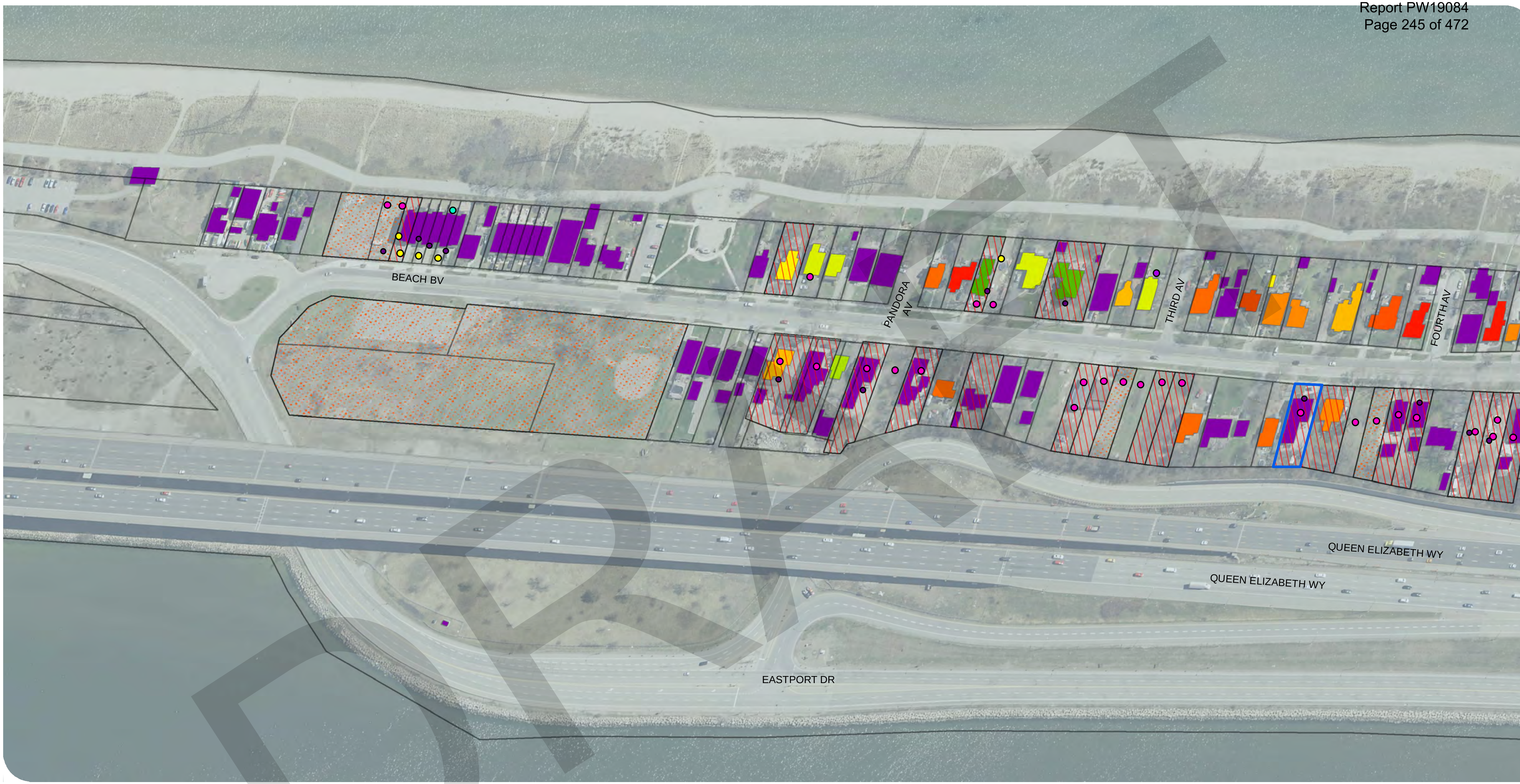
PROJECT: 17-5898
STATUS: DRAFT
DATE: 08/30/17



CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 2

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

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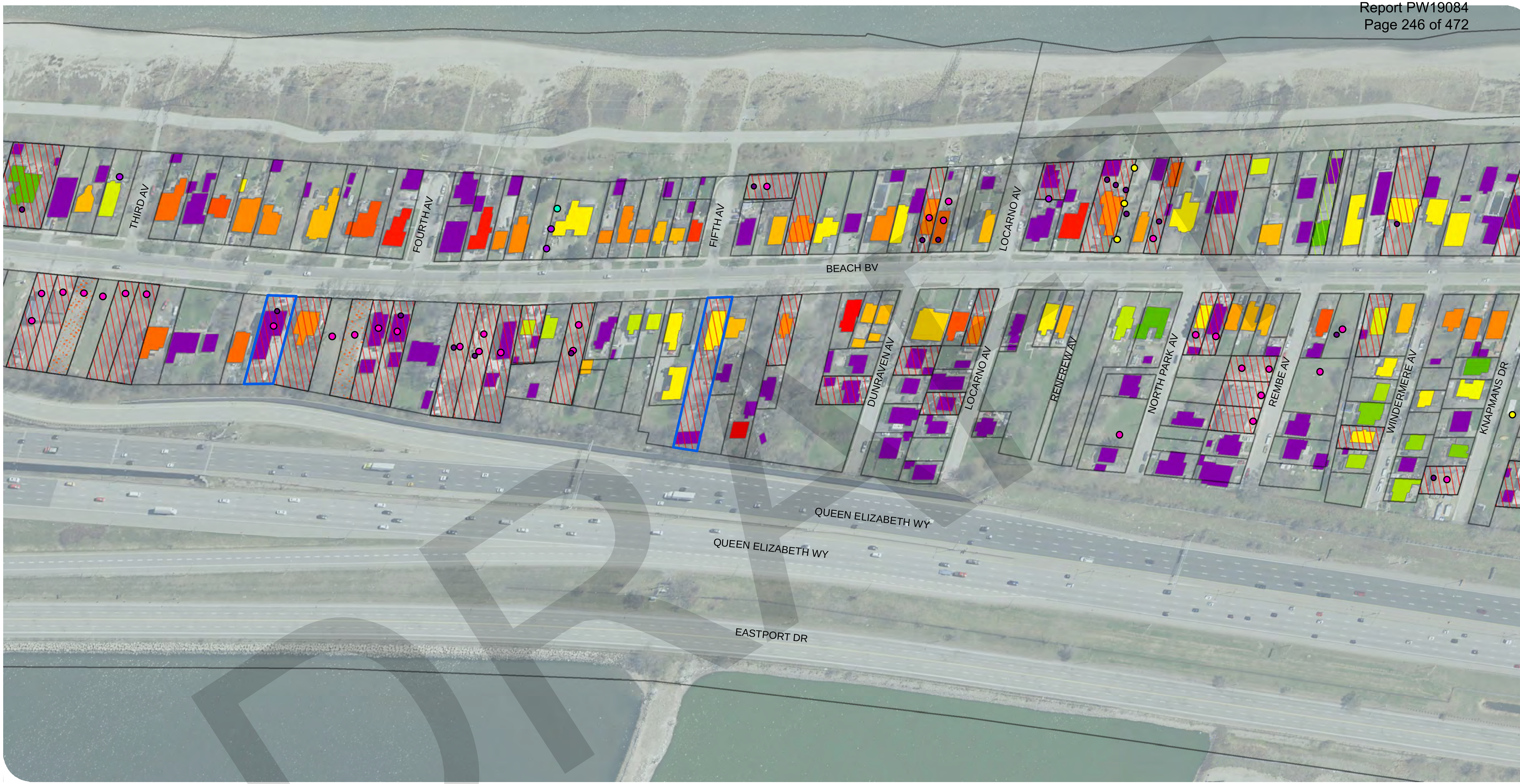
PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17



CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 3

BASEMENT DEPTH MBGS (COUNT)

No Information (74)
0.4 (1)
0.9 (4)
1 (2)
1.1 (1)
1.2 (8)
1.3 (1)
1.4 (13)
1.5 (2)
1.6 (12)
1.7 (2)
1.8 (2)
1.9 (1)
2 (3)
3 (2)

Builing Permits (10 Years)

Type
Residential (45)
Vacant Lands (2)

Building Permits for Basements (1)

Development Applicatons (10 Years)

File Type
Formal Consultation (3)
Land Division (3)
Site Plan (18)
Zoning Amendment (1)

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 50 100 200 Metres

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PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 4

BASEMENT DEPTH MBGS (COUNT)

No Information (202)

0.2 (2), 0.4 (5), 0.5 (4), 0.6 (9), 0.7 (2), 0.8 (5), 0.9 (4), 1 (4), 1.1 (2), 1.2 (11), 1.3 (1), 1.4 (6), 1.5 (2), 1.6 (5), 1.7 (1), 1.8 (2), 2 (2)

Builing Permits (10 Years) Type

Commercial (2)
Institutional (3)
Residential (76)
Utilities (5)
Building Permits for Basements (2)

Development Applicatons (10 Years)

File Type

Formal Consultation (2)
Land Division (5)
Site Plan (24)

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 50 100 200 Metres

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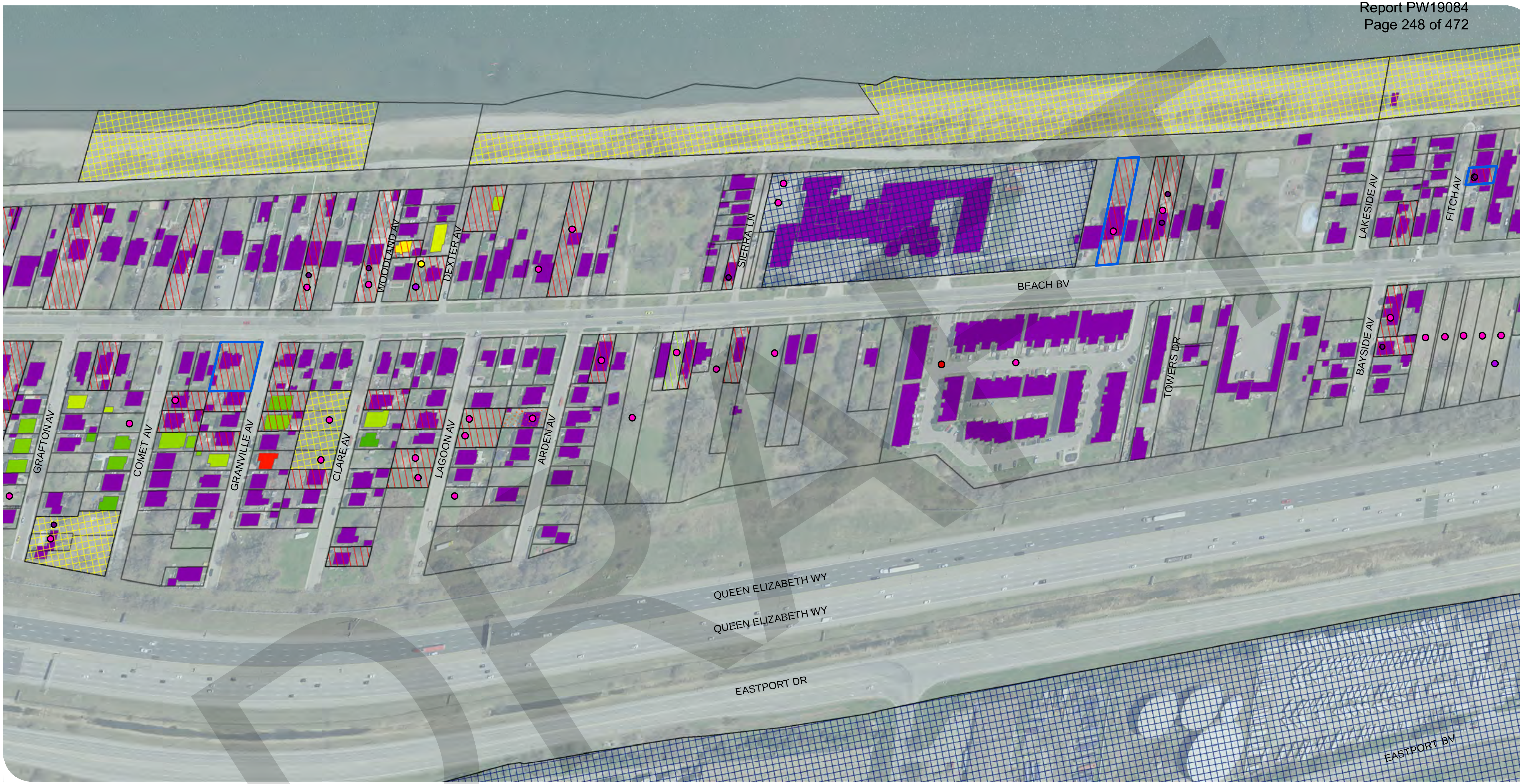

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 5

BASEMENT DEPTH **MBGS (COUNT)** No Information (114) | 0.8 (1) | 1 (1) | 1.2 (1)

Builing Permits (10 Years)
Type
Commercial (3)
Institutional (10)
Residential (26)
Utilities (2)
Vacant Lands (1)
Building Permits for Basements (1)

Development Applicatons (10 Years)
File Type
Condominium (1)
Formal Consultation (1)
Land Division (1)
Site Plan (18)

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 55 110 220 Metres

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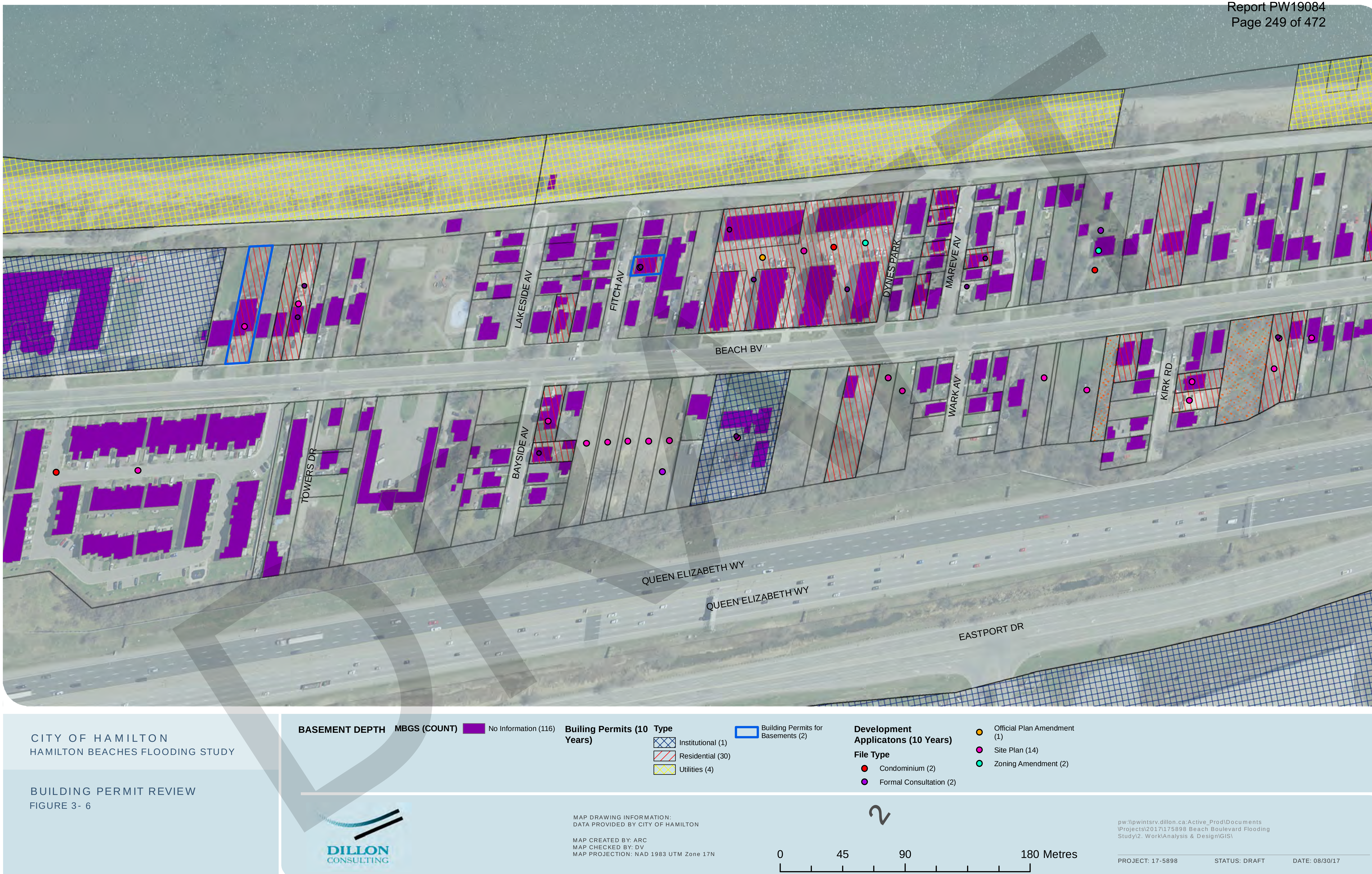
PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17



CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 6

BASEMENT DEPTH **MBGS (COUNT)** No Information (116)

Builing Permits (10 Years) **Type**
Institutional (1)
Residential (30)
Utilities (4)

Building Permits for Basements (2)

Development Applicatons (10 Years)
File Type
Condominium (2)
Formal Consultation (2)
Official Plan Amendment (1)
Site Plan (14)
Zoning Amendment (2)

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MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

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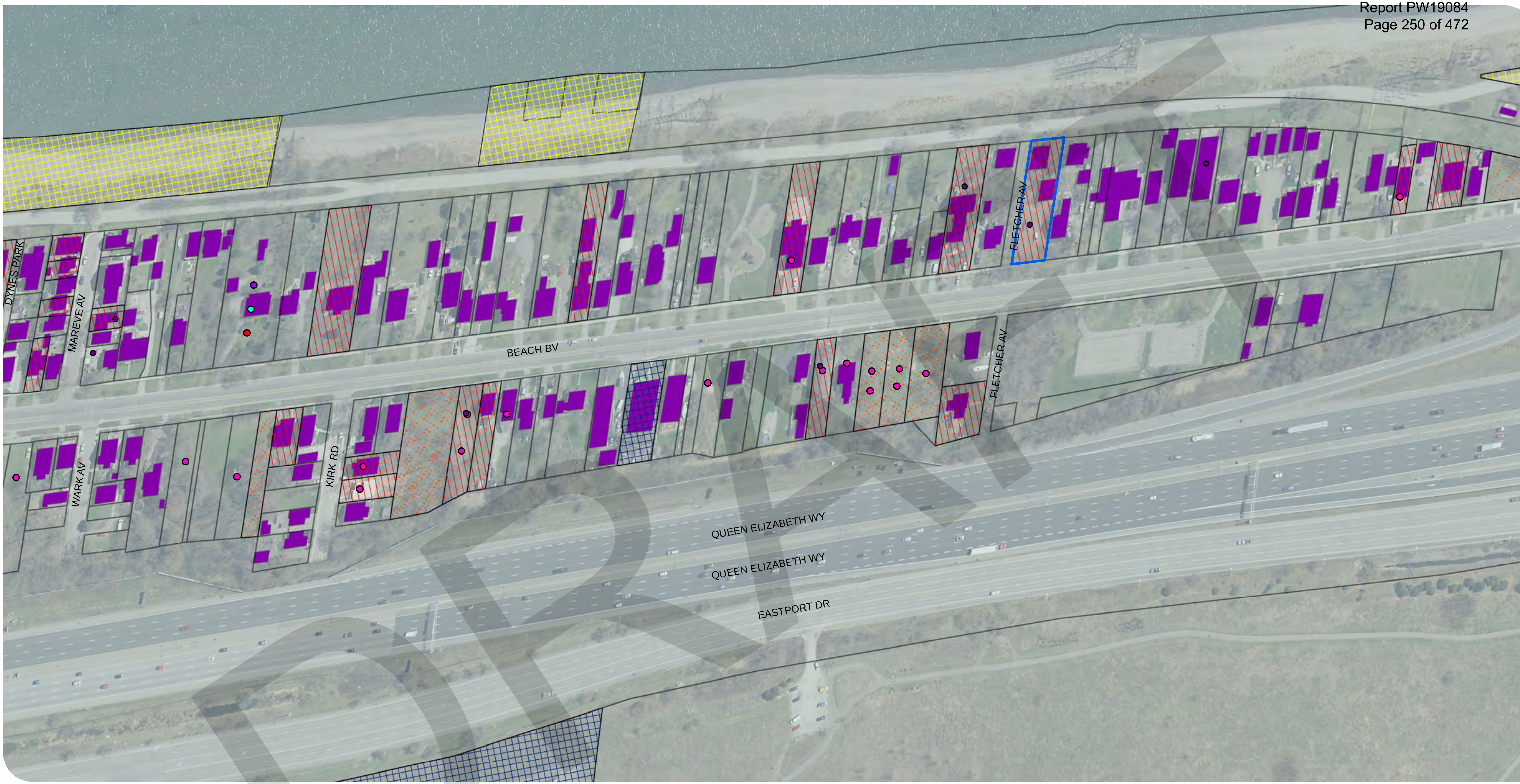

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

BUILDING PERMIT REVIEW
FIGURE 3- 7

BASEMENT DEPTH **MBGS (COUNT)** No Information (88)

Builing Permits (10 Years)
Residential (15)
Utilities (2)
Vacant Lands (6)
Building Permits for Basements (1)

Type
Institutional (4)

Development Applicatons (10 Years)

File Type
Site Plan (14)

DILLON CONSULTING

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF HAMILTON

MAP CREATED BY: ARC
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

0 40 80 160 Metres

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PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17

Appendix I

Outlet Size Estimation

Assumptions	
Slope	0.25%
Cover	0.6
Lake Lvl	74.85

Diameter	Wall Thickness	D+1w
300	70	0.37
375	76	0.45
450	64	0.51
525	89	0.61
600	95	0.70
675	102	0.78
750	108	0.86
825	114	0.94
900	121	1.02
975	127	1.10
1050	133	1.18
1200	146	1.35

Catchment	Ground Elv MASL	Length m	Δh Pipe m	Δh Elev m	Pipe D mm
Eastport	76.00	106.4	0.266	0.55	-
Hamilton Harbour	76.00	152.3	0.381	0.55	300
Dunraven	75.90	109.0	0.273	0.45	-
Lagoon	75.99	95.6	0.239	0.54	-
Townhouse	76.00	103.0	0.258	0.55	-
Bayside	75.88	80.0	0.200	0.43	-
Fletcher	76.00	167.5	0.419	0.55	300

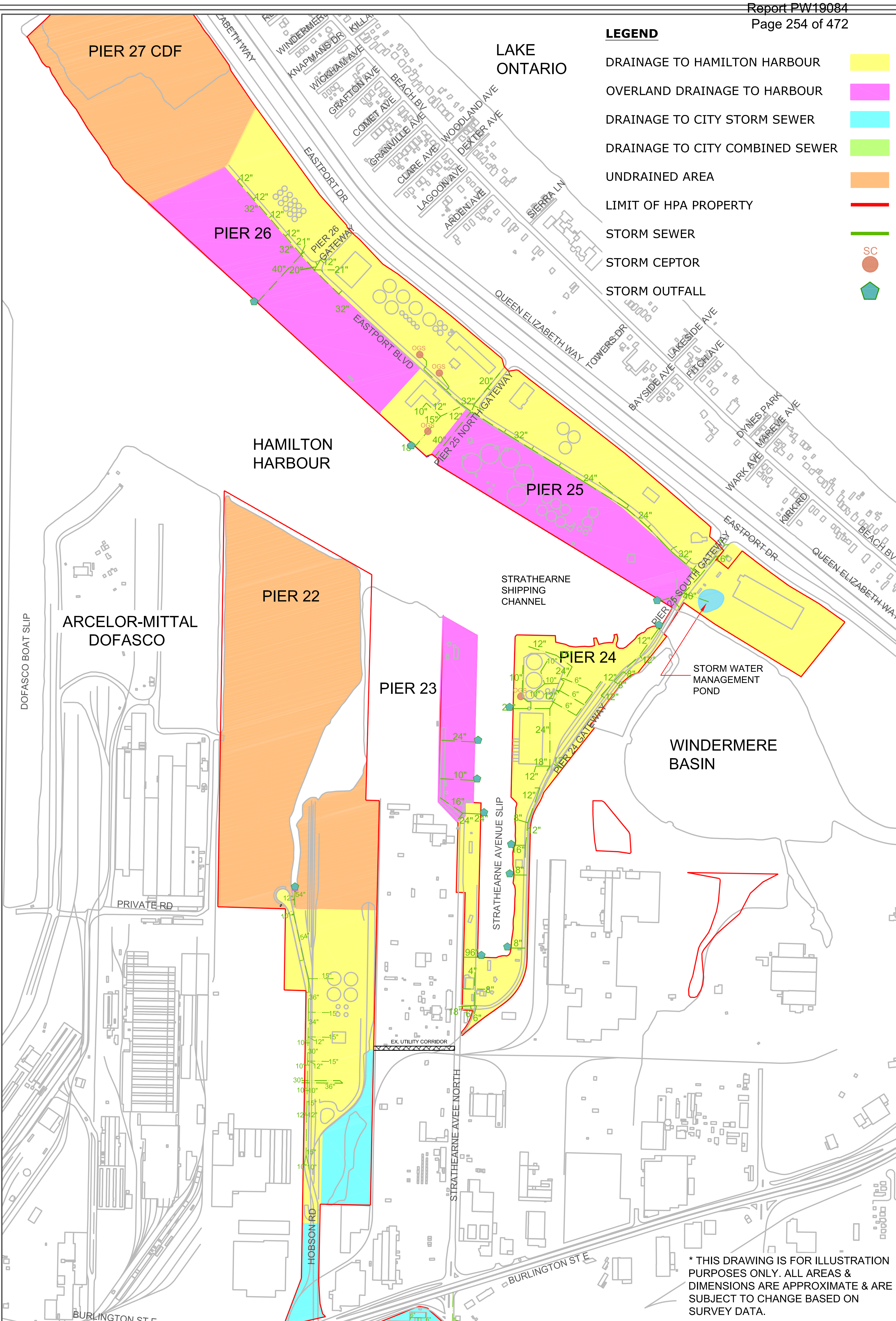
Catchment	Flow L/s	Slope (-)	n (-)	D m	D mm	D+1W m	Ground Elv MASL	Length m	Δh Pipe m	Lake Lvl m
Eastport	223	0.0025	0.013	0.53	600	0.70	76.00	106.4	0.266	74.44
Hamilton Harbour	521	0.0025	0.013	0.73	750	0.86	76.00	152.3	0.381	74.16
Dunraven	604	0.0025	0.013	0.77	825	0.94	75.90	109.0	0.273	74.09
Lagoon	799	0.0025	0.013	0.855	900	1.02	75.99	95.6	0.239	74.13
Townhouse	557	0.0025	0.013	0.745	750	0.86	76.00	103.0	0.258	74.28
Bayside	1232	0.0025	0.013	1.005	1050	1.18	75.88	80.0	0.200	73.90
Fletcher	682	0.0025	0.013	0.805	825	0.94	76.00	167.5	0.419	74.04

Catchment	Flow L/s	Slope (-)	n (-)	D m	D mm	D+1W m	Ground Elv MASL	Length m	Δh Pipe m	Lake Lvl m
Eastport	223	0.005	0.013	0.465	525	0.61	76.00	106.4	0.532	74.25
Hamilton Harbour	521	0.005	0.013	0.64	675	0.78	76.00	152.3	0.762	73.86
Dunraven	604	0.005	0.013	0.675	750	0.86	75.90	109.0	0.545	73.90
Lagoon	799	0.005	0.013	0.75	825	0.94	75.99	95.6	0.478	73.97
Townhouse	557	0.005	0.013	0.655	675	0.78	76.00	103.0	0.515	74.11
Bayside	1232	0.005	0.013	0.885	900	1.02	75.88	80.0	0.400	73.86
Fletcher	682	0.005	0.013	0.71	750	0.86	76.00	167.5	0.838	73.70

Catchment	Q L/s	D mm	D+1W m	Ground Elv MASL	Length m	Δh Pipe m	Overt MASL	ΔH m	n (-)	Kc (-)	Ke (-)	Q L/s
Eastport	223	300	0.37	76.00	106.4	0.266	74.76	1.15	0.013	0.105	0.5	378
Hamilton Harbour	521	375	0.45	76.00	152.3	0.381	74.57	1.15	0.013	0.078	0.5	574
Dunraven	565	375	0.45	75.90	109.0	0.273	74.58	1.05	0.013	0.078	0.5	635
Lagoon	751	450	0.51	75.99	95.6	0.239	74.64	1.14	0.013	0.061	0.5	1111
Townhouse	528	375	0.45	76.00	103.0	0.258	74.69	1.15	0.013	0.078	0.5	680
Bayside	1154	450	0.51	75.88	80.0	0.200	74.57	1.03	0.013	0.061	0.5	1132
Fletcher	638	450	0.51	76.00	167.5	0.419	74.47	1.15	0.013	0.061	0.5	883

Appendix J

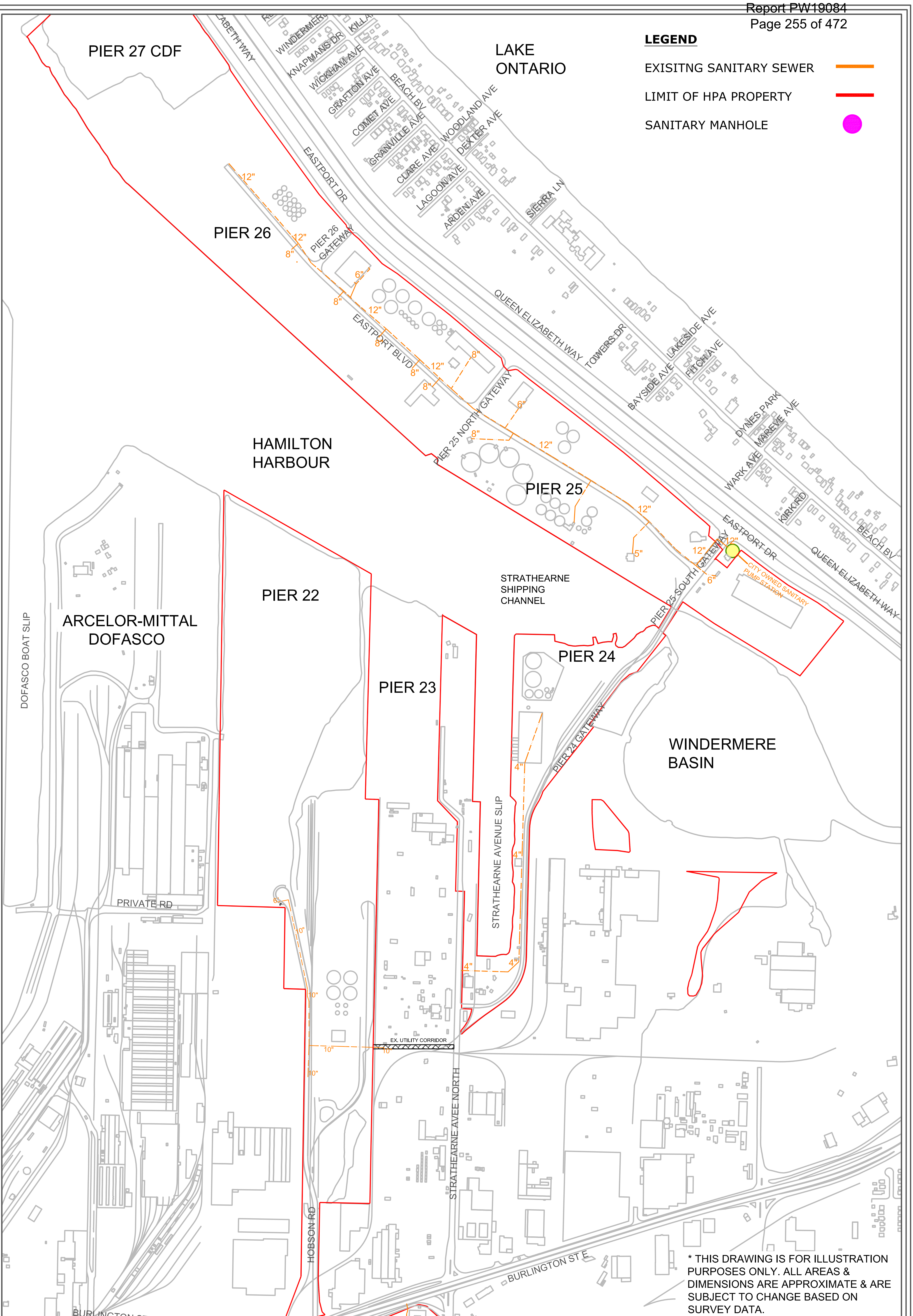
Figures Provided by HPA



HAMILTON PORT• AUTHORITY
Administration Portuaire de Hamilton
Canada

TITLE: STORM WATER DRAINAGE (PIER 22-26)		DATE: OCTOBER 2009
SCALE: 1:7,500	REVISION NO. 0	DRAWN BY: M.K.

S:\Engineering\DRAWINGS\GENERAL\MASTER INFRASTUCTURE



HAMILTON PORT• AUTHORITY
Administration Portuaire de Hamilton
Canada

TITLE: EXISITNG SANITARY SEWERS (PIER 22-26)	DATE: OCTOBER 2009
SCALE: 1:7,500	REVISION NO. 0
DRAWN BY: M.K.	

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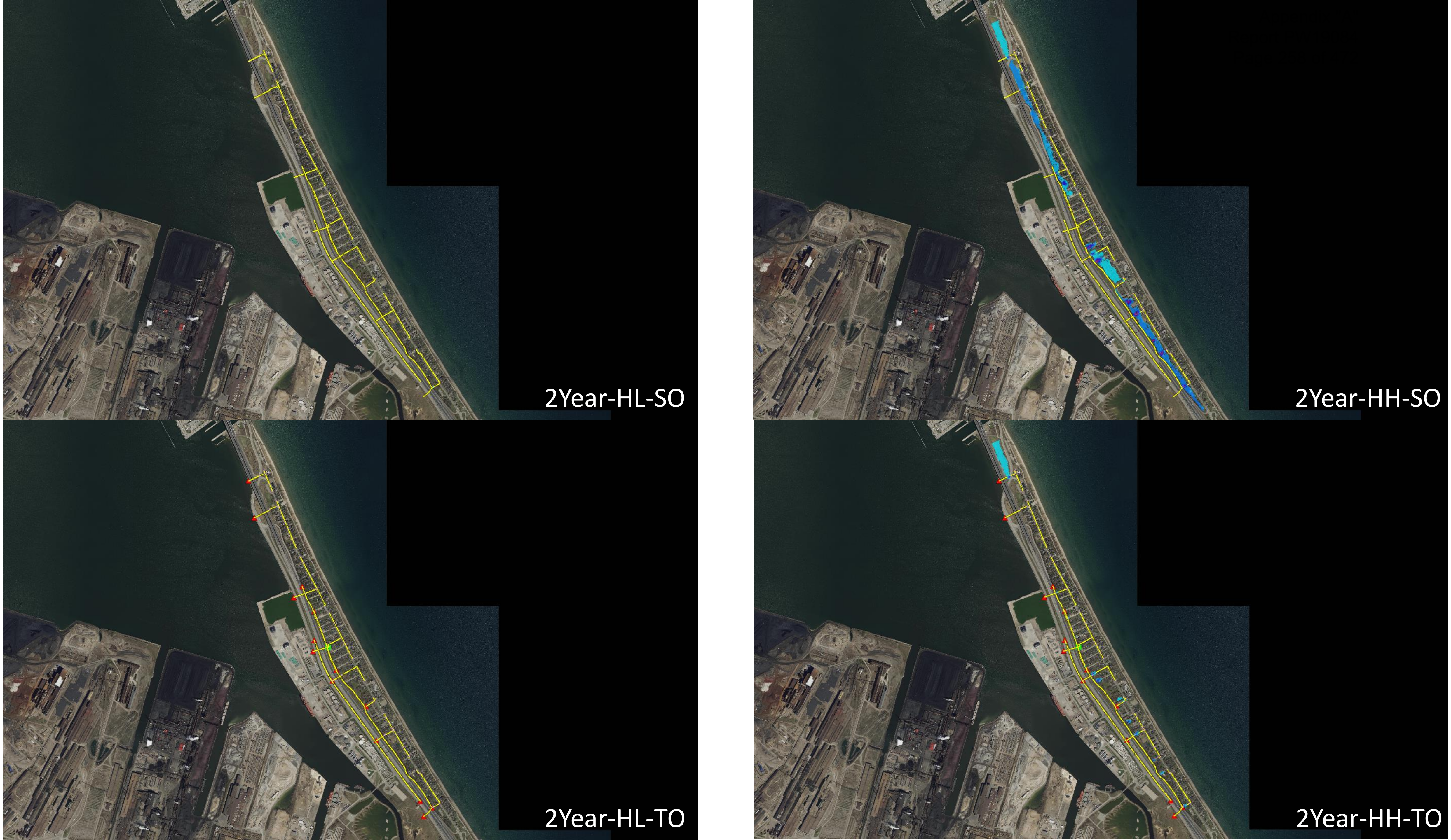
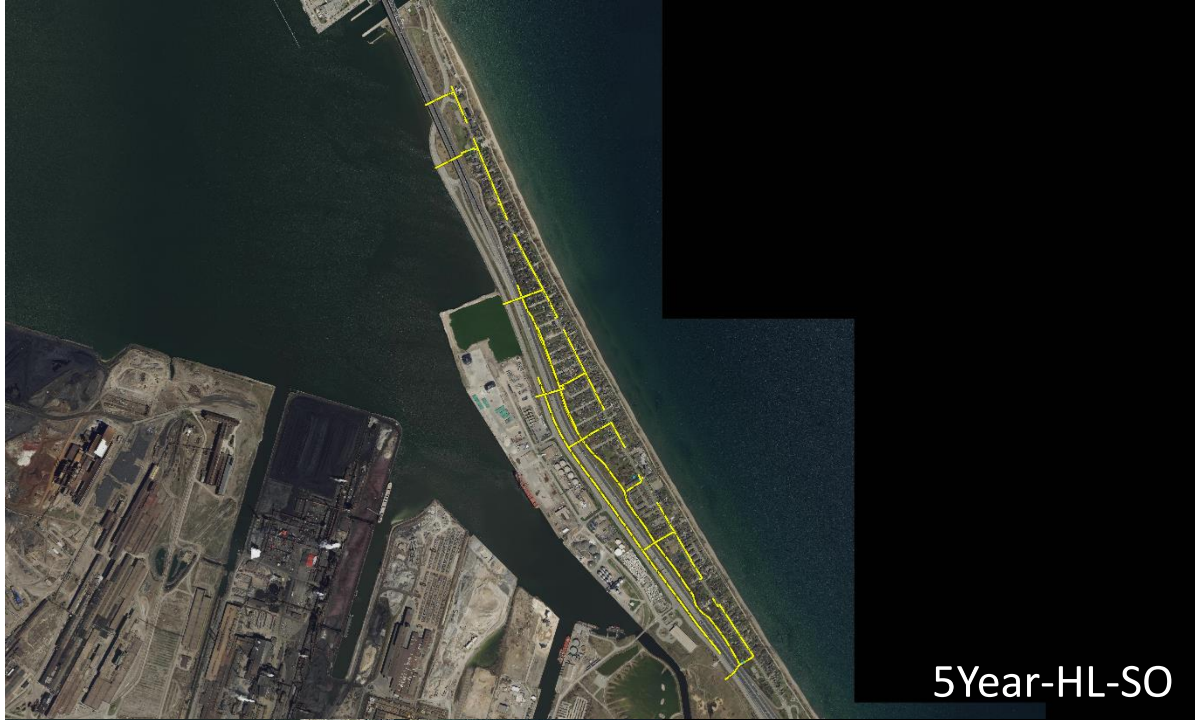
Appendix K

PCSWMM Ponding Summary

		SINGLE								TRIPLE							
System	Lake Level	74.27				75.88				74.27				75.88			
	Storm	2Year	5Year	10Year	100Year	2Year	5Year	10Year	100Year	2Year	5Year	10Year	100Year	2Year	5Year	10Year	100Year
Eastport	Eastport				0.12	0.28	0.29	0.29	0.31				0.12	0.28	0.29	0.29	0.31
Hamilton Harbour	Hamilton Harbour Outlet	0.02	0.03	0.03	0.04	0.09	0.09	0.09	0.1	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Dunraven	Dunraven Avenue				0.29	0.3	0.31	0.32	0.33				0.29	0.15	0.27	0.28	0.3
Grafton	Locarno Avenue				0.26	0.27	0.27	0.28	0.29				0.26		0.02	0.24	0.26
	Renfrew Avenue				0.22	0.3	0.3	0.31	0.32				0.22			0.05	0.28
	North Park Avenue					0.2	0.2	0.21	0.22								0.19
	Rembe Avenue					0.19	0.19	0.2	0.2					0.07	0.07	0.07	0.19
	Windermere Avenue																
	Knapmans Drive																
	Wickham Avenue					0.07	0.07	0.07	0.07					0.07	0.07	0.07	0.07
	Grafton Avenue																
	Comet Avenue																
	Granville Avenue																
	Clare Avenue					0.54	0.54	0.54	0.54					0.14	0.14	0.14	0.15
Lagoon	Lagoon Avenue					0.4	0.4	0.4	0.41					0.35	0.35	0.35	0.39
	Arden Avenue				0.41	0.43	0.43	0.43	0.44				0.41	0.3	0.3	0.3	0.43
Townhouse	Townhouse System		0.09	0.12	0.15	0.11	0.12	0.12	0.15		0.09	0.12	0.15	0.12	0.11	0.12	0.15
Bayside	Towers Drive				0.31	0.42	0.42	0.43	0.44				0.31	0.2	0.2	0.2	0.34
	Bayside Avenue			0.19	0.33	0.39	0.4	0.4	0.42			0.18	0.32	0.2	0.2	0.26	0.33
	Wark Avenue				0.4	0.49	0.49	0.49	0.51				0.4	0.26	0.26	0.26	0.38
Fletcher	Kirk Road				0.29	0.37	0.38	0.38	0.4				0.29	0.15	0.15	0.15	0.3
	Fletcher Avenue	0.04	0.08	0.22	0.26	0.32	0.32	0.32	0.34			0.22	0.26	0.17	0.18	0.22	0.26


2Year-HL-SO
2Year-HH-SO
2Year-HL-TO
2Year-HH-TO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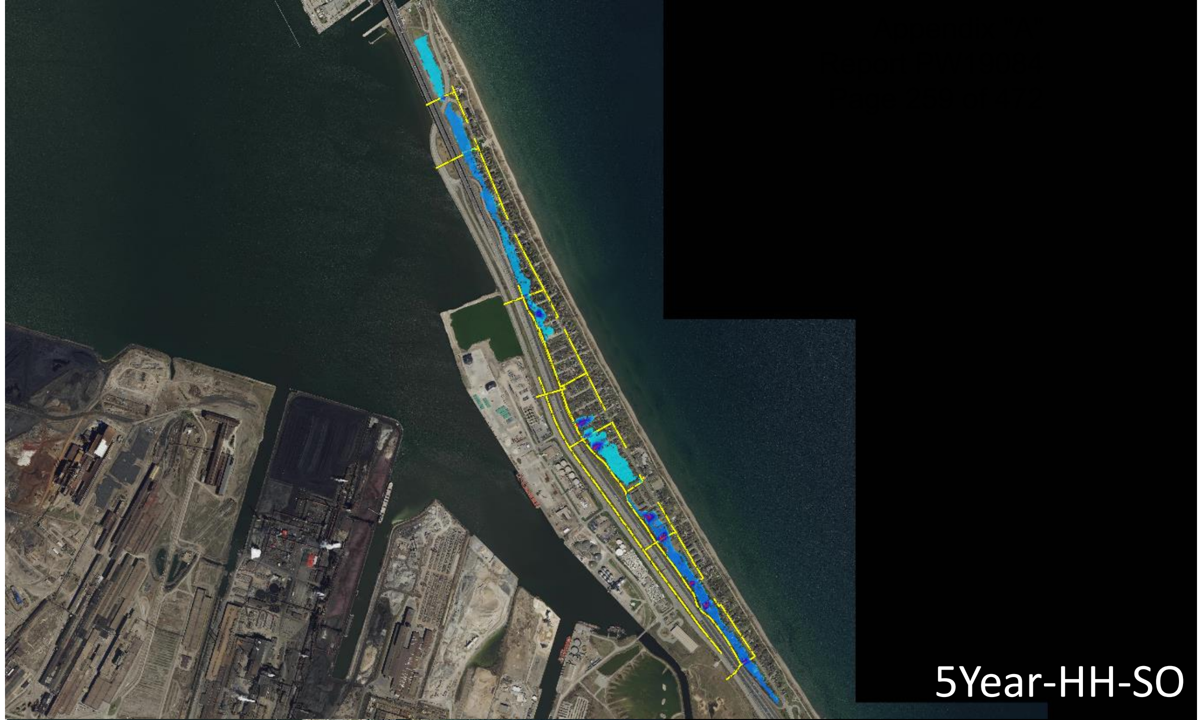
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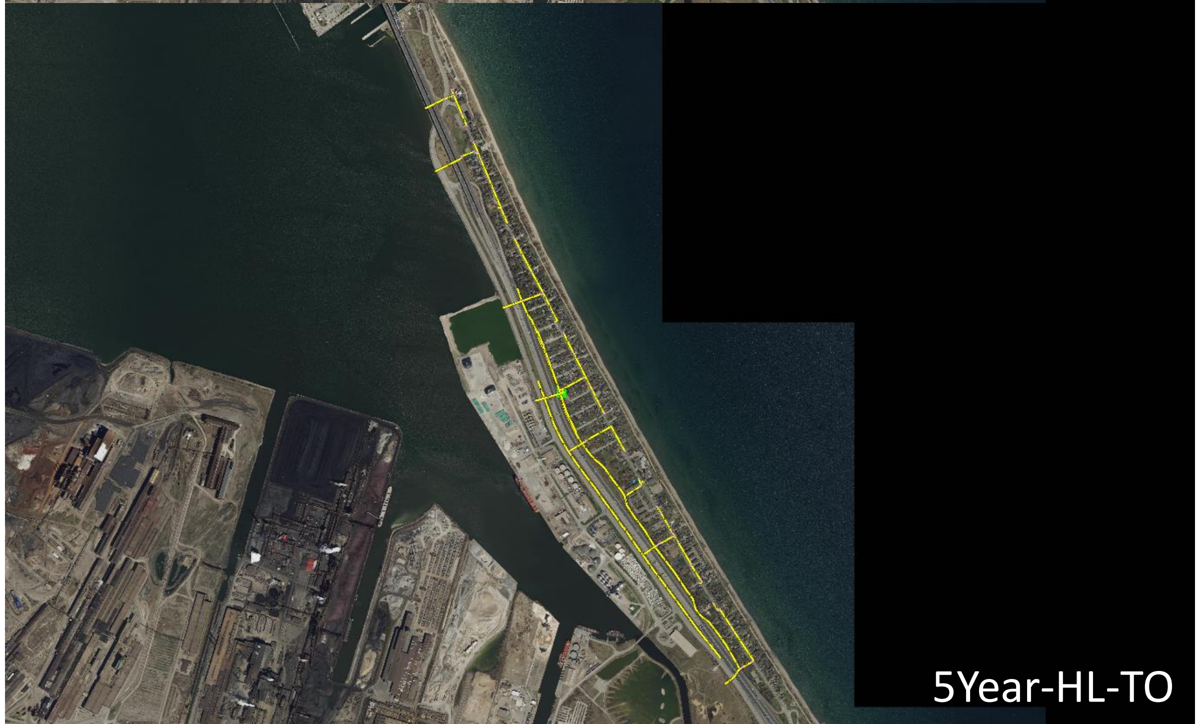
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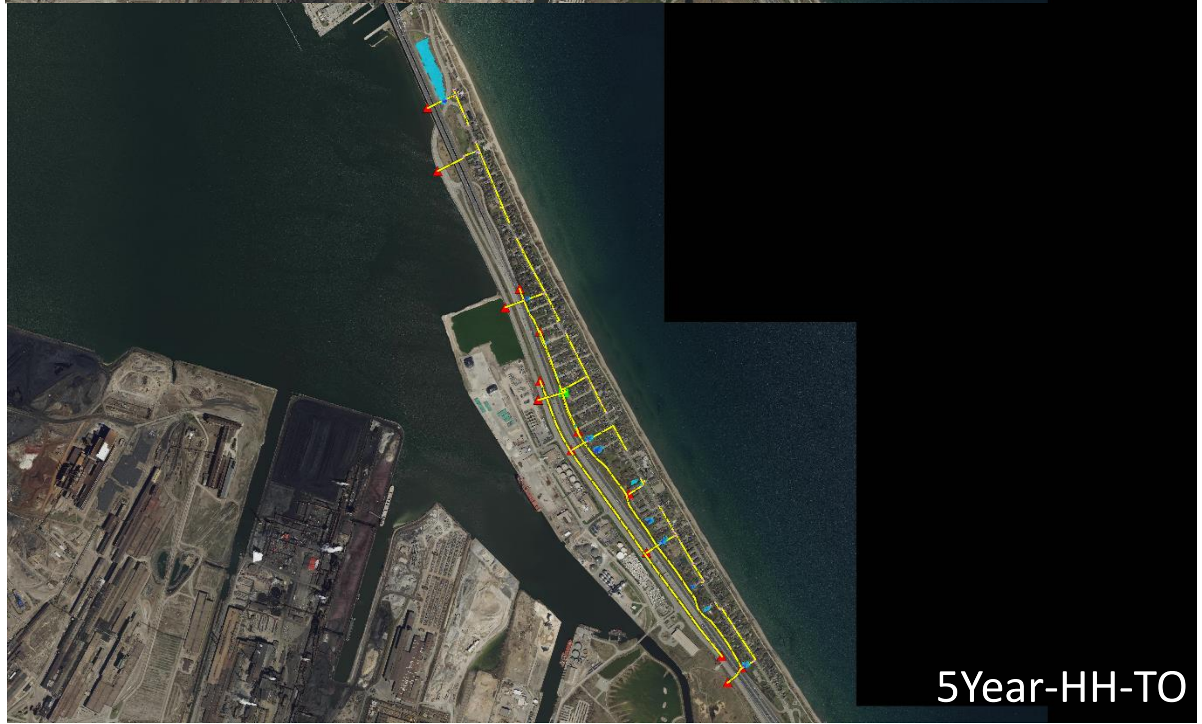
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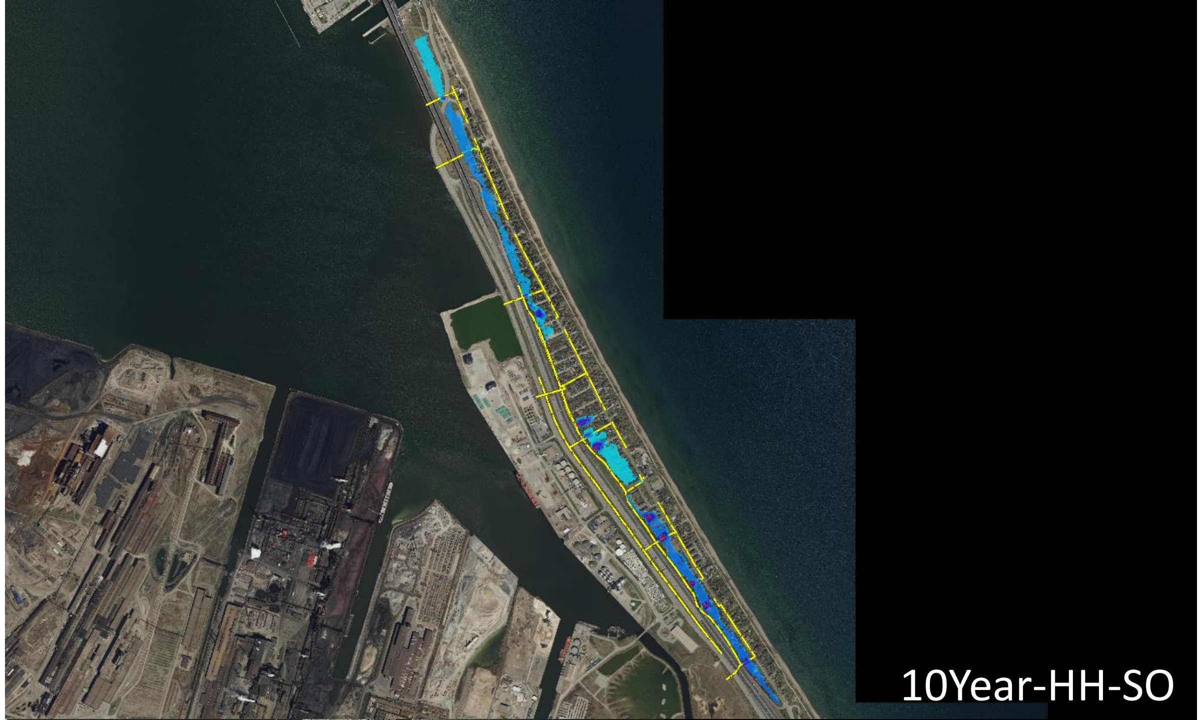
10Year-HL-SO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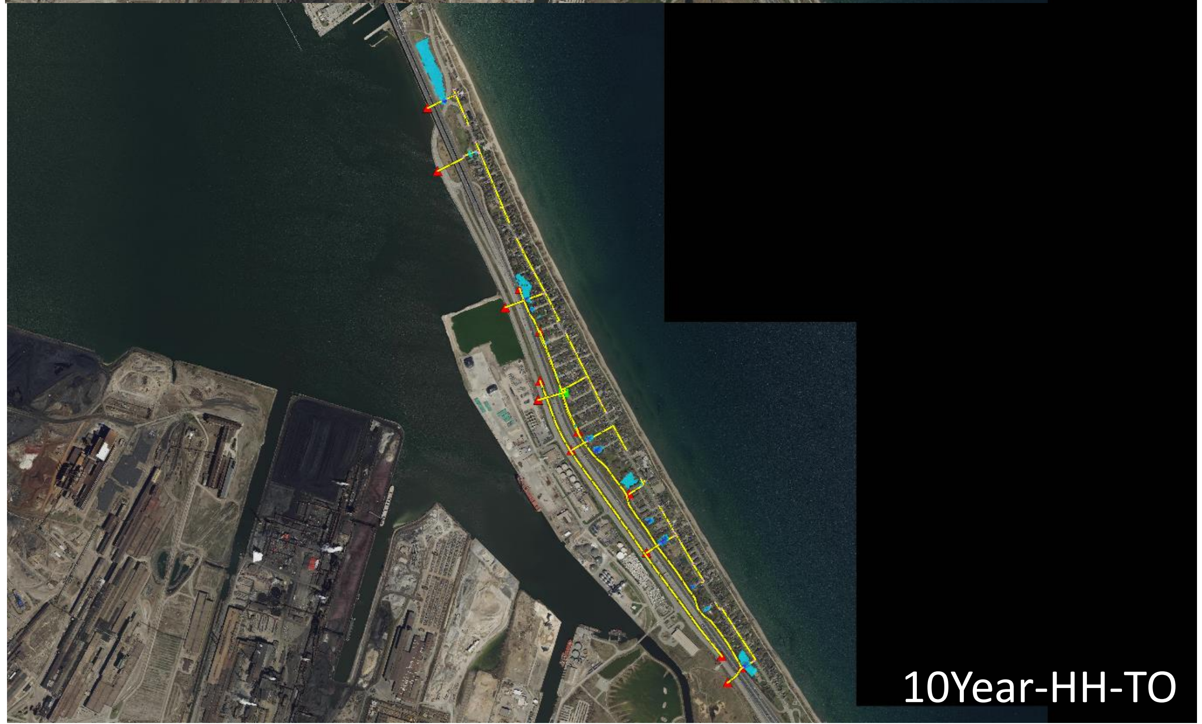
10Year-HL-TO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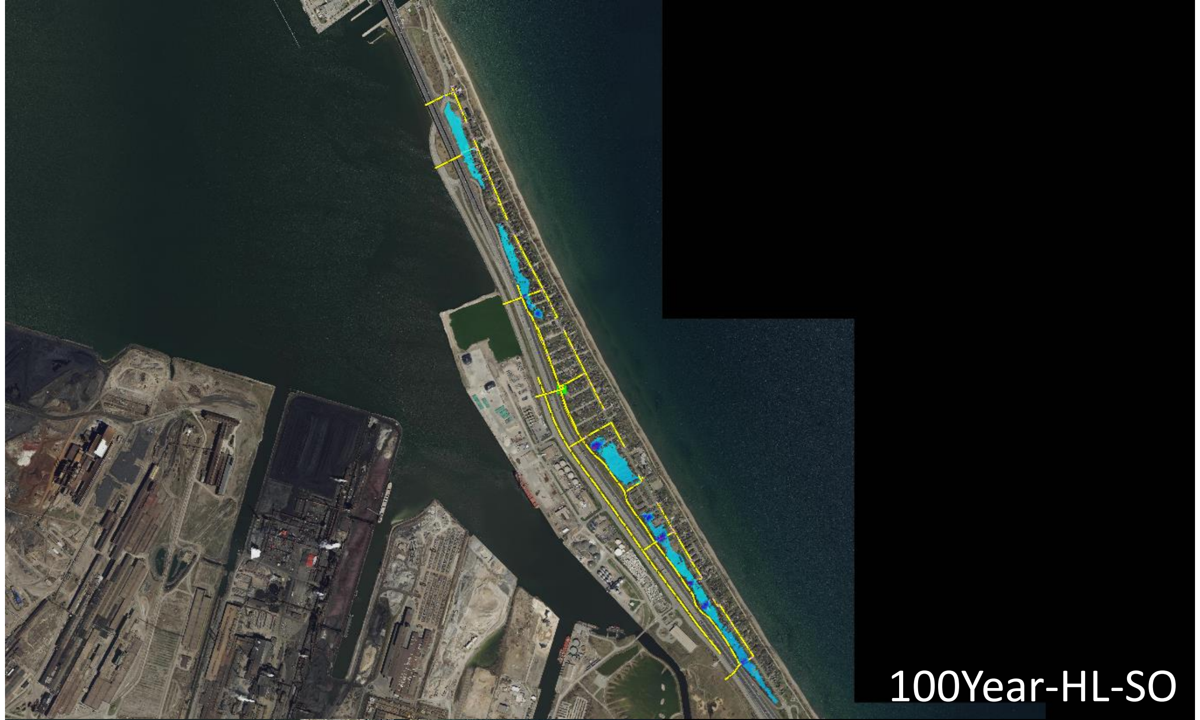
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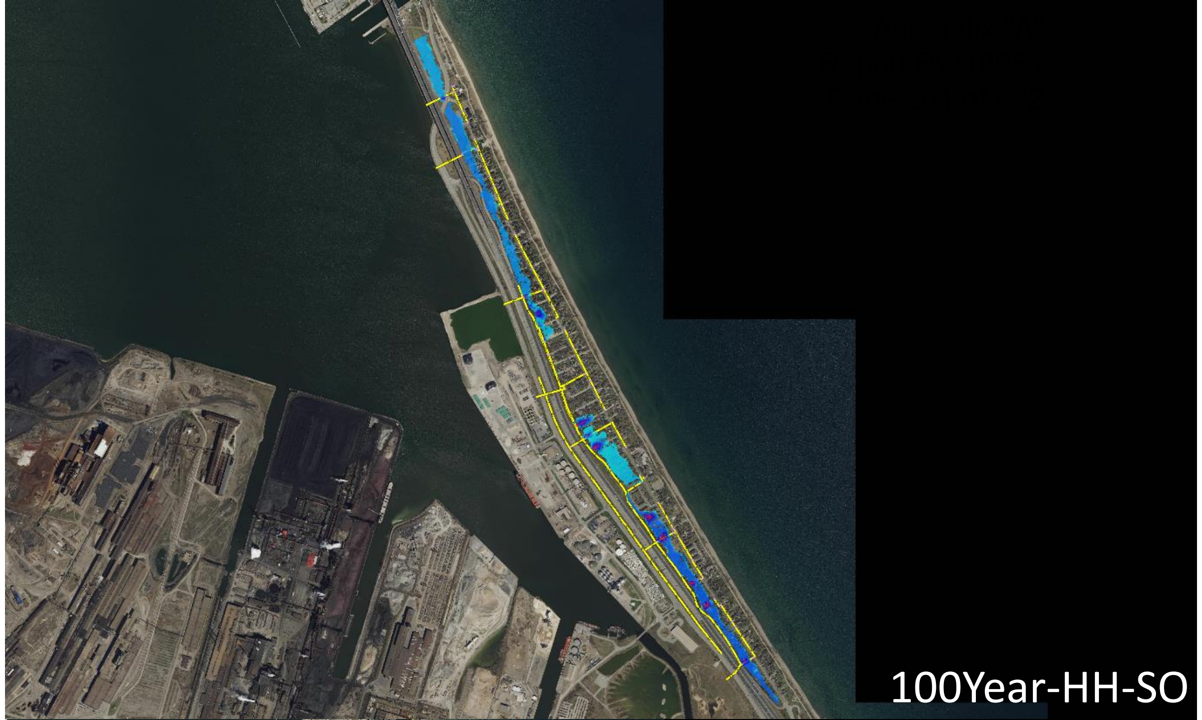
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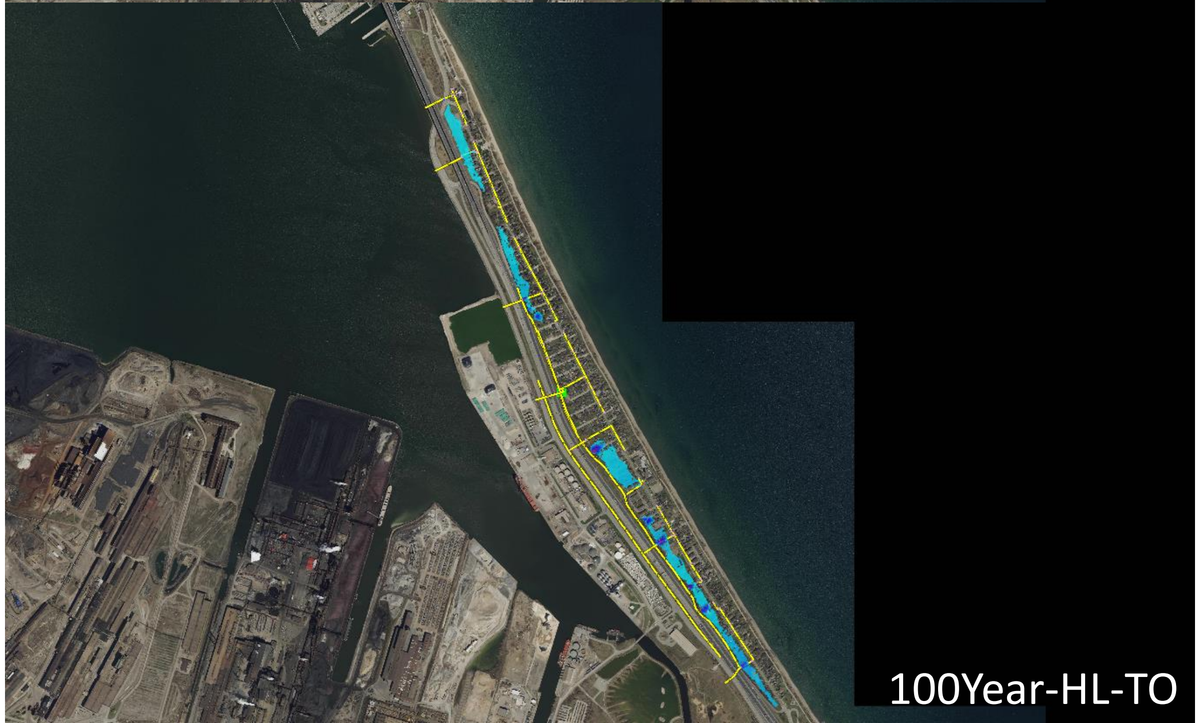
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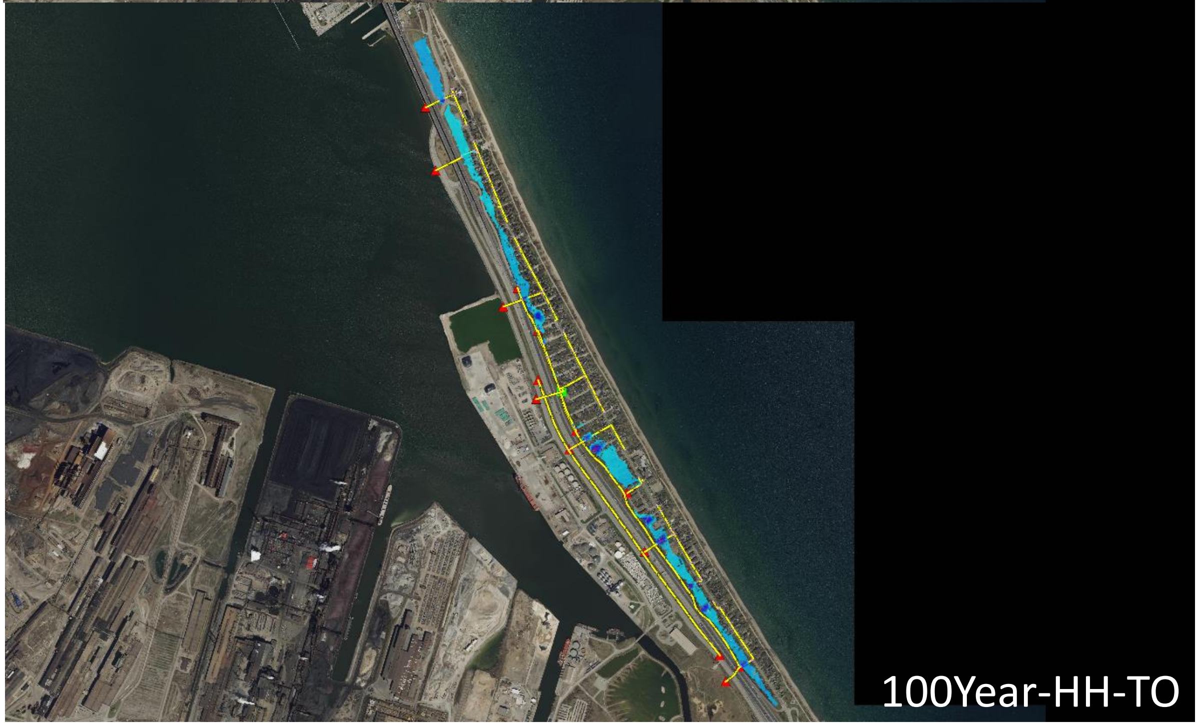
100Year-HH-TO

Appendix L

Drawings and GIS Layers Reviewed

DILLON CONSULTING

Drawing Name	Agency	Contract No.	Drawing Set No.	Discription
Beach Boulevard Interceptor	City of Hamilton	PW-09-43 (S)	09-S-11	Proposed 900mm Dia Force Main Construction Crossing the Queen Elizabeth Way
Beach Boulevard Interceptor	City of Hamilton	PW-11-54 (S)	11-S-20	Proposed Pumping Station, Storm Sewer and Ditch Construction
Northeast Gateway Study	City of Hamilton	PD-00-35		
Pipeline Route Sheet	City of Hamilton		M-1904-83	
Arden Ave	City of Hamilton	ER-63-110	A-293	
Beach Boulevard Plan - 1938			B-167-WW	
QEW Connection - 1958	City of Hamilton		B-309-H	
Beach Boulevard Plan	City of Hamilton		B-354-S	Catch basin and Manholes South End of Skyway Bridge
Plan and Profile of Storm Sewers			B-396-S	
General Maps of Area - 1962	Township of Saltfleet		B-404-BW	
General Maps of sewers - 1964			B-445-S	
New Meter for Burlington Beach	City of Hamilton		C-101-WW	
Beach Pumping Station	City of Hamilton		C-131-WW	
Post-Chlorinating Building	City of Hamilton		F-135-WW	
Depth of Hamilton Harbour - 1963	Canadian Hydrographic Service		H-393-M	
Grading, Drainage, Granular Base and Hot-mix Paving	Provine of Onario - Department of Highways	62-301	H-400	
Woodward Ave to Parkdale Pumping Station	City of Hamilton		B-310	
Mareve Avenue	City of Hamilton	EW-65-3	M-136-W	
Sewage Treatment Plant Outfall	City of Hamilton		O-72-S	
Report of Pollution of Burlington Bay	Departmet of Health of Ontario		P-95-S	
King to Beach - 1957	City of Hamilton		Q-34-H	
QEW Connection - 1957	City of Hamilton		Q-35-H	
Ontario Hydro Transmission Line	The Hydro-Electric Power Commission of Ontario		Q-62-H	
Wark Avenue - 1966	City of Hamilton	EW-65-34	W-159-W	
Beach Road Storm Connection at C.N.R. Crossing	City of Hamilton	ER-68-52	65-S-129	
East Port Industrial Park - Proposed Sanitary Sewer, Forcemain and Watermain	City of Hamilton	RHW-83-74	83-S-9	Drawings that show parts of Easport Dith.

