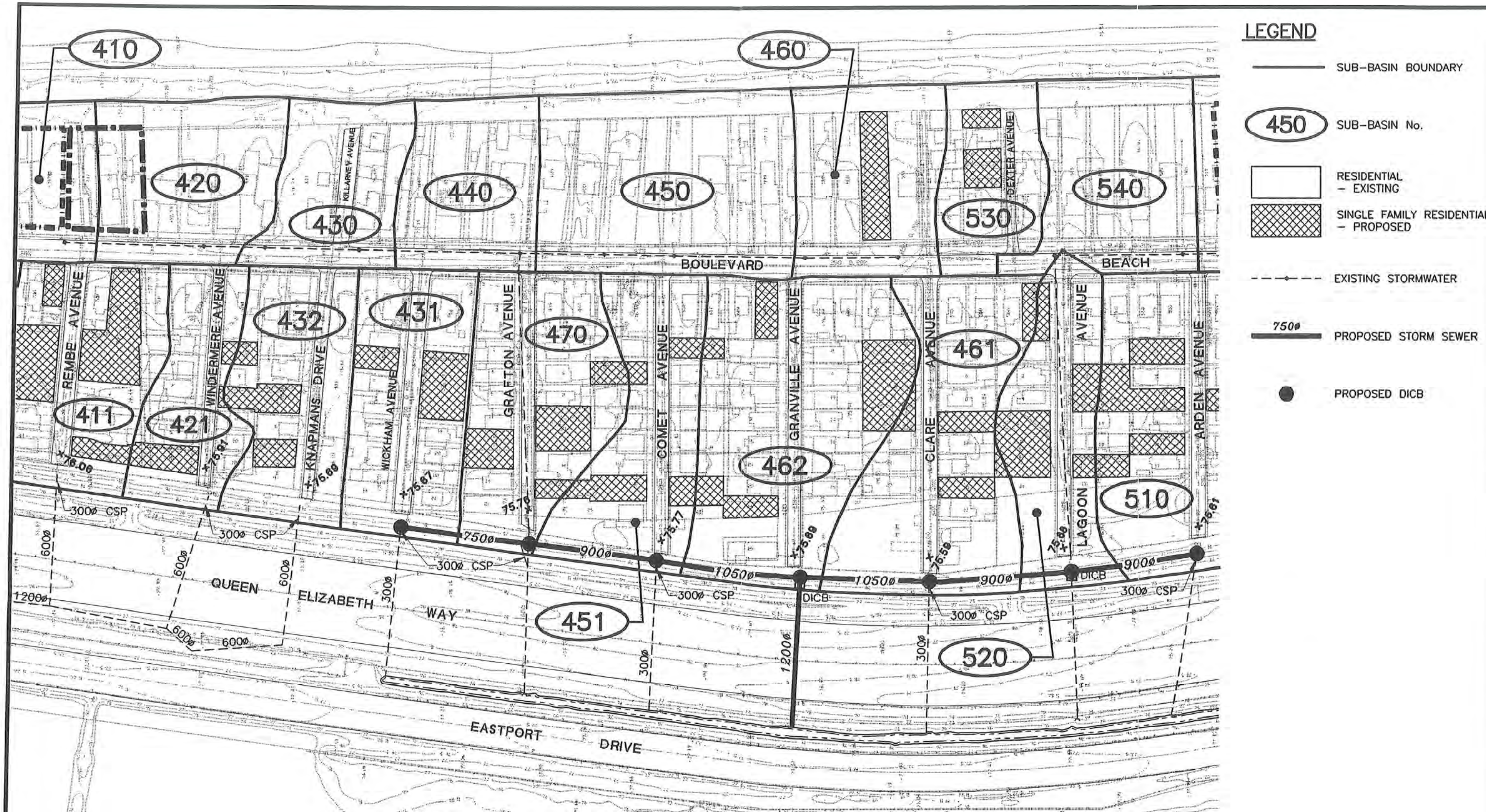
Appendix A

Background Information

Appendix A1

Excerpts from Master Drainage Plan, Hamilton Beach (MMM, July 1999)



CLIENT

CITY OF HAMILTON

TITLE

OPTION 2A
(GRAVITY DRAINAGE TO EXISTING DITCH)

Marshall Macklin Monaghan
Consulting Engineers . Surveyors . Planners
80 Commerce Valley Dr. E, Thornhill, Ont. L3T 7N4
Tele (905)882-1100 Fax (905)882-0055

Checked J.P.	Drawn AutoCAD/B.K.B.	
Date JULY 29 1999	Proj. No. 1499015-01-101	
Scale AS SHOWN	Figure No. 4.2A	Gr.No. 01

Appendix A2

Excerpts from Hamilton Beach Pumping Station Class EA (City of Hamilton, 2007/2008)

ALTERNATIVES FOR CONSIDERATION:

A number of alternative solutions have been considered as part of this study. The following flood protection alternatives have been identified and evaluated:

Alternative 1 Do Nothing
Alternative 2 Gravity Storm Sewer Outlet from Grafton Avenue under the QEW to ditch at Eastport Drive
Alternative 3A Pumped Outlet from Grafton Avenue under the QEW to a ditch at Eastport Drive
Alternative 3B Pumped Outlet from Grafton Avenue under the QEW to a ditch at Eastport Drive with a Stormwater Detention Pond
Alternative 3C Pumped Outlet from Grafton Avenue to Lake Ontario

Table 1 provides a summary of the conclusions drawn from the evaluation of the alternatives.

Table 1 - Summary of the Evaluation of Alternatives

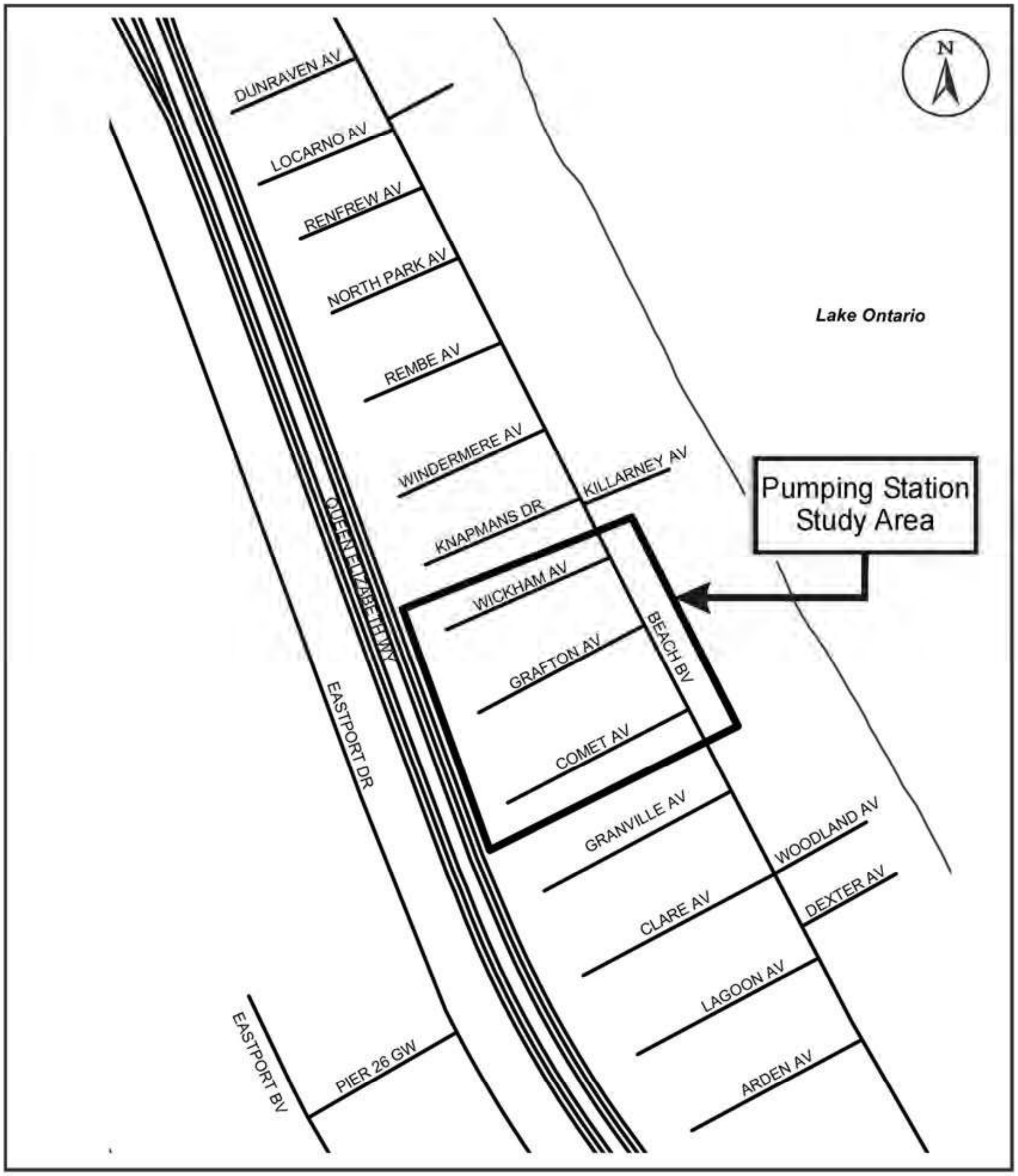
ALTERNATIVE	CONCLUSION
Alternative 1	Does not provide the required level of flood protection. ***Not Recommended***
Alternative 2	Most cost-effective alternative. Does not provide the required level of flood protection. ***Not Recommended***
Alternative 3A	Similar construction cost to Alternatives 3B and 3C. Provides the required level of flood protection. ***Recommended***
Alternative 3B	Similar construction cost to Alternatives 3A and 3C. Alternative not feasible due to impacts of the high water table on the stormwater detention pond. ***Not Recommended***
Alternative 3C	Similar construction cost to Alternatives 3A and 3B. Alternative not feasible due to timing associated with approval requirements for the new outlet to Lake Ontario. ***Not Recommended***

Preferred Solution

Alternative 3A was selected as the preferred alternative. The pumping station will be located in a vacant lot (owned by the Ministry of Transportation) at the terminus of Grafton Street just east of the QEW. The pumping station will generally include a wet well, a superstructure, pumps and motors, standby power, controls and valves. A concrete gravity sewer will convey flows from a collection manhole at Grafton Avenue to the wet well of the pumping station. The flow from the pumping station will then be conveyed through a forcemain under the QEW to a ditch at Eastport Drive.

Appendix A

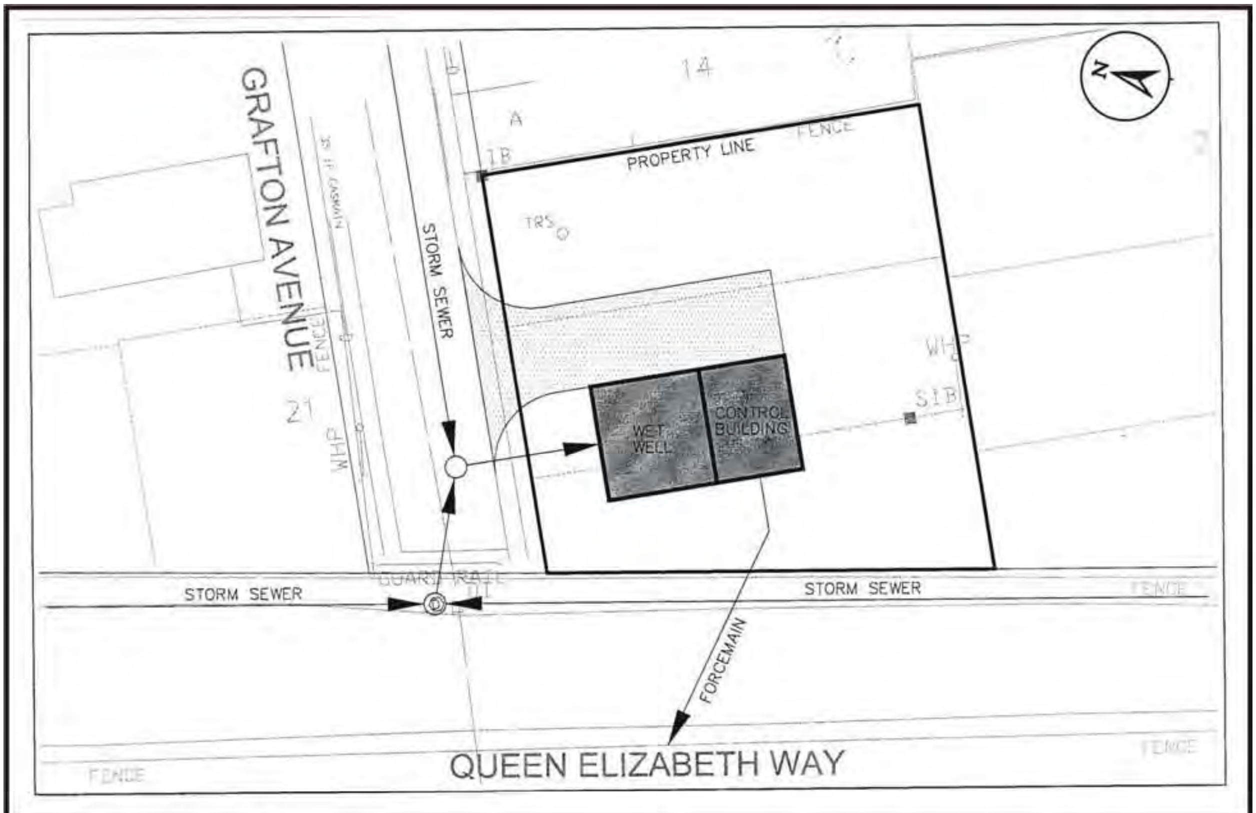
Key Plan



Hamilton Public Works	**Beach Boulevard Storm Water Pumping Station** Pumping Station Study Area		
	General Manager Scott Stewart C.E.T.	November 2007	Map Not to Scale

Appendix B

Site Plan



Hamilton Public Works	**Beach Boulevard Storm Water Pumping Station**		
	General Manager Scott Stewart, C.E.T.	**October 2007**	**Map Not to Scale**

Appendix A3

Excerpts from Existing Conditions Drainage Investigation & Preliminary Design of Flood Protection for Beach Blvd Community (MRC, 2008)

Table 1.4 - Summary of Ponding in Beach Community East of the QEW During the August 24, 1982 Storm Event [a]

Street Name	Drainage Area (ha)	Peak Flow (m^3/s)	Volume Of Ponding (m^3)	Was Ponding Observed After the November 29, 2005 Storm Event[b]? (Yes/No)
Dunraven Avenue	1.9	0.22	0	Yes
Locarno Avenue	1.5	0.16	0	No
Renfrew Avenue	0.9	0.06	0	No
North Park Avenue	1.3	0.12	0	No
Rembe Avenue	1.8	0.11	0	Yes
Windermere Avenue	1.5	0.13	40	Yes (significant)
Knapmans Drive	1.5	0.09	77	No
Wickham Avenue	1.5	0.13	32	Yes
Grafton Avenue	1.0	0.08	23	No
Comet Avenue	1.9	0.14	53	Yes (significant)
Granville Avenue	1.6	0.10	45	Yes (significant, pumped by affected house owner)
Clare Avenue	2.2	0.15	56	Yes
Lagoon Avenue	0.9	0.05	31	Yes (significant)
Arden Avenue	1.9	0.06	77	Yes
Bayside Avenue				Yes
Wark Avenue				No
Kirk Avenue				No

Note:

a) The August 24, 1982 storm event generated approximately 93.8 mm of precipitation over an eight hour period (approx.). Lake levels on the day of the storm event were 74.79 m.

b) Approximately 27 mm of precipitation were recorded during the November 29, 2005 storm event.

Table 1.5 - Minimum Rainfall Intensity Causing Flooding at Various Lake Levels

Lake Water Level	Study Reach		Minimum Rainfall Intensity Causing Flooding (mm/hr)
Low (74.5 m)	Outlet to Hamilton Harbour:	QEW Sta. 15+900 to QEW Sta. 16+450 (Dunraven Avenue to Knapmans Drive)	50
	Outlet to Redhill Creek:	QEW Sta. 16+450 to QEW Sta. 18+700 (Wickham Avenue to Wark Avenue)	30
High (75.0 m)	Outlet to Hamilton Harbour:	QEW Sta. 15+900 to QEW Sta. 16+450 (Dunraven Avenue to Knapmans Drive)	45
	Outlet to Redhill Creek:	QEW Sta. 16+450 to QEW Sta. 18+700 (Wickham Avenue to Wark Avenue)	27
Extreme (75.5 m)	Outlet to Hamilton Harbour:	QEW Sta. 15+900 to QEW Sta. 16+450 (Dunraven Avenue to Knapmans Drive)	35
	Outlet to Redhill Creek:	QEW Sta. 16+450 to QEW Sta. 18+700 (Wickham Avenue to Wark Avenue)	25

The results confirm that, due to the low elevation of the Study Area, water levels in Lake Ontario have a significant impact on the capacity of the existing drainage infrastructure in the Beach Community. During the of high lake levels flooding within the study reach occurs at much lower precipitation intensities.

Table 2.5 - Preliminary Capital Costs of Flood Protection Alternatives

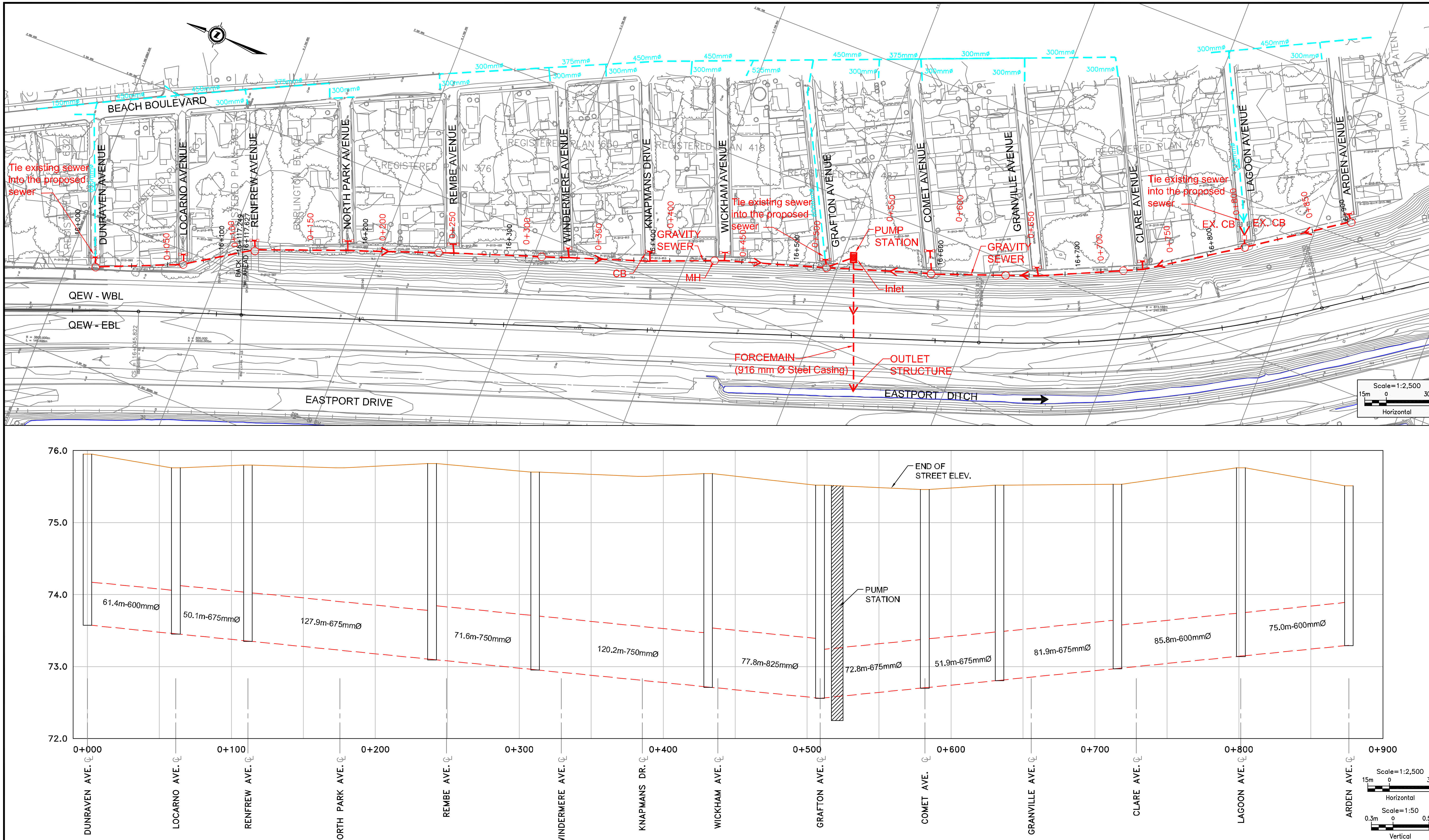
Flood Protection Alternative		Preliminary Capital Cost Estimates for 25 Year Level of Flood Protection	Comments
Alternative 1	Gravity Storm Sewer Outlet to Eastport Ditch	\$2,760,000	Does not provide the required level of flood protection for the 25 year event. **Not Recommended**
Alternative 1(1)	Gravity Storm Sewer Outlet to Eastport Ditch with Pipe Storage	\$3,010,000	Does not provide the required level of flood protection for the 25 year event. **Not Recommended**
Alternative 2A	Pumped Outlet to Eastport Ditch	\$5,890,000	Provides the required level of flood protection. **Recommended**
Alternative 2A(1)	Pumped Outlet to Eastport Ditch with Pipe Storage and Smaller Pumps	\$5,930,000	Provides the required level of flood protection. Higher capital cost than for Alternative 2A. **Not Recommended**
Alternative 2B	Pumped Outlet to Eastport Ditch with Storm Water Detention Pond	\$6,070,000	Provides the required level of flood protection. Pond construction not feasible due to uplift forces. **Not Recommended**
Alternative 2C	Pumped Outlet to Lake Ontario	--	Cannot construct in a timely manner, requires environmental permits for the new lake outlet. **Not Recommended**

2.4 EVALUATION OF FLOOD PROTECTION ALTERNATIVES

Table 2.6 identifies the advantages and disadvantages of the considered Flood Protection Alternatives 1, 2A, 2B and 2C. The table does not address Sub-Alternatives 1(1) and 2A (1) which was discounted from further analysis due to cost considerations.

Table 2.6 - Evaluation of Flood Protection Alternatives

Alternative	Advantages	Disadvantages	Conclusions
Alternative 1 – Gravity Storm Sewer Outlet	• Lower construction cost (pump station not required)	• Severe flooding within the study limits during the 25 year storm under normal and high lake levels • Installation of 1200 mm pipe under QEW difficult and expensive • Deep excavation of Eastport Ditch required (high maintenance)	• Does not provide the required level of flood protection. **Not recommended**
Alternative 2A – Pumped Outlet under QEW to Eastport Ditch	• Smaller crossing under the QEW than for Alternative 1, easier and less expensive construction • Relatively minor modification required to Eastport Ditch at outlet	• More expensive than Alternative 1	• Provides the required level of flood protection. **Recommended**
Alternative 2B – Pumped Outlet under QEW to Eastport Ditch with Storm Water Detention Pond	• Smaller pumps than in Alternative 2A • Smaller forcemain than in Alternative 2A	• Significant uplift acting on the floor and sides of the dry pond • More land required than in Alternative 2A	• Similar construction cost to Alternative 2A • Alternative not feasible due to uplift forces acting on the pond **Not recommended**
Alternative 2C: Pumped Outlet to Lake Ontario	• Forcemain installed by open cut	• New outlet to Lake Ontario requires significant time commitment to secure environmental permits. • Longer forcemain required • Special outlet design • Environmental impacts associated with a lake outlet	• Similar or potentially higher capital cost compared to costs of Alternatives 2A and 2B • Alternative not feasible due to timing associated with approvals for the new outlet **Not recommended**



MRC

ALTERNATIVE 2A : PUMPED OUTLET UNDER QEW TO EASTPORT DITCH

QEW BEACH BOULEVARD-FLOOD PROTECTION OF BEACH BOULEVARD COMMUNITY

EXHIBIT

2.2

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Appendix A4

Excerpts from Lake Ontario – St. Lawrence River Plan 2014 (IJC, 2014)

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:

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

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:

$$\text{Pte. Claire level} = 16.57 + \left[\left(R_{Pt.Claire} \times Q_{L.St.Louis} / 604.0\right)^{0.58}\right]$$

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

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Annex C

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

Appendix A5

Excerpts from Beach Boulevard Community Stormwater Ponding Study (Dillon, 2019)

Table A1: Summary of Reported Flooding Instances in the Beach Boulevard Community (as per Dillon, 2019; new reports are noted in green)

Street	Minimum Elevation (mASL)	Master Drainage Plan (MMM, 2019) Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
Eastport Drive	-	-	-	Visible	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

Street	Minimum Elevation (mASL)	Master Drainage Plan (MMM, 2019) Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
					05/04/2017 – Property Flooded 05/05/2017 – Several Basements Flooded 05/06/2017 – Street Flooded 05/23/2017 – Flooded Catchbasin 05/24/2017 – Property Flooded 05/26/2017 – Property Flooded 08/04/2017 – Flooded Sidewalk 08/09/2017 – Flooded Area 02/15/2018 – Flooded Area Except Alley and Catchbasin 06/25/2019 – Property 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

Street	Minimum Elevation (mASL)	Master Drainage Plan (MMM, 2019) Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
					06/29/2009 – Catch Basin Flooded 07/22/2012 – Basement Flooded 06/14/2017 – Flooded Catchbasin 07/07/2017 – Flooded Catchbasin
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
Wickham Avenue	75.83	Chronic Flooding	Low to Moderate Flooding	Visible Flooding	05/17/2002 – Several Basements Flooded 06/01/2011 – Street Flooded

Street	Minimum Elevation (mASL)	Master Drainage Plan (MMM, 2019) Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
					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

Street	Minimum Elevation (mASL)	Master Drainage Plan (MMM, 2019) Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
					07/21/2017 – Flooded Catchbasin
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 05/25/2017 – Flooded Street
Sierra Lane	-	-	-	No Visible Flooding	06/01/2017 – Flooded Catchbasin
Tower’s Drive	75.8	-	-	No Visible Flooding	05/13/2017 – Basement Flooded
Lakeside Avenue	76.72	-	-	Visible Flooding	No documented Service Requests