Drawing Name	Agency	Contract No.	Drawing Set No.	Discription
East Port Development - Pier 25 - Stage 1	City of Hamilton	180112	84-S-54	
Windermere Basin Storm Drainage	City of Hamilton		91-S-69	
QEW Crossing for Proposed Sanitary Sewer	City of Hamilton	802-111	92-S-1	Some information and about basement depths in the study area.
Proposed Sanitary Sewer - Phase 1	City of Hamilton	802-111	92-S-57	Information and about basement depths in the study area.
Proposed Sanitary Sewer - Phase 2	City of Hamilton	802-111	93-S-1	Information and about basement depths in the study area.
QEW Crossing for Proposed Sanitary Sewer	City of Hamilton		93-S-40	Some information and about basement depths in the study area.
Low Lift Pumping Station	City of Hamilton		04-W-29	
Woodland Avenue	City of Hamilton	EW-71-5	74-W-515	
48" Saltfleet Trunk Watermain	City of Hamilton	823-09	76-W-608	
Watermain Cleaning	City of Hamilton	802-19	80-W-29	
Cameron Avenue - Proposed Watermain	City of Hamilton	813-49	81-W-29	
Beach Boulevard - Proposed watermain	City of Hamilton	T111-22	82-W-25	
Beach Boulevard - Proposed watermain	City of Hamilton	802-65	86-W-1	
Granville Ave - Proposed Watermain	City of Hamilton		86-W-21	
East Port Watermain	City of Hamilton		86-W-31	
Skyway Park	City of Hamilton	PW-11-04	09-P-24	
Modifications of Burlington Channel Vertical Lift Bridge and Approaches	Public Works Canada	41412		
QEW Grading	Provine of Onario - Department of Highways	443-97-00	2005-2008	
Eastport Drive - Sidewalk Extension and Granular Trail	City of Hamilton	C15-06-12	12-P-02	
Proposed Sewage Pumping Station No. 3 & 4	City of Hamilton	RHW-92-61	92-S-55	
QEW Grading	City of Hamilton	86-74	94-H-33	

Drawing Name	Agency	Contract No.	Drawing Set No.	Discription
Van Wagners' Beach Boulevard	City of Hamilton	PW-04-40 (HSW)	04-H-80	Road Reconstruction and Storm Sewer Removal near study area
MTO New Construction	City of Hamilton	86-74	83-74-C5	
Eastport Sewage Pumping Station	City of Hamilton	816-18	83-S-68	
Stormwater Drainage	Hamilton Port Authority			

Shapefile Name	Shapefile Description	Source	Type	Extent	LastUpdate	Update Frequency
ALLEYS	The layer is to help understand what alleys exist throughout the urban area of the City of Hamilton and if they are Publically owned or Private. Additionally the inventory describes publically owned (City of Hamilton ownership) which alleys are Assumed maintained and serviced by the City and those that are Unassumed. This layer can also be used in conjunction with the ALLEYS_CENTERLINE featureclass that will reflect additional details within the Alleyway property extents. Using Teranet property boundaries and property ownership information, the following inventory shows alleyway extent. Each polygon is unique and associated by a Teranet PIN. Additional information is attributed to the alley polygon as it relates to information gathered from city records and city bylaws. Geomatics and Corridor Management Section maintain the layer and rely on information communicated from Planning and Economic Development Department, Real Estate Section to adjust the layer with changes in ownership and alleyway status changes.	Parcels	Area	Full Coverage		
ALLEYS_CENTERLINE	The layer is to help understand what parts of alleys exist throughout the urban area of the City of Hamilton and if they are Publically owned or Private. Additionally the inventory describes publically owned (City of Hamilton ownership) which alleys are Assumed maintained and serviced by the City and those that are Unassumed. This layer can also be used in conjunction with the ALLEYS featureclass that will reflect Alleyway property extents. The alley centerlines were drawn following the center of the ALLEYS featureclass that is Teranet property based. Attribute information from the ALLEYS polygon feature is carried to the lines that fall within its extent. This includes property ownership information and researched city alleyway status along with city bylaws. Each centerline is unique and topologically correct and associated by a Teranet PIN (Property Identity Number). Where multiple Centerline segments are within an ALLEYS polygon, the lines are attributed with a PIN sequence number PIN_SEQ. PIN + PIN_SEQ together creates a unique identifier and child records of the parent ALLEYS polygon. Geomatics and Corridor Management Section maintain this layer and rely on information communicated from Planning and Economic Development Department Real Estate Section to adjust the layer with changes in Ownership and alleyway status changes.	Parcels	Line	Full Coverage		
ASSET_BRIDGE_TXT	Bridge ID text for use in conjunction with the ASSET_BRIDGES feature.	Schematic	Text	Full Coverage		Daily
ASSET_BRIDGES	Point features representing bridge and culvert structures that are >=3 metres in span, including City, rail and private bridges.	Schematic	Point	Full Coverage		Daily
ASSET_HANSEN_CENTRELINE	An Oracle copy of the Asset Management road network table as it exists in Hansen.	Combination	Line	Full Coverage		Dynamic
BEACHES	Point location for City of Hamilton public recreational bathing beaches.	Schematic	Point	Full Coverage	June, 2017	Static
BELL_CANADA_DUCT		Combination	Line	Full Coverage	March, 2013	Yearly
BELL_CANADA_STRUCTURE		Combination	Point	Full Coverage	March, 2013	Yearly
BIKEWAYS	Line features representing existing and proposed bikeways in the City of Hamilton. Further information on some metadata for this feature can be found here: G:\Tabular\Documents\BIKEWAYS_descriptions_for_TYPE_field.docx.	Combination	Line	Full Coverage	February, 2013	Yearly
BIKEWAYS_EXISTING	Oracle view of BIKEWAYS showing only the records with a STATUS of EXISTING, CONSTRUCTED or DETAILED DESIGN, CONSTRUCTED. Further information on some metadata for this feature can be found here: G:\Tabular\Documents\BIKEWAYS_descriptions_for_TYPE_field.docx.	Schematic	Line	Full Coverage		Dynamic
BUILDINGS	Polygon feature representing buildings which were compiled by digitizing the building footprints from the aerial photography. Most residential buildings were compiled as "best-fit" rectangles. Smaller units, such as sheds, may not be captured.	Ortho2012	Area	Full Coverage		Dynamic
BUILDINGS_TXT	Text representing the names of some of the larger and more prominent buildings in Hamilton.	Schematic	Text	Partial		Dynamic
CITY_ALLEYS	Please refer to ALLEYS as the most up-to-date data set. The alleyway data is a compilation of all the known city and private alleyways in the City of Hamilton. The geospatial component of this project was extracted from the Teranet mapping and the starting point was a custom Land Registry data extract, obtained from Teranet to populate the majority of the ownership fields. In many cases, the lands that were not moved forward to LTCQ during automation and are still in the registry system require a compressive title search to confirm ownership. All the known information, for example, By-Laws, have been added, but are not a complete inventory of all the By-Laws. Staff verification is still necessary.	Combination	Area	Full Coverage		Dynamic
CITY_ROAD_WIDENING	The proposed ultimate road widening layer was created using the "Road Classification and Right-of-Way Width Project" final report dated June 2009, all proposed widenings should be confirmed with the current Official Plan. Staff verification is still necessary.	Combination	Area	Full Coverage		Monthly
COAXIAL_CABLE_DUCT		Combination	Line	Full Coverage		Yearly
COAXIAL_CABLE_STRUCTURE		Combination	Point	Full Coverage		Yearly
DTM_2002_CONT_TXT	Contour text (in metres). Use in conjunction with the DTM_2002_CONTOURS feature.	Schematic	Text	Full Coverage	2002	Static
DTM_2002_CONTOURS	1 metre contours as generated by GeoMedia Grid using the 2002 DTM data. Category 'type' determines major and minor contours, the major ones being every 10 metres.	Ortho2002	Line	Full Coverage	2002	Static
DTM_2007_CONT_TXT	Contour text (in metres). Use in conjunction with the DTM_2007_CONTOURS feature.	Schematic	Text	Full Coverage	2007	Static
DTM_2007_CONTOURS	1 metre contours as generated by FME (Feature Manipulation Engine) using the 2007 DTM data. Category 'type' determines major and minor contours, the major ones being every 10 metres.	Ortho2007	Line	Full Coverage	2007	Static
DTM_2010_CONT_TXT	Contour text (in metres). Use in conjunction with the DTM_2010_CONTOURS feature.	Schematic	Text	Full Coverage	2010	Static
DTM_2010_CONTOURS	1 metre contours as generated by FME (Feature Manipulation Engine) using the 2010 DTM data. Category 'type' determines major and minor contours, the major ones being every 10 metres.	Ortho2010	Line	Full Coverage	2010	Static
DTM_2014_CONTOURS	1 metre contours as generated by GeoMedia Grid 2014 using the 2014 DTM data. Category 'type' determines major and minor contours, the major ones being every 10 metres.	Ortho2014	Line	Full Coverage	September, 2015	Static
EME_DRAINAGE	Environmental Monitoring and Enforcement. This layer provides information on the City of Hamilton's natural drainage sites by its streams, swamps, shorelines and ditches.	Combination	Line	Full Coverage	July, 2016	Yearly
EME_WATERSHED	Environmental Monitoring and Enforcement. The Watershed layer provides information on where the surface water contained in that area will drain to.	Combination	Area	Full Coverage	July, 2016	Yearly
HHI_PRIM_ARC	Horizon Utilities primary hydro lines. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Line	Partial	October, 2008	Static
HHI_PRIM_AREA	Horizon Utilities primary hydro areas. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Area	Partial	October, 2008	Static
HHI_PRIM_LINE	Horizon Utilities primary hydro lines. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Line	Partial	October, 2008	Static
HHI_PRIM_POINT	Horizon Utilities primary hydro points. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Point	Partial	October, 2008	Static
HHI_SEC_AREA	Horizon Utilities secondary hydro areas. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Area	Partial	October, 2008	Static
HHI_SEC_LINE	Horizon Utilities secondary hydro lines. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Line	Partial	October, 2008	Static
HHI_SEC_POINT	Horizon Utilities secondary hydro points. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Point	Partial	October, 2008	Static

Shapefile Name	Shapefile Description	Source	Type	Extent	LastUpdate	Update Frequency
HHI_SEC_TEXT	Horizon Utilities secondary hydro text. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Text	Partial	October, 2008	Static
HHI_SERV	Horizon Utilities service lines. Note: this data requires field verification if there are proposed works to be done that may affect the utility.	Schematic	Line	Partial	October, 2008	Static
HORIZON_CHAMBERS		External	Point	Full Coverage		Static
HORIZON_DUCT		External	Line	Full Coverage		Static
HRCA_FLOODPLAINS	Hamilton Region Conservation Authority floodplains. Please note that this data is not accurate and should not be used for legal purposes.	External	Area	Full Coverage		Static
INTRINSIC_GW_SUSCEPTIBILITY	This feature identifies groundwater susceptibility to contamination by assigning a high, medium, or low susceptibility to each area. This layer combines information from the Grand River Source Protection Area Assessment Report (August 16, 2012) Map 4-1 titled Aquifer Vulnerability, Halton Assessment Report (January 26, 2012) Figure 6.6 titled Intrinsic Groundwater Susceptibility, Hamilton Assessment Report (February 9, 2012) Figure 6.3 titled Intrinsic Groundwater Susceptibility, and Niagara Peninsula Source Protection Act Assessment Report (November 28, 2013) Figure 4.3 titled Groundwater Vulnerability Rules 37(1)/37(2)/38(1). Maps located on \\corona\world\Public Works\Hamilton Water\Source Protection Maps\Assessment Report Maps\INTRINSIC_GW_SUSCEPTIBILITY\.	External	Area	Full Coverage	August, 2015	Yearly
LAKE_TXT	Use in conjunction with the LAKES feature.	Schematic	Text	Full Coverage		Static
LAKES	Minor lake features, captured from aerial photography.	Ortho1992	Area	Full Coverage	1992	Static
LED_CONVERSION_COLLECTORS			Point	Full Coverage		Dynamic
MAJOR_LAKE_FILL	Water fill for Cootes Paradise, Hamilton Harbour and Lake Ontario.	Schematic	Area	Full Coverage		Static
MINOR_STM_SEPARATED_D	Each polygon represents the drainage area (subcatchment) for each individual pipe segment in the complete separated storm sewer system comprising the major and minor storm flow routes.Each polygon is assigned an ID corresponding to the Hansen ID of the manhole or inlet the area drains to. (Layer is under construction, and is updated as required by Capital Plan preparation or as new subdivisions are approved).	Schematic	Area	Full Coverage		Dynamic
MINOR_STM_SEPARATED_L	Each polygon represents the drainage area (subcatchment) for each individual pipe segment in the trunk separated storm sewer system comprising the major and minor storm flow routes. Each polygon is assigned an ID corresponding to the Hansen ID of the manhole or inlet the area drains to. (Layer is under construction, and is updated annually...or as required).	Schematic	Area	Full Coverage	December, 2006	Yearly
MNR_NRVIS_WATER	NRVIS (Natural Resources and Values Information System). Water polygons from the Ministry of Natural Resources. Last updated November, 2005.	External	Area	Full Coverage	November, 2005	Static
MNR_NRVIS_WETLANDS	NRVIS (Natural Resources and Values Information System). Data from the Minstry of Natural Resources. Last updated May, 2006.	External	Area	Full Coverage	May, 2006	Static
MNR_SOLRIS_WETLANDS	SOLRIS (Southern Ontario Land Resource Information System) is a land mapping project which uses satellite imagery, state-of-the-art mapping technology and field testing to provide ecological land classification mapping. Project partners include the Ministry of Natural Resources and Ducks Unlimited. Last updated November, 2005.	External	Area	Full Coverage	November, 2005	Static
MNR_SOLRIS_WOODLANDS	SOLRIS (Southern Ontario Land Resource Information System) is a land mapping project which uses satellite imagery, state-of-the-art mapping technology and field testing to provide ecological land classification mapping. Project partners include the Ministry of Natural Resources and Ducks Unlimited. Last updated November, 2005.	External	Area	Full Coverage	November, 2005	Static
MNR_WETLAND	Not all wetlands have been identified and mapped. Active maintenance is ongoing throughout the province. The currency and accuracy of the spatial representation is variable and requires on-the-ground verification. Certain attributes identify which wetlands have been evaluated with the Ontario Wetland Evaluation System (OWES) and of those which ones have been designated as Provincially Significant wetlands (PSW). Sources for wetland data included Wetland Interim (OBM/NTS), Forest Resource Inventory (FRI), Southern Ontario Land Recourse Inventory System (SOLRIS) and MNR district data. Wetlands are lands that are seasonally or permanently flooded by shallow water as well as lands where the water table is close to the surface; in either case the presence of abundant water causes the formation of hydric (moist) soils and has favoured the dominance of either hydrophytic (water loving) or water tolerant plants. Data provided by the Ministry of Natural Resources through Land Information Ontario. Further information can be found on G:\Tabular\Documents\MNR_WETLAND.pdf.	External	Area	Full Coverage	August, 2014.	Static
MNR_WOODED_AREAS	Data from the Ministry of Natural Resources. Received June 2003.	External	Area	Full Coverage	June, 2003	Static
MNR_WRIP_WATERFLOW	Last updated November, 2005.	External	Area	Full Coverage	November, 2005	Static
MOE_WELLS	This well feature has been provided by the Ministry of the Environment, February 2007. For information on structure and codes, refer to G:\Tabular\Documents\MOE_Wells.TXT. Licence expires in December 2008.	External	Point	Full Coverage	February, 2007	Static
NRNC1_COLLECTOR	Oracle view displaying only the collector roads from NRNC1_ROADSEG.	External	Line	Extended	2003	Static
NRNC1_FREEWAY	Oracle view displaying only the freeways from NRNC1_ROADSEG.	External	Line	Extended	2003	Static
NRNC1_LOCAL_STREET	Oracle view displaying only the local roads from NRNC1_ROADSEG.	External	Line	Extended	2003	Static
NRNC1_RAMPS	Oracle view displaying only the ramps from NRNC1_ROADSEG.	External	Line	Extended	2003	Static
NRNC1_ROADSEG	National Road Network, Canada, Level 1. Copyright Natural Resources Canada.	External	Line	Extended	2003	Static
OBM_CONTOUR	Ontario Base Map data from the Ministry of Natural resources. Data captured from aerial photography taken in 1975 and 1982.	External	Line	Full Coverage		Static
OBM_LAKE_ELEVATION_PNT	Ontario Base Map data from the Ministry of Natural resources. Data captured from aerial photography taken in 1975 and 1982.	External	Point	Full Coverage		Static
OBM_SPOT_HEIGHT	Ontario Base Map data from the Ministry of Natural resources. The height in metres is an attribute of the point feature. Data was captured from aerial photography taken in 1975 and 1982.	External	Point	Full Coverage		Static
ORTHO_1999_COVERAGE	Area feature showing the coverage of the aerial photography that was flown in May 1999. Coverage consisted of the urban areas of Hamilton only. 12.5 cm resolution.	Ortho1999	Area	1999 Ortho Coverage		Static
ORTHO_2002_COVERAGE	Area feature showing the coverage of the aerial photography that was flown in April 2002. Coverage includes the entire City of Hamilton at 20 cm resolution.	Ortho2002	Area	2002 Ortho Coverage		Static
ORTHO_TILES	Individual ortho tiles covering the entire City of Hamilton including a 1 km buffer where available. The tiles are attributed with whether they are available for 1999, 2002, 2005 or 2007 orthos. Each tile is 1km by 1km and 15 cm digital resolution for the 2007 orthos.	Ortho2005	Area	Extended		Static
PARCEL	Ownership-based parcels from Teranet Inc. This feature contains only the assessable parcel features. Non-assessable parcels are in the PARCEL_ROADS feature.	External	Area	Full Coverage		Quarterly
PARCEL_ADDRESS_PNT	Points generated from the PARCEL_ADDRESS_TXT feature. Created in order to use the addresses in spatial queries.	Schematic	Point	Full Coverage		Daily

Shapefile Name	Shapefile Description	Source	Type	Extent	LastUpdate	Update Frequency
PARCEL_ASSESSMENT	This description of the PARCEL_ASSESSMENT feature was copied from Teranet's Product Description document. "The intent with assessment mapping is to map only assessable parcels. One major category of land which is not assessed is roads. Thus, in southern Ontario and the settled parts of northern Ontario, assessment mapping appears as blocks of land separated by the road pattern. In the unsettled areas of the north, most assessable parcels will coincide with certain types of Crown parcel and assessment maps will appear as islands of parcels within large areas where there are no assessment parcels. Assessment parcels are generally created for railways and these are generally broken by roads, rivers and Map Block boundaries. All railway parcels which fall within one municipality and which have the same owner may receive the same ARN. For more information of this data, please refer to the directory G:\Tabular\Documents\TeranetOPMA.	Parcels	Area	Full Coverage		Quarterly
PARCEL_BLOCK_INDEX	An index of the Teranet blocks. Now includes the 1 km buffer zone of our new delivery area.	Schematic	Area	Full Coverage	July, 2005	Static
PARCEL_OASYS	An Oracle view joining the PARCEL graphics with data from the OASYS table. This view contains more detailed property information than the PARCEL_ASSESSMENT view.	Parcels	Area	Full Coverage	November, 2008	Quarterly
PARCEL_PUBLIC_LANDS	A parcel view where the Oasys names identifier is equal to "L" (Local government and public utilities), "P" (Provincial government including agencies) or "G" (Federal government including agencies). Displays only owner records where PRIME_SUB=0000.	Parcels	Area	Full Coverage		Quarterly
PARCEL_ROADS	Ownership-based parcels from Teranet Inc. This feature contains only the non-assessable parcel features. Ex. Roads, alleys, etc. The assessable parcels are in the PARCEL feature.	Parcels	Area	Full Coverage	March, 2009	Quarterly
PARKING_CONTROL_AREAS		Schematic	Area	Full Coverage		Static
PARKING_LOTS	Currently includes the Municipal Car Parks only.	Combination	Area	Partial		Yearly
PARKS	An Oracle view of the PED_PARKS_OS feature representing only the parks within the City of Hamilton. Area is in hectares.	Combination	Area	Full Coverage		Dynamic
PARKS_OPERATIONS_DISTRICTS	Boundary Layer that shows the Districts used by Parks and Cemeteries for all aspects of operations and planning. Note that these district boundaries are similar to, but not to be confused with, the totally separate GIS feature used by Public Works called PW_ROAD_MAINT_DISTRICTS.	Schematic	Area	Full Coverage	February, 2016	Static
PED_BYLAW_NUMBER	A file number that is associated with a zoning code to a site-specific property or properties. Indicates that a change has been made to the original zoning designation.	Schematic	Text	Full Coverage		Dynamic
PED_CITY_PROPERTIES	City of Hamilton owned and leased properties. Still under development. Detailed metadata located on G:\Tabular\Documents\Metadata for ORACLE_PED_CITY_PROPERTIES.doc.	Parcels	Area	Full Coverage		Dynamic
PED_DEV_APP	Point locations of development applications.	Parcels	Point	Full Coverage		Daily
PED_ZONING_BNDRY	The zoning boundary delineates the extent of an area representing a specific zone within the mapsheets.	Combination	Area	Full Coverage		Dynamic
PED_ZONING_CODE	The zone code is text for the zoning boundary feature and designates the permitted use for each property. Use in conjunction with the feature PED_ZONING_BNDRY.	Schematic	Text	Full Coverage		Dynamic
PRISM_PRIVATE_DRAIN	PD. Private Drains.	Schematic	Point	Full Coverage		Dynamic
PW_BENCHMARKS	Survey benchmarks from varying sources.	Survey	Point	Full Coverage	September, 2007	Static
PW_ROAD_GRIDS			Area	Full Coverage		Static
RAILWAY_BRIDGE	Railway features crossing over another feature. Originally captured by aerial photography.	Ortho2007	Line	Full Coverage	Sept, 2010	Static
RAILWAY_LINE	A centreline for the railway. Originally captured by aerial photography.	Ortho2007	Line	Full Coverage	Sept, 2010	Static
RAILWAY_TUNNEL	Railway features crossing under another feature. Originally captured by aerial photography.	Ortho2007	Line	Full Coverage	Sept, 2010	Static
RAILWAYS	An Oracle view combining the three graphic features RAILWAY_BRIDGE, RAILWAY_LINE and RAILWAY_TUNNEL.	Ortho2007	Line	Full Coverage	Sept, 2010	Static
RIVERS	Line feature representing water courses and originally captured by 1992 aerial photography.	Ortho1992	Line	Full Coverage	2000	Static
ROAD_ACCESS_RAMP	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_ACCESS_RMP_BRIDGE	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_CUT	Used for the GO360 Permit Tracking desktop application.		Point			Dynamic
ROAD_HIGHWAY_CASING	ROAD_HIGHWAY_CTRLN buffered by 10 metres.	Combination	Line	Full Coverage		Dynamic
ROAD_HIGHWAY_CTRLN	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_INTERSECTIONS	A point feature representing the intersection of 3 or more road segments. Linked to Hansen through the COMPKEY field.	Combination	Point	Full Coverage		Dynamic
ROAD_MAINT_DIST	Used for the GO360 Permit Tracking desktop application.		Area			Dynamic
ROAD_MAJOR_BRIDGE	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_MAJOR_CASING	ROAD_MAJOR_CTRLN buffered by 30 metres.	Combination	Line	Full Coverage		Dynamic
ROAD_MAJOR_CTRLN	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_MAJOR_INTERSECT	These segments complete the ROAD_MAJOR_CASING feature where they intersect with the ROAD_MINOR_CASING feature.	Combination	Line	Full Coverage		Dynamic
ROAD_MINOR_BRIDGE	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_MINOR_CASING	ROAD_MINOR_CTRLN buffered by 20 metres.	Combination	Line	Full Coverage		Dynamic
ROAD_MINOR_CTRLN	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_MINOR_INTERSECT	These segments complete the ROAD_MINOR_CASING feature where they intersect with the ROAD_PRIVATE_CASING feature.	Combination	Line	Full Coverage		Dynamic
ROAD_PRIVATE_CASING	ROAD_PRIVATE_CTRLN buffered by 20 metres.	Combination	Line	Full Coverage		Dynamic
ROAD_PRIVATE_CTRLN	Street centreline feature. Attributes include the street name, cross streets, left and right address ranges, etc.	Combination	Line	Full Coverage		Dynamic
ROAD_SIDEWALK	Sidewalks captured from the 2010 aerial photography. Source is First Base Solutions. City contact for source data is Gord McGuire.	Ortho2010	Line	Full Coverage	Spring, 2010	Static
SEW_ZONES	This layer divides the City into east and west sewer zones in order to designate responsibility areas for east and west crews. The current divide between the zones is Upper/Lower Wentworth Street.		Area	Full Coverage	April, 2017	Static
SEWER_BACK_WATER_VALVE	Valves which are installed to prevent sewer backups on properties.	Schematic	Point	Full Coverage		Dynamic
SEWER_CATCHBASINS	A catchbasin is a chamber or well, usually at the street curb line, for the admission of surface water to a sewer or sub-drain, having at its base a sediment sump to retain grit and below detritus the point of overflow. Originally captured by Roadware in May, 2005.	GPS	Point	Partial		Dynamic
SEWER_CHAMBER		Combination	Point	Full Coverage		Dynamic
SEWER_FLOOD_COMP_GRANT			Area	Full Coverage		
SEWER_FLOOD_DATES			Area	Full Coverage		
SEWER_FLOW_ARROW	Oriented points to show the direction of flow for the SEWER_MAINS. Types include storm, sanitary and combined.	Combination	Point	Full Coverage		Dynamic
SEWER_INDEX	A index to the sewer sheet areas. Each sewer sheet determines the naming convention of the features withing that area.	Combination	Area	Full Coverage		Static
SEWER_LATERAL_ZONES		Schematic	Area	Full Coverage		Static
SEWER_LIFT		Schematic	Point	Full Coverage		Dynamic

Shapefile Name	Shapefile Description	Source	Type	Extent	LastUpdate	Update Frequency
SEWER_MAIN	A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. "Sanitary" sewers carry household, industrial, and commercial waste. "Storm" sewers carry runoff from rain or snow. "Combined" sewers handle both. This feature includes the sewer mains types combined, force, sanitary and storm.	Combination	Line	Full Coverage		Dynamic
SEWER_MH	All sewer manholes including catchbasins, combined, sanitary and storm.	Combination	Point	Full Coverage		Dynamic
SEWER_MH_LEAD	A leader line for the SEWER_MH_TXT to be used where the text cannot be placed next to the SEWER_MH feature.	Schematic	Line	Full Coverage		Dynamic
SEWER_MISC_LEAD	A leader line for the SEWER_MISC_TXT to be used where the text cannot be placed next to a feature.	Schematic	Line	Full Coverage		Dynamic
SEWER_NODE	All sewer nodes including cross, elbow, inlet, manhole pump, outfall, reducer, stub, tee and valve types.	Combination	Point	Full Coverage		Dynamic
SEWER_NODE_LEAD	A leader line for the SEWER_NODE_TXT to be used where the text cannot be placed next to the SEWER_NODE feature.	Schematic	Line	Full Coverage		Dynamic
SEWER_NODE_TXT	Use in conjunction with the SEWER_NODE and SEWER_NODE_LEAD features.	Schematic	Text	Full Coverage		Dynamic
SEWER_SERVICE_LINE	Sanitary laterals.	Combination	Line	Full Coverage	November, 2009	Static
SEWER_SIGN		Schematic	Point	Full Coverage		Dynamic
SEWER_TREATMENT	Sewer treatment plant.	Schematic	Area	Full Coverage		Dynamic
SEWER_USE_LAWS		Schematic	Area	Full Coverage		Dynamic
SEWER_VALVE	All sewer valves including air, blow off and line types.	Combination	Point	Full Coverage		Dynamic
SHORELINE	Includes the shoreline for Lake Ontario, Hamilton Harbour and Cootes Paradise as captured from 1992 aerial photography. Some minor updates have been made since.	Ortho1992	Line	Full Coverage	1992	Static
SMN_STRUCT_GRADE	Sewer CCTV inspection results.	Schematic	Line	Full Coverage		Weekly
SRFCE_WTR_INTAKE_PROT_ZONE_PLY	This feature identifies intake protection zones associated with surface water, which need protection from possible threats, and assigns vulnerability scores of 1, 2, 4.8, or 6 to each area. This layer combines information from the Niagara Peninsula Source Protection Act Assessment Report (November 28, 2013) Figure 11.2 titled Grimsby WTP IPZ-1/IPZ-2 Delineations and Hamilton Assessment Report (February 9, 2012) Figure 6.1 titled Woodward Intake Protection Zone (IPZ). Maps located on \\corona\world\Public Works\Hamilton Water\Source Protection Maps\Assessment Report Maps\SRFCE_WTR_INTAKE_PROT_ZONE_PLY\.	External	Area	Partial	August, 2015	Yearly
SRFCE_WTR_INTAKE_PROT_ZONE_PNT	This feature identifies the centroids of the intake protection zones associated with surface water.	External	Point	Partial	August, 2015	Yearly
STORM_STORAGE_BASIN		Schematic	Area	Full Coverage	April, 2010	Static
STORM_STORAGE_BASIN_INLET		Schematic	Point	Full Coverage		
STORM_STORAGE_BASIN_OUTLET		Schematic	Line	Full Coverage		
STREETCENTERLINE	An Oracle view combining all the ROAD centrline features.	Combination	Line	Full Coverage		Dynamic
SURVEY_DIST	Used for the GO360 Permit Tracking desktop application.		Area			Dynamic
TRAILS	Trails within the City of Hamilton. Includes existing and proposed.	Combination	Line	Full Coverage		Dynamic
TRAILS_EXISTING	An Oracle view of the TRAILS feature displaying only the existing trails within the City of Hamilton.	Combination	Line	Full Coverage		Dynamic
TRAILS_RETIRED	Contains the trails that have been removed from the TRAILS feature.	Combination	Line	Full Coverage		Dynamic
TRANSMISSION_LINE	The transmission lines as captured from 1992 aerial photography.	Ortho1992	Line	Partial	1992	Static
TREE_FUTURE_PLANTING	Potential locations for new trees to be planted within the City's road allowance were captured using GPS, 2006.	GPS	Point	Urban Area		Dynamic
TREE_INVENTORY	Trees within the City's road allowance were captured using GPS, 2006.	GPS	Point	Urban Area	2006	Static
UTI_GAS_PIPES	Schematic layer of Union Gas/Duke Energy gas distribution pipes found within the City of Hamilton. The feature differentiates the size of pipes and the pressure value for each pipe. Pipe material and install dates are also part of the feature class. This data has been provided by Union Gas/Duke Energy. Field verification has not been completed at this time.	External	Line	Full Coverage	June, 2010	Yearly
UTI_HYDRO_ONE_OVERHEAD	Schematic layer of large overhead transmission lines throughout the City of Hamilton. This feature has been supplied by Hydro One. Field verification has not been completed at this time.	External	Line	Full Coverage	June, 2010	Yearly
UTI_HYDRO_ONE_STRUCTURES	Schematic layer of large hydro transmission structures throughout the City of Hamilton, including poles and hydro towers. This feature has been supplied by Hydro One. Field verification has not been completed at this time.	External	Point	Full Coverage	June, 2010	Yearly
UTI_HYDRO_ONE_UNDERGRND	Schematic layer of large underground transmission lines throughout the City of Hamilton. This feature has been supplied by Hydro One. Field verification has not been completed at this time.	External	Line	Full Coverage	June, 2010	Yearly
UTI_PIPELINES	Schematic layer of large pipeline utilities found within the City Of Hamilton. The features consist of Natural Gas Transmission, Oil and Petroleum Transmission, Liquid Hydrogen, Liquid Nitrogen, Oxygen and District Heating and Cooling. This feature has been collected from various sources, to create a layer that is a compilation of all large utilities. Field verification has not been completed at this time.	Combination	Line	Full Coverage	June, 2010	Yearly
UTI_POLES	Location of utility poles owned by the City, by public utilities such as Hydro, Bell, etc. or privately owned. Source is First Base Solutions. City contact for source data is Gord McGuire.	Ortho2010	Point	Full Coverage	Spring, 2010	Static
UTI_TELECOM_FIBER	Schematic layer of large telecommunication utilities found within the City of Hamilton. The features consist of underground cables owned by companies such as: Bell Canada, Rogers/Group Telecom, Level3 Communications, Cogeco Cable and AllStream Communications. This feature has been collected from various sources, to create a layer that is a compilation of all large utilities. Field verification has not been completed at this time.	Combination	Line	Full Coverage	June, 2010	Yearly
VEGETATION	For trees, the intention was to capture individual trees in parks and all trees within the road right-of-way (defined as the area in front of buildings or in line with buildings), or when there are no buildings, approximately 20 metres either side of the centreline of the road. The intent was not to collect trees behind buildings or in back yards. Masses of trees will be captured using the "TREELINE/WOODED AREA" type. Only hedges that appear to be along dividing lines between properties were captured. The edge of marshes were also digitized.	Ortho1990	Compound	Old City of Hamilton		Static
WATER_BACKFLOW_PREVENTOR			Point	Full Coverage		Dynamic
WATER_HYDRANT	A water source consisting of an upright pipe, usually in a street, connected to a water main with a valve to which a hose can be attached, for example, by the fire department.	Combination	Point	Full Coverage		Dynamic
WATER_HYDRANT_BRANCH		Schematic	Line	Full Coverage		Dynamic
WATER_HYDRANT_LEAD	A leader line for the WATER_HYDRANT_TXT to be used where the text cannot be placed next to the WATER_HYDRANT feature.	Schematic	Line	Full Coverage		Dynamic
WATER_INDEX	A index to the water sheet areas. Each water sheet determines the naming convention of the features withing that area.	Schematic	Area	Full Coverage		Static
WATER_MAIN	All water mains within the City of Hamilton.	Schematic	Line	Full Coverage		Dynamic
WATER_MAINT_DISTRICT	Water Maintenance District. These two district areas are used to divide the Water and Sewer features into two DGN files, respectively, when exporting them to Microstation design files.	Schematic	Area	Full Coverage		Dynamic
WATER_METERS	Includes seasonal meters.	Schematic	Point	Full Coverage		Dynamic
WATER_MISC_LEAD	A leader line for the WATER_MISC_TXT.	Schematic	Line	Full Coverage		Dynamic

Shapefile Name	Shapefile Description	Source	Type	Extent	LastUpdate	Update Frequency
WATER_NODE	All water nodes including cross, elbow, pumping station, reducer, stub and tee types.	Combination	Point	Full Coverage		Dynamic
WATER_NODE_LEAD	A leader line for the WATER_NODE_TXT to be used where the text cannot be placed next to the WATER_NODE feature.	Schematic	Line	Full Coverage		Dynamic
WATER_SERVICE_LINE		Schematic	Line	Full Coverage		Dynamic
WATER_SMPLG_STN	Water sampling station.	Schematic	Point	Full Coverage		Dynamic
WATER_VALVE	All water valves including air, backflow, blowoff, check, level, line, pressure reducing, service and tapping types.	Combination	Point	Full Coverage		Dynamic
WATER_VALVE_LEAD	A leader line for the WATER_VALVE_TXT to be used where the text cannot be placed next to the WATER_VALVE feature.	Schematic	Line	Full Coverage		Dynamic
WW_PRESSURE_DIST	Each polygon represents the boundary of each water pressure district and comprises all demand areas contained within that boundary.	Schematic	Area	Full Coverage	December, 2006	Yearly
WW_SAN_SEWER	Each polygon represents the drainage area (subcatchment) for each individual length of sanitary sewer.	Schematic	Area	Full Coverage		Dynamic
WW_STORM_COMB	Each polygon represents the drainage area (subcatchment) for each individual length of combined sewer. Each polygon is assigned an ID corresponding to the Hansen ID of the manhole or inlet the area drains to.	Schematic	Area	Full Coverage		Dynamic
WW_WATERMAIN	Each polygon represents the water demand area for each point in the detailed model of the waterworks system. The detailed model comprises all watermains in the distribution system. Polygons are assigned ID's corresponding to the Hansen ID of the point of application of the demand on the system in the detailed model of the waterworks system.	Schematic	Area	Full Coverage		Dynamic

Appendix M

Property Ownership


BEACH BOULEVARD
QUEEN ELIZABETH WAY
EASTPORT DRIVE
BAYSIDE AVE
LEGEND
LIMIT OF QEW
M.T.O. LIMIT OF BUFFER CONTROL
PIN LIMIT
CITY STREET LIMIT
TITLE ISSUE BETWEEN CITY AND MTO (REQUIRES REVIEW)
M.T.O. SOUND WALL
NOTE : INFORMATION ON THIS SKETCH WAS COMPILED FROM DEEDS VM244699, VM244702 & VM244706 AND TERANET RECORDS AS OF NOVEMBER 2018. MAY NOT REFLECT CURRENT LAND OWNERSHIP.
DATE : NOVEMBER 22, 2018
FILE : Y:nhood\Hambcha\06-6701-03\July 2018 Drainage Issue\08-9-12_1-2018.dgn


BEACH BOULEVARD
QUEEN ELIZABETH WAY
EASTPORT DRIVE
DUNBAREN AVE
LOCARNO AVENUE
NORTH PARK AVE
REMBE AVENUE
WINDERMERE AVENUE
WICKHAM AVENUE
GRAFTON AVENUE
GRANVILLE AVENUE
HAMILTON HARBOUR
LEGEND
LIMIT OF QEW
M.T.O. LIMIT OF BUFFER CONTROL
PIN LIMIT
CITY STREET LIMIT
TITLE ISSUE BETWEEN CITY AND MTO (REQUIRES REVIEW)
M.T.O. SOUND WALL
NOTE : INFORMATION ON THIS SKETCH WAS COMPILED FROM DEEDS VM244699, VM244702 & VM244706 AND TERANET RECORDS AS OF NOVEMBER 2018. MAY NOT REFLECT CURRENT LAND OWNERSHIP.
DATE : NOVEMBER 22, 2018
FILE : Y:nhood\Hambcha\06-6701-03\July 2018 Drainage Issue\08-9-12_1-2018.dgn

Appendix N

GLAM 2017 Plan Evaluation

Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee

Summary of 2017
Great Lakes Basin Conditions and Water Level Impacts to Support Ongoing Regulation Plan Evaluation

November 13, 2018




A report to the Great Lakes Boards and the International Joint Commission
Covering the period Jan. 1, 2017 to Dec. 31, 2017

Cover photo: *Top left: Erosion of dunes along Lake Superior on Duluth's Park Point (photo credit: Bob King / rking@duluthnews.com; Top right: High water conditions near Fair Haven, New York (photo credit: U.S. Army Corps of Engineers, June 2017); Bottom left: Coastal flooding and beach washout near Ontonagon, MI (Lake Superior) after 24-October-2017 storm (photo credit T. Lancioni,2017); Bottom right: Lake Saint-Pierre (Pierreville) in Nicolet-Yamaska Regional County Municipality (photo credit: Transport Canada National Aerial Surveillance Program, May 2017)*

GLAM Committee Membership

Blue text identifies other International Joint Commission Board and Committee affiliations.

United States	Canada
Arun Heer, Co-Chair U.S. Army Corps of Engineers, Great Lakes and Ohio River Division Secretary, International Lake Ontario – St. Lawrence River Board, International Lake Superior Board of Control	Wendy Leger, Co-Chair Environment and Climate Change Canada
Don Zelazny New York State Department of Environmental Conservation	Jonathan Staples Ontario Ministry of Natural Resources and Forestry International Niagara Working Committee Member
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Bill Werick	Jean Morin Environment and Climate Change Canada
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John Allis U.S. Army Corps of Engineers, Detroit District International Lake Superior Board of Control Alternate Regulation Representative	Jacob Bruxer Environment and Climate Change Canada International Lake Superior Board of Control and International Lake Ontario - St. Lawrence River Board, Regulation Representative

Bryce Carmichael, Co-Secretary U.S. Army Corps of Engineers, Great Lakes and Ohio River Division Secretary, International Niagara Board of Control	*Mike Shantz, Co-Secretary* Environment and Climate Change Canada

NOTE: *The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee was established by the International Joint Commission and is comprised of an equal number of members from the United States and Canada. Members of the Committee serve at the pleasure of the IJC and are expected to be full participants in all activities of the Committee. As with all IJC Boards and Committees, the GLAM Committee members serve in their personal and professional capacity, not as a representative of their agencies or employers.*

The GLAM Committee expresses it sincere appreciation to the following associates for their contributions to this report:

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Executive Summary

This is a special report of the International Joint Commission's (IJC) Great Lakes – St. Lawrence River Adaptive Management (GLAM) Committee covering the hydroclimate, flows and water level conditions, as well as their impacts on multiple interests, experienced in 2017 throughout the Great Lakes-St Lawrence River system. The focus is on the extraordinary conditions caused by record rainfall, runoff and the resulting high water levels on Lake Ontario and the St. Lawrence River in 2017. The information gathered for the 2017 event will be used to support the primary objective of the GLAM Committee: to evaluate the regulation of outflows from Lake Superior and Lake Ontario, and the effects of this regulation on interests throughout the system. This on-going evaluation will help the IJC to better regulate water releases from Lake Ontario and Lake Superior and the information compiled for this report will be used over time to adaptively manage and improve the rules governing those releases.

The information gathered came from a variety of sources in both countries; however, much of the quantitative economic and environmental data on impacts from high water levels in 2017 required to support the validation of models used to evaluate the performance of the regulation plans is not available. The GLAM Committee will continue to refine the impact models as more data become available and the ongoing evaluation of the regulation plans will focus on the priority areas identified in this report.

Lake Ontario and St. Lawrence River – the story in 2017

During 2017, the Lake Ontario – St. Lawrence River experienced one of the most extreme hydrologic events recorded in the basin in over 100 years. The simultaneous occurrence of record-breaking rainfall over both the Lake Ontario and St. Lawrence River basins, combined with high inflows from Lake Erie and record flows out of the Ottawa River, culminated in new record high water levels on Lake Ontario and the St. Lawrence River and extensive impacts across various interests and regions. Lake Ontario's daily level peaked at 75.88 m (248.95 ft) in late May, the highest recorded on the lake since records began in 1918. Water levels downstream on the St. Lawrence River also approached (and in some cases exceeded) record highs. At Lake Saint-Louis near Montreal, levels were close to record highs throughout much of the spring and new record highs were set for the months of June, July and August.

Impacts from high water conditions

Coastal properties across Lake Ontario and the St. Lawrence River in New York, Ontario and Quebec experienced significant impacts from flooding, erosion and damage to shore protection structures. Impacts were widespread across the basin, with some areas experiencing greater impacts than others. Reports of flooded homes, roads, driveways, trails, lawns, emergency response and extensive sandbagging efforts to protect houses and properties made the news for months. Reports of shoreline erosion and loss of beaches, vegetation and land, decks and docks were common on the south and north shores of Lake Ontario. There were reports of shore protection structures failing or being damaged by wave action with the high water conditions, leaving properties even more vulnerable. States of emergency were issued across all US counties bordering Lake Ontario and the upper St. Lawrence River and for a number of Canadian municipalities, particularly on the lower St. Lawrence River during the peak flooding in May 2017.

Municipal and industrial water and wastewater uses experienced some direct impacts such as increased storm water infiltration in wastewater collection systems and treatment plants leading to sewer overflows, though these may have been due to the excessive rainfall rather than the high lake and river levels in some cases. Nonetheless, by all accounts, the millions of users of larger municipal water and wastewater systems were able to rely on necessary services in 2017.

Commercial navigation experienced impacts due to very high velocities on the St. Lawrence River. To ensure safe navigation and prevent losses that would have arisen with a closure of the Seaway, this sector applied a number of mitigation measures to adapt to the extreme conditions. Despite the associated costs and delays due to the necessary mitigation measures, it was still a very productive year for the commercial navigation sector due to robust economic demand.

The **hydropower** sector reported some adverse impacts related to the high water despite overall increases in energy production realized in 2017 through the Moses-Saunders and Beauharnois dams. These impacts included losses to future production opportunity due to increased spillage of water, increased operating costs to mobilize crews more frequently for additional gate operations and to clean additional debris and the need to defer maintenance on various pieces of equipment.

Environmental impacts from water levels are often most influenced by seasonal and multi-year cycles, and the effects of high water in 2017 are expected to be more apparent in future years. Field data from the surveillance in 2017 did show a reduction of percent cover of meadow marsh from 2015, as predicted by the wetland vegetation response model used to evaluate Lake Ontario regulation plans. The GLAM Committee is working with environmental agencies in 2018 to measure shifts in vegetative guild areas caused by 2017 water level conditions, but evident only in subsequent years, because of the lag in response from plant communities.

Recreational boating and tourism activities were negatively impacted throughout the Lake Ontario – St. Lawrence River in 2017 due to problems with flooded docks and marina facilities, shoreline access and floating and submerged debris, with some locations appearing to be more vulnerable than others. The GLAM Committee is conducting a marina and yacht club survey to better document 2017 impacts.

Reviewing Lake Ontario regulation plans evaluations: perspectives from 2017

The GLAM Committee reappraised several aspects of Lake Ontario regulation plans evaluations in light of the record high levels in 2017. The key findings are presented in Section 7, while Section 6.3 of this report provides the analysis and rationale for these major findings.

Key Findings

- The year 2017 was unusually wet across the entire Great Lakes with record-breaking precipitation and water levels on the Lake Ontario-St. Lawrence River system, but Lake Ontario and St. Lawrence River levels under Plan 2014 were not higher than they would have been had the International Lake Ontario-St. Lawrence River Board been operating under Plan 1958D and previous operating and deviation authorities **(see Finding 7.1**).
- Environmental outcomes from 2017 conditions are important in validating environmental models used in plan evaluations, but impacts are not expected to be realized immediately. Additional years of monitoring wetlands' response to 2017 high water levels is needed to complete the wetlands model validation **(see Finding 7.9)**.
- Plan 2014 generally performed as it was expected to under extreme weather and water supply conditions, in that it helped to reduce, but could not eliminate the coastal damages and flooding that occur during such extreme events, while also attempting to balance and minimize impacts on other interests. A fresh review of particular items related to how the plan performed in 2017 might provide insights that could be used to improve the way regulation plans are tested and evaluated in the future. This includes:
  - The impacts of modifying certain rules of Plan 2014, including the maximum outflow limits that balance upstream and downstream high water levels (F-limit) and that balance high water conditions with protections for navigation (L-limit) should continue to be reviewed **(see Finding 7.5)**. Plan 2014's maximum limits are defined based on decades of board experience in balancing coastal impacts above and below the dam and balancing those impacts with maintaining safe water velocities and river levels for ships in the St. Lawrence Seaway. An updated analysis of impacts supported by socio-economic and environmental performance indicators, informed by what was learned in 2017, would allow the GLAM Committee to better understand and explain the tradeoffs and balances inherent in the current limits and other Plan 2014 rules; and
  - Changes to the trigger levels that authorize the board to deviate from Plan 2014 should continue to be investigated. Even though the GLAM Committee found that no significant water level reduction could have been achieved in 2017 as a result of any realistic adjustment to the existing high trigger levels (see Section 6.3.2.2), adjustment of trigger levels was the most common suggestion offered by the public to reduce coastal damages. Ongoing analysis, building on previous studies

by the IJC, supported by lessons learned in 2017 and future years, and covering a wide array of inflow conditions should be investigated **(see Finding 7.6)**.

- The hydroclimate conditions of 2017 raised some questions about future plan evaluations. Specifically:
    - The unprecedented ice and precipitation conditions, and the effects this had on regulated outflows and the water levels that occurred in 2017, highlighted the importance of further and more detailed analysis of such unique scenarios to complement the historical and stochastic hydrologic analyses that have been performed previously **(see Finding 7.7)**; and
    - Improvements in seasonal forecasts are still a work in progress and it may be years, even decades, before they have the skill to inform regulation plan decisions, so a first step is to test the hypothesis that forecasts could reduce flooding while protecting uses. A next step would be to assess the risk of incorrect forecasts **(see Finding 7.8)**.

The upper Great Lakes

All of the upper Great Lakes began 2017 with water levels above average and they remained above average throughout the year. Water levels from June to December 2017 on Lake Superior approached the recorded monthly maximums set in 1985. Lake Michigan-Huron had a higher than average rise from April through July, and Lake Erie came within 15 cm (5.9 in) of its 1986 monthly record high level for May.

Impacts from high water conditions

Data collected by the GLAM Committee indicates that the above average water levels in the upper Great Lakes were tolerated well by the municipal and industrial sector, hydropower and commercial navigation. Recreational boating and tourism, for the most part, also seemed to benefit from the higher water levels, with the exception of some minor, temporary impacts to marinas on Lake Erie. However, there were adverse coastal impacts on all of the upper Great Lakes in 2017, primarily occurring during periods of strong winds and waves, which accelerated coastal erosion. These impacts were a concern frequently cited by coastal interests during 2017; nevertheless, they were generally able to cope with the levels experienced. Ecosystem responses were not detected from just one year of data; however, there is currently research underway in Georgian Bay that might help validate existing ecosystem modelling assumptions.

Reviewing Lake Superior regulation plan evaluations: perspectives from 2017

Regulation of Lake Superior outflows has much less influence on the levels of the upper Great Lakes than regulation of flows through the Moses-Saunders Dam has on Lake Ontario and the St. Lawrence River, and the incremental impacts of different regulation plans tend to be smaller and harder to discern on any of the upper Great Lakes, particularly during a single year and when water levels are within historical ranges. One exception, though, is the St. Marys River, where water levels are more sensitive to changes in the outflow from Lake Superior and, as a result, regulation decisions can significantly change impacts. In recent years, including 2017, the board has deviated from Plan 2012 in order to accommodate expected temporary reductions in hydropower plant capacity on the St. Marys River and reduce the potential that these reductions may have in causing adverse impacts related to high and fluctuating flows in the St. Marys Rapids. Reduced hydropower plant capacity can occur as a result of both expected (e.g., maintenance) and unexpected (e.g., mechanical failure) turbine outages. The timing and magnitude of such occurrences varies and is not easy to predict, but when they do vary during periods of higher levels and flows, more water is typically released through the St. Marys Rapids to offset the lost hydropower capacity and maintain Lake Superior outflows. Such conditions were not considered during the development of Plan 2012.

The 2017 deviation strategy by the board allowed for reduced and more gradual flow changes in the St. Marys Rapids, which resulted in slightly less flooding on Whitefish Island and may have reduced environmental impacts, without causing problems for the commercial navigation industry. The 2017 operations suggest that the GLAM Committee should investigate modifications to Plan 2012 to produce these sorts of benefits routinely, perhaps using predictions of available turbine capacity as an input. Because the expected benefits of the board's deviations for the St. Marys River fish habitat and the reduction in high water damages to Whitefish Island are now qualitative, research to quantify the relationship between flows over the rapids and the environmental and coastal benefits could help produce more beneficial rules.

Key Finding

High outflows from Lake Superior in 2017, as in other recent years, have highlighted two potential impacts on the St. Marys River requiring further analysis. Additional regulation plan performance indicators should be developed in order to i) assess potential impacts of various release scenarios on the spawning habitats of native fish species in the river and ii) to capture flooding impacts on the river and Whitefish Island adjacent to the St. Marys Rapids (**see Finding 7.4**).

Great Lakes basin as a whole

The GLAM Committee reported two key findings on data availability and model improvements that relate to the entire Great Lakes Basin (7.2 and 7.3).

First, while performance indicators generally captured critical sectors in 2017, conditions raised questions about model details and on-going monitoring required for validation. Little quantitative economic and environmental data on impacts from the high water levels in 2017 are available, but such data are essential for the improvement of regulation plan evaluation estimates. Some impacts could not be compared with existing performance indicators, either because the data were not available to support the comparison, or because the impacts observed weren't directly captured by the existing performance indicators. The GLAM Committee is in the process of estimating some impacts, has supported efforts by others to do so, and will report on these efforts in the future as the data become available **(see Finding 7.2**). The Committee realizes the importance of pursuing on-going monitoring needs into the future to validate models and update performance indicators as needed to support the ongoing review of the regulation plans.

Second, simulations of water levels and flows under Plan 2012 and Plan 2014, as well as alternative regulation strategies, should be continually tested and improved as appropriate to minimize inherent uncertainties **(see Finding 7.3).**

Contents

1.0 Introduction

The International Joint Commission (IJC) and their **International Lake Superior Board of Control (ILSBC)** and **International Lake Ontario-St. Lawrence River Board (ILOSLRB)** serve to manage the outflows of Lake Superior and Lake Ontario in accordance with Orders of Approval issued by the IJC under the 1909 Boundary Waters Treaty. Outflows are managed under widely varying hydrological and climatic (hydroclimate) conditions, including changes in precipitation and temperature, which are two primary drivers of water levels in the system. The intent of outflow management is to achieve expected outcomes over the long-term. Outflows are managed using regulation plans - rules that guide how much water is released through the regulatory structures under a range of possible conditions to meet the needs of various water-using interests throughout the basin. The Great Lakes-St. Lawrence River system is large, dynamic and diverse - always changing and often in ways that cannot be predicted. As a result, it is critical that outflow management and its associated benefits are tracked over time to ensure outcomes and trade-offs across a wide range of socio-economic and environmental interest categories are as expected and continue to be achieved as the system changes. This is the mandate of the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee, a 16-member binational committee established by the IJC in January 2015. This report is the GLAM Committee's summary of basin conditions and regulation outcomes and covers the period of January 1, 2017 to December 31, 2017. The intent is to provide an overview of climate and hydrological (water supplies, water levels and flow) conditions within the Great Lakes – St. Lawrence system through the year and to highlight their importance in the plan review process. It is also to identify and document any observed, reported and anecdotal evidence of impacts, both positive and negative, of water levels and flows and compare these actual results against simulated results to test alternative scenarios and conditions.

While all the Great Lakes were well above average in 2017, Lake Ontario and the St. Lawrence River started out fairly typical for water levels. However, the cumulative effect of highly variable winter weather, unprecedented ice conditions, massive spring storms and exceptional rainfall within the Lake Ontario and St. Lawrence River basin resulted in record high water levels, flooding and, in places, intense coastal damages. Many residents and communities suffered significant financial and emotional stress along with the physical damages.

This report serves to document observed impacts and the information will be used to support an adaptive management approach towards the on-going assessment of regulation plan performance to inform future improvements.

1.1 Purpose and objectives

The GLAM Committee reports directly to the ILSBC and the ILOSLRB, as well as to the International Niagara Board of Control (INBC). The primary objectives of this GLAM Committee report to the boards are to:

- review and evaluate the performance of the Lake Superior and Lake Ontario regulation plans based on 2017 conditions and new information gathered;
- determine how long-term regulation plan evaluations may be influenced by what was learned in 2017;
- identify pieces missing to adequately evaluate plan operations and rules; and
- use information gathered and learned to prioritize next steps in the ongoing review of the regulation plan.

This report and its Annexes support the Committee's essential mission to coordinate the required monitoring, modelling and assessment related to the ongoing evaluation of regulation plans on the Great Lakes – St. Lawrence River, and report that information back to the ILSBC, ILOSLRB and the IJC. By documenting critical information regarding hydroclimate conditions, effects associated with observed water levels and flows and simulations of alternative regulation strategies, this report provides critical information to help support the adaptive management process. The overarching adaptive management strategy provides a roadmap of where the GLAM Committee is going and what is needed to conduct a full evaluation of the regulation plans within the requirements of the IJC Directive. The annual work plans are driven by this long-term strategy, but also by what is learned each year.

Ultimately, the GLAM Committee is to track performance of the regulation plans over time with the intent of providing the necessary information to the boards and the IJC for improving water management outcomes. Plan performance must be considered under a range of water level conditions. Based on the conditions of 2017, performance indicators may need to be revisited to account for the impacts of extreme conditions not currently captured by models. It may take several years of monitoring and evaluation to fully understand how well the performance indicators represent what actually happened in 2017 and subsequent years. This report, covering conditions in 2017, provides a starting point for reviewing plan performance and identifying priority areas for further investigation in support of adaptive management.

1.2 Overall GLAM Committee approach to ongoing regulation plan review

As part of the GLAM Committee's on-going process to review the regulation plans, a strategy has been established that includes efforts to perform a regular check-up of what has been happening over recent years in terms of water levels and supplies, the management of outflows and the effects these have on various interests. The idea is to generate a stream of information that will identify and assess priorities for future work. It should be noted that it is not possible for the GLAM Committee to track each and every interest on an annual, ongoing basis, nor update every tool utilized in the evaluation process at this level of frequency. It was nevertheless determined to be important for the GLAM Committee to continually stay abreast of the critical aspects required to evaluate regulation plans so that proper maintenance and updating of the data and tools can occur when necessary and can be done efficiently.

In accordance with the IJC directive (http://ijc.org/en_/GLAM/Directive), this review of the existing regulation plans will consider not only whether the plans are meeting intended objectives over time, but also how the Great Lakes – St. Lawrence River system may be changing, and how that might alter the outcomes of water regulation and the decisions made on how best to regulate outflows. Regulation plan performance is not evaluated in isolation or using absolute outcomes. Instead, performance is typically evaluated on a relative scale against some baseline condition such as an existing regulation plan or the case without regulation. The ability to evaluate a regulation plan begins with the calculation of water levels and flows resulting from hydrologic conditions and a given regulation plan. Water levels and flows are then used as the primary inputs to predictive models which use performance indicators to assess the potential positive and negative impacts to various interests including municipal and industrial water uses, hydropower, navigation, riparian land owners, recreational boating and tourism and the environment. The better the ability to understand and predict future water levels and impacts from changing water supplies, the more robust water management planning will be. In 2017, unprecedented high water levels throughout the Lake Ontario-St. Lawrence River system due to extreme water supply conditions illustrated the impacts of system-wide high water and the importance of understanding other potential future water supply conditions, and improving tools to estimate outcomes under such exceptional conditions. It also provided a unique opportunity to conduct further testing to examine the effects and limitations of outflow management under extreme conditions and to test whether outcomes could have been improved using different regulation choices.

The GLAM Committee activities build, in part, from two previous IJC studies, including the Lake Ontario-St. Lawrence River Study (LOSLRS) from 2000 to 2006 and the International Upper Great Lakes Study (IUGLS) from 2007 to 2012. In the IUGLS, the evaluation of alternative regulation plans was framed by the expected impacts of Lake Superior outflow regulation on both Lake Superior and Lakes Michigan-Huron water levels. However, due to a combination of physical and operational constraints on the system, outflow regulation can do little to reduce long-term water level fluctuations on Lakes Michigan-Huron without resulting in a disproportionate increase in extreme water level fluctuations on Lake Superior (IUGLS, 2012). Performance indicators and more broadly defined coping zones (see Section 5.1.1) were used to identify potential water level and flow impacts on the key interest groups. The IUGLS resulted in a recommended regulation plan being proposed to the IJC which was, after considerable public consultation, adopted as Plan 2012 and implemented at the beginning of 2015. The LOSLRS provided an improved understanding of the effects of Lake Ontario outflow regulation on a variety of interests, including the environment. It also helped lead to an improved understanding of the overall functioning of the Lake Ontario-St. Lawrence River system and the impacts of potential climate scenarios. Through the LOSLRS, three alternative regulation plans were recommended for the IJC's consideration, one of which eventually led to the development and implementation of the current regulation plan known as Plan 2014. This plan was implemented in January 2017 after considerable public consultation and with concurrence of governments.

The plan evaluation developed under the IUGLS and LOSLRS produced options with varying mixes of performance results relative to the baseline conditions used during those efforts. Ideally, a regulation plan would be superior in every aspect relative to the baseline condition, but typically, gains in one area are accompanied by losses in other areas. Ultimately, it is up to the IJC to decide whether those trade-offs are acceptable as they did with both Plan 2012 for Lake Superior outflows and Plan 2014 for Lake Ontario outflows. Moving forward, the GLAM Committee is responsible for acquiring and using information on regulation plan outcomes to support the boards in assessing plan performance using existing established decision criteria, such as those enumerated in the IJC's Orders of Approval. The intent is to support the boards in providing recommendations to the IJC for possible regulation plan changes and improvements.

The GLAM Committee will use information from this annual assessment to support the long-term adaptive management process by:

- Gathering evidence about the water levels and flows throughout the upper Great Lakes system and the Lake Ontario and St. Lawrence River in 2017 and the impacts, both positive and negative, that occurred because of them;
- Adding new information and gaining new insights into what is likely to occur under a range of conditions and extremes such as 2017, that had only previously been simulated;
- Where feasible, compare the actual observed impacts to the expected impacts based on existing models and tools; and
- Analyze the differences between the modeled and actual impacts, both positive and negative, to:
    - Determine where impact models should be improved;
    - Report on how the plan performed under alternative hydroclimate conditions in comparison to what would have been expected under the previous regulation plans 1977A and 1958D with Deviations; and
    - Report on data and information that would help contribute to the ongoing and overarching question "Are the regulation plans performing as expected and are there possible outcomes that can be improved?".

Monitoring and model validation are critical components of the adaptive management process to ensure that the outcomes of the modeled results are realized in real-world operations. The GLAM Committee must coordinate the monitoring and assessment efforts to validate and update models and assess changing conditions over time. This is no small task and will take considerable ongoing monitoring efforts and assessment to evaluate the regulation plans under a variety of conditions over a number of years, potentially even decades. It is important to note that monitoring and analysis based on only a single year is not enough to draw conclusions on the long-term performance of a regulation plan. However, the information gathered in 2017 is vital to support prioritization of ongoing GLAM Committee activities including improvements to existing plan evaluation tools and possible areas where the performance of the existing regulation plans for Lake Superior and Lake Ontario outflows can be improved.

1.3 Report structure and content

While the report covers the entire Great Lakes-St. Lawrence River basin, it separates results into two sections. The first covers the upper Great Lakes area associated with ILSBC and affected by Lake Superior outflows, including Lakes Superior, Michigan-Huron, Erie and the connecting channels for the St. Marys and Niagara rivers (Note, however, that there is negligible effect of regulation of Lake Superior outflows on Lake Erie and the Niagara River). The second covers the Lake Ontario-St. Lawrence River system associated with the ILOSLRB and Lake Ontario outflow management.

The report was compiled with the input from various GLAM subject matter experts working in groups. The three main groups were the hydroclimate working group, the impact assessment working group and the plan review and evaluation group. The impact assessment group consisted of six sub-groups tasked with compiling the impacts to the main six interest areas of the Great Lakes: municipal and industrial water use, hydropower, commercial navigation, coastal, ecosystem and recreational boating. These experts conducted outreach where necessary to collect information from industry and local interests to ensure that the reported information was as fulsome as possible.

The conditions in 2017 were extraordinary across the Lake Ontario-St. Lawrence River system and, as a result, the ILOSLRB produced a report in June 2018 titled "Observed Conditions and Regulated Outflows in 2017" (ILOSLRB, 2018) that outlines in detail the causes of the record high water levels in 2017 on Lake Ontario and the St. Lawrence River, as well as the regulation of outflows by the board during the event. This GLAM report provides a summary of information on the effects of 2017 water level conditions on various interest categories and how this information will be used going forward. It also initiates preliminary water level simulations of alternative outflow management strategies. Key findings are provided to support both the ILSBC and ILOSLRB as well as guide long-term GLAM Committee efforts. Given the extreme conditions within the Lake Ontario-St. Lawrence River system, an additional set of Annexes (referred to as the Annex 1-Impact Assessment and Annex 2-Plan Review) has been prepared to provide further detail on the impacts of what occurred in 2017 across various sectors and regions in the Lake Ontario-St. Lawrence River system and implications for model improvements to support ongoing evaluation of the regulation plan.

2.0 The Great Lakes – St. Lawrence River System

The Great Lakes are a series of interconnected lakes shared between Canada and the United States. From west to east they are Superior, Michigan, Huron, Erie and Ontario. They span more than 1,200 kilometers (750 miles) and collectively cover an area of more than 244,000 km^2 (94,000 m^2). The lakes cover about 1/3 of the area in the Great Lakes basin (Figure 2-1) which has a total drainage area of 766,000 km^2 (296,000 m^2) and provides drinking water and water use to more than 30 million people. These vast inland freshwater seas are the largest surface freshwater system on Earth. Only the polar ice caps contain more fresh water. They contain 84% of North America's surface fresh water and about one fifth of the world's supply of surface fresh water (USEPA, n.d.)

Water flows from Lake Superior to Lakes Huron and Michigan, southward to Lake Erie, and finally northward to Lake Ontario and down the St. Lawrence River to the Atlantic Ocean. On average, a drop of water which finds its way into Lake Superior from runoff or rainfall takes more than two centuries to travel through the Great Lakes system and along the St. Lawrence River to the ocean. The travelling time is based on retention times or how long, on average, it takes for each of the lakes to replace its water with new water (Statistics Canada, 2010). The surfaces of Lakes Superior, Huron, Michigan and Erie are all close in elevation above sea level (Figure 2-2). Lakes Michigan and Huron are hydrologically considered one lake, as their surfaces are at the same elevation above sea level and are joined through the Straits of Mackinac. Lake Ontario is significantly lower, so the four upper lakes are commonly called the "upper Great Lakes" and will be referred to as such within this report. The upper Great Lakes include the four Great Lakes mentioned (Superior, Michigan, Huron and Erie), their drainage basins, and the connecting channels of the St. Marys River, the Straits of Mackinac, the St. Clair River system (including Lake St. Clair and the Detroit River) and the upper Niagara River above the Falls (Figure 2-1).

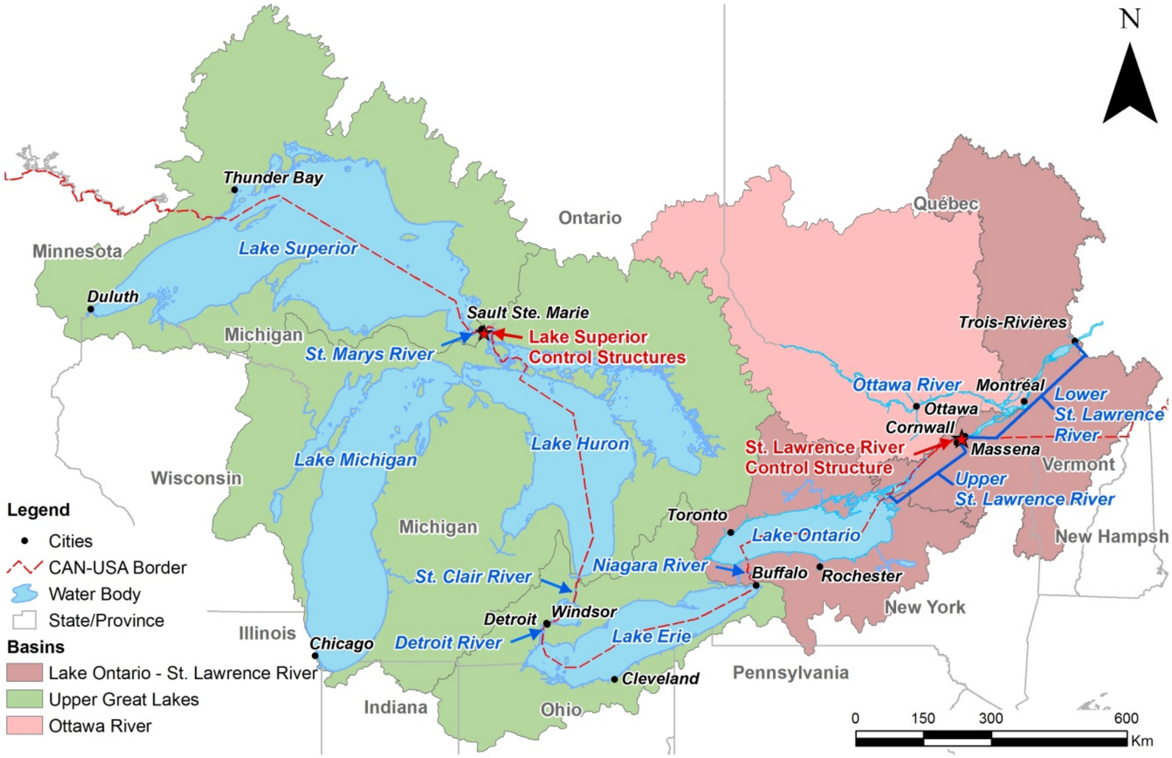


Figure 2-1: Great Lakes-St. Lawrence River system (Source: ECCC)

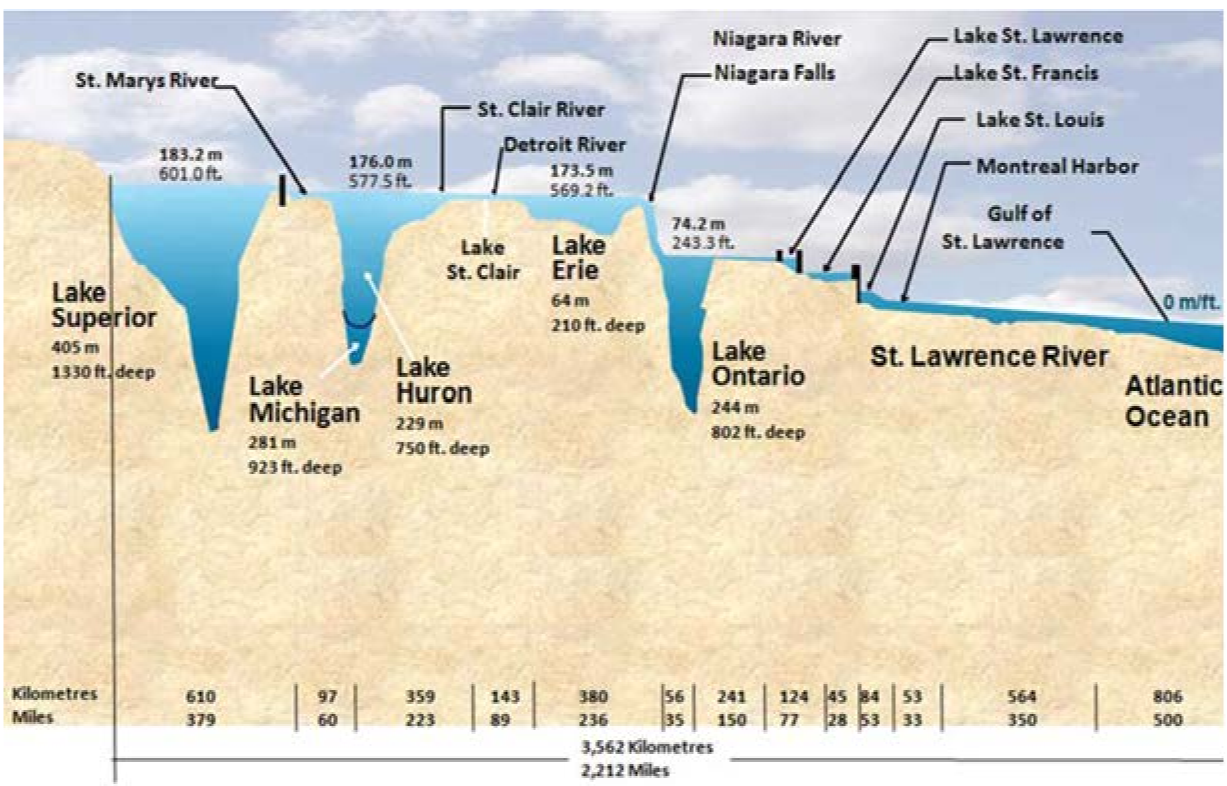


Figure 2-2: Water surface profile of the Great Lakes System (IGLD 1985) (Source: IUGLS, 2012)

The Lake Ontario – St. Lawrence River system covers the Niagara River below the Falls, the Welland Canal, Lake Ontario, the upper St. Lawrence River above the dam and the lower St. Lawrence River below the dam through to Trois-Rivières where the effects of the ocean tides become the dominant factor affecting water levels. The system also includes the vast amounts of water that enter into the St. Lawrence River from the Ottawa River basin below the dam in the Montreal area.

There are two locations on the Great Lakes-St. Lawrence River system where dams are used to manage outflows from one lake to another. The first is on the St. Marys River between the cities of Sault Ste. Marie, MI and Sault Ste. Marie, ON and controls the water flows from Lake Superior into Lake Huron. In the area known as the St. Marys Rapids, the St. Marys River falls approximately 6 meters (20 feet) in a distance of 1.2 kilometers (0.75 mile) (Figure 2-2). Since 1797, when the first lock was built to allow boats to bypass these rapids, various navigation and power structures have been erected along the river. Today, water is routed through a series of structures that stretch across the St. Marys River, including three hydropower plants, a series of navigation canals and locks, and a gated dam at the head of the rapids known as the Compensating Works. The release of water from Lake Superior has been regulated since the completion of the Compensating Works in 1921.

The second location where flow regulation occurs is on the St. Lawrence River at Cornwall, ON and Massena, NY. The St. Lawrence River hydropower project was approved by the IJC in 1952. This authorized the construction of the Moses-Saunders hydropower dam and Long Sault spillway dams at Cornwall, ON and Massena, NY, which together are used to control the outflow from Lake Ontario. The hydropower project included channel excavation to enlarge the river's flow capacity and also facilitated building the series of navigation locks and deepening of sections of the river channel for navigation as part of the St. Lawrence Seaway construction during the 1950s (Figure 2-1). The area immediately upstream of Moses-Saunders Dam is known as Lake St. Lawrence. Lake St. Lawrence was created when the Moses-Saunders Dam went into operation in 1958 and serves as a forebay for the dam. Large increases in outflows cause large and rapid drops in water levels on Lake St. Lawrence. Conversely, large reductions in outflows result in large and rapid water level rises on Lake St. Lawrence (ILOSLRB, 2018).

The IJC oversees the management of outflows from Lake Superior and Lake Ontario by the power companies that operate the dams on the St. Marys River and on the St. Lawrence River at Cornwall/Massena. The structures were built and are operated in accordance with the IJC Orders of Approval. Outflows are set according to IJC-approved regulation plans which are designed to meet the operating criteria contained in the Orders of Approval. A regulation plan is a set of rules and limits that specify how much water to release under differing water level and water supply conditions. It is important to note that ability to alter lake levels through the regulation plans is limited and is dominated by changes in water supplies, which are driven by weather.

As previously noted, the IJC established boards to regulate the outflows in accordance with the regulation plans. The ILSBC was established to regulate monthly outflows in accordance with the IJC's 1914 Order of Approval. Since 1978, the IJC has issued several supplements to the

1914 Order, with the most recent occurring in July of 2014. The current regulation plan, known as Plan 2012, was established by the 2014 Orders and was implemented in January 2015. Plan 2012 replaces the previous Plan 1977A that was in operation between 1990 and 2014. Plan 2012 does not result in significantly different levels from Plan 1977A in most cases, but provides a more robust plan, taking into account a broader possible range of water supplies, and is expected to provide fewer month-to-month changes in flow on the St. Marys River compared to the previous plan, along with a more natural flow relationship to Lake Superior levels (IUGLS, 2012).

The International St. Lawrence River Board of Control was originally established in 1952 and was renamed the ILOSLRB as part of the 2016 revision to the Orders of Approval. The board regulates weekly outflows to meet the conditions and criteria of the Order of Approval. It monitors water supplies, river ice conditions and levels of Lake Ontario and the St. Lawrence River through Trois-Rivières, which is the downstream limit of the influence of regulation on water levels. The previous regulation plan, which had been in place since 1963, was known as Plan 1958-D. Plan 2014, which became effective on January 7, 2017, prescribes a new set of rules that the board must ordinarily follow in setting the outflows from Lake Ontario through the St. Lawrence River. Plan 2014 was designed to provide more natural variation of water levels of Lake Ontario and the St. Lawrence River than would occur using the previous regulation plan, Plan 1958-D with deviation (Plan 1958-DD), which was found to have negatively impacted the environment (IJC, 2014). This effort to have more natural variability is considered critical for the restoration of ecosystem health in the system. Over the long-term, the plan is expected to continue to moderate extreme high and low levels, better maintain system-wide levels for navigation, frequently extend the recreational boating season in the upper St. Lawrence River and slightly increase hydropower production relative to Plan 1958-DD (IJC, 2014). For more information on the Lake Ontario-St. Lawrence River system and the regulation of outflows, please refer to the board report "Observed Conditions and Regulated Outflows in 2017" (ILOSLRB, 2018).

A partial structure also exists above Niagara Falls on the Niagara River, known as the Chippawa-Grass Island Pool (CGIP) Control Structure. This structure does not regulate the outflows of Lake Erie; rather, is it used for apportionment purposes for directing water to the power plants or over Niagara Falls in order to meet the objectives of an institutional agreement between Canada and the United States known as the Niagara River Treaty of 1950. The purpose of the Treaty is to ensure water required for domestic, sanitary and navigation purposes is available, while preserving the scenic beauty of Niagara Falls and allowing for the diversion of water for hydropower purposes. Operation of this structure is the responsibility of the power entities, Ontario Power Generation (OPG) and New York Power Authority (NYPA), supervised by the IJC's INBC (http://www.ijc.org/en_/inbc).

3.0 The Regulation Plans

This section provides additional detail regarding the regulation plans for Lake Superior and Lake Ontario outflows. For a more detailed description of Plan 2014 and how it functions, please refer to the ILOSLRB report "Observed Conditions and Regulated Outflows in 2017" (ILOSLRB, 2018). It should be noted that, for both plans, their ability to alter lake levels in response to short-term variances of regulated outflows is very limited as actual water levels in Lakes Superior and Ontario are dominated by water supplies. The challenge is to balance the objectives of the regulation plans given the limitations of existing control structures, the natural hydrologic systems and the unpredictability of weather events.

3.1 Plan 2012 for Lake Superior outflows

Plan 2012 was the recommended plan identified during the IUGLS. Plan 2012 is a set of rules for how much flow to let out of Lake Superior into Lake Michigan-Huron through the St. Marys River under varying conditions. The basic objectives and limits for the regulation plan are set out in the IJC's 1914 Order of Approval which acknowledges the needs of various interest groups on Lake Superior and the St. Marys River including navigation, hydropower and riparian owners. Since 1978, the IJC has issued several additions to the original Order and in July 2014, the IJC issued a new Supplementary Order of Approval that enabled the ILSBC to adopt Regulation Plan 2012 as the means for regulating Lake Superior outflows henceforth.

Plan 2012 was developed to try to maintain much of the natural variability in lake levels that existed using Plan 1977A, while recognizing the capacities of the current structures at Sault Ste. Marie, winter flow restrictions to reduce ice jams, and a broader range of possible water supplies in the lakes. It also retains the balancing principle of water levels on Lake Superior and Lake Michigan-Huron of the previous plan (1977A). Plan 2012 begins with more natural flows, meaning that when Lake Superior water supplies trend above normal, lake releases are increased and as supplies trend below normal, lake releases are decreased. The Plan then applies a balancing principle which adjusts the outflows depending on the difference of each lake's level from seasonal target levels based on average conditions. The Plan sets limits to respect physical and operational limits. For example, the November maximum is 3260 m^3/s (115,120 ft^3/s), except if Lake Superior is greater than 183.9 m (603.3 ft). Plan 2012 also determines the flow to be released through the rapids and multi-use allocation.

The overall objectives of Plan 2012 are to improve existing benefits to stakeholders throughout the upper Great Lakes system relative to Plan 1977A, balance Lake Superior and Lake Michigan-Huron water levels relative to their long-term average conditions and follow more natural month-to-month outflow patterns in the St. Marys River. Additionally, Plan 2012 is designed to avoid infrequent but serious adverse effects on spawning habitat of lake sturgeon and provide smaller month-to-month flow changes in the St. Marys River.

In most cases, it is anticipated that outflows will be set as is prescribed by Plan 2012. However, as authorized by 2014 Order of Approval, the board may deviate from the plan in certain circumstances or may ask the IJC to approve other deviations from the plan that the board believes are beneficial.

3.2 Plan 2014 for Lake Ontario outflows

The objective of Plan 2014 release rules, as described in the IJC's report to governments on Plan 2014 (IJC, 2014) is to return the Lake Ontario-St. Lawrence River system to a more natural hydrological regime, while limiting impacts to other interests. The 1956 Orders' criteria under Plan 1958-D did not address contemporary considerations such as environmental and recreational boating needs and were designed using historically observed water supplies up to 1954, which consisted of a shorter period of record and did not include several more extreme supply sequences occurring since its development (ILOSLRB, 2018). Regulation of outflows with Plan 1958-D with deviations, as practiced beginning in the 1960s, was found by the Lake Ontario-St. Lawrence River Study Board to have harmed the environment (LOSLRS, 2006). After 14 years of scientific study, extensive public engagement and consideration of many alternative plans, the Commission concluded that Plan 2014 offered the best opportunity to reverse some of the harm to the environment while balancing upstream and downstream uses and minimizing possible increased damage to shoreline protection structures (IJC, 2014). The IJC issued an updated Supplementary Order of Approval on December 8, 2016 after obtaining the concurrence of the governments of Canada and the United States. This Supplementary Order replaces the 1952 and 1956 Orders and includes revised and additional regulation criteria based on the Commission's findings and the performance of Plan 2014 release rules with 1900 to 2008 hydrologic conditions.

Lake releases for Plan 2014 begin with a sliding rule curve based on the pre-project stage-discharge relationship such that as Lake Ontario levels or water supplies increase, outflows increase and as water levels or supplies decrease, outflows decrease. The Plan then uses a series of flow "limits" to address specific conditions. Table 3-1 provides a very brief summary of the various limits that apply. For more detail, please refer to the "Observed Conditions and Regulated Outflows in 2017" report (ILOSLRB, 2018).

Table 3-1: Plan 2014 flow limits (Source: IJC, 2014)

Limit	Description
"F" Limit	multi-tier rule that defines the maximum flow to limit flooding on Lake Saint-Louis and near Montreal in consideration of the level of Lake Ontario
"I" Limit	also referred to as the Ice limit; limits the maximum flows for ice formation and stability during ice cover formation
"J" Limit	defines the maximum change in flow from one week to the next unless another limit takes precedence
"L" Limit	defines the maximum outflow that can be released from Lake Ontario while still maintaining adequate levels and safe velocities for navigation in the international section of the St. Lawrence River
"M" Limit	defines the minimum limit flows to balance low levels of Lake Ontario and Lake Saint-Louis primarily for Seaway navigation interests

In addition to the plan limits, criterion H14 of the 2016 Orders of Approval authorizes the board to deviate from the rules of Plan 2014 when Lake Ontario water levels are extremely high or low. The IJC's December 2016 Directive on Operational Adjustments, Deviations and Extreme Conditions, defines extreme high and low levels of Lake Ontario to be used as thresholds to authorize major deviations from the Plan. The ILOSLRB is required to follow the regulation plan when levels are within these triggers. However, Plan 2014 allows for minor deviations to respond to short-term needs on the river (e.g. short-term hydropower maintenance, assistance to commercial vessels due to unanticipated low levels, assistance for boat haul-out) that are limited to +/- 2 cm (0.79 in) impact on Lake Ontario. The directive also allows for operational adjustments when actual within-week conditions differ significantly from the forecasted conditions used to calculate the regulation plan flow. For more information on deviations and operational adjustments, please refer to the IJC's December 2016 Directive on Operational Adjustments, Deviations and Extreme Conditions.

4.0 Summary of 2017 Hydroclimate Conditions and Observed Water Levels and Flows

Water levels and outflow regulation plans are influenced most predominantly by the hydroclimate conditions of the basin and whether it is wet or dry, cold or warm over any given year and over longer-term patterns. The conditions observed across the Great Lakes – St.

Lawrence River basin in 2017 included higher than average seasonal temperature and precipitation. The majority of the region experienced a wet spring with persistent heavy rain and snowfall, causing a pronounced rise in Great Lakes levels across the system. These conditions were most severe in the Lake Ontario-St. Lawrence River basin, which experienced a relatively wet winter followed by record rainfall in the spring, resulting in record water levels and flows.

The ILOSLRB's May 2018 report ("Observed Conditions and Regulated Outflows in 2017") makes clear that the weather and water supply conditions in 2017 dictated the outflows that were released during 2017 and limited the board's ability to regulate water levels upstream and downstream of the Moses-Saunders dam. The board report provides a detailed explanation of why Lake Ontario reached record high levels in 2017, including a comprehensive description of the 2017 hydroclimate conditions and their role in causing the record levels that occurred.

Hydroclimate is defined as the study of the influence of climate upon the waters of the land including the energy and moisture exchanges between the atmosphere and the earth's surface. This report also addresses the 2017 hydroclimate conditions, but not only has a different scope (i.e., it covers all of the Great Lakes) but a somewhat different purpose than the board report. While both reports consider the interaction of regulation rules and weather on water levels, in this report the focus of the GLAM Committee is to consider how 2017 conditions might inform their IJC directive to assess whether future water supplies will be different from those used to test the current management of levels and flows. By examining what occurred and searching for clues about how to improve future outcomes under similarly severe conditions, the GLAM Committee asks: "What can be learned from the 2017 hydroclimate conditions that could influence future plan evaluations and help improve the Lake Superior and Lake Ontario regulation plans?"

4.1 Overview of the 2017 Great Lakes hydroclimate

This section provides a general overview of weather, water supply, water levels and flow conditions in 2017 across the entire Great Lakes-St. Lawrence River system, in order to provide the context for all subsequent sections of this report. It includes a general overview for the entire basin and then an assessment of the hydroclimate for the upper Great Lakes and for the Lake Ontario-St. Lawrence River portion of the system.

4.1.1 Overview for the Great Lakes

It was a wet year overall for the Great Lakes (Figure 4-1) with generally near to above average precipitation across the basin, and most of the areas north of the lakes seeing the 2017 precipitation totals 10 to 50% greater than average. Most of the Great Lakes region experienced a wet spring with persistent heavy rain and snowfall; in particular, portions of the province of Ontario experienced more than twice the average amount of precipitation in April and May. Fall was wet in the central Great Lakes, with the state of Michigan experiencing record October rainfall.

The temperature was at least 0.5ºC above the annual average for most of the Great Lakes region, with some areas over 1.0ºC above average (Figure 4-2). There were also a few areas around the west end of Lake Superior and the south end of Lake Michigan that were closer to average overall for 2017. As a result of these higher than average temperatures, especially during the cold season months (almost all of the basin experienced near-record to record-breaking high temperatures in January and February), snow accumulations and snow cover duration were less than normal. Fall warm spells in September and October set temperature records in some eastern areas of the region.

Winter and fall warm spells led to record warm temperatures in parts of the basin and the Great Lakes maximum ice cover for the year was 35% below the long-term average, at just 19.4% areal coverage (National Oceanic and Atmospheric Administration (NOAA) and Environment and Climate Change Canada (ECCC), 2018) (NOAA: GLERL, n.d.). More information on climate trends and impacts for the entire Great Lakes Basin can be found in the Annual Climate Trends and Impacts Summary for the Great Lakes Basin produced by NOAA and ECCC.

The primary driver of water levels across the Great Lakes-St. Lawrence River basin is the amount of water coming into the system, referred to as *water supplies*. Total water supplies to the lakes, termed Net Total Supplies (NTS), is the combination of the water that is entering from the upstream lake (inflow) as well as water entering from the lake's basin itself, known as Net Basin Supplies (NBS). NBS is the total of the precipitation that falls directly on the lake surface and the runoff that enters the lake through tributaries and the surrounding drainage basin, minus the evaporation that comes off the lake. The NBS is computed in two different ways: the "component" method uses measurements and modelled estimates of the three main components of NBS, i.e., precipitation, runoff and evaporation; whereas the "residual" method calculates the NBS as the residual water necessary to account for the change in storage (i.e., monthly lake level change) and the measured amount of inflow and outflow from the lake via their connecting channels.