Street	Minimum Elevation (mASL)	Master Drainage Plan (MMM, 2019) Flooding	November 29, 2005 (MRC, 2008)	June 8, 2017	City of Hamilton Service Requests
Bayside Avenue	75.88	-	Low to Moderate Flooding	Visible Flooding	04/01/2017 – Street/Basement Flooded 04/04/2017 – Street Flooded
Fitch Avenue	76.78	-	-	No Visible Flooding	No documented Service Requests
Mareve Avenue	76.8	-	-	Visible Flooding	05/13/2019 – Property Flooded
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 05/13/2017 – Street/Property/ Basement Flooded 07/04/2017 – Street Flooded
Dynes Park Avenue	-	-			05/25/2017 – Property Flooded


Map Data 2017 Google
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


Map Data 2017 Google
Grafton Ave
Wickham Ave
Knapmans Dr
Windermere Ave
Transport Canada NASP / Natural Resources Canada CCRP – Aerial Photo Flood Observations 2017-06-08 - 142200

Map Data 2017 Google
Arden Ave
Lagoon Ave
Clare Ave
Granville Ave
Comet Ave
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

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

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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	

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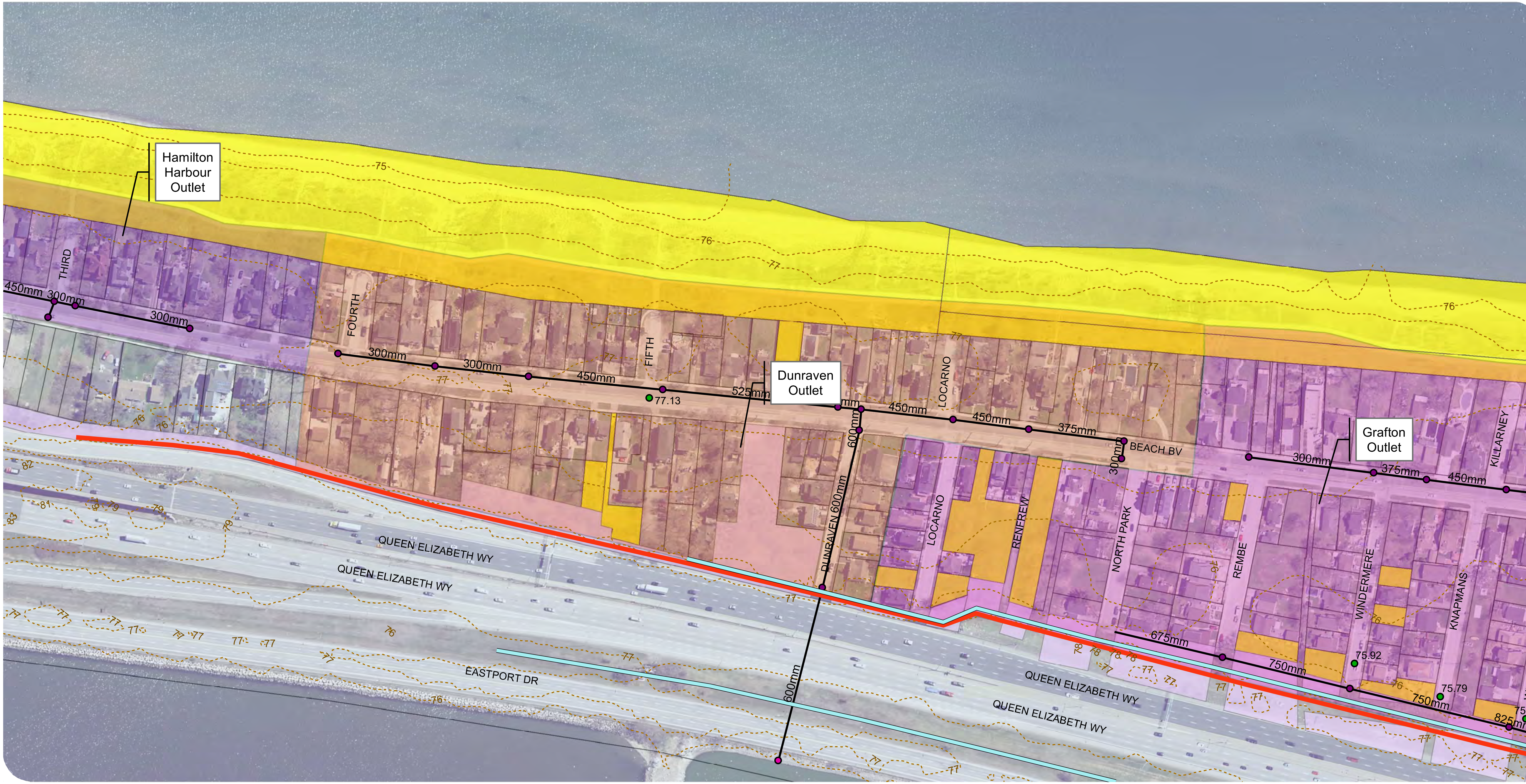

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-3

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

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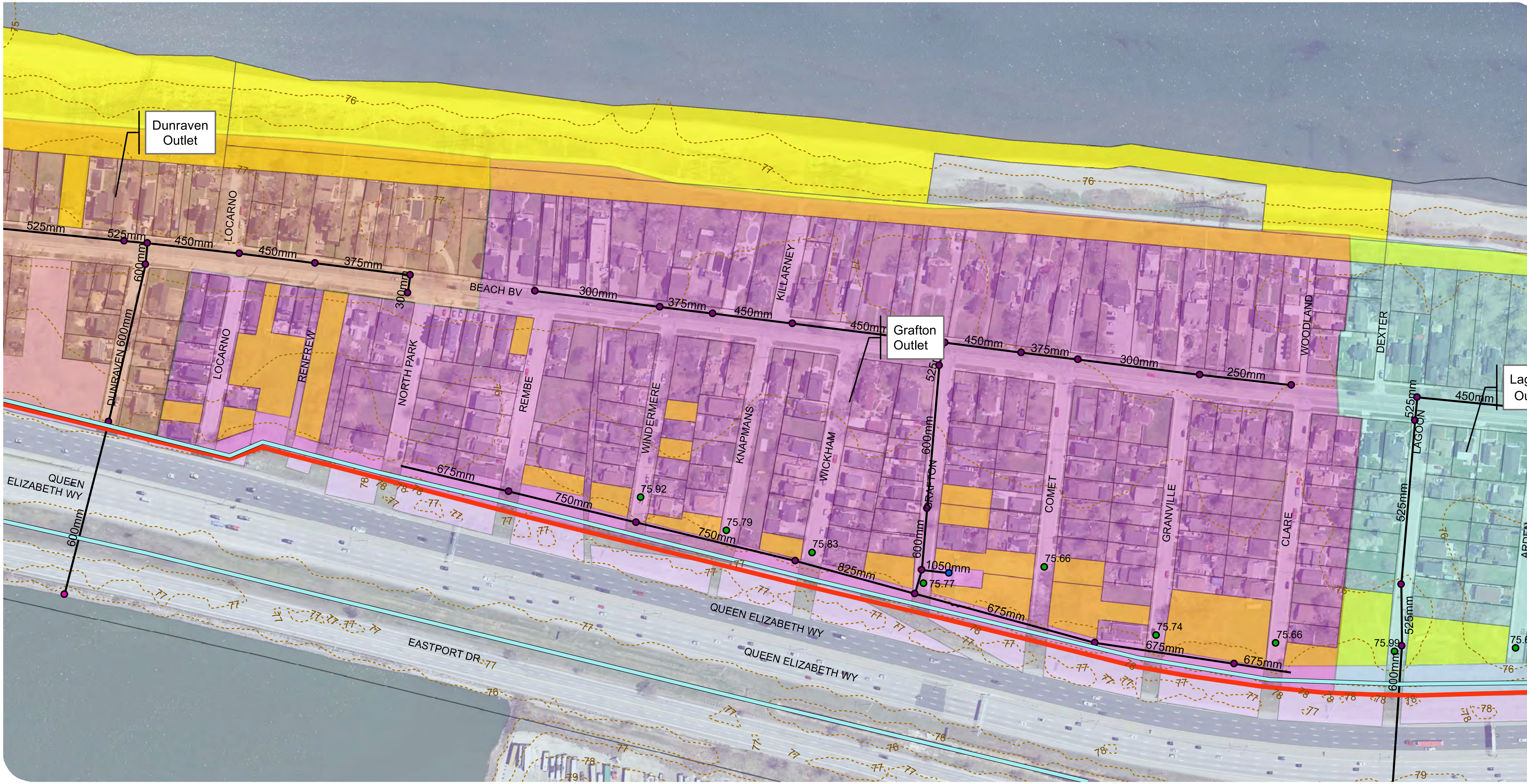

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-4

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

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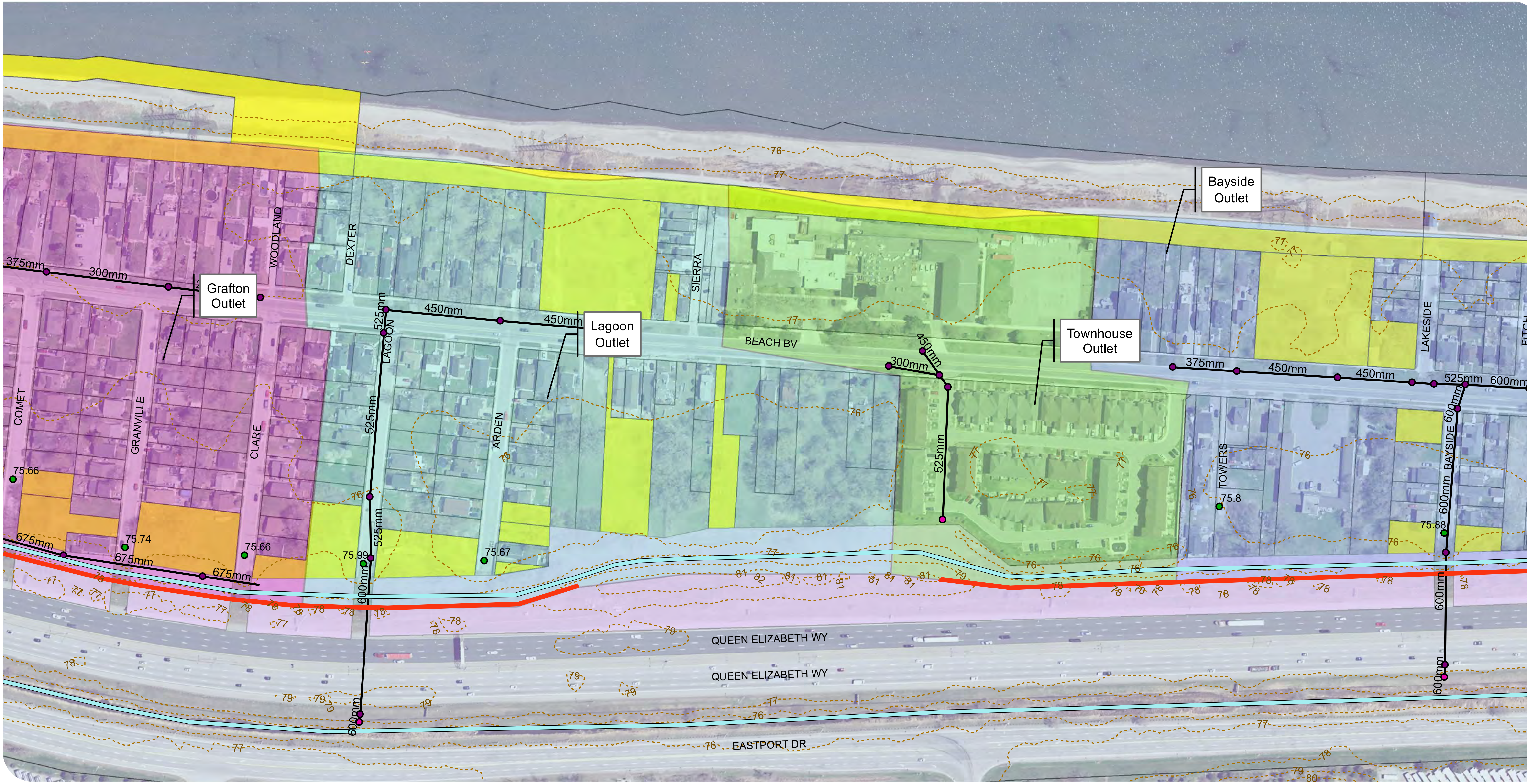