Figure 4-3 compares 2017 to average component NBS while Figure 4-4 shows 2016, 2017 and average monthly residual NBS. Runoff into the Great Lakes was significantly higher than

Precipitation Anomaly (Annual)

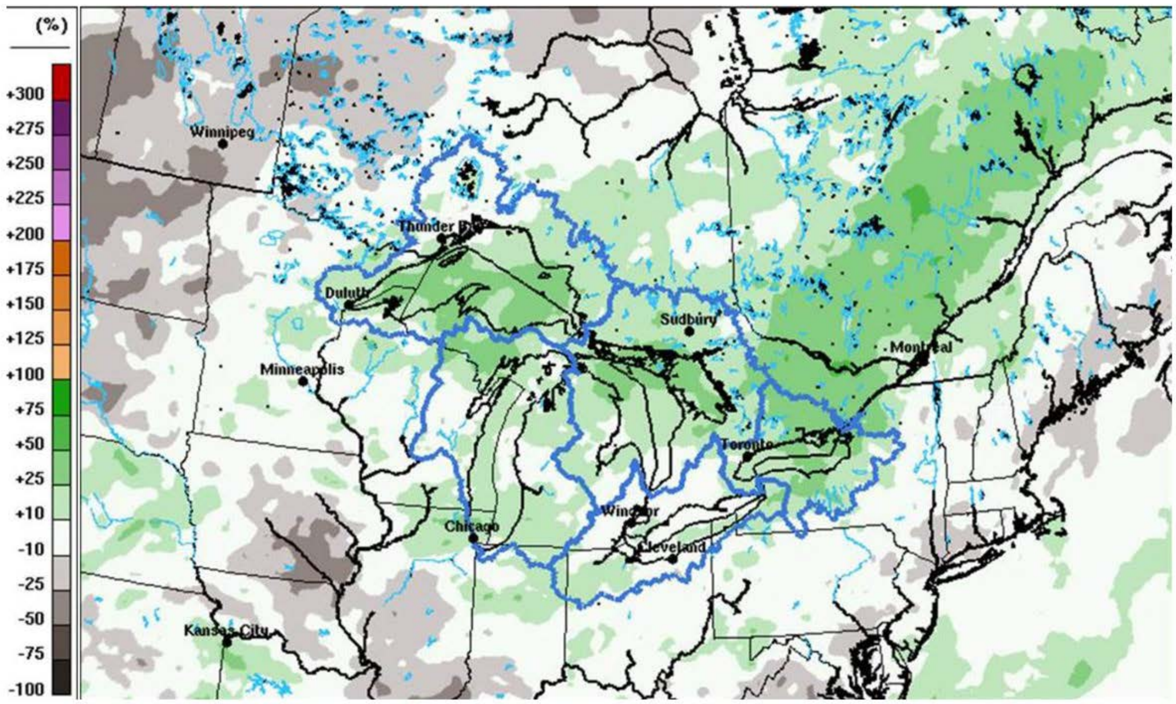


Figure 4-1: Map displaying annual anomalies for total precipitation accumulation in the Great Lakes region. Anomalies for precipitation are % departure from the 2002-2016 mean. Data for precipitation data is a merged dataset containing ECCC model and Numerical Weather Prediction (NWP) model data. Figure created by ECCC.

Temperature Anomaly (Annual)

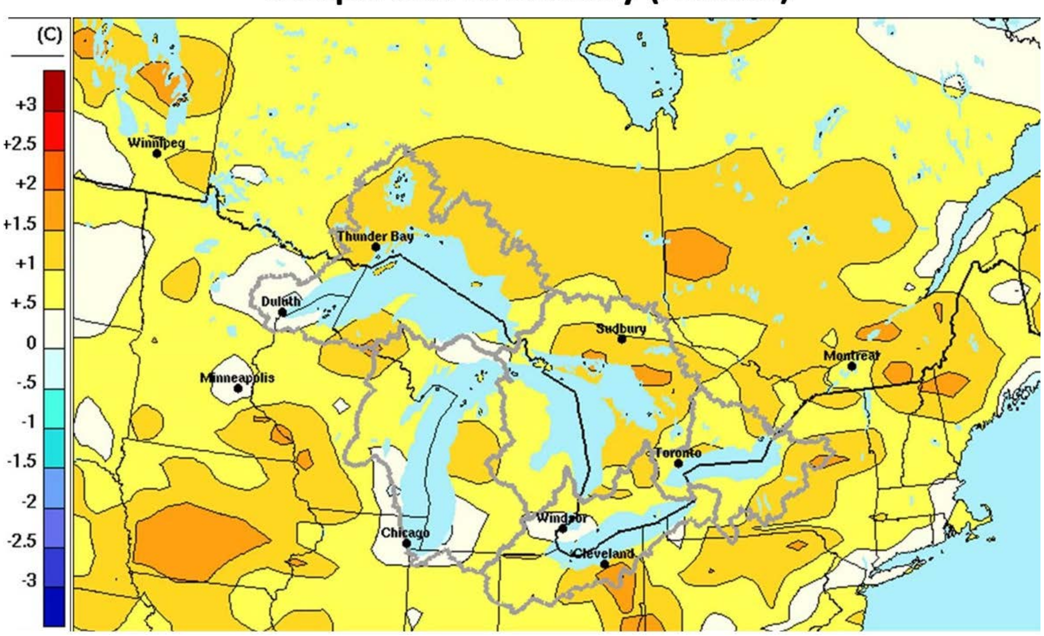


Figure 4-2: Map displaying annual anomalies for temperature in the Great Lakes region. Anomalies for temperature are departures from the 1981-2010 mean. Data for temperature are from ECCC model output. Figure created by ECCC.

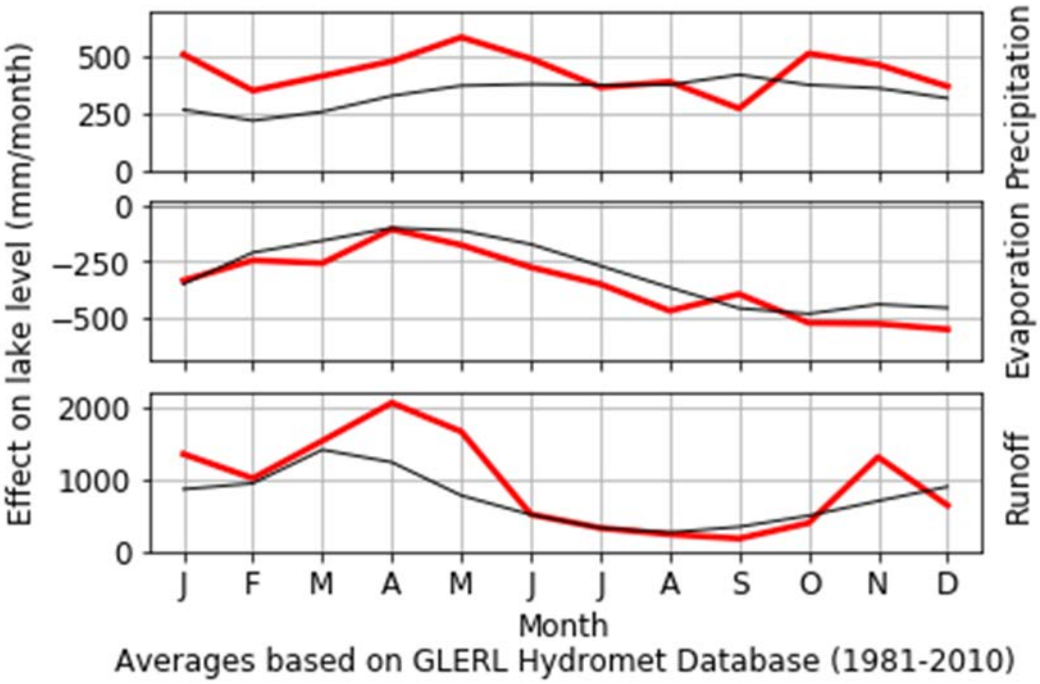


Figure 4-3: Great Lakes Basin NBS components from the GLERL Hydromet Database, red - 2017, black - 1981-2010 average. (Source: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 2017)

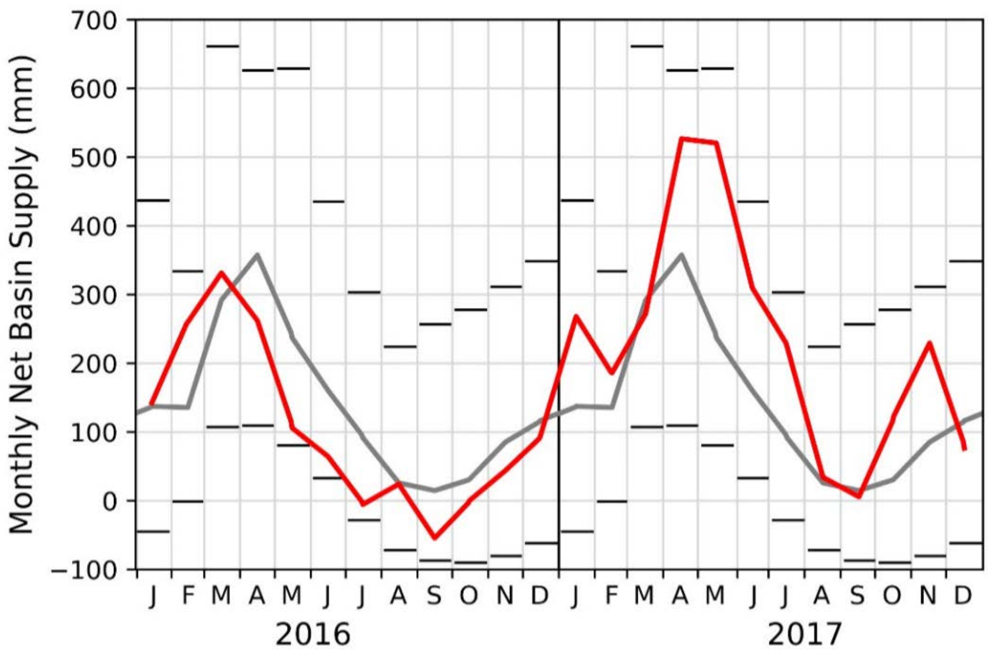


Figure 4-4: Great Lakes Basin residual NBS– (red) compared to the 1981-2010 average (black) for 2016 and 2017. (Source: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 2017)

average in the first half of 2017, and monthly precipitation was average or higher over the Great Lakes in 2017, except for the month of September. Evaporation over the lakes was fairly close to average throughout the year, and runoff into the lakes was much higher than average in March through June and again in November. The overall NBS for the entire Great Lakes basin was wet for the entire year of 2017 and was dominated by what occurred over the Lake Ontario basin in 2017.

Water levels on the upper Great Lakes, including Lake Superior, Lakes Michigan-Huron and Lake Erie all began 2017 well above long-term average levels, while Lake Ontario started the year very near its long-term monthly average. With the above average precipitation in the basin, water levels in the five Great Lakes remained above average throughout the year, continuing a similar trend during the past several years for the upper Great Lakes. Water levels are based on lakewide averages and are discussed in 4.1.2 and 4.1.3 below. Note that lake-wide average water levels are computed from a network of stations located around the lakes. Water levels at individual locations can vary depending on weather conditions, including winds, barometric pressure, storm surge and wave heights

4.1.2 Hydroclimate highlights for the Upper Great Lakes

As discussed in the previous section, it was generally wet over the Great Lakes basin in 2017, including the upper Great Lakes (Superior, Michigan-Huron and Erie).

It was generally wet on Lake Superior throughout the year, with all months except for July recording above average precipitation. Of particular note was that the precipitation on Lake Superior was almost twice the average during both January and December of 2017. The evaporation over the lake was generally higher than average both at the beginning and end of the year, while runoff was either close to the average or slightly above for the entire year. Not surprisingly, given the generally above-average precipitation and runoff, the residual NBS was above average for most of the year, with only March and November coming in below average (Figure 4-5).

Precipitation over Lake Michigan/Huron was close to its average for most months of the year, with the exceptions of April, June and October, which were well above average, and September, which was the only month that recorded well below average precipitation (Figure 4-6). September was actually the fifth driest on record for that month, but this was followed by its wettest October on record. The lake evaporation was generally a bit higher than average while runoff was very close to average the entire year. The residual NBS followed the precipitation with most of the year being above average and only falling slightly below average during the last few months of the year.

On Lake Erie, the precipitation was generally close to average with only May being well above average and September well below (Figure 4-7). A storm system on November 5 produced 72 mm (2.85 in) of precipitation in Erie, PA, a record for daily November precipitation for the location (NOAA and ECCC (2017)). The lake evaporation was close to average most of the year

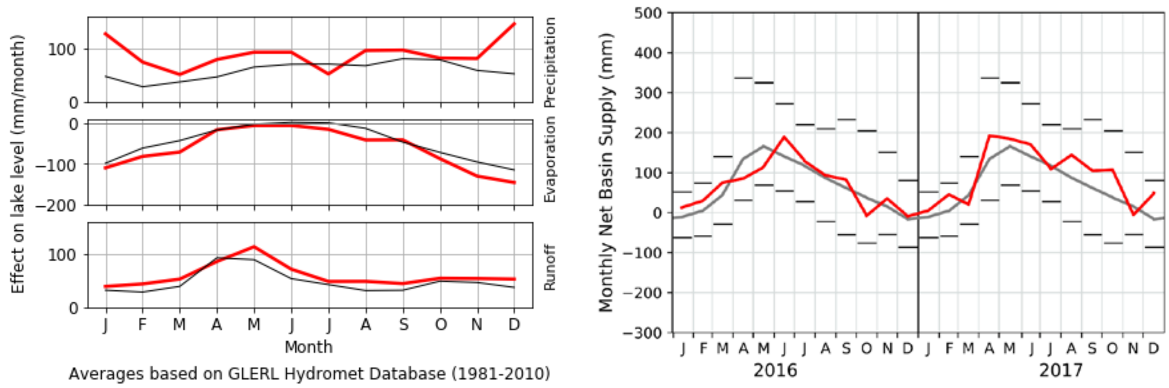


Figure 4-5: Lake Superior 2017 NBS components (left) and residual NBS for 2016-2017 (right)

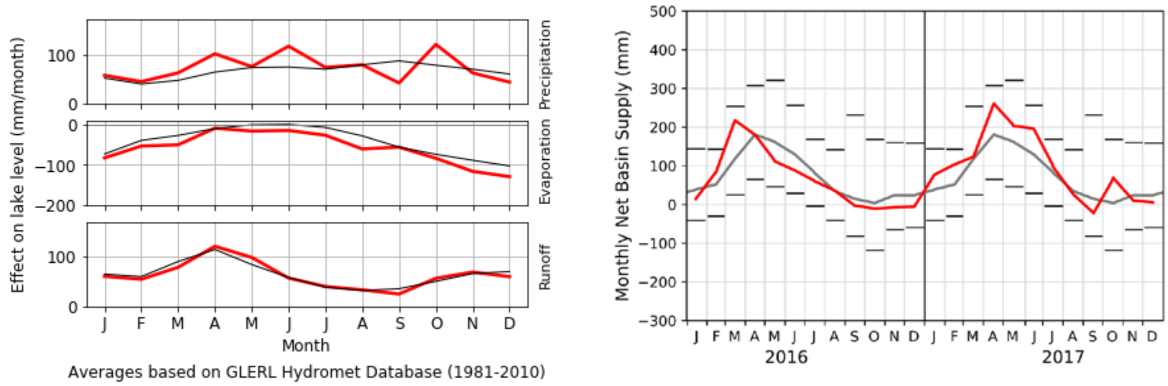


Figure 4-6: Lake Michigan-Huron 2017 NBS components (left) and residual NBS for 2016-2017 (right)

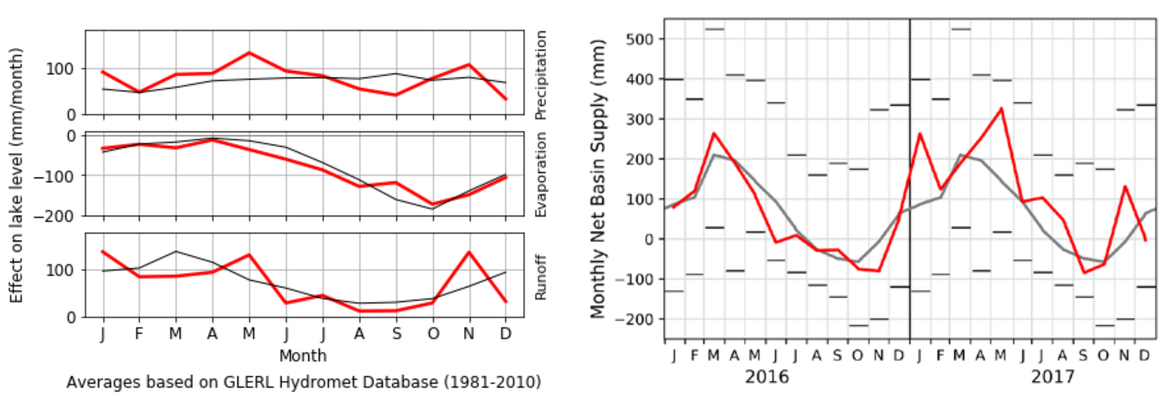


Figure 4-7: Lake Erie 2017 NBS components (left) and residual NBS for 2016-2017 (right)

NOTE: NBS is the total of the precipitation that falls directly on the lake surface and the runoff that enters the lake through tributaries and the surrounding drainage basin, minus the evaporation that comes off the lake. The NBS is computed in two different ways: the "component" method uses measurements and modelled estimates of the three main components of NBS, i.e., precipitation, runoff and evaporation; whereas the "residual" method calculates the NBS as the residual water necessary to account for the change in storage (i.e., monthly lake level change) and the measured amount of inflow and outflow from the lake via their connecting channels.

except for a below average month in September. The runoff was near or slightly below average in most months, but May and November were well above average, while December was well below. The residual NBS showed significantly above average values during the spring, peaking in May, and from there it decreased, becoming below average in September before recovering in November.

As a result of their levels at the start of the year and overall wet conditions throughout, all the upper Great Lakes experienced well above average water levels in 2017 (Figure 4-8).

After starting 2017 above average, Lake Superior saw a greater than average rise in water levels from April through October, leading to water levels near the recorded monthly maximums set in 1985 from June to December. In October, Lake Superior's monthly level of 183.81 m (603.05 ft) was just 10 cm (3.9 in) below the highest water level recorded in any month on record in October 1985. By the end of December, the water levels had gone down, resulting in an end of year water level that was 18 cm (7.1 in) higher than when it began 2017.

Water levels started and remained well above average on Lake Michigan-Huron throughout the year. Due primarily to high precipitation in April and June, the lake recorded a higher than average rise from April through July. After the summer, the lake level experienced close to the typical seasonal decline and ended the year 26 cm (10.2 in) higher than it began the year.

Overall, above average NBS on Lake Erie, particularly in January and May, lead to an above average rise in water levels in the spring. The lake came within 15 cm (5.9 in) of its 1986 monthly record high level for May and within 21 cm (8.2 in) of the highest recorded level on Lake Erie set in June 1986 of 175.04 m (574.3 ft). The lake had a pretty typical seasonal decline during the summer and fall and the lake was 18 cm (7.1 in) higher at the end of the year compared to where it started in 2017.

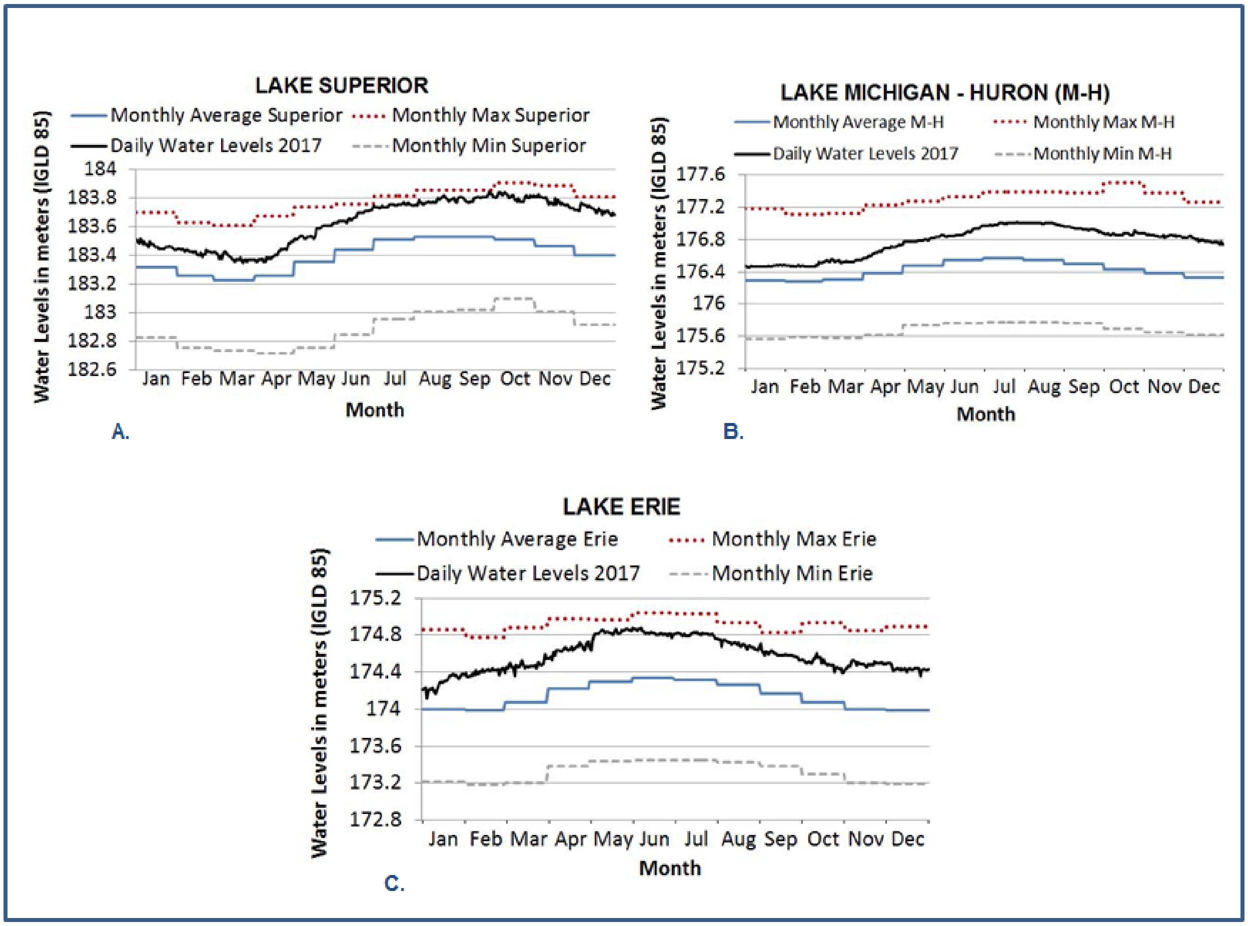


Figure 4-8: Maximum and Average 1918-2017 Monthly Water Levels and Daily Average Water Levels from 2017 for Lake Superior (A), Lake Michigan-Huron (B), and Lake Erie (C). (Source: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 2017)

In terms of temperatures, January and February were unusually warm across the upper Great Lakes basin. The following spring and summer months were closer to normal, but starting again in autumn, temperatures were generally unseasonably warm across the basin in September and October. For example, Chicago experienced seven consecutive days with record breaking warm temperatures up to 35ºC (95ºF) from September 20-26. Later in November, record cold temperatures were set in many parts of southern Ontario, New York and Pennsylvania.

A strong wind event on October 24 led to straight-line-wind damage and high waves along the southern coastline of Lake Superior. Wind gusts as high as 124 kph (77 mph) resulted in downed trees and power lines leading to road closures and widespread power outages. A wave up to 9.1 m (30 ft) in height was also reported during this event, which is the highest ever recorded on the lake (NOAA: National Weather Service, 2017).

Snow Water Equivalent (SWE) describes the equivalent amount of liquid water stored in the snow pack. It indicates the water column that would theoretically result should the whole snow pack melt instantaneously. Not all basin snowmelt makes it directly to the Great Lakes but the amount that does is captured as part of the runoff component discussed earlier in this section.

Based on data provided by the Snow Data Assimilation System (SNODAS), during the winter of 2016-17, both Lake Superior and Lake Huron had a pretty typical sequence of SWE compared to the 2010-2016 average (Figure 4-9A and B)). Lake Michigan started out the winter season with higher SWE, but showed a steady decline starting around the beginning of 2017 (Figure 4-9C). The early fall of 2016 saw a dramatic accumulation of snow in Lake Erie to well above the average value, but then quickly declined and remained low for the rest of the season (Figure 4-9D).

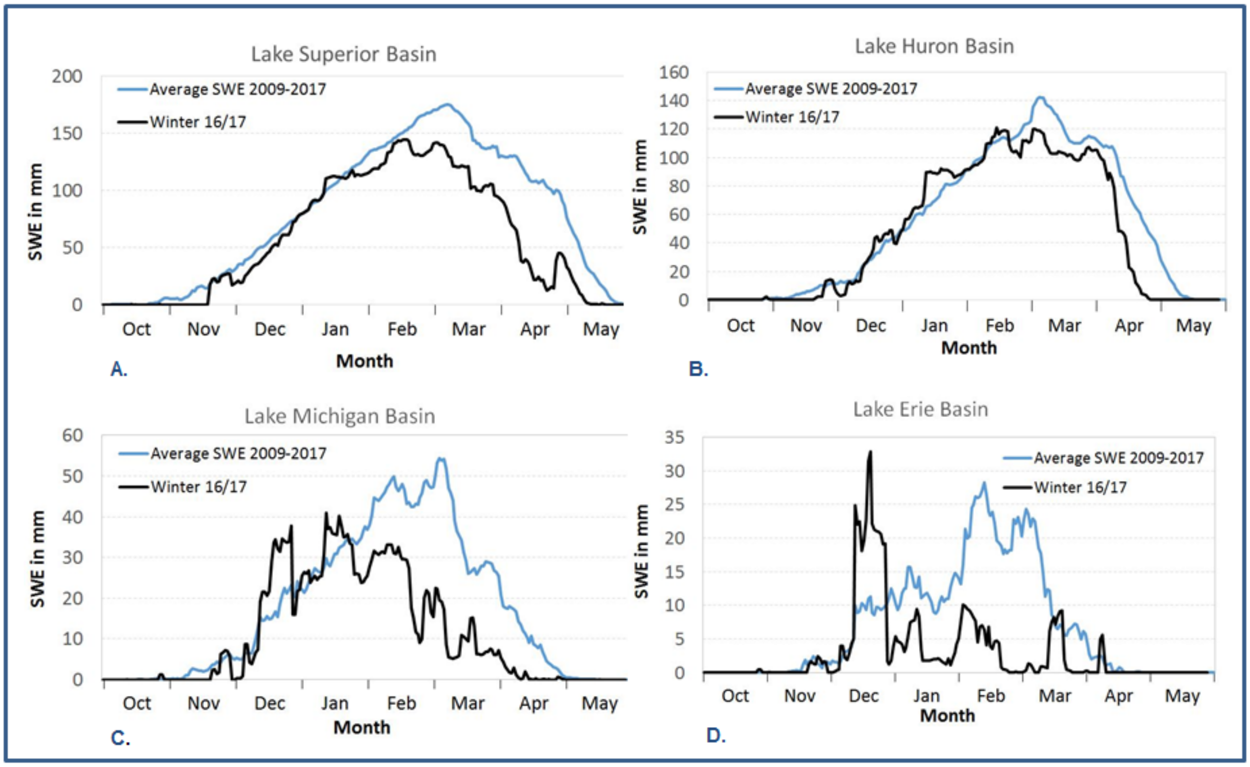


Figure 4-9: SWE from the Snow Data Assimilation System (SNODAS) for each of the upper Great Lakes

4.1.3 Hydroclimate highlights for Lake Ontario – St. Lawrence River

The Lake Ontario – St. Lawrence River experienced perhaps the most extreme hydroclimate conditions recorded in the basin in over 100 years during 2017, as generally wet conditions from January through March were followed by two of the wettest months ever recorded in April and May, raising water levels throughout the system and culminating in new record highs (Figure 4-10).

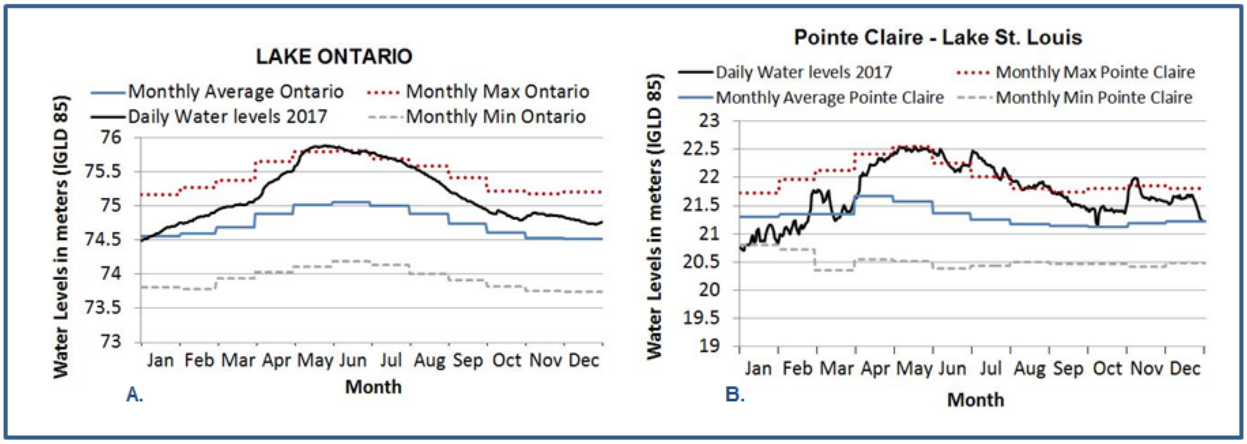


Figure 4-10: Maximum and Average 1918-2017 Monthly Water Levels and Daily Average Water Levels from 2017 for Lake Ontario (A) (Source: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 2017) and the St. Lawrence River at Point Claire on Lake Saint-Louis near Montreal, QC (B) (Source: Government of Canada).

As fully documented in the board's report, the most significant aspects of this event began in April, as a series of large, heavy storms passed through the region throughout the month, quickly raising water levels of Lake Ontario and the St. Lawrence River. These storms also saturated the land surface and raised water levels of inland rivers and tributaries, the most significant of which is the large Ottawa River basin, which feeds into the St. Lawrence River near Montreal. The wet conditions continued and culminated in two extremely large and slow-moving systems that passed through the region back-to-back, the first from April 29 to May 1 and the second from May 4-8. Ottawa River flows set record highs on May 8, and combined with high inflows from Lake Erie, the result was an exceptional volume of water entering the Lake Ontario - St. Lawrence River system during this period.

The water level on Lake Ontario started the year very close to its average. As the first three months of the year were generally wet, the lake level rose more than average, and began April around 30 cm (11.8 in) above the average. The extreme water supplies in the spring contributed to the record-breaking rise in Lake Ontario during the months of April and May, and the lake peaked at 75.88 m (248.95 ft) in late May, the highest level ever recorded on the lake since records began in 1918. Levels remained high through the summer, but as conditions became relatively drier and high outflows were released, the level of the lake fell dramatically in the subsequent months, breaking record declines in August and September 2017. The level of Lake Ontario was about 25 cm (9.8 in) higher than average at the beginning of October and stayed at about this level relative to average until the end of the year.

Water levels on the St. Lawrence River as measured at Point Claire on Lake Saint-Louis (Figure 4-10 B) began the year below average, continuing a trend that had begun in the summer of 2016. In February, water levels edged upward with a sudden and pronounced rise following a significant thaw event marked by thunderstorms and rainfall. Levels varied through March responding to flows, weather and ice conditions but rose quickly throughout the first three weeks of April following another thaw event again marked by thunderstorms and rainfall. Water levels rose throughout the first third of May as Ottawa River outflows rose rapidly due to heavy rainfall. Levels generally fell in June as the Ottawa River outflows declined but rose again following heavy rainfalls in the latter half of the month. Lake Saint-Louis levels in June, July and August set new record high monthly means. Water levels began to decline through the fall but remained above average. As they neared average in October, another storm hit and levels on the St. Lawrence River rose rapidly towards the end of the month. By the end of the year, Lake Saint-Louis declined to near-average levels.

The main trend of the extraordinary weather patterns experienced in late April and early May 2017 were what is referred to as a high-amplitude or meridional flow pattern (Figure 4-11), which are characterized by deep pressure ridges and troughs that tend to direct the general air flow pattern from north-to-south or from south-to-north. This type of pattern can result in storms following a path directly over the Great Lakes after obtaining moisture from the Gulf of Mexico, and this occurred in late April and early May 2017. These storm systems are often slow moving and thus have lots of time to release their moisture over an area, which adds to the amount of precipitation they deliver. In late April and early May 2017, this effect was augmented by an area of high pressure over the east coast of North America, which caused the moisture-laden systems to slow down even more and resulted in well above-normal precipitation totals across Lake Ontario, the St. Lawrence and Ottawa Rivers (Figure 4-12).

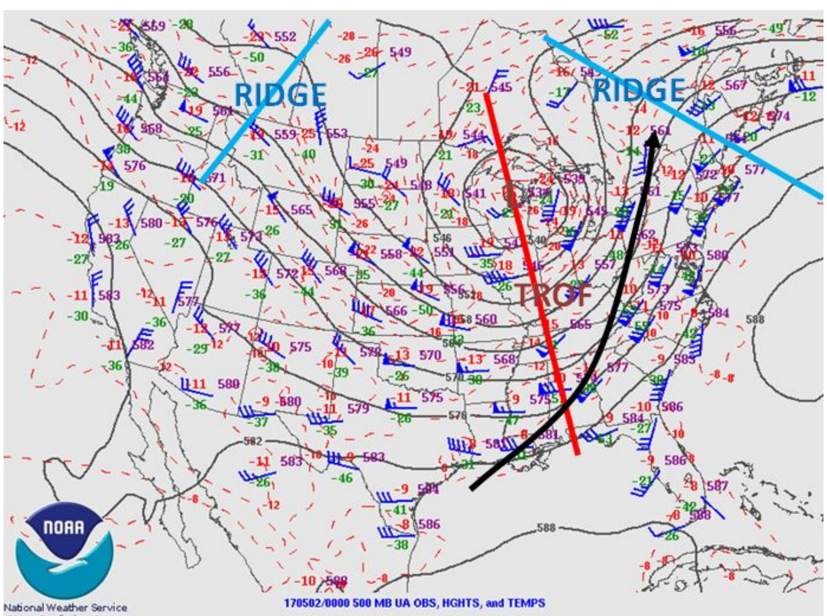


Figure 4-11: Analysis of 00z (8 p.m. EDT) May 2nd, 2017 500mb chart courtesy of the National Weather Service Storm Prediction Centre. Ridge lines have been drawn in blue, and troughs in red. The general steering flow from the Gulf of Mexico has been depicted by the black arrow. (Source: NOAA, Storm Prediction Centre, 2017)

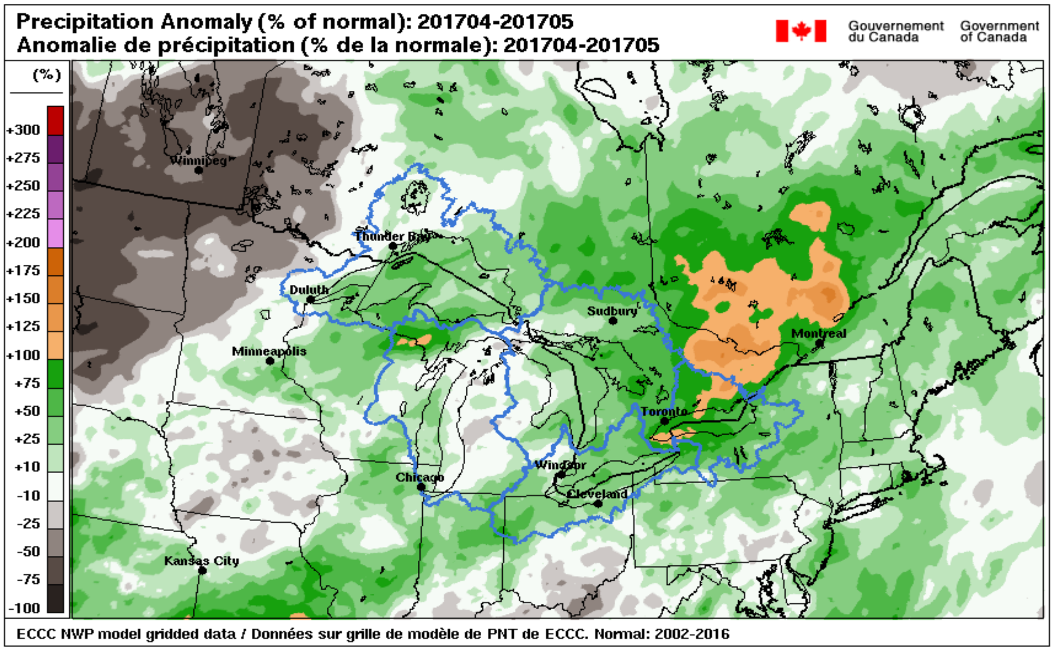


Figure 4-12: Anomaly for total precipitation accumulation in April and May 2017 in the Great Lakes region based on % departure from the 2002-2016 mean. Precipitation data are a merged dataset containing ECCC model and Numerical Weather Prediction (NWP) model data. (Source: ECCC – Meteorological Service of Canada)

After the wet spring, the rest of the summer and early fall saw closer to average precipitation on Lake Ontario. However, another extremely wet month came in October when the lake saw almost as much precipitation as it did during May. A particularly strong storm late that month helped maintain high runoff conditions into November.

In 2017, fluctuating temperatures during the winter months influenced Lake Ontario outflows and water levels primarily due to their role in creating unique ice conditions in the St. Lawrence River. January and February were much warmer than average, with record-breaking warm temperatures in February across much of the Great Lakes basin. This was followed by much colder temperatures in March, all of which contributed to an unprecedented freeze-thaw cycle, with an ice cover forming and then melting five times on the St. Lawrence River. As explained in the board's report (ILOSLRB, 2018), these variable ice conditions required outflows to be nearly continuously adjusted to avoid disturbing the fragile ice cover and potentially causing it to collapse and create ice jams.

The influence of wind and waves can, of course, greatly increase the problems associated with high water levels. Depending on the direction and strength of the wind, waves can build up over a long fetch on large lakes such as Lake Ontario. Both wind speed and wave height, which are tightly correlated, are greatly dependent on local conditions; however, generally speaking, the highest wind speeds tend to occur in the spring and fall.

To get an idea of wind conditions on Lake Ontario during the spring of April and May 2017, when lake levels were approaching their peak and a number of wind-related high water events were also noted, data from a buoy located off the north coast of Lake Ontario near Prince Edward Point (Lat 43.79N Long 76.87W) were examined. Based on these data, the average and maximum wind speeds during April and May were typical when compared to the historical record of this station that goes back to 1992. The measured maximum wave heights recorded at this buoy during April and May were 1.24 m (4.07 ft) and 1.56 m (5.12 ft), respectively. In the historical record, the maximum wave height for April averages 1.9 m (6.23 ft) and for May it averages 2.4 m (7.87 ft). There is nothing in this data record that indicates there was anything unusual about the wind speed or wave height during these two months of the year at this location. Nevertheless, with the record high water levels, even these relatively normal wind and wave conditions and storm surge (e.g. April 30, 2017) were an important contributor to shoreline impacts as discussed in Section 5.

In the Lake Ontario basin, data from the US Army Corps of Engineers (USACE) indicates that the daily SWE value was a little higher at the beginning of February than the 2009 to 2017 average for that time of year (Figure 4-13). However, the warm temperatures during February resulted in a dramatic drop in the SWE. It recovered somewhat during March but was then followed by the typical late season melt.

In the Ottawa River basin, the SWE in the southern half of the basin was slightly below average at the beginning of April, while in the northern half it was above average, although values were well below what had been seen in the previous year.

Looking specifically at the NBS components for Lake Ontario, the story was dominated by the very wet spring (Figure 4-14). The precipitation on the lake was double the average during the months of May and October and only significantly below average during September. The lake evaporation was close to average for the entire year. The runoff into the lake rebounded from a slightly below average start to well over double the average amount during May. It then gradually decreased over the summer before jumping well above average during November.

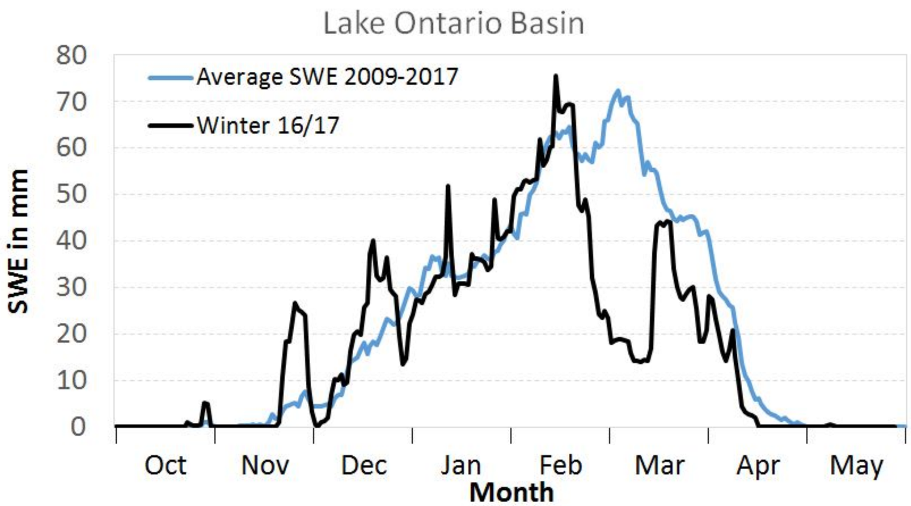


Figure 4-13: Lake Ontario SWE from the Snow Data Assimilation System (SNODAS)

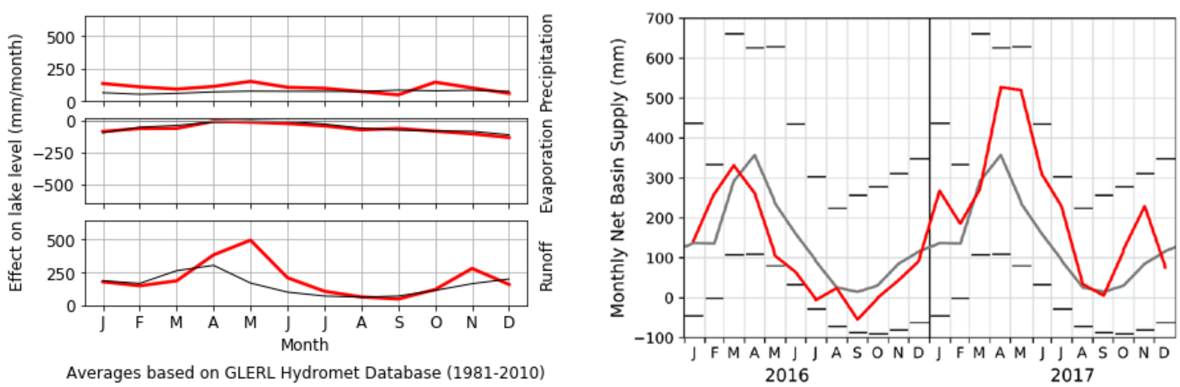


Figure 4-14: Lake Ontario 2017 NBS components (left) and residual NBS for 2016-2017 (right)

NOTE: NBS is the total of the precipitation that falls directly on the lake surface and the runoff that enters the lake through tributaries and the surrounding drainage basin, minus the evaporation that comes off the lake. The NBS is computed in two different ways: the "component" method uses measurements and modelled estimates of the three main components of NBS, i.e., precipitation, runoff and evaporation; whereas the "residual" method calculates the NBS as the residual water necessary to account for the change in storage (i.e., monthly lake level change) and the measured amount of inflow and outflow from the lake via their connecting channels.

4.2 Could the hydroclimate conditions of 2017 have been predicted?

Total water supplies to the Lake Ontario and Ottawa River basins are a primary driver of water level changes in the system and as a result, represent an important aspect of outflow regulation on the St. Lawrence River. Plan 2014 incorporates indicators of future water supply conditions, as did its predecessor Plan 1958-DD, in an attempt to reduce the frequency and severity of extreme water levels from what would occur without regulation.

During the LOSLRS and subsequent efforts, a range of simulations were done to illustrate the potential benefit of improved forecasts of water supply conditions should sufficient improvements become available in the future. The results suggested that in theory at least, foreknowledge of wet or dry weather three to six months in advance could improve regulation plan performance in some situations by providing the opportunity to adjust outflows in time to reduce, though not eliminate, the risk of extreme water levels. So how well did existing long-range seasonal forecasts predict the extreme conditions of 2017 and can anything be learned from the event to improve predictions in the future?

The long-range forecasts did not do well. As an example, the North American Multi-Model Ensemble (NMME) is a multi-model seasonal forecasting system that uses forecast data produced by research centers from both the US and Canada. Each month the NMME uses data from a suite of individual models to create six-month global forecasts of both temperature and precipitation. These are among the most sophisticated seasonal forecasting models currently available.

Figure 4-15 below shows the distribution of NMME model forecasts for Lake Ontario precipitation done in March 2017 for the following six months. The figure indicates a wide range of possible precipitation forecasts were produced by the various models (see the figure caption for a detailed description of the figure), ranging from above-normal (red) "wet" conditions to below-normal (blue) "dry" conditions, but with most model forecasts falling in the near-normal (grey) category. Very few of the forecasts exceeded the historical ranges, indicating that extreme precipitation was not considered likely in the months of April and May. Interestingly, the average of the forecasted May precipitation was slightly below the historical average for the month, suggesting that most models were calling for a drier-than-normal May.

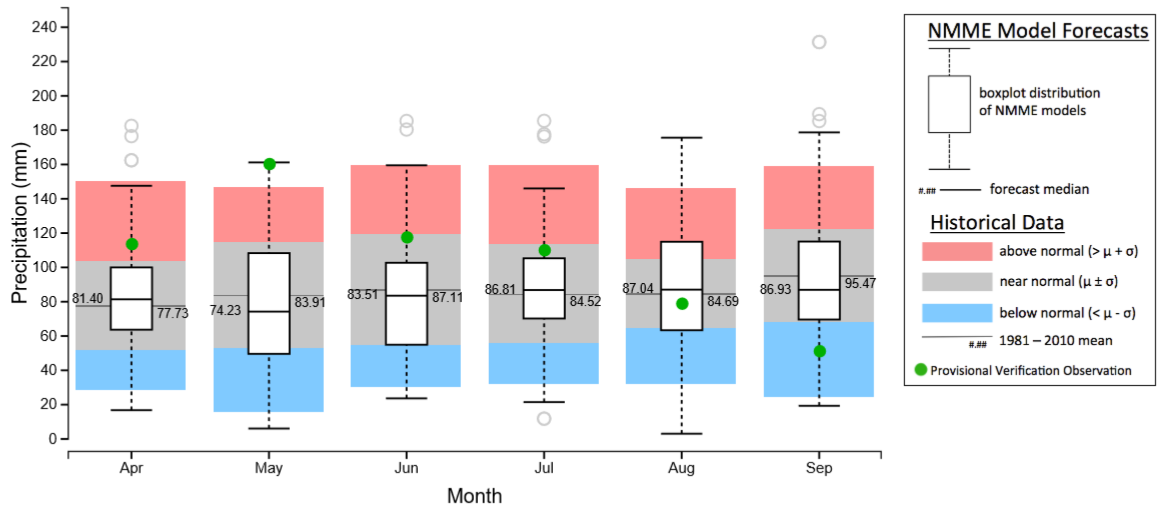


Figure 4-15: Distribution of NMME six month forecasts made in March 2017. The red, grey, and blue bars represent above, near, and below average ranges based on 1981-2010 data, respectively. The box for each month represents the 25th to 75th percentile while the horizontal black bar in the middle of the box is the median of all the forecast models and the green dot is the actual value of precipitation for that month. (Source: NOAA – Great Lakes Environmental Research Laboratory (GLERL), March 2017)

The green dots show actual precipitation that occurred, with above-normal precipitation in April followed by well-above normal precipitation in May. Thus, it can be seen that even one month in advance there were no reliable signals in the available forecasts that the precipitation during the spring of 2017 was going to be extreme. Furthermore, forecasts three to six months in advance tend to be even more uncertain, and while an accurate forecast this far in advance might allow the lowering of lake levels ahead of extreme supplies, it is also possible that other factors may preclude it (this was indeed the case in 2017, as ice conditions would have limited flows from January through March and prevented the high outflows that would have been necessary to lower Lake Ontario in advance of what were unpredicted extreme water supplies later in spring).

The question remains, is there any way of improving these forecasts? What if, for example, the same climatological conditions preceded the 2017 high water as had preceded high water events in previous years, then perhaps a forecast of high water could be made whenever those conditions appeared.

Teleconnection patterns are the name given to large-scale patterns of pressure and circulation anomalies that can encompass large areas of the globe. Depending on the teleconnection pattern, one can persist from weeks to months to years and have significant impact on weather patterns many thousands of kilometers away. These patterns reflect the changes that are seen in the atmospheric wave and jet stream patterns across the planet. The teleconnection patterns that are generally thought to have some influence on North American weather to varying degrees are: The North Atlantic Oscillation (NAO), Pacific/North American pattern (PNA), the El Niño-Southern Oscillation (ENSO), and the Arctic Oscillation (AO).

Typically, correlations between the teleconnections and weather patterns are strongest when the teleconnections are either in the high or low end of their ranges, but this was not the case for any of these teleconnection patterns during the first half of 2017: NAO 0.3 (ranges from -3 to +3), PNA 0.3 (ranges from -3 to +3), ENSO 0.1 (ranges from -2 to +3), and AO 0.4 (ranges from -4 to +4). Thus, there was no indication from the values of the teleconnection patterns that there would be record high precipitation over Lake Ontario during April and May.

A recent paper (Carter and Steinschneider, 2018) catalogues similarities and differences among seven modern Lake Ontario floods (1951, 1952, 1973, 1974, 1976, 1993, and 2017) and using other referenced work, provides a high-level overview of the climatic drivers and teleconnection patterns of interest. Although there were significant high-water years on record before 1951, there was less recorded about climate phenomena that could help explain the cause of the high levels.

In six of the seven flood years (the one exception being 1993), wintertime precipitation over the Great Lakes was above average and most were well above average. Four of the six years were also coincident with low values of ENSO (commonly referred to as La Niña), including 1951, 1974, 1976 and 2017. Historically, La Niña years have shown a tendency towards relatively dry weather conditions in the southern US, and wet conditions in the north and in southern Canada, including the Great Lakes, and this was indeed the case in 2017. Physically, this happens because the jet stream in the eastern Pacific moves north and more water moves through an atmospheric “river” of water vapor over the Pacific northwest. The fact that there are some common ocean and atmospheric conditions present in some of these high-water years suggests the possibility that floods could be forecast with a somewhat greater degree of accuracy in advance.

However, not all La Niña years have resulted in wet winter weather on the Great Lakes or in high water levels later in spring. This is, in part, because ENSO is just one of the influences of weather in the Great Lakes, and there are many effects that are not captured in these teleconnections.

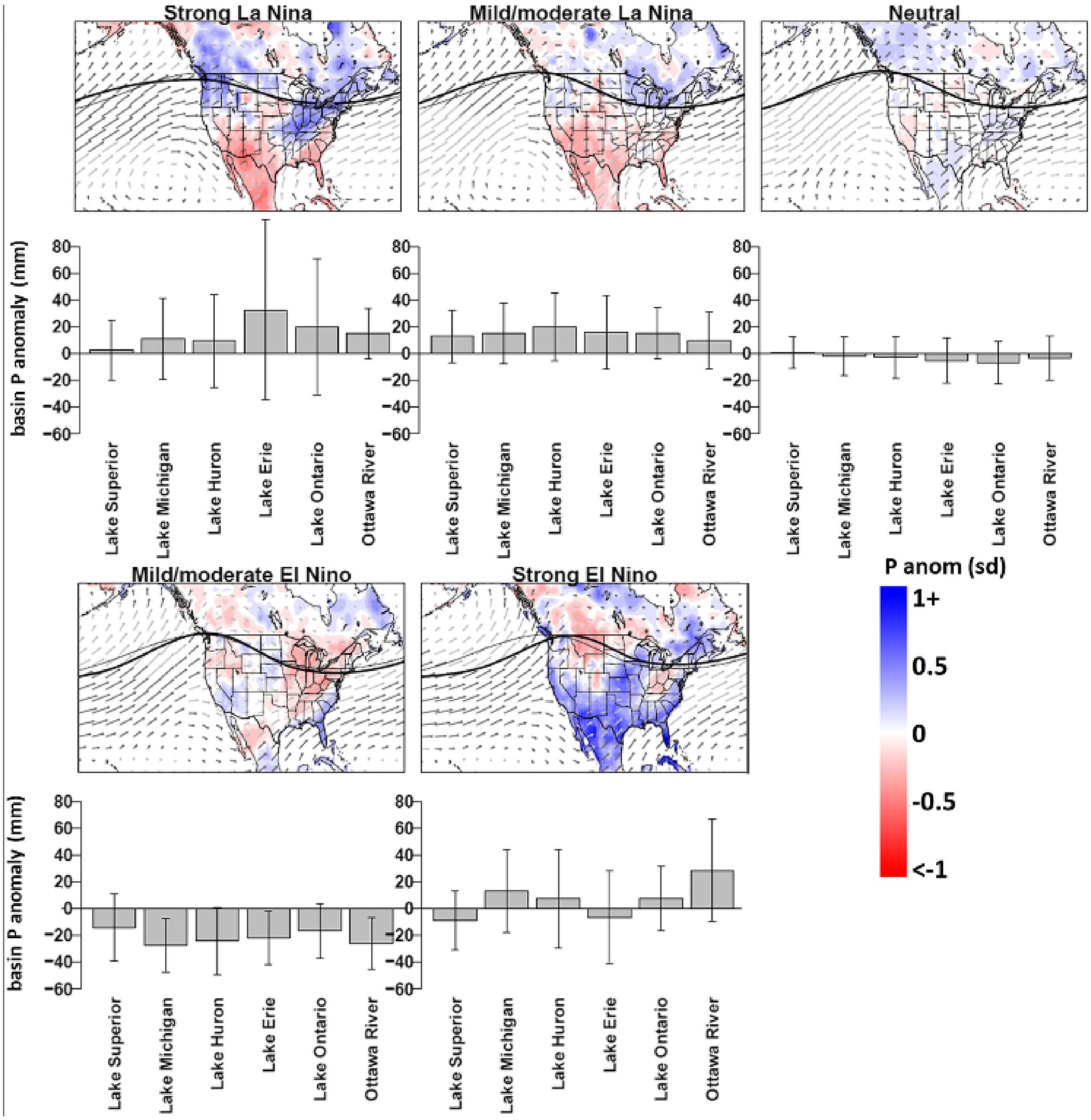


Figure 4-16: Great Lakes and Ottawa River cumulative precipitation anomalies for December through March, categorized based on ENSO conditions (Source: Carter and Steinschneider, 2018).

As can be seen in Figure 4-16, while both strong and mild/moderate La Niña years have shown an overall tendency towards above average winter precipitation (as indicated by the positive grey bars) in the Great Lakes and Ottawa River basins, not all years have shown this (as indicated by the black whiskers both above and below zero). Nor have all wet winters resulted in high water conditions in spring of the subsequent year. This indicates that although ENSO conditions may have some effect on the weather patterns on the Great Lakes, they are by no means a perfect indicator and there are certainly other important factors that influence high water conditions in the basin.

So, are there other global factors that could be used in combination with La Niña to forecast high water levels? Testing of the regulation plans during the LOSLRS showed that Lake Ontario levels over 75.5 meters are caused in great part by high NBS. High inflows from Lake Erie can contribute to these high levels, but high Lake Erie inflows are also somewhat more predictable, and regulation plans take that into account (LOSLRS, 2006). As was evident during the extreme wet conditions in 2017, high springtime NBS resulting from both heavy over-lake and over-land precipitation, may be an even more important driver of Lake Ontario flooding. Carter and Steinschneider (2018) argue that while ENSO conditions in the Pacific Ocean may provide some indication of winter weather conditions in the Great Lakes, teleconnection patterns in the Atlantic Ocean may be more indicative of spring weather, specifically, the position of the North Atlantic subtropical high (NASH). The NASH causes air flow to turn clockwise around a center with high atmospheric pressure located roughly due east of Florida. The position and orientation of the western edge of the NASH is a strong driver of summertime precipitation in the southeastern United States and may have some influence on springtime precipitation on the eastern Great Lakes.

Carter and Steinschneider (2018) have argued that the position of the western edge of the NASH may be connected to high springtime NBS on Lake Ontario. For example, of the seven flood years reviewed, four showed high spring precipitation anomalies, and three of these, including 2017, corresponded to years where the western ridge of the NASH was shifted furthest west than normal (Figure 4-17).

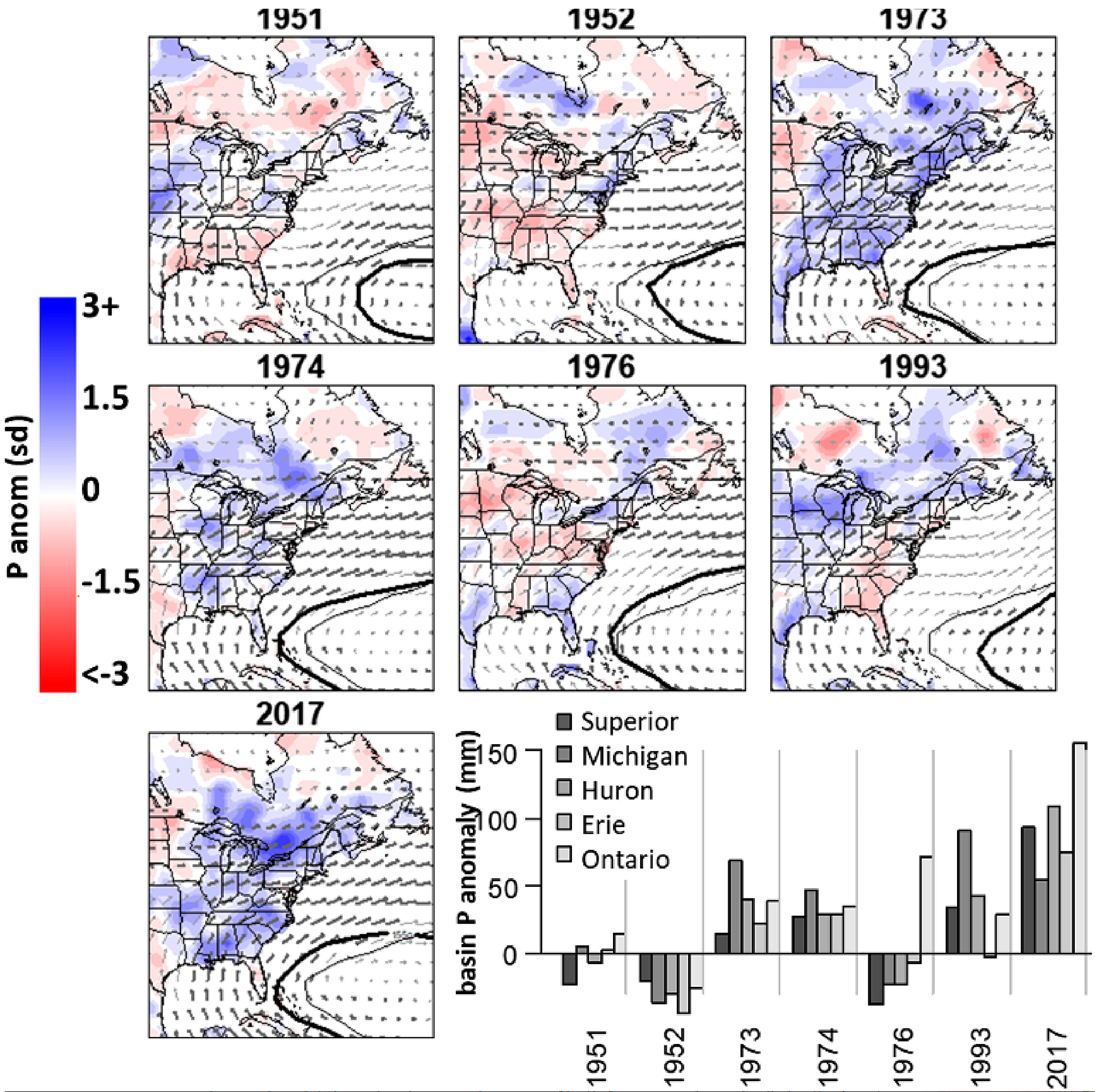


Figure 4-17: Great Lakes cumulative precipitation anomalies for April through June for seven historical high water years categorized based on NASH conditions (Source: Carter and Steinschneider, 2018).

This suggests that efforts to produce a forecast of high lake levels based on ENSO and NASH may hold some promise. The first step would be to further investigate the relationship between these teleconnection patterns, water supplies and Great Lakes water levels. Even if strong relationships are indicated, it would then be necessary to determine how well and how far in advance these factors can be forecasted, given any actions taken through outflow regulation would need to occur weeks, if not months, in advance to have a meaningful impact at reducing risk. Although there exists some skill in the forecasting of ENSO, at the moment, there is no forecast of NASH that has shown any skill in accurate prediction.

As illustrated by the recent work of Carter and Steinschneider (2018) and the results of the predictive capacity of the current operational models (NMME), a considerable gap remains between available long-term water supply forecasts and operational decisions. Improving the skill of long-term water supply forecasts is an area of active research and there is the potential that such work will improve forecast confidence and accuracy in the future. In the long-term, regulation of Lake Ontario outflows may benefit from forecast improvements that provide sufficient lead time (and confidence) to support lowering or raising of levels in anticipation of extreme conditions to reduce their frequency and severity. However, such improvements seem to be a ways off and even if successful, are not likely to eliminate trade-offs between interests.

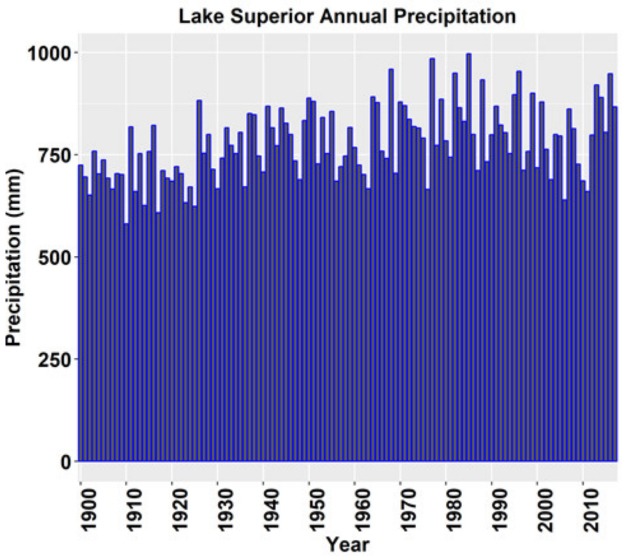
4.3 How did 2017 fit with historical conditions?

In addressing the GLAM Committee's directive of assessing whether future water supplies will be different from those used to test the current outflow regulation plans, it is important to track historical data to assess whether conditions may be changing over time. It is widely understood that climate is not stationary and that decadal and longer-term trends are to be expected (Livingstone, 2008). It is only through on-going monitoring that the magnitude and direction of those trends can be detected across the Great Lakes. The conditions of 2017 were undoubtedly highly unusual, but the GLAM Committee is interested in knowing just how unusual they were relative to the historical record and whether these conditions are consistent with recent data conditions that might indicate a trend and possibly a greater chance of such conditions occurring again or occurring more frequently in the future. Such trends, if they exist, could inform the robustness of the regulation plan evaluations.

This section examines the various components of the NBS including over-lake precipitation, lake evaporation and basin runoff, and the recent conditions across the five Great Lakes basins and how 2017 compared with recent historical data.

Although there are many different variables that are available, this report will focus on the ones that are relevant when considering the regulation plans that currently exist, namely precipitation, runoff, and evaporation. Currently the longest consistent source of this type of data for the Great Lakes comes from NOAA's Great Lakes Environmental Research Laboratory (GLERL) based on their Advanced Hydrological Prediction System (AHPS). Also note that the data from the most recent years is considered preliminary.

As with any sequence of meteorological data, there is a lot of variability in the annual totals and this can mask longer-term trends. Thus, it can be useful to summarize the data over longer time periods. This can be seen in the total over-lake precipitation for Lake Superior: while there is a lot of variation in the annual data, a general trend is much more easily seen in the data averaged over decadal periods (Figure 4-18). In this case, it appears a trend towards increasing precipitation has occurred during the last century, although it has somewhat leveled out since the 1970s. The total for 2017 (1080.1 mm; 42.5 in) continued the pattern of high over-lake precipitation over the last few years.



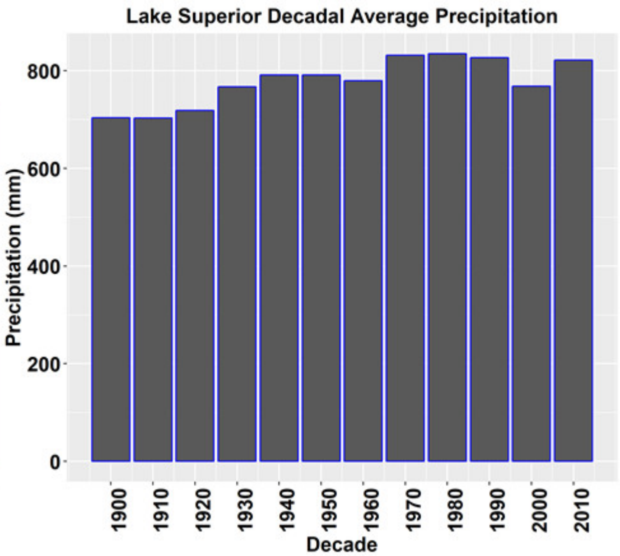


Figure 4-18: Annual and decadal over-lake precipitation for Lake Superior.

The Lake Superior lake evaporation shows a clear trend of increasing values (note that reliable evaporation data only goes back to the 1950s) with a notable jump between the 1990s and the 2000s (Figure 4-19). For 2017, the lake evaporation (713.9 mm; 28.1 in) was one of highest seen in the historical record. While runoff into the lake has seen a general reduction over the past three decades (Figure 4-20), the value for 2017 (713.1 mm; 28.1 in) was the highest seen in the past 20 years.

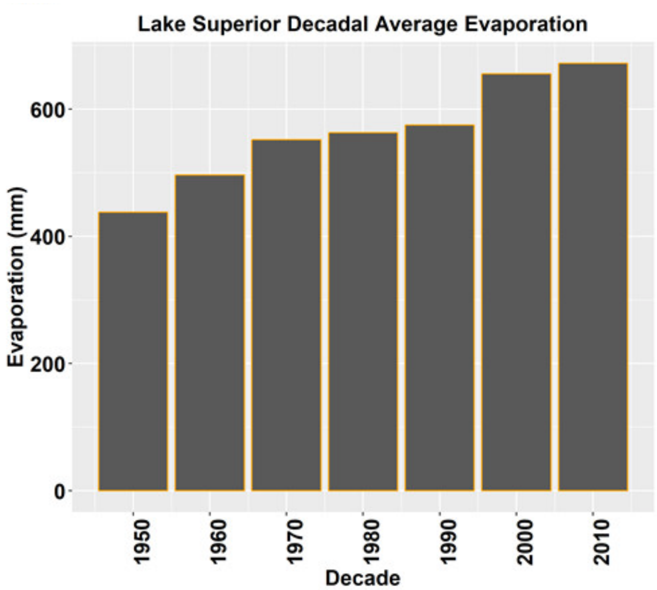


Figure 4-19: Lake Superior decadal average evaporation

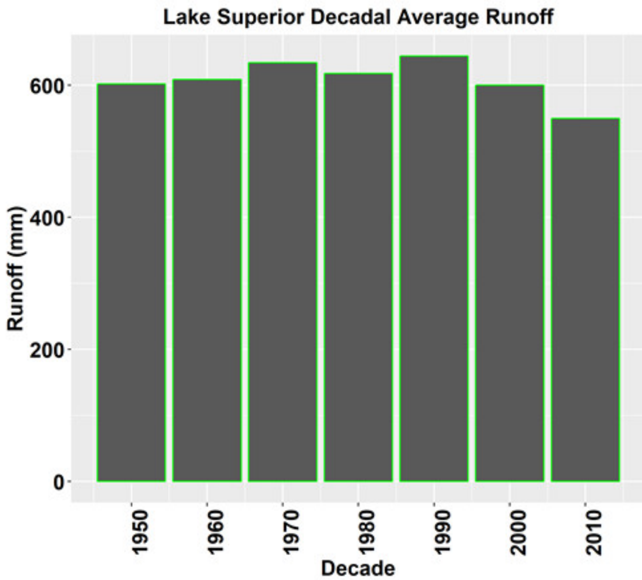


Figure 4-20: Lake Superior decadal average runoff

As in Lake Superior, Lakes Michigan/Huron have also seen a general rise in over-lake precipitation over the past century and a general levelling off in the most recent decades (Figure 4-21). The 2017 over-lake precipitation (877.7 mm; 34.6 in) is a little higher than the average value for the past few decades. Lake evaporation experienced a marked increase between the decade of the 1990s and the 2000s, with 2017 (688.3 mm; 27.1 in) coming in about the same as the average for the 2010s (Figure 4-22).

The amount of runoff coming in to Lakes Michigan/Huron has seen a sharp reduction in value in the most recent decade, with the decade of the 2010s being the lowest in the records going back to 1950 (of course, this decade is incomplete and the addition of a couple more years may change this finding, but likely not significantly) (Figure 4-23). Although the value for 2017 (751.4 mm; 29.6 in) was above the 2010 decadal average, it was still less than the previous four decadal averages.

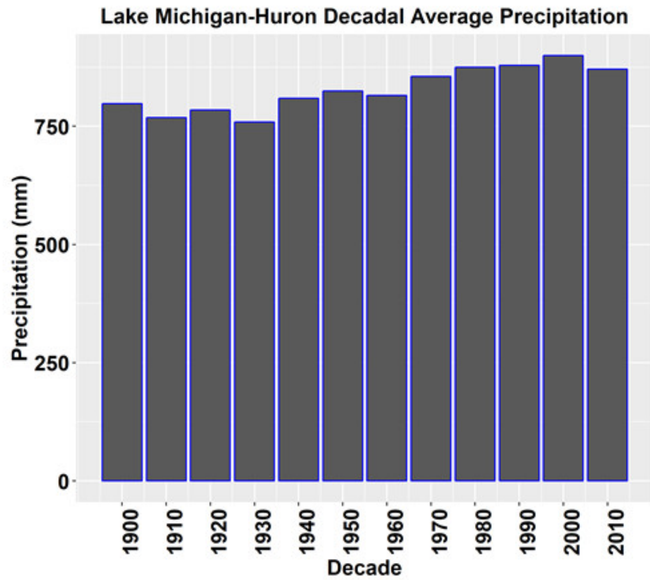


Figure 4-21: Lake Michigan-Huron decadal average precipitation

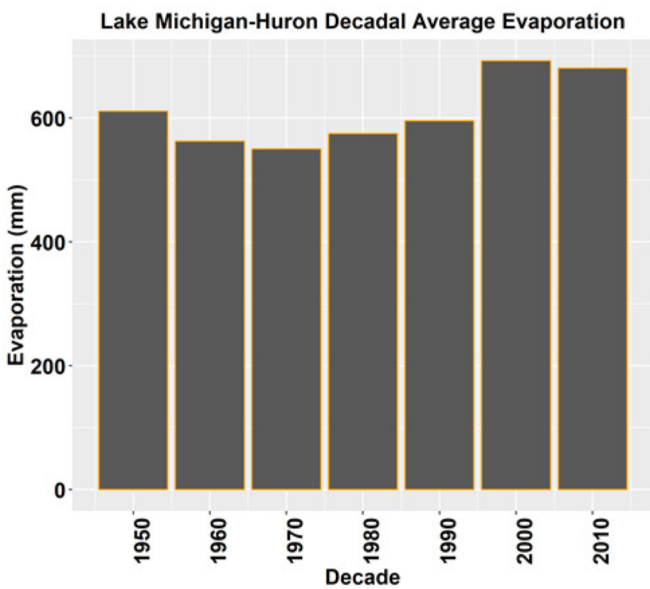


Figure 4-22: Lake Michigan-Huron decadal average evaporation

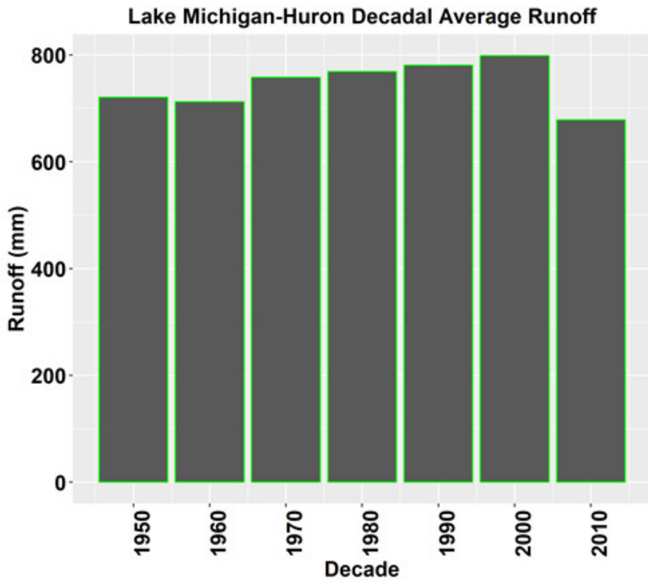


Figure 4-23: Lake Michigan-Huron decadal average runoff

The over-lake precipitation on Lake Erie has seen generally increasing values since the middle of the last century, although so far, the current decade is slightly below the value for the decade of the 2000s (Figure 4-24). The value for 2017 (927.1 mm; 36.5 in) was the highest in the past six years. Although the lake evaporation has been increasing, there was not the same sharp rise seen on Lake Erie as in the previous lakes (Figure 4-25). The amount of evaporation in 2017 (956.0 mm; 37.6 in) was just a little less than the average of the past decade. Once again, runoff saw a marked decrease during the last decade coming into Lake Erie (Figure 4-26). With the increase in precipitation, it can be assumed that overland evaporation also had to increase in the past decade. The 2017 value for runoff (826.6 mm; 32.5 in) was the highest seen since 2011, but less than the decadal average for the 2000s.

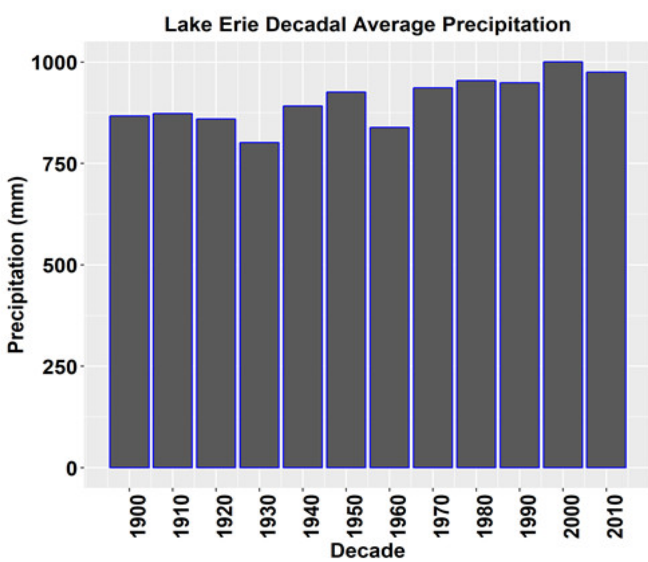


Figure 4-24: Lake Erie decadal average precipitation

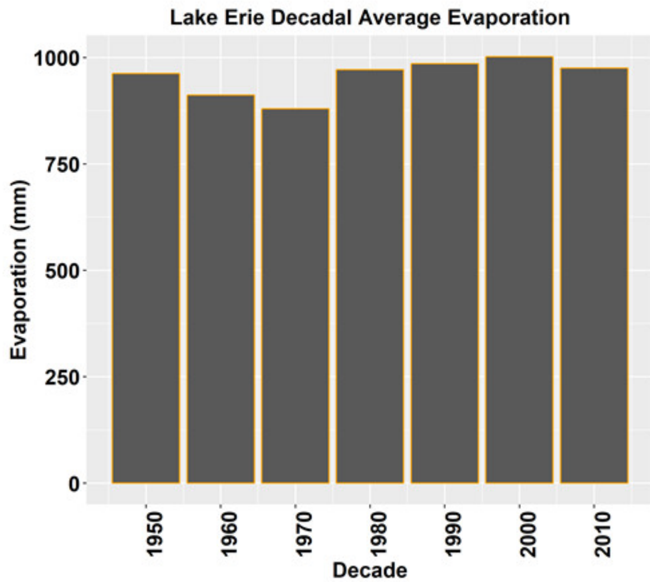


Figure 4-25: Lake Erie decadal average evaporation

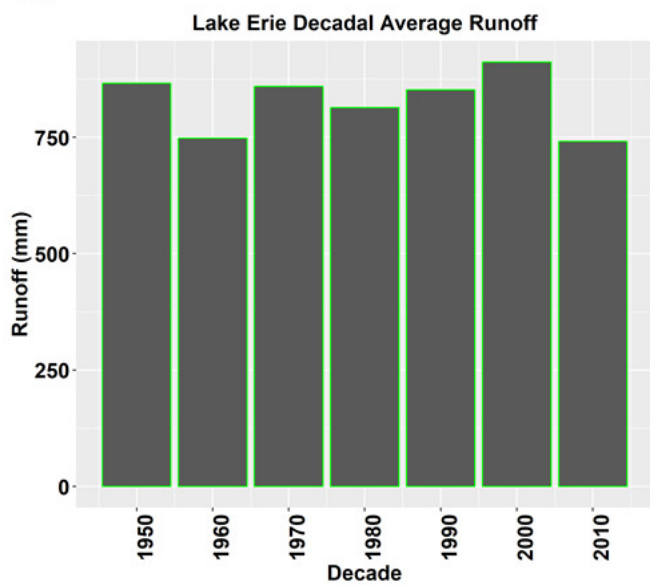


Figure 4-26: Lake Erie decadal average runoff

After rising in the decades of the latter half of the last century, the over-lake precipitation on Lake Ontario has remained relatively steady the last few decades (Figure 4-27). In 2017, the total over-lake precipitation value (1222.2 mm; 48.1 in) was the highest total in the recorded history of the lake which goes back to 1900. Evaporation over the lake has shown a steady decadal increase since the 1990s (Figure 4-28). The value for 2017 (742.4 mm; 29.2 in) was typical of what we have seen in the past decade. The runoff into Lake Ontario has seen a dramatic decrease in the last decade; in fact, since records began in 1950, four of the lowest five values have occurred since 2012 (Figure 4-29). However, the 2017 value (2363.4 mm) did not fit this trend whatsoever and was instead the highest value of runoff into Lake Ontario on record.