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

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	

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NOTES:
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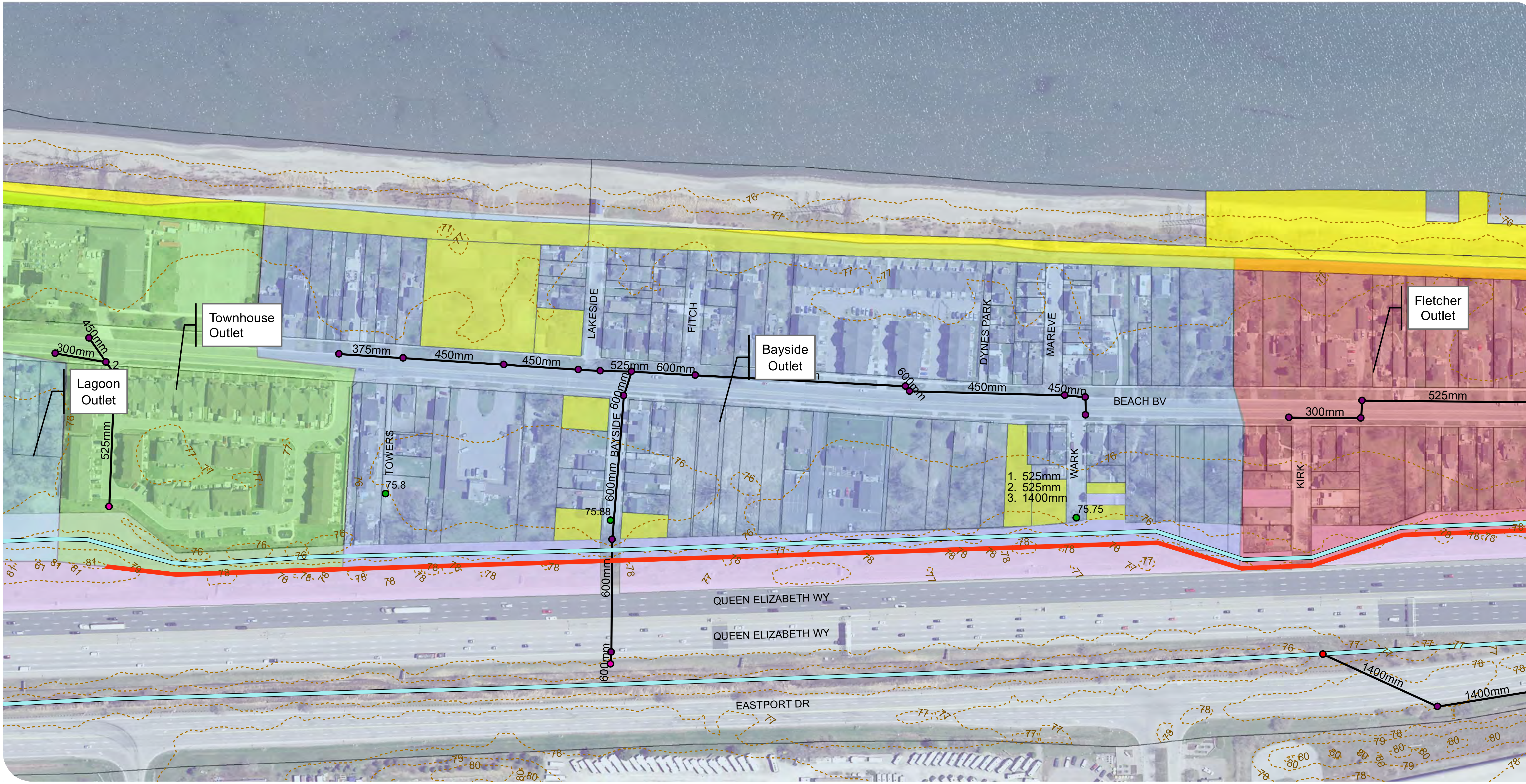

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

EXISTING STORM NETWORK
FIGURE 1-6

- 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

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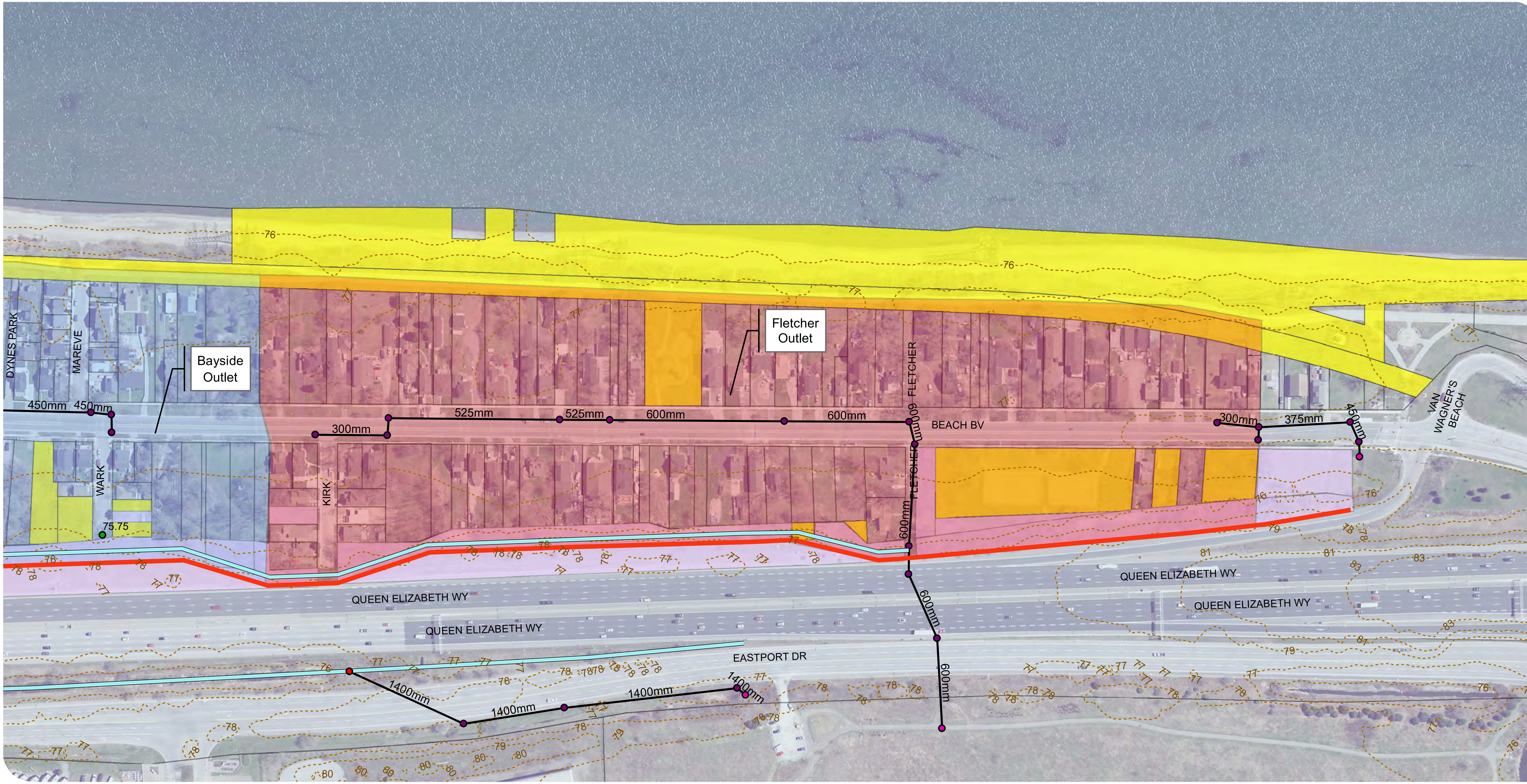

CITY OF HAMILTON
HAMILTON BEACHES FLOODING STUDY

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

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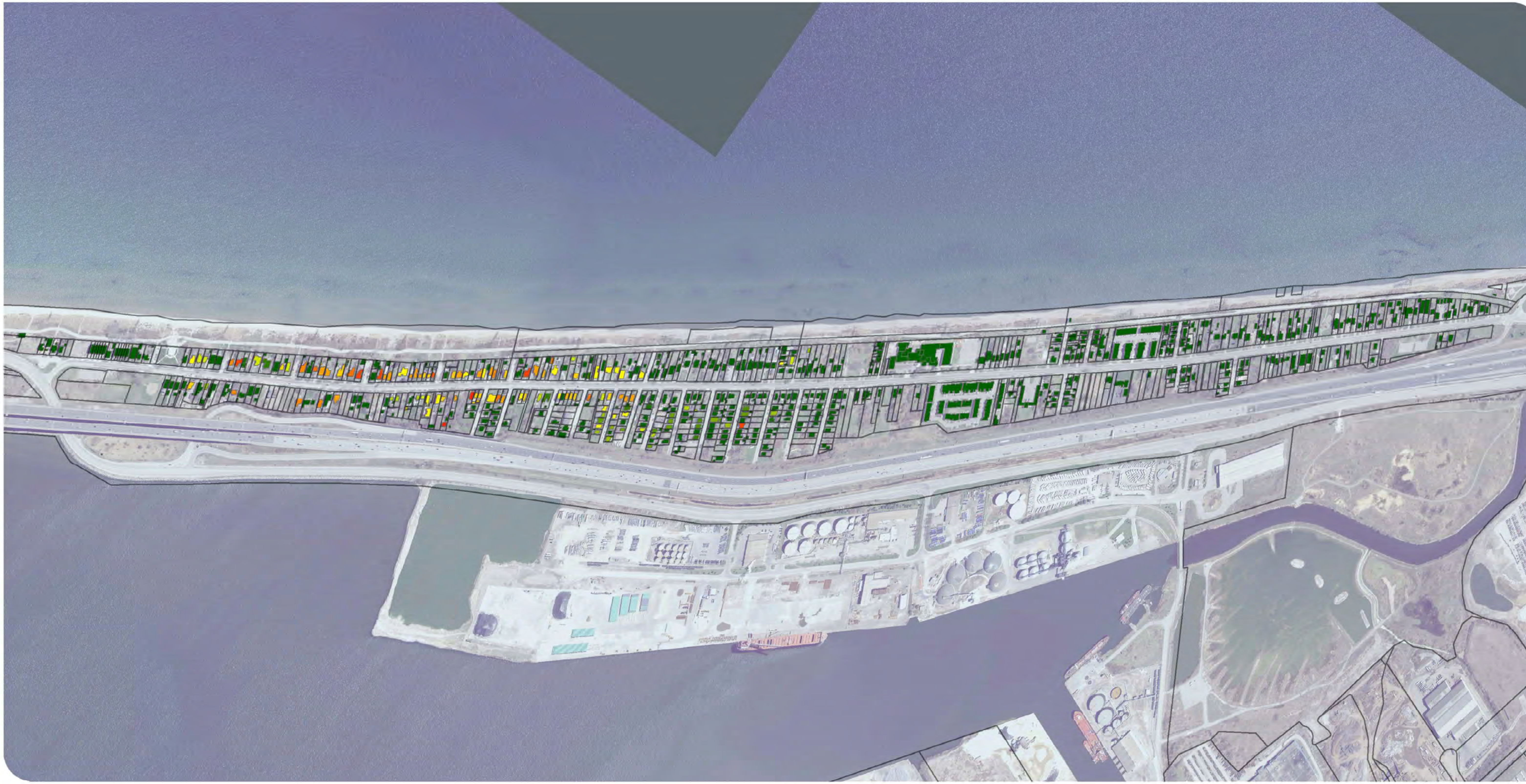
PROJECT: 17-5898 STATUS: DRAFT DATE: 02/04/19



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

0 200 400 800 Metres

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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)
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	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: ARO
MAP CHECKED BY: DV
MAP PROJECTION: NAD 1983 UTM Zone 17N

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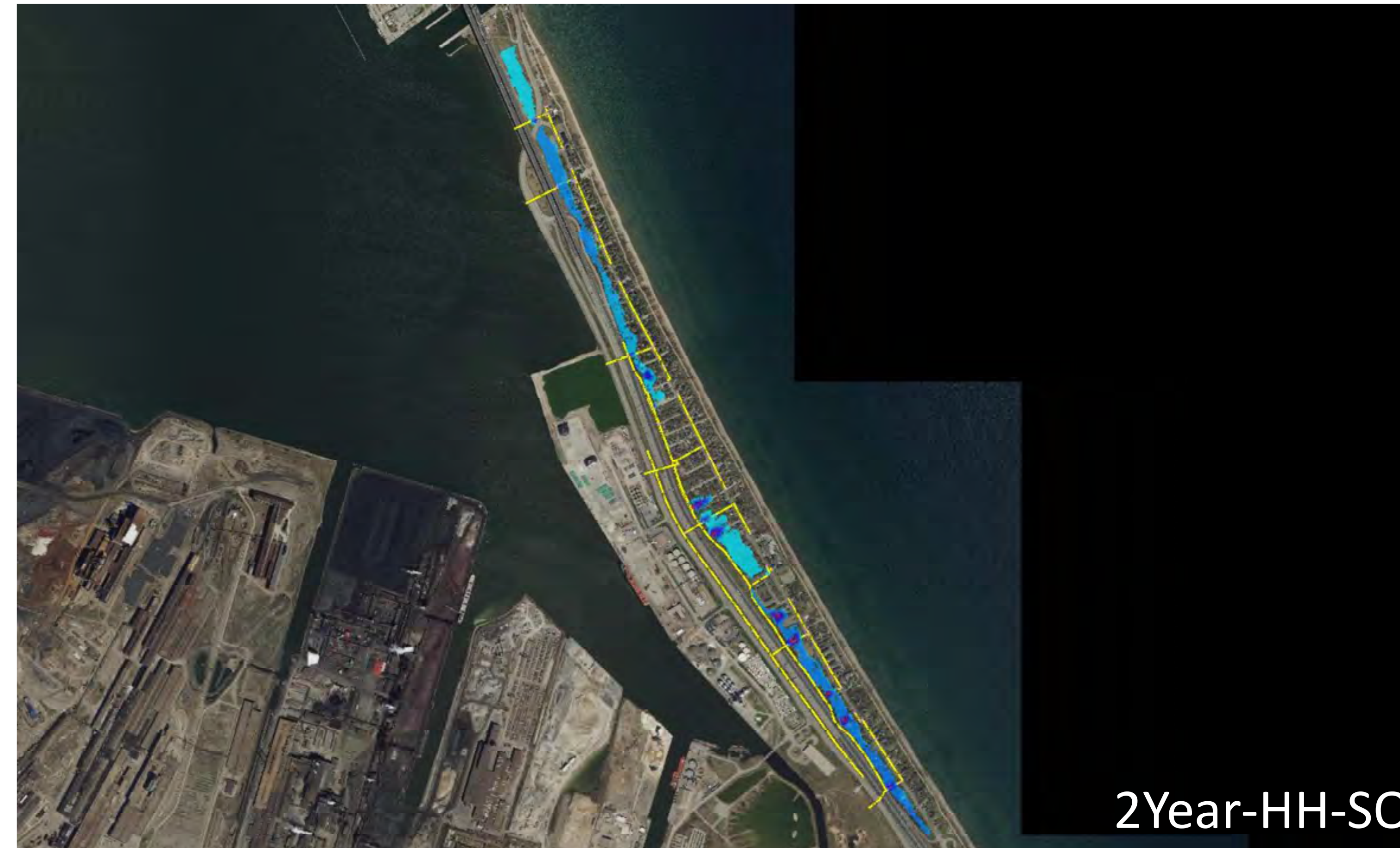
PROJECT: 17-5898 STATUS: DRAFT DATE: 08/30/17