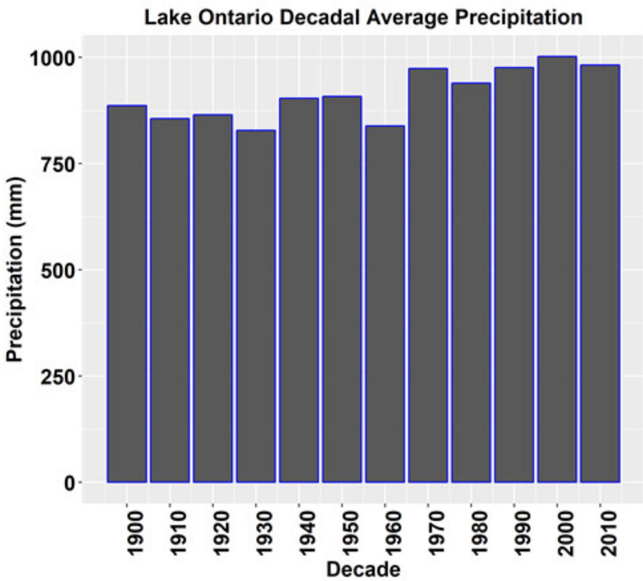


Figure 4-27: Lake Ontario decadal average over-lake precipitation

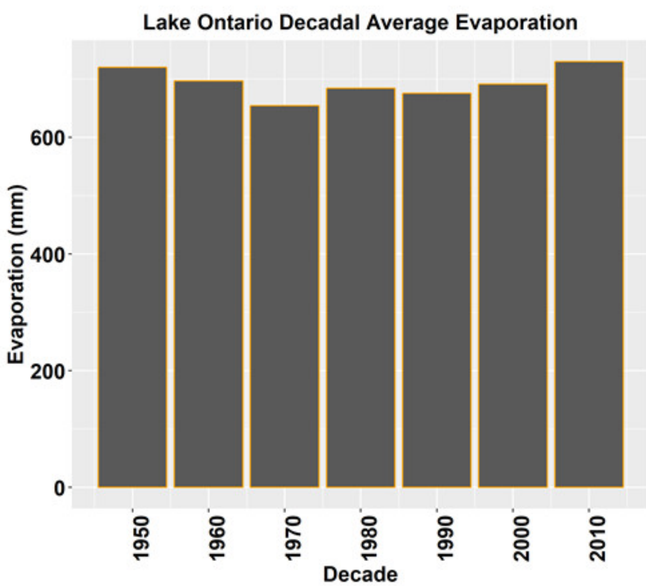


Figure 4-28: Lake Ontario decadal average evaporation

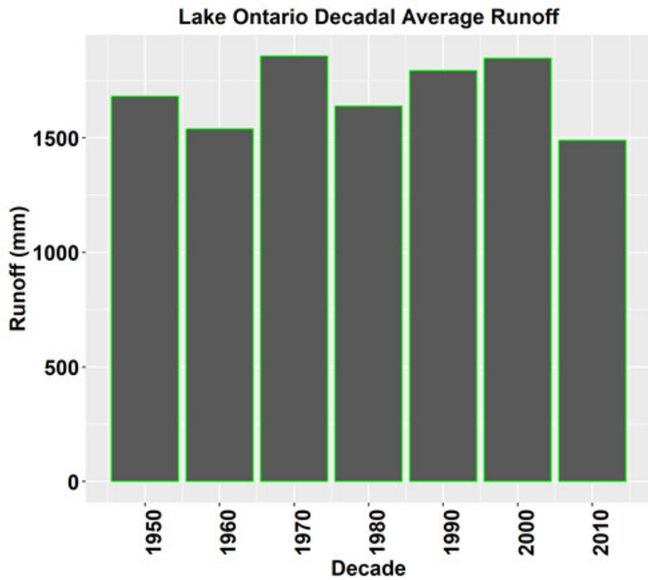


Figure 4-29: Lake Ontario decadal average runoff

It is possible that recent trends in over-lake precipitation and evaporation may continue into the future given a changing climate, but it is beyond the capabilities of the current state of research to confidently state when these types of condition will be repeated. The conditions in 2017, while a rare occurrence, seem to mostly fit within the range of water supply conditions used during the past IJC studies (IUGLS and LOSLRS), which were based largely on historical climate conditions, supplemented with statistical and climate models describing potential future scenarios. However, it is unclear whether such conditions may occur more frequently in the future.

4.4 What was extraordinary about the 2017 Great Lakes hydroclimate?

4.4.1 Record precipitation on both the Lake Ontario and Ottawa River basins

The Ottawa River basin covers an area of 146,300 km^2 (56,480 square miles) and is the largest tributary to the lower St. Lawrence River. The flow of the Ottawa River combines with the outflow from Lake Ontario upstream of Montreal, and as a result, it is critical in the regulation of Lake Ontario and the St. Lawrence River.

Figure 4-30 depicts what an extraordinary precipitation year 2017 was for Lake Ontario and the Ottawa River basin. Total precipitation over Lake Ontario during April-May (source data from GLERL (Hunter et al., 2015)) from 1900-2017 is plotted against the same parameter at the City of Ottawa in the southern part of the Ottawa River basin (source data from ECCC meteorological

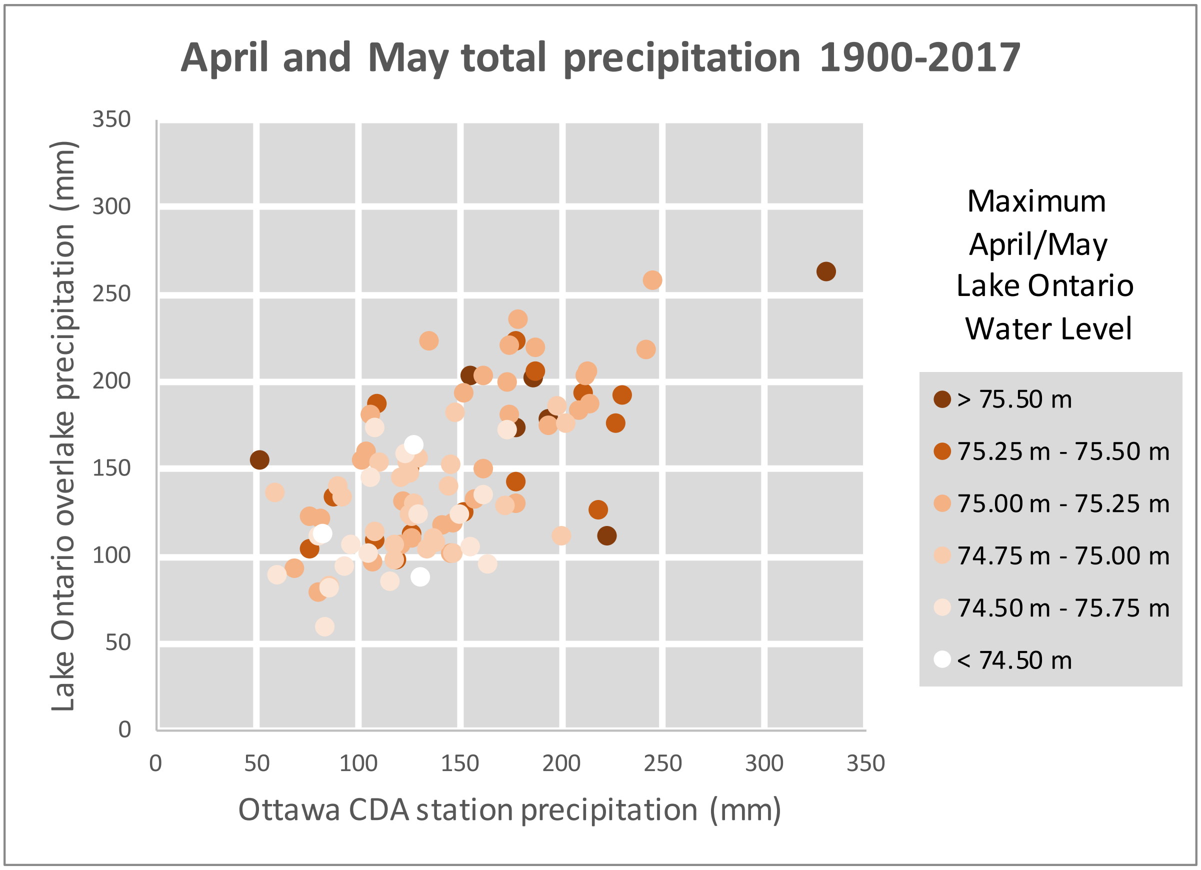


Figure 4-30: Comparison of the total April and May 2017 precipitation between over-lake Lake Ontario precipitation and the meteorological station "Ottawa CDA".

station “Ottawa CDA” at the Central Experimental Farm in the City of Ottawa; this station was used to represent the Ottawa River basin as it had data back to 1900). Each year is a dot and each dot is color coded to show the maximum monthly Lake Ontario elevation during April-May in that year. The year 2017 stands far apart from the past 117 years, setting records for high water levels, Lake Ontario basin precipitation and Ottawa River basin precipitation. Under a stationary climate, there would only be a 0.6% chance of this happening in a given year (or a 1 in 160-year event).

For the Ottawa CDA station, the total precipitation for April 2017 of 159.0 mm (6.26 in.) was the highest seen in the historical record (0.7% chance or a 1 in 148-year event), while the 172.4 mm (6.79 in.) in May was the third highest in the record (0.7% or 1 in 136-year event). The combined April and May total was the highest in the historical record (0.6% or 1 in 166-year event).

The April 2017 total over-lake precipitation for Lake Ontario of 111.8 mm (4.40 in.) was the fifth highest seen in the record (0.8% chance or a 1 in 119-year event). For May, the total of 150.3 mm (5.92 in.) was the second highest only behind 1919 when 152.1 mm (5.99 in.) fell (0.8% chance or a 1 in 127-year event). The total for both April and May of 2017 was 262.1 mm (10.32 in.), which is the highest in the record (0.8% chance or a 1 in 132-year event), but only slightly higher than the 257.6 mm (10.14 in.) in 2011.

The extreme precipitation in the Lake Ontario and the Ottawa River basins was further exacerbated by high inflows to Lake Ontario from Lake Erie. The wet conditions in the Lake Ontario basin in 2017 (Figure 4-31) are further illustrated through the weekly NTS for the year, which includes the effects of both Lake Ontario NBS and Lake Erie inflows. As shown in Figure 4-32, NTS exceeded record highs on multiple occasions in 2017, the most notable being the start of May, where NTS exceeded the highest values ever previously recorded (1900-2016).

Although it is difficult to attribute conditions in one particular year to the effects of climate change, one of the predicted outcomes from climate change is more severe storms and extreme precipitation. One sequence of climate parameters based on the most recent future climate scenarios used during the IUGLS suggests that months with extreme precipitation over Lake Ontario would be anywhere from two to three times more common during 2050 when compared to the current climate (MacKay and Seglenieks, 2013). The U.S. National Climate Assessment for 2018 Great Lakes Synthesis report indicates that the tendency towards more intense precipitation events is projected to continue into the future (GLISA, 2018;D’Orgeville et al., 2014; Notaro, M. et al.), although it also notes that model projections for precipitation changes are less certain than those for temperatures (GLISA, 2018; Pryor et al. 2013; Kunkel et al. 2013). The runoff amounts of 2017 were within the bounds of the water supply data used to evaluate the plans in the LOSLRS, but for the GLAM Committee it raises the question of whether our simulations adequately test the possibility of a significant upward shift in magnitude and/or frequency of high precipitation and runoff. This is further discussed in Section 6.

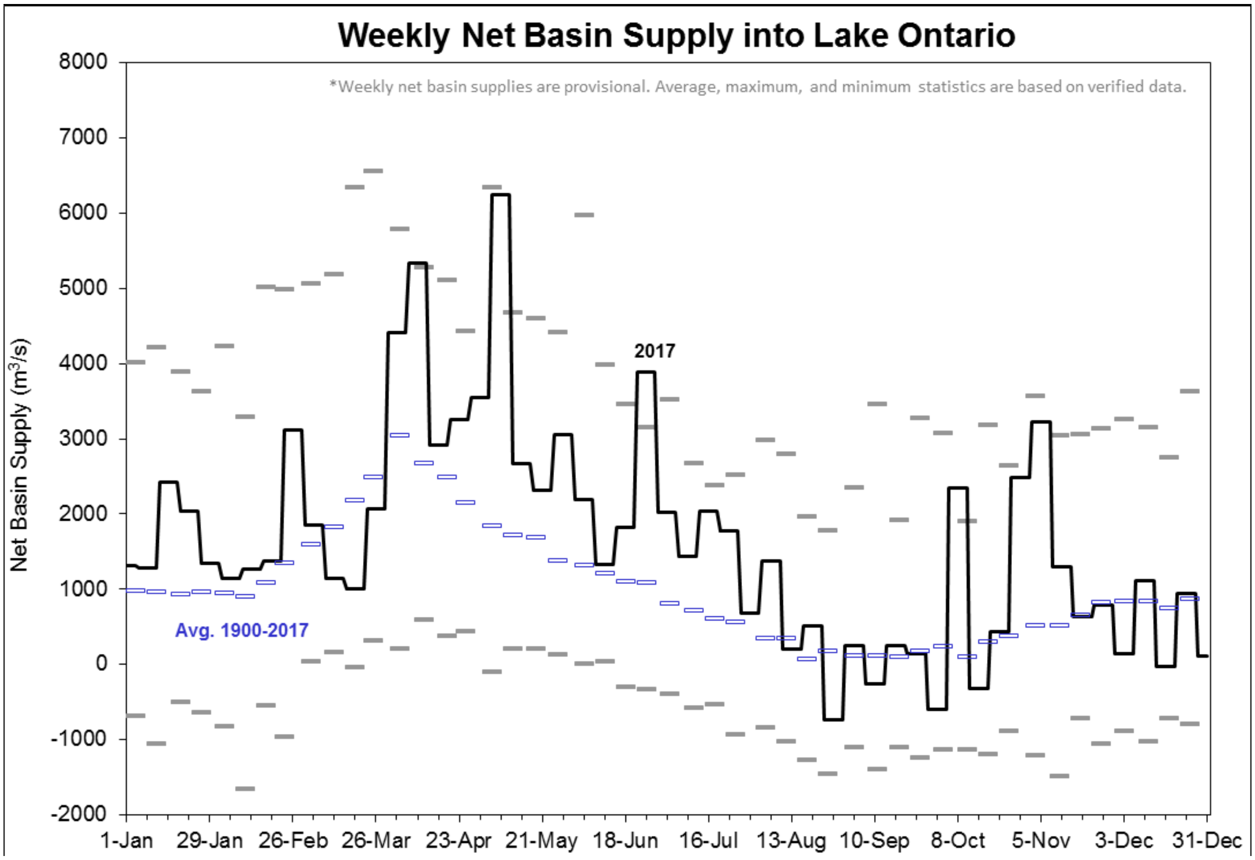


Figure 4-31: Weekly net basin supplies (NBS) for the Lake Ontario basin in 2017. (Source: International Lake Ontario – St. Lawrence River Board)

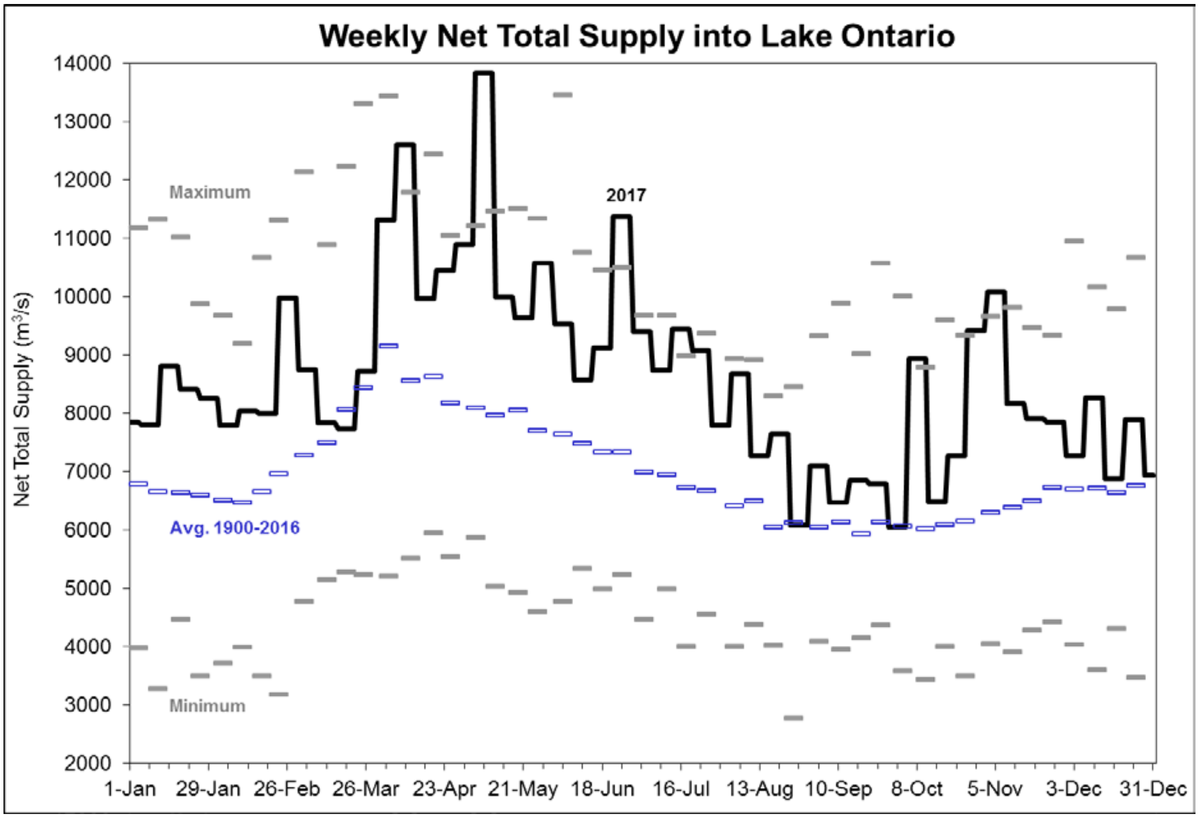


Figure 4-32: Weekly net total supplies (NTS) for the Lake Ontario basin in 2017. (Source: International Lake Ontario – St. Lawrence River Board)

4.4.2 Fluctuating ice conditions

The ice conditions along the St. Lawrence River and downstream of the Moses-Saunders Dam at Beauharnois in early 2017 also influenced the regulated outflows from Lake Ontario that were released during the winter. Formation of a stable ice cover in the critical areas of the St. Lawrence River is important as it reduces the risk of ice jams, which can severely restrict outflows and potentially result in flooding upstream. As ice begins to form, outflows are typically reduced to lower the current velocities in the St. Lawrence River, which helps prevent the fragile ice cover from breaking up or collapsing on itself, and also reduces the potential for frazil ice development (i.e., super-cooled ice crystals), which can accumulate and further increase the risk of ice jams at critical locations. Once an ice cover has formed and is stable, these risks are reduced and outflows can be safely increased. However, if the ice cover becomes unstable or breaks up subsequently, flow must be again reduced in order to reduce the risks upstream and downstream.

During many years since regulation of Lake Ontario and the St. Lawrence River began, the pattern seen in the St. Lawrence River has generally been that cold temperatures at the beginning of winter would create an ice cover in the critical sections (i.e., the Beauharnois Canal and international section of the river), and then this ice would remain stable during the winter and eventually melt out when warmer temperatures returned in the spring. Historically, ice records on the St. Lawrence River date back to 1961; however, early records generally only include dates of first and last ice on the St. Lawrence River, and they do not describe fluctuations in temperatures and/or ice conditions in detail. More detailed records including such information have only been kept since about the year 2000.

In 2017, ice briefly came and went during the mild and near record warm temperatures in January and February, before reforming again as temperatures became unusually cold in March over the Lake Ontario-St. Lawrence River basins. Substantial ice cover formed and disappeared twice on the St. Lawrence River during March 2017, both unprecedented events. Overall, the winter experienced five periods of ice formation in the critical areas of the St. Lawrence River, which is likely the most freeze/thaw cycles ever seen on the river (the board report ("Observed Conditions and Regulated Outflows in 2017") covers ice conditions in greater detail).

Future climate scenarios generally agree that higher temperatures, especially during the winter period, are more likely to be seen in the coming decades (GLISA, 2018). There is some evidence of this in the historical record. For example, using data from the airport at Dorval, QC, which is near Montreal and not far from Beauharnois or Moses-Saunders dams, during the decades of the 1960s and the 1970s there were no years that 25 or more days in January and February recorded temperatures above zero. During the 1980s, there was one of these years; the 1990s saw two; while the 2000s recorded this only once. However, since 2010 this has already happened four times, including 2017.

Thus, it is not unreasonable to expect the pattern of warmer temperatures and, by extension, fluctuating ice conditions to continue, and such potential patterns and trends are an important consideration and area of research for GLAM, given they can influence outflow regulation and the ability of regulation plans to release water during the winter months.

4.5 Key findings: what can be learned from the 2017 hydroclimate conditions?

While the NBS of 2017 was very wet across the Great Lakes basin and even record-breaking in some weeks over the Lake Ontario basin, it was the combined precipitation over the Lake Ontario and Ottawa River basin with high inflows from Lake Erie that made 2017 so extraordinary. The unusual St. Lawrence River ice conditions in 2017 added to the extreme levels. What these unusual events in 2017 highlight is the importance of testing plausible extreme conditions in coordination with GLAM's plan evaluation efforts. The GLAM Committee recognizes the importance of continued analysis in this area, particularly in terms of how extreme hydroclimate conditions may be able to impact outflow regulation.

While extremes have happened in the past, there is no doubt that 2017 was a rare event within the historical record. Whether the conditions of 2017 are more likely to happen in the future is difficult to assess. The high water supplies were unforeseen by most seasonal forecasts at the start of the year, indicating that extreme precipitation was not likely in April and May of 2017. In addition, it should be remembered that long-range seasonal precipitation predictions are still very much a work in progress. Research and development of more sophisticated long-term forecasting tools is an involved process requiring multiple years and substantial resources. This is an area of ongoing research globally, but long-range seasonal precipitation predictions will continue to be a challenge going forward. Though the existing forecasting models show some potential improvements in skill over the past couple years, it is unclear how these models could currently be leveraged to assist the GLAM Committee's long-term goals of plan review and evaluation. Furthermore, the accuracy of such forecasts decreases at longer lag times, whereas outflow release decisions would need to be modified weeks or months in advance to significantly reduce the risk of high water levels and flooding on Lake Ontario and the St. Lawrence River.

A preliminary analysis of the implications of varying hydroclimate conditions is initiated in Section 6 of this report and is further described in the Annex 2-Plan Review. Future work in this area is anticipated.

5.0 Impact Assessment of 2017 Water Levels and Flows

5.1 Introduction

This section provides a general overview of impacts experienced across a range of sectors in 2017 throughout the Great Lakes-St. Lawrence system based on observed water levels and conditions. Unless otherwise indicated, there are two geographic regions referred to in describing the various interest categories: the upper Great Lakes (lakes Superior, Michigan, Huron, Erie and the connecting channels) and Lake Ontario and the St. Lawrence River above the dam at Cornwall/Massena and below the dam to Trois-Rivières. **It is important to clarify that this report is not intended to represent a full economic or environmental analysis of high water impacts in 2017. Instead, the intent is to capture the critical types of impacts and get a sense of the geographic distribution to support long-term efforts to validate and improve existing models linking water level changes to impacts and ultimately, evaluate the performance of the outflow regulation strategies that are currently in place. In certain cases, data are still being collected. If and when these datasets become available, the GLAM Committee will look to incorporate the information into future analyses and reports. In general, there is a lack of standard after-event damage survey information collected and reported on by various levels of government. This has been identified as a critical limitation to the GLAM Committee in undertaking model validation activities.**

5.1.1 Performance indicators and coping zones

Six key interest categories are covered in this review, including municipal and industrial water use, commercial navigation, hydropower, shoreline property interests, environmental interests and recreational boating and tourism. All of these sectors are affected by changes in Great Lakes water levels or flows in the connecting channels and all were impacted to varying degrees by high water levels in 2017 across the entire Great Lakes-St. Lawrence Region, particularly on the Lake Ontario-St. Lawrence River system. In documenting impacts and benefits, the GLAM Committee paid particular attention to the existing performance indicators that had been established by the previous IJC studies (both LOSLRS and IUGLS) and had been part of the models used in the evaluation and ultimate selection of the existing regulation plans.

Performance indicators represent a quantifiable measure of the relationship between an economic, social or environmental benefit or cost and different water levels and flows in the Great Lakes-St. Lawrence River system. These relationships must:

- represent something of significance to the interest;
- demonstrate a measurable sensitivity to water level changes; and
- have confidence/certainty in the data and science that support it.

Performance indicators were not meant to be used in isolation or to reflect absolute impacts, rather they were designed to be used in a relative comparison of regulation plan alternatives. They were to represent broader societal impacts and capture outcomes and tradeoffs between interests and over broad geographic scales. A full list of the performance indicators used for both the upper lakes and the Lake Ontario-St. Lawrence River system during the past IJC studies can be found in Appendix 1. The record conditions of 2017 on Lake Ontario and the St. Lawrence River were outside the range of conditions for which data were available to develop the existing performance indicators. Therefore, information from 2017 is critical to support the validation and improvement of a number of the LOSLRS performance indicators and to add new information and give new insights into what is likely to occur under conditions that had only previously been simulated.

Coping zones were water level zones used exclusively during the IUGLS and defined generally by the water level regime (level, range, rate of change, frequency), location and other factors that cause vulnerabilities for a particular interest, such as a lack of resilience. Resiliency can affect any interest's ability to cope with water levels and is defined as the capacity to recover quickly from difficulties (see box below).

The coping zones were defined as a reflection of an interest's ability to "cope" with a given water level regime and included three levels of progressively more challenging water level conditions as follows:

- Zone A – A range of water level conditions that the interest would find tolerable;
- Zone B – A range of water level conditions that would have unfavourable, though not irreversible, impacts on the interest; and
- Zone C – A range of water level conditions that would have severe, long-lasting, or permanent adverse impacts on the interest.

The conditions in 2017 on the upper Great Lakes remained within previously defined coping zones established during the IUGLS. Further information on coping zones can be found in Appendix 1.

This section of the report describes each interest category, their general sensitivity to water level fluctuation, and summarized specific positive and negative impacts from the high water levels in 2017. Due to the extensive damages on Lake Ontario and the St. Lawrence River as a result of the record high water levels in 2017, the Annexes have been prepared to provide supplementary details and information for this portion of the Great Lakes-St. Lawrence River system.

RESILIENCY

Resiliency is defined as the ability to recover from or adjust easily to misfortune or change. The GLAM Committee does not use resiliency in the same way as they would a performance indicator or coping zone to evaluate how a change in water levels would affect an interest. Nevertheless, the resilience of an interest plays a big part in how those performance indicators and coping zones are defined. For example, the municipal and industrial interest category tends to be quite resilient to water level changes because the consequences are so large for negative impacts that they tend to be conservative when constructing major plants to ensure service to the public is not interrupted. This, in turn, affects how a performance or coping zone is defined for this interest. Likewise, changes to the commercial navigation industry over the past 10-20 years, such as the inclusion of bow thrusters, improved power-to-length ratios and automatic information systems (AIS), have made them more resilient to water level and flow changes over the years. These changes need to factor back into the algorithms developed for performance indicators in terms of an interest's sensitivity to water level changes.

5.2 Municipal and industrial water use

The municipal and industrial water use impact category broadly considers the impacts of fluctuating water levels on fresh and wastewater treatment for municipalities, industrial users and domestic residential users. It focusses on the importance of having enough water to ensure adequate intake capacity while not having so much water that shoreline infrastructure facilities (e.g. treatment plants) suffer damages.

Total water withdrawals in the upper Great Lakes basin were estimated during the IUGLS at about 112,000 ML/day (29,800 Mgal/day), with four major uses accounting for about 98 percent of the water withdrawals in the upper Great Lakes basin: thermoelectric power generation (75 percent); industrial uses (13 percent); public supplies (nine percent); and, irrigation (one percent). Most of this water is returned to the basin. Consumptive uses (that is, uses that do not return water to the system) account for less than one percent of the outflows (IUGLS, 2012). On Lake Ontario and the upper St. Lawrence River, at the time of the LOSLRS report, it was estimated that about 6.3 million residents along the shores of Lake Ontario and the upper St. Lawrence (both Ontario and the US) rely on water withdrawals from the lake and river and there were about 2.3 million residents who rely on the lower St. Lawrence River (LOSLRS, 2006).

Secure access to clean freshwater has been a driver in development along the Great Lakes-St. Lawrence River. Water withdrawals remain critical for metropolitan areas, customers of public supply facilities, agricultural facilities and the general industry of the Great Lakes and St. Lawrence River. Potential water supply interruptions, therefore, are a concern for the Great Lakes-St. Lawrence River population. Even temporary interruptions can have serious health and financial implications. It is not surprising therefore, that during both the IUGLS and LOSLRS, the IJC found that for the most part, the municipal, industrial and domestic water use category is resilient to water level changes within the historical range (LOSLRS, 2006; IUGLS, 2012). Any vulnerabilities that were found to exist could not be differentiated between alternative regulation plans in either study. Therefore, neither Plan 2012 nor Plan 2014 are expected to make things better or worse for this interest relative to the regulation plans that they replaced. In other words, while impacts are possible at the extremes, they would be expected regardless of the regulation plan. The one exception mentioned was private shore wells, but the data were incomplete and did not allow for a full assessment.

5.2.1 UPPER GREAT LAKES - Municipal and industrial water use

Sensitivity to Water Levels and Outflows: The supply of drinking water and the treatment of wastewater can both be affected by changing water levels. On the upper Great Lakes, quantifiable performance indicators of these impacts were not possible during IUGLS due to the size and scope of the upper Great Lakes and the relatively small differences in levels produced by alternative regulation plans. Instead, water level coping zones were identified to characterize potential operational problems of municipal, industrial and domestic water uses associated with fluctuations in water levels and flows (Bartz and Inch, 2011). Some impacts associated with high water levels include flooding of buildings, erosion and shore protection issues (similar to the coastal interests), infrastructure inundation (such as tunnels) and increased operating costs when infiltration into the plant is higher, thus raising the demand for water (IUGLS, 2012). Impacts associated with low water levels could include increased water quality problems and potential water intake problems if water depths are insufficient. Historically, on the upper Great Lakes, water levels have not caused failures of municipal water intakes and therefore this interest was considered to be fairly resilient to water level fluctuations within the historical range. However, based on surveys of critical water levels reported by many specific facilities along the lakes, extreme levels at or outside the historical range could cause unusable or compromised water intakes, sedimentation problems/increased operations and maintenance requirements and reduced water quality (LOSLRS, 2006; IUGLS, 2012). Potential impacts from extreme water levels at or beyond historical ranges are substantial given the tens of thousands of surface and groundwater intake structures/pipes in place, ranging from high capacity intakes for major metropolitan areas to those for individual household usage. Actions to minimize risks, such as installing flood-proof equipment, improving shore protection, building flood levees under high water or extending intake pipes into deeper water during low water would likely be taken well before a serious crisis condition is reached as the consequences are too great to afford the risk (IUGLS, 2012).

Summary of Observed 2017 Impacts: The GLAM Committee is not aware of high water level impacts directly to municipal water supply systems or wastewater treatment systems found along the upper Great Lakes in 2017.

Model Assessment: For the upper Great Lakes, no specific performance indicator was developed during the IUGLS related to this interest group. This was because the sample size of responses from a survey (questionnaire) of municipal facilities undertaken at the time was not large enough on the various lakes and, in some cases, the survey responses were too vague to develop quantitative relationships to water levels (IUGLS, 2012). Instead, general coping zones guidance was developed (Bartz and Inch, 2011) related to i) the population served by public water systems that are affected at high and low water levels and ii) the number of water withdrawal facilities where problems are expected to occur and/or where operations may cease along with the optimal operating range and levels where modifications are necessary for intakes and outfalls. In 2017, the water levels were within the range that this interest is expected to cope well, based on an understanding developed during the IUGLS. No information was found through media or spot-check phone calls with municipal water facilities that would counter this expectation at this time. While it is expected that the coping zones will need to be reviewed at some point in the future, there was nothing from 2017 that would highlight this as a priority.

Key Findings and Next Steps: Based on the information available, the GLAM Committee is not aware of significant loss of water supply or wastewater service in 2017 due to water level conditions on the upper Great Lakes. Moving forward, the GLAM Committee will look to reassess the coping zones used during the IUGLS and their appropriateness in future assessments.

5.2.2 LAKE ONTARIO-ST. LAWRENCE RIVER - Municipal and industrial water use

Summary of Performance Indicators: There were two primary performance indicators related to municipal and industrial impacts developed during the LOSLRS to capture potential water level impacts to this sector. They were:

- Infrastructure Performance Indicator: "drinking water production plant infrastructure costs required to adapt to critical levels identified" (LOSLRS, 2006)
- Taste and Odor Performance Indicator: "the costs of upgrading municipal drinking water treatment plants to treat taste and odor compounds" (LOSLRS, 2006)

In addition to the identified performance indicators, background information was gathered on other potential impacts as they relate to private self-supplied residential users. Given a lack of data and the relatively small number of users compared with those serviced by the broader public water supply and wastewater treatment facilities (e.g. Figure 5-1), water level criteria were used to identify water levels that were likely to cause problems for self-supply users, but the economic impact was not quantified as part of the overall plan evaluation effort.

Figure 5-1: RC Harris Water Treatment Plant, Toronto, Ontario. Photo Credit: City of Toronto website: https://www.toronto.ca/services-payments/water-environment/tap-water-in-toronto/fast-facts-about-the-citys-water-treatment-plants/.

Sensitivity to Water Levels and Outflows: During the LOSLRS, the general findings for the Lake Ontario and upper St. Lawrence River were that most water levels within the historical ranges could be managed by existing water supply facilities (LOSLRS, 2006). Under extremely low water conditions, the reduced depth of water above intakes leads to reduced plant capacity and this has been identified as a concern for some facilities, particularly in the upper St. Lawrence River. There is also the possibility that taste and odor problems increase under low water conditions, although there are likely other factors that would also contribute to such problems. Under high water conditions, water supply and wastewater infrastructure can be at risk of inundation which reduces service capacity. One particular issue raised in the past on Lake Ontario was the need to sandbag a Monroe County Water Authority pumping station to protect against flooding (LOSLRS, 2006).

On the lower St. Lawrence River, water supply issues relate to taste and odor, frazil ice and reduced intake capacity and these are primarily associated with low water conditions. Three of thirty utilities identified capacity limitations under low water levels. Wastewater treatment plants and outflows can be susceptible to high water conditions but, based on survey results conducted during the LOSLRS, they were not considered overly sensitive and found to be marginal in comparison with the other performance indicators so no high water performance indicator was developed in this category (LOSLRS, 2006).

Summary of Observed 2017 Impacts: High water levels on both Lake Ontario and the St. Lawrence River in 2017 led to some direct impacts for municipal water supply. For example, the Monroe County Water Authority noted that levels were within 1-2 feet of flooding some critical potable water supply infrastructure. Elsewhere in the system and, based on follow up with a number of US water treatment operators, there were also impacts to operations including increased lift station infiltration. While these direct impacts are noteworthy and directly impacted a number of users, the information currently available to the GLAM Committee suggests that most of the larger municipal systems and the millions of customers they serve remained operational throughout 2017 and were generally able to handle the extreme conditions, albeit with adaptive responses in some cases that included sand-bagging. Detailed information is still limited in some areas, particularly on the lower St. Lawrence River, and it is possible that there were impacts that the GLAM Committee is not currently aware of.

On the wastewater side, high water levels created additional operational challenges and caused damages in some areas. In New York, responses from 31 wastewater treatment plants were logged and of those, six reported some degree of negative impacts to plant operations. The most commonly reported impact was storm water infiltration leading to combined sewer overflows and sanitary sewer overflows which could have been the result of high precipitation and runoff and not a direct impact of water levels. Sodus Point in particular reported some sandbagging requirements to protect some lift station facilities. There were also reports of excessive pump operation requirements in the towns of Sodus Point, Clayton and Ontario, NY. In addition to these impacts, a number of operators also reported an increase in the frequency of times when untreated sewage was released and partly attributed that to a higher amount of infiltration into the sewage system due to high water levels. It is unclear, based on the current responses, what other factors (such as excessive precipitation) contributed to those incidences. The City of Hamilton, ON noted that high lake levels reduced the capacity of some of their combined sewer overflow tanks as they were submerged by lake water, particularly their Strachan and Eastwood facilities (City of Hamilton, 2017). There were also many examples where drainage (sewer) capacity was reduced in low lying areas immediately adjacent to the shoreline, requiring operational investments by municipalities (e.g. portions of Sodus Point, Monroe County, Niagara-on-the-Lake, Hamilton, Toronto, etc.).

The GLAM Committee has not yet identified any locations where primary wastewater treatment facilities could not be operated due to the high water conditions. Detailed information is still limited in some areas, particularly on the lower St. Lawrence River, and it is possible that there were impacts that the GLAM Committee is not currently aware of.

Information on impacts to industrial water users is not readily available at this time and information on impacts to self-supply domestic water users is limited. Certainly, there were reports of impacts to shore wells and septic systems (both inundation and erosion of leach beds) and this was reported through the responses received to an online, self-reporting questionnaire distributed to property owners by Conservation Ontario (see box below; Figures 5-2 and 5-3). Based on the on-line questionnaire results, impacts to shorewells were reported most predominately in Prince Edward County and Lennox and Addington County on the Lake Ontario shoreline within the Province of Ontario and in Jefferson and Monroe counties on the New York shoreline. While the reported numbers were higher in the US, a larger percentage of Canadian respondents reporting impacts to shore wells. The GLAM is not able to quantify the extent of those impacts at this time as the GLAM surveys do not represent a statistically representative sample and it was not possible for the GLAM Committee to determine if the impact was directly related to high water levels, or caused by the excessive rain, runoff and high groundwater tables.

Further information on Lake Ontario-St. Lawrence River municipal and industrial impacts can be found in Annex 1-Impact Assessment of this report. There are still gaps in available information and the GLAM Committee is gathering further data from municipal and industrial operators. That work is expected to be completed by April 2019.

SHORELINE PROPERTY OWNERS IMPACTS

In 2017, the GLAM Committee initiated a process to help gather information on impacts from high water conditions on shoreline property owners. The GLAM Committee effort complemented and extended a previous **independent** survey effort undertaken by the New York Sea Grant and Cornell University for the New York shoreline earlier in 2017 (New York Sea Grant and Cornell University, 2018). For the GLAM Committee effort, the IJC contracted Conservation Ontario to develop and implement an on-line, self-reporting questionnaire that property owners could complete (based in part on questions used previously in the New York Sea Grant and Cornell Survey). The questionnaire was designed to gather information on the type and extent of shoreline impacts. Conservation Ontario provided a brief project summary and the GLAM Committee often refers to this as the Conservation Ontario survey. However, the GLAM Committee has continued to work with the results for analysis and reporting purposes and is the basis for a number of maps and graphs in the impact assessment sections of this report.

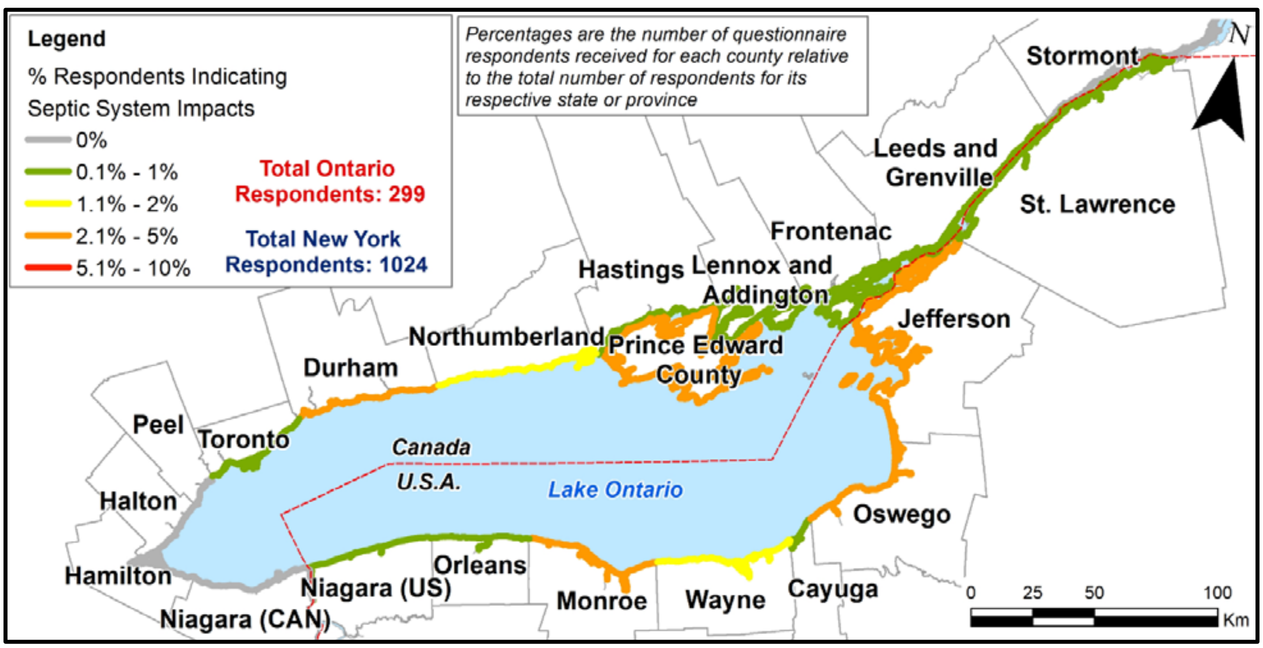


Figure 5-2: Percent of survey responses indicating septic flooding (shown as a relative % by County relative to total number of that reported impact for Country) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

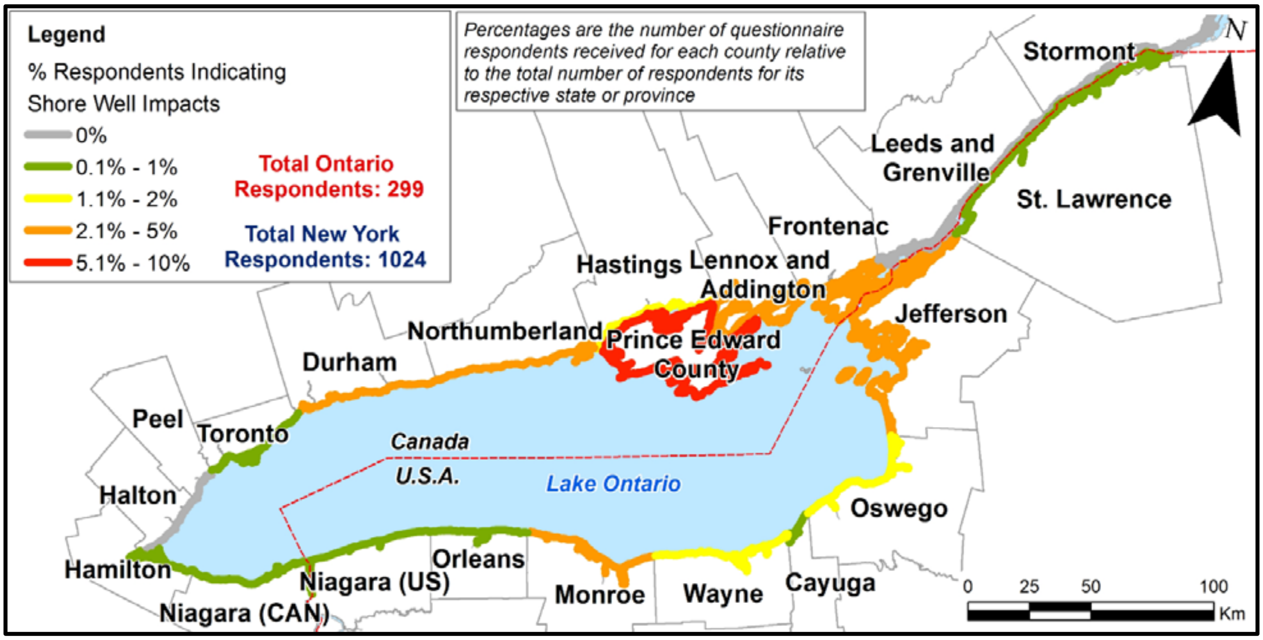


Figure 5-3: Percent of survey responses indicating shore well flooding (shown as a % by County relative to total number of that reported impact for Country) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Model Assessment: Based on the information and performance indicators developed during the LOSLRS, the vast majority of municipal water supply and wastewater services would be expected to remain operational during high water levels within the historical range. Water levels exceeded historic maximums in 2017 but, based on the limited preliminary information available (mainly from direct follow up with a few operators from the US shoreline), it appears that the vast majority of service on Lake Ontario was able to be supplied in 2017, which is consistent with the conclusions in the LOSLRS. However, there were reports of specific operational challenges and adaptive responses in some locations, as well as more general challenges with drainage in low lying areas serviced by municipal sewer networks on Lake Ontario that are not captured in the current performance indicators and require further assessment by the GLAM Committee to determine whether they should be represented in the impact models, and if so, how. In addition, 2017 conditions may shed light on potential high water impacts to self-supply domestic water users that were not captured in the impact models developed during the LOSLRS. It is expected that similar issues would have been observed on the lower St. Lawrence River, but the GLAM Committee has little information available for lower St. Lawrence River impacts at this time. Efforts are underway to initiate a contract to survey a number of municipal and industrial facilities on both Lake Ontario and the St. Lawrence River and gather further information in support of longer-term GLAM Committee activities. The GLAM Committee has little validation information available regarding industrial water users and it is not yet clear how that gap will be filled. Once gathered, further processing and review of the impact information is needed before a full comparison can be completed between results from the existing models and observed conditions.

Key Findings and Next Steps: Based on the limited information currently available to the GLAM Committee, there were impacts and operational responses required in a number of locations on Lake Ontario and the St. Lawrence River due to high water levels in 2017 that caused direct impacts to some users. However, users of larger municipal water and wastewater systems were able to rely on the necessary services in 2017 despite the extreme high water conditions. Less information is currently available regarding self-supply residential users and industrial users. Based on responses to the self-reporting survey, impacts in those categories were not evenly distributed along the Lake Ontario shoreline.

There were no reported impacts to industrial water users due to the 2017 events, but this is not to say there weren't any. Industry responses to enquiries were incredibly sparse. It is not conclusive to say that the handful of responses indicating no impacts is an accurate representation of the entire industrial community on Lake Ontario and the St. Lawrence River.

The performance indicator for evaluation of municipal and industrial water users on the Lower St. Lawrence River is "based on the cost of upgrading municipal drinking water treatment plants to treat taste and odor compounds" and "based on costs required to adapt plants to lower than critical levels" and while no high water level concerns were expressed for water treatment plants, high water levels were suspected to have an impact on wastewater treatment plants in the case of floods. Even in this situation, most of the wastewater outfalls on the St. Lawrence River are equipped with check values protecting them from backflow (LOSLRS, 2006 - Annex 2). Information on the costs of any plant upgrades or renovations was unattainable from 2017, highlighting the challenges in assessing impacts to this sector. Given the lack of data for this sector, the GLAM Committee is seeking to collect information from municipal and industrial operators on the Lake Ontario – St. Lawrence River system on impacts and thresholds associated with 2017 conditions to support long-term adaptive management activities.

5.3 Commercial navigation

Commercial navigation captures domestic and international fleets of bulk carriers, tankers, barges and other commercial ships transporting goods in the Great Lakes-St. Lawrence Seaway system (IUGLS, 2012; IJC, 2014) as well as ocean-going vessels that call on the Port of Montreal (Figures 5-4 and 5-5). There are four key geographical sections that are considered for commercial navigation: the upper Great Lakes from Lake Erie above the Welland Canal through to Duluth, MN on Lake Superior; Lake Ontario (and the Welland Canal connecting Lake Erie to Lake Ontario); the Lake Ontario Section of the St. Lawrence Seaway to Montreal (Montreal Harbour to Lake Ontario); and the St. Lawrence Navigation Channel (Port of Montreal to Trois-Rivières) which can accommodate ocean-going vessels larger than those that can transit the Seaway. An estimated 237,868 jobs and $35 billion in economic activity have been attributed to the Great Lakes-St. Lawrence River system (not including the economic benefits of container movements to and from the Port of Montreal to overseas markets) (Martin and Associates, 2018). Commerce transiting the St. Lawrence Seaway portion (Lake Erie to the Port of Montreal) supported 92,661 jobs and $12.9 billion in economic activity. The Port of Montreal is the highest volume container port in eastern Canada and one of the fifteenth largest in North America. This port handles more than 35 million tons of cargo annually and over 1.2 million Twenty Foot Equivalent Units (TEUs) containers (Port of Montreal, 2018). The Port of Montreal supported 2,673 direct jobs in 2017 (Martin and Associates, 2018)

During the IUGLS, in consultation with experts of the Great Lakes -St. Lawrence River navigation community, the IJC concluded that the current Lake Superior outflow regulation plan, Plan 2012, would provide additional economic benefits in terms of transportation costs to commercial navigation interests. The plan was compared under a wide variety of wet and dry water supply conditions with the old regulation plan (Plan 1977A) and was found to provide a more robust plan that performed better under a wide range of potential future water supply scenarios. During the LOSLRS, the IJC, in consultation with experts of the Great Lakes -St. Lawrence River navigation community, concluded Plan 2014 would provide about the same benefits as Plan 1958-DD by including rules to support adequate levels for full-draft ships at all points in the navigation channel, from Lake Ontario to Lake Saint-Louis. It would also maintain about the same transportation costs related to the need to light-load ships as a result of limited draft depths during low water levels and similar costs related to delays from high velocities during high outflows.

Figure 5-4: Port of Montreal. Photo credit: Montreal Port Authority, 2012.

Figure 5-5: Map of the Great Lakes –St. Lawrence Seaway

5.3.1 UPPER GREAT LAKES – Commercial navigation

Sensitivity to Water Levels and Outflows: Outflow regulation under Plan 2012 affects water levels and flows throughout the upper Great Lakes system, most notably in the St. Marys River and including the “Rock Cut” channel on the west side of Neebish Island, south of Sault Ste. Marie, MI where water levels are particularly sensitive to changes in outflows from Lake Superior as well as low water periods that occur during relatively dry periods (Figure 5-6). Commercial navigation is particularly sensitive to low water conditions, which can require reduced navigation speeds and draft and a reduction in cargo carried. The shipping industry in the upper Great Lakes generally benefits from higher levels, as ships can carry more cargo with fewer trips. The above average water levels throughout the Great Lakes-St. Lawrence system in 2017 should, therefore, have been generally beneficial to commercial shipping, but this is only when moderately high water levels are observed, as was the case for the upper Great Lakes in 2017. Impacts increase with more extreme levels and several expensive mitigation measures must be imposed to maintain safe navigation, as was experienced on the lower part of the system on Lake Ontario and the St. Lawrence River in 2017, but not on the upper Great Lakes. Higher water levels also can damage and disable loading/unloading facilities and impact safe operation of navigation locks if levels reach the top of approach walls or lock gates (IUGLS, 2012).

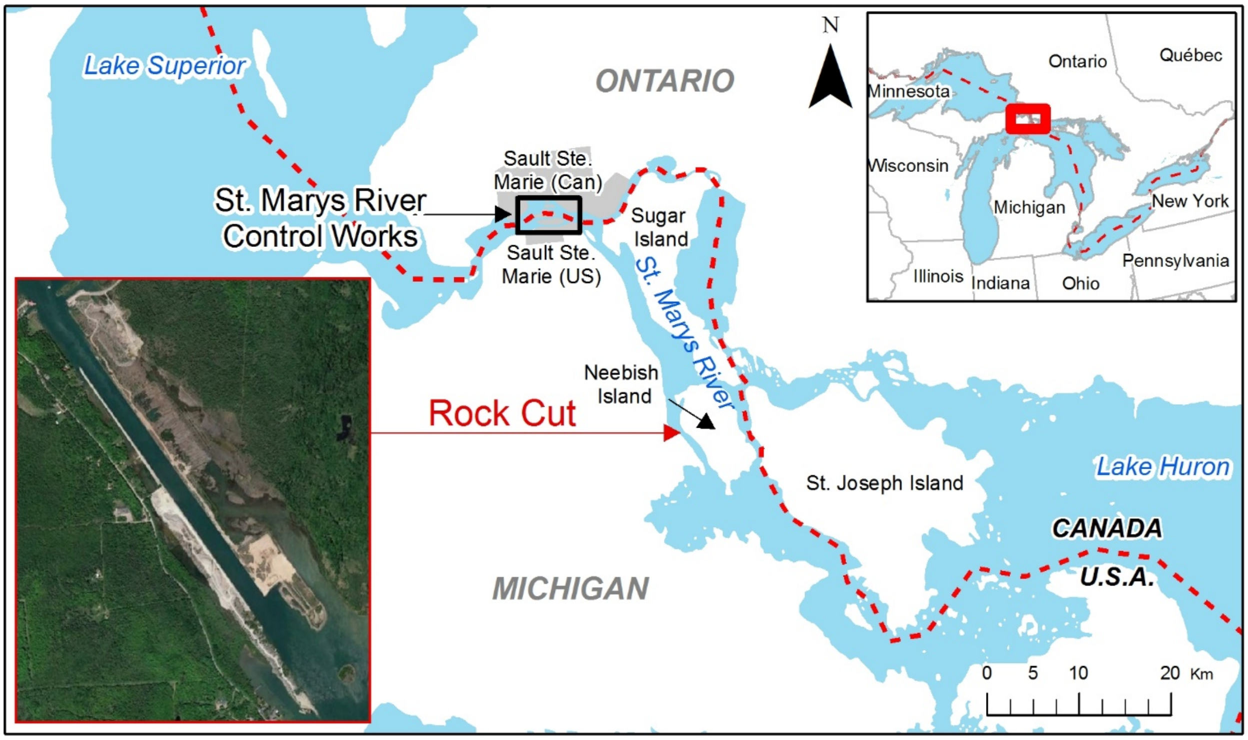


Figure 5-6: Location of “Rock Cut” leading into the St. Marys River (Source: ECCC)

Summary of Observed 2017 Impacts: The year 2017 saw higher water levels on all the Great Lakes. On the upper Great Lakes, a particular area of concern for shippers is typically the St. Marys River and Rock Cut (Figure 5-6). Flow, velocity and depth may limit the carrying capacity in these locations more so than the dock depths, however there were no impacts on the upper portion of the system found in 2017.

Table 5-1 compares the monthly freight tonnage passing through the St. Marys Falls Canal for 2016 and 2017. Single trip tonnage records were set in August and September 2017 at the Soo Locks. These higher monthly tonnages were mostly a result of the economic demand for raw material and not a direct result of higher water levels; however, the higher water levels provided the opportunity for the single trip tonnage records to occur. Had levels been below chart datum, the tonnage records would not have been set.

Table 5-1: Freight Tonnage moved through the St. Mary Falls Canal in 2017 (Source: US Army Corps of Engineers, Detroit District, Soo Area Office)

Freight Tonnage moved through the St. Marys Falls Canal			
Month	**2016 Net Tons**	**2017 Net Tons**	**Increase/Decrease**
March	999,703	1,423,568	423,865
April	6,214,977	7,045,959	830,982
May	7,159,615	8,125,048	965,433
June	7,540,657	8,552,164	1,011,507
July	7,236,489	8,692,701	1,456,212
August	7,446,741	8,645,393	1,198,652
September	7,789,090	8,946,754	1,157,664
October	7,315,668	7,676,940	361,272
November	6,844,907	7,882,489	1,037,582
December	6,783,280	7,076,676	293,396
January	2,148,641	1,264,176	-884,465
Total	67,479,768	75,331,868	7,852,100

Model Assessment: During the IUGLS, an economic performance indicator was developed for commercial navigation based on shipping costs along each route at different depths in each calendar month. Coping zones were also developed for the interest based on “ideal conditions” for the shipping industry (Zone A) and those at which the impact from changing water levels would begin to arise. These coping zones were developed on a lake-wide scale (one for each upper Great Lake) and for the southwest pier of Lake Superior (St. Marys River). Based on this assessment, the levels and flows experienced during 2017 were expected to provide generally positive conditions for shipping and were within the “A” coping zone and range of water levels the shipping industry would find tolerable.

The USACE Detroit District maintains a database to track tonnage passing through the Soo Locks. The GLAM Committee members are working with the Soo Lockmasters and USACE Federal Navigation team to collect monthly tonnage data and historic annual tonnage data to compare to lakes Superior and Michigan-Huron water levels (with respect to chart datum). In order to capture some of the inter-lake shipping routes, federal harbor data can be gathered from the USACE Detroit District Operations Office and Federal Navigation team to determine which docks are most susceptible to varying water levels. A quick analysis of the monthly tonnage data and water level data from the past six years is shown in Figure 5-7. Note the slight increase in tonnage in 2014, which followed a number of consecutive low water years (2000-2013).

Although this is a narrow dataset (only six years), it is unlikely that regulated water levels are the main determinant of shipping traffic through the Soo Locks. There are economic and market supply and demand factors to be considered. Was there a high demand for a specific commodity in 2014, for example? Was there an economic reason? Further analysis of general sector trends would be prudent for commercial navigation.

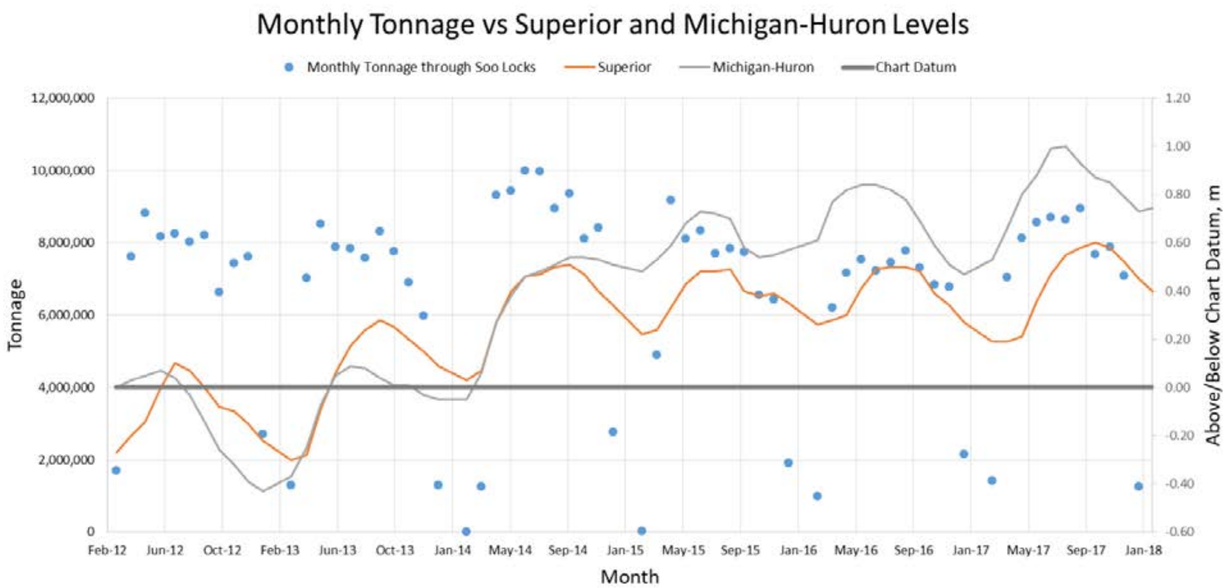


Figure 5-7: Monthly tonnage on Lake Superior and Lakes Michigan-Huron (Source: USACE, Detroit District)

The GLAM Committee was already considering the need for a new model of shipping costs, largely because the data used to develop the previous IUGLS performance indicators are outdated and do not capture the technological advances on some ships which allow them to transit more efficiently and safely. As well, navigation impacts in one area can have corresponding or related effects elsewhere in the system, so a system-wide model to replace the existing separate Lake Ontario – St. Lawrence and upper Great Lakes models makes sense.

Key Findings: On the upper Great Lakes, 2017 levels were within the "A" coping zone which means that the commercial docks inventoried during the IUGLS had sufficient dock depths and dock heights for ship accessibility. Levels during 2017 ranged from 45 cm (1.5 ft) to 1.2 m (4 ft) above chart datum across the upper Great Lakes which is within the criteria for increased water levels while maintaining minimum dock heights. The one exception was at the Detroit River where the reported three-foot increase in level would be acceptable for 96% of the docks. Levels on Lake St. Clair (the Detroit River reference point) were 0.76 m to 1.2 m (2.5-4 ft) above chart datum which would mean some docks inventoried during the IUGLS would be inaccessible due to flooding. However, there were no reports of such incidents. It is possible that the reference point of Lake St. Clair may be too conservative and needs to be replaced with Low Water Datum elevations for the Detroit River, specifically. Further investigations will occur in the future. As well, as discussed in the model assessment section, a full Great Lakes-St. Lawrence River commercial navigation model should be considered.

5.3.2 LAKE ONTARIO-ST. LAWRENCE RIVER – Commercial navigation

Sensitivity to Water Levels and Outflows: Outflow regulation under Plan 2014 affects water levels and flows throughout Lake Ontario - St. Lawrence River system downstream to about Trois- Rivières, and commercial navigation occurs and is affected by these conditions throughout this area, including the Montreal to Lake Ontario (MLO) portion of the St. Lawrence Seaway and at the Port of Montreal. Commercial navigation is particularly sensitive to low water conditions, which can at times require reduced navigation speeds and draft reductions, which result in reduced cargo carried and increased costs. Therefore, critical commercial navigation priorities on the Lake Ontario - St. Lawrence River system include the need to reduce the risk of low water levels throughout the system and maintain the continued ability of the board to accommodate, as necessary and when conditions permit, transit of particular vessels through short-term minor deviations. The stability and predictability of water levels, high or low, can also be a critical factor, particularly in the St. Lawrence River, as loading decisions are sometimes made weeks in advance for international vessels arriving in the Port of Montreal and those transiting the Seaway. Stable and predictable levels help to minimize risks of groundings, loss of control, collisions, oil/chemical spills and issues related to safe transit velocities. In terms of high water impacts, high levels typically result in higher outflows and velocities in the St. Lawrence River, which can also be a serious concern to commercial navigation due to increased risks (of groundings, loss of control, collisions, oil/chemical spills) and issues related to safe transit velocities. If water levels at Iroquois Lock were to reach 75.61 m (248 ft.), the lock would be flooded, and its operation would no longer be possible, stopping shipping until levels fall below this threshold.

Summary of Observed 2017 Impacts: The year 2017 saw the highest flows ever recorded over a sustained period of time on the St. Lawrence River. These flows required the shipping industry to take exceptional measures to ensure safe transit and prevent a shutdown of the Seaway. High water level problems which lead to velocity issues in portions of the Seaway have been a concern in the past and were among the primary issues during the 2017 record high water level conditions (with record outflows of up to 10,400 m^3/s). As Lake Ontario levels declined and high flows remained, the Seaway was also concerned with low levels in Lake St. Lawrence.

The biggest commercial navigation impact in 2017 related to the exceptional flows in the St. Lawrence River and the implementation of a series of mitigation measures (i.e., restrictions imposed and services added by the Seaway to ensure safe vessel transits could continue despite the challenging conditions). These measures included:

- speed restrictions between Iroquois Lock and Tibbets Point (imposed starting 2 May)
- caution that fenders on approach wall at Iroquois Lock may not be visible (3 May)

- additional speed restrictions for the St. Lawrence River from Lake Saint-Louis to Lake Ontario (8 May and 15 May)

- no meeting or passing permitted in critical areas (American and Brockville Narrows, Wiley-Dondero Canal; 16 May revised 19 May)

- request to exercise caution when navigating in areas of high cross currents (Galop, Toussaint and Ogden Islands, Copeland Cut and Polly's Gut; 16 May)

- request for mariners to operate at the lowest safe speed to minimize wake, particularly near shoreline areas (16 May)

- zero tolerance for ships' draft in excess of the maximum permissible draft and reminder to operate at the lowest safe speeds to minimize ship wake, particularly when navigating close to shore (13 June)

- a number of transit requirements (13 June), including:
    - requirements that all ships equipped with a bow thruster shall have the bow thruster operational when transiting the Montreal to Lake Ontario section of the Seaway;
    - all Tall Ships and Tows (Tug/Barge) transiting the Montreal to Lake Ontario section of the Seaway shall be capable of making a minimum of 8 knots through the water;
    - no transits of Dead Ship tows permitted; and
    - ships unable to transit safely at these flows may be subject to transit restriction

- assignment of ship inspectors to mission-critical navigation monitoring (13 June), cancelled (23 June)

- modifications to critical areas identified as no meeting or passing zones (American and Brockville Narrows and Wiley-Dondero Canal; 13 June)

- tug assisted ships at Iroquois lock as and when requested (14 June)

- no ship meets downstream of Beauharnois Lock 3 (14 June) due to high outflows from Pointe des Cascades control dam and the increased cross-currents

- request to exercise caution when navigating in additional identified critical areas in the vicinity of Cardinal and Canada Island (20 June)

- draft reduction to 8.0 m for upbound vessels in the Montreal to Lake Ontario (MLO) section (27 June)

Table 5-2 provides a list of the mitigation measures taken and the timeline for implementation, while Figure 5-8 illustrates Lake Ontario water levels and outflows during the period that mitigation measures were in effect.

Table 5-2: Timing of Seaway Imposed Mitigation Measures

SEAWAY-IMPOSED MITIGATION MEASURE	DATES IN 2017 MEASURE WAS APPLICABLE (NOTE: only key dates included here to shorten timeline illustration)																						
	5/2	5/3	5/7	5/8	5/14	5/15	5/16	5/18	5/19	6/12	6/13	6/14	6/20	6/22	6/23	6/27	7/23	7/24	8/10	8/11	8/22	9/14	10/2
Speed restrictions Iroquois Lock to Tibbets Point	■	■	■																				
Notice that Iroquois Lock fenders may not be visible		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Further speed restrictions (South Shore Canal to Tibbets Point)				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Further speed restrictions (Brockville Narrows to Prescott)						■	■	■	■	■	■	■	■	■	■	■	■	■					
No meeting/passing in critical areas							■	■															
No meeting/passing in critical areas (revised)									■	■													
No meeting/passing in critical areas (revised)											■	■	■	■	■	■	■	■	■	■	■		
Caution for navigating in high cross current areas							■	■															
Caution to minimize wakes							■	■															
Reminder to minimize wakes											■	■	■	■	■	■	■	■	■				
Zero tolerance for exceeding maximum permissible drafts											■	■	■	■	■	■	■	■	■				
Bow thrusters must be operational											■	■	■	■	■	■	■	■	■	■	■	■	
Tall Ships & Tows capable of 8-knot minimum											■	■	■	■	■	■	■	■	■	■	■	■	
No Dead Ship tows											■	■	■	■	■	■	■	■	■	■	■	■	
Transit restricted for ships unable to transit safely											■	■	■	■	■	■	■	■	■	■	■	■	
Ship inspectors reassigned to monitor navigation											■	■	■	■									
Tug assisted ships at Iroquois lock as and when requested												■	■	■	■	■	■						
No meets downstream of Beauharnois Lock 3 (high outflows/cross-currents)												■	■	■	■	■	■	■	■	■	■	■	■
Caution for strong currents Cardinal to Canada Island													■	■	■	■	■	■	■	■	■	■	■
Upbound draft reduction to 8.0 m																■	■	■	■				
Lake Ontario water level (m IGLD 1985)	75.58	75.59	75.74	75.76	75.84	75.85	75.85	75.87	75.86	75.82	75.81	75.80	75.77	75.76	75.80	75.80	75.65	75.66	75.50	75.49	75.37	75.09	74.92
Lake Ontario outflow (m3/s)	7250	7010	6210	6390	7910	8320	8720	9210	9260	10190	10210	10290	10400	10400	10420	10390	10390	10390	9880	9920	9870	8960	8620

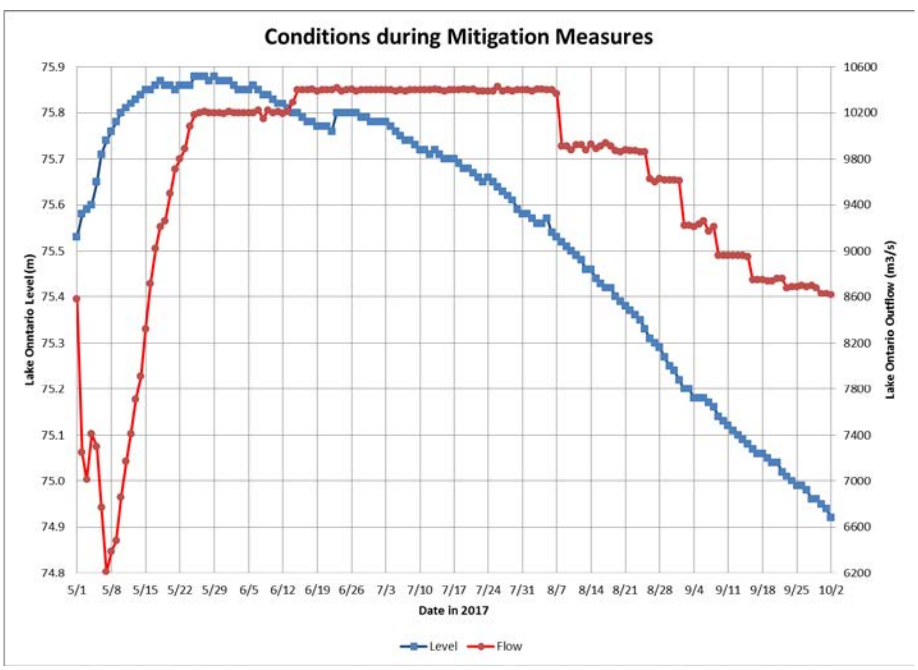


Figure 5-8: Graph showing Lake Ontario water levels and outflows during the period that mitigation measures were in effect.

These mitigation measures resulted in the maintenance of safe navigation in more challenging conditions. Decreased maneuverability, ship speed management and increases in ship rental costs were the main impacts to the trade. Fuel costs also went up as a result of the delays. In their report on “Navigation at High Flows – 2017”, the St. Lawrence Seaway Management Corporation (SLSMC,2018) reported that transit times increased by two or more hours from the typical 24-hour upbound transit or 22-hour downbound transit times through the MLO section, as ships took the necessary precautions to safely navigate the system (especially during the period when flows were 10,200 m^3/s or higher). Iroquois Lock proved to be the most impacted by the high flows as vessel approaches to the lock both downbound and upbound were considerably more difficult. The tug that was made available for assistance was used on a regular basis, either assisting with the use of lines or simply being on stand-by in the event it was needed. Sixty-one percent of vessels requested tug assistance, with more requests by downbound vessels.

Another impact, albeit a lesser one, was the reduced number of “walk-throughs” performed at Iroquois Lock (i.e., ships moving through the locks without the use of mooring lines). Typically, there are approximately 1500 walk-throughs per year at Iroquois, but in 2017 there were only 72 recorded walk-throughs (all in March and April, prior to the higher flows). This translated to slower lockage time as lock personnel had to secure mooring lines. There was also reduced availability of ship inspectors for ship inspections due to their reassignment to the critical command center in the SLSMC Operations Center from 13 to 23 June, so that a marine officer would be on duty at all times. Nevertheless, despite the mitigation measures imposed and the challenging conditions many ships faced in 2017, the St. Lawrence Seaway reported 4,119 vessel transits, up nine percent from 2016. Total cargo transported was also up almost nine percent from 2016 (Table 5-3).

The Port of Montreal had some minor impacts from the high water levels, most notably some pavement and concrete were damaged at the port due to inundation and erosive action during the spring. As well, some ships needed to be moved around the port to avoid their hulls riding up onto the docks. Power to many docks had to be cut as a safety measure from 7 to 17 May 2017, when water levels reached +3 m (+9.8 ft) above chart datum at Pier 1. Despite these impacts, the Port of Montreal generally benefited from the high water levels, reporting record loads of 37.8 million tons (Mt) in 2017. This broke the previous record, set in 2016, of 35.4 Mt.

Table 5-3: Statistics on commercial navigation traffic through the Seaway (Source: St. Lawrence Seaway Management Corporation, 2017)

SEAWAY MONTHLY TRAFFIC RESULTS
December 2017

Traffic (in thousands of tonnes)	SLSMC - Combined Traffic			
	Year to Date		Change from 2016	
	2016	2017	Tonnes	%
Total Cargo	35 010	38 121	3 111	8.89%
All Grain	11 266	10 069	-1 197	-10.62%
Iron Ore	6 233	8 039	1 806	28.97%
Coal	2 248	2 257	9	0.40%
Dry Bulk	8 892	10 485	1 593	17.92%
Liquid Bulk	3 685	3 790	105	2.85%
General Cargo	2 628	3 426	798	30.36%

Vessel Transits	2016	2017	Transits	%
Total Transits	3 774	4 119	345	9.14%

The St. Lawrence Seaway Management Corporation

Model Assessment: High velocities in the Seaway between Ogdensburg and Long-Sault would be expected under conditions such as those experienced in 2017 as would variable water levels at different points in the river due to the high discharges. In the existing commercial navigation model, such conditions would result in an increase in transportation costs through the system (a negative impact) due to increased fuel usage, longer transit times and in some cases reduced loading capacity. The record water level and flow conditions of 2017 offered a rare opportunity to measure ship performance and impacts to commercial navigation under high channel velocities on the St. Lawrence River. Mitigation measures taken by the shipping industry in 2017 all relate to transportation delays/costs. Mitigation measures taken by the industry due to high velocities and the associated costs of such measures could help in the development of a new system-wide commercial navigation model. An updated model would allow for further assessment of the existing Plan 2014 L-Limit rules established for safe navigation and additional discussion is included in the Annexes to this report. It is not yet clear if a performance indicator using transportation costs will be possible because impacts to individual shipping companies and cargo owners are not readily available in a form that can be shared. Mostly due to the fact that these results concern highly proprietary details on business contracts and commercial trade patterns. It may be that some other metric is necessary and further work on this will be required.

Key Findings: While commercial navigation experienced impacts due to high velocities on the St. Lawrence River, they also were able to tolerate higher flows than expected or than had ever occurred before without shutting down navigation. Overall, despite mitigation measures, it was a very productive year for the commercial navigation sector, largely due to economic demand.

The GLAM Committee did not validate the model using the 2017 level and flow data to measure how well it estimated shipping impacts in these extraordinary conditions but may do so in the future as part of an effort to improve the navigation model.

The data used to develop the transportation cost performance indicator for commercial navigation on Lake Ontario and the St. Lawrence River is out of date and needs updating/modifying and this should be considered a high priority. In order to accomplish this, the GLAM Committee intends to review the transportation cost performance indicator based on information gained in 2017 to update the performance indicator for the shipping sector. As noted in the model assessment section, it is not yet certain if transportation costs will be possible due to highly proprietary details on business contracts and commercial trade patterns. It may be that some other metric is necessary and further work on this will be required.

5.4 Hydropower

The hydropower generation interest represents “owners/operators of the hydroelectric generating stations on the Great Lakes-St. Lawrence River system and the value of energy produced”. On the upper Great Lakes, there are two hydropower generating stations located on the US side of the St. Marys River, at Sault Ste. Marie, MI – the US government and Cloverland Electric Cooperative (CEC) stations. There is one station on the Canadian side, the Francis H. Clergue Generating Station, owned and operated by Brookfield Renewable Energy, Inc., at Sault Ste. Marie, ON. The three stations on the St. Marys River have a combined capacity of about 115 MW. The IJC’s Orders of Approval govern use of water by hydropower stations along the St. Marys River and the IJC’s ILSBC ensures outflows are released from Lake Superior in accordance with these Orders.

Further down the system there are three hydropower plants located on the Niagara River separating the upper Great Lakes from Lake Ontario because of the Niagara Escarpment. The Robert Moses dam (owned and operated by NYPA) is located at Lewiston, NY and has a total generating capacity of about 2675 MW (Figure 5-9). On the Canadian side, Sir Adam Beck 1 and Sir Adam Beck 2 generating stations (owned and operated OPG) are located across the border at Queenston, ON and have a total generating capacity of about 2,000 MW. These stations generate much more electricity than those on the St. Marys River because of the higher head made possible by the drop over the Niagara Escarpment and the higher flow of the Niagara River. Several smaller generating plants, with a total capacity of about 180 MW, also use the waters of the Welland Canal. The amount of water available for the plants on the Niagara River and Welland Canal depends on Lake Erie’s level and its outflow as well as the Niagara River Treaty of 1950.

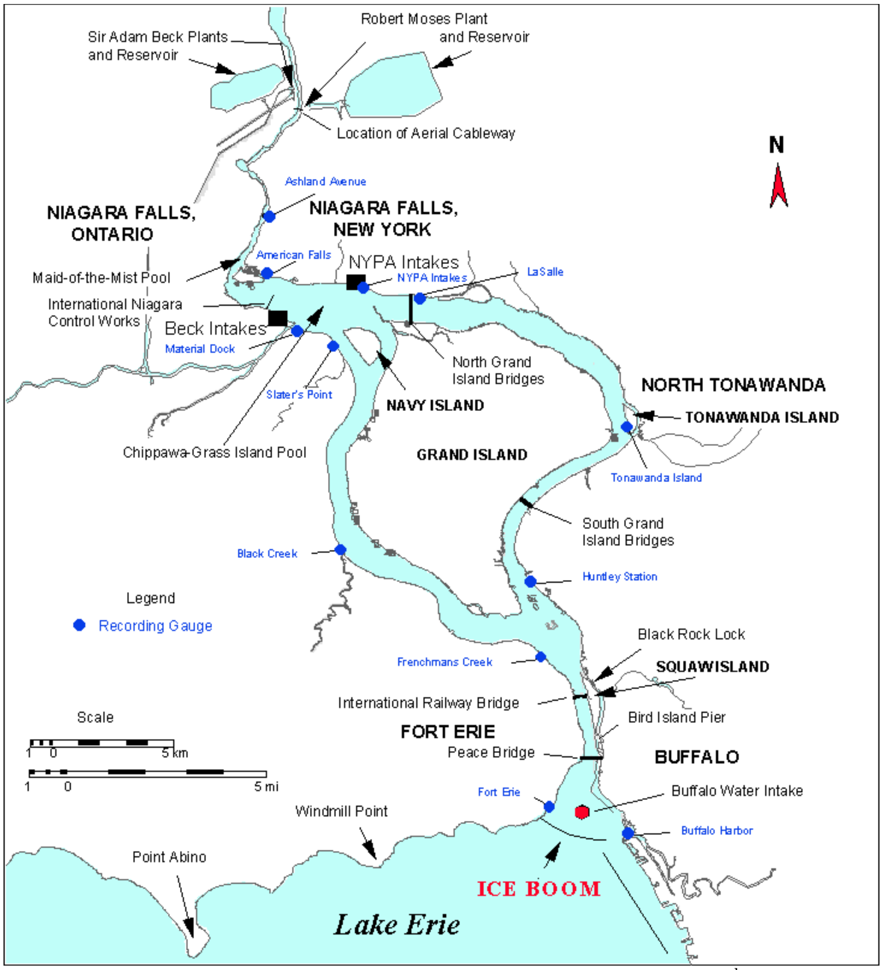


Figure 5-9: Locations of Beck and Moses Dams (Source: INBC 130th Semi-annual report: 28 March, 2018)

Moving down the system, two hydroelectric generating stations are located on the international section of the St. Lawrence River located between Massena NY and Cornwall ON, including the Robert Moses station owned and operated by the NYPA and the Robert H. Saunders station owned and operated by OPG. Together, these stations are known as the Moses-Saunders Dam. Further downstream at the outlets of Lake St. Francis are the Beauharnois and Les Cedres stations of Hydro-Quebec (IJC, 2014). Combined, these power plants have a generating capacity of 3820 MW (1957 MW at the Moses-Saunders and 1853 MW at Beauharnois-Les Cedres) and produce enough energy to meet the needs of about two million homes.

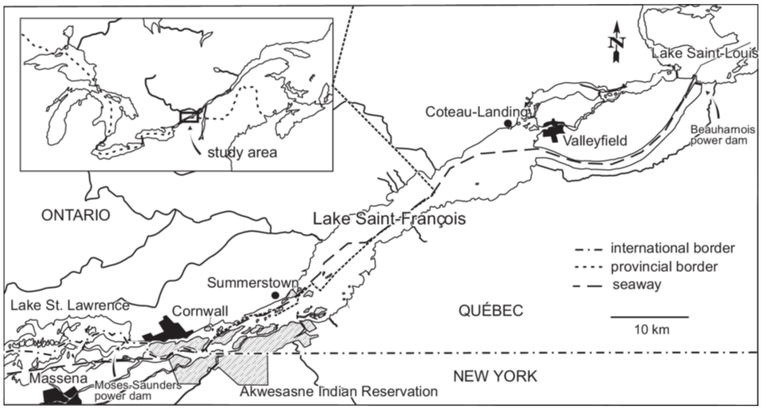


Figure 5-10: Locations of Moses-Saunders and Beauharnois Dams (Source: ECCC)

5.4.1 UPPER GREAT LAKES - Hydropower

Sensitivity to Water Levels and Outflows: The amount of electricity that the hydropower stations produce depends on available head (*i.e.*, the difference in water levels upstream and downstream of the plants) and the amount of flow through to the stations. In some cases, high water conditions enable hydropower operators to increase power generation. However, very high levels and flows can have adverse impacts on their operations. For example, very high lake levels and corresponding outflows can result in “excess” water diverted through the spillway and thus a missed opportunity to generate additional power due to lack of available hydropower capacity (IUGLS, 2012). Similarly, high water levels downstream, which can be compounded by high flow through a station/spillway, can result in lower headwater and higher tailwater elevations and therefore reduce the operating head on the station and reduce hydropower generation. Low water conditions tend to have greater impact on hydroelectric generation, forcing stations to operate below capacity and reducing revenues (IUGLS, 2012).

Following the IUGLS, it was noted that hydropower plant maintenance activities can also be a cause of reduced hydropower capacity during high water periods, and this can result in large, frequent fluctuations in St. Marys Rapids flow and water levels and unintended and potentially adverse outcomes in the St. Marys Rapids unless strategies can be developed to address them. The effects of Lake Superior outflow regulation on any changes in the Lake Erie levels and Niagara River flows that result from different Lake Superior regulation plans are small, particularly in comparison to the much greater effects of changes in water supply, and Plan 2012 does not have any significant impact on the power generation on the Niagara River.

Summary of Observed 2017 Impacts: Owing in part to multiple other factors, the upper Great Lakes water levels and flows did not have a significant impact on hydropower operations at the Cloverland, Brookfield or US Government plants during 2017, although a significant storm event in late October 2017 did lead to water levels approaching critical levels at the Cloverland plant for a short period of time, requiring a temporary response. Scheduled maintenance at plants and work in the Cloverland Electric Company canal resulted in significant reductions in hydropower capacity which have required reduced flows through the Cloverland plant, as has been the case for multiple years during the recent period of relatively high outflows, which required regulation plan deviations. Maintenance activities at the Brookfield Renewable power plant also resulted in outages which affected regulated outflows. The outages have been analyzed for their impacts to regulated outflows and effects of these outages on the St. Marys Rapids have attempted to be addressed in the Board of Control's deviation strategy. The US Government Plant had no concerns regarding operations and power production at current levels and did not attribute any issues to water levels. They reported their operation is driven by the market and demand for power.

Flows in the Niagara River have experienced an increase beginning in 2015. As a result of the weather conditions seen in the Lake Erie basin during April and May of 2017, the water level of Lake Erie rose quickly at the beginning of May. The impact of the higher water levels were compounded by more frequent and sustained southwest winds pushing water and ice into the head of the Niagara. As a result, the flows in the Niagara River were some of the highest experienced since 1998. Despite these factors, the management of the CGIP and the International Niagara Control Works (INCW) above Niagara Falls resulted in no falls flow violations in 2017. Also, the level of the CGIP is regulated under the INBC's 1993 Directive. The unusual conditions in 2017 did not keep the power entities from operating the INCW to adhere to the requirements of the 1993 Directive. The INBC oversees the operation of the control works by the power entities, and the board has been in communication with the power entities to get feedback on how the high water levels impacted the operation of the control works. Though the increased flows had no overall impact on the regulation of the CGIP and subsequent power production, they did create some challenges with respect to Maid of the Mist Pool levels. The power entities worked with the tour boat operators in the Maid of the Mist Pool to establish a protocol regarding these levels. The power entities made careful considerations of their operations to reduce adverse effects on the water levels in the Maid of the Mist Pool during tour boat operations.

Power entities' compensation rates and mechanisms are confidential, so it is not possible to put benefits and impacts in dollar terms with respect to 2017 conditions. OPG 2017 Public Revenue Statement noted that OPG generated ~ 1TW more energy across all of its facilities in 2017 than 2016. This increase in generation was primarily driven by increased water availability in Eastern Ontario (St. Lawrence, Ottawa and Madawaska Rivers). At the Saunders generating station, OPG generated slightly more energy than forecasted in 2017. However, there was an increase in energy production that did not have a direct economic benefit to OPG. The regulatory framework in which the Saunders generating station operates within prevents OPG from economically benefitting due to any favorable difference between forecast and actual water availability. Similarly, NYPA's St. Lawrence – FDR Power Project generated ~11 percent more energy than forecast in 2017. However, NYPA did not realize an economic benefit from the increased generation due to depressed market prices for the energy. In fact, NYPA's revenue fell by 20 percent between 2016 and 2017.

Model Assessment: A model assessment of the upper Great Lakes was not performed this reporting period. If the hydropower performance indicators are to be used to quantify economic impacts in the future, an updated energy market value analysis should be completed since the existing model uses prices developed during the IUGLS. In addition, the lack of ability to acquire revenue data from hydropower production may mean the performance indicator needs to be revisited.

Key Findings: The upper Great Lakes water levels and flows did not have a significant impact on hydropower operations on the St. Marys River in 2017. The above-average water levels and outflows through the St. Marys River, along with continued maintenance activities in both Canada and the US, resulted in flows available for hydropower production that often exceeded the capacity of the plants and any surplus water was not used for generation and instead was released through the St. Marys Rapids.

A reassessment of the energy market value and the inability to acquire economic information has implications to the hydropower performance indicators moving forward.

5.4.2 LAKE ONTARIO-ST. LAWRENCE RIVER - Hydropower

Sensitivity to Water Levels and Outflows: Outflow regulation affects water levels and flows throughout the Lake Ontario-St. Lawrence River system which, in turn, has impacts on hydropower generation. Hydropower generation is particularly sensitive to low water conditions, which results in decreased generation. The stability and predictability of water levels and outflows can be a critical factor, particularly in the St. Lawrence River, as generation forecasts and market prices are affected by changing conditions and uncertainty of forecasting. Extreme high water supplies and resulting high levels, as were experienced in 2017, can also be a concern due to issues such as increased spillage, head loss, deferral of planned maintenance, increased operations and maintenance and other associated increased costs.

Following the LOSLRS, it was concluded that, under Plan 2014, the slightly higher and more natural seasonal autumn through spring Lake Ontario levels that benefit coastal ecosystems also would slightly increase the hydraulic head and thus, energy production at the Moses-Saunders power plants. Plan 2014 can also slightly increase the amount and value of hydropower produced at the Hydro-Quebec plants, as there tends to be less spillage of water and a higher percentage of the water can pass through the Beauharnois generating station. Although the higher Lake Ontario levels also would slightly reduce the head at the Niagara power plants, the net effect would be to increase the production of hydropower at all these plants by about 0.4%, or enough to supply the needs of about 8,000 homes. During LOSLRS, the primary performance indicator used (as advised by the economic experts) was the increase in the value of hydropower energy caused by a change in regulation plans. In addition, important metrics, termed the stability and predictability of flows, were developed. More-stable releases change less from week-to-week, while more-predictable releases change less from month-to-month. When possible, hydropower producers will take turbines out of production for maintenance only when the water release can be routed through other turbines that remain in service. A large, unexpected release increase may require spilling part of the release (that is, releasing the water but not running it through a turbine to create electricity). Plan 2014 provides slightly more stable and predictable releases, thereby reducing the chance of energy losses during turbine maintenance compared with plan 1958-DD.

Summary of Observed 2017 Impacts: 2017 saw the highest flows ever recorded over a sustained period of time through the Moses-Saunders dam on the St. Lawrence River, resulting in greater than forecasted energy production, but requiring the power entities to take measures to keep units running for extended periods of time to minimize the need for increased spillage of water. The plants were run at full available capacity for months, requiring some important maintenance activities to be deferred to later dates and while additional maintenance cannot be considered a “cost” (as running units more equates to additional compensation from increased power generation), it must be noted that there can be considerable cost overruns when plants are run for extended periods and generating units suffer breakdowns. Additionally, operation and maintenance costs for some activities were higher than initially forecasted due to the higher flow. For example, mobilizing crews to perform extra dam or spillway operations and increased debris clearing in the forebay resulted in higher operating costs in 2017.

Model Assessment: In its 2014 report on Plan 2014, the IJC estimated a market value of the roughly 25 million MWh of energy generated from the hydropower dams on the St. Lawrence River as approximately $1.5 billion USD a year at a market rate of $60/MWh (based on a previous estimate provided by Synapse Energy Economics Inc. in 2005 (IJC, 2006)). It should be noted that 2017 rates in each of the three jurisdictions (New York, Ontario and Quebec) were likely considerably lower than this. GLAM recognizes that this market value estimate is likely overestimated nowadays and will seek updated information if possible. In its 2006 report, the LOSLRS calculated an economic baseline for hydropower under Plan 1958-DD as the economic surplus (i.e., net operating revenues minus economic cost of capital, before deduction of taxes, transfer payments and special pricing) of $250 million USD for Moses-Saunders, and $100 million USD for Beauharnois-Cedars. This calculation does not consider the value of energy that may have been foregone at other sites due to the increase in generation at Moses-Saunders. Since the load did not necessarily increase, the generation at other plants would have decreased. Again, GLAM recognizes that these previous estimates are likely inflated nowadays and will seek updated information with respect to Plan 2014 when performing future plan evaluations. As with the upper Great Lakes, inability to acquire dollar values from hydropower production means the performance indicator needs to be reevaluated by the GLAM Committee moving forward.

Key Findings: Though increases in energy production were realized in 2017 through the Moses-Saunders dam, owing to the high outflows and some periods of increased head at the plant, the hydropower sector also saw some adverse impacts related to the high water, such as losses to production opportunity due to increased spillage of water, increased operating costs, and the need to defer maintenance on various equipment. Future work will require a reassessment of the energy market value and hydropower pricing. Increased flows at hydropower projects resulted in several associated impacts to the hydropower sector. Mobilizing crews more frequently for additional gate operations raised the costs for operations in 2017. Additional gate operations also carry an associated incremental yet immeasurable increase in maintenance costs due to wear and tear on the mechanical and electrical equipment employed to raise and lower the gates.

Due to the inability to collect the data necessary to assess the existing performance indicators, it is necessary to develop a strategy for modifying or replacing the existing indicator. The existing performance indicator is “value to society of energy produced – based on megawatt hours by quarter month, valued using estimated market values for each quarter month of the year” (LOSLRS, 2006). As stated, power entities’ compensation rates and mechanisms are confidential. Without the estimated market values per quarter month, it is not possible to assess this performance indicator with the information available. It will also be useful for GLAM to complete assessment of potential errors in the Long Sault Dam rating curve, including the need for further flow verification measurements. The rating curve should be updated as necessary to improve the accuracy and precision of reported spillage rates.

5.5 Coastal

The coastal impact category is focused on direct impacts to shoreline infrastructure, primarily residential, along the Great Lakes and St. Lawrence River shoreline. The coastal impact sector is defined as individuals and organizations with a direct interest in the property along the shorelines and connecting channels of the Great Lakes and the St. Lawrence River (riparian property), particularly private property owners (IUGLS, 2012; IJC, 2014). During IUGLS, there were an estimated 93,400 properties along the upper Great Lakes shorelines and connecting channels (63,700 in the United States and 29,700 in Canada) (IUGLS, 2012). Based on the 2006 IJC’s LOSLRS report, the Lake Ontario and the St. Lawrence River are estimated to have approximately 25,000 properties directly along or within close proximity to the Lake Ontario and upper St. Lawrence River shoreline and approximately 60% of the Lake Ontario-St. Lawrence River shoreline is devoted to residential land use. Of these, approximately 3,000 are estimated to be located below the elevation of 76.2 m (250 ft) and at risk of flooding (LOSLRS Annex2, 2006). On the lower St. Lawrence River, approximately 5,770 single-family dwellings fall within the 1-100 year flood zone (IJC, 2014). High water levels and wind driven waves which can lead to flooding of property and infrastructure, contribute to accelerated bluff recession rates (erosion) and reduce the lifespan of existing shoreline protection used to stabilize shorelines. Areas of the Great Lakes exposed to large waves are considered open coast shoreline and in those areas, wave action can be a significant contributor to shoreline impacts when combined with high water levels, storm conditions and short-term storm surge. These conditions can contribute to accelerated bluff recession, damage existing shoreline protection, damage and/or destroy homes and other structures on shoreline properties and lead to storm induced flooding which can result in significant damages over the duration of the storm event. Since Great Lakes water levels can remain elevated for prolonged periods of time (weeks to years), multiple storm events can occur during an extended period of high water levels. Low water level conditions typically reduce the threat of flooding for shoreline property owners and can lead to an apparent reduction in bluff recession rates, although the conditions can also lead to increased scouring at the base of bluffs and at the toe of shore protection which can increase vulnerability in subsequent high water periods (Baird, 2004). There can also be low water issues associated with exposure of mudflats, water access issues, etc. (Baird, 2010).

5.5.1 UPPER GREAT LAKES - Coastal

Sensitivity to Water Levels and Outflows: Based on the IUGLS, the IJC concluded that Plan 2012 for the outflows of Lake Superior would provide modest benefits to the coastal interest group based primarily on reductions to the total costs of maintaining shoreline protection in lakes Superior and Michigan-Huron. While this was the primary performance indicator assessed, consideration was also given to high water level and low water level statistics and the robustness of the regulation plan in its capacity to meet particular regulation objectives under a broad range of plausible future hydrological scenarios, including those related to climate change.

Coping zones were developed in the IUGLS to help evaluate regulation plan options by allowing plan formulators to predict the impacts from extreme water levels. Zone A captures a range of water level conditions that the interest would find tolerable, Zone B a range of water level conditions that would have unfavorable though not irreversible impacts on the interest, and Zone C being a range of water level conditions that would have severe, long-lasting or permanent adverse impacts on the interest. The coastal working group further defined zones A, B, and C relative to coastal sensitivities and economics based on US and Canadian sites along the upper Great Lakes (see Table 5-4).

Table 5-4: Summary of coastal coping zones defined by the Coastal Zone Technical Working Group (IUGLS, 2012)

	Zone A	**Zone B**	**Zone C**
Adaptation	Interests should largely be adapted to conditions in this range, having already built some shore protection structures. If levels persist for several years at the extremes of this zone, there is the risk that interests will adapt to a narrower range and neglect or breach shore protection structures or build in locations unsuitable in the long-term.	Adaptation to levels in this zone may be limited and require construction of additional shore protection; structure modification; dredging beyond maintenance dredging; temporary repurposing or temporary loss of use of shoreline or set-back requirements.	Adaptation within this zone may require shore protection and building modifications beyond the means of most; major infrastructure modifications such as moving roads or major structures; permanent loss or relocation at some locations is possible.
Most Vulnerable Hot Spot	Cohesive bluffs with little beach to protect them from high water and storm surge. Places with existing shore protection if these are not maintained or are breached.	Cohesive bluffs with little beach to protect them from high water and storm surge. Places with or adjacent to existing shore protection, that may not be adequate for more extreme conditions.	Cohesive bluffs with little beach to protect them from high water and storm surge. Places with or adjacent to existing shore protection, that may not be adequate for more extreme conditions.
Ability to Recover	Can adapt to and recover from most damages that occur in this range. In some areas, however, there is the potential for significant bluff failure that could result in permanent loss.	Generally able to recover but may have some significant losses due to high water level related erosion. Capital investments made to adapt to this zone may not be able to increase resilience to future Zone B levels.	Some interests may not be able to recover completely, particularly those affected by water level related dune and bluff erosion.
Severity of Net Financial Loss	Generally minimal loss in this range, but potential for significant localized loss if storm surge causes bluff to fail.	May be significant but most are able to pay cost out of revenues, financing and insurance claims.	Substantial losses, in some cases exceeding ability of organizations or individuals to repay. Those that do rebuild likely to require borrowing from future assets to

	Minimal to moderate, depending on cost of maintenance and degree of neglect of existing shore protection.		cover the net costs. May result in request for federal emergency aid.
Suggested Indicators for Assessing Thresholds	Permits for shore protection (USACE/State); media reports of damages; insurance claims; set-back requirements and other local land use regulations.		

Summary of Observed 2017 Impacts: Water levels in all of the upper Great Lakes were above average throughout 2017. Lake Superior was well above average throughout the year and, with the exception of November, remained within 10 cm (3.9 in) of the maximum recorded monthly water level from June to December 2017. This high water level combined with a couple of major storms at the end of October 2017 led to significant coastal flooding and erosion of public and private property. On October 24, the largest wave recorded in the past 30 years occurred near Marquette, MI with offshore wave heights peaking near 9.1 m (30 ft) and measured wind gusts at 124 km/h (77 mph). Examples of some of the impacts are shown in Figures 5-11 to 5-16. There is less information on impacts on the Canadian shoreline but, based on information provided by staff from the Ontario Ministry of Natural Resources and Forestry, there were some local flooding issues where the Chippewa area meets Lake Superior in December of 2017. Otherwise, there were few reports of impacts.

Figure 5-11: Powerful waves from 27-Oct-2017 big storm chewed into the dunes along Lake Superior on Duluth's Park Point between -about 800 and 900 Lake Avenue South, turning them into a line of "cliffs". Photo credit: Bob King / rking@duluthnews.com - http://www.duluthnewstribune.com/news/4351737-park-point-residents-assess-damage-worry-about-future-storms.

Figures 5-12 and 5:13: 24-October-2017 storm causing wave run-up to wash large stone and debris up on Lakeshore Blvd. in Marquette, MI. Photo credit: Great Lakes Coastal Reporting Tool (http://superiorwatersheds.org/report-erosion-hazard.

Figure 5-14: Erosion along the Lake Michigan bluffs in Mount Pleasant, WI prompted property owner to tear down a teetering garage. Property owner lost 6-8 feet of property since April 2016. Photo credit: Sears, M. Milwaukee Journal Sentinel, 2016.

Figure 5-15: Reported coastal erosion at Ontonagon Township Park and Campground. For the past three years staff have been monitoring the rate of erosion and measured 120-ft of shoreline loss since 2014. Erosion has caused closure of selected campsites and impacts to power utilities. Photo credit: Superior Watershed Partnership and Land Trust – Great Lakes Coastal Reporting Tool.

Figure 5-16: Shoreline inundation at a park in Sault Ste. Marie, Ontario in October 2017. Photo credit: https://www.sootoday.com/local-news/high-water-on-st-marys-river-15-photos-748392.

There were also reports of localized flooding along the St. Marys River in Sault Ste. Marie during a wind event in October, 2017 (see Figure 5-16) and the ILSBC issued news releases throughout the summer and fall of 2017 cautioning users of some expected flooding of low-lying areas of Whitefish Island and that some recreational trails and features in these areas would likely be inundated (http://ijc.org/en_/ilsbc/) (see Figure 5-17).

Figure 5-17: Recreational trails on Whitefish Island prone to flooding in 2017 (picture taken in 2014). Photo credit: ECCC.

As shown in Figure 5-18 below, water levels in 2017 on Lake Superior hovered near or above the High A-B transition coping zone. The expected sensitivities described in Zones A and Zone B (see Table 5-4) appear to be representative of 2017 media reports of coastal erosion, flooding, and impacts of shoreline protection.

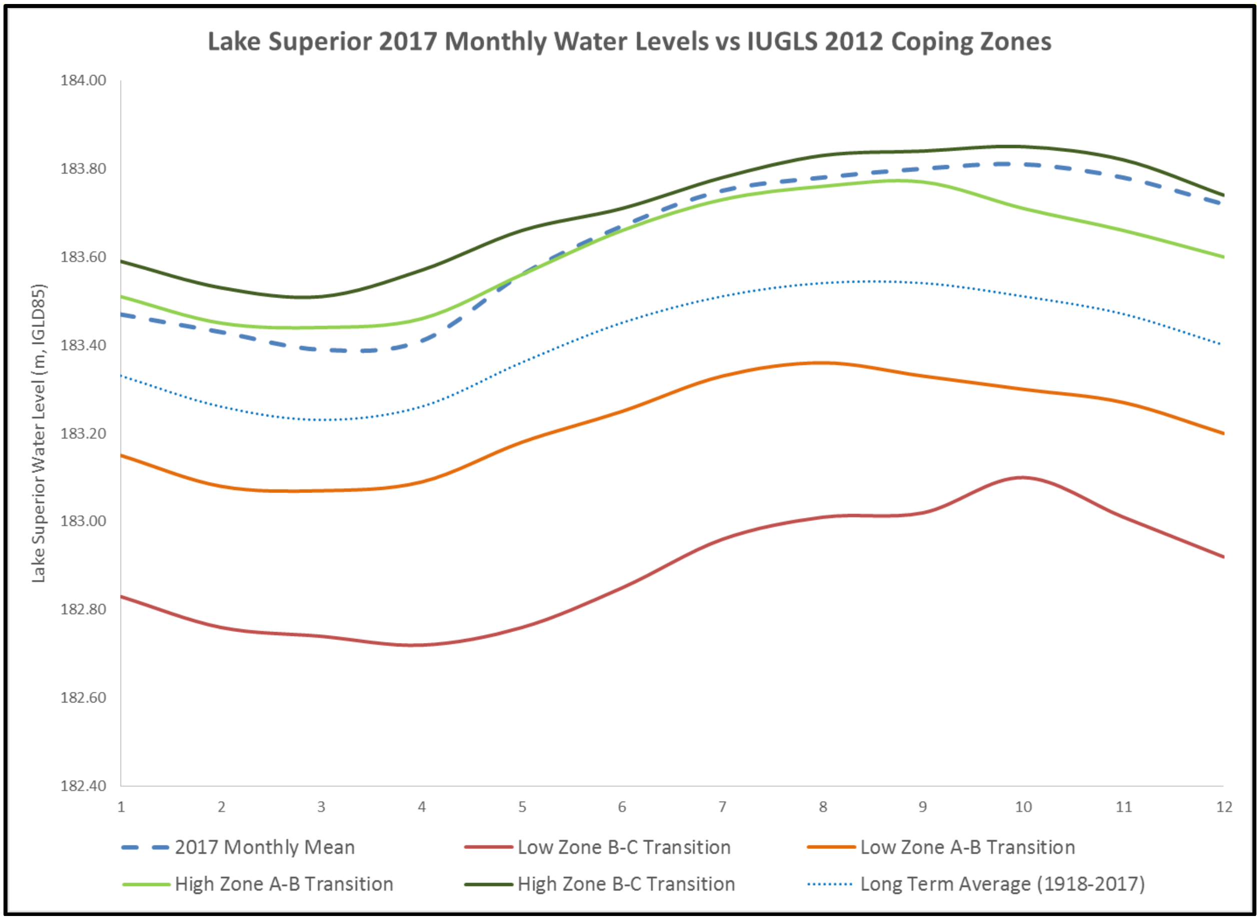


Figure 5-18: Comparison of Lake Superior 2017 Monthly water levels relative to the coastal coping zones that were established for Lake Superior in the 2012 IUGLS. (Source: USACE Detroit)

Figure 5-19 is a summary of permit applications received by year from USACE-Detroit District Regulatory office on Lake Superior, whose regulatory footprint includes all of the Michigan shoreline of Lake Superior. Minnesota and Wisconsin shorelines are under the regulatory jurisdiction of USACE- St. Paul District. The figure summarizes the number of permits for new, replacement and improvement permits of shoreline projects (i.e. groins, seawall, rip-rap, etc.) relative to the lakewide elevation of that year. As water levels on Lake Superior have begun to rise since 2013 or approach the high coping zones, so has the number of permit applications.

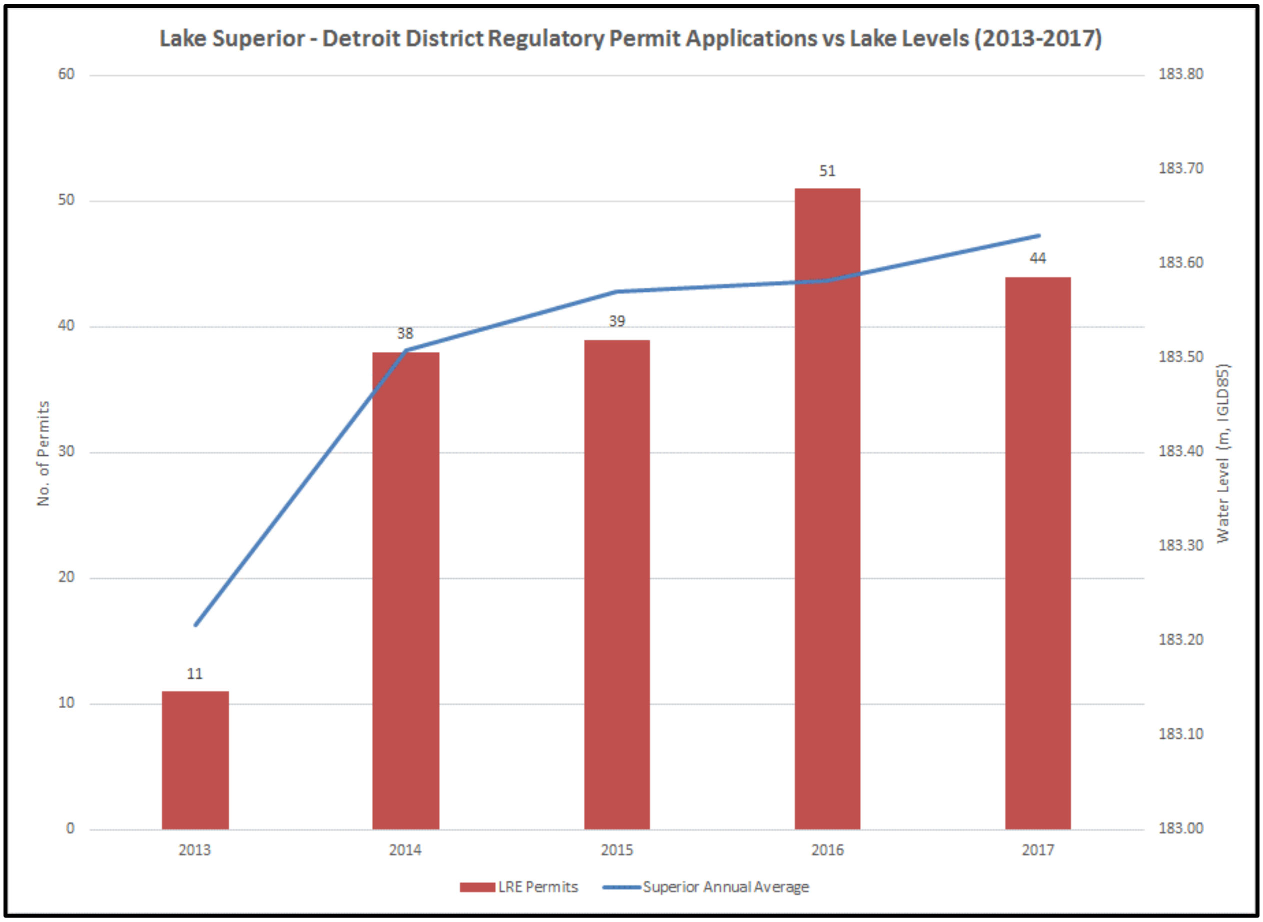


Figure 5-19: Comparison of permit applications per year received by USACE's Detroit District Regulatory Office (LRE) versus annual average water level for Lake Superior. Permit applications summarized in this graph fall under Code of Federal Regulation 33 Part 322 – Permits for Structures in or Affecting Navigable Waters of the US focusing on project types that fall under shore protection (i.e. seawall, groin, riprap placed for shore protection, etc). (Source: USACE, Detroit District)

Lakes Michigan-Huron remained above average throughout the year, but at least 38 cm (~15 in) below the maximum recorded levels. While it is expected that higher rates of erosion are occurring compared with the low water level years throughout the 2000s, there were little to no indications based on media reports or discussions with shoreline managers of flooding or unusually high erosion or shore protection structure damages found. Nottawasaga Valley Conservation Authority, located on the south shore of Georgian Bay, reported that on November 16, 2017, higher lake levels combined with strong northwest winds caused the main beach area at Wasaga Beach to be flooded, with flooding of the edge of the public road in this area. The Town used temporary sand dykes along the beach to attempt to mitigate against the high water levels and wave uprush. There were also various reports of increased problems due to shoreline erosion along the Lake Huron shoreline of Ontario.

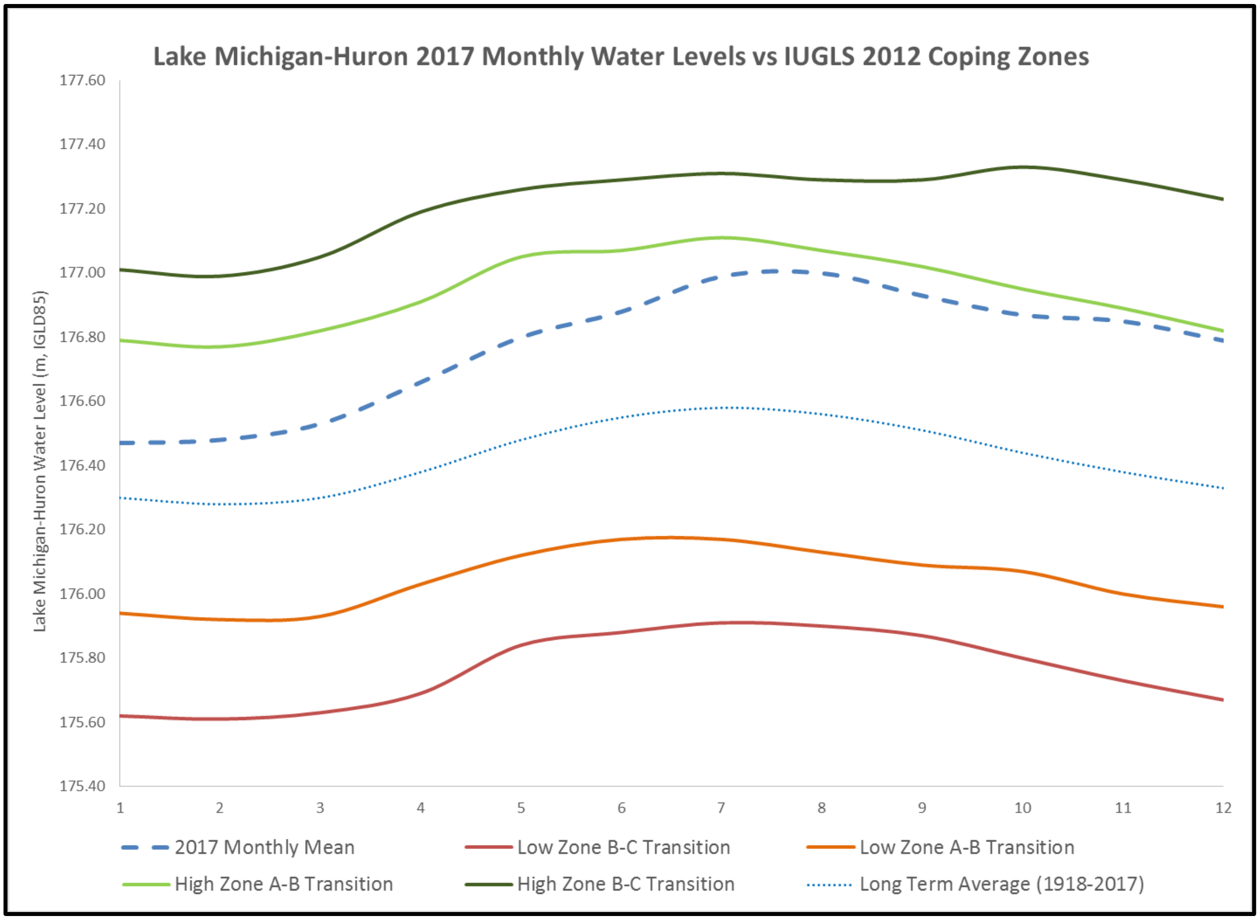


Figure 5-20: Comparison of Lake Michigan-Huron 2017 monthly water levels relative to the coastal coping zones that were established for Lake Michigan-Huron in the 2012 IUGLS. (Source: USACE Detroit)

Water levels in 2017 on Lake Michigan-Huron stayed within the tolerance of the low and high coping zones previously defined during the IUGLS, nearing the High A-B transition coping zone in the late fall (Figure 5-20). The expected sensitivities described in Zones A and Zone B (see Table 5-4 above) appear to be representative of 2017 media reports of coastal erosion, flooding and impacts of shoreline protection.

Lake Erie also remained high throughout the year and was within 15 cm (~6 in) of monthly record high water levels in May 2017 and within 21 cm (~8 in) of the maximum level on Lake Erie of 175.04 m (574.3 ft) International Great Lakes Datum (IGLD) recorded in June 1986. There was a notable increase of permit applications through the USACE-Buffalo District Regulatory office for Lake Erie shore protection structures when compared with both 2015 and 2016 (Figure 5-21). On the Canadian shoreline, the Lower Thames Conservation Authority reported issues of the dyke overtopping at Rondeau Provincial Park and some homes experiencing shore protection failure in June, 2017. Essex Region Conservation Authority reported a spike in applications for shoreline repairs and shoreline damages on the east coast of Pelee Island and along the Lake Erie shoreline west of Point Pelee between Leamington and Kingsville (Essex Region Conservation Authority, personal communication, June 13, 2017).

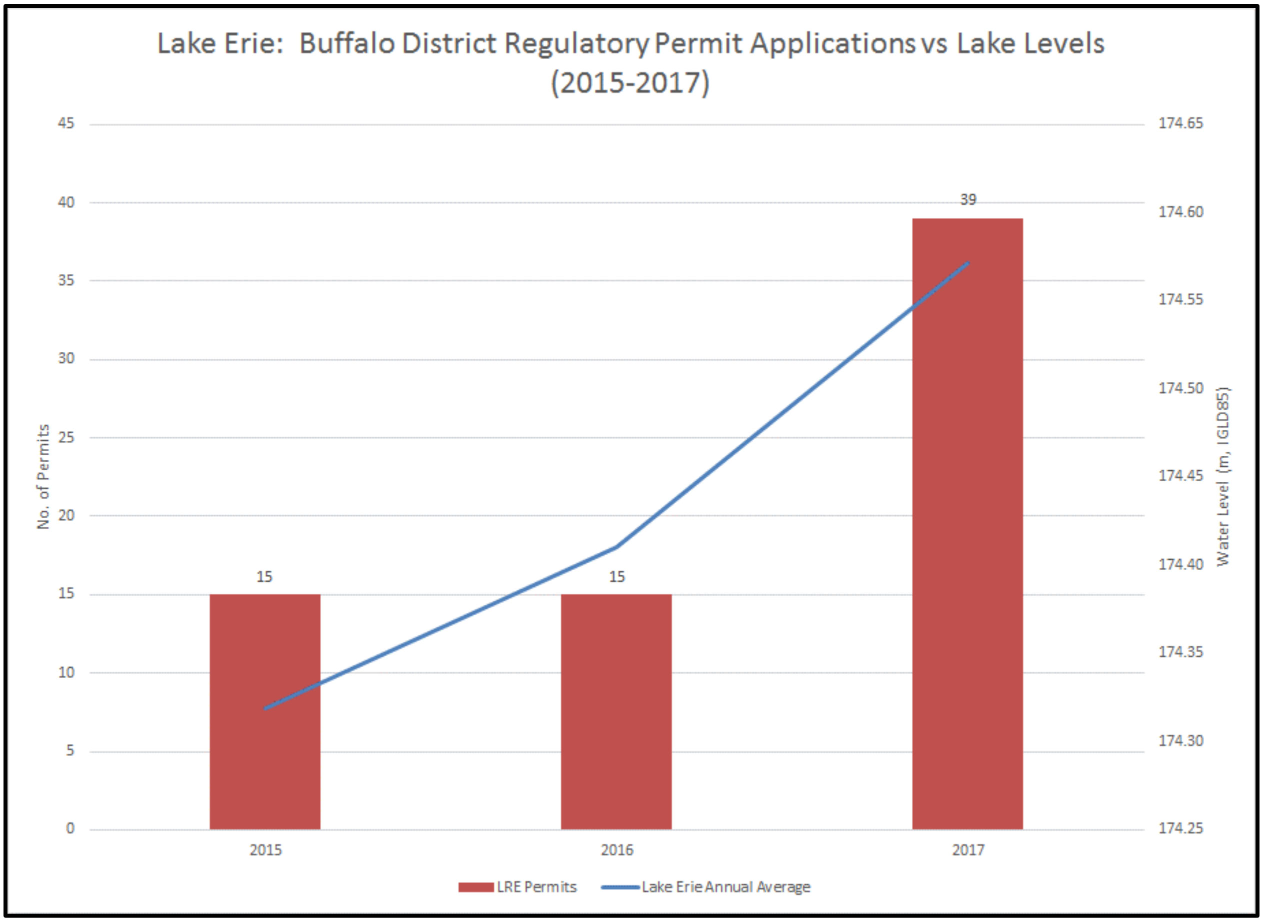


Figure 5-21: Lake Erie permit applications for Buffalo District compared with water levels (2015-2017) (Source: USACE Detroit District)

Long Point Conservation Authority reported a lack of beach at the provincial park and erosion of exposed shore protection. Water levels in 2017 on Lake Erie hovered near or above the High A-B transition coping zone (Figure 5-22). The expected sensitivities described in Zones A and Zone B (see Table 5-4 above) appear to be representative of 2017 media reports of coastal erosion, flooding and impacts of shoreline protection.

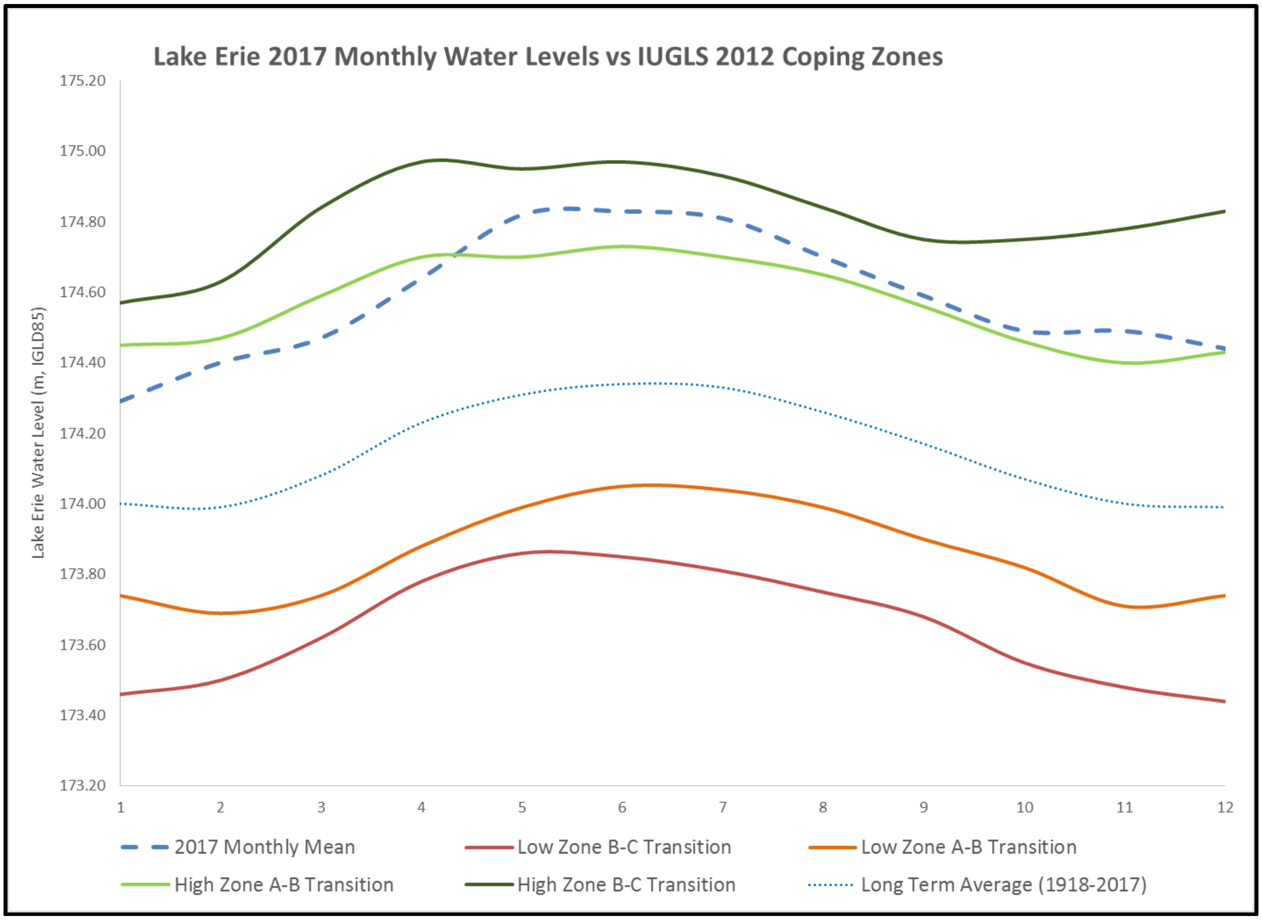


Figure 5-22: Comparison of Lake Erie 2017 monthly water levels relative to the coastal coping zones that were established for Lake Erie in the 2012 IUGLS. Water levels of 2017 on Lake Erie hovered near or above the High Zone A-B transition for the coastal coping zones. (Source: USACE Detroit)

Model Assessments: The primary performance indicator used to compare coastal impacts associated with alternative regulation plans during IUGLS was the cost of maintaining existing shoreline protection. In addition to the modelled indicator, coping zones were developed as a more general approach to comparing plan performance. Within the supporting documentation of the 2012 IUGLS, a number of suggested ways were listed for assessing the high and low thresholds of the coastal coping zones. For high water coping zones, it was suggested to monitor resident flood damages by magnitude ($) and spatial distribution, which could be done through insurance claims reporting or complaints to local municipalities. Another possible way to track indicator and coping zone outcomes was the implementation of new shore protection or replacement of existing protection by tracking of permit issuance and construction value. The latter approach was attempted for the upper Great Lakes for 2017 using best available information for USACE's regulatory offices, but without collecting information related to costs. Further efforts in this regard need to be evaluated and prioritized by the GLAM Committee as it is not yet clear how beneficial this information could be in the on-going plan review.

Another important consideration when evaluating plan performance is the impact the outflow decisions have on Whitefish Island. Whitefish Island is Batchewana First Nations land, and is primarily recreational with hiking trails, small pavilions and visitor information booths. The island is located immediately downstream of the Compensating Works gates adjacent to the rapids and substantial portions of the island flood as more gates are opened. While flooding of the island is unavoidable and expected under higher gate openings, the board attempts to minimize impacts to the island when possible. During the IUGLS, there was no specific indicator developed for Whitefish Island coastal impacts, most notably, flooding of recently developed areas of the Island. The GLAM Committee considers a Whitefish Island flooding performance indicator an important priority and included the initiation of its development in the FY18 work plan. However, progress was limited and the work will continue in FY19 and possibly beyond depending on available resources.

Key Findings and Next Steps: Coastal impacts on the upper Great Lakes were primarily storm driven. While all the lakes were above average, the shoreline interests were primarily able to cope with the levels experienced. There are no existing coastal performance indicators for the St. Marys River where the implications of a change to the regulation plan may be the greatest and this is something that the GLAM Committee should explore further. It had been identified as part of previous GLAM Committee work plans, but progress has been limited so far.

5.5.2 LAKE ONTARIO-ST. LAWRENCE RIVER - Coastal

Sensitivity to Water Levels and Outflows: During the development of Plan 2014, the IJC concluded that coastal damage would occur no matter the regulation plan, but that Plan 2014 would increase damages to coastal interests on Lake Ontario and the upper St. Lawrence River when compared to the previous regulation plan (1958-DD). Model results suggest most of the expected damage would be realized in the cost of maintaining shore protection structures with only very minor increases expected to flooding and erosion damages on Lake Ontario over the previous regulation plan. Based on an assessment of potential flooding damages to downstream interests on the lower St. Lawrence River (downstream of the Moses-Saunders dam), these interests are vulnerable to water level changes, but there were no differences found in impacts or benefits between the old regulation plan and Plan 2014.

There were three primary performance indicators used during the LOSLRS to represent impacts to coastal property owners along the Lake Ontario shoreline for the comparison of regulation plan options, including:

- First floor flooding of residential buildings;
- Erosion to developed (i.e. with building) but unprotected land; and
- Shore protection maintenance costs.

The first-floor flooding performance indicator was applied to all shoreline areas in the database including many of the larger embayments around the lake. However, due to the importance of wind and waves in combination with water levels, the erosion and shore protection maintenance indicators were applied to only the open coast shorelines and not to the shoreline within protected embayments or the Bay of Quinte where wave action was considered minimal. On the upper St. Lawrence River from the Thousand Islands through to the Moses-Saunders dam, the primary performance indicator was first floor flooding of residential buildings.

On the St. Lawrence River downstream of the Moses-Saunders Dam, the primary performance indicator was first floor residential flooding, although there were also non-economic metrics on the lower river such as kilometers (miles) of roads flooded. In simplest terms, all the Lake Ontario, upper St. Lawrence River, and lower St. Lawrence River coastal performance indicators generally equate high water levels with increased maintenance costs to shoreline property owners.

Summary of Observed 2017 Impacts: ***NOTE - Much of the information currently available to the GLAM Committee to assess these impacts is descriptive and anecdotal, and efforts will be ongoing to further quantify impacts going forward. To support the current assessment, the GLAM Committee gathered information from a variety of sources including aerial imagery, shoreline site visits, damage reports by various agencies, media reports, and permitting summaries. As has been noted in previous sections, the GLAM Committee also worked with Conservation Ontario to develop and implement an online, self-reporting questionnaire for shoreline property owners to seek direct input on the kinds of problems faced due to high water levels in 2017. The questionnaire method was not considered a statistically representative sample, so it is not possible to test for statistical differences in results from the different sub-groups (e.g. Canada vs. US). An overall description of impacts is provided here with further details and regional descriptions provided as reference in the Annex 1-Impact Assessment.***

Record high water levels in 2017 directly impacted property owners along the Lake Ontario and St. Lawrence River shoreline. Damage to homes, properties, and shore protection structures due to flooding and erosion were widespread across the Lake Ontario shoreline. By mid-April of 2017, coastal impacts were being commonly reported along the Lake Ontario shoreline and extensive media attention surrounding the coastal damages heightened in May and June as water levels rose rapidly and reached record high levels. Impacts continued to be reported through the summer and into the fall months, although at a reduced rate. Reports of flooded homes, roads, driveways, trails, lawns, emergency response and extensive sandbagging efforts to protect houses and properties made the news. Reports of shoreline erosion and loss of beaches, vegetation and property (e.g. land, decks and docks) were common. There were also reports of shore protection structures failing or being damaged by the high water conditions making property owners even more vulnerable to the high water conditions. States of emergency were issued in many locations including all U.S. counties bordering the Lake Ontario and upper St. Lawrence River shoreline.

On the Canadian shoreline, a local state of emergency was declared for a portion of the Clarington shoreline as well as all of Prince Edward County. The Mohawks of the Bay of Quinte also declared an emergency for their territory in response to the high water levels. On the lower St. Lawrence River, emergencies were declared in numerous municipalities in May 2017 during the peak flood conditions. Table 5.5 lists the municipalities, separating ones directly on the St.

Lawrence River from those on the north shore of Montreal Island that were more directly influenced by record high outflows from the Ottawa River. It should be noted that there are many other municipalities on the lower St. Lawrence River that suffered from flooding issues but did not declare states of emergency. They dealt with the situation on their own.

Table 5-5: Municipalities in the Province of Quebec with local states of emergency during the peak flood conditions of May 2017 (Source: Urgence Quebec, 2017),

Municipalities located on the St-Lawrence/Lake Saint-Louis and impacted by the water management of Lake Ontario
Région Mauricie-Municipalité Yamachiche
Région Lanaudière-Municipalité Sainte-Geneviève-de-Berthier
Région Lanaudière- Municipalité Saint-Barthélemy
Région Lanaudière- Municipalité Saint-Ignace-de-Loyola
Région Lanaudière- Municipalité Lavaltrie
Région Lanaudière- Municipalité La Visitation-de-l ’île-Dupas
Région Lanaudière- Municipalité Berthierville
Région Montérégie – Municipalité Pincourt
Région Montérégie – Municipalité L’ïle Perrot
Région de Montréal - Ville de Montréal (portions of Montréal also border Lake of Two Mountains)
Municipalities located on Lake of Two Mountains (primarily influenced by Ottawa River flow):
Région Laval- Ville de Laval
Région Laurentides- Municipalité Saint-Eustache
Région Laurentides- Municipalité Deux-Montagnes
Région Montérégie- Municipalité Rigaud
Région Montérégie - Municipalité L’île Cadieux
Région Montérégie – Municipalité Terrasse-Vaudreuil
Région Montérégie – Municipalité Pointe Fortune

Flooding was the most commonly reported impact by respondents of the self-reporting survey relative to the total number of responses in each Country, followed by erosion and damages to shore protection structures (Figure 5-23). Survey respondents indicated the degree to which they were impacted by the high water levels (1 being low, 10 being high). A higher proportion of the US respondents indicated an impact level of 8, 9, or 10 while a higher proportion of Canadian respondents indicated an impact of 7 or lower (Figure 5-24).

Adaptive actions were taken in many locations to counteract the impacts of the high water to varying degrees of success. Based on observations from USACE emergency response site visits, there were situations where local authorities, residents and business owners were unfamiliar with correct methods of employing sandbag defenses and flood water pumping methods, thus causing the improper installation of these defenses (USACE Buffalo District site visit reports: e.g. Sodus Point, NY, May 19, 2017).

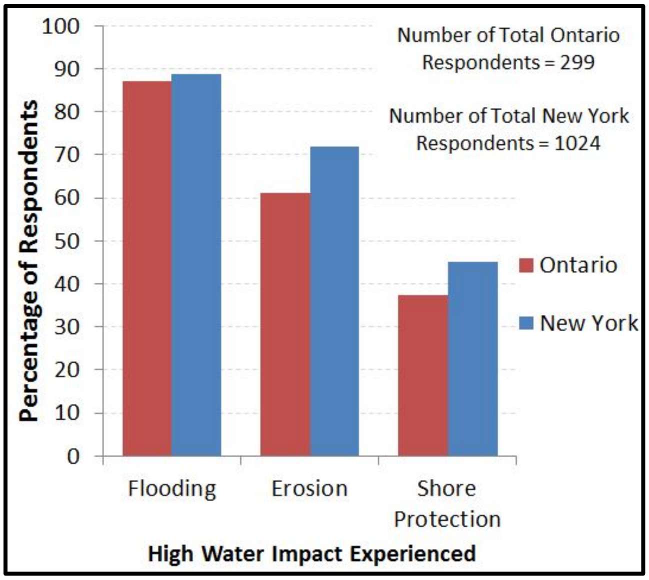


Figure 5-23: Percentage of New York (US) and Ontario (Canada) respondents on Lake Ontario reporting flooding, erosion and shore protection impacts (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

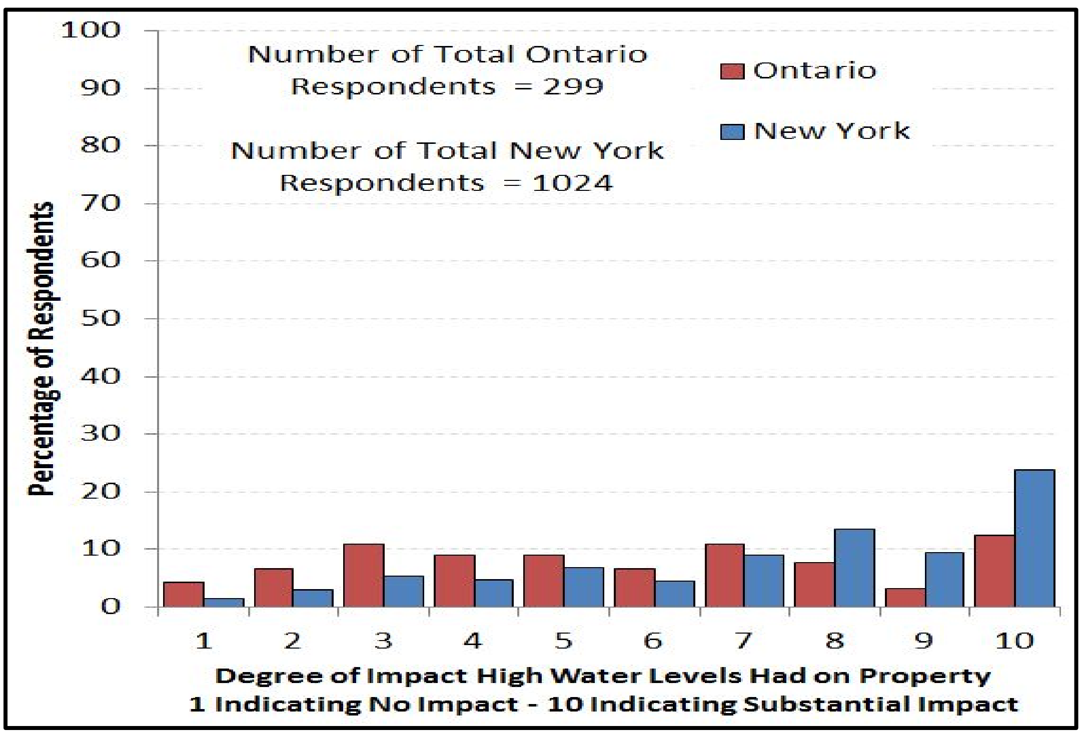


Figure 5-24: Degree of impact due to high water levels as identified by survey respondents (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

A number of media reports also highlighted the psychological impacts of flooding to people that live along the shoreline. A recent report by the Intact Centre on Climate Adaptation (June 2018) highlights both the worry and stress associated with flooding and the need to take time off to deal with flood related response (Decent and Feltmate, 2018). While the Decent and Feltmate report focuses on flooding based on short-term rainfall events in an urban environment, similar issues were experienced by flooding victims along the shoreline as illustrated by comments received through the Conservation Ontario survey. One respondent referred to it as “a truly devastating experience” and there were a couple of responses noting the stress of needing to constantly monitor the situation to ensure pumps were working. Another respondent said, “It was also quite stressful as we didn’t know when or if the water would recede and how it would affect our property” and another noted “the length of time of the flood was a horrendous experience”. Related to the responses on stress was the personal financial toll, including the concern about the long-term implications.

<u>Flooding - Lake Ontario and the Upper St. Lawrence River:</u> Flooding of residential property and buildings along the Lake Ontario shoreline was observed with particularly hard-hit areas including the Olcott and Greece shoreline, Sodus Point, Fair Haven, and stretches of Oswego and Jefferson County on the US side as well as portions of Toronto Island, Clarington, Brighton, and Prince Edward County on the Canadian side (See Figure 5-25). Photographic examples of impacts are provided in Figures 5-26 to Figure 5-29. On the upper St. Lawrence River, shoreline flooding was observed on both the Canadian and US shoreline, particularly in the Thousand Islands area. While flooding was the most prominent impact reported on Lake Ontario and the upper St. Lawrence River in the self-reporting questionnaire, the type of flooding varied, with the most commonly reported impact to lawns and docks and a small percentage reporting first floor flooding (Figure 5-30). A separate and independent survey, undertaken by New York Sea Grant and Cornell University earlier in 2017, also reported a much lower percentage of first floor flooding when compared with other flooding impacts (New York Sea Grant and Cornell University, 2018). Evidence from the aerial imagery and site visits indicated a high degree of sandbagging efforts to prevent first floor flooding in the more vulnerable areas and 35% of respondents in Ontario and 40% of respondents in New York who experienced flooding also indicated taking this step to protect their property. According to the survey results, property owners that undertook adaptive actions such as sandbagging, pumping and clean-up reported that their costs to undertake such actions were generally less than $1,000.

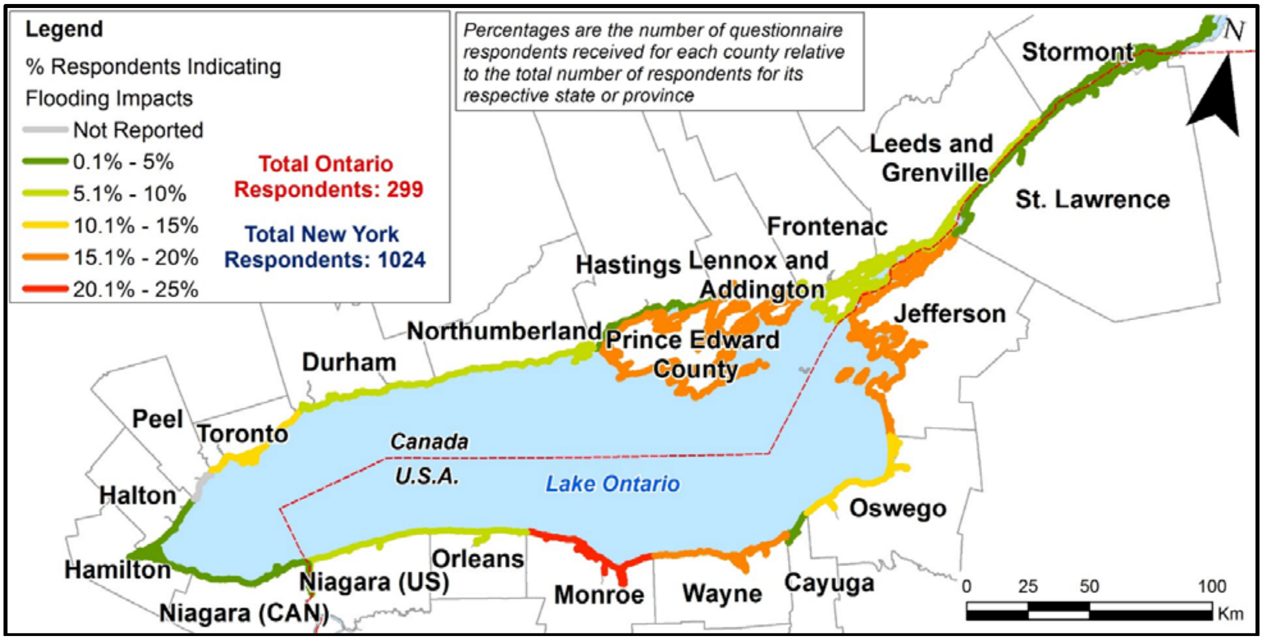


Figure 5-25: Flooding impacts, by county or municipality (based on a relative scale using the number of flooding impacts in each county relative to the total number of responses for the country in which that county falls) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Figure 5-26 and 5-27: US shoreline flooding photos submitted through shoreline survey. Photo credits: Kevin Herrick, taken July 7, 2017 (left); Robert Rutz, taken April 30, 2017 (right).

Figure 5-28: Sandbagging on Toronto Island, May 26, 2017. Photo credit: ©Toronto and Region Conservation (TRCA)

Figure 5-29: Cedar Crest Beach Road. The photo on the left was taken May 25, 2017. Photo credit: Clarington Fire and Emergency Services. The photo on the right was taken June 14, 2017. Photo credit: ECCC.

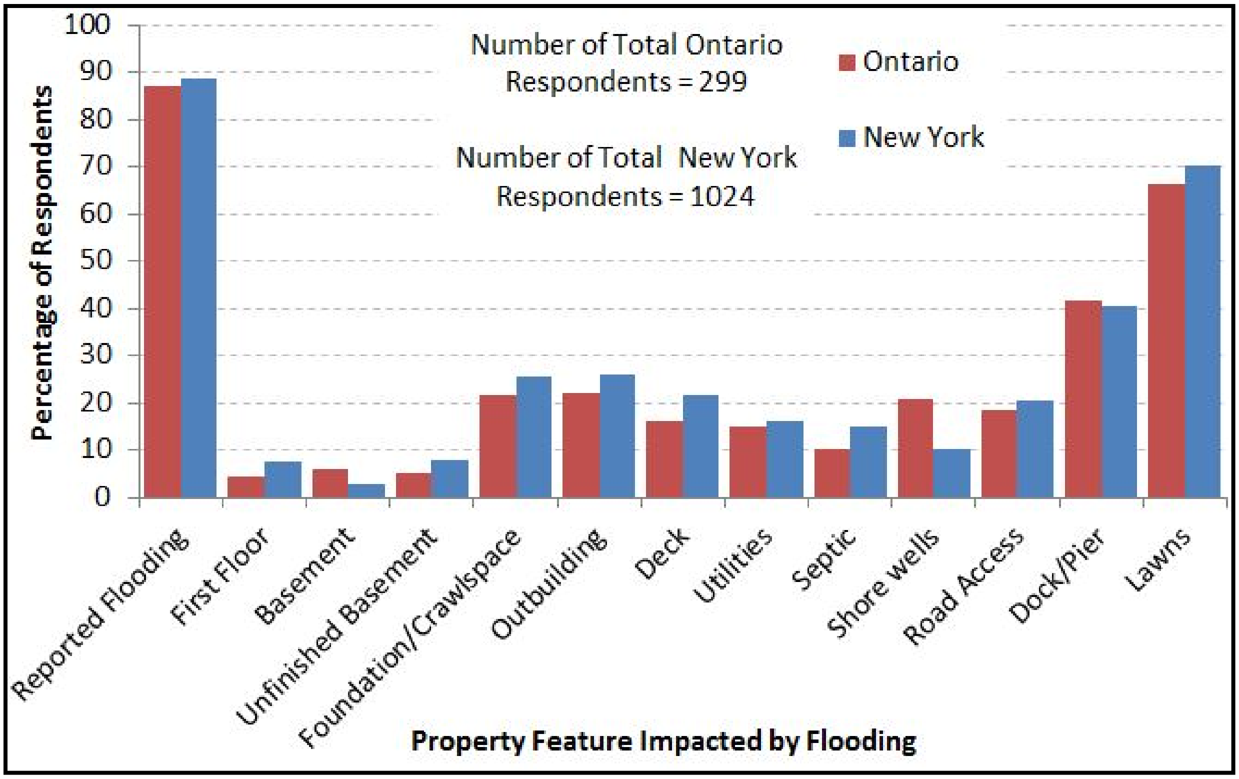


Figure 5-30: Types of flooding impacts reported by US and Canadian respondents to Conservation Ontario questionnaire (reported as percentage of respondents by province or state) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

<u>Flooding - Lower St. Lawrence River:</u> Downstream of the Moses-Saunders dam, the most significant and extensive flooding occurred during the Ottawa River freshet in early May. Flood damages associated with high St. Lawrence River levels (which were driven by a combination of record Ottawa River flows and high flows through the St. Lawrence, which were being set in an attempt to balance high levels and flooding upstream and downstream) occurred in the Lake Saint-Louis area as well as the Sorel and Lake Saint-Pierre area downstream to Trois-Rivières. Oblique imagery collected by Transport Canada during the flood peak was used to provide a general assessment of some of the more critically impacted areas. Those areas are highlighted in Figure 5-31 and an example of the imagery from the Sorel area is included for reference (Figure 5-32). Based on this visual assessment it was clear that entire neighbourhoods were affected and according to municipal reports over two thousand homes were either directly impacted or isolated as a result of the flooding on the lower St. Lawrence River. Municipal reports during the flooding period indicated over 1100 homes were evacuated across 24 municipalities, either because of flooding in the community or because access to roads was cut-off due to the flooding (Source: Centre des Opérations Gouvernementales, 2017). There were numerous examples of extensive sandbagging efforts. Record high outflows from Lake Ontario beginning in late May 2017 kept levels high and near flood levels much longer than they would have been otherwise on the St. Lawrence River near Montreal. While there were media reports of costs associated with flooding in the Province of Quebec during the spring event, it was not possible to differentiate

costs associated only with the St. Lawrence River from those on the Ottawa River and other parts of the province.

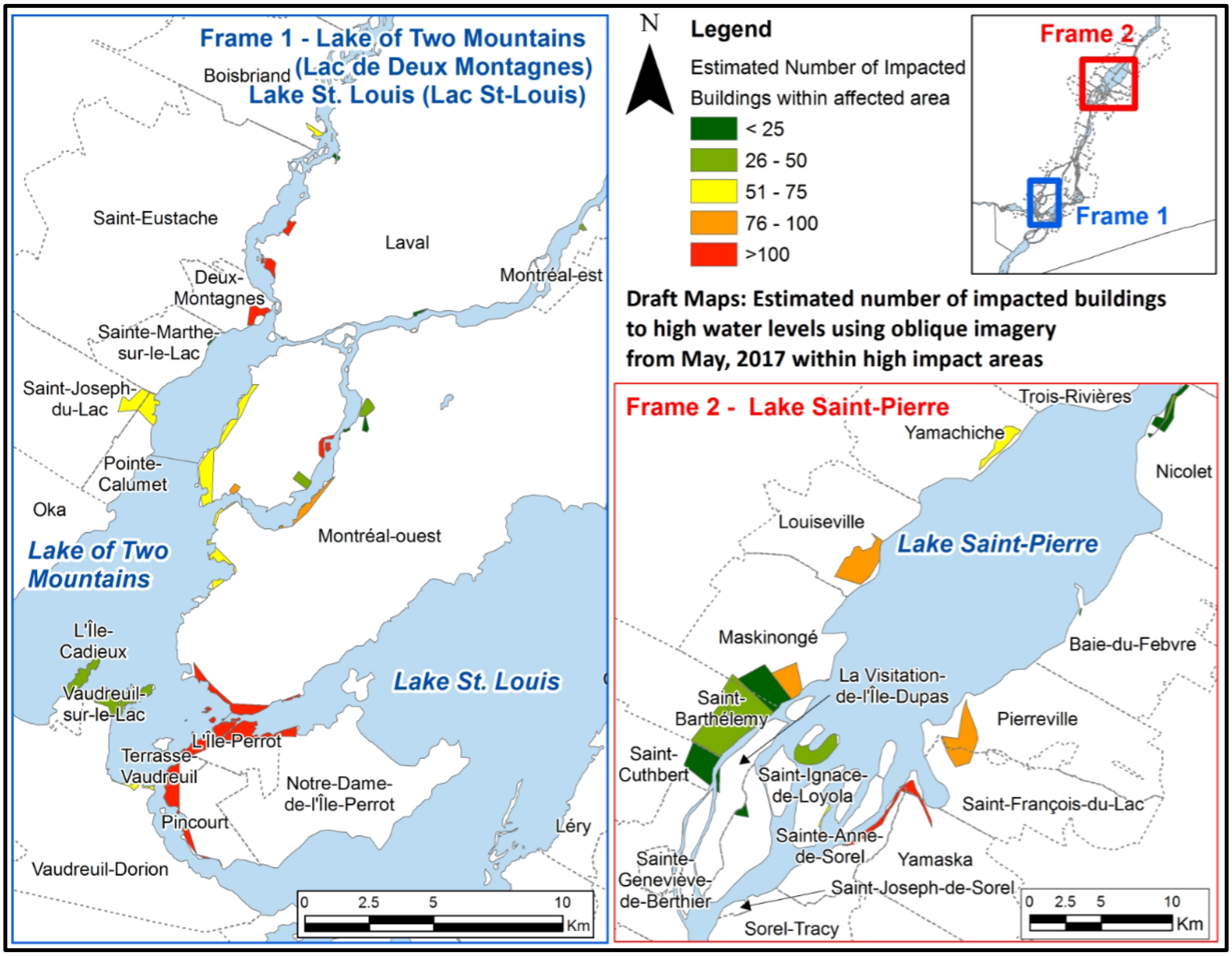


Figure 5-31: Preliminary map of high concentration building impacts identified through oblique imagery review (Source: ECCC/IJC estimates based on aerial imagery collected through the Transport Canada National Aerial Surveillance Program in May 2017.)

Figure 5-32: High water in the Chenail-du-Moine area near Sorel on May 9, 2017. Photo credit: Transport Canada National Aerial Surveillance Program, 2017.

Shoreline Erosion – Lake Ontario-Upper St. Lawrence River: Shoreline bluff recession (erosion) was evident from the aerial imagery and site visits in many locations along the Lake Ontario shoreline and appeared to be due to the combination of high water levels, wave action and saturated ground conditions from persistent rainfall in many areas. Based on the responses to the self-reporting survey for shoreline property owners, erosion impacts were more commonly reported in counties/municipalities on the south, east and northeast shoreline of the lake relative to the total number of survey responses in each country (Figure 5-33). Most commonly, residents reported loss of shoreline that directly impacted their property to varying degrees including loss of vegetation, loss of access to the beach/water and other infrastructure that was directly adjacent to the shoreline (Figure 5-34). In the most extreme cases, homes and buildings needed to be evacuated due to risk that the building itself would possibly fail (i.e. collapse or be condemned), although based on the information currently available to the GLAM Committee from the sources listed earlier, this did not appear to be a common occurrence relative to the overall number of buildings directly adjacent to the Lake Ontario shoreline. A high percentage of respondents in New York State indicated “other” as one of their impacts, suggesting impacts were not captured by the pre-defined categories in the survey. However, a review of the responses in the “other” category indicates that many US respondents included “shore protection damages” within this category. For reporting purposes, responses to questions on shore protection are discussed separately in the next section.

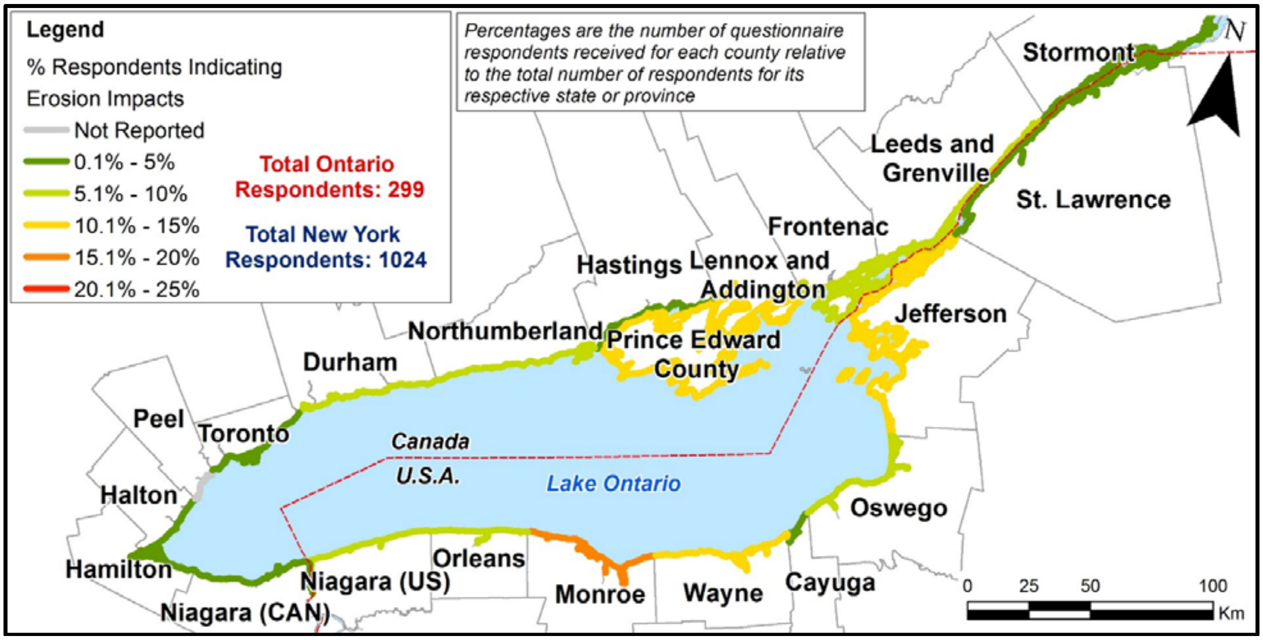


Figure 5-33: Survey responses indicating erosion impacts, by county or municipality (based on a relative scale using the number of erosion impacts in each county relative to the total number of responses for the country in which that county falls) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

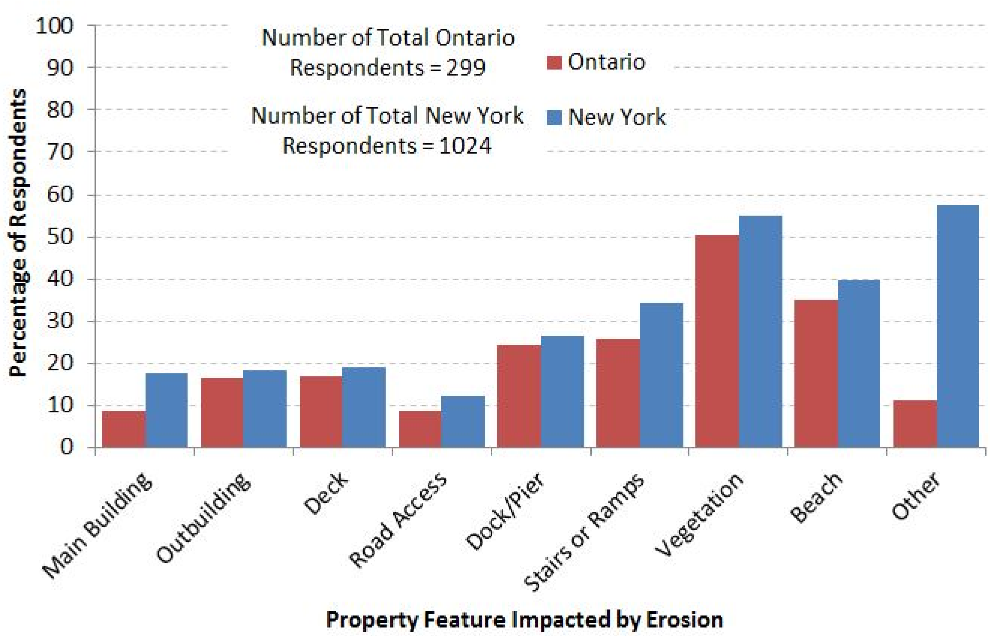


Figure 5-34: Percent of respondents indicating property features impacted by erosion (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Public lands and shoreline trails were also damaged by erosion (Figure 5-35). Such impacts would not be captured by the erosion performance indicator developed during the LOSLRS as that indicator only considers properties with buildings on them. A number of park properties required immediate action to stabilize the shoreline and protect further loss of land and direct impacts to infrastructure such as trails.

Figure 5-35: Shoreline erosion at Confederation Beach Park, City of Hamilton (photo taken May 17, 2017). Photo credit: City of Hamilton.

Shoreline Erosion – Lower St. Lawrence River: A detailed study on shoreline erosion on the lower St. Lawrence River is being undertaken through partner agencies. The GLAM Committee was not able to acquire the detailed project scope since it is not yet available. Further effort will be required to pursue this information in the future.