2Year-HL-SO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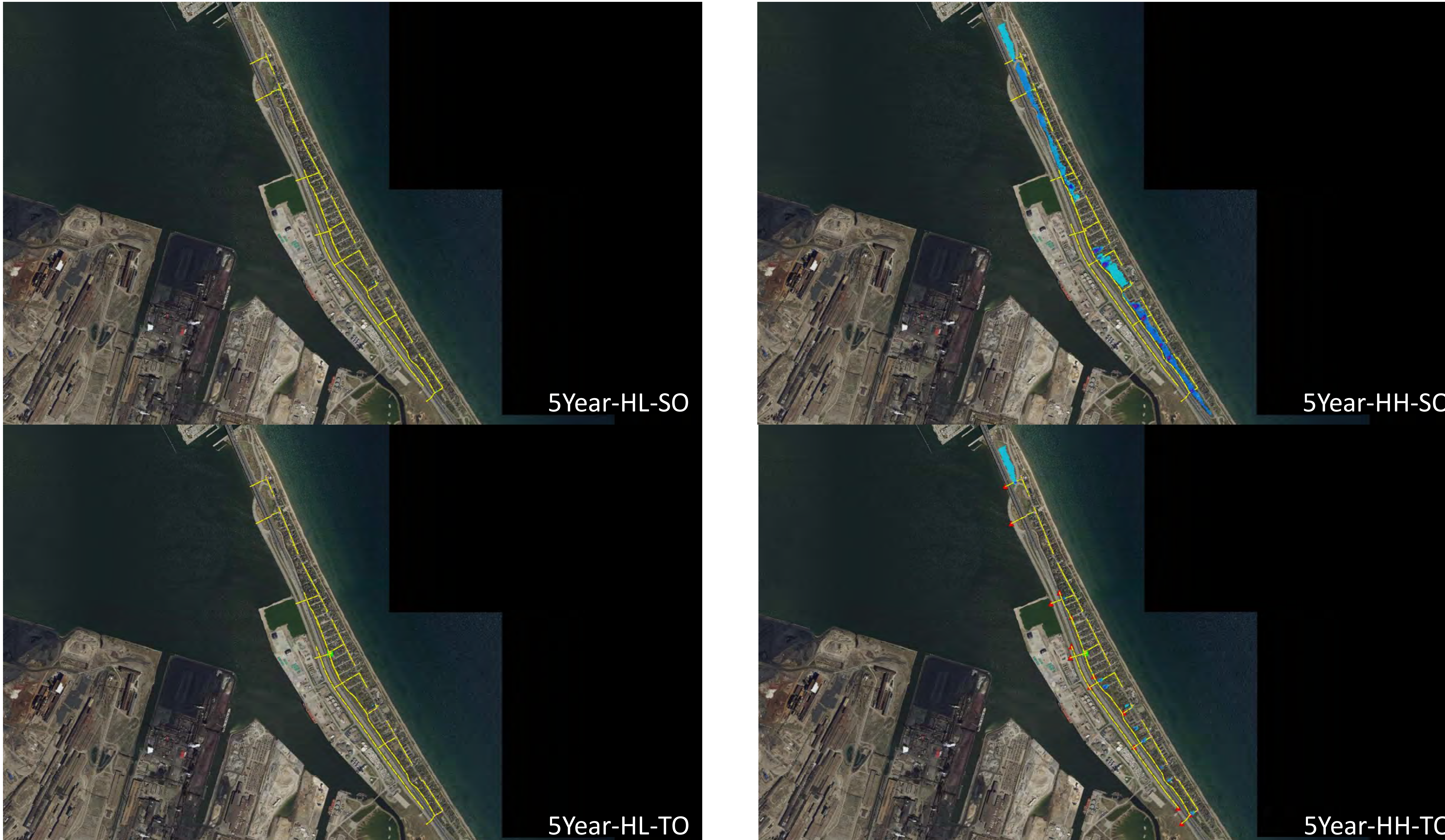
2Year-HL-TO