Shoreline Protection Impacts – Lake Ontario-Upper and the St. Lawrence River: Damages were observed to existing shoreline protection structures in many locations including private residences and public shorelines (Figure 5-36 and 5-37). Given the replacement value of shoreline protection, overall costs associated with these impacts appear to be high. For example, the City of Toronto estimated potential repair requirements of $7.38 million as a result of high water level conditions in 2017 (City of Toronto, 2018). Based on the responses to the Conservation Ontario self-reporting survey, the Canadian counties with the highest percentage of reported shore protection impacts relative to the overall response rate were Northumberland and Prince Edward County. On the US shoreline, both Monroe and Jefferson Counties had a high percentage of the total respondents in this category (Figure 5-38).

Figure 5-36: Overtopping of shore protection, Stoney Creek, ON. Photo credit: ECCC, May 2017.

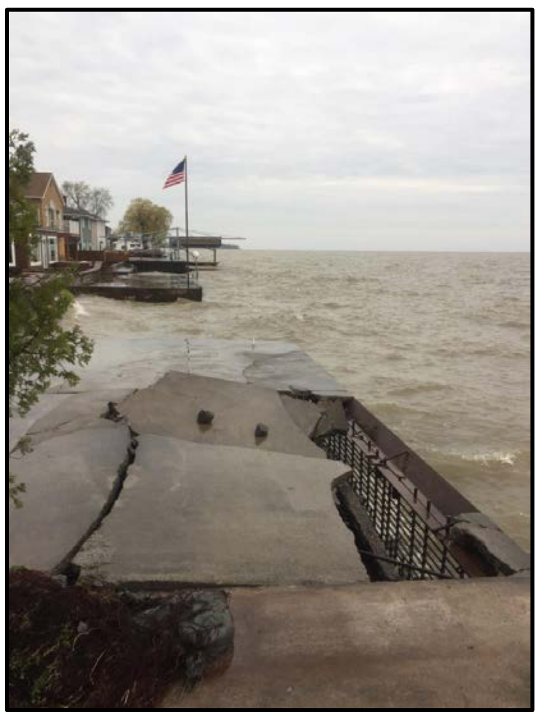


Figure 5-37: US shoreline shore protection photos submitted through shoreline survey. Photo credit: L. Frosini, taken May 21, 2017.

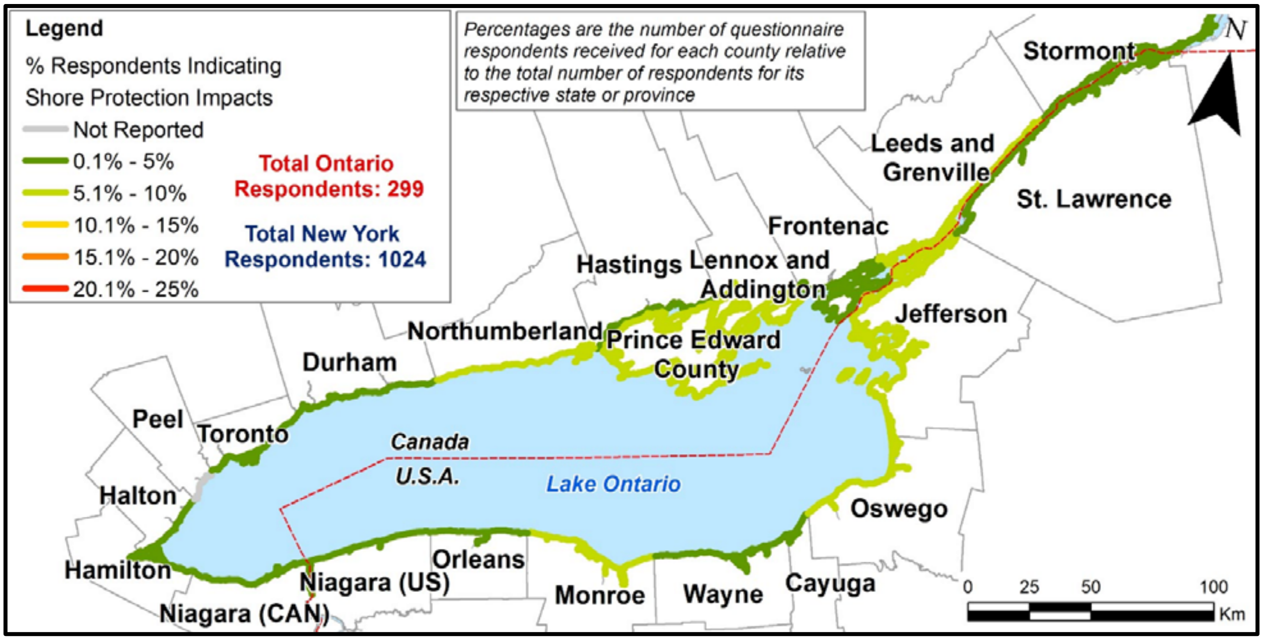


Figure 5-38: Survey responses indicating shore protection impacts, by county or municipality (based on a relative scale using the number of shore protection impacts in each county relative to the total number of responses for the country in which that county falls) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Shoreline Protection Impacts – Lower St. Lawrence River: As flooding was the performance indicator used on the lower river during the LOSLRS and the primary adverse impact experienced in 2017, the GLAM Committee has not pursued information on impacts to shoreline protection structures on the lower St. Lawrence River. A detailed study on shoreline erosion in the lower St. Lawrence River is being undertaken through partner agencies and the GLAM Committee will be able to follow this study. The detailed project scope is not yet available. Further effort will be required to pursue this information in the future.

Model Assessment: The three primary performance indicators representing impacts to coastal property owners on Lake Ontario are first floor flooding of residential buildings, erosion to developed but unprotected land and shore protection structure maintenance costs. The primary performance indicator on the St. Lawrence River is first floor flooding. The GLAM Committee has only completed a preliminary comparison of performance indicator results to the available descriptive information of coastal impacts based on similar high years from the historical record and from water supply scenarios. Based on the existing models, it was expected that there would be first floor flooding damages at various locations along the Lake Ontario and upper St. Lawrence River shoreline under 2017 water level conditions (~250 individual properties) and that first floor flooding damages would increase quickly as water levels rose above 75.6 m (248 ft). It was also expected that shore protection maintenance would represent some of the greatest coastal impacts due to the total number (over 4,500) and value of existing shore protection and the significant costs required to make repairs if damaged. Erosion rates were also expected to increase above long-term rates necessitating new shoreline protection in areas where it was not previously installed. On the lower river, first floor flooding of homes and inundation of roads directly along the St. Lawrence River were expected at levels observed in 2017. The existing model suggests the greatest impacts along the St. Lawrence River would be downstream of Montreal in the Sorel and Lake Saint-Pierre areas which seems to be consistent with what was observed on the lower river during late April and early May of 2017 when low-lying areas were inundated. Overall, the types of impacts observed in 2017 appear to be consistent with broad categories used to represent potential regulation plan impacts to shoreline property owners throughout the Lake Ontario – St. Lawrence River system but further assessment is required to determine how closely actual impacts aligned with the modelled estimates of at-risk locations. It is important to note that no performance indicators are designed or able to capture all potential impacts. They are developed as indicators of response under various water level conditions and the intent was not to quantify all impacts, but to have indicators that could potentially differentiate regulation plan alternatives.

While much of what was observed in 2017 was consistent with the broad characterizations of the existing performance indicators, the record high water levels of 2017 on Lake Ontario and the St. Lawrence River also led to related impacts that are not directly captured by existing performance indicators. For example, the cost to install new shore protection to protect public infrastructure such as shoreline trails and park facilities was not considered in the shore protection performance indicator that only addressed protecting homes or buildings. The flooding indicator did not consider impacts beyond those related to first floor inundation, such as flood water surrounding homes or impacting crawl spaces and storage buildings, inundation of secondary buildings (e.g. sheds or garages), and the extensive sand bagging operations and expense. In the on-line property survey, first floor flooding represented a fairly small percentage of the number of individuals reporting flooding impacts which is consistent with expectation but also suggests there are a range of other potential flooding concerns that are not directly assessed in the model and are of concern to property owners. Finally, a number of media reports also highlighted the psychological impacts of flooding to people that live along the shoreline and this was also reflected in answers to the on-line shoreline survey where people also noted stress related to the personal financial toll, including the concern about the long-term implications (see the LOSLR Annex 1-Impact Assessment for more details). While it may not be possible to incorporate such psychological impacts into a measurable performance indicator, it is important to recognize these impacts in the context of significant high water events.

Recognizing again that performance indicators are to be representative of impacts, but will never capture all impacts, further processing and review of the impact information is needed before a comparison can be completed between results from the existing models and observed conditions. In addition, further review of the performance indicators is needed to make sure the most significant impacts observed under actual water level conditions are adequately represented.

Key Findings and Next Steps: On Lake Ontario and the St. Lawrence River, impacts from record high water levels were widely distributed across the lake and river shorelines, although there were particularly hard-hit areas. To date, much of the information available to document impacts is descriptive rather than quantitative and based on self-reporting surveys, photographs and interpretation of aerial imagery. The GLAM Committee is awaiting formal reporting by various state and provincial agencies on 2017 impacts and so a comprehensive database of the distribution of property level impacts is not currently available.

The conditions in 2017 caused significant impacts to coastal interests throughout the entire system. Coastal property owners on the US and Canadian shores of Lake Ontario and the St. Lawrence River as well as property owners along the lower St. Lawrence River all experienced damages due to flooding, erosion and failed shoreline protection structures. Assessment of the aerial imagery datasets, Conservation Ontario questionnaire results, and site visit reports indicate that the most commonly reported impacts were flooding, followed by erosion and then impacts to shore protection structures.

Based on the information currently available to the GLAM Committee in the form of questionnaire responses, aerial imagery datasets and site visit reports, there is reasonable confidence in the reporting of the types of impacts and the areas affected. However, information is not yet available to quantify a specific number of properties impacted due to a number of factors, such as the inherent uncertainty in the reliability of the questionnaire responses and the possibility of error in the aerial imagery assessment. To this end, there are a number of measures that could be taken to improve the evaluation of the coastal performance indicators:

- Consider whether the current definitions of the performance indicators need to be reevaluated based on observed response to actual system conditions. For example, should the erosion metric be applied where shoreline protection infrastructure other than residential buildings were at risk in 2017;
- Study the correlation of areas employing sandbag defenses and the number of instances of first floor flooding in those areas; and
- Continue efforts to obtain official statistics on flood damages and use these data to validate the modeled estimates of first floor flood damages at various static lake levels. A level of 75.6 m (248 ft) and below is especially significant to consider in this analysis due to reports of coastal properties being damaged at these levels.

5.6 Ecosystem

The ecosystem interest broadly captures “the biological components of the natural environment of Great Lakes and the St. Lawrence River, together with the ecological services they provide to people who live and work in the region” (IUGLS, 2012; IJC, 2014). This includes habitat conditions influenced by water level and flow conditions, notably nearshore coastal wetland habitats, as well as the bird, fish, mammals, invertebrate, amphibian and reptiles that are directly impacted by water level and flow conditions on Lake Ontario and the St. Lawrence River for some critical portion of their life cycle.

5.6.1 UPPER GREAT LAKES – Ecosystem

Sensitivity to Water Levels and Outflows: On the upper Great Lakes, a range of possible indicators were considered across the large geographic area that could be used to represent potential regulation plan impacts, both positive and negative. While water level fluctuations affect varying habitats and species differently, some general characteristics were identified and expected responses associated with water level changes on the upper Great Lakes as well as flows in the St. Marys River. Through the development of an Integrated Ecological Response Model 2 (IERM2) and associated coping zones, potential vulnerabilities and benefits from changing water levels were characterized to broadly compare regulation plan alternatives.

Coastal wetlands in the Georgian Bay area were found to be particularly sensitive to low water levels during the IUGLS, partly because of the geomorphology of the shoreline and the limitations due to the Precambrian Shield and natural shelf that would allow wetlands to migrate downslope. Questions were raised during that time as to whether wetlands would be able to recover when high water returned. The GLAM Committee is aware of research that has been conducted and is awaiting results which should be released soon.

Generally speaking, detailed performance indicators were not practical during the IUGLS given the limited impact that regulation of outflows can have on the upper Great Lakes system. The one exception was to the St. Marys River. While specific ecosystem performance indicators were not developed for the St. Marys River during the IUGLS, some priority items were identified for follow-up from the IUGLS to validate assumptions. Three of these priorities for the St. Marys River included:

- Verifying the potential benefits of slowing the speed of gate setting changes at the Compensating Works to reduce the risk of fish and other aquatic animals from being flushed out of or stranded in the St. Marys Rapids; and
- Determining whether additional environmental benefits could be achieved by increasing the minimum gate setting to increase the wetted surface area and provide additional habitat in the St. Marys Rapids.

Summary of Observed 2017 Impacts: Coping zones for ecosystem interests established in the IUGLS are different from ones in the other five interests in two ways. First, the high and low water levels that cause problems for municipal water systems, navigation, hydropower, coastal development and recreational boating are generally good for ecosystems. Second, ecosystem coping zone definitions are generally complex, often combining water level, time of the year and persistence. The existing tools from the IUGLS to measure the impacts of NBS and water level to the 34 individual ecosystem indicators is best set up to compare regulation plans that were studied and not annual water level variations of the recent past (IERM2 Coping Zone Calculator). Development of a different tool to evaluate recent annual changes in water level respective to the established IUGLS ecosystem indicators is a task for future GLAM efforts.

Further studies by ECCC are underway examining the potential impacts of climate changes and water levels on Great Lakes coastal wetlands. Results will not be available for another four years.

Model Assessment: Through the development of the Integrated Ecological Response Model 2 (IERM2) and associated coping zones during the IUGLS, potential vulnerabilities and benefits from changing water levels were broadly characterized and used to compare regulation plan alternatives. It was generally concluded during IUGLS that the small differences between regulation plans tested did not result in detectable ecosystem response on Lake Superior and Lakes Michigan-Huron. However, with the implementation of Plan 2012, one of the areas that was identified to potentially be sensitive to changes in a regulation plan were ecosystems on the St. Marys River. To begin to address this specific area, a two-dimensional hydrodynamic model was developed covering the full extent of the St. Marys River by USACE. Work in 2017 focused on recreating the gated flow scenarios from 2015. In 2015, a partial-gate strategy was implemented to more evenly spread water across the rapids. These scenarios were contrasted with a more traditional full-gate opening approach. Water depths and velocities were computed on an approximate 4 m (13.1 ft) grid throughout the rapids. These data combined with LiDAR, photogrammetric data, temperature and limited biological data were compiled using an IERM developed for the St. Marys Rapids. The IERM predicts areas where various fish species are likely to spawn and their fry are able to survive. Work is expected to continue in the future with the goal of optimizing habitat based on the St. Marys Fisheries Task Group. For example, a US Geological Survey (USGS) Biological Station team received funding for fiscal year 2018 from USEPA for a three-year sampling plan to collect larval fish in the St. Marys Rapids. The collected samples and recorded species will be used as future validation for the UGL-IERM2 model relative to target species for spawning in the rapids (lake sturgeon, whitefish, and walleye). In addition, a proposal request for 2018 (via the IJC's International Watersheds Initiative) has been made to support the collection of sidescan sonar identifying substrate throughout the St. Marys Rapids and St. Marys River. The project will produce a map that will detail locations of silt/clay/mud, sand, cobble or bedrock in the project area. The spatial locations of substrate will build finer resolution in the IERM ecohydraulic model and improve prediction of target species spawning habitat and influences of water level and velocity changes in the rapids.

Modeling work is expected to continue with the goal of optimizing habitat based on ecohydraulic model outputs and insight from St. Marys Fisheries Task Group.

Key Findings and Next Steps: It is clear that GLAM needs a fully functional eco-hydraulic model in the St. Marys Rapids to establish the impacts of various release scenarios on the spawning habitats of native species. While an IERM2 model is currently under development, it is not ready to produce reliable results at the time of this report. Once the model has been updated, calibrated and validated then results can be used to guide the potential development of environmental performance indicators for the St. Marys Rapids. Also, there is currently research underway in Georgian Bay by McMaster University and additional studies being done by ECCC that may help validate assumptions that water level fluctuations are beneficial to wetland health.

5.6.2 LAKE ONTARIO – ST. LAWRENCE RIVER – Ecosystem

Sensitivity to Water Levels and Outflows: Thirty-one ecosystem performance indicators were developed covering Lake Ontario, the upper St. Lawrence River (above the dam) and lower St. Lawrence River (below the dam) during the LOSLRS. These indicators were chosen by experts based on their sensitivity to water levels changes, their significance in terms of ecosystem function and services to a region and based on the confidence in the scientific results. Coastal wetlands provide an ecologically important and biologically diverse transitional zone between open water and land. The coastal wetland meadow marsh indicator for Lake Ontario was established as a fundamental indicator of ecosystem response to water level changes as it provides diverse wetland vegetation reflecting the history of the range and duration of water level changes and provides important species habitat.

There have been many studies over the past twenty years indicating that the suite of performance indicators developed for the initial study would respond, to varying degrees, to extreme water levels and flows. A period of high water levels, for example, as occurred in 2017 on Lake Ontario, is expected to have the effect of forcing a wetland's shrub zone to a higher elevation and allowing expansion of the meadow marsh communities. Monitoring how coastal wetland habitats change with respect to elevation is important for teasing apart the influence of water-level management and other factors that play a role in habitat change, such as invasive species, alterations to adjacent upland areas, or other changes in hydrologic inputs. However, from a resourcing perspective it is not feasible to investigate the responses of all the LOSLRS performance indicators to the 2017 conditions. Therefore, efforts were concentrated on identifying which of these indicators would be most affected and which indicators were already being monitored. Indicators theorized to show a large response to a high water level event including those which were being monitored in 2017, such as meadow marsh, are reported on in this section and in more detail in Annex 1-Impact Assessment. Efforts to develop methods for long term monitoring programs to collect data on indicator response in the future were taken and fully detailed monitoring programs are currently in the works.

Following the LOSLRS, it was concluded that, under Plan 2014, a more natural variability in water levels would produce significant environmental gains when compared to the previous plan 1958-DD. The strong correlations between plant types and flooding history provide the scientific evidence. In order to effectively assess the impacts of the 2017 event on the ecosystem, several efforts were tracked. Surveys of wetland plant communities were done in prescribed areas on Lake Ontario where surveys had been conducted in recent years. Surveys prior to 2017 provide a comparative baseline for the performance of meadow marsh in 2017. Additionally, various federal, state and provincial government agencies that were conducting studies on relative fish and animal species that make up some of the performance indicators were willing to collaborate their findings and provide a snapshot of how those indicators performed in 2017. On the lower

St. Lawrence River, while there are numerous ecosystem indicators that are sensitive to water level changes, there is not expected to be a significant change in water levels from the old plan to the new plan. Nevertheless, the extreme events of 2017 provide a good test of modelled results.

When discussing the impacts of high water to the ecosystem performance indicators, it should be emphasized that many of the environmental indicators are responding to seasonal and multi-year cycles and take time to respond. Many of the performance indicators currently being monitored are expected to see measurable impacts due to a high water event over several years and not within a matter of months. This fact remains a challenge for the GLAM Committee. It is impossible to report on some of the ecosystem impacts from the 2017 high water event on Lake Ontario and the St. Lawrence River until they have come to fruition. For this report, the ecosystem section focuses on data collected to date and the results of models and expert opinion on expected outcomes. Follow-up monitoring will be needed to determine if these outcomes are realized over the coming years.

Summary of Observed 2017 Impacts: The impacts from the 2017 event on Lake Ontario and the St. Lawrence River are largely unclear at this point. Some early results from wetland monitoring efforts are indicating some vegetation response is occurring even within the high water year. Model results on the lower river are mixed. There is much data collection and analysis remaining to be done. Data collected in 2017 can be used to inform comparative years in the future. Observed impacts to the wetland plant communities are summarized in the surveys of 32 specific sites around the entire Lake Ontario shoreline. Results from this survey are summarized in the Annex 1-Impact Assessment.

The efforts of wetland surveying by the Canadian Wildlife Service (CWS) and New York Department of Environmental Conservation (NYDEC), supported by the IJC's International Watersheds Initiative, include some information on the initial impacts to wetland plant communities at elevations above typical meadow marsh communities. NYDEC and CWS have committed to share data and pursue analysis using the peer-reviewed ordination method used to delineate wetland plant communities. A summary of the CWS and the New York Natural Heritage Program (under NYDEC) surveillance efforts are included in Annex 1-Impact Assessment. It is noted that the full extent of inundation of these higher elevation communities were not expected to be realized for this year's monitoring effort, however, early indication from this year's monitoring does indeed indicate some vegetation response. Further monitoring in the coming years will be necessary to determine how these vegetation responses are reflected in future years.

Several additional performance indicators were expected to be impacted due to the 2017 conditions. At this point, no data have been collected on these performance indicators to corroborate the anticipated impacts. Further efforts are being pursued to establish responses from these performance indicators. Additional performance indicators expected to be impacted due to the 2017 conditions are as follows:

- Changes in bird nesting habitat due to the availability of specific plant species sought by endangered/ threatened bird species;

- Typha (cattail) die-back due to long term exposure to high water as predicted in the wetlands model;
- Possible invasion of Phragmites to replace cattails after disturbance;
- Fish spawning increase due to expanded spawning habitat; flooding increases size of the nearshore, providing more cover for fish spawning and survivability;
- Shorelines experiencing heavy tree loss creating debris fields and the associated impacts to water quality and/or species habitat; and
- Shoreline changes such as cut-back of dunes and subsequent habitat loss for dune nesting birds, and the breaching of barrier beaches causing the exposure of protected wetlands to open lake waves.

The GLAM Committee is currently actively engaged in the development of long-term monitoring programs to collect response data on specific performance indicators. As part of this effort, the project on state of science of remote sensing for ecosystem indicators is currently underway (an IJC International Watersheds Initiative project (Ryerson, 2018)) and should provide some specific methodologies to establish long term monitoring programs that the GLAM Committee could manage with its limited resources.

Modelling Assessment: The LOSLRS developed an extensive IERM covering 32 environmental indicators, notably nearshore coastal wetland habitats, as well as the bird, fish, mammals, invertebrate, amphibian, and reptiles that are directly impacted by water level and flow conditions on Lake Ontario and the St. Lawrence River for some critical portion of their life cycle. In order to identify the specific performance indicators on Lake Ontario and the upper St. Lawrence River impacted by 2017 conditions, two approaches were employed. The first was an analysis of the original LOSLRS performance indicator algorithms linking outcomes to water levels and a comparison of the thresholds associated with those algorithms and the observed 2017 conditions indicating impacts to specific species indicators. The second was an analysis of the IERM model results employing a representative water supply year from the historic series to represent the conditions observed in 2017.

The LOSLRS performance indicator algorithms were developed with the input of various professional experts that set metrics for some of the more critical species indicators. In order to establish which species were likely impacted by the 2017 conditions, an assessment of the water level fluctuations and static quarter month levels was done with respect to the individual indicator’s algorithms identified to be key environmental indicators in the LOSLRS. These algorithms define specific conditions during quarter month time frames that are expected to impact the performance of that species in that year. For example, during quarter months 18 through 26 (roughly the 2nd week of May through the 2nd week of July), Lake Ontario water level fluctuations exceeding a raise or drop of more than 0.2 m (0.66 ft) per quarter month (approximately 1 week) are expected to negatively impact the wetland birds Least Bittern and Black Tern, which are considered species at risk and designated as Vulnerable by MNRF and Threatened or Endangered by NYSDEC. The 2017 conditions did not exceed a 0.2 m (0.66 ft) fluctuation in any specific quarter month within the targeted timeframe, therefore there was no negative impact forecasted by the algorithm for these species. Another factor in the success rate of these wetland birds is the mean water depth below nests within the emergent marsh areas of wetlands. For nesting to be successful, Least Bittern need a mean water depth between 0.2 meters (0.66 ft) and 1.0 meter (3.28 ft) below their nest. The mean elevation of emergent marsh for all types of hydrogeomorphically classified wetlands in 2017 was 74.92 m (245.80 ft), as established in the 2017 field sampling analysis of the US wetlands. In 2017, Lake Ontario crested at 75.88 m (248.95 ft) in quarter month 21 which translates to a mean water depth of 1.04 m (3.41 ft) within the emergent marsh zone. This is slightly above the algorithm's anticipated maximum water depth below nests for Least Bittern at several different study locations in the sensitive quarter month time frames. Therefore, Least Bittern's reproductive potential was identified by the algorithm to be negatively impacted by the 2017 conditions. The Least Bittern was the only key environmental indicator assessed to be negatively impacted by 2017 conditions.

The second method's modeling runs performed on the ecosystem performance indicators revealed that a comparative high water year selected from the historic set of water supplies produced the most impacts in the performance indicators of the Least Bittern, Virginia Rail, Black Tern, and upper St. Lawrence River muskrat housing density. The original study algorithm placed significant impact on these bird species related to high water events occurring during the months of May, June and July. This, of course, means that the 2017 event would be expected to significantly benefit these performance indicators. Though the exploratory model results indicated significant positive impacts to muskrat housing density, the study algorithm emphasized impacts to this performance indicator during high water events from September through February. While water levels were significantly lower in the fall compared to their record high spring and early summer levels, they did remain well above average into the fall months. The NYDEC has a monitoring program ongoing for muskrat which could help validate the algorithm for this performance indicator in future years, but data for muskrats was unavailable prior to the finalization of this report.

Lake Ontario Wetlands algorithm

The IERM calculates wetland vegetation elevation response based on Lake Ontario water levels using the:

- *dewatering elevation* (highest peak quarter-month water level) for vegetation response to dry conditions; and
- *flooding elevation* (fourth highest quarter-month water level around the peak to represent the highest month of flooding) for vegetation response to wet conditions.

High water levels such as those experienced in 2017 are expected to flood and result in the die-off of upland shrubs and trees and meadow marsh up to the flooding elevation. The flooding elevation as described above for 2017 is 75.81 m IGLD85 (248.72 ft) and the IERM algorithm predicts the Cattail-dominant meadow marsh plant community would rise in elevation up to 75.81 m IGLD 85 (248.72 ft). The IERM algorithm is currently programmed to have vegetation respond to water levels from the year before, in other words the die-off of upland shrubs and trees and meadow marsh would be expected to occur in 2018, one year after the 2017 high water levels. The 2017 conditions cause the IERM algorithm to predict that meadow marsh and upland vegetation will remain unaffected in 2017 by high water levels. Those plant communities would be expected to die-off up to 75.81 m IGLD 85 (248.72 ft) in 2018 in the IERM algorithm. This is discussed further in the Annex 1-Impact Assessment.

Lower River IERM Analysis for 2017: Several environmental performance indicators were developed during the LOSLRS that aimed to quantify/qualify the impacts of discharge regulation on fauna and flora on the lower St. Lawrence River. The 11 indicators presented in the Annex 1-Impact Assessment are the key indicators selected from a large number of environmental indicators (more than 200) developed for the Lower St. Lawrence River that were found to be the most sensitive, significant and having the greatest level of certainty in terms of the science and model results. Model results of the 2017 conditions on these 11 indicators can be found in the Annex 1-Impact Assessment and indicate a mix of positive and negative scores across the performance indicators demonstrating what would be expected by the model under these conditions. The GLAM Committee has not yet been able to track down any monitoring data to help verify the model results.

Key Findings and Next Steps: When discussing the impacts of high water to the ecosystem performance indicators, it should be emphasized that many of the environmental indicators are responding to seasonal and multi-year cycles and take time to respond. Many of the performance indicators currently being monitored are expected to see measurable impacts due to a high water event over several years and not within a matter of months.

Field data from the surveillance of the Canadian wetlands done by CWS in 2017 (IJC International Watershed Initiative project) show a reduction of percent cover of meadow marsh from 2015. This is to be expected as the flooding of these species during the growing season affect the meadow marsh species, resulting in smaller coverage area of this particular vegetation guild. It should be noted that shifts in guild extent resulting from 2017 water level conditions will not be immediately evident as there is a lag in response from the various plant communities. In order to ensure that the wetland response to 2017 conditions is adequately monitored and recorded, GLAM has contracted with CWS in 2018 to conduct monitoring of wetlands at 16 sites in Canada. The objective of the 2018-2019 collection effort is to assess the vegetation zonation at the 16 sites. Data collected from this monitoring effort will provide a data set that can be leveraged to track the wetlands response to the 2017 conditions over time. It is imperative for model validation and future evaluation of the wetland response performance indicator on Lake Ontario that these data are collected over the next few years.

In addition to the immediate need for field surveys, GLAM is actively exploring potential methods for long term monitoring programs that can be applied to various ecosystem performance indicators. During GLAM’s 2017 data collection efforts, the need for monitoring data of the species-specific performance indicators on the lower St. Lawrence River was identified. There was no available monitoring data from 2017 with which results of the lower St. Lawrence IERM model runs could be verified. It is essential to develop a plan to collect data on the lower river species performance indicators so we can validate the model results in the future. Remote sensing technologies are being explored to help inform this effort and a remote sensing subject matter expert workshop was held on March 26th and 27th of 2018 (Ryerson, 2018). This effort will be dependent upon taking the first step to identify the performance indicators that are best suited to a long term monitoring plan and developing the monitoring plan around that small set of indicators.

5.7 Recreational boating and tourism

The IUGLS looked at water level impacts to recreational boating activity, marinas and coastal tourism including cruise ship traffic (IUGLS, 2012). There was one recreational boating and tourism performance indicator used to evaluate regulation plans during the IUGLS. The indicator was the change in availability of boat slips across the study area and was represented as a Pass/Fail score based on whether changes were considered disproportionate for a particular lake or region. The coastal tourism and cruise ship sectors were not represented by a performance indicator. Data on boating activities and trends is fairly limited and was identified as an area that required further investigation through adaptive management (IUGLS, 2012).

During the LOSLRS, the recreational boating interest group was defined as including “pleasure boating and fishing, marinas and the commercial cruise ship industry” (IJC, 2014). As noted in the IJC’s Plan 2014 report, “Analysis undertaken for the IJC’s Lake Ontario-St. Lawrence River Study found that recreational boaters in the US and Canada spent an estimated $430 million on boating-related trips taken on Lake Ontario and the St. Lawrence River in 2002.” (IJC, 2014). The primary performance indicators were total possible boating days lost and net economic value lost (willingness-to-pay). These measures provide an estimate of both recreational loss and economic loss as water levels change (IJC, 2006). The willingness-to-pay performance indicator was developed based on estimates of days boated and net economic value by water reach, country (US or Canada), water access method (private dock, marina, launch ramp, charter boat), boat type (sail or power), and boat length class. Net economic value was estimated based on boat owners’ willingness-to-pay for boating over and above what they are already paying. The performance indicator was applied based on geographic regions that included Lake Ontario, the upper St. Lawrence River broken into three sections and referred to as Alexandria Bay, Ogdensburg, and Lake St. Lawrence and the lower St. Lawrence River which was divided into the Lake Saint-Louis, Montreal, and Lake Saint-Pierre sections (see Figure 5-39).

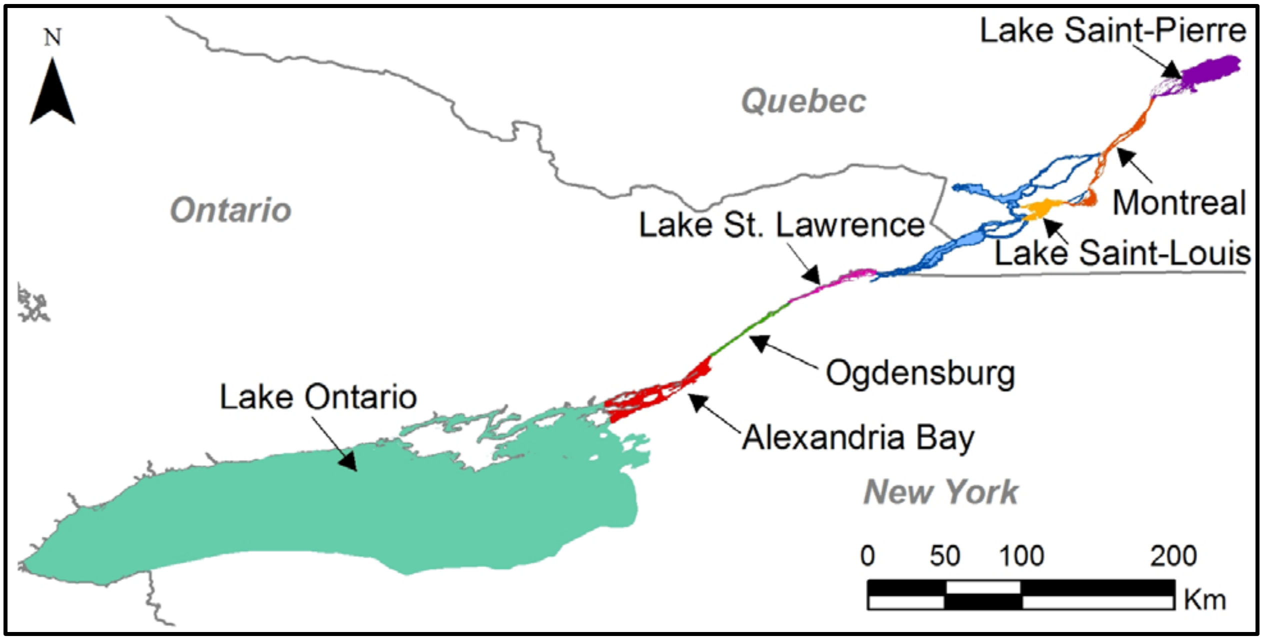


Figure 5-39: Recreational boating reaches as used for the LOSLRS recreational boating performance indicator (Source: International Lake Ontario – St. Lawrence River Study Board, 2006, Annex 2)

Tourism was considered during the LOSLRS as part of the Recreational Boating and Tourism Technical Working Group activities. However, as noted on page 39 of Annex 2 of the LOSLRS (2006), "the economic advisors to the study recommended that the tourism-related IMPLAN (Impact Analysis and Planning model) results not be used because they were not comparable with measures used by other interest groups." As a result, the primary indicator for recreational boating and tourism impacts was the willingness-to-pay indicator of recreational boating activity.

5.7.1 UPPER GREAT LAKES – Recreational boating and tourism

Sensitivity to Water Levels and Outflows: While boaters and marina operators are sensitive to water level fluctuations on the upper Great Lakes, including both low and high water levels, marina operations were found to be more dramatically impacted by low water levels when compared to high water levels (IUGLS, 2012).

During the IUGLS, coping zones (for explanation, see Section 5.1.1) were developed to describe potential impacts under varying water levels for the recreational boating sector (Table 5-6).

Table 5-6: Summary of Rec Boating Coping Zones relative to Marina Slips. (Source: IUGLS 2012)

	Zone A	Zone B	Zone C
Max WL (m)	Superior: 184.3 Michigan-Huron: 177.3 Erie:174.8	Superior: There is a jump from Zone A to C between 184.3 and 184.6 Michigan-Huron: 177.3 (According to 'Out of Business' and 'Slip Loss' numbers, there is a jump from Zone A to Zone C after 177.3) Erie: 174.8 – 174.95	Superior: > 184.6 Michigan-Huron: > 177.6 Erie: > 174.95
Min WL (m)	Superior: 182.8 Michigan-Huron: 176.1 Erie: 173.61	Superior: 182.5 Michigan-Huron: 175.5 Erie: 173.61 – 173.46	Superior: <181.9 Michigan-Huron: < 175.2 Erie: <173.46
Rate of Change	Quick drops or rises are generally considered a negative as interest does not have time to adjust	A quick return to Zone A regime would be beneficial. A further drop/rise, or prolonged period at this elevation could push interest to Zone C	Any length of time in Zone C would make it difficult for many of the marinas to remain operational
Slip Loss	Less than 5%	5% - 30%	Greater than 30%
Adaptation	Interest will take action to protect investment even within this zone, however, expenditures are within expectations	Property owners likely to take action to protect their investment. Could make them more resilient next time levels are at extremes and help them within Zone A levels	Existing adaptation not sufficient shore protection overtopped or useless because levels are so low. Hazard zones have been exceeded.
Suggested Indicators for Assessing Thresholds	Slip losses and interview responses regarding 'out of business' levels	Slip losses and interview responses regarding 'out of business' levels	Slip losses and interview responses regarding 'out of business' levels

The IUGLS found that recreational boating would not be measurably impacted by a change from Plan 1977A to Plan 2012 (no disproportional losses). This was based on a measure of the usability of boating slips and a pass/fail score based on whether one region of the system might suffer dis-benefits relative to another region.

Summary of Observed 2017 Impacts: Generally speaking, slightly above average water levels on the upper Great Lakes are considered beneficial to the recreational boating sector as they allow recreational boats to get in and out of marinas and harbors more easily. However, no data have been gathered to date by the GLAM Committee to document negative or positive impacts of above average water levels in 2017 on the recreational boating and tourism sector. There were no negative reports to the ILSBC in 2017 and water levels in 2017 fit within the IUGLS defined coping zones for recreational boating (Figures 5-40 to 5-42). There has been no formal validation of these coping zones since the 2012 IUGLS.

Water levels in 2017 on Lake Erie hovered near or above the Zone A Max transition coping zone. The expected sensitivities and slip losses described in Zones A (< 5 % slip loss) are closely representative to 2017 media reports where there were some temporary negative impacts to floating docks but no permanent loss or damage to slips and access.

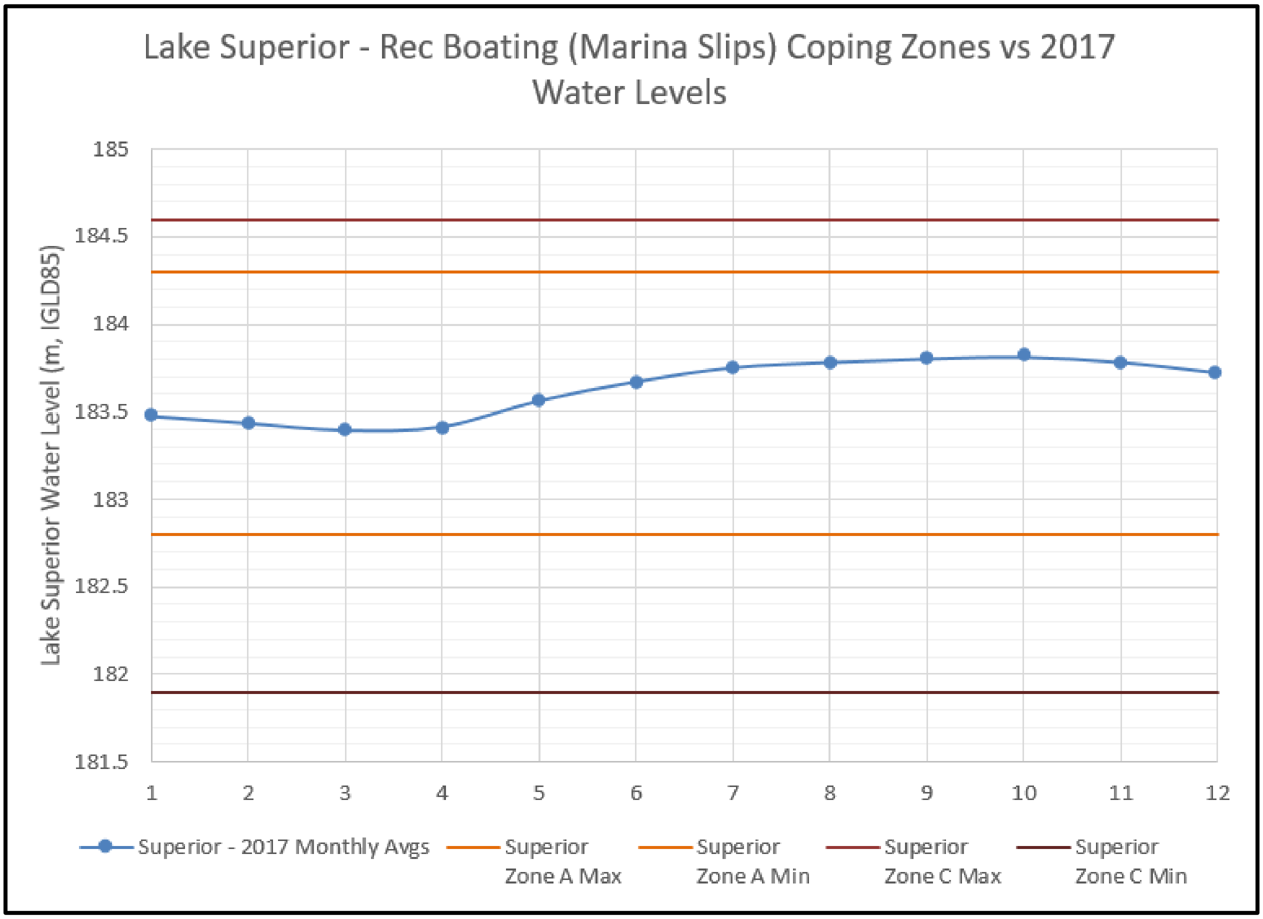


Figure 5-40: Coping zones for Lake Superior Recreational Boating (Marina slips) compared with 2017 water levels (Source: USACE, Detroit District)

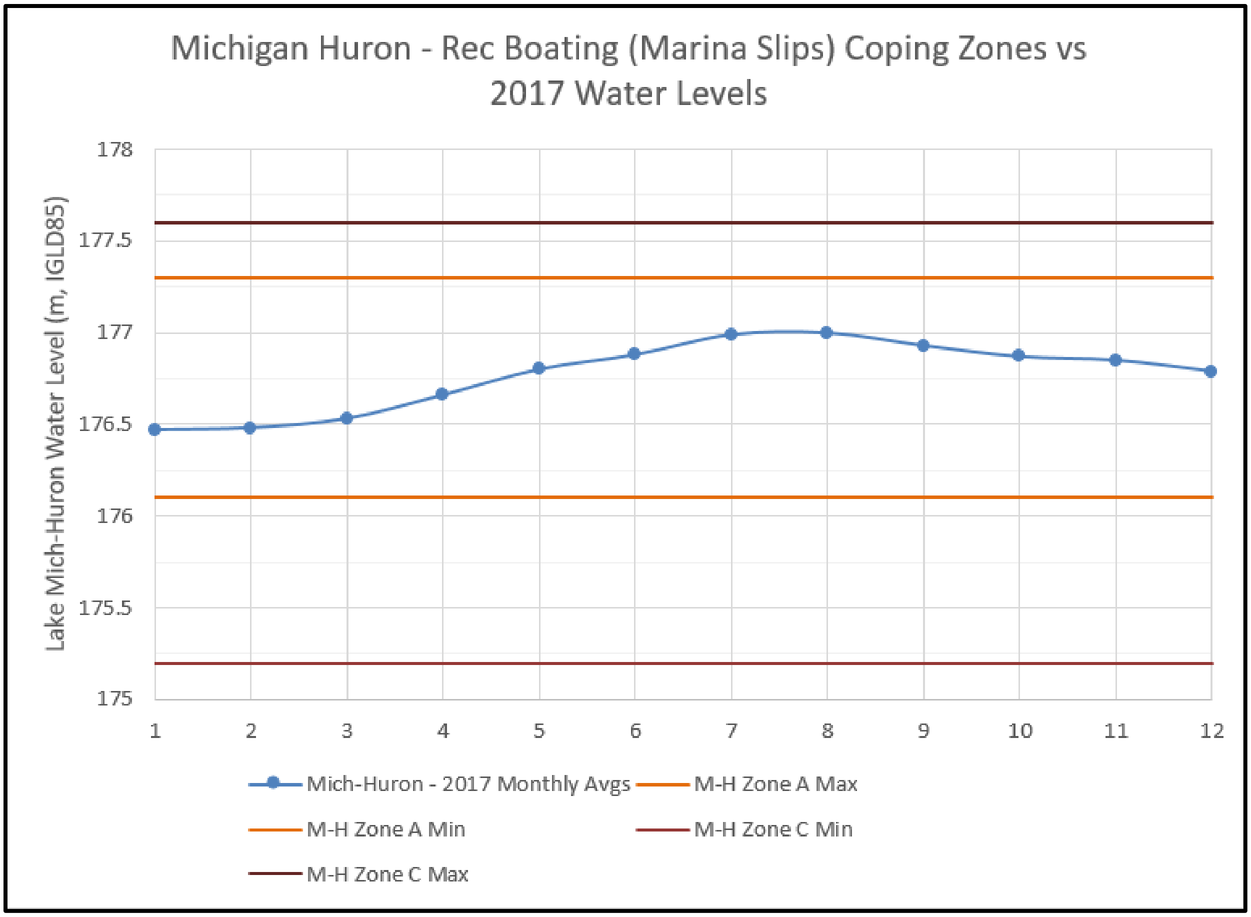


Figure 5-41: Coping zones for Lakes Michigan-Huron Recreational Boating (Marina slips) compared with 2017 water levels (Source: USACE, Detroit District)

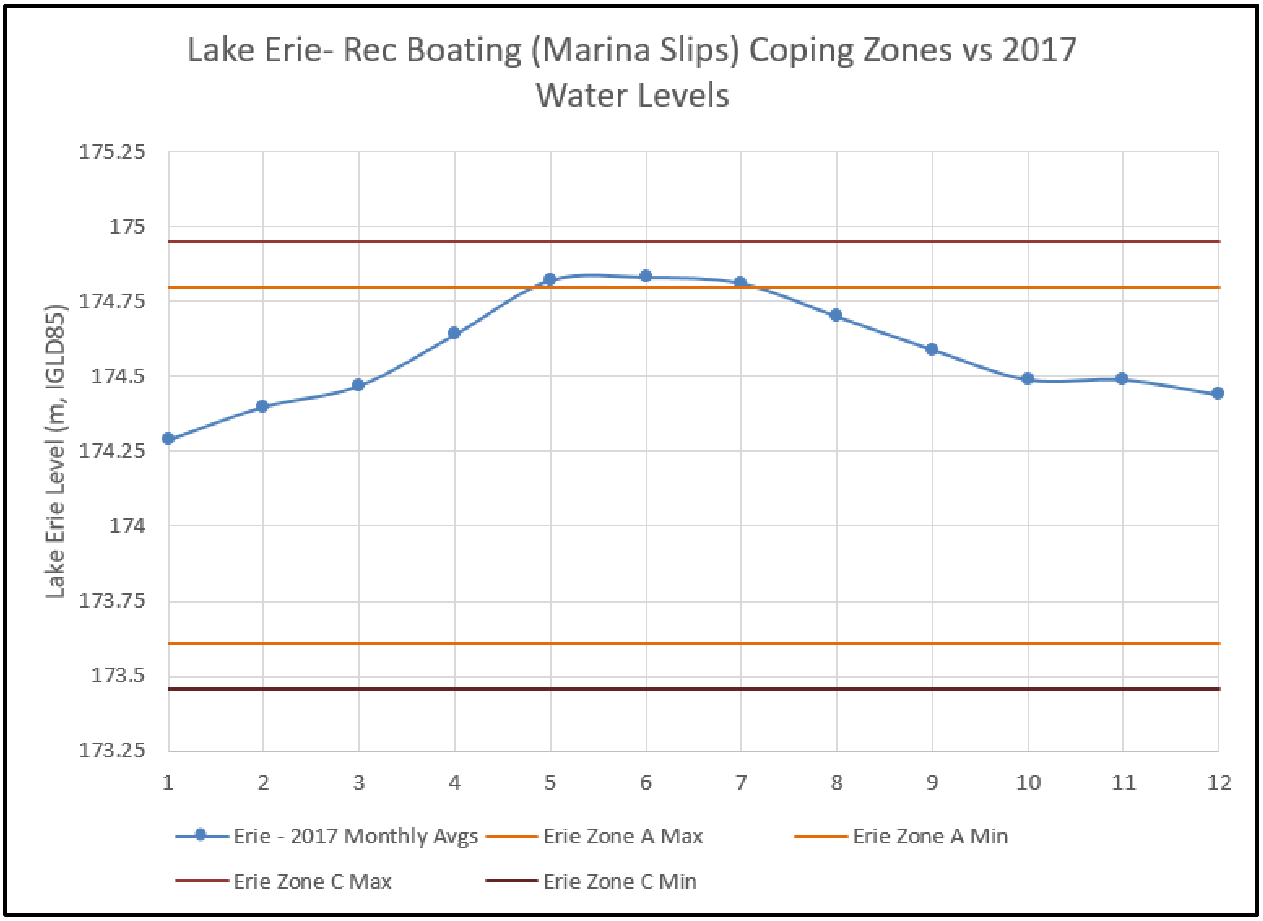


Figure 5-42: Coping zones for Lake Erie Recreational Boating (Marina slips) compared with 2017 water levels (Source: USACE Detroit)

Model Assessment: There has been no attempt by the GLAM Committee to validate either the one performance indicator used during the IUGLS, which was the change in availability of boat slips across the study area represented as a Pass/Fail score, or the coping zones developed during the IUGLS. Consideration of this will be given future attention as the GLAM Committee grapples with needs and priorities, as this sector is minimally affected by the regulation plan.

Key Findings and Next Steps: Recreational boating and tourism activities on the upper Great Lakes did not appear to be negatively impacted in 2017, with the exception of some impact to Lake Erie marina operators. Otherwise, it would appear the levels of 2017 have been generally positive for recreational boating. Given that this interest is not particularly sensitive to Lake Superior outflow regulation changes, it is not yet clear how much effort will be applied to this sector in future analyses, or whether existing information is sufficient.

5.7.2 LAKE ONTARIO-ST. LAWRENCE RIVER – Recreational boating and tourism

Sensitivity to Water Levels and Outflows: As with the upper Great Lakes, recreational boaters on Lake Ontario and the St. Lawrence River are sensitive to both low and high water levels. In the development of the LOSLRS performance indicators, impacts during lower water periods were considered particularly critical as recreational boating activity declines and even stops in some places. This is due to low water levels reducing the ability to use boat launches or causing docks to no longer be usable due to limited draft for the types of boats that would normally use such facilities. Of course, impacts are also experienced under high water conditions such as those observed in 2017 as recreational boating opportunities are reduced where water levels inundate non-floating docks or boat ramp facilities. Impacts can vary from site to site with some locations with deeper water and floating docks able to tolerate greater water level variability compared with locations with shallow water and/or non-floating docks (see Figure 5-43). Recreational boating activity varies seasonally and during the LOSLRS, willingness-to-pay estimates were adjusted monthly from April to October. The vast majority of boating activity typically takes place between late June and early September making water levels during that period particularly important to this sector when comparing overall regulation plan performance.

Figure 5-43: Platform added to fixed dock to gain access to sailboat, Oak Orchard Creek in Orleans County. Photo credit: Diane Kuehn, 2017.

During the LOSLRS, the IJC concluded based on their analyses of various water supply sequences, that Plan 2014 could reduce average recreational boating benefits on Lake Ontario and the river upstream of Ogdensburg, NY and increase them on Lake St. Lawrence and the river downstream of the Moses-Saunders dam. However, further consultation with the interest during public meetings and hearings revealed considerable support from upper St. Lawrence River boaters because of the greater chance of higher water levels in the fall which would extend the boating season and because many had floating docks which are less sensitive to water level fluctuations.

Summary of Observed 2017 Impacts: ***NOTE - Much of the information currently available to the GLAM Committee to assess these impacts is descriptive and anecdotal and efforts are ongoing to further quantify impacts. To support the current assessment, the GLAM Committee gathered information from a variety of sources including a review of available oblique imagery acquired during the high water period (Figure 5-44) and responses to the Conservation Ontario self-reporting survey (Figure 5-45), as well as public reporting by marinas through their social media sites. An overall description of impacts is provided here with further details and regional descriptions provided as reference in the Annex 1-Impact Assessment.***

Recreational boating opportunities were reduced in many areas of the Lake Ontario, upper St. Lawrence, and lower St. Lawrence River shoreline during the extreme high water levels of 2017. In general, recreational boating impacts appeared to be most common in Monroe and Wayne Counties along with Prince Edward County and portions of the upper St. Lawrence River. Impacts were experienced in other areas as well but did not appear to be as concentrated. Many marinas experienced significant impacts to operations as non-floating docks were inundated (e.g. Figure 5-46) and other facilities (e.g. electrical hookups) were damaged. Given the extreme high water conditions, many locations with floating docks were also negatively impacted or required short-term modifications to maintain access. Many state, provincial, and municipal boat ramps were impacted leading to prolonged closures in some cases. It is possible that above average water levels later in August and into September and early October combined with nice weather allowed for some additional boating activity in that period compared to typical years, but further work is required to verify that possibility.

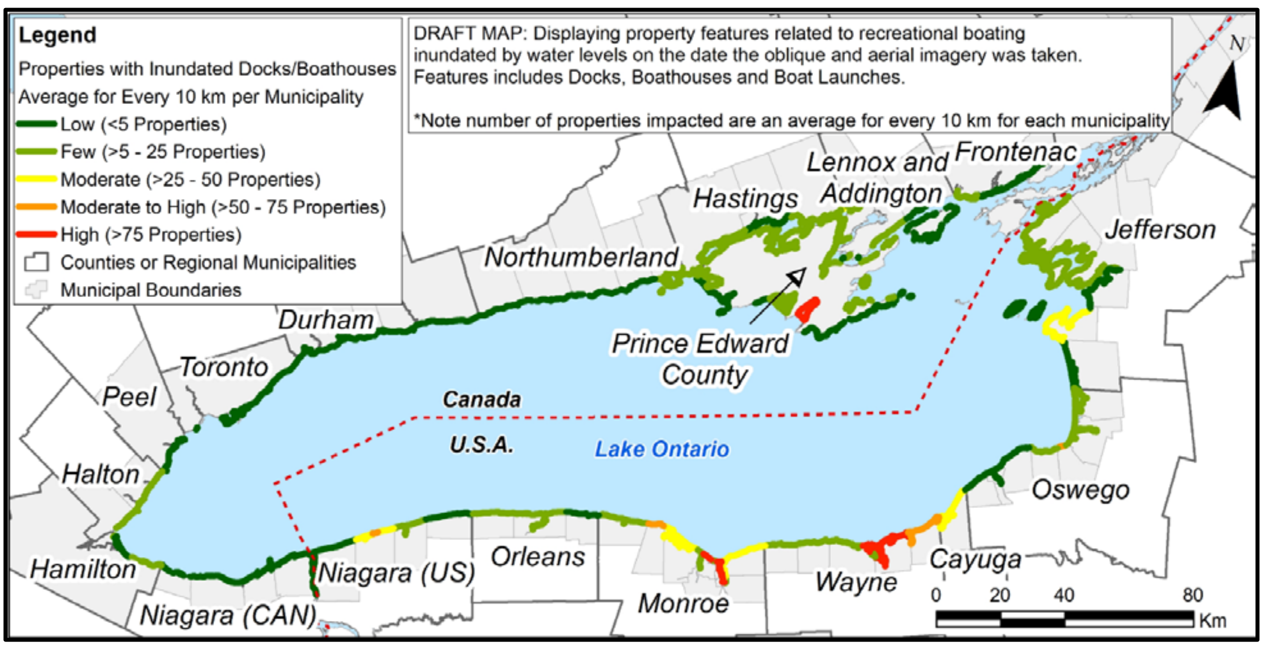


Figure 5-44: Representation of impacts identified through oblique imagery review (Source: ECCC/IJC estimates based on aerial imagery collected through the Transport Canada National Aerial Surveillance Program in May 2017)

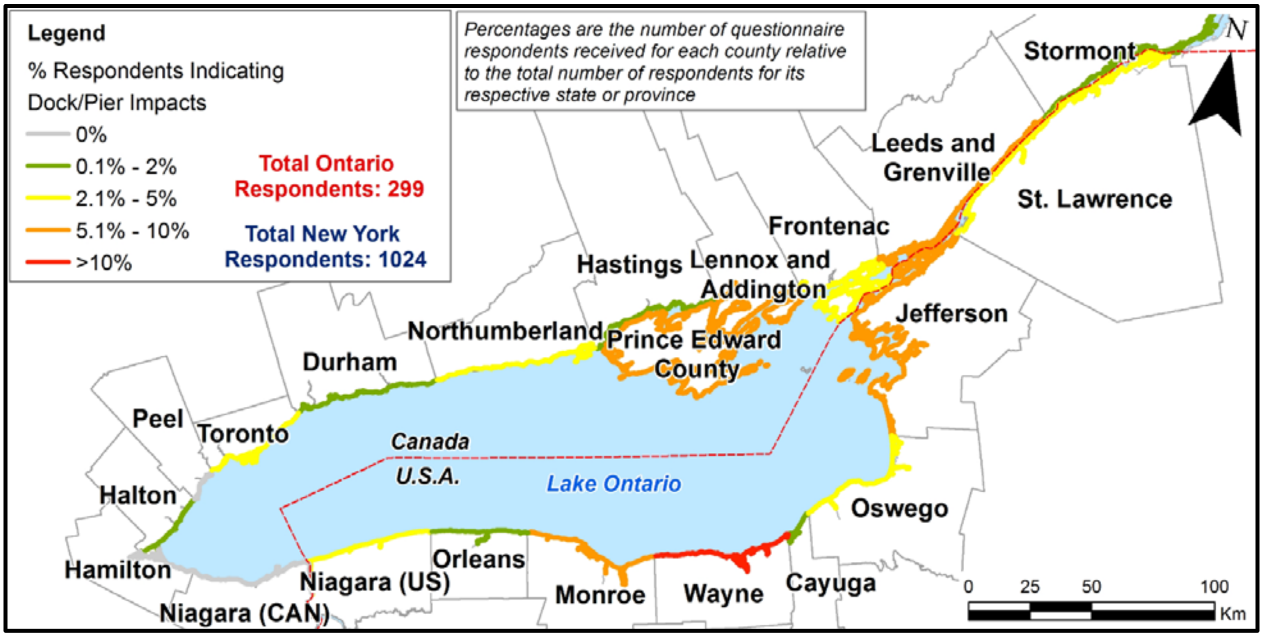


Figure 5-45: Percent of survey responses indicating dock/pier flooding (shown as a relative % by County relative to total number of that reported impact for Country) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Figure 5-46: Kingston Yacht Club, June 14, 2017. Photo credit: ECCC.

In the Lake St. Lawrence area, water level impacts varied widely throughout the boating season. As with Lake Ontario and the upper St. Lawrence River in the Thousand Islands area, extreme high water conditions early in the year (May, June) led to inundation of docks and boating facilities and a reduction in boating opportunities. However, record high outflows starting in late May and continuing through July caused a drawdown of water levels in the Lake St. Lawrence area. As Lake Ontario levels continued to decline through the summer and outflows remained very high, low water level problems were observed on Lake St. Lawrence which required a short-term flow reduction over the October 6-October 8, 2017 weekend to allow boat haul-out, a situation not untypical in any given year and under the previous regulation plan.

On the lower St. Lawrence River, high water levels during May directly impacted boating facilities and, in turn, recreational boating opportunities (Figure 5-47). High outflows throughout late May, June and into July kept water levels near record levels in the Lake Saint-Louis area but the GLAM Committee does not currently have information on how recreational boating opportunities were impacted during that period. The same can be said for recreational boating downstream in the Montreal and Lake Saint-Pierre reaches. The GLAM Committee is working with the IJC to initiate a contract to gather further information in this area through a survey of marina operators and that information will support long-term GLAM Committee model validation efforts.

Figure 5-47: Beaconsfield Yacht Club showing inundation to a portion of the shoreline facilities on May 7, 2017. Photo credit: (left) Transport Canada - National Aerial Surveillance Program, (right) Jacob Bruxer, ECCC, May 5, 2017.

Tourism impacts were reported throughout the system and included loss of beach and facility access at state, provincial, and municipal parks, along with impacts to lodging and other private shoreline facilities. In the Thousand Islands area of the upper St. Lawrence River, over 82% of tourism operations responding to a survey conducted by the 1000 Islands International Tourism Council reported some degree of negative impact due to high water levels (1000 Islands International Tourism Council, 2017). As well, tour boat operators in the Thousand Islands area saw a reduction in passengers during the peak flood periods. There were many reports of loss-of-use impacts to public parks along the shoreline including the need to move festivals or shut down sites altogether. For example, Toronto Island was closed for 88 days from May 4 to July 30, 2017 with a loss of ferry revenues alone being estimated at $4.50 million (City of Toronto, 2018).

Model Assessment: All recreational boating willingness-to-pay curves developed during LOSLRS indicated a loss in recreational boating opportunity under high water conditions with the upper threshold at which boating impacts occur and the sensitivity to high water conditions differing for each geographic reach (see Annex 1-Impact Assessment for a further example). This appears consistent with anecdotal information from 2017 as there were many reports in the media and otherwise about negative operational impacts during the period and a reduction in boater activity, as well as boat ramp closures, particularly during the peak water level conditions throughout the system. Further investigation is needed by the GLAM Committee to understand how adaptive responses impacted recreational boating opportunities and allowed for continued functioning in some areas despite extreme conditions, for example making temporary or longer-term facility modifications to allow continued access. One area not included in the willingness-to-pay performance indicator is direct impact damages to shoreline facilities such as docks, storage buildings, etc. There is some crossover with the coastal performance indicators (e.g. flooding of residential buildings) but there were a number of examples where marina facilities appeared more sensitive to the high water conditions (i.e. they started flooding at lower water levels) due to their proximity to the shoreline and further investigation of these thresholds is required. It is also important for the GLAM Committee to establish a performance indicator that can be maintained and monitored into the future and there is some concern that willingness-to-pay may not lend itself well to such updates. This will need to be further explored to determine if a simpler proxy can be found.

There were no broader tourism related performance indicators used during the LOSLRS. Given anecdotal information from 2017, there may be opportunities for the GLAM Committee to develop or revisit relevant performance indicators in this area. For example, loss of beach use had local impacts at a number of state, provincial, and municipal locations. While the LOSLRS coastal technical working group tested a preliminary performance indicator related to beach impacts, it was not included in the overall evaluation based on advice of the economic advisors at the time and may need to be revisited. Also not captured by existing performance indicators was the significant impact to tourism caused by the closure of parks and particularly Toronto Island and other state and provincial parks which may have negatively affected the local economy. As has been mentioned earlier, while the performance indicators are not expected to capture all impacts, they are expected to be measurable representatives of the key impacts that are sensitive to water levels and significant to the interest category (i.e. they represent what people care about).

Key Findings and Next Steps: Recreational boating and tourism activities were negatively impacted throughout the Lake Ontario – St. Lawrence River in 2017. As with the coastal impacts, recreational boating impacts varied based on site specific conditions with some locations appearing to be more vulnerable than others. A priority is the initiation of a marina and yacht club owner survey to gather direct information on thresholds and impacts during 2017.

Due to the inability to assess the current performance indicator, it is necessary to reassess the current indicators for recreational boating. Assessing total possible boating days lost and net economic value lost or willingness-to-pay is not possible with the information available following the 2017 event. Additionally, GLAM intends to pursue the following activities:

- Investigate developing a performance indicator to track tourism, perhaps through reported numbers of visitors to beaches and shore adjacent parks;
- Better define regional high water thresholds throughout the system (some sites are very sensitive to high water conditions while others are less sensitive and GLAM does not yet have enough information from 2017 to assess any overall reductions in recreational boating activities);

- Look at how the timing and duration of flooding events impact overall recreational boating activity on Lake Ontario and the St. Lawrence River (e.g. how significant is a delay in the start of the season to overall recreational boating activity?) and how that compares to the LOSLRS performance indicator;
- Revisit how certain positive and negative impacts spanning multiple impact categories are captured by existing performance indicators. For example, potential overlaps or gaps between the coastal indicators and the recreational boating and tourism indicators related to flooding of non-residential buildings (e.g. marina buildings) or loss of use impacts (e.g. closure of park facilities); and
- Assess how fishing activity may be influenced by water levels as part of a performance indicator review.

6.0 Plan Review and Evaluation

What can be learned from the application of the regulation plans for the outflows from lakes Superior and Ontario in 2017 that could inform plan improvements? This section addresses that question for both lakes, with heavy emphasis on the Lake Ontario-St. Lawrence River plan because of the record high water levels and flows in that basin. The analysis is based on water levels, not economic or environmental impacts because the GLAM Committee is still in the process of gathering and documenting those impacts. In the future, the GLAM Committee will present an analysis using economic and environmental performance indicators informed by impacts in 2017, but for now, this section highlights areas where the impact analysis is expected to add essential insights into the on-going plan review.

6.1 Introduction

The IJC requires the GLAM Committee to support the ILSBC and the ILOSLRB in the on-going assessment of the regulation plans to “make recommendations to the IJC for modifications to the regulation plans to address what has been learned and/or to address changed conditions of the system[1]”. The GLAM Committee has developed the evaluation process used in this chapter to provide an immediate retrospective and to generate one year of information for 2017 that can be added to future assessments to support a long-term plan assessment.

The GLAM Committee is working to establish an annual plan evaluation that contributes to the long-term evaluation strategy by:

1. Analyzing how water levels and flows in the Great Lakes-St. Lawrence River system are influenced by particular hydrologic conditions in any given year (e.g. 2017);
2. Using net changes from a baseline regulation setting to clarify the impact of a regulation decision. In this report, GLAM uses the former regulation plan, pre-project conditions

[1] IJC 2015 Directive to the GLAM Committee

(the unregulated hydraulic conditions) and, in the case of Plan 2014, even compares simulated variations from Plan 2014 to the actual Plan 2014 results;

3. Assessing not only water levels but the impacts, such as flood damage, shipping efficiency or power production. GLAM is in the process of acquiring impact data from 2017, so will not be able to include impact assessments in this report. This analysis will continue into the future; and
4. Supporting a multi-year analysis using a wide range of hydrologic and other conditions. There are several reasons for using multi-year evaluations:
    a. One year influences the next. Water levels do not return to the same level at the end of every year, so the ending level from the previous year can be an important input influencing the outcomes from the next year;
    b. Regulation rules that work well in some years and supply conditions may not work as well as they could in others. For example, because no one can predict the supply of water into the Great Lakes, regulation plans must hedge for the possibility of dry or wet futures. Rules that are best at avoiding drought levels might exacerbate flooding in wet years, and vice versa; and
    c. Many of the expected positive outcomes of the regulation plans, especially environmental ones, are only expected to be realized after several years, or possibly even decades, as they too depend on water supply conditions.

Based on the above, simulations of flows out of Lake Superior and out of Lake Ontario were conducted under a variety of scenarios to assess the influence of a number of factors related to the extreme water levels event of 2017. Again, this represents a very preliminary analysis of water levels and flows only. It does not include an assessment of negative or positive environmental or economic impacts which will be part of the longer-term, on-going review of the regulation plans.

6.2 Lake Superior: review of Plan 2012 performance based on conditions in 2017

In 2017, some of the water that normally would have been released from Lake Superior through the hydropower plants could not be because some of the turbines were shut down for maintenance at different times. Consequently, under strict application of Plan 2012 rules, the St. Mary's Rapids would have borne much more of the impact from month to month flow changes and this may have damaged the fishery and caused flooding impacts on Whitefish Island. The ILSBC, with the approval of the IJC, attempted to reduce the risk of these impacts by deviating from Plan 2012. The deviation strategy was based on a projection of how much hydropower flow capacity would be lost between April and November (and updated monthly) due to scheduled hydropower maintenance, and then rather than releasing all surplus flow through the St. Marys Rapids each month, deviations were employed to allow the deficit to be spread more evenly and gradually across the period affected by the maintenance of the plants. The deviations were relatively small in terms of the total release of water through the St. Marys River, and in fact the ILSBC strategy was designed to ensure that approximately the same amount of water was released in total in order to minimize any effects on Lake Superior and Lake Michigan-Huron levels.

Nonetheless, should different releases have produced better outcomes? GLAM compared flows and levels simulated under several alternative regulation strategies to the actual flows and levels that occurred in 2017. Including the actual flows and water levels, seven release scenarios were compared:

Scenario 1: Recorded levels and flows (“Actual”): This represents the actual water levels and flows that were recorded during 2017 and were the result of the actual weather and water supply conditions that occurred within the upper Great Lakes as well as the executed regulation strategy employed by the ILSBC.

Scenario 2: Simulated (“actual”) levels and flows (“Simulated Actual”): This scenario represents a model simulation of the water levels and flows that occurred in 2017. The bi-nationally coordinated water supply conditions recorded in 2017 were used as model inputs and the actual deviation strategy employed by the ILSBC was simulated using the Coordinated Great Lakes Regulation and Routing Model (CGLRRM). Calibration parameters within the model were adjusted with the objective of simulating as closely as possible the actual flow and water level conditions that occurred in 2017. As a result, differences between this scenario and Scenario 1 represent the residual model error, which would include both inaccuracies in recorded water supplies and in model calibration parameters. The same coordinated water supply conditions and calibrated model parameters from this scenario were then used to simulate all other alternative scenarios (described below) in order to provide a fair and consistent comparison of the effects of different regulation strategies alone.

Scenario 3: Plan 2012 with Operationally Expected Side Channel Capacity (“P2012_OpExpectedSC”): This simulation was run to most closely reflect the conditions that would have occurred had the ILSBC not deviated from Plan 2012 during 2017. It uses the recorded 2017 water supplies and assumed Plan 2012 was followed without any deviations. This scenario used expected side channel capacities (i.e. hydro-power capacities that were expected at the time regulation calculations were performed each month) to set the Compensating Works gate setting at the start of each month (consistent with how gates are actually set operationally) and then the actual side-channel capacity (which can at times vary from that expected at the start of the month) was used to simulate the total St. Marys River outflow, the St. Marys Rapids flow, and the resulting water levels. This simulation captures the impacts that scheduled hydro-power outages would have had on Plan 2012 performance.

Scenario 4: Plan 2012 with Actual Side Channel Capacity (“P2012_ActualSC”): This simulation is similar to Scenario 3 above, the only difference being that the expected side-channel capacity was not used to set the Compensating Works gates at the start of each month. Instead, the actual side-channel capacity was used both to set the gates and to simulate flows and water levels. This scenario provides a slightly less accurate reflection of operations that would have occurred under Plan 2012, since under actual operations the ILSBC must estimate expected side-channel capacity when setting gates each month and does not know with exact certainty what the actual side channel capacity will be. However, this scenario was necessary to allow for a consistent comparison to simulations using the old regulation Plan 1977A (described below), as the currently available model for the old plan does not have the same flexibility as the Plan 2012 model used to simulate the more complex operational expected side channel scenario.

Scenario 5: Plan 2012 with Max Side Channel Capacity ("P2012_MaxSC"): This simulation is also similar to Scenario 3 in that it uses the recorded 2017 water supplies and assumes Plan 2012 was followed without any deviations, but in this case no limitations to the maximum side channel flow were applied. As a result, this simulation best represents how Plan 2012 would have performed if there was no hydropower maintenance in 2017 and the actual side channel capacity was at the full maximum values estimated during the IUGLS.

Scenario 6: Plan 1977A with Actual Side Channel Capacity ("P77A_ActualSC"): Similar to the previously described Plan 2012 simulations, the recorded 2017 water supplies were used, but in this case the regulation rules from Plan1977A were used without any deviations to simulate how the previous regulation plan would have performed during the same conditions experienced in 2017. Similar to Scenario 4 for Plan 2012, this simulation used the actual side channel capacity both to set the Compensating Works gate setting and to simulate water levels and flows. When compared to Scenario 4, this analysis provides a check to determine if the performance of Plan 2012 that was expected during the IUGLS is being realized under actual conditions, including any benefits expected from Plan 2012 in comparison to Plan 1977A.

Scenario 7: Plan 1977A with Max Side Channel Capacity ("P77A_MaxSC"): This simulation is similar to Scenario 5 for Plan 2012 in that it uses the recorded 2017 water supplies, but in this case it assumes Plan 1977A was followed without any deviations (as in Scenario 6) but with no limitations to the maximum side channel flow applied. This simulation was added to better compare with the Plan 2012 maximum side channel simulation as this most closely represents how performance of the different regulation plans were compared and assessed during the IUGLS. Note that during the IUGLS the differences between Plan 1977A and Plan 2012 were found to be relatively small, and it is to be expected that there will be many years where these scenarios show very similar results.

Figure 6-1, Figure 6-2 and Figure 6-3 show the water levels on Lake Superior, Lake Michigan-Huron, and the flows through the St. Marys River and St. Mary Rapids resulting from each of the different release scenarios listed above.

An important consideration when evaluating the difference between these plans is the flow through the St. Marys Rapids and the gate setting at the compensating works associated with that flow. The St. Marys Rapids is an important spawning location and overall fishery and is directly impacted by the amount of flow released from the compensating works gates. Another important consideration when evaluating plan performance is the impact the decisions have on Whitefish Island. Whitefish Island is Batchewana First Nations land, and is primarily recreational with hiking trails, small pavilions and visitor information booths. The island is located immediately downstream of the Compensating Works gates adjacent to the rapids, and substantial portions of the island flood as more gates are opened. While flooding of the island is unavoidable and expected under higher gate openings, the ILSBC attempts to minimize impacts to the island when possible. Figure 6-3 shows what the St. Marys Rapids flow would have been for each scenario to better evaluate the impacts of regulation decisions on the rapids themselves and Whitefish Island.

Actual vs Simulated “Actual” Conditions (Scenarios 1 and 2)

As noted above, differences between actual recorded water levels and flows and those simulated using the recorded water supplies and the ILSBC’s regulation strategy in 2017 represents the residual model error. As shown in Figure 6-1, the actual recorded conditions that occurred in 2017 are closely replicated by the simulated conditions, with small differences observed in lake levels (max of 1 cm (0.4 in.)) and flows (less than 100 m^3/s (3,500 cfs)). To ensure that the differences observed in the other scenarios were attributed only to the differences in regulation strategies and not caused by these residual model errors, the same coordinated water supply conditions and calibrated model parameters from this scenario were then used to simulate all other alternative scenarios (described below).

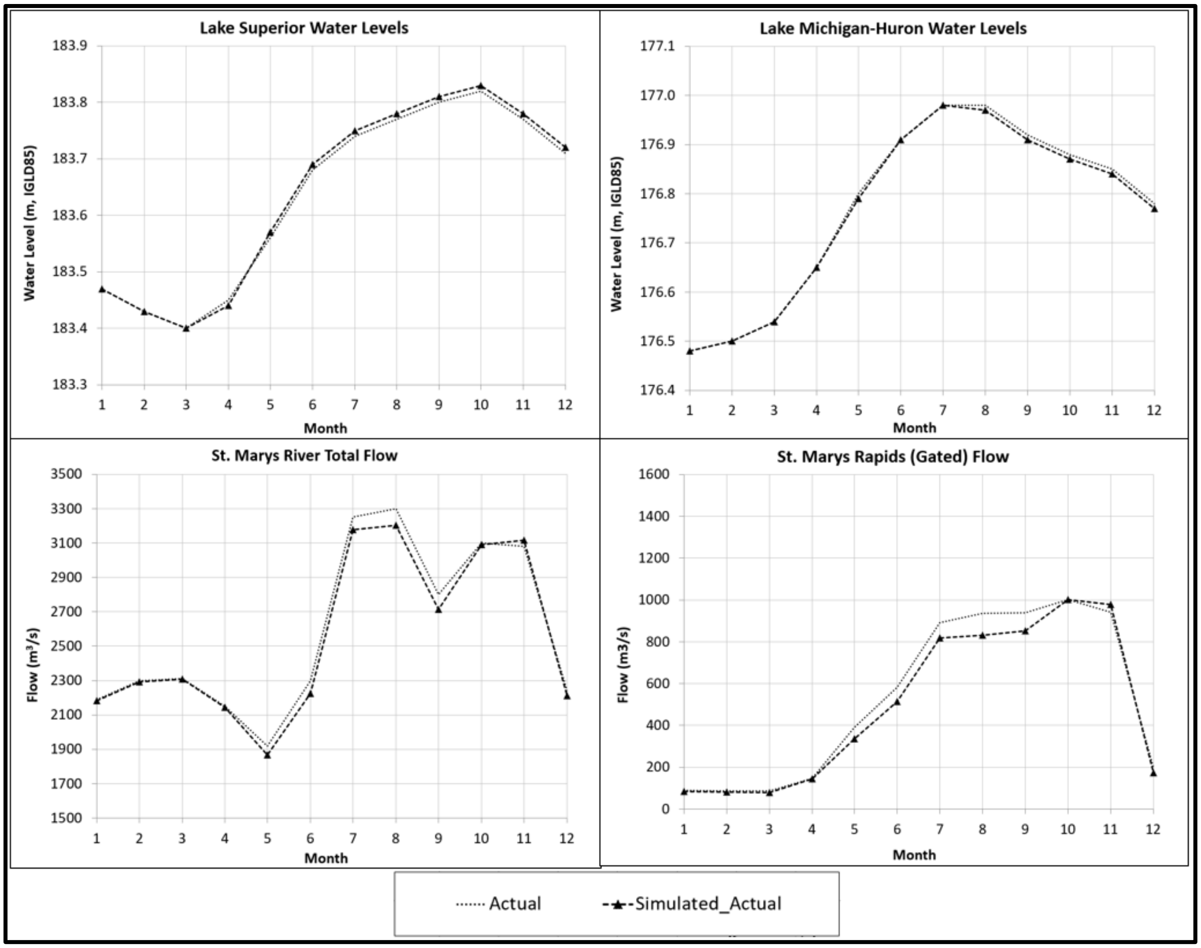


Figure 6-1: Actual water level and flow conditions (Scenario 1) compared to model simulated "actual" conditions (Scenario 2). Both scenarios include effects of ILSBC deviation strategy.

<u>Simulated "Actual" vs. Plan 2012 Conditions (Scenarios 2 – 5)</u>

These scenarios, shown in Figure 6-2, illustrate the impacts of the deviation strategy that the ILSBC executed in 2017 in comparison to what would have occurred following Plan 2012. As shown, the water levels on lakes Superior and Michigan-Huron show very little differences between any of the different scenarios. This is not surprising as the deviation strategy executed by the ILSBC was intended to release roughly the same total flow during the year, just spread differently across the spring, summer, and fall months. The largest water level differences among any of the scenarios for Lake Superior occurred in June where the difference was a maximum of 4 cm (1.6 in.) when comparing the simulated actual level and Plan 2012 assuming maximum side-channel capacity was available. The differences during all other months and scenarios were less than this. Comparing the simulated actual level with the Plan 2012 simulation that used the operationally expected side-channel flow (i.e., Scenario 3, which is the closest representation of what would have occurred in 2017 had Plan 2012 been followed while the hydropower outage occurred) shows that Lake Superior levels were at most 3 cm (0.8 in.) higher in June, but only 2 cm (0.8 in.) higher in the summer of 2017 as a result of the ILSBC regulation strategy. On Lake Michigan-Huron, the simulated water levels from the various scenarios are even more similar, with a maximum difference of 2 cm (0.8 in.) between any scenarios, and levels were at most only 1 cm (0.4 in.) lower due to the ILSBC deviation strategy. These water level differences are extremely small and would not be expected to result in any measureable positive or negative stakeholder impacts.

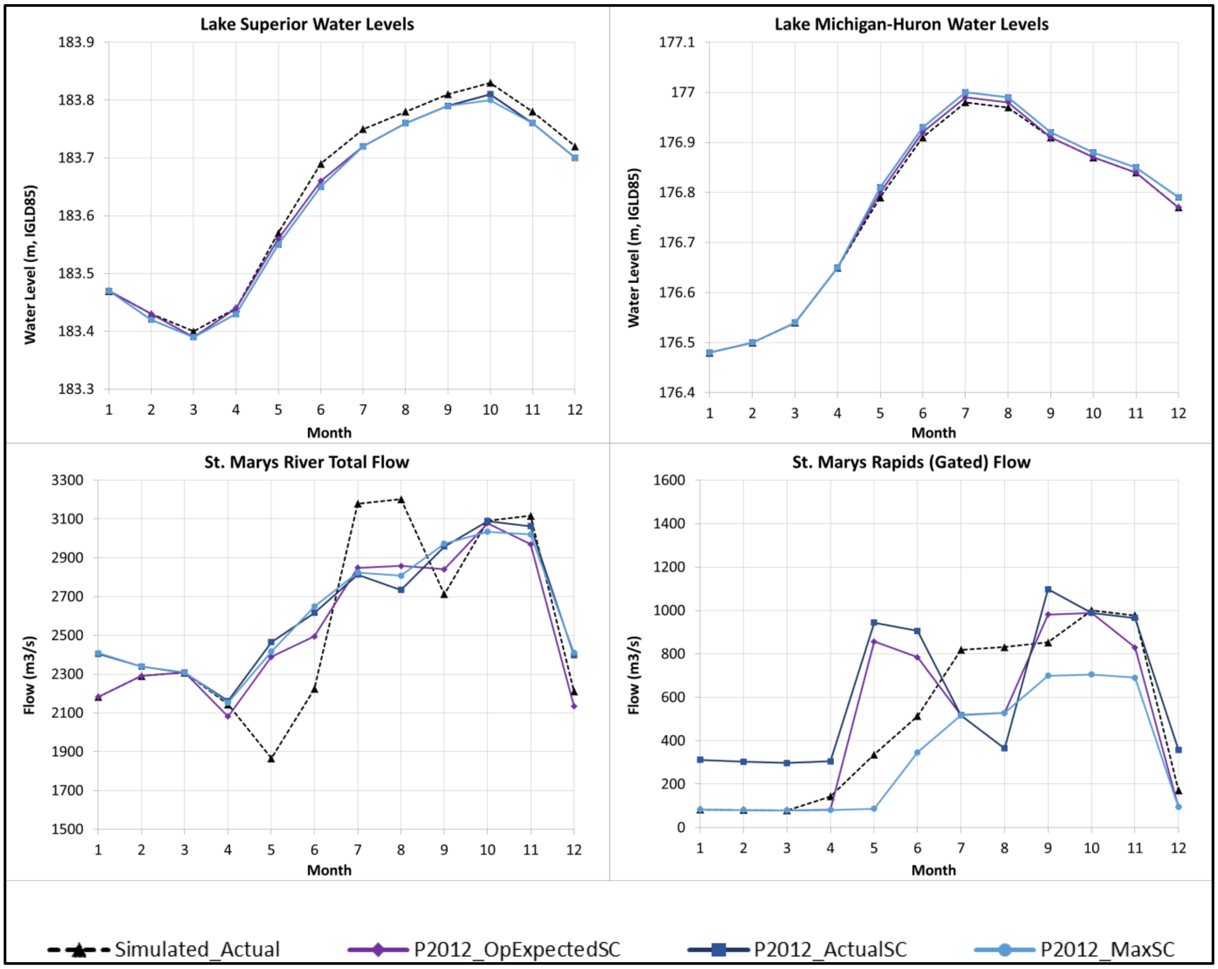


Figure 6-2: Simulated “actual” conditions (including effects of ILSBC deviation strategy) compared to simulated Plan 2012 conditions with and without side-channel capacity limitations.

When comparing the total flow of the St. Marys River, actual flows were lower than those specified by Plan 2012 in May, June and September, higher than those specified by Plan 2012 in July and August, and approximately the same in other months. These fluctuations in total flow allowed for much smoother flow changes in the St. Marys Rapids, where hydraulic conditions are much more sensitive to fluctuating flows. The highest total St. Marys River flows that occurred in July and August under the 2017 deviation strategy were more than would have been prescribed by Plan 2012. As was noted during the IUGLS, higher flows in the river can result in flooding of Soo Harbor just downstream of the Soo Locks and can result in navigation concerns. However, this total flow increase was relatively small and did not cause water levels to rise enough to cause flooding in Soo Harbor. Also, the increase did not generate any known problems for the commercial navigation industry.

St. Marys Rapids flows show large variations between the two regulation strategies, with the simulated actual flows showing much less variation than the flows that would have occurred under Plan 2012 with actual side-channel flow limitations in 2017. This was expected as this was the primary reason for deviating from Plan 2012 flow in 2017. Due to the scheduled and unscheduled hydropower outages, large month-to-month variations would have been necessary in the St. Marys Rapids flow in order to pass the total St. Marys River flow that Plan 2012 prescribed. Interestingly, the simulated actual flows show a similar pattern to the Plan 2012 flows with maximum side-channel capacity available, suggesting that, given the hydropower maintenance that occurred, the ILSBC's deviation strategy resulted in actual flows that more closely resembled the expected performance of Plan 2012 from the IUGLS in the St. Marys Rapids. Also notable is that the smaller peak flow resulted in less flooding on Whitefish Island than would have occurred had Plan 2012 been strictly followed, while the smoother transitions are expected to benefit the environmental health of the rapids.

Based on these observations, it appears the deviation strategy did achieve the intended objective of reducing high and fluctuating flows through the St. Marys Rapids while producing no measureable negative impacts. GLAM is currently developing tools and indicators that can be used to perform this analysis using a more quantitative approach in future reports.

<u>Simulated "Actual" vs. Plan 2012 vs Plan 1977A Conditions (Scenarios 2 – 7)</u>

A comparison of simulated actual and Plan 2012 conditions was also made to the former regulation Plan 1977A, which was the benchmark plan that the performance of all other regulation plans were compared against during the IUGLS. When comparing these simulations, observations can be made to determine if the anticipated benefits of switching to the new plan would have been realized under the conditions the plan was originally evaluated against.

Similar to the previous analysis, water level differences on Lake Superior and Lake Michigan-Huron between the two plans are minimal, but interesting observations can be made in the total St. Marys River and St. Marys Rapids flow differences. An anticipated benefit of switching from Plan 1977A to Plan 2012 was that Plan 2012 would produce more gradual flow changes from month to month and provide slightly lower peak flows. As shown in Figure 6-3, in the bottom left total river flow graph, Plan 2012 would have indeed provided a more gradual increase in flows during the spring and summer season than Plan 1977A, which would have seen flows fluctuate more widely during this time, including much higher flows in May and June 2017. However, Plan 2012 would have resulted in a more abrupt reduction in flows in the fall ahead of the winter minimum gate setting.

Perhaps most notable are the differences in St. Marys Rapids flows between the two regulation plans, shown in the bottom right of Figure 6-3. In particular, the higher flows prescribed by Plan 1977A during May 2017 combined with the hydropower maintenance activities would have resulted in much higher St. Marys Rapids flows during this month; in fact, all 16 gates would have been opened had the old regulation Plan 1977A been strictly followed. Plan 2012 also would have seen large fluctuations due to hydropower maintenance, though less so than those that would have occurred under Plan 1977A. In contrast and as noted previously, the ILSBC's deviation strategy provided much more gradual flow changes and smoother flow fluctuations overall.

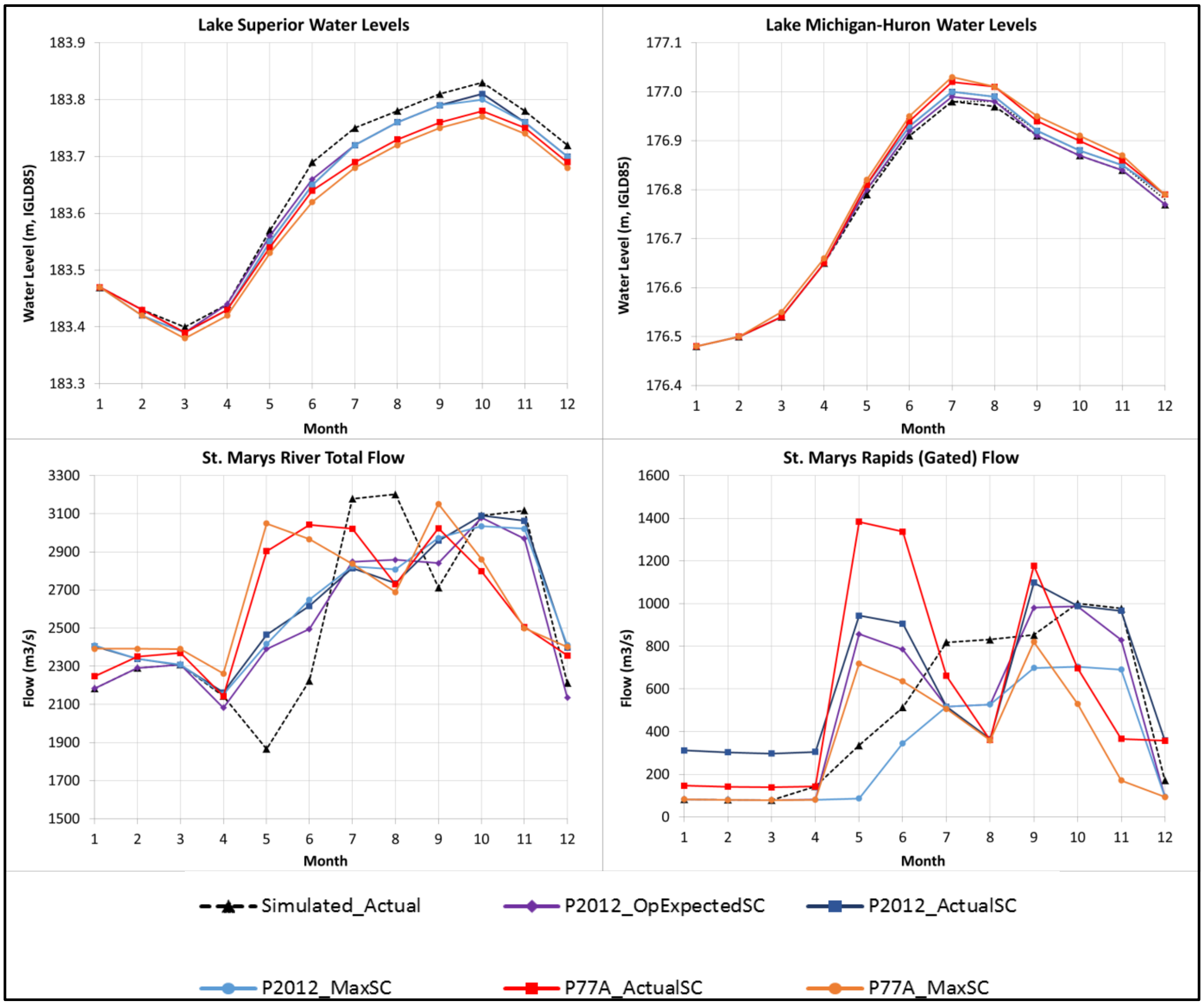


Figure 6-3: Simulated "actual" conditions (including effects of ILSBC deviation strategy) compared to simulated Plan 2012 and Plan 1977A conditions, both with and without side-channel capacity limitations.

6.3 Lake Ontario: review of Plan 2014 performance based on conditions in 2017

This section provides some preliminary analysis of Plan 2014 performance based on water level and flow simulations. It does not include an assessment of negative or positive environmental or economic impacts which will be part of the longer-term, ongoing review of the regulation plans. The year 2017 provided a unique opportunity to look at various aspects of plan performance under extreme conditions, but it must be noted that plan performance must ultimately be assessed under a range of conditions to determine whether overall objectives are being met. This section is meant to provide an immediate retrospective review of how Plan 2014 performed during the extreme conditions of 2017, allowing the GLAM Committee to further identify and differentiate between the hydrologic conditions that occurred, how Plan 2014 responded to those conditions and the effects each had on water levels and flows throughout the basin. This section presents an abbreviated version of what is included in Annex 2 – Plan Review. For a more detailed discussion of this analysis, please refer to that Annex.

Section 6.3 covers three areas of investigation. The first is an assessment of how the hydrological conditions in 2017 impacted the regulation of outflow and how Plan 2014 would have performed if conditions had been different, including had there been more or less challenging ice conditions, fewer spring storm events, or a different starting water level in January 2017. The second analysis focusses on the effects of modified outflow regulation strategies on water levels and flows in 2017, including the effects of modified Plan 2014 rules and maximum flow limitations, alternative criterion H14 thresholds for determining when the ILOSLRB could deviate, alternative ILOSLRB deviation strategies and comparisons between observed Plan 2014 conditions and simulations of the old regulation plan 1958-DD and pre-project outlet conditions. The final analysis focusses on a specific question from the GLAM Committee directive to assess whether future water supplies might be different than those used to evaluate regulation plans. This analysis provides a review of 2017 conditions in light of both model uncertainty and also in consideration of how observed water levels and hydroclimate conditions compared to those used in the development and evaluation of the regulations plans, and what this might mean for future evaluations.

While this review will generate just one year of information, which in itself is insufficient to fully evaluate regulation plan performance given the uncertainty and variability in water supply conditions from year-to-year and over longer time-spans, the results of this review increase our understanding of the system and can be added to future assessments which will also include the assessment of environmental and economic performance indicators to support a long-term plan assessment.

6.3.1 Effects of hydrologic conditions in 2017 for Lake Ontario and the St. Lawrence River

Weekly operational simulations of water levels and flows were completed using various modifications to the observed hydrologic conditions in 2017. The modifications represent minor changes or "perturbations" of the uncontrolled natural factors, external to regulation, and the results of these simulations help to better define the effects that each of the hydrologic factors had on the extreme water levels and outflows in 2017. These simulations can be considered sensitivity analyses of the factors considered.

The simulations include analyses of the effects of:

a) St. Lawrence River ice conditions. This is covered in section0, immediately below;

b) spring water supplies (in this case April and May), including the multiple heavy precipitation events in April and May that occurred across the basin and resulted in record NTS to Lake Ontario and record Ottawa River flows into the St. Lawrence River. This is covered in section 6.3.1.2; and
c) a higher Lake Ontario level at the start of 2017 (Section 6.3.1.3).

The rules of Plan 2014 are followed throughout Section 6.3.1 only; the hydrologic inputs are varied. A longer discussion of these simulations is described in detail in Annex 2-Plan Review. The following provides the key elements and findings.

SIMULATING WEEKLY REGULATION DECISIONS

The analysis of hydrologic inflows and plan rules assessed within this section use a "Weekly Operational Simulation" method which closely aligns with the actual process of regulating outflows. It is a manually intensive approach that involves reviewing conditions week-by-week, and at times day-by-day, throughout the Lake Ontario – St. Lawrence River basin, including actual water supplies and ice conditions, as well as operational considerations (such as hydropower outages, ship requests, boat haul-outs, Seaway ship transits, downstream flooding concerns, etc.) to determine if operational adjustments or deviations from the plan might have been necessary. The effects of these on flows and levels is assessed, and then regulated outflows from Lake Ontario are computed, along with water levels throughout the Lake Ontario – St. Lawrence system, and recomputed if necessary (e.g.,

6.3.1.1 The impact of ice conditions on levels and flows

St. Lawrence River ice conditions during the period of January to March 2017 were very unusual because of highly variable winter temperatures. The ice conditions over this three month period are described in detail in the ILOSLRB report "Observed Conditions and Regulated Outflows in 2017" (ILOSLRB, 2018). Punctuated by a record five freeze-thaw cycles of the river ice cover, highly variable temperatures, and a relatively warm period followed by colder unprecedented ice forming conditions in March, ice conditions were very unusual in 2017 and a challenge from an operational perspective for managing outflows over this three month period.

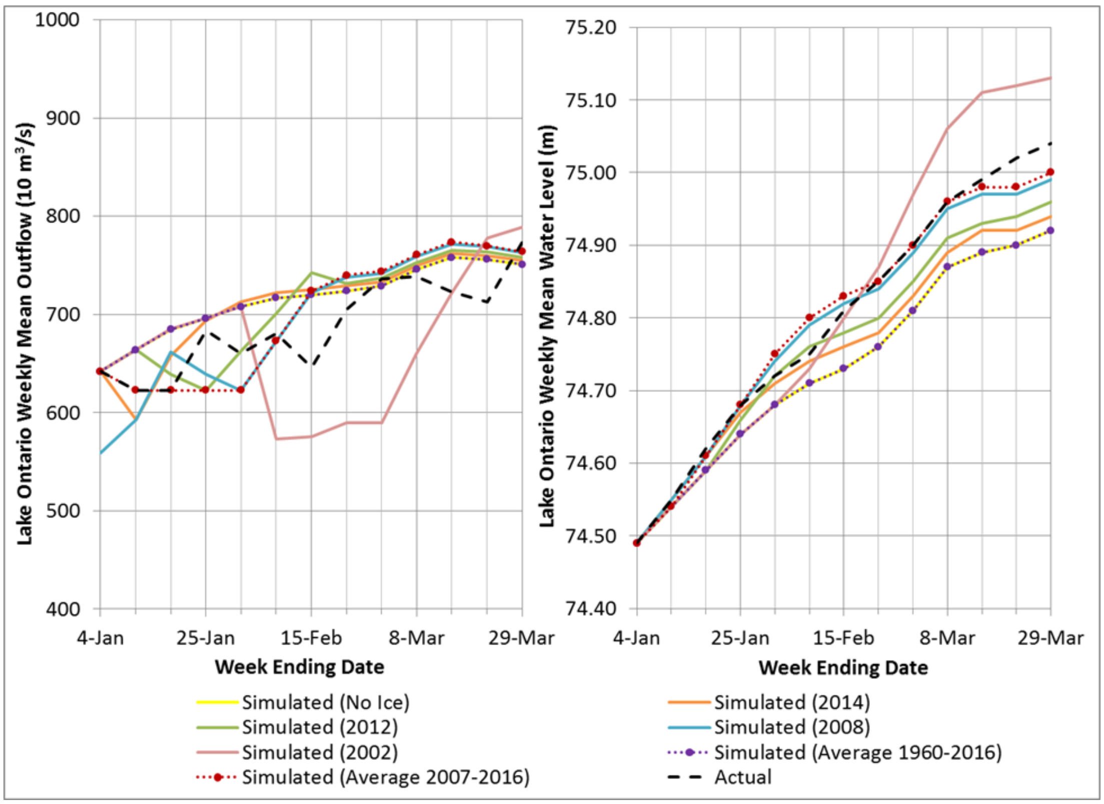


Figure 6-4: January-March 2017 outflows and water levels under various ice formation sequences

Simulations of various ice scenarios were completed and compared to actual water levels and flows from January to March 2017. The completed analysis (Figure 6-4**Error! Reference source not found.**) shows that, in comparison to other hydrologic factors, the unusual ice formation sequence played a relatively small part in raising water levels in 2017, having only contributed about 4 cm (1.6 in) more to water levels rising than what would have occurred under average ice conditions seen over the past decade. Had ice conditions been minimal and posed no restrictions on outflows, water levels would have been at most 12 cm (4.7 in) lower by March 31, 2017. In comparison, water levels rose 60 cm (23.6 in) during the January to March period overall, as a result of the generally above-average water supply conditions during this period.

Moreover, the 12 cm (4.7 in) maximum difference in water levels from actual conditions would have occurred in the highly unlikely scenario that ice conditions imposed no restrictions on outflows. This is not to say that ice conditions are not important. For example, in the 2002 scenario, which was the most challenging scenario reviewed in terms of ice conditions and the effects on regulated outflows, the ice conditions could have contributed as much as a 9 cm (8.3 in) difference in water levels compared to 2017, and as much as 21 cm (8.3 in) in comparison to the scenario where ice posed no limitations on outflows. Yet in 2017, the effects on water levels from variable ice conditions were far less of a contributor than other hydrologic factors during the winter months January through March. Further details of this analysis can be found in Annex 2-Plan Review (2.2.1).

6.3.1.2 The relative impact of water supplies in different time periods

April and May were extremely wet across the Lake Ontario and Ottawa River basins as was demonstrated in the ILOSLRB's report ("Observed Conditions and Regulated Outflows in 2017") and in Section 4 of this report. Figure 6-5 shows five notable storms that occurred during this period and the impacts they had on cumulative precipitation totals at five weather stations around the Lake Ontario – St. Lawrence River basin. The heavy precipitation resulted in significant increases in the net inflows to Lake Ontario and the St. Lawrence River, including the inflows from Lake Erie and the Ottawa River. To better understand the effects of these different factors, individually and collectively, the GLAM Committee simulated water levels and flows under seven alternative inflow scenarios (depicted in Figure 6-6) and compared the results to what actually occurred in 2017 (Figure 6-7).

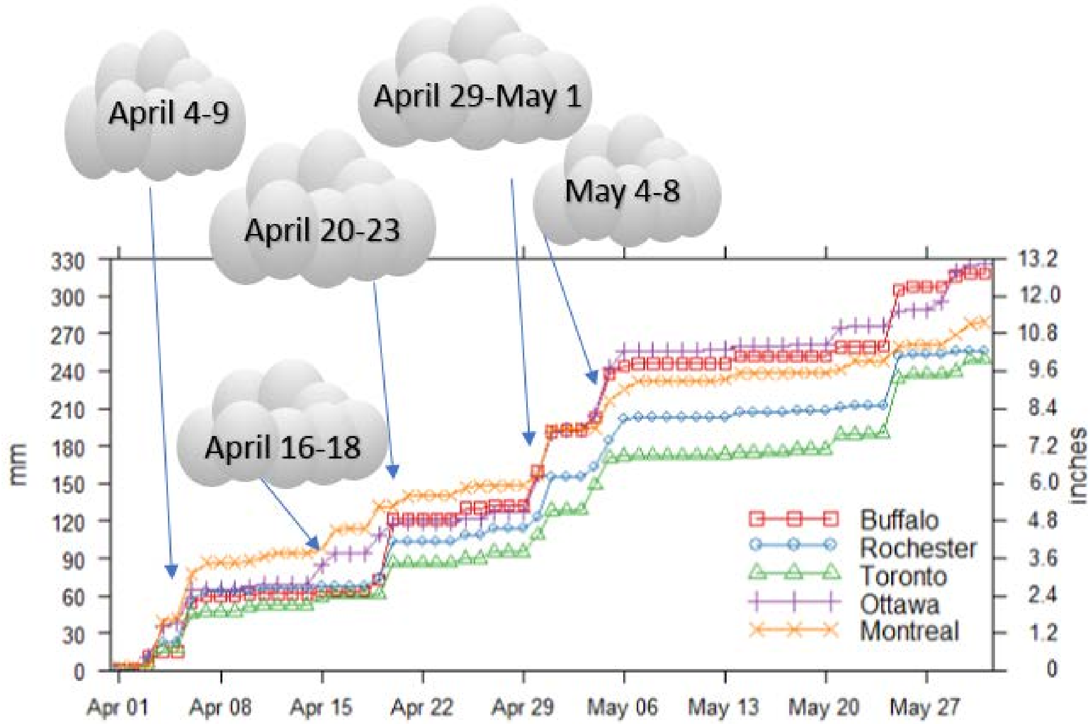
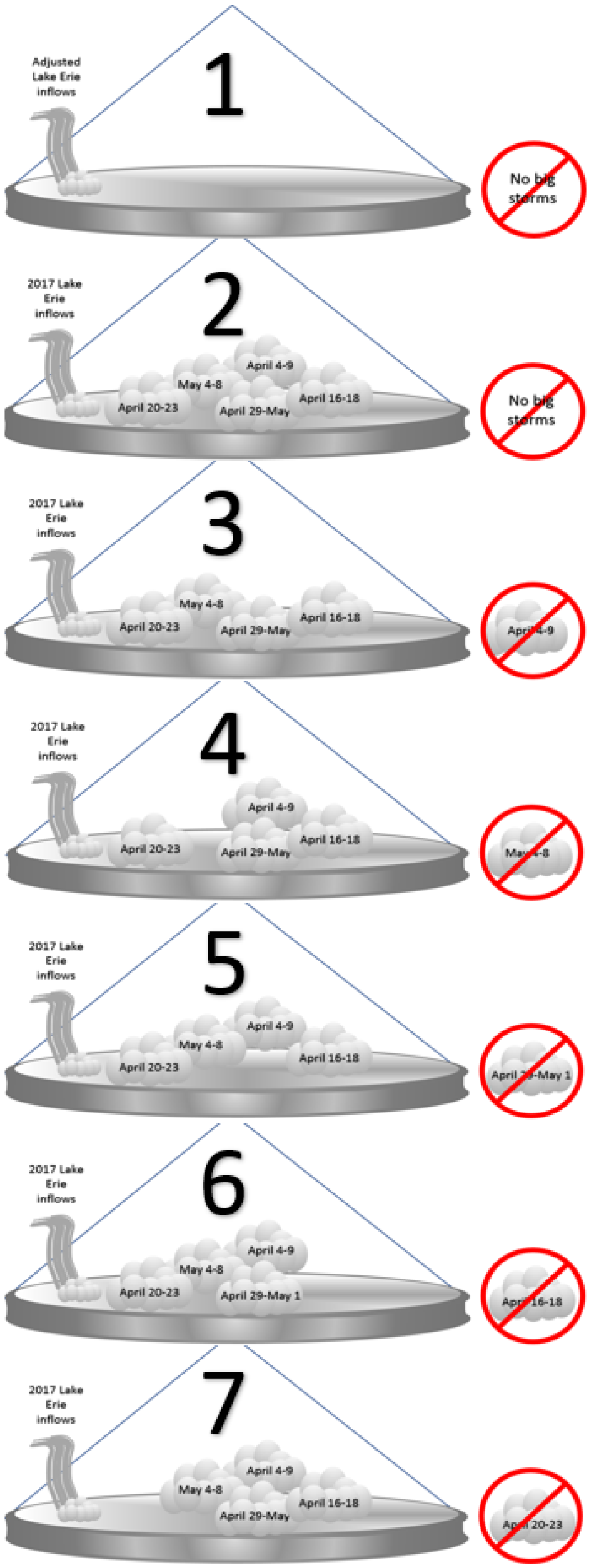


Figure 6-5: Cumulative April-May precipitation at five stations with five storms used in alternative hydrology simulations



1. Lake Ontario peak reduced by 42 cm (17 inches); Lake St. Louis peak reduced by 21 cm (8.3 inches).

2. Lake Ontario peak reduced by 39 cm (15 inches); Lake St. Louis peak reduced by 19 cm (7.5 inches)

3. Lake Ontario peak reduced by 25 cm (9.8 inches); Lake St. Louis peak unchanged.

4. Lake Ontario peak reduced by 16 cm (6.3 inches); Lake St. Louis peak unchanged.

5. Lake Ontario peak reduced by 14 cm (5.5 inches); Lake St. Louis peak unchanged.

6. Lake Ontario peak reduced by 5 cm (2 inches); Lake St. Louis peak unchanged.

7. Lake Ontario peak reduced by 3 cm (1.2 inches); Lake St. Louis peak unchanged.

Figure 6-6: Depiction of seven alternative inflow scenarios used for simulations

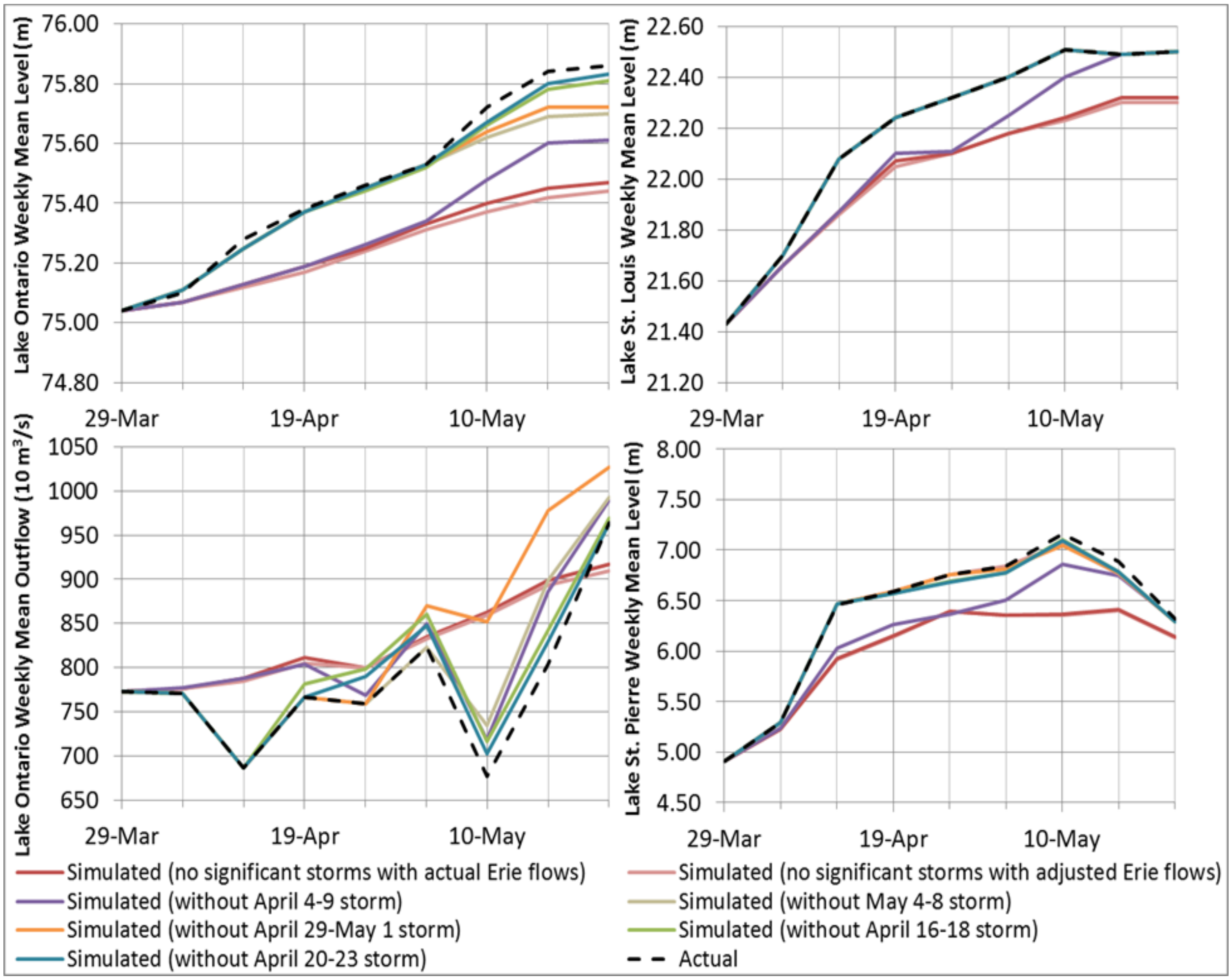


Figure 6-7 - Lake Ontario outflows, Lake Ontario water levels, Lake Saint-Louis water levels and Lake Saint-Pierre water levels under various alternative spring water supply scenarios.

The simulations allowed the GLAM Committee to identify and differentiate between the hydrologic conditions that occurred, how Plan 2014 responded to those conditions and the effects each had on water levels and flows throughout the basin. This analysis may help the GLAM Committee develop better NBS datasets to use for testing or even refining Plan 2014 in the future.

Alternative inflow sequences to Lake Ontario and the St. Lawrence River (including NBS, Lake Erie inflows and Ottawa River flows) were created by reducing those portions of the actual 2017 sequences to remove the increases that occurred as a result of the most significant storm events in April and early May. Further details are provided in the Annex 2-Plan Review. Based on this analysis, and as demonstrated in Figures 6-6 and 6-7, removal of the April 4-9 storm (Scenario 3) had the greatest impact on peak Lake Ontario and Lake Saint-Louis levels in the simulation. When only the April 4-9 storm was eliminated from the simulation and NBS were otherwise kept the same as what actually occurred in 2017, the peak Lake Ontario level would have been 25 cm (9.8 in) below the actual 2017 peak level. Lake Saint-Louis would have also been maintained lower than actual levels in April, but still would have peaked at levels comparable to actual peak 2017 levels in May due to the extremely high Ottawa River flows and the similarly extreme wet conditions on Lake Ontario, which would have increased Lake Ontario levels to above 75.60 m (248 ft) by mid-May. At levels above 75.60 m (248 ft), outflows would have been adjusted to maintain levels at 22.48 m (73.8 ft) on Lake Saint-Louis, the highest tier of the F-limit.

Removal of each of the May 4-8 (Storm Scenario 4) and April 29-May 1 (Storm Scenario 5) storms also significantly reduced peak Lake Ontario water levels in the simulations. The removal of the May 4-8 storm resulted in Lake Ontario water levels that were 16 cm (6.3 in) lower than actual peak levels, while the removal of the April 29-May 1 storm resulted in peak Lake Ontario water levels 14 cm (5.5 in) below actual peak levels. When either of the April 29-May 1 or May 4-8 storm events are removed, Lake Saint-Louis levels would still have been comparable to actual 2017 levels because outflows would have been adjusted to maintain the same F-limit tiers. The removal of the April 16-18 or April 20-23 storms had little impact on peak Lake Ontario or Lake Saint-Louis water levels. This analysis shows the additive effect of a series of moderately rare precipitation anomalies in one year tracking over the same basin one after another. Further details of this analysis can be found in Annex 2-Plan Review (2.2.2).

6.3.1.3 The impact of higher Lake Ontario Water levels at the start of 2017

In 2016, the fall and early winter levels of Lake Ontario were close to average, but they were set under the old regulation Plan 1958-D; how would the water levels that occurred later in 2017 have been affected had Plan 2014 been in effect previously? Plan 2014 was implemented operationally on January 7, 2017, but prior to its implementation, water levels and flows under Plan 2014 had been simulated continuously from 2001 to the end of 2016. At the end of the simulation, Lake Ontario levels were 10 cm (4 in) higher than the actual Lake Ontario levels on December 30, 2016. For the purposes of this review, the GLAM Committee continued to simulate Plan 2014 for 2017 with Lake Ontario levels starting 10 cm (3.9 in) higher to determine how much effect that would have had on peak 2017 water levels. The results are shown in Figure 6-8.

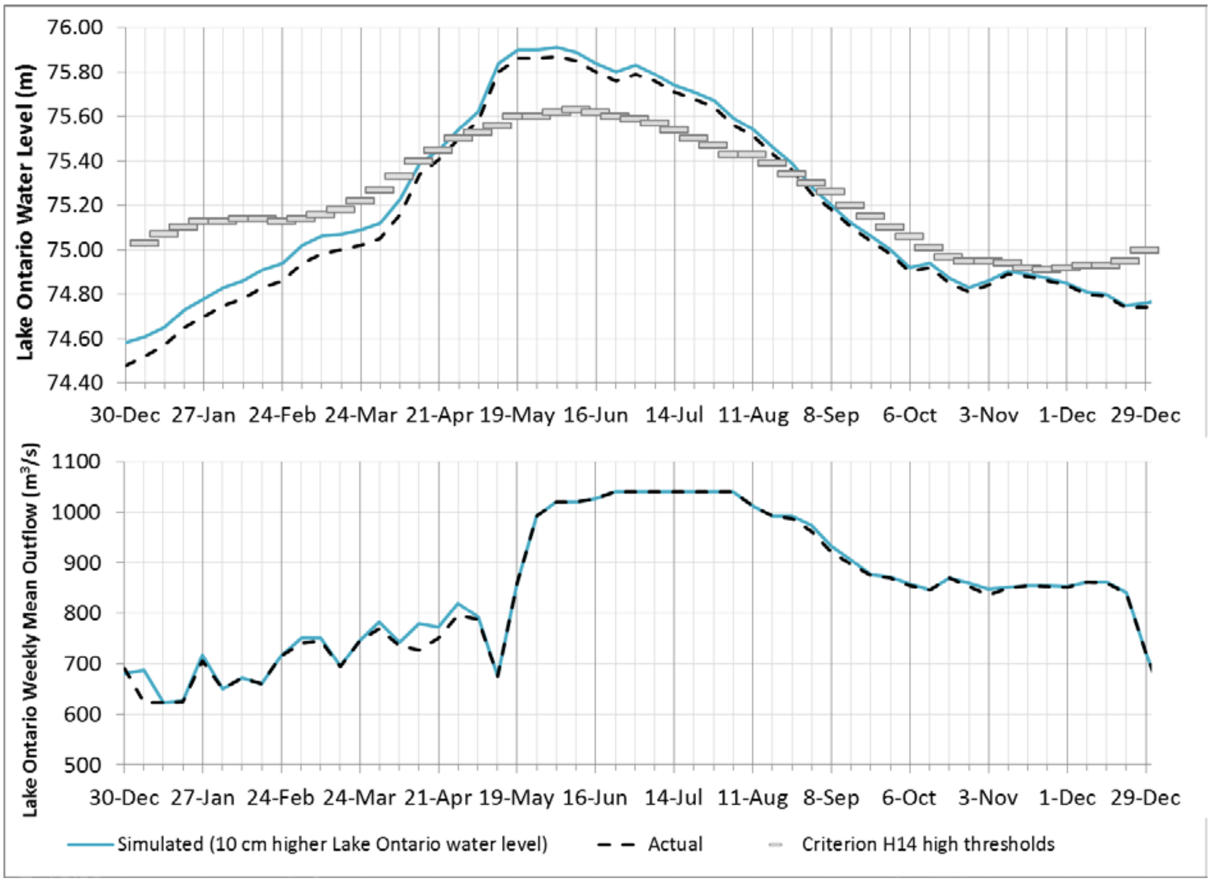


Figure 6-8: Lake Ontario levels and releases in 2017 simulated based on actual and 10 cm higher January 1st Lake Ontario elevation

The simulation shows that the initial 10 cm (4 in) difference at the beginning of the year is gradually reduced over time. The peak Lake Ontario level would have been 4 cm (1.6 in) higher than the actual peak observed in 2017 and levels would have been only 2 cm (less than an inch) higher by the end of the 2017. There are several reasons for this gradual reduction, but all are related to the fact that because water levels would have started the year higher, the Plan 2014 prescribed outflows would have also generally been higher when this was possible. Had Lake Ontario started at higher levels, higher rule curve flows would have been prescribed and could have been released during a handful of days in the winter that outflows were not limited by ice conditions, and this would have had a small effect on lowering water levels. Second, because the simulated Lake Ontario level was higher when Lake Saint-Louis started to rise and the F-limit was first imposed, the initial Lake Saint-Louis level that was maintained and the corresponding F-limit outflows that were released were also higher (see Annex 2-Plan Review for F-limit thresholds). The peak level would have been 4 cm (1.6 in) higher at this time. These higher levels continued later into the simulation and this would have also caused slightly higher releases in accordance with the L-limit beginning in the fall, again causing levels to converge towards the end of the year.

Higher starting levels on Lake Ontario would not have increased the peak level of 22.48 m (73.75 ft) maintained at Lake Saint-Louis since this is the highest tier of the F-limit.

6.3.2 Effects of modified outflow regulation strategies in 2017

In these scenarios, the actual hydrologic conditions observed in 2017 were used for each simulation and then alternative outflow regulation scenarios were developed and applied to simulate the outflows that would have been released and the water levels that would have occurred throughout the system, given these alternative outflow strategies. These scenarios were used to test the implications of modified rules and maximum flow limitations within the plan; alternative criterion H14 thresholds for when the ILOSLRB could deviate; alternative ILOSLRB deviation strategies; and comparisons between observed Plan 2014 conditions and simulations of the old regulation plan 1958-DD and pre-project outlet conditions. Further details of these analyses are presented in Annex 2-Plan Review (2.3).

6.3.2.1 Modifying the rules balancing flooding above and below the dam

The F-limit rules of Plan 2014 prescribe maximum outflow limits to balance high water impacts on Lake Ontario and the upper river with those on Lake Saint-Louis and downstream. A number of scenarios based on modifications to the Plan 2014 F-limit rules were tested for their impacts on water levels. The two most significant changes to the F-limit that were evaluated result in the greatest impacts on water levels upstream and downstream: one of these maintained Lake Saint-Louis at a maximum of only the 22.33 m (73.26 ft), which would have provided the most significant protection to Lake Saint-Louis and more than the F-limit currently provides; while the other, which involved a modified F-limit with Lake Saint-Louis maintained at only the single, highest tier level of 22.48 m (73.75 ft), illustrates the effects of providing more significant protection to Lake Ontario than the F-limit currently provides.

Under the first of these scenarios, lower outflows from Lake Ontario would have been required beginning on May 5 to maintain Lake Saint-Louis levels at 22.33 m (73.26 ft). As a result of the lower flows, Lake Ontario would have peaked at a level that was 6 cm (2.4 in) higher than the actual peak observed at the beginning of June. Under the second scenario, it would have been possible to release higher Lake Ontario outflows (rule curve) than actually occurred (F-limit) in early April without exceeding 22.48 m (73.75 ft) at Lake Saint-Louis. Starting April 16, flow adjustments would have been required to maintain 22.48 m (73.75 ft) thereafter, though in general these outflows also would have been higher given the higher level maintained at Lake Saint-Louis. As a result, Lake Ontario would have been 10 cm (3.9 in) lower by the beginning of June but flooding downstream along the St. Lawrence River would have been prolonged as the maximum level (22.48 m; 73.75 ft) would have occurred as early as April 16, 19 days prior to actual conditions.

In summary, these scenarios help demonstrate how the F-limit balances high water upstream and downstream and how modifications to the F-limits would alter that balance at the expense of upstream or downstream conditions. While changes to the F-limit could have lowered Lake Ontario levels without raising peak Lake Saint-Louis levels, they would have prolonged downstream flooding for weeks as is demonstrated by Figure 6-9 below showing water levels at Lake Saint-Louis and downstream at Sorel just above Lake Saint-Pierre. Furthermore, it is important to note that these modified releases would have been required well before the ILOSLRB had any reliable forecast of those later storms, so the ILOSLRB would have had to trade certain flooding on Lake Saint-Louis and further downstream in the St. Lawrence for a reduction in risk of uncertain flooding on Lake Ontario, a decision that would have had mixed effects in 2017, but only negative impacts in most years.

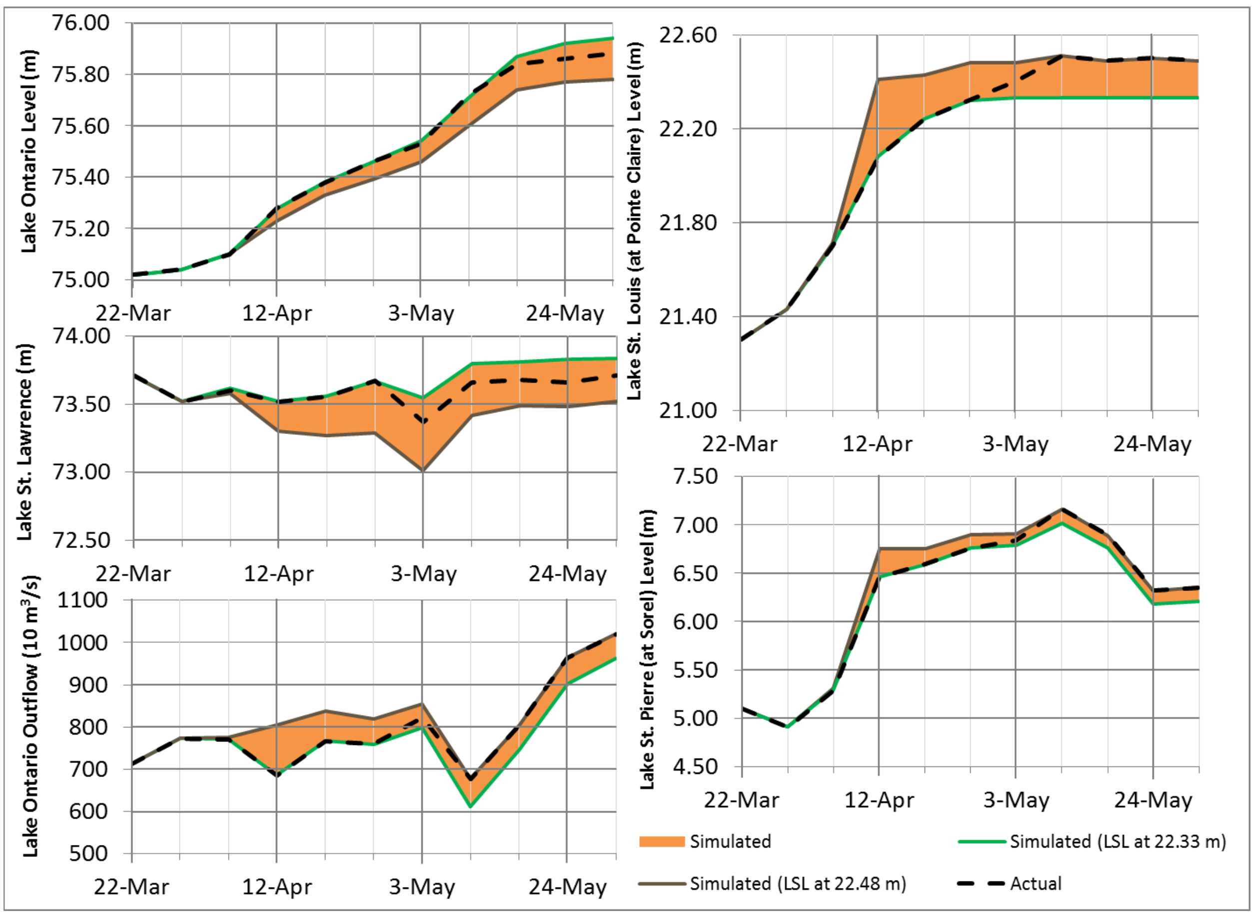


Figure 6-9: Simulated Lake Ontario outflows, Lake Ontario water levels, Lake St. Lawrence water levels, Lake Saint-Louis water levels and Lake Saint-Pierre water levels based on modified F-limit rules compared to actual outflows and water levels in 2017.

6.3.2.2 Modified criterion H14 high trigger levels

Under the H14 criterion of the December 8, 2016 Order of Approval, the ILOSLRB is given the authority to deviate from the rules set in Plan 2014 when Lake Ontario levels reach or exceed high and low water level trigger levels specified in a directive to the ILOSLRB. The high-water triggers for each quarter-month are set at levels that are expected to be exceeded only two percent of the time. Many expressed concern in 2017 that the trigger levels were too high, meaning the ILOSLRB would have to wait too long to deviate from Plan 2014, resulting in higher than necessary Lake Ontario levels.

To determine the effects of lowering the high triggers on Lake Ontario and St. Lawrence River levels, the GLAM Committee simulated Plan 2014 with five and ten percent exceedance level triggers (levels that are expected to be exceeded five and ten percent of the time, respectively). Results indicated that these changes made no difference in outflows or water levels in 2017 because in either scenario, when water levels crossed the trigger levels the ILOSLRB would have been operating under the Plan 2014 F-limit. This is assuming that the ILOSLRB would have made similar decisions in either of these scenarios as it did in 2017, given the ILOSLRB chose to follow the F-limit to continue balancing high water impacts upstream and downstream, even after levels crossed the actual H14 thresholds.

To determine how low the trigger levels would have to be in order for there to be a meaningful effect on Lake Ontario levels, the GLAM Committee simulated 2017 conditions using trigger levels lowered by as much as one foot as a sensitivity test (refer to Annex 2 – Plan Review (2.3.2) for more details). As Figure 6-10 shows, even one-foot lower triggers had a relatively small effect, lowering peak Lake Ontario levels by 6 cm (about 2 in) at the most.

There are several reasons why lowering the triggers has so little effect in 2017, as explained in Annex 2-Plan Review, but, for example, as 2017 operations showed, outflows may be limited by ice conditions, or downstream flooding. Furthermore, this effect is only possible because Lake Ontario water levels would have exceeded the high threshold levels in mid-February 2017 instead of the end of April. Given high-water impacts had yet to occur and there was no indication that they would, and based on past operations as recently as 2016, when the ILOSLRB had discretionary authority to deviate from Plan 1958-D but did not use it under similar scenarios, it seems highly unlikely that the ILOSLRB would have conducted major deviations at that time.

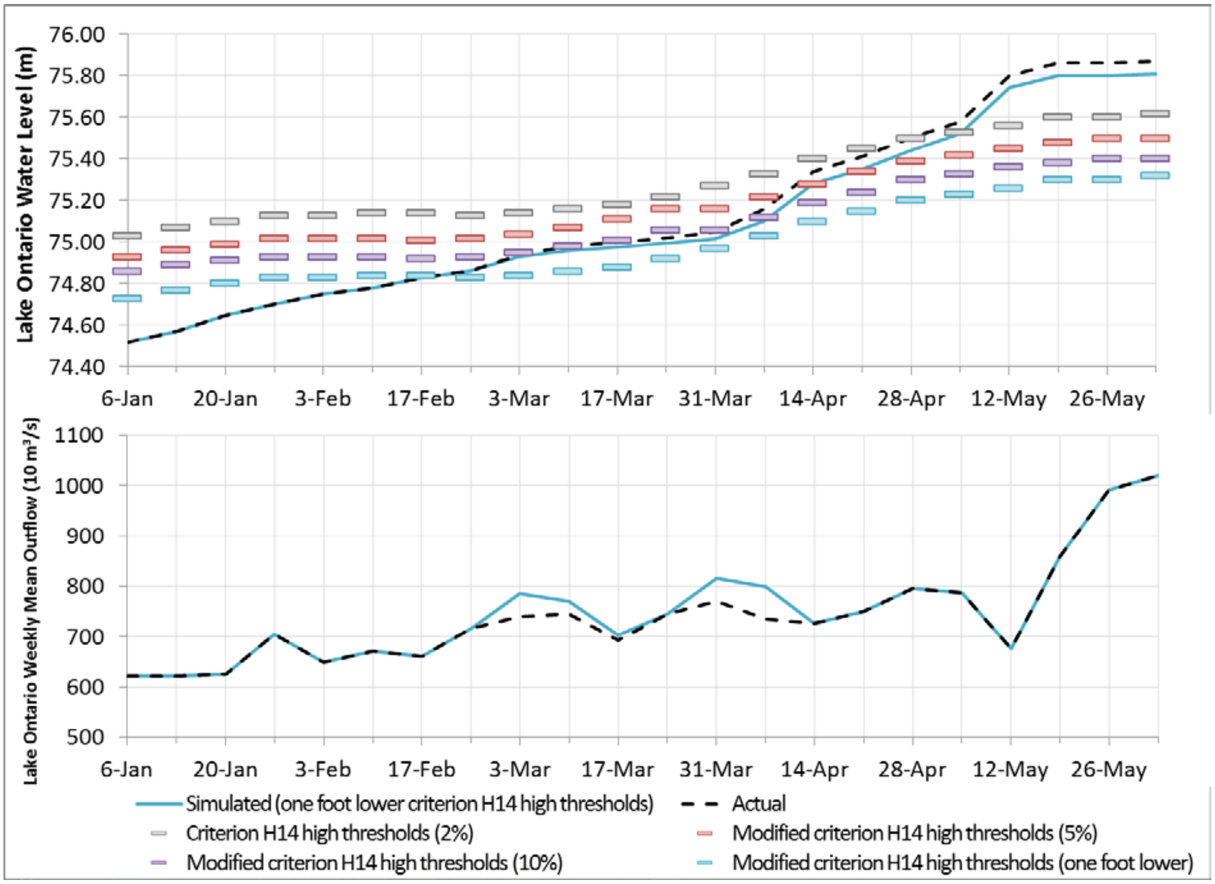


Figure 6-10: Lake Ontario levels and releases based on alternative deviation triggers

6.3.2.3 Modified rules for navigation safety

The L-limit of Plan 2014 sets flows to maintain safe water velocities and river levels for ships in the St. Lawrence Seaway. The ILOSLRB had authority to conduct major deviations from the end of April to the beginning of September 2017. During that time, the maximum amount of water possible was released from Lake Ontario while considering the balancing of high water impacts upstream and downstream and the continued operation of commercial navigation through the St. Lawrence Seaway. This included the release of maximum L-limit flows starting on August 8. After Lake Ontario levels fell back below the criterion H14 high threshold levels in September 2017, outflows remained high and were largely constrained by the Plan 2014 maximum L-limit to the end of the year.

Two sets of modified L-limit applications are tested here to estimate how much more rapidly the reduction in the Lake Ontario levels might have been during this time of declining water levels, had slightly higher flows been released. This would have provided coastal landowners along Lake Ontario with somewhat more rapid relief from the higher levels that occurred earlier in the year, but absent of new evidence to the effects on commercial navigation, the risks such a strategy would impose to shipping are unknown.

Two scenarios were tested by increasing the plan-prescribed L-limit flows by up to an additional i) 200 m^3/s and ii) 300 m^3/s. The impacts to water levels and outflows of these scenarios are illustrated in Figure 6-11. Had up to 200 m^3/s more than the plan-prescribed L-limits been released, Lake Ontario levels would have been 8 cm (3 inches) lower by the end of December. Had up to 300 m^3/s more flow been released, this would have caused a 10 cm (3.9 in) reduction over the same time period.

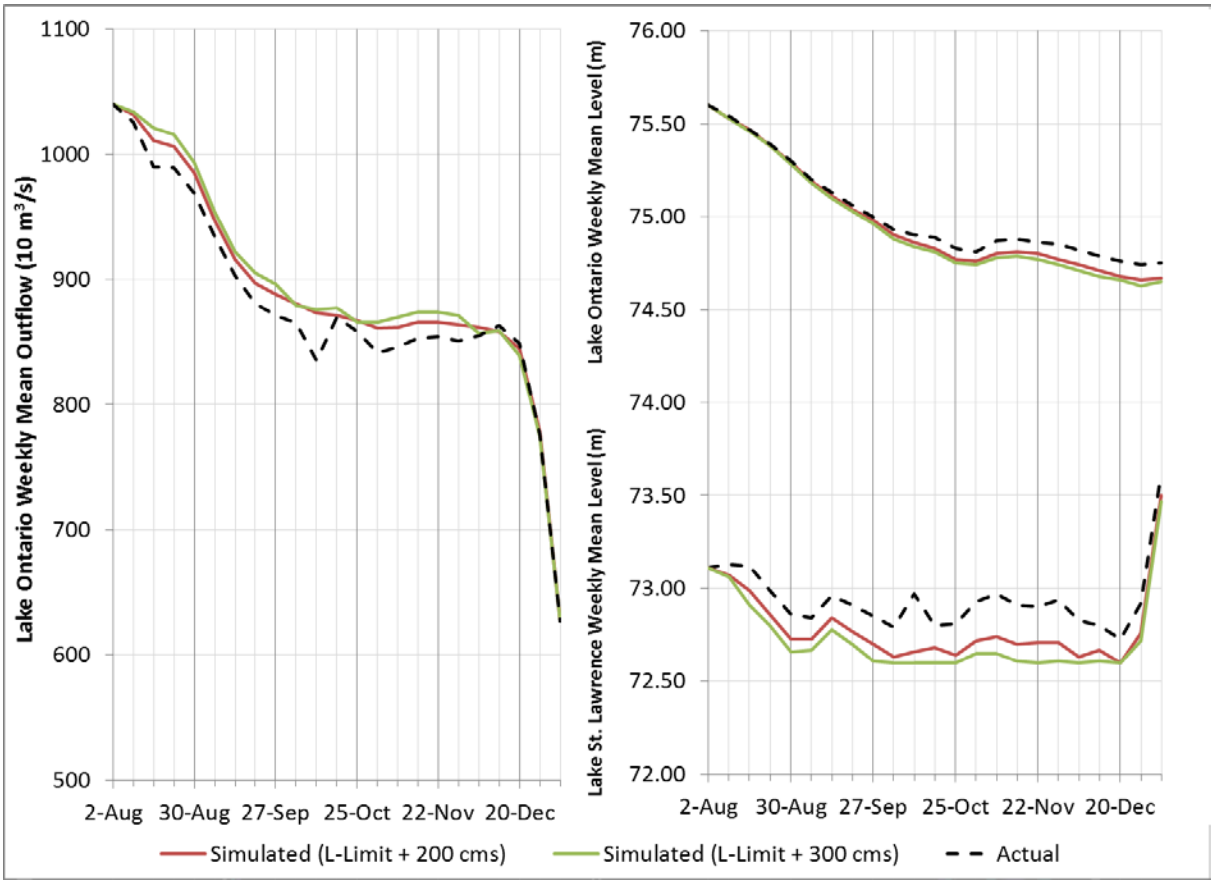


Figure 6-11: Simulations of Lake Ontario outflows, Lake Ontario water levels and Lake St. Lawrence water levels based on modified L-limit flows compared to actual outflows and water levels in 2017.

6.3.2.4 Modified major deviation scenarios

From June 14 to August 8, 2017 outflows were maintained at 10,400 m^3/s, the highest sustained outflow on record. Despite these record-high flows, there remains interest in understanding the potential impacts on water levels and flows had higher outflows been maintained.

Three alternative major deviation scenarios were simulated and compared to actual conditions: a simulation of explicit application of Plan 2014 flows with no major deviations in 2017, and two extreme simulations of major deviations which demonstrate the effects of maximum possible outflows that may have been physically possible in 2017. Each of the latter two of these scenarios included increasing outflows to maximum channel capacity (up to 11,500 m^3/s) in mid-

June (instead of 10,400 m^3/s), and they are differentiated by the fact that one scenario returns to Plan 2014 flows when levels fall below criterion H14 high threshold levels, while the other continued to release the maximum outflows through the end of the year (until flow reductions were required for ice management). It should be noted that the ILOSLRB did not have authority to deviate in this manner (i.e., continuing to deviate after levels of Lake Ontario had fallen below criterion H14 levels), but this extreme scenario demonstrates the maximum outflows possible within physical limits of the system. Note that in both of these simulations, the top tier of the F-limit was respected and Lake Saint-Louis levels were maintained at or below 22.48 m (73.8 ft) and it was also ensured that Lake St. Lawrence levels were maintained above 71.80 m (235.6 ft) to protect water intakes (consistent with an aspect of the Plan 2014 I-limit).

It is important to note that these preliminary simulations do not outline the potential impacts to various interests throughout the system, including the impacts on commercial navigation, to shoreline interests below the Moses-Saunders dam, or to hydropower interests, boaters or the environment upstream of Moses-Saunders dam on Lake St. Lawrence, where levels would have been reduced significantly had releases exceeded 10,400 m^3/s on an ongoing basis. Section 5.4 of the "Observed Conditions and Regulated Outflows in 2017" report includes additional information on the ILOSLRB's considerations for maintaining record-high outflows in 2017 and the potential impacts of exceeding 10,400 m^3/s. These simulations are simply meant to illustrate potential impacts to water levels if alternative major deviations were conducted in 2017.

These scenarios would have had little or no effect on flood damages around Lake Ontario, but they would lower end-of-year levels, possibly reducing water levels and the risk of a potential repeat of high water conditions in 2018. Given high water conditions did not occur in 2018, any potential benefits of either strategy would not have been realized. In other years, such lowering could induce drought conditions and damages. In all years, these extreme strategies would likely cause substantial damages to many sectors both above and below the dam.

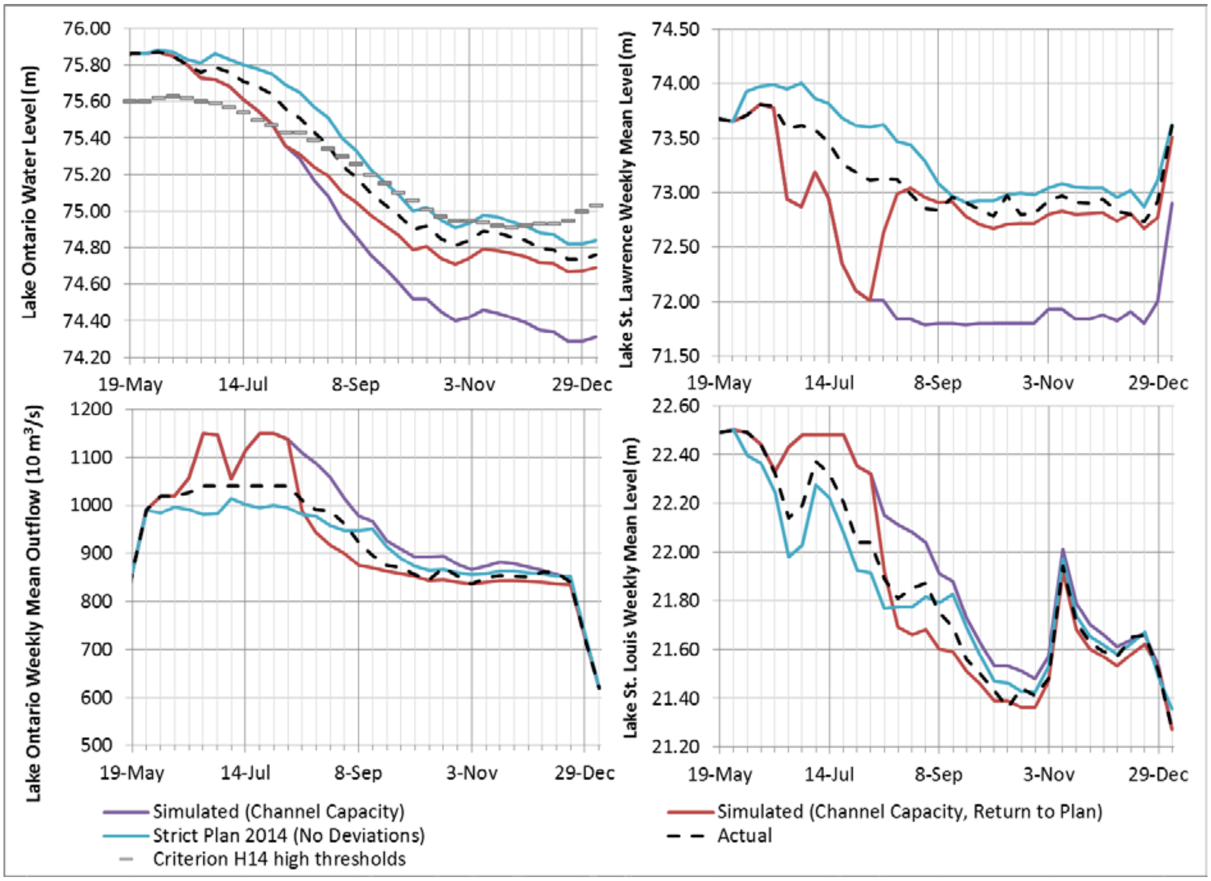


Figure 6-12: Simulated Lake Ontario outflows, Lake Ontario water levels, Lake St. Lawrence water levels and Lake Saint-Louis water levels based on modified major deviation scenarios

As Figure 6-12 shows, the simulation of maximum channel capacity flows through the end of the year resulted in the largest impact on water levels. In this scenario, Lake Ontario water levels would have been 45 cm (1.5 ft) lower by the end of December. The extreme flows (if feasible on a sustained basis) would have maintained Lake Saint-Louis at flood stage longer and would have exceeded flows that were considered the maximum for safe commercial navigation during 2017 operations, with the expectation that St. Lawrence Seaway and all international shipping on the Great Lakes would have to be shut down for the year. Extremely low levels on Lake St. Lawrence would also be expected. See Section 5.4 of the "Observed Conditions and Regulated Outflows in 2017" report for additional details on the potential adverse effects (ILOSLRB, 2017).

The alternative major deviation scenario that was simulated (applying outflows of up to 11,500 m^3/s until water levels fell below the criterion H14 high threshold levels) would have resulted in Lake Ontario water levels that were 15 cm (5.9 in) lower at the beginning of September, but only 7 cm (2.8 in) lower by the end of December. This is because the higher flow releases earlier in the summer would lower the lake faster, resulting in lower water levels by September as well as lower outflows at that time because the L-limit is a function of lake levels.

Had the ILOSLRB not conducted any major deviations (i.e. if the ILOSLRB had followed the Plan 2014 rules explicitly during the period when they had deviation authority), Lake Ontario levels would have peaked 1 cm (0.4 in) higher and would have been 15 cm (5.9 in) higher at the beginning of September. Those higher levels would have allowed higher than actual flows (while maintaining safe navigation) after September, and as a result, Lake Ontario levels would have been 8 cm (3.2 in) higher than actual levels by the end of December (see section 2.3.4 of Annex 2-Plan Review for further details).

6.3.2.5 Plan 2014 compared with pre-project channel water levels and outflows

A simulation was conducted to compare actual levels and outflows in 2017 to pre-project conditions. Pre-project represents what outflows would have occurred under the channel capacity just before the project was built, that is, with no regulation. The results are shown in Figure 6-13.

Under the pre-project simulation, Lake Ontario water levels would have been higher at the beginning of the year and would have been higher than actual 2017 levels throughout the year. Actual Lake Ontario levels dropped because of higher outflows possible with regulation in June; the pre-project peak would have occurred in the first week of July, reaching a level about 18 cm (7.1 in) higher than the actual 2017 peak. Levels at the end of 2017 would have been about 76 cm (2.5 ft) higher than actual Plan 2014 levels. On the lower river on Lake Saint-Louis, water levels would have peaked about 53 cm (1.7 ft.) higher with unregulated, pre-project outflows.

The regulation plans include outflow management to create a stable ice cover to avoid the ice-jam floods that were common before the dam was built. The pre-project levels and flows do not account for the potential for ice jams under pre-project conditions which would have the potential to cause extreme flooding on the upper St. Lawrence River above the dam and in the St. Lawrence River above the Beauharnois dam. Ice jam flooding can happen very quickly with extreme and devastating results.

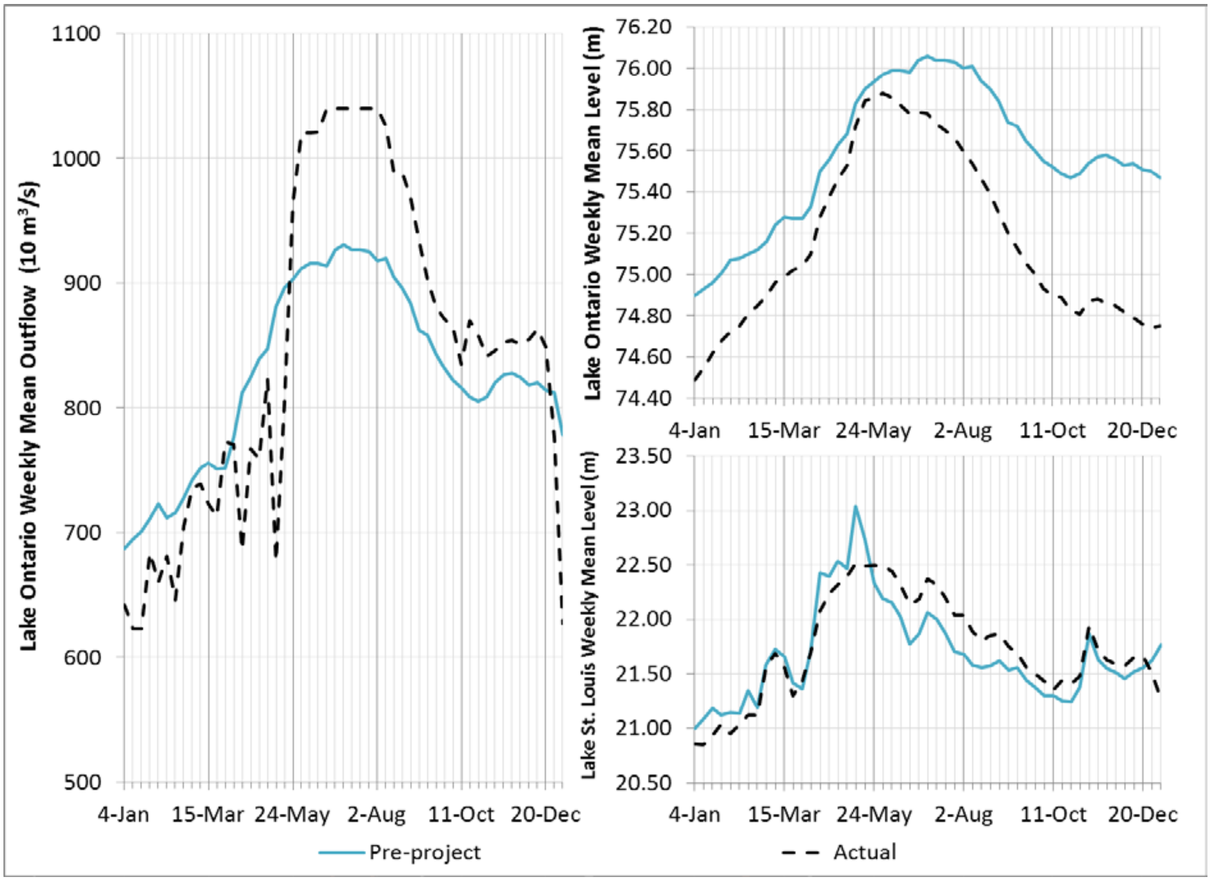


Figure 6-13: Simulated pre-project Lake Ontario outflows, Lake Ontario water levels and Lake Saint-Louis water levels compared to actual water levels and outflows in 2017.

6.3.2.6 Plan 2014 compared with Regulation Plan 1958-D with deviations

Plan 2014 was implemented January 7, 2017. This alternative scenario replaces the Plan 2014 releases that occurred in 2017 with estimates of the releases that would have occurred had the previous regulation Plan 1958-D with deviations (1958-DD) remained in operation.

A discussion of the way flows were simulated is included in section 2.3.5 of t Annex 2-Plan Review. Figure 6-14 compares the actual Lake Ontario outflows and water levels in 2017 to the Plan 1958-D prescribed outflows and water levels that would have occurred in 2017 had the ILOSLRB followed the Plan 1958-D rules strictly, without deviating (dotted grey series). The simulated outflows and water levels that could have occurred in 2017 under operation of Plan 1958-D with deviations are indicated by the shaded orange series.

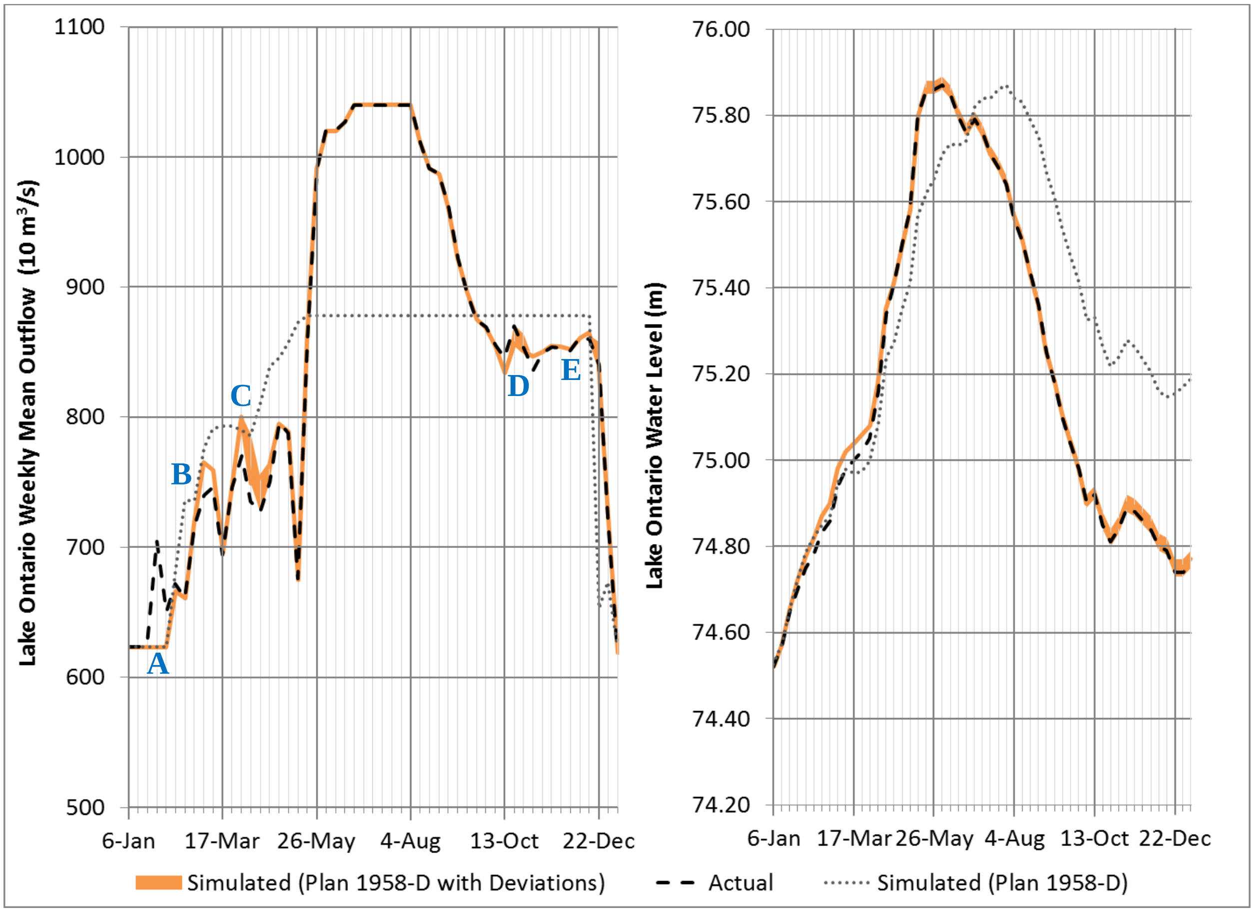


Figure 6-14: Simulated Plan 1958-D with deviations (shaded orange series) and simulated Plan 1958-D prescribed outflows and water levels (dotted grey series) compared to actual outflows and water levels in 2017

Outflows (and therefore water levels) would have been nearly identical under Plan 1958-D with deviations in 2017. Specific time periods where outflows could have differed are denoted with letters **A** through **E** in Figure 6-14 and described below.

In January, Plan 1958-D typically specified a maximum flow of 6230 m^3/s to allow for ice formation (even when ice was not actually forming) while Plan 2014 allows for a higher flow until ice formation actually begins (**A**). It is unlikely that the ILOSLRB would have decided to deviate from Plan 1958-D and release flows above 6230 m^3/s in January, given that there was no indication that conditions would be extremely wet later in the spring and the level of Lake Ontario was slightly below the long-term average. As further evidence, as recently as in 2016 the ILOSLRB did not deviate under similar conditions. The Plan 1958-D prescribed flow would have been higher than the Plan 2014 prescribed flow during the weeks ending March 3 through March 17 (**B**), and there would have been limited opportunities during this period to release these higher flows. Otherwise, the same outflow adjustments would have been required for ice management, but these would have been considered deviations from Plan 1958-D. The ILOSLRB likely would have released flows greater than the Plan 1958-D prescribed outflows in the short period between March 25 and April 5, after ice conditions in the St. Lawrence River no longer limited the outflows, and before the onset of the Ottawa River freshet (**C**).

The Plan 2014 F-limit is largely based on how the ILOSLRB used to operate under Plan 1958-D during the spring Ottawa River freshet. During those periods, the ILOSLRB would normally deviate from Plan 1958-D, as it did not include an F-limit, in order to balance upstream and downstream high water levels and impacts. So, beginning April 5, it was assumed that the ILOSLRB would have deviated from Plan 1958-D prescribed outflows, as it had in the past and in a similar manner to how outflows were operationally adjusted under the Plan 2014 F-limit, to balance upstream and downstream flooding damages.

Based on the results of this Plan 1958-D simulation, the level of Lake Ontario would have peaked within +/- 2 cm (0.8 in) of the actual peak in June 2017. As the ILOSLRB had authority to deviate from Plan 2014 by this point, it was assumed that thereafter, the ILOSLRB operating under Plan 1958-D would have also deviated and released the same record-high outflows through much of the summer. The ILOSLRB likely would have come to the same consensus to decrease outflows to maintain safe conditions for navigation beginning on August 8. As per actual operations in 2017, the ILOSLRB likely would have allowed a similar deviation from Plan 1958-D in October to allow boat haul-out on Lake St. Lawrence (**D**) and a similar test of flows above the maximum L-limit in December (**E**). Beginning on December 25, it was assumed that the ILOSLRB would have decreased flows to facilitate ice formation, as ice had started forming in the Beauharnois Canal.

Based on the results and uncertainties of this simulation, by the end of 2017, the level of Lake Ontario would have been within +/- 3 cm (1.2 in) of the actual level had the ILOSLRB been operating under Plan 1958-D instead of Plan 2014.

6.3.3 Observed 2017 Water Levels and Hydroclimate Conditions Compared to Those Used in Plan Evaluation

Part of the charge to the GLAM Committee is to help the IJC boards with improved understanding of the system and to address future conditions. A key question the GLAM Committee is to address is whether future water supplies will be different from those used to test the current management of levels and flows. In the LOSLRS, it was recognized that the future will not be a repeat of the past; especially when it comes to the weather that drives the water supplies in the Great Lakes-St. Lawrence River system. The LOSLRS Board and the IJC acknowledged that even without the effects of increased greenhouse gases in the atmosphere, we could be confident that there will be periods of higher and lower water supplies sometime in the future due to the natural variation in climate. Therefore, the LOSLRS Board chose to test all alternative regulation plans using a stochastically generated supply sequence to evaluate their hydraulic range and economic benefits.

Unlike past studies that had often assumed a certain stationarity to climate and assumed what had happened in the past was a good reflection of the future, the LOSLRS attempted to look beyond the past and attempted to identify alternative future hydroclimate sequences that may be possible. It did this by generating a large 50,000-year sequence of stochastically generated supplies to each of the Great Lakes, the Ottawa River and other downstream tributary flows. While this stochastic time series was based on the statistical characteristics of the twentieth century supplies (LOSLRS, 2006), it generated a greater range of conditions to test regulation plans and included several more extreme wet and dry events than had occurred historically. The stochastic hydrology model included important probabilistic relationships between the supplies from one year to the next, their seasonal patterns and their quarter-month to quarter-month correlations (LOSLRS, 2006). Important statistical properties of the system were preserved such as the mean, standard deviation and the probability that wet or dry conditions would occur in the various drainage basins at the same time. For the most part, the stochastic supply sequence was used to assess differences in average annual benefits between alternative regulation plans.