2Year-HH-TO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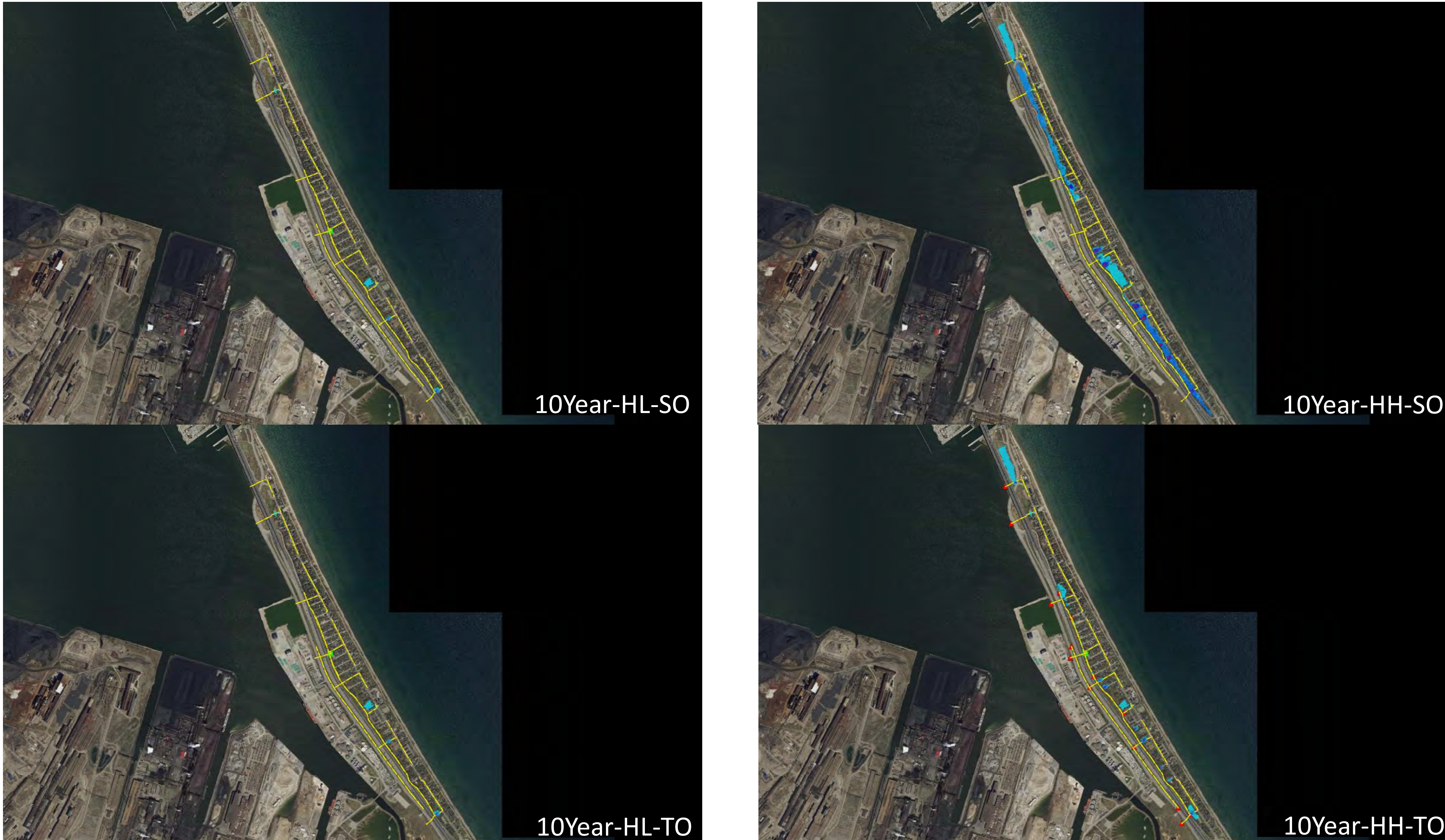
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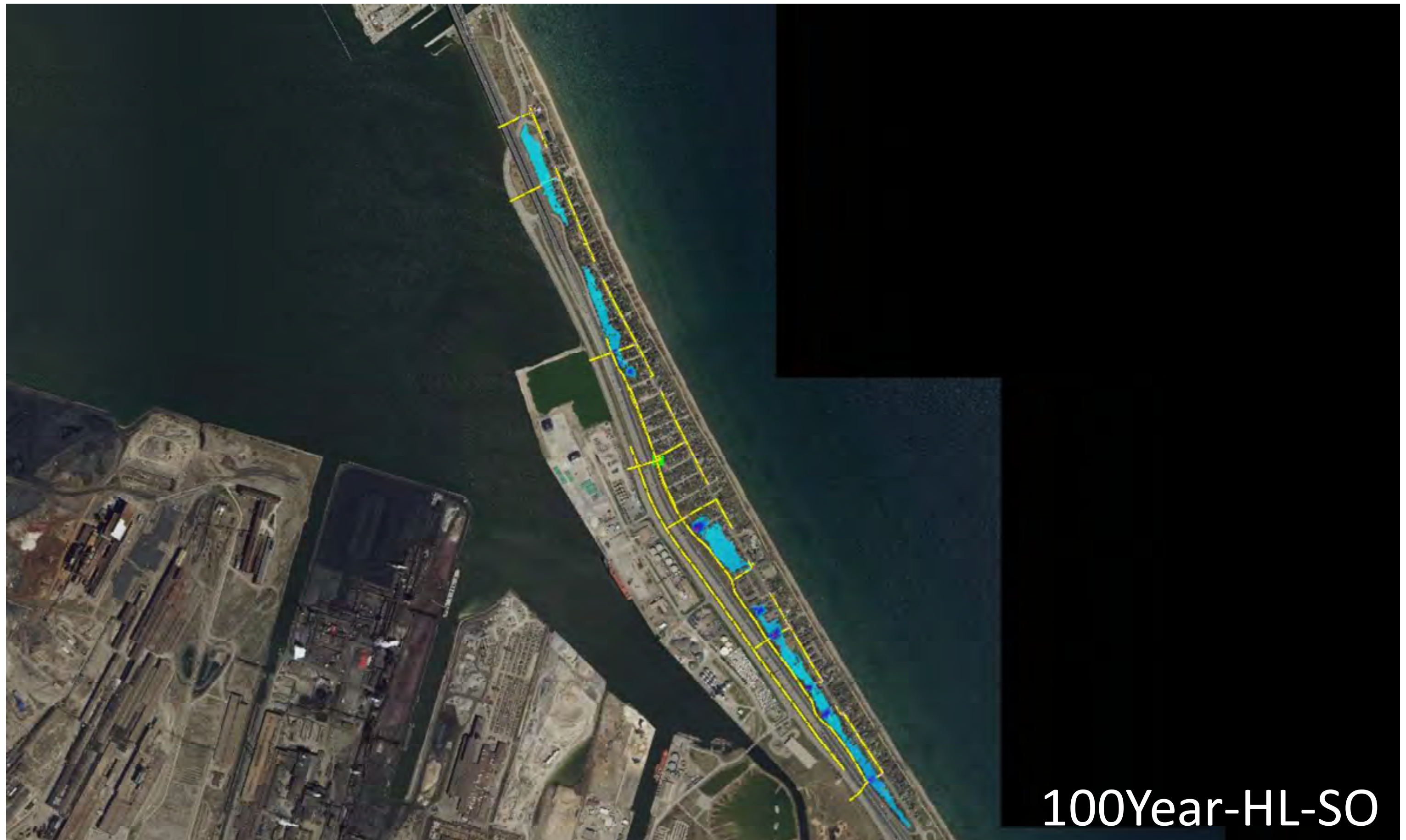
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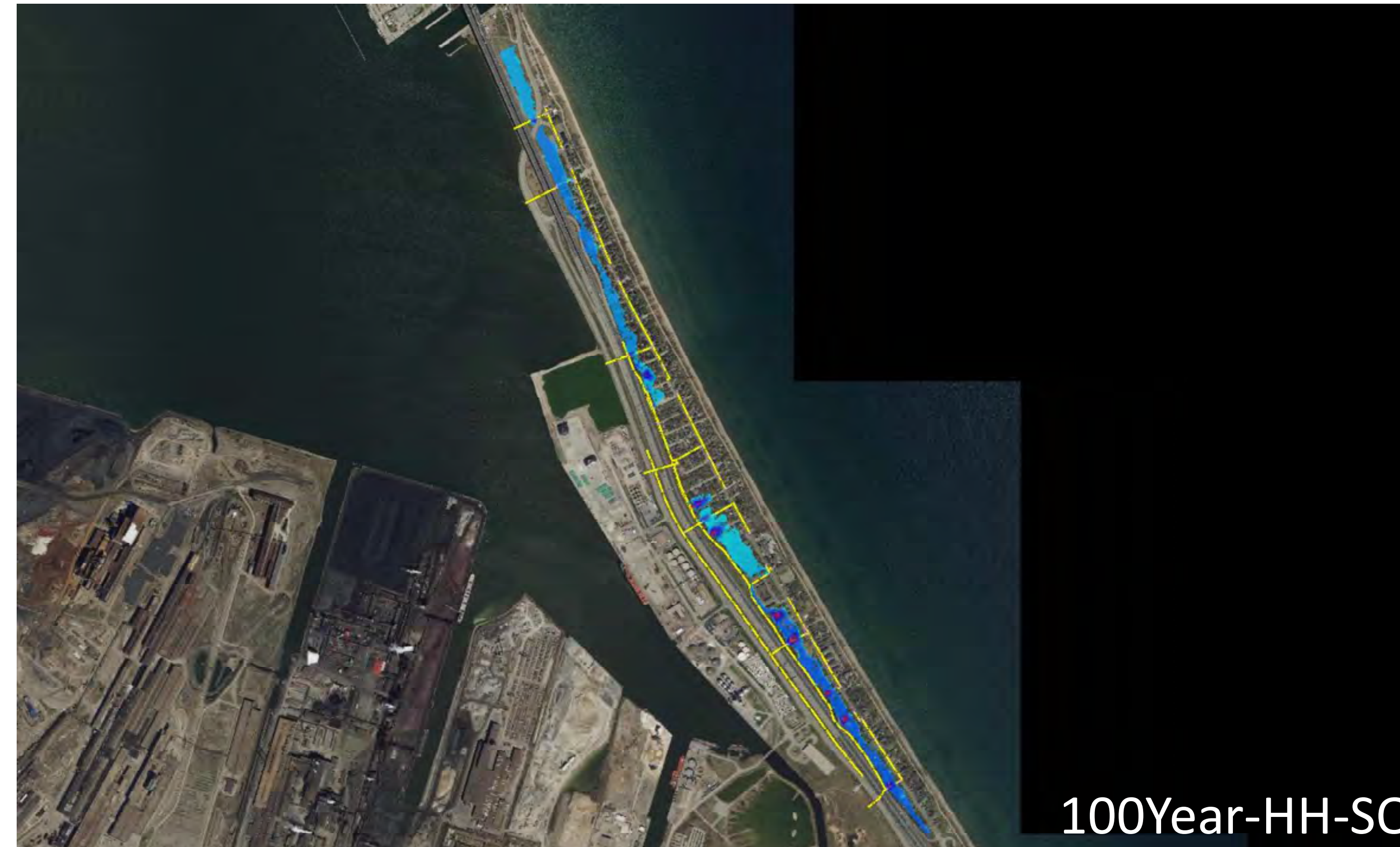
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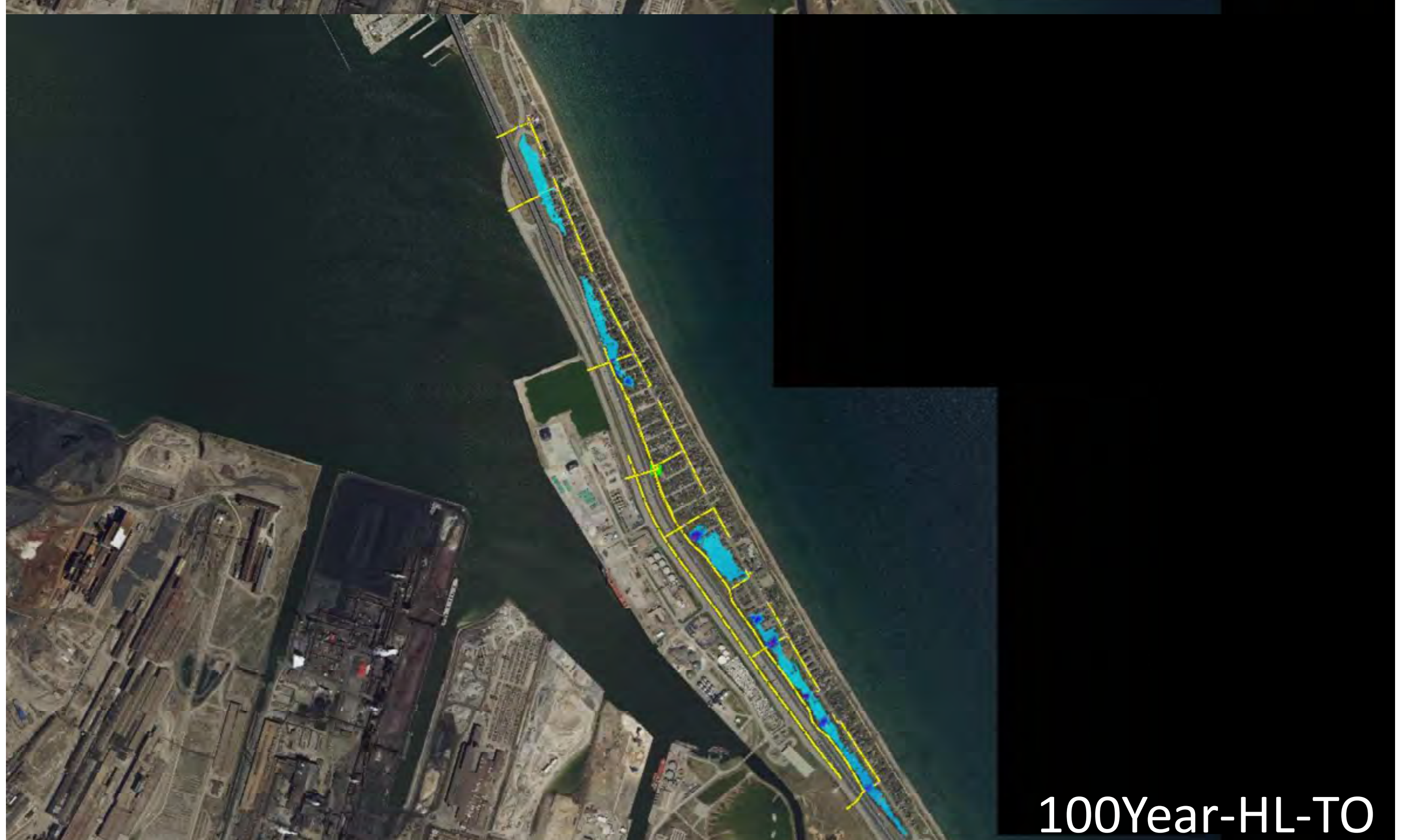
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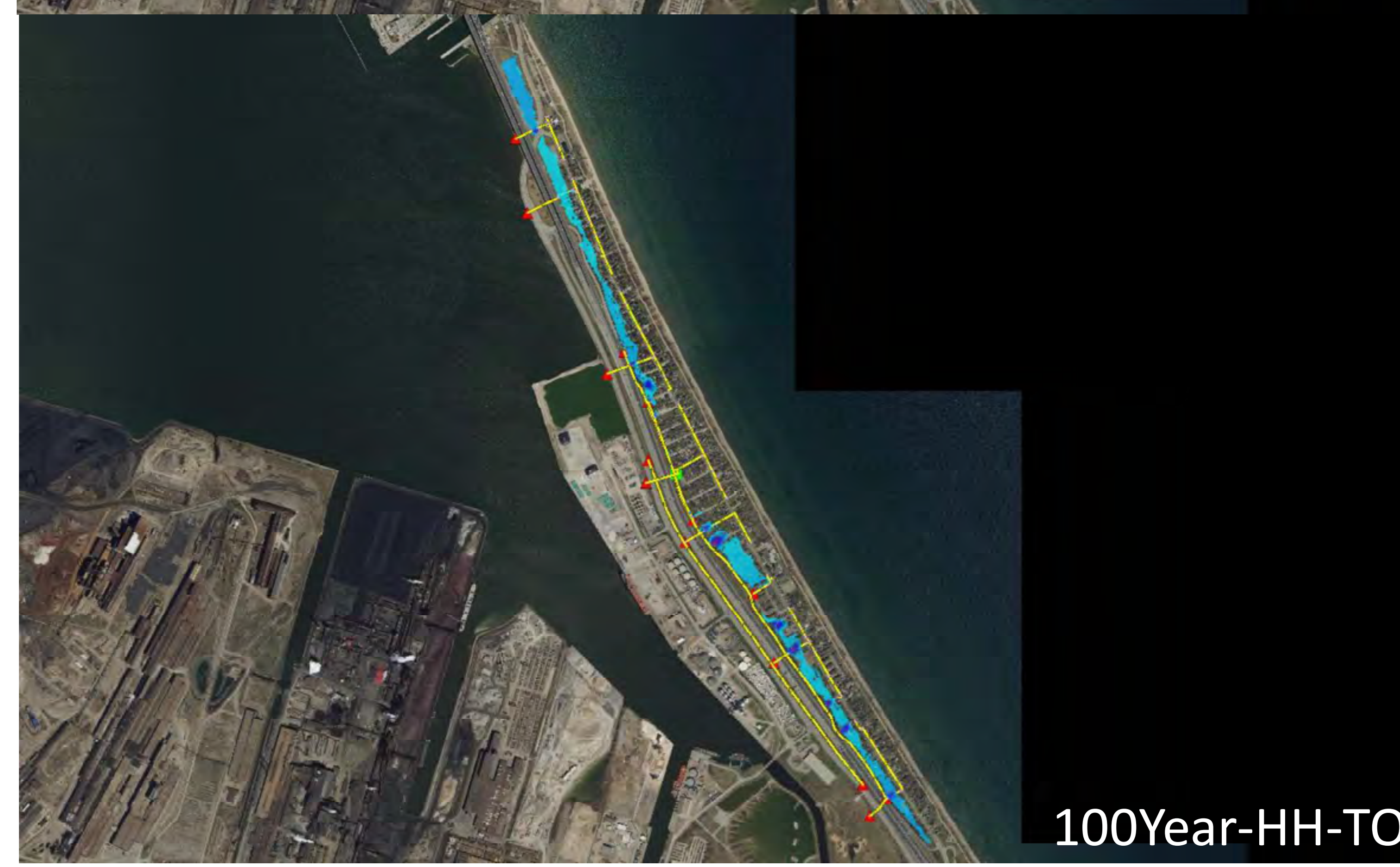

100Year-HH-TO

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 ○ Capital Cost (if new outlet and pipe crossing needed): $200,000 ○ Operational Cost: Regular cleaning and pipe maintenance • Future Activities ○ 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 ○ Capital Cost: $300,000 ○ Operational Cost: Regular cleaning and pipe maintenance • Future Activities ○ 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. ○ Capital Cost (Hamilton Harbour Outlet): $2,200,000 ○ Capital Cost (Lake Ontario Outlet)[1]: $2,400,000 ○ 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 ○ Capital Cost: $2,300,000 ○ Operational Cost: Regular cleaning and pipe maintenance • Future Activities ○ Further calculations required to confirm necessary capacity of gravity outfall. ○ 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. ○ Capital Cost (Eastport Ditch Outlet): $3,000,000 ○ Capital Cost (Lake Ontario Outlet) [1]: $2,900,000 ○ Operational Cost: $15,000/year plus regular cleaning and pipe maintenance. • Future Activities ○ Further calculations required to confirm the capacity of a pumping station. ○ Environmental Assessment for pumping station.
Grafton	Not considered in this analysis		

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
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 ○ Capital Cost: $1,900,000 + potential property acquisition cost (1 undeveloped lot and 1 residential lot) ○ Operational Cost: Regular cleaning and pipe maintenance • Future Activities ○ Further calculations required to confirm the necessary capacity of gravity outfall and stormwater management facility. ○ Confirm capacity of Eastport ditch is sufficient to prevent additional backwater effects on outlet. ○ 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. ○ Capital Cost (Eastport Ditch Outlet): $3,200,000 ○ Capital Cost (Lake Ontario Outlet): $3,400,000 ○ Operational Cost: $20,000/year plus regular cleaning and pipe maintenance • Future Activities ○ Further calculations required to confirm the capacity of a pumping station. ○ 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 ○ 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 ○ Capital Cost: $1,800,000 + property acquisition costs (2 undeveloped lots) ○ Operational Cost: Regular cleaning and pipe maintenance • Future Activities ○ Further calculations required to confirm the necessary capacity of gravity outfall and stormwater management facility. ○ Confirm capacity of Eastport ditch is sufficient to prevent additional backwater effects on outlet. ○ Purchasing of land at the bottom of Towers Drive. ○ 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. ○ Capital Cost (Eastport Ditch Outlet): $4,300,000 ○ Capital Cost (Lake Ontario Outlet) [1]: $3,700,000 ○ Operational Cost: $25,000/year plus regular cleaning and pipe maintenance. • Future Activities ○ Further calculations required to confirm the capacity of a pumping station. ○ 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 ○ Capital Cost: $2,400,000 + property acquisition costs (3-4 residential lots). ○ Operational Cost: Regular cleaning and pipe maintenance. • Future Activities ○ Further calculations required to confirm the necessary capacity of gravity outfall and stormwater management facility. ○ Purchasing of land at the bottom of Kirk Road. ○ 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. ○ Capital Cost (Hamilton Harbour Outlet): $3,200,000 ○ Capital Cost (Lake Ontario Outlet) [1]: $3,000,000 ○ Operational Cost: $20,000/year plus regular cleaning and pipe maintenance. • Future Activities ○ Further calculations required to confirm the capacity of a pumping station. ○ 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

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. • Consider the implementing a Stormwater Utility Fee that would encourage the use of lot level controls and could help fund upgrades to the stormwater system. • 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 all COH owned property sales until the recommendations of this study are available for review and accepted by the COH. • 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 backflow preventers 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:

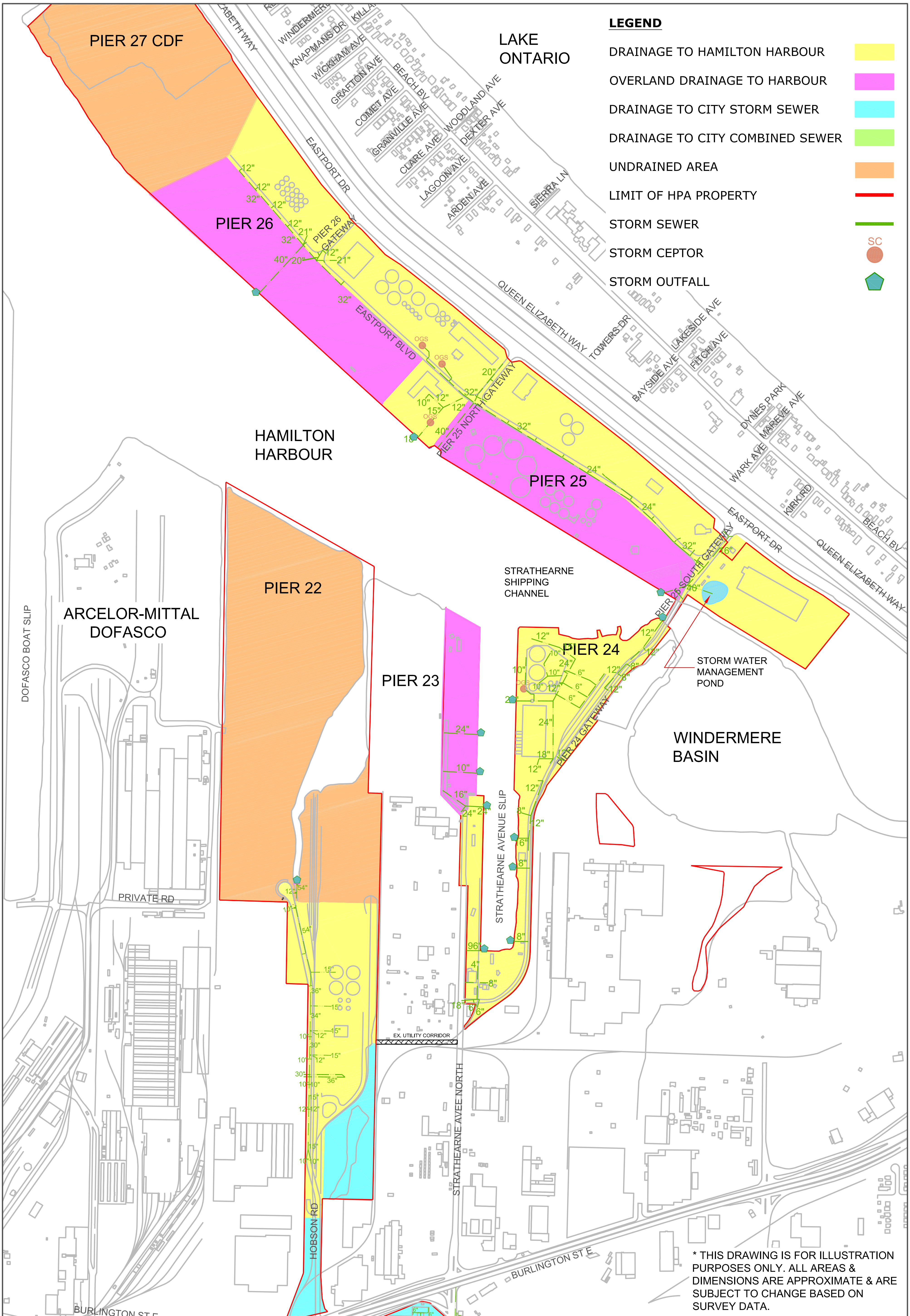
- Gravity Outlet Detailed Design: 3 – 6 months
- Environmental Assessment for Pumping Station: 8 – 24 months

- 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.



HAMILTON PORT• AUTHORITY
Administration Portuaire de Hamilton
Canada

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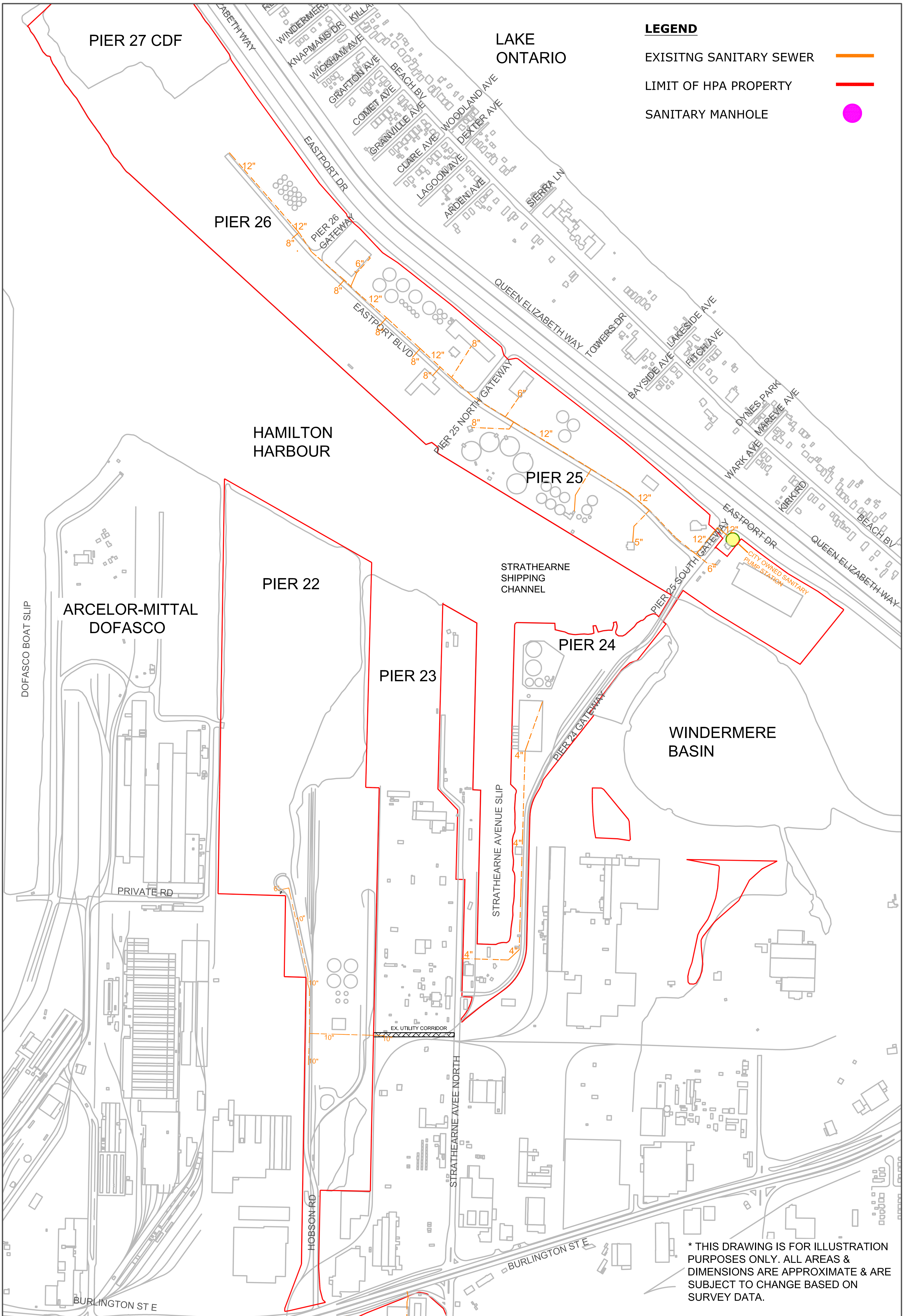

HAMILTON PORT• AUTHORITY
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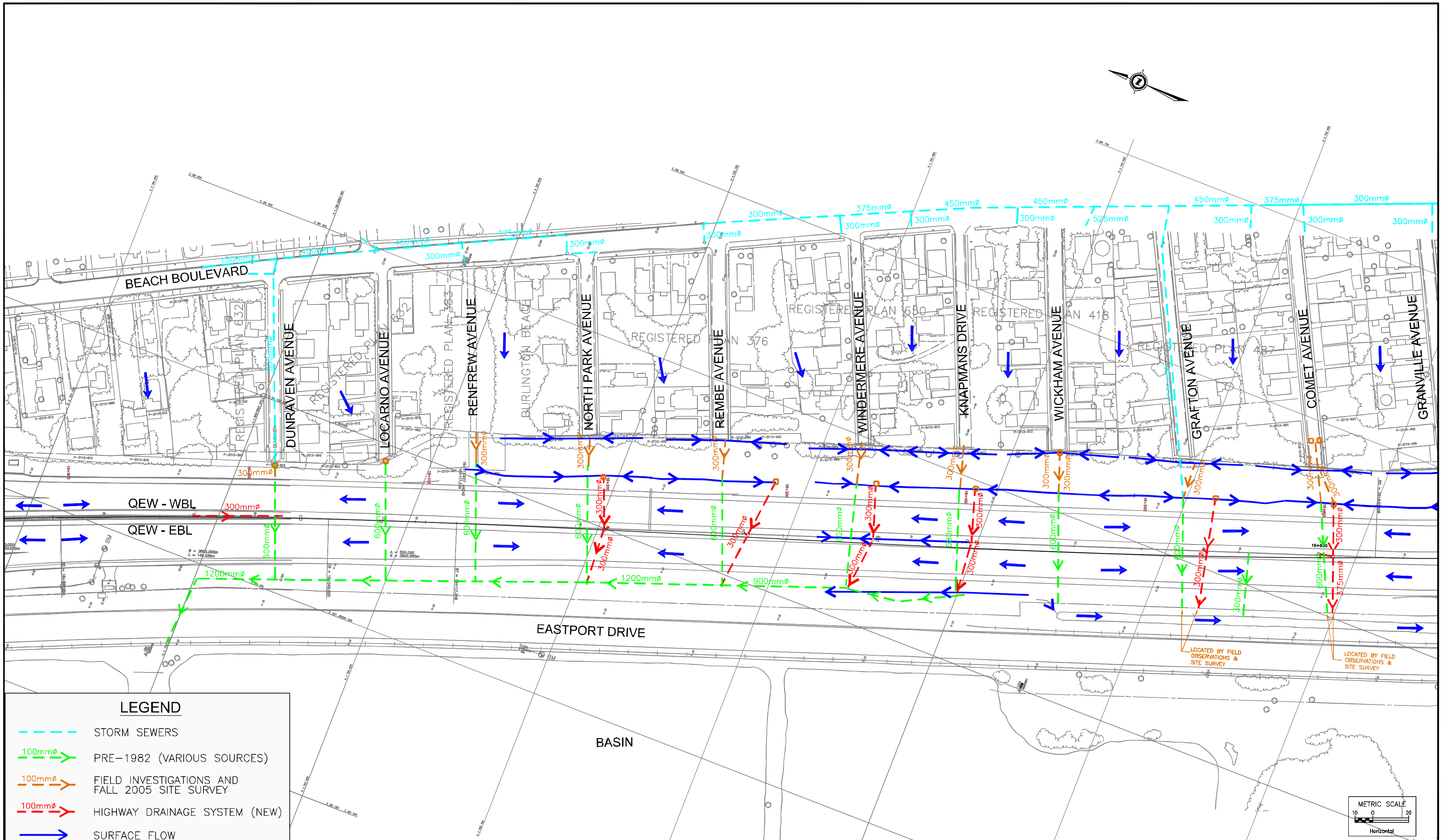
Appendix A6

Field Reconnaissance and Comparison to MRC (2008) Data



MRC

SIGNIFICANT COMPONENTS OF THE EXISTING DRAINAGE INFRASTRUCTURE
QEW STA. 15+900 TO QEW STA. 16+665 (DUNRAVEN AVENUE TO COMET AVENUE)

EXISTING CONDITIONS DRAINAGE INVESTIGATION
QUEEN ELIZABETH WAY - BURLINGTON SKYWAY BRIDGE TO BURLINGTON STREET (G.W.P. 441-97-00)

EXHIBIT
1.3

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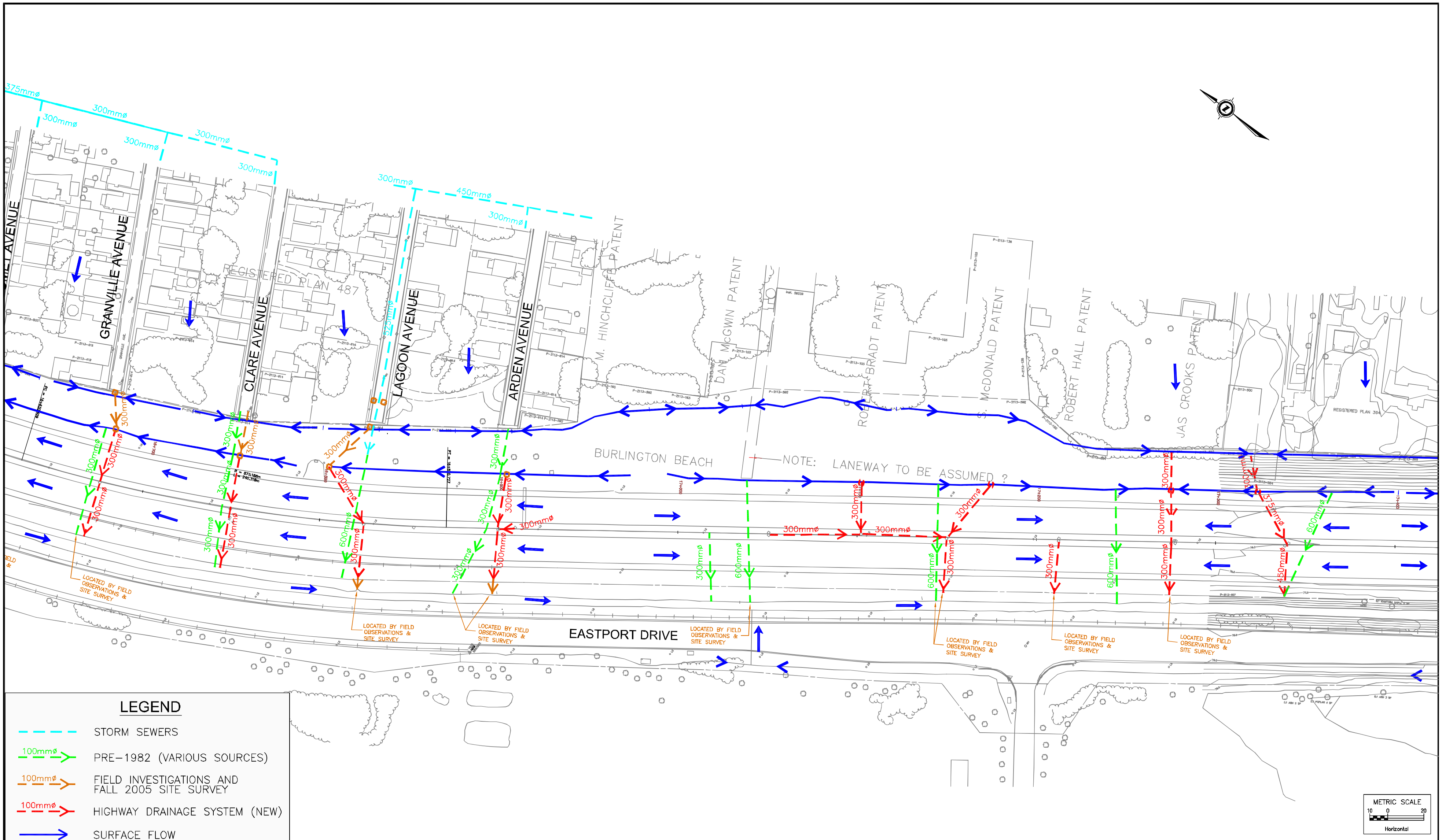

MRC

SIGNIFICANT COMPONENTS OF THE EXISTING DRAINAGE INFRASTRUCTURE
QEW STA. 16+620 TO QEW STA. 17+425 (GRANVILLE AVENUE TO ARDEN AVENUE)

EXISTING CONDITIONS DRAINAGE INVESTIGATION
QUEEN ELIZABETH WAY - BURLINGTON SKYWAY BRIDGE TO BURLINGTON STREET (G.W.P. 441-97-00)

EXHIBIT
1.4

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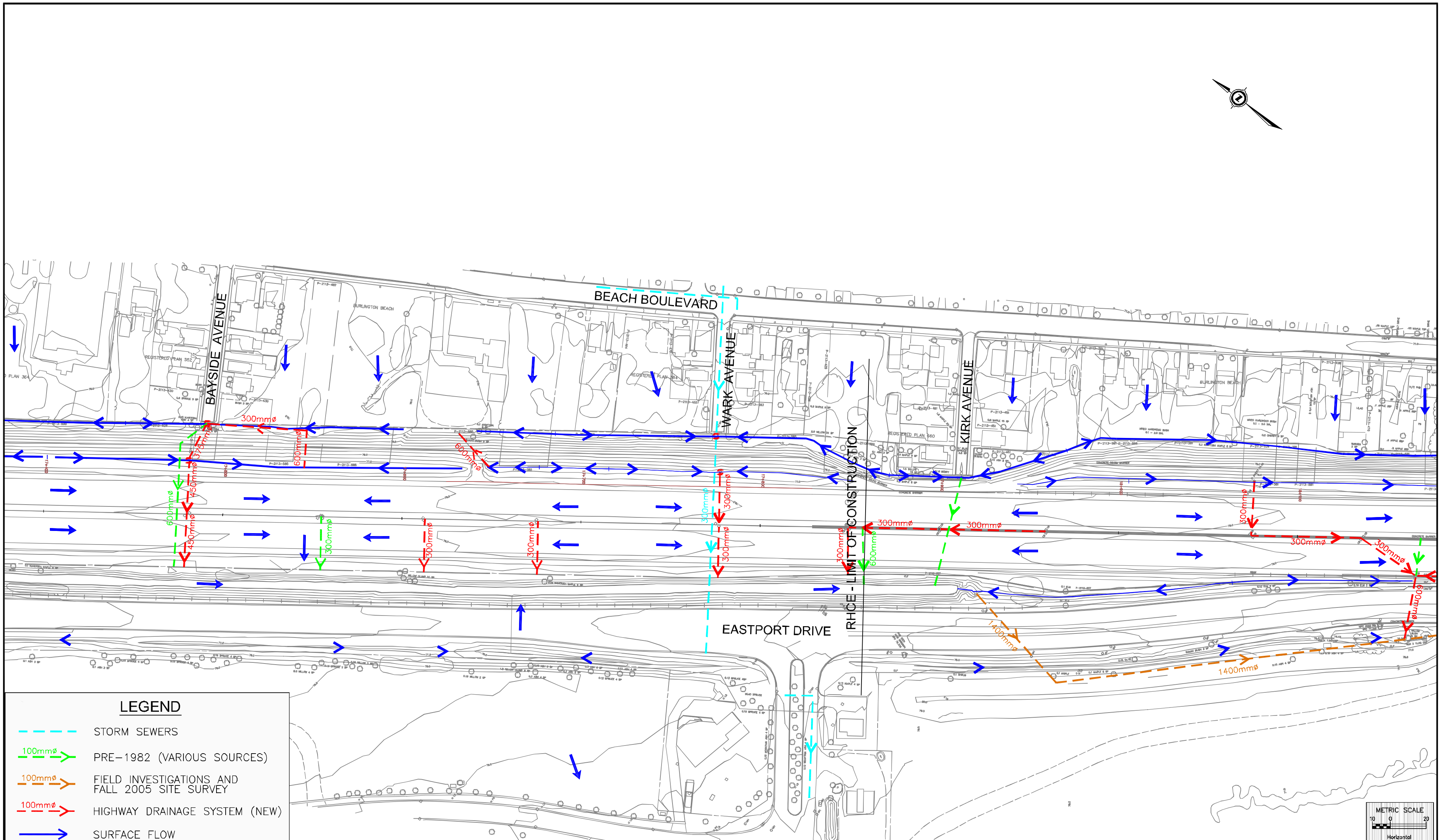

MRC

SIGNIFICANT COMPONENTS OF THE EXISTING DRAINAGE INFRASTRUCTURE
QEW STA. 17+380 TO QEW STA. 18+180 (BAYSIDE AVENUE TO KIRK AVENUE)

EXISTING CONDITIONS DRAINAGE INVESTIGATION
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EXHIBIT
1.5

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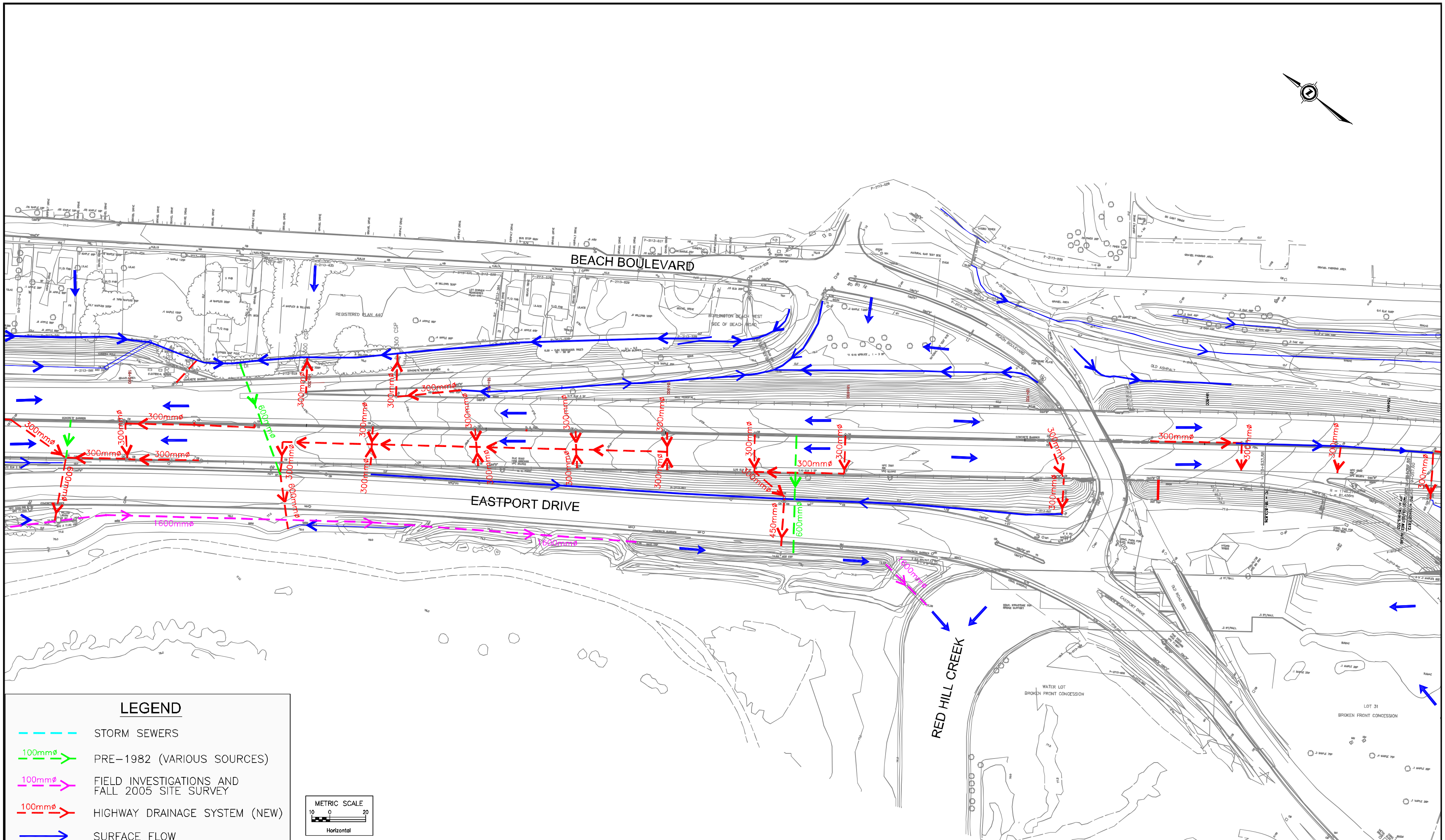

MRC

SIGNIFICANT COMPONENTS OF THE EXISTING DRAINAGE INFRASTRUCTURE
QEW STA. 18+370 TO QEW STA. 18+930

EXISTING CONDITIONS DRAINAGE INVESTIGATION
QUEEN ELIZABETH WAY - BURLINGTON SKYWAY BRIDGE TO BURLINGTON STREET (G.W.P. 441-97-00)

EXHIBIT
1.6

MODIFIED: 06/07/24 15:34:59 DRAWING NAME: K5132-CSP-AS CONSTRUCTED-EXHIBIT 6.DWG