The GLAM Committee is charged with comparing actual observations to planned regulation plan results, so must take the differences between operations and planning models into consideration, and consider the accuracy with which models represent reality, and determine what may be lost by using these generalizing techniques, and whether it is significant.

Annex 2-Plan Review provides a preliminary review of 2017 conditions in light of both model uncertainty and also in consideration of how observed water levels and hydroclimate conditions compared to those used in the development and evaluation of the regulations plans, and what this might mean for future evaluations. Annex 2-Plan Review includes the following assessments:

1. **Ice Conditions (Annex 2 - 2.4.2.1):** Highly variable ice conditions occurred in 2017. Further review is needed as to how 2017 ice conditions (formation and stability) relate to historical conditions used to evaluate regulation plan alternatives.
2. **Simulation of Lake Saint-Louis Water Levels (Annex 2 - 2.4.2.2) in Plan 2014:** Given extreme water levels throughout the system in 2017, it was determined that further validation of the simulated Lake Saint-Louis levels is required.
3. **Simulation of Lake Ontario Levels (covered here and in Annex 2 – 2.4.2.3):** How the Lake Ontario water level in 2017 compares with the water level simulated from the 50,000 year stochastic hydrologic time series.
4. **Water supplies (Annex 2 - 2.4.2.4):** The water supplies in April and May 2017 exceeded those that had occurred during the historical period of record 1900-2008 used to evaluate regulation plans. How do they compare to other water supply scenarios used in plan evaluation, including the 50,000 year stochastic scenarios? Climate change scenarios need to be updated for this analysis and that will be done in the future.
5. **Ottawa River flows (Annex 2 - 2.4.2.5):** Similar to above, record flows were set in 2017, how do these compare to other scenarios used in plan evaluation? Also, how does the combination of high water supplies to Lake Ontario and high Ottawa River flows compare to the plan evaluation time series?

Only the second and third simulations are discussed briefly here as their findings seemed particularly pertinent.

6.3.3.1 Differences between simulated and operational Plan 2014 Lake Saint-Louis (Pt. Claire) levels

During the summer of 2017, a review of previous quarter-monthly simulation results for Plan 2014 revealed significant discrepancies in Lake Saint-Louis water levels in a small number of scenarios as a result of an error in how those levels were calculated in the simulations.

In previous Plan 2014 simulations, it was found that the quarter-monthly F-limit calculation was not applied correctly in the model code for Plan 2014 when Lake Ontario water levels were above 75.75 m (248.52 ft). Recall that the Plan 2014 F-limit is a multi-tiered rule that attempts to balance high water conditions upstream and downstream by ensuring levels of Lake Saint-Louis are maintained below certain thresholds depending on the level of Lake Ontario. To accomplish this in the simulation model, a stage-discharge relationship is used to determine the Lake Saint-Louis outflow corresponding to each of the F-limit tiers, this flow is reduced by the Ottawa River and local tributary flows, and then the remainder is used to set the Lake Ontario outflow accordingly. However, an error was identified whereby the Lake Saint-Louis outflow was multiplied by a factor of 10 within the model whenever Lake Ontario was above 75.75 m (248.52 ft), which allowed the Lake Saint-Louis level to rise substantially and effectively removed any level of protection from this area of the system. The result is that there are discrepancies with simulated water levels in some of the most extreme wet scenarios of the stochastic Plan 2014 results from the LOSLRS. Historical results from the LOSLRS were not affected by this coding issue since simulated quarter-monthly Lake Ontario levels in the historical simulation (and in fact, actual historical levels, prior to 2017) had never rose above 75.75 m (248.52 ft). This is also likely what kept the coding error from being identified until now. With the code correction, for the stochastic simulation, the maximum simulated Lake Ontario level is changed from 76.62 m (251.38 ft) to 76.66 m (251.51 ft) (increase of 4 cm (1.6 in)), while the maximum Lake Saint-Louis level is reduced from 23.33 m (76.54 ft) to 22.81m (74.84 ft) (decrease of 52 cm (20.5 in)).

6.3.3.2 Observed 2017 Conditions Compared with the Stochastic Supply Sequence

Lake Ontario levels are the cumulative result of the timing and magnitude of different inflows and the releases from the Moses-Saunders Dam. The relationship between input and outcome is not simple. Plan 2014 was designed and tested using both historical water supplies and a broad range of potential future water supply conditions and a primary source for these water supplies was the statistically generated times series of 50,000 years of water supplies and tributary flows. The highest lake level reached in the stochastic simulation using Plan 2014 was 76.66 m 251.5 ft), which came during an extreme water supply sequence, but while the quarter-monthly NTS (flows from Lake Erie plus local inflows to Lake Ontario) were very high in that sequence, they were not the highest in the 50,000-year stochastic test data.

The 2017 conditions were extreme, exceeding conditions that occurred historically, and while similar conditions are captured within the stochastic series used to evaluate regulation plan performance, such occurrences are rare (see Figure 6-15). Continued research as to whether such conditions will continue to be rare, or whether they will occur more frequently, is necessary for the purposes of developing regulation plans and ensuring robust performance over time.

More information on this analysis is provided in Annex 2-Plan Review.

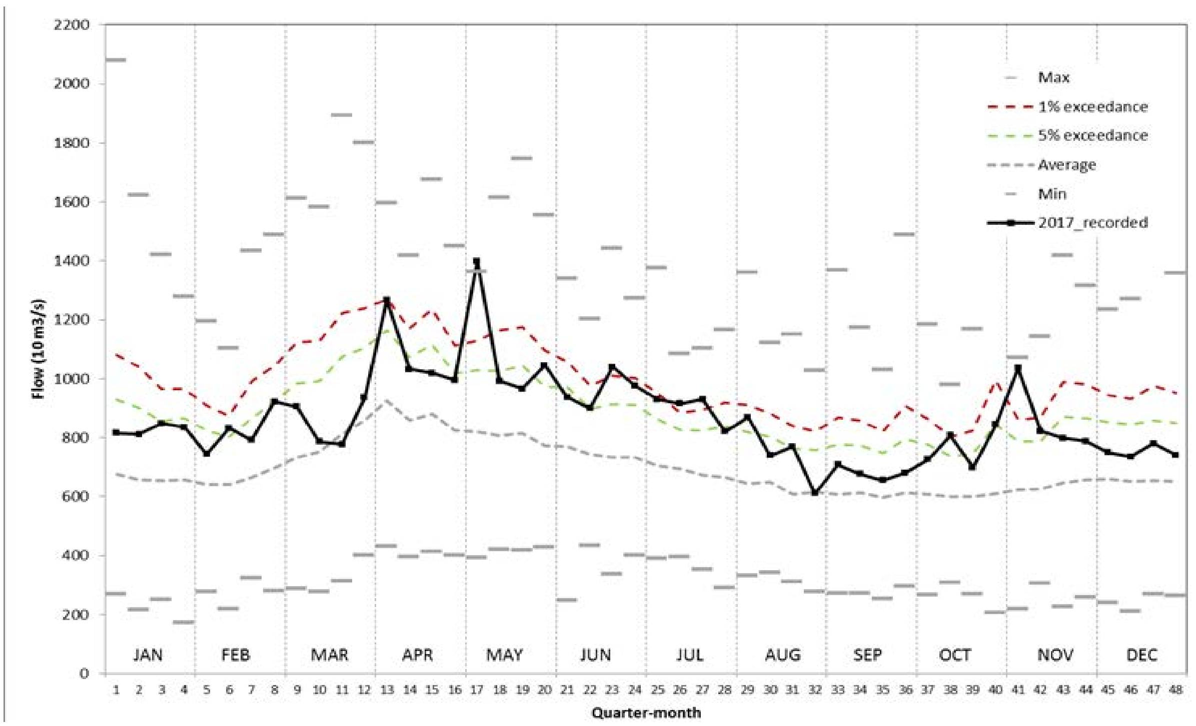


Figure 6-15: 2017 NTS versus NTS range for the entire stochastic series

6.4 Findings and suggested next steps for on-going plan evaluation analyses

The Orders of Approval for both Lake Superior and Lake Ontario require the IJC to review the results of applying the Plan 2012 and Plan 2014 rules. This includes an assessment of how well the observed impacts of water levels compare to those predicted by the research and models used to develop and select the plans. This review can be used to re-evaluate performance and trade-offs which may lead to changes to the regulation plans. Ideas for improvements can come from the particular conditions in any one year or more general observations, for example, that there might be advantages for using a navigation model that covers the entire Great Lakes - St. Lawrence River system. In this report, the focus is on the former, ideas that arise from conditions in 2017, with suggestions for more general assessments where it makes sense.

6.4.1 Plan review findings - Upper Great Lakes

On Lake Superior, the ILSBC deviated from Plan 2012 releases in 2015 and 2016 based, in large part, on a revised and lower estimate of how much flow could be passed through the side channels to hydropower turbines. Greater deviations were required in 2017 when the closure of some turbines for maintenance reduced side channel capacity even more. As discussed in6.2 Lake Superior: review of Plan 2012 performance based on conditions in 2017, the 2017 deviation strategy allowed for much smoother flow changes in the St. Marys Rapids without causing problems for the commercial navigation industry. Smaller peak flows in the rapids resulted in less flooding on Whitefish Island, while the smoother transitions were consistent with objectives of Plan 2012 which, based on qualitative research, are expected to benefit the environmental health of the rapids (IUGLS, 2012).

The 2017 operations suggest that the GLAM Committee should investigate modifications to Plan 2012 to produce these sorts of benefits routinely, perhaps using predictions of available turbine capacity as an input. Because the benefits for the St. Marys fishery and the reduction in high water damages to Whitefish Island are now qualitative, research to quantify the relationship between flows over the rapids and the environmental and coastal benefits could help produce more beneficial rules.

6.4.2 Plan review findings - Lake Ontario-St. Lawrence River system

The hydrologic events of 2017 provided an extreme challenge to the regulation of Lake Ontario and the St. Lawrence River and regulation Plan 2014. The results show that Plan 2014 generally performed as it was expected to under extreme weather and water supply conditions in that it provided greater flexibility to manage difficult ice conditions through the winter of 2017 and, to the extent that this was possible, it attempted to minimize and balance the flood risks during the extreme spring weather conditions, which would have occurred regardless of the regulation plan in place. Nonetheless, the analysis in Section 6 revealed some opportunities for improving the way regulation plans are tested and evaluated in the future. The findings can be classified into three categories:

1. Reconsideration of historical and stochastic modelling inputs
2. Re-evaluation of the plan model processes and algorithms
3. Reconsideration of plan evaluation and ranking process

Each is discussed in separate sub-sections below.

6.4.2.1 Reconsideration of historical and stochastic modelling inputs

The evaluation and ranking of Lake Ontario regulation plans since the LOSLRS have depended in large part on the assumption that a stochastically generated set of simulation model inputs including net basin and total water supplies, tributary flows and ice conditions accurately represents the range of future hydrologic conditions that could be expected. No one can be sure of the degree to which weather conditions in 2017 were caused by climate change, but the analysis in Section 6.3.1 shows that high water levels in 2017 were caused by the sequence and simultaneous occurrence of significant events, some apparently independent from one another (warm February followed by a cold March, extremely wet April and May). While some of these events may be captured in the stochastic series to some degree, they raise questions about how frequently such events may occur in the future, and whether the stochastic datasets provide an accurate characterization of the conditions under which plans will be operated.

In 2017, there were record net basin and total supplies and Ottawa River discharges. In most, but not all cases, the 2017 inflows fell within the maximum stochastic inflows, but the extraordinary severity of spring precipitation aligns with expectations of severe storms under climate change. The influence of climate change is difficult to prove or disprove, so no one can be sure whether 2017 was an extraordinarily rare event for the climate in this region, or a moderately rare event in a climate that is shifting. The use of the existing LOSLRS stochastic hydrology is logically consistent with the former interpretation. If the latter is true, the existing stochastic hydrology could be misrepresenting the risk of high inflows and should be updated to reflect a changing climate.

Air and surface water temperature trends over the past decades support climate change projections for warmer temperatures in the future, which could change ice formation and winter runoff patterns and evaporation from the lake surface. The ice formation cycles that occurred in 2017 are unprecedented in the historical record and un-represented in the stochastic ice condition indicator dataset. Section 6.3.1.1 shows that this year’s ice formation raised water levels several centimeters given the conditions in 2016-2017. The current ice data applied along with the stochastic water supply set is simply a sampling from the approximately 40 years of ice record available at the time of the LOSLRS. These ice data include a time series of ice status indicators so that the impacts of ice formation and roughness are included in plan testing, but there are no indicator strings in those data matching what happened in 2017, so the stochastic simulations cannot reveal the impact 2017 ice formation patterns would have in combination with different water supply sequences and antecedent water levels.

Climate change projections for warmer temperatures could also affect the timing and rates of runoff from winter rains and snowmelt. It may be that there will be more winter rain and snowmelt events with less snow accumulation and/or the time between snowmelt and heavy spring rains will increase under climate change to a degree not well represented in the current stochastic data (Notaro, 2015; Whitfield and Cannon, 2000; Barnett et al., 2005). Evaporation and precipitation may each increase under climate change, but the timing of the two may also change in ways not well represented in the current stochastic data (Music et al., 2015, Notaro, 2015; GLISA, 2018). However, the significant uncertainties in how these factors will change with a changing climate remains a challenge in developing a new stochastic dataset as well as changing the rules of regulation plans to respond to this uncertainty.

This section also makes evident that high Lake Ontario levels can be caused by the sequence and simultaneous occurrence of climate factors, so forecasting research that predicts simple parameters like the amount of spring precipitation may not forecast high water levels. The GLAM Committee concludes that to be useful, fall forecasts should be tested according to their ability to predict high spring Lake Ontario levels, not simply high NBS or NTS. Even with such research, it could be many years or decades until the skill of such forecasts is to a level that might influence regulation plan decisions.

6.4.2.2 Re-evaluation of the model processes and algorithms

Section 6.3.2 shows that Lake Ontario levels could have been reduced somewhat in 2017 by modifying the F and L limits, although modifications may alter the balance of impacts upstream and downstream. These current limits are part of Plan 2014 rules and 1958-DD practice that were based on long standing perceptions about protecting navigation safety and balancing flooding above and below the dam. There is no evidence to date that suggests that changing those practices would improve outcomes in any significant way. Changing these limits would shift impacts or risks from one area or interest to another. Any future analysis should focus the assessment on a broad range of extreme and difficult water supply conditions as well as socio-economic and environmental performance indicators.

Section 6.3.2.2 shows no water level reduction would have resulted from any realistic adjustment of the H14 high trigger levels based on 2017 conditions. The reductions in 2017 that could have been caused by one-foot lower trigger levels would, if acted upon by the ILOSLRB, cause deviations from Plan 2014 rules about 20% of the time, eviscerating the nature of the plan. People who suffered through the high levels often expressed the belief that lower trigger levels would have helped. Based on the 2017 analysis, the GLAM Committee does not believe that examining changes to the triggers provides much promise in terms of looking for plan improvements during extreme water supply conditions. However, as with the limits, any future analysis of the H14 high trigger should include attention on a broader range of extreme water supply conditions as well as socio-economic and environmental performance indicators.

The simulation of water levels in the river is based on regression equations using past levels, tributary flows and releases from Lake Ontario. Given extreme water levels in 2017, it was determined that re-examining the regressions used to simulate Lake Saint-Louis and further downstream levels could produce meaningful improvements in the validity of the simulation model under extreme flow conditions.

Section 6.3.2.7 summarized the discovery of a coding issue in the simulation of Plan 2014 that, when Lake Ontario is above 75.75 m, can underestimate Lake Ontario levels and overestimate levels at Pointe Claire. The GLAM Committee concludes that the implications of the quarter-monthly simulation of Pointe Claire levels for Plan 2014 be investigated to determine the effects it may have on plan evaluations and inherent upstream and downstream tradeoffs. This may include re-running the full stochastic evaluations to determine the implications for the calculation of the performance indicator results.

6.4.3 Next steps: reconsideration of plan evaluation process

6.4.3.1 Upper Great Lakes: The development of new shorter-term plan evaluation tools

Computer models were developed during the IUGLS (2007-2012) to analyze and compare the performance of differing regulation plans. The plans had to be tested under many different hydrologic conditions, so they used century long time series data. These models are not designed for the comparison of different water level regulation rules over only one or two years. The GLAM Committee is currently developing short term evaluation tools. Once these tools are developed, the GLAM Committee will produce quantitative reviews of Plan 2012 performance in the current and recent years.

6.4.3.2 Lake Ontario – St. Lawrence River: extensive scenario testing

The LOSLRS Board based much of their plan ranking on expected values of economic benefits calculated as averages from stochastic simulations and environmental performance indicators simulated using the historic record. Expected values are averages of the impacts times the probability of the impact, and ranking based on those averages suggests how the plans are most likely to perform. Scenario analysis can be used in addition to expected value calculations to test a plan's robustness in the face of unusual combinations of conditions. An additional approach that can be used to complement the average annual impacts based on stochastic hydrology, is scenario analysis, where plan rules are tested with many short-term input data sets. This approach was used by the IUGLS Board (IUGLS, 2007-2012) and to a lesser degree during and after the LOSLRS. Section 6.3.3 and Annex 2-Plan Review revealed that there is some evidence that suggests the stochastic inputs do not fully represent the future conditions Plan 2014 will be applied under and this leads the GLAM Committee to conclude that more extensive scenario analysis would be beneficial in testing Plan 2014:

- In some cases, such as in ice formation, there is no doubt that the stochastic data do not represent what happened in 2017 and the implications of this should be fully reviewed and evaluated;
- The use of average benefits of regulation plan performance is useful because it incorporates the results from all events weighted by their probability of occurrence, but it takes attention away from rare events that have the greatest impact on stakeholders (or

interests) and which (if possible) may be the most important for regulation plans to attempt to better address, particularly if the probability of such rare events is expected to increase in the future; and

- There is some evidence that the probability, magnitude and timing of temperature, precipitation, evaporation and runoff may be changing. Section 6.3.1 shows that the coincidence and sequencing of these factors can raise water levels. Presumably, the stochastic simulation includes the correlations among these parameters found in the historic record. Scenario analysis would allow the creation of uncharacteristic but plausible combinations of these parameters.

7.0 Key Findings and Next Steps

The GLAM Committee has developed this special report of conditions in 2017 as a component of its long-term adaptive management process to review and improve outflow regulation on the Great Lakes. The year 2017 was impactful and challenging, particularly for the interests of the Lake Ontario-St. Lawrence River system. It offered a critical test of both Plan 2012 and Plan 2014 and a challenge for the GLAM Committee in initiating a reporting process for event-based data and information. Information learned in 2017 will be used to guide GLAM Committee activities in the coming year and beyond, as resources become available. The following sections highlight critical findings and potential next steps.

7.1 The year 2017 had extraordinary conditions across Lake Ontario and the St. Lawrence River basin, but Plan 2014 did not contribute to record high water levels

Finding: 2017 was unusually wet across the entire Great Lakes with record-breaking precipitation and water levels on the Lake Ontario-St. Lawrence River system. These conditions caused widespread damages to coastal communities and other interest categories upstream and downstream of the Moses-Saunders dam. The GLAM Committee analyses of conditions and plan performance in 2017 supports the ILOSLRB finding that Plan 2014 did not cause, or meaningfully exacerbate, the flooding and associated damages that occurred in 2017. The analysis showed that the outflows released in 2017 under the new regulation plan were very similar to those that would have been released had the board still been operating under the old regulation plan with previous operating and deviation authorities.

Next Steps: The GLAM Committee will continue to analyze data gathered from 2017 and future years to support the on-going evaluation of the regulation plans and search for improvements.

7.2 Great Lakes Basin: Quantitative data on impacts from the high water levels in 2017 is not widely available and is required for performance indicator model validation

Finding: Performance indicators generally captured critical sectors in 2017, but conditions raised questions about model details and on-going monitoring required for validation. While the GLAM Committee pursued various potential data sources, much of the data was not available for public distribution and in many cases, quantitative economic and environmental impact data was not being actively collected nor consolidated. In most cases, it was difficult (if not impossible) to get the appropriate quantitative data required to validate existing economic and environmental performance indicators used in the existing models. This raises the question about revisiting performance indicators to support long-term plan evaluation. Some areas seem more critical than others and the GLAM Committee will need to prioritize performance indicator validation efforts to efficiently guide its collection of critical data. There were some impacts that could not be compared with existing performance indicators, either because the information was not available to support the comparison, or because the impacts observed were not directly captured by the existing performance indicators. The impacts experienced in 2017 not captured by existing performance indicators may or may not reflect important issues affecting relative comparisons of plan performance. Either way, it does highlight the need for regular review and updating of the performance indicators as part of the adaptive management process.

Next Steps: Once the studies of 2017 impacts are completed, the GLAM Committee should compare the results to model predictions, report on the accuracy of performance indicator model predictions and modify the performance indicator functions, if necessary. The GLAM Committee should continue to pursue on-going monitoring needs to validate models and update performance indicators as required to support the ongoing review of the regulation plans. As well, the GLAM Committee should revisit the significance, sensitivity and certainty of all of the performance indicators to ensure they can effectively be used in future plan reviews and evaluations.

7.3 Great Lakes Basin: Simulation models will continue to be improved

Finding: The simulations of water levels and flows under Plan 2012 and Plan 2014, as well as alternative regulation strategies, should be continually tested and improved as appropriate to minimize inherent uncertainties. For example, on Lake Ontario and the St. Lawrence River system, the simulation of Lake Saint-Louis levels is uncertain under very high water supply conditions, as are the effects that such conditions may have throughout the lower St. Lawrence River. On the upper Great Lakes, the maximum combined capacity of the side channels, which carry flow to the hydropower plants on the St. Marys River, is reduced at times of hydropower maintenance activities, but the effects of these reductions in capacity were not considered when

Plan 2012 was evaluated. To reduce the impacts on the St. Marys Rapids during periods of high flows and reduced capacity, the ILSBC has had to deviate annually since the plan was implemented in 2015.

Next Steps: The simulation and evaluation models will be improved, and the new models used during subsequent evaluations will be periodically reviewed and updated as appropriate.

7.4. Upper Great Lakes: New performance indicators need to be developed for the St. Marys River

Finding: Lake Superior outflow regulation has the greatest effect on the St. Marys River. While the ILSBC has tried to minimize the potential negative impacts of high and fluctuating flows in the St. Marys Rapids by deviating from Plan 2012 during recent years, there is insufficient monitoring data or metrics to validate the effects of the ILSBC's deviation strategies. The St. Marys Rapids ecosystem and the low-lying adjacent shoreline of Whitefish Island are particularly sensitive to high flows or changes in flows through the Compensating Works. Performance indicators need to be developed to quantify and better understand the impacts in the St. Marys Rapids, and these can be used to inform future evaluations of regulation plan performance as well as the effects of potential deviation strategies.

Next Steps: Continue efforts to develop ecosystem and flooding performance indicators and models for the St. Marys River.

7.5 Lake Ontario-St. Lawrence: The impacts of modifying the F and L limits should be studied

Finding: The GLAM Committee examined some of the rules of Plan 2014, including the maximum flow limits within the plan. Plan 2014's maximum limits were established over decades of board operation based on expert knowledge and experience in balancing coastal impacts above and below the dam (F-limit) and balancing those impacts with maintaining safe water velocities and river levels for ships in the St. Lawrence Seaway (L-limit). A review of how these limits applied during 2017 showed that altering them would not eliminate or significantly reduce the high flows and water levels that occurred, but it would shift the effects from one geographic location and/or interest to another. The impacts of such actions on various interests are uncertain. While the LOSLRS did investigate the effects of altering these limits, the performance indicators used to model the impacts of these limits must be reviewed and informed by 2017 conditions and the trade-offs associated with these limits re-evaluated to better understand and explain the implications of modifying these limits and other plan rules.

Next steps: The GLAM Committee will continue to design and implement studies to review and evaluate the socio-economic and environmental implications of modifications to the limits and other plan rules to better understand and explain the inherent tradeoffs and balances of the plan rules and limits under a broad range of extreme conditions.

7.6 Lake Ontario-St. Lawrence: Changes to trigger levels do not substantially influence water levels under the extreme conditions seen in 2017

Finding: The GLAM Committee examined the trigger levels for board deviations and whether lower trigger levels could have provided additional flood relief upstream and downstream in 2017. This analysis indicates that no significant reduction of 2017 water levels would have resulted from any realistic adjustment of the H14 high trigger levels. A full analysis beyond 2017 conditions has not yet been completed and is needed to assess the value of changes to trigger levels under other extreme conditions than what occurred in 2017.

Next Steps: Any future analysis of trigger levels will be done as part of a full review of all rules within Plan 2014. Such analysis builds on previous studies by the IJC and is supported by lessons learned in 2017 and future years. It should also include an assessment of a broad array of extreme water supply scenarios as well as socio-economic and environmental performance indicators.

7.7 Lake Ontario-St. Lawrence: 2017 hydroclimate conditions highlight the importance of using scenario analyses to test and evaluate plan performance

Finding: Two components of 2017 weather conditions promote consideration of *scenario testing* (comparing regulation plans using short, extreme inputs) to complement *expected value testing* (using the products of impacts of many different input sets times the probability of that input set occurring). The first condition was the unprecedented forming and melting of ice in the St. Lawrence River five times in 2017 and the effects this had on regulated outflows and the water levels that occurred. The stochastic data used in the evaluation of the current plan during and after the LOSLRS included many different starting dates and durations of ice cover formation, but did not include a scenario in which ice went through several cycles of forming and melting in one year. The second condition was the record precipitation measured at stations on the Lake Ontario basin and on the Ottawa River basin, each exceeding historical maximums.

Expected value analysis offers the best assessment of the overall performance of regulation rules under a wide variety of conditions, but the response in very unusual scenarios is dampened by the low probability associated with those events. Climate change challenges the assumption that those probabilities can be estimated well. Scenario testing using many different plausible but extreme conditions would allow the GLAM Committee to test how well plans perform under extreme conditions not thought likely, offering the chance to adjust plan rules to better accommodate very unusual conditions. It should be used in combination with expected value testing so that the adjusted plan continued to perform well over a wide variety of conditions while also performing about as well as any plan could in plausible but extreme conditions.

Next Steps: A new set of model inputs should be created expressly for continued scenario testing beyond what has previously been analyzed and a framework for evaluating plan performance on the basis of both scenario and expected value tests should continue to be devised to test a plan's robustness in the face of unusual combinations of conditions.

7.8 Lake Ontario-St. Lawrence: Continue to investigate the value of forecasting high Lake Ontario water levels to support plan improvements

Finding: Analyses of the 2017 conditions provided evidence that high Lake Ontario water levels can be caused by the sequence and simultaneous occurrence of different climate factors, so forecasting research that predicts simple parameters like the amount of Lake Ontario spring precipitation may not forecast high water levels. The GLAM Committee concludes that to be useful, fall forecasts should be tested according to their ability to predict high Lake Ontario water levels, not just high NBS or NTS.

No such forecast exists now, but there may be some potential for trying to produce one based on ocean conditions in the fall. Given that it may be years, even decades or perhaps never, before seasonal forecasts have the skill to inform regulation plan decisions, a first step is to test the hypothesis that forecasts could reduce flooding while balancing the needs of other interests.

Next Steps: The GLAM Committee should test perfect forecasts and evaluate the implications of using more realistic imperfect forecasts as a means to reduce flooding while balancing other interests. The Committee should also identify the risk of incorrect forecasts. If results are promising, the GLAM Committee should investigate methods to evaluate different relationships between ocean conditions and Lake Ontario levels to improve seasonal forecasts. This would be done recognizing effective seasonal forecasts as a long-term goal.

7.9 Lake Ontario - St. Lawrence: Some notable changes in percent coverage appeared to occur at specific elevations where vegetation communities were flooded by higher water levels in 2017

Finding: Shifts in wetland vegetation extent resulting from 2017 water level conditions will not be immediately evident as there is a lag time for response in some guilds. However, field data from the surveillance of the Canadian and U.S. wetlands done in the fall of 2017 show some notable changes in percent coverage at specific elevations where vegetation communities were flooded by higher water levels in 2017. The meadow marsh guild appears to have experienced the most change out of all guilds in 2017. Not surprisingly, the average cover for meadow marsh was lower in 2017, compared with previous data, as these species were stressed by flooding for a large portion of the growing season.

Next Steps: Additional years of monitoring the wetlands' response to the 2017 high levels as well as response to lower water level conditions is needed to complete the validation of the meadow marsh algorithm.

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Appendix 1: Performance Indicators and Coping Zones

Performance Indicators used in LOSLRS, 2006

Key Environmental Performance Indicators

Lake Ontario

Vegetation:

1. *Wetland Meadow Marsh Community - Total surface area, supply-based (ha)

Fish:

2. Fish Guild (Low Vegetation, 18C) - Spawning habitat supply
3. *Fish Guild (High Vegetation, 24C) - Spawning habitat supply
4. Fish Guild (Low Vegetation, 24C) - Spawning habitat supply
5. *Northern Pike – Young-of-year recruitment (#ha)
6. Largemouth Bass – Young-of-year recruitment (#ha)

Birds

7. *Virginia Rail (RALI) - Median reproductive index (index)
8. Least Bittern (IXEX) - Median reproductive index (index) (Species at risk)
9. *Black Tern (CHNI) - Median reproductive index (index) (Species at risk)
10. Yellow Rail (CONO) - Preferred breeding habitat coverage (ha) (Species at risk)
11. King Rail (RAEL) - Preferred breeding habitat coverage (ha) (Species at risk)

Upper St. Lawrence River

Fish:

12. Fish Guild (Low Vegetation, 18C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence
13. *Fish Guild (High Vegetation, 24C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence
14. Fish Guild (Low Vegetation, 24C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence
15. *Northern Pike – Young-of-year (YOY) recruitment (#ha) from Thousand Islands to Lake St. Lawrence
16. Largemouth Bass – YOY recruitment (#ha) from Thousand Islands to Lake St. Lawrence
17. *Northern Pike – YOY net productivity (grams (wet wt.)/ha) in Thousand Islands area

Birds:

18. *Virginia Rail (RALI) - Median reproductive index (index) on Lake St. Lawrence

Mammals:

19. *Muskrat (ONZI) - House density in drowned river mouth wetlands (#ha) in Thousand Islands area

Lower St. Lawrence River

Fish:

20. *Golden Shiner (NOCR) - Suitable feeding habitat surface area (ha) from Lake St. Louis to Trois-Rivières
21. Wetland Fish - Abundance index (ha) in Lower St. Lawrence River
22. *Northern Pike (ESLU) - Suitable reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières
23. Eastern Sand Darter (AMPE) - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières (Species at risk)
24. *Bridle Shiner (NOBI) - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières (Species at risk)

Birds:

25. Migratory Wildfowl - Floodplain habitat surface area (ha) from Lake St. Louis to Trois-Rivières
26. Least Bittern (IXEX) - Reproductive index (index) from Lake St. Louis to Trois-Rivières (Species at risk)
27. *Virginia Rail (RALI) - Reproductive index (index) from Lake St. Louis to Trois-Rivières
28. *Migratory Wildfowl - Productivity (# juveniles) from Lake St. Louis to Trois-Rivières
29. Black Tern (CHNI) - Reproductive index (index) from Lake St. Louis to Trois-Rivières

Herpetiles

30. Frog species - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières
31. Spiny Softshell Turtle (APSP) - Reproductive habitat surface area (ha) from Lake St. Louis to Trois-Rivières (Species at risk)

Mammals

32. *Muskrat (ONZI) - Surviving houses (# of houses) from Lake St. Louis to Trois-Rivières

*Priority subsets of key environmental indicators

Economic Performance Indicators

Coastal Performance Indicators

Lake Ontario

1. Flood Damages - The economic damages to developed properties based on high water levels, calculated on a county basis.
2. Erosion of Developed Parcels - Damage based on the cost of adding shore protection once the shoreline is within a defined distance from the house, calculated on a county basis. The value of lost material is not determined.
3. Shore Protection Maintenance - The cost of replacing shore protection damaged by water levels, calculated on a county basis.

Upper St. Lawrence River

4. Flood Damages - The economic damages to developed properties based on high water levels, calculated on a county basis. Based on U.S. counties only due to lack of availability of Canadian parcel data for upper St. Lawrence River regional municipalities.

Lower St. Lawrence River

5. Flood Damages - Damages associated with high water levels in the St. Lawrence River below the dam on a municipality basis; based on water levels at the closest gauge location (eight used for the river).
6. St. Lawrence River Shore Protection - The cost of replacing shore protection damaged by water levels. Each structure was placed in one of 80 structure zones on the Lower St. Lawrence River. These zones were selected on the basis of location and similarity of hydrodynamic conditions (local wind, wave, river flow and level, and shipping climate).

Non-Economic Performance Indicators (Reported in Board Room and Contextual Narrative)

- St. Lawrence River Flooding Non-Economic Impacts - Number of expropriated homes; kilometres of roads flooded, and area of flooded land. Damages are determined on a municipality basis; based on water levels at the closest gauge location (eight used for the river).
- St. Lawrence River Erosion - Land lost due to erosion. Impacts are determined for 27 high-erosion sites along the lower St. Lawrence River. No measurable economic loss as a result of land lost.

Commercial Navigation

7. Transportation Costs on Lake Ontario - Based on tonne-km travel time. Costs rise as travel time increases and are a function of minimal available channel depth on the lake.
8. Transportation Costs on the Seaway - Based on tonne-km travel time. Costs rise as travel time increases and are a function of minimal available channel depth along the Seaway, Seaway low-level wait time, and Seaway gradient delays (fall between gauges) and associated delay costs due to high-flow velocities between Ogdensburg - Cardinal, Cardinal-Iroquois HW, Iroquois TW - Morrisburg, Morrisburg - Long Sault.
9. Transportation Costs below the Port of Montreal - Based on tonne-km travel time. Costs rise as travel time increases and are a function of minimal available channel depth at Sorel andTrois-Rivières.

Hydropower

10. Value of energy produced based on station head, flow, efficiency rate and price of electricity.
11. Cost of foregone peaking opportunities (NYPA and OPG only) based on weekly averaged regulated release and value of peaking opportunity.
12. Predictability/stability of flows to maximize efficiency based on changes in flow and foregone energy production.
13. Frequency and severity of spill at Long Sault Dam during spawning season.

Recreational Boating

14. Net economic benefits lost by recreational boaters and charter boat patrons as water level varies from ideal levels for boating for six reaches (Lake Ontario, Alexandria Bay, Ogdensburg, Lake St. Lawrence, Lake St. Louis, Montreal Harbour, and Lac St. Pierre)

Municipal and Industrial Water Uses

15. Water Quality Infrastructure Costs Avoided on the lower St. Lawrence River - based on cost of upgrading municipal drinking water treatment plants to treat taste and odor compounds.
16. Water Supply Infrastructure Costs Avoided on the lower St. Lawrence River - based on costs required to adapt plants to lower than critical levels.

Coping Zones for the Upper Great Lakes for Coastal, Recreational Boating, Municipal and Industrial Water Uses and Commercial Navigation used in IUGLS, 2012 (hydropower and ecosystem to follow)

Lake Superior Coping Zones (Water Levels) (from IUGLS, 2012)

			Month											
Interest	Water Level (WL) Conditions	Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coastal	High WL	Zone C	183.59	183.53	183.51	183.57	183.66	183.71	183.78	183.83	183.84	183.85	183.82	183.74
		Zone B	183.51	183.45	183.44	183.46	183.56	183.66	183.73	183.76	183.77	183.71	183.66	183.60
	Acceptable WL	Zone A	183.51-183.15	183.45-183.08	183.44-183.07	183.46-183.09	183.56-183.18	183.66-183.25	183.73-183.33	183.76-183.36	183.77-183.33	183.71-183.30	183.66-183.27	183.60-183.20
	Low WL	Zone B	183.15	183.08	183.07	183.09	183.18	183.25	183.33	183.36	183.33	183.30	183.27	183.20
		Zone C	182.83	182.76	182.74	182.72	182.76	182.85	182.96	183.01	183.02	183.10	183.01	182.92
Recreational Boating	High WL	Zone C	Recreational Boating Off-Season			184.6	184.6	184.6	184.6	184.6	184.6	184.6	Recreational Boating Off-Season	
		Zone B				184.3	184.3	184.3	184.3	184.3	184.3	184.3		
	Acceptable WL	Zone A				184.3-182.8	184.3-182.8	184.3-182.8	184.3-182.8	184.3-182.8	184.3-182.8	184.3-182.8		
	Low WL	Zone B				182.8	182.8	182.8	182.8	182.8	182.8	182.8		
		Zone C				181.9	181.9	181.9	181.9	181.9	181.9	181.9		
Municipal and Industrial Water Users	High WL	Zone C	184.6	184.6	184.6	184.6	184.6	184.6	184.6	184.6	184.6	184.6	184.6	184.6
		Zone B	184.3	184.3	184.3	184.3	184.3	184.3	184.3	184.3	184.3	184.3	184.3	184.3
	Acceptable WL	Zone A	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72	184.3-182.72
	Low WL	Zone B	182.72	182.72	182.72	182.72	182.72	182.72	182.72	182.72	182.72	182.72	182.72	182.72
		Zone C	181.6	181.6	181.6	181.6	181.6	181.6	181.6	181.6	181.6	181.6	181.6	181.6
Commercial Navigation	High WL	Zone C	184.7	184.7	184.7	184.7	184.7	184.7	184.7	184.7	184.7	184.7	184.7	184.7
		Zone B	184.4	184.4	184.4	184.4	184.4	184.4	184.4	184.4	184.4	184.4	184.4	184.4
	Acceptable WL	Zone A	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2	184.4-183.2
	Low WL	Zone B	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2	183.2
		Zone C	182.6	182.6	182.6	182.6	182.6	182.6	182.6	182.6	182.6	182.6	182.6	182.6

Location: Lake Superior (from IUGLS, 2012)

Interest	Water Level Regime Characteristic	Zone A	Zone B	Zone C
Coastal	Frequency of extremes	Some impacts possible near extremes of Zone A. Higher frequency of extremes would cause some problems to most sensitive stakeholders	Zone B levels are likely to cause problems for moderately sensitive stakeholders and a higher frequency of extremes will exacerbate problems	Zone C levels will cause problems for moderately sensitive stakeholders. A higher frequency of extremes are expected to lead to large changes in the coastal riparian stakeholder community
	Duration	On high end, can withstand this range with minimal damage, regardless of duration, except under extreme (>1% exceedance surge/storm event). On low end of Zone A, persistent conditions (multiple consecutive years) will be a problem for riparians.	Longer duration of Zone B high levels will increase potential for coincidence of large storm event. Persistence of two consecutive years (or more) with max levels within Zone B likely to be of concern to stakeholders and potential exists for damages ranging from moderate to substantial, depending on storm events. On low end, two consecutive years (or more) with Zone B low levels will be of concern to stakeholders	One year with water levels exceeding high Zone C transition is likely to cause moderate damages. Coincidence of a small to moderate storm event will increase damages considerably and an extreme event will cause substantial damages. On low end, conditions have not been experienced within historic record and are likely to be of concern, even for one year.
	Rate of Change	Rapid rising to Max. or lowering to Min. levels will reduce time to adapt and will cause concern but severity of consequences will be minimal	Physical modifications (protection, dredging, etc.) are likely as adaptation to Zone B levels. Rapid rising to Max. or lowering to Min. levels within Zone B may eliminate ability to undertake necessary modifications.	Rapid rising above Max. Zone C threshold or lowering below Zone C threshold will restrict ability to take adaptive measures (e.g. construct shore protection) and will likely lead to substantial damages
	Seasonality	Historically, Lake Superior levels peak in July-October period and reach minimum in Feb-Apr, on average. Peak return period surge events for Thunder Bay tend to be greatest in summer and fall based on Baird (2010) analysis and so coincide with peak levels limiting the consequence of changes in seasonality.		
Recreational Boating	Frequency of extremes	During 30 year snapshot of the boating season (April through November), 0% of months exceed Max. and 0% of months are less than Min.	0% of months exceed Max. and 0% of months are less than Min.	0% of months exceed Max. and 0% of months are less than Min.
	Duration	Can withstand this range with minimal damage	Can withstand this range with minimal damage	
	Rate of Change	Quite resilient	Quite resilient	Quite resilient
	Seasonality			
Commercial Navigation	Frequency of extremes	Max. - level outside of historic record Min. - levels lower than min. have generally occurred only once in past 6 decades.	Neither high/low levels have been experienced in the historic records	Neither high/low levels have been experienced in the historic records
	Duration		Shippers are typically able to cope via light loading, however, extended periods (2-3 yrs) increase likelihood of end users considering a shift in modes of transportation	
	Rate of Change	Stable levels are preferred over rapidly varying levels	Stable levels are preferred over rapidly varying levels	Stable levels are preferred over rapidly varying levels
	Seasonality	For Min: June to Oct. for first level; Apr, May, Nov., & Dec. for second level	For min: June to Oct. for first level; Apr., May, Nov., & Dec. for second level	For min: June to Oct. for first level; Apr., May, Nov., & Dec. for second level
Municipal and Industrial Water Uses	Frequency of extremes	The Max. is the historic monthly high plus 3 sd. The Min. is the historic monthly Min.	The Upper and Lower Levels are where operational problems begin and before the elevations where the first facility operations cease.	Levels are significantly outside historical record and pre-project levels simulation.
	Duration	Can withstand this range with minimal problems.	Short term duration can be tolerated; levels for weeks or months are expected to cause operational issues.	Short term duration (12 to 24 hours) can be tolerated by public water supplies; levels for weeks or months will cause operational issues in some facilities, require capital changes or shut down facilities. This is the elevation where operations begin to cease.
	Rate of Change	Quick drops or rises generally can be handled in this	A quick rate of change from A to B can be tolerated. May	The quicker Zone C is reached from Zone B, the greater the

Interest	Water Level Regime Characteristic	Zone A	Zone B	Zone C
		zone.	require some operational changes if levels remain	chance for disruption in water supply.
	Seasonality	Timing of seasonal peaks are not an issue.	Winter temperatures around freezing might cause frazzle ice in some intakes. Some intakes might be more vulnerable to operational issues in winter levels as they are the seasonal low.	Same as B

Lake Michigan-Huron Coping Zones (Water Levels) (from IUGLS, 2012)

Interest	Water Level (WL) Conditions	Zone	Month: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coastal	High WL	Zone C	177.01	176.99	177.05	177.19	177.26	177.29	177.31	177.29	177.29	177.33	177.29	177.33
		Zone B	176.79	176.77	176.82	176.91	177.05	177.07	177.11	177.07	177.02	176.95	176.89	176.82
	Acceptable WL	Zone A	176.79-175.94	176.77-175.92	176.82-175.93	176.91-176.0.	177.05-176.12	177.07-176.17	177.11-176.17	177.07-176.13	177.02-176.09	176.95-176.07	176.89-176.00	176.82-175.96
	Low WL	Zone B	175.94	175.92	175.93	176.03	176.12	176.17	176.17	176.13	176.09	176.07	176.00	175.96
		Zone C	175.62	175.61	175.63	175.69	175.84	175.88	175.91	175.90	175.87	175.80	175.73	175.67
Recreational Boating	High WL	Zone C	Recreational Boating Off-Season			177.6	177.6	177.6	177.6	177.6	177.6	177.6	Recreational Boating Off-Season	
		Zone B				177.3	177.3	177.3	177.3	177.3	177.3	177.3		
	Acceptable WL	Zone A				177.3-175.8	177.3-175.8	177.3-175.8	177.3-175.8	177.3-175.8	177.3-175.8	177.3-175.8		
	Low WL	Zone B				175.8	175.8	175.8	175.8	175.8	175.8	175.8		
		Zone C				175.5	175.5	175.5	175.5	175.5	175.5	175.5		
Municipal and Industrial Water Users	High WL	Zone C	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6
		Zone B	177.21	177.21	177.21	177.21	177.21	177.21	177.21	177.21	177.21	177.21	177.21	177.21
	Acceptable WL	Zone A	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58	177.21-175.58
	Low WL	Zone B	175.58	175.58	175.58	175.58	175.58	175.58	175.58	175.58	175.58	175.58	175.58	175.58
		Zone C	174.6	174.6	174.6	174.6	174.6	174.6	174.6	174.6	174.6	174.6	174.6	174.6
Commercial Navigation	High WL	Zone C	177.5	177.5	177.5	177.5	177.5	177.5	177.5	177.5	177.5	177.5	177.5	177.5
		Zone B	177.2	177.2	177.2	177.2	177.2	177.2	177.2	177.2	177.2	177.2	177.2	177.2
	Acceptable WL	Zone A	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75	177.2-175.75
	Low WL	Zone B	175.75	175.75	175.75	175.75	175.75	175.75	175.75	175.75	175.75	175.75	175.75	175.75
		Zone C	175.15	175.15	175.15	175.15	175.15	175.15	175.15	175.15	175.15	175.15	175.15	175.15

Location: Lake Michigan-Huron (from IUGLS, 2012)

Interest	Water Level Regime Characteristic	Zone A	Zone B	Zone C
Coastal	Frequency of extremes	On high end, can withstand this range with minimal damage, regardless of duration, except under extreme (> 10 year return period (10% exceedance) surge/storm event). On low end of Zone A, persistent conditions (multiple consecutive years) will be a problem for riparians.	Longer duration of Zone B high levels will increase potential for coincidence of large storm event. Persistence of two consecutive years (or more) with Max. levels within Zone B likely to be of concern to stakeholders and potential exists for damages ranging from moderate to substantial depending on storm events. On low end, two consecutive years (or more) with Zone B low levels will be of concern to stakeholders.	One year with water levels exceeding high Zone C threshold is likely to cause moderate damages. Coincidence of a small to moderate storm event will increase damages considerably and an extreme event will cause substantial damages. On low end, conditions have not been experienced within historic record and are likely to be of concern, even for one year.
	Duration	On high end, can withstand this range with minimal damage, regardless of duration, except under extreme (>10 year return period (10% exceedance) surge/storm event). On low end of Zone A, persistent conditions (multiple consecutive years) will be a problem for riparians.	Longer duration of Zone B high levels will increase potential for coincidence of large storm event. Persistence of two consecutive years (or more) with Max. levels within Zone B likely to be of concern to stakeholders and potential exists for damages ranging from moderate to substantial depending on storm events. On low end, two consecutive years (or more) with Zone B low levels will be of concern to stakeholders	One year with water levels exceeding high Zone C threshold is likely to cause moderate damages. Coincidence of a small to moderate storm event will increase damages considerably and an extreme event will cause substantial damages. On low end, conditions have not been experienced within historic record and are likely to be of concern, even for one year.
	Rate of Change	Rapid rising to Max. or lowering to Min. levels will reduce time to adapt and will cause concern but severity of consequences will be minimal	Physical modifications (protection, dredging, etc.) are likely as adaptation to Zone B levels. Rapid rising to Max. or lowering to Min. levels within Zone B may eliminate ability to undertake necessary modifications.	Rapid rising above Max. Zone C threshold or lowering below Zone C threshold will lead to substantial damages
	Seasonality	Historically, Lake Huron/ Georgian Bay levels peak in June-August period and reach minimum in January-March, on average. Peak return period surge events for Honey Harbour (based on nearby Collingwood gauge) tend to be greatest in winter/spring and fall based on Baird (2010) analysis. Moving peak annual levels into the fall (Sept-Nov) would increase potential for event damages.		
Recreational Boating	Frequency of extremes	During 30 year snapshot of the boating season (April through November), 3% of months exceed Max. and 19% of months are less than Min.	3% of months exceed Max. and 0% of months are less than Min.	0% of months exceed Max. and 0% of months are less than Min.
	Duration	Can withstand this range with minimal damage	Either extreme will cause significant damage until actions are taken to adapt. Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch' and Fall 'Haul-out'.	Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch' and Fall 'Haul-out'. Many would have difficulty surviving longer than one season.
	Rate of Change	Quick drops or rises are generally considered a negative as interest does not have time to adjust.	A quick return to zone A regime would be beneficial. A further drop/rise, or prolonged period at this elevation could push interest to Zone C	Any length of time in Zone C would make it difficult for many of the marinas to remain operational.
	Seasonality	Lows are worse in the fall, winter and spring	Lows are worse in the fall, winter and spring	Same as B
Commercial Navigation	Frequency of extremes	Max - has been exceeded in 1952, 1973-74 and 1985-56; Min. - levels lower than Min. have generally occurred only once in past six decades.	Levels have been within this range since 1918	
	Duration		Shippers are typically able to cope via light loading, however, extended periods (2-3 yrs) increase likelihood of end users considering a shift in modes of transportation	

Interest	Water Level Regime Characteristic	Zone A	Zone B	Zone C
	Rate of Change	Stable levels are preferred over rapidly varying levels	Stable levels are preferred over rapidly varying levels	Stable levels are preferred over rapidly varying levels
	Seasonality	For Min: May to Sep. for first level; Apr. & Oct. to Dec. for second level	For Min: May to Sep. for first level; Apr. & Oct. to Dec. for second level	For Min: May to Sep. for first level; Apr. & Oct. to Dec. for second level
Municipal and Industrial Water Uses	**Frequency of extremes**	The Max. is 0.9 foot (0.29 m) less than the historic record; the Min. is the historic record. The Max. and Min. pre-project simulation are outside of Zone A.	Max. is Max. historical record + 3 ft (0.9 m); Min. is Min. historical Min. - 3.2 ft (1 m). Contains some extreme levels of pre-project simulation and historic record levels.	Levels are outside historical record.
	Duration	Can withstand this range with minimal problems.	Short term duration can be tolerated; levels for weeks or months are expected to cause operational issues.	Short term duration (12 to 24 hours) might be tolerated by public water supplies; levels for weeks or months will cause operational issues in some facilities, require capital changes or shut down facilities. This is the elevation where operations begin to cease.
	Rate of Change	A quick rate of change within A can be tolerated.	A quick rate of change from A to B can be tolerated. May require some operational changes if levels remain.	The quicker Zone C is reached from Zone B, the greater the chance for disruption in water supply.
	Seasonality	Timing of seasonal peaks are not an issue.	Winter temperatures around freezing might cause frazzle ice in some intakes. Some intakes might be more vulnerable in winter levels as they are the seasonal low.	Same as in B.

Lake Erie Coping Zones (Water Levels) (from IUGLS, 2012)

Interest	Water Level (WL) Conditions	Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Month											
Coastal	High WL	Zone C	174.57	174.63	174.84	174.97	174.95	174.97	174.93	174.84	174.75	174.75	174.78	174.83
		Zone B	174.45	174.47	174.59	174.70	174.70	174.73	174.70	174.65	174.56	174.46	174.40	174.43
	Acceptable WL	Zone A	174.45-173.74	174.47-173.69	174.59-173.74	174.70-173.88	174.70-173.99	174.73-174.05	174.70-174.04	174.65-173.99	174.56-173.90	174.46-173.82	174.40-173.71	174.43-173.74
	Low WL	Zone B	173.74	173.69	173.74	173.88	173.99	174.05	174.04	173.99	173.90	173.82	173.71	173.74
		Zone C	173.46	173.50	173.62	173.78	173.86	173.85	173.81	173.75	173.68	173.55	173.48	173.44
Recreational Boating	High WL	Zone C	Recreational Boating Off-Season			175.6	175.6	175.6	175.6	175.6	175.6	175.6	Recreational Boating Off-Season	
		Zone B				175.3	175.3	175.3	175.3	175.3	175.3	175.3		
	Acceptable WL	Zone A				175.3-173.8	175.3-173.8	175.3-173.8	175.3-173.8	175.3-173.8	175.3-173.8	175.3-173.8		
	Low WL	Zone B				173.8	173.8	173.8	173.8	173.8	173.8	173.8		
		Zone C				173.5	173.5	173.5	173.5	173.5	173.5	173.5		
Municipal and Industrial Water Users	High WL	Zone C	176.1	176.1	176.1	176.1	176.1	176.1	176.1	176.1	176.1	176.1	176.1	176.1
		Zone B	175.04	175.04	175.04	175.04	175.04	175.04	175.04	175.04	175.04	175.04	175.04	175.04
	Acceptable WL	Zone A	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18	175.04-173.18
	Low WL	Zone B	173.18	173.18	173.18	173.18	173.18	173.18	173.18	173.18	173.18	173.18	173.18	173.18
		Zone C	171.6	171.6	171.6	171.6	171.6	171.6	171.6	171.6	171.6	171.6	171.6	171.6
Commercial Navigation	High WL	Zone C	175.3	175.3	175.3	175.3	175.3	175.3	175.3	175.3	175.3	175.3	175.3	175.3
		Zone B	175	175	175	175	175	175	175	175	175	175	175	175
	Acceptable WL	Zone A	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5	175-173.5
	Low WL	Zone B	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5	173.5
		Zone C	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9

Location: Lake Erie (from IUGLS, 2012)

Interest	Water Level Regime Characteristic	Zone A	Zone B	Zone C
Coastal	Frequency of extremes	On high end, can withstand this range with minimal damage, regardless of duration, except under extreme (> 10 year return period (10% exceedance) surge/storm event). On low end of Zone A, persistent conditions (multiple consecutive years) will be a problem for riparians.	Longer duration of Zone B high levels will increase potential for coincidence of large storm event. Persistence of two consecutive years (or more) with max levels within Zone B likely to be of concern to stakeholders and potential exists for damages ranging from moderate to substantial depending on storm events. On low end, two consecutive years (or more) will Zone B low levels will be of concern to stakeholders	One year with water levels exceeding high Zone C threshold is likely to cause moderate damages. Coincidence of a small to moderate storm event will increase damages considerably and an extreme event will cause substantial damages. On low end, conditions have not been experienced within historic record and are likely to be of concern, even for one year.
	Duration	On high end, can withstand this range with minimal damage, regardless of duration, except under extreme (>10 year return period (10% exceedance) surge/storm event). On low end of Zone A, persistent conditions (multiple consecutive years) will be a problem for riparians.	Longer duration of Zone B high levels will increase potential for coincidence of large storm event. Persistence of two consecutive years (or more) with max levels within Zone B likely to be of concern to stakeholders and potential exists for damages ranging from moderate to substantial depending on storm events. On low end, two consecutive years (or more) will Zone B low levels will be of concern to stakeholders	One year with water levels exceeding high Zone C threshold is likely to cause moderate damages. Coincidence of a small to moderate storm event will increase damages considerably and an extreme event will cause substantial damages. On low end, conditions have not been experienced within historic record and are likely to be of concern, even for one year.
	Rate of Change	Rapid rising to Max. or lowering to Min. levels will reduce time to adapt and will cause concern but severity of consequences will be minimal	Physical modifications (protection, dredging, etc.) are likely as adaptation to Zone B levels. Rapid rising to Max. or lowering to Min. levels within Zone B may eliminate ability to undertake necessary modifications.	Rapid rising above Max. Zone C threshold or lowering below Zone C threshold will lead to substantial damages
	Seasonality	Historically, Lake Erie levels peak in May-July period and reach minimum in November-February, on average. Peak return period surge events for Kingsville (further west) tend to be greatest in winter/spring and fall based on Baird (2010) analysis. Moving peak annual levels into the spring (April-May) or fall (Sept-Nov) would increase potential for event damages.		
Recreational Boating	Frequency of extremes	During 30 year snapshot of the boating season (April through November), 12% of months exceed Max. and 16% of months are less than Min.	0% of months exceed Max. and 0% of months are less than Min.	0% of months exceed Max. and 0% of months are less than Min.
	Duration	Can withstand this range with minimal damage	If prolonged: between zero and 30% of marinas go out of business, and slip loss between five and 30%	If prolonged: more than 30% of marinas go out of business, and slip loss greater than 30%
	Rate of Change	Quick drops or rises are generally considered a negative as interest may need to adapt (dock adjustments).	Quick drops or rises are generally considered a negative as interest does not have time to adjust.	The quicker Zone C is reached from Zone B, the greater the damage will be as there will be little time to prepare or react.
	Seasonality	Seiches (flooding and ice damage) are worse in the winter.	Seiches (flooding and ice damage) are worse in the off season	Same as B
Commercial Navigation	Frequency of extremes	Max - exceeded for 2 months in 1986; Min. - levels lower than Min. have generally occurred only once in past six decades.	Levels have been within this range since 1918	Levels have been within this range since 1918
	Duration		Shippers are typically able to cope via light loading, however, extended periods (2-3 yrs) increase likelihood of end users considering a shift in modes of transportation	
	Rate of Change	Stable levels are preferred over rapidly varying levels	Stable levels are preferred over rapidly varying levels	Stable levels are preferred over rapidly varying levels
	Seasonality	For min: Apr to Oct. for first level; Nov. & Dec. for second level	For min: Apr to Oct. for first level; Nov. & Dec. for second level	For min: Apr to Oct. for first level; Nov. & Dec. for second level

Interest	Water Level Regime Characteristic	Zone A	Zone B	Zone C
Municipal and Industrial Water Uses	Frequency of extremes	Max. is record high; Min. is historic low.	Levels are outside historic range. Based in part on where operational problems occur.	Levels are outside historical record. Based on reported levels where operations cease.
	Duration	Can withstand this range with minimal problems	Short term duration can be tolerated; levels for weeks or months are expect to cause operational issues.	Short term duration (12 to 24 hours) can be tolerated; levels for days or months will cause operational issues in some facilities, require capital changes or shut down facilities. This is the elevation where operations begin to cease.
	Rate of Change	A quick rate of change within A can be tolerated.	A quick rate of change from A to B can be tolerated. May require some operational changes if levels remain	The quicker Zone C is reached from Zone B, the greater the chance for disruption in water supply.
	Seasonality	Timing of seasonal peaks are not an issue.	Winter temperatures around freezing might cause frazzle ice in some intakes. Some intakes might be more vulnerable in winter levels as they are the seasonal low.	Same as B

Location: St. Marys River: Hydropower Coping Zones (from IUGLS, 2012)

Hydropower coping zones table for the Cloverland Plant in the St. Marys River. Levels in metres (IGLD 1985), flows in m^3/s (Rose and Yee, 2011)

Zone	L Superior Outflows	L Superior Levels	Others, m^3/s	Cloverland capacity 850	US Plant capacity 405	Brookfield capacity 1140	Comments
A ideal	2374	183.45	94	**735**	405	1140	Equal share of available hydro water without spills.
A ideal	2374	183.45	94	**850**	290	1140	Equal share of available hydro water without spills.
A	2036~2409	183.26~183.47	94	**566~770**	405	971~1140	Adequate water for peaking operations (Cloverland IS curve).
A/B	Below 1236	182.74	94	**311**	260	571	Limited to winter. Cloverland and US Plant minimum for ice management and heating. US Plant lockage needs 40 m^3/s.
B	Below 716	182.34	94	**311 minimum**	0	311	Limited to winter. Assuming US Plant not requiring water for ice management, lockage and heating.
B		184.25					Overtopping bulkheads causing water onto generator floor.
B		**Max Tailrace 177.77 m at U.S. Slip**					Maintain level below the top of tailrace tunnel to avoid water in generator pits.
High B	Below 1526	182.94	94	**311 minimum**	405	716	Limited to winter. 311 m^3/s minimum for ice management and heating.
B/low C	Above 1084	182.63	94	**90 minimum**	405	495	90 m^3/s minimum for energy market.
B/low C		**Min Tailrace 175.96 m at US Slip**					To prevent cavitation damage causing loss of generation.
C	Below 904	182.51	94	**0**	405	405	Cloverland Zone C situation due to zero water allocation.

Ecological Performance Indicators for Lake Superior and Lake Michigan-Huron

Summary table of the eight primary IUGLS ecological performance indicators (taken directly from IUGLS, 2012, pg. 70)

PI Code	Zone C Condition	Performance Indicators	Goal is to Avoid Zone C
SUP-01	SUP-01 measures the degree to which natural **peak water level** events on Lake Superior, which occur roughly on a 30-year cycle, are lowered by regulation		Prevent/minimize range compression for Lake Superior
SUP-02	SUP-02 measures the degree to which there is a **drawdown** of Lake Superior following a peak water level 'event'. SUP-01 and SUP-02 scores closer to pre-project (and larger than 1977A) are better		Prevent/minimize range compression for Lake Superior
SUP-04	Peak summertime water level rises above 184.0 m (603.7 ft) for **three or more** consecutive years	Wild rice abundance in Kakagon Slough, near Duluth, MN	Maintain viability of wild rice population
SUP-05	Mean spring (Apr-May) water level is more than 0.67 m (2.2 ft) below the mean level for the preceding 10-year period for **seven or more** consecutive years	Northern pike habitat and population in Black Bay on the north shore of Lake Superior	Prevent significant decline in northern pike abundance
SMQ-01	Mean flow rate during June maintained below 1,700 m3/s (60,035.5 ft3/s) for **five or more** consecutive years	Lake sturgeon spawning habitat	Provide suitable spawning area for lake sturgeon
SMQ-02	Mean flow rate during May-June maintained below 2,000 m3/s (70,600 ft3/s) for **seven or more** consecutive years	Maintenance of flushing flows in the channel into Lake George (A small lake near Sault Ste. Marie, ON)	Maintain substrate in Lake George channel
LMH-07	Mean growing season (Apr-Oct) water level is less than 176.00 m (577.4 ft) for a period of **four or more consecutive years**	Fish and wildlife community eastern Georgian Bay wetlands	Maintain fish access to eastern Georgian Bay wetlands (current conditions)
LMH-08	Mean growing season (Apr-Oct) water level is less than 176.12 m (577.8 ft) for a period of **four or more consecutive years**	Fish and wildlife community eastern Georgian Bay wetlands	Maintain fish access to eastern Georgian Bay wetlands (+100 yr conditions)

Appendix 2: List of Acronyms

AO – Arctic Oscillation

CGIP - Chippewa–Grass Island Pool

CWS – Canadian Wildlife Service

ECCC - Environment and Climate Change Canada

ENSO – El Niño-Southern Oscillation

FEPS - Flood and Erosion Prediction System

GLAM – Great Lakes – St. Lawrence River Adaptive Management

GLERL – Great Lakes Environmental Research Laboratory

IERM – Integrated Ecological Response Model

IGLD – International Great Lakes Datum

IJC – International Joint Commission

ILOSLRB – International Lake Ontario-St. Lawrence River Board

ILSBC - International Lake Superior Board of Control

IMPLAN - Impact Analysis and Planning model

INBC – International Niagara Board of Control

IWI - International Watersheds Initiative

IUGLS – International Upper Great Lakes Study

LOSLRS – Lake Ontario - St. Lawrence River Study

NAO – North Atlantic Oscillation

NASH – North Atlantic subtropical high

NMME – North American Multi-Model Ensemble

NOAA – National Oceanic and Atmospheric Administration

NYDEC - New York Department of Environmental Conservation

NYPA – New York Power Authority

NBS – Net Basin Supply

NTS – Net Total Supplies

OPG – Ontario Power Generation

PI – Performance Indicators

PNA – Pacific/North American pattern

SWE – Snow Water Equivalent

USACE – United States Army Corps of Engineers

USEPA – United States Environmental Protection Agency

USGS – United States Geological Survey

Appendix 3: Glossary of Terms

ADAPTIVE MANAGEMENT – A planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modeling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change.

ARTIC OSCILLATION (AO) – A pattern in which atmospheric pressure at polar and middle latitudes fluctuates between negative and positive phases. The North Atlantic Oscillation is often considered to be a regional manifestation of the AO.

AUTHORITY – The right to enforce laws and regulations or to create policy.

AVERAGE WATER LEVEL – The arithmetic average of all past observations (of water levels or flows) for that month. The period of record used in this Study commences January 1900. This term is used interchangeable with monthly-mean water level.

BASIN; WATERSHED – The region or area of which the surface waters and groundwater ultimately drain into a particular course or body of water.

BASIN (GREAT LAKES – ST. LAWRENCE RIVER) – The surface area contributing runoff to the Great Lakes and the St. Lawrence River downstream to Trois Rivières, QC.

BARRIER BEACH – An offshore ridge of unconsolidated material (sand, pebbles, etc.) that runs parallel to a coastline, is formed in part by high tides and acts as a natural barrier.

BLUFF – A steep bank or cliff or variable heights, composed of glacial tills and lacustrine deposits consisting of clay, silt, gravel and boulders.

***BOUNDARY WATERS TREATY OF 1909* –** The agreement between the United States and Canada that established principles and mechanisms for the resolution of disputes related to boundary waters shared by the two countries. The International Joint Commission was created as a result of this treaty.

CHART DATUM – The water level used to calculate the water depths that are shown on "navigation charts" and are a reference point for harbor and channel dredging. Also known as Low Water Datum.

CLIMATE – The prevalent weather conditions of a given region (temperature, precipitation, wind speed, atmospheric pressure, etc.) observed throughout the year and averaged over at least 30 years.

CLIMATE CHANGE – A non-random change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

COAST – The land or zone adjoining a large body of water.

COASTAL EROSION – The wearing away of a shoreline as a result of the action of water current, wind and waves.

COMPENSATING WORKS – A set of gated dams located at the mouth of the St Marys rapids, which are part of a series of regulatory structures on the St. Marys River used in the management of the outflow of water from Lake Superior. The works consists of 16 gates, half of which are on the American side, and the other half on the Canadian side of the river.

COMPUTER MODELLING – The use of computers to develop mathematical models of complex systems or processes.

CONNECTING CHANNELS – A natural or artificial waterway of perceptible extent, which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. On the Great Lakes, the Detroit River, Lake St. Clair and the St. Clair River comprise the connecting channel between Lake Huron and Lake Erie. Between Lake Superior and Lake Huron, the connecting channel is the St. Marys River.

CONSERVATION AUTHORITY - Local watershed management agencies that deliver services and programs to protect and manage impacts on water and other natural resources in partnership with all levels of government, landowners and many other organizations.

CONSERVATION ONTARIO - Conservation Ontario is the umbrella organization which represents all of the conservation authorities in Ontario. This nonprofit organization was founded in 1980/81. Conservation Ontario is the network of 36 Conservation Authorities

COPING ZONE – A range of water level zones defined generally by the water level regime (level, range, rate of change, frequency), location and other factors that cause vulnerabilities for a particular interest and reflect an interest's ability to "cope" with a given water level regime.

DEVIATIONS – Temporary changes to a regulation plan to provide beneficial effects or relief from adverse effects to an interest, without causing appreciable adverse effects to any of the other interests.

DIRECTIVE – An IJC instruction to a new or existing Board or Committee specifying their terms of reference, including tasks and responsibilities.

DRAINAGE BASIN – The area that contributes runoff to a stream, river, or lake.

DUNE – A mound or ridge of sand or other loose sediment formed by the action of wind or waves

DYKE – A wall or earth mound built around a low lying area to prevent flooding.

ECOHYDRAULIC – Models that integrate the physics and biotic response through algorithms relating water levels and other climate drivers to flora and faunal responses.

ECOSYSTEM – A biological community in interaction with its physical environment, and including the transfer and circulation of matter and energy.

EL NINO-SOUTHERN OSCILLATION (ENSO) - An irregularly periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting climate of much of the tropics and subtropics.

ENVIRONMENT – Air, land or water; plant and animal life including humans; and the social, economic, cultural, physical, biological and other conditions that may act on an organism or community to influence its development or existence.

EROSION – The wearing away of land surfaces through the action of rainfall, running water, wind, waves and water current. Erosion results naturally from weather or runoff, but human activity such as the clearing of land for farming, logging, construction or road building can intensify the process.

FLOOD AND EROSION PROTECTION SYSTEM (FEPS) – A series of numerical models including COSMOS that compile and evaluate shoreline data to compute flood and erosion damages.

FLOODING – The inundation of low-lying areas by water.

FLOODPLAIN – The lowlands surrounding a watercourse (river or stream) or a standing body of water (lake), which are subject to flooding.

FRAZIL ICE – Stream ice with the consistency of slush, formed when small ice crystals develop in supercooled stream water as air temperatures drop below freezing. These ice crystals join and are pressed together by newer crystals as they form.

FRESHET – The sudden overflow or rise in level of a stream as a result of heavy rains or snowmelt.

GEOMORPHOLOGY – The field of earth science that studies the origin and distribution of landforms, with special emphasis on the nature of erosional processes.

GROUNDWATER – Underground water occurring in soils and in pervious rocks.

HABITAT – The particular environment or place where a plant or an animal naturally lives and grows.

HAZARD ZONES – An area of land that is susceptible to flooding, erosion, or wave impact.

HYDRAULICS – The study of the mechanical properties of liquids, including energy transmission and effects of the flow of water.

HYDRAULIC MODELING – The use of mathematical or physical techniques to simulate water systems and make projections relating to water levels, flows and velocities.

HYDROCLIMATE – The study of the influence of climate upon the waters of the land including the energy and moisture exchanges between the atmosphere and the Earth's surface and energy and moisture transport by the atmosphere.

HYDROELECTRIC POWER – Electrical energy produced by the action of moving water.

HYDROLOGIC ATTRIBUTES – Statistics on water levels and stream flows.

HYDROLOGIC CYCLE – The natural circulation of water, from the evaporation of seawater into the atmosphere, the transfer of water to the air from plants (transpiration), precipitation in the form of rain or snow, and runoff and storage in rivers, lakes and oceans.

HYDROLOGIC MODELING – The use of physical or mathematical techniques to simulate the hydrologic cycle and its effects on a watershed.

HYDROLOGY – The study of the properties of water, its distribution and circulation on and below the earth's surface and in the atmosphere.

ICE JAM – An accumulation of river ice, in any form which obstructs the normal river flow.

INTEGRATED ECOLOGICAL RESPONSE MODEL (IERM) – Establishes the framework for evaluating, comparing, and integrating the responses for the environmental performance indicators.

INTERESTS – In the context of the report, the groups or sectors served by the waters of Lake Ontario and the St. Lawrence River, including municipal and industrial water uses, commercial navigation, hydroelectric power generation, coastal development, ecosystems, and recreational boating. Under the Boundary Waters Treaty of 1909, the interests of domestic and sanitary water uses, navigation and hydroelectric generation and irrigation are given order of precedence in water uses in the development of regulation plans.

INTERNATIONAL GREAT LAKES DATUM (IGLD) – The elevation reference system used to define water levels within the Great Lakes-St. Lawrence River system. Due to the movement of the earth’s crust, the “datum” must be adjusted every 30-40 years.

INTERNATIONAL JOINT COMMISSION (IJC) – International independent agency formed in 1909 by the United States and Canada under the *Boundary Waters Treaty* to prevent and resolve boundary waters disputes between the two countries. The IJC makes decisions on applications for projects such as dams in boundary waters, issues Orders of Approval and regulates the operations of many of those projects. It also has a permanent reference under the Great Lakes Water Quality Agreement to help the two national governments restore and maintain the chemical, physical, and biological integrity of those waters.

INTERNATIONAL REACH – The portion of the St. Lawrence River that is between Lake Ontario and the Moses-Saunders Dam.

INTERNATIONAL LAKE ONTARIO - ST. LAWRENCE RIVER BOARD – Board established by the International Joint Commission originally in its 1952 Order of Approval and renamed from the St. Lawrence River Board of Control in 2017 with the implementation of Plan 2014 and the revised Order of Approval. Its main duty is to ensure that outflows from Lake Ontario meet the requirements of the Commission’s Order.

LAKE ONTARIO - ST. LAWRENCE RIVER STUDY (LOSLRS) – A study, sponsored by the IJC and completed in 2006, to examine the effects of water level and flow variations on all users and interest groups and to determine if better regulation is possible at the existing installations controlling Lake Ontario outflows.

LA NINA - The positive phase of the El Niño Southern Oscillation and is associated with cooler-than-average sea surface temperatures in the central and eastern tropical Pacific Ocean

LIDAR – which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.

LIGHT LOAD – A load less than the ship capacity, required when a fully loaded ship would be too close to the channel bottom because of low water levels.

LOWER ST. LAWRENCE RIVER – The portion of the St. Lawrence River downstream of the Moses-Saunders Dam is called the lower St. Lawrence. It includes Lake St. Francis, Lake Saint-Louis, Montreal Harbour, Lake Saint-Pierre and the portions of the River connecting these lakes as far downstream as Trois-Rivieres, QC.

MARINA – A private or publicly-owned facility allowing recreational watercraft access to water and offering mooring and related services.

MARSH – An area of low, wet land, characterized by shallow, stagnant water and plant life dominated by grasses and cattails.

MEASURE, STRUCTURAL – Any measure that requires some form of construction. Commonly includes control works and shore protection devices.

MODEL, COMPUTER – A series of equations and mathematical terms based on physical laws and statistical theories that simulate natural processes.

MONTHLY MEAN WATER LEVEL – The arithmetic average of all past observations (of water levels or flows) for that month.

NET BASIN SUPPLY (NBS) – The net amount of water entering one of the Great Lakes, comprised as the precipitation onto the lake minus evaporation from the lake, plus groundwater and runoff from its local basin. The net basin supply does not include inflow from another Great Lake.

NET TOTAL SUPPLY (NTS) – The Net Basin Supply plus the inflow from another Great Lake

NORTH ATLANTIC OSCILLATION (NAO) - A weather phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low and the Azores high (also known as the North Atlantic subtropical high). The NAO controls the strength and direction of westerly winds and location of storm tracks across the North Atlantic and varies over time with no particular periodicity.

NORTH ATLANTIC SUBTROPICAL HIGH (NASH) – Also known at the “Azores High” is a large subtropical semi-permanent centre of high atmospheric pressure typically found south of the Azores in the Atlantic Ocean, situated around the latitudes of 30^{o}N. It forms one pole of the

North Atlantic oscillation, the other being the Icelandic Low. The system influences the weather and climatic patterns of vast areas of North Africa and southern Europe, and to a lesser extent, eastern North America.

OBLIQUE IMAGERY - aerial photography that is captured at approximately a 45 degree angle with the ground.

ORDERS OF APPROVAL – In ruling upon applications for approval of projects affecting boundary or transboundary waters, such as dams and hydroelectric power stations, the IJC can regulate the terms and conditions of such projects through Orders of Approval to maintain specific targets with respect to water levels and flows in the lakes and connecting channels.

PACIFIC/NORTH AMERICAN (PNA) PATTERN - A climatological term for a large-scale weather pattern with two modes, denoted positive and negative, and which relates the atmospheric circulation pattern over the North Pacific Ocean with the one over the North American continent.

PEAKING – The variation of hourly water flows above and below the daily average flow (for instance, midday flow higher than evening and night flows), primarily due to hydroelectric generating operations during which water is stocked during periods of off-peak demand in order to increase hydroelectric power generation at peak periods.

PERFORMANCE INDICATOR – A measure of economic, social or environmental health. In the context of the Study, performance indicators relate to impacts of different water levels in Lake Ontario and the St. Lawrence River.

PLAN FORMULATION METHOD – A particular way of searching for a better regulation plan; mathematical optimization based on economic benefits, for example.

PONDING – The variation of daily water flows above and below the weekly average flow (for instance, average weekday flow higher than average weekend flow), primarily due to hydroelectric generating operations.

PUBLIC INTEREST ADVISORY GROUP (PIAG) – The group of volunteers from the United States and Canada that worked to ensure effective communication between the public and the 2006 International Lake Ontario-St. Lawrence River Study Board.

REFERENCE – A request from government for the IJC to study and recommend solutions to transboundary issue. The word is derived from Article IX of 1909 *Boundary Waters Treaty*, which stipulates that such issues “shall be referred from time to time to the International Joint Commission for examination and report, whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred.”

REGULATION PLANS – In the context of the report, the control of waterflows through regulatory structures to meet the needs of various water-using interests in a basin. These plans have incorporated the specific objectives established in the IJC’s Orders of Approval, established monthly or weekly outflow levels, and allocated flows to various water-using interests, such as hydroelectric generation.

REGULATORY STRUCTURES – Adjustable structures, such as a gated dam that can be raised or lowered to adjust water levels and flows both upstream and downstream.

REVETMENT – A natural (e.g., grass, aquatic plants) or artificial (*e.g.*, concrete, stone, asphalt, earth, sand bag) covering to protect an embankment or other structure from erosion.

RIPARIAN – Of, relating to or found along a shoreline.

RIPARIANS – Persons residing on the banks of a body of water. Typically associated with private owners of shoreline property.

RUNOFF – The portion of precipitation on the land that ultimately reaches streams and lakes.

SHORE WELL – A well close to a lake in which the well water levels are directly influenced by lake levels.

SHORELINE – Intersection of a specified plane of water with the shore.

SIDE CHANNEL FLOW - Considered the sum of hydropower, navigation, municipal and industrial and all other flow that does not go through the Compensating Works on the St. Marys River.

SNOW WATER EQUIVALENT (SWE) - Is the amount of water contained within the snowpack. It can be thought of as the depth of water that would theoretically result if you melted the entire snowpack instantaneously.

STAKEHOLDER – An individual, group, or institution with an interest or concern, either economic, societal or environmental, that is affected by fluctuating water levels or by measures proposed to respond to fluctuating water levels within the Lake Ontario–St. Lawrence River Basin.

STOCHASTIC SUPPLIES – Statistically generated simulated sequences of water supply conditions based on historical climate variability.

TROPOPAUSE - The tropopause is the transitional area between the troposphere (the lowest atmospheric layer) and the stratosphere (the second layer of the earth's atmosphere) and is about 6 to 11 miles above the surface of the earth, just below the start of the stratosphere.

UPPER ST. LAWRENCE RIVER – The portion of the St. Lawrence River upstream of the Moses-Saunders Dam is called the upper St. Lawrence River. It includes the entire river from Kingston/Cape Vincent to the power dam and locks at Cornwall-Massena, including Lake St. Lawrence.

WATER LEVEL – The elevation of the surface of the water of a lake or at a particular site on the river. The elevation is measured with respect to average sea level.

WATER SUPPLY – Water reaching the Great Lakes as a direct result of precipitation, less evaporation from land and lake surfaces.

WATERFOWL – Birds that are ecologically dependent on wetlands for their food, shelter and reproduction.

WAVE – An oscillatory movement in a body of water which results in an alternate rise and fall of the surfaces.

WAVE CREST – The highest part of a wave.

WETLANDS – An area characterized by wet soil and high biologically productivity, providing an important habitat for waterfowl, amphibians, reptiles and mammals.

WILLINGNESS TO PAY (WTP) – The maximum amount that a consumer will pay for a given item or service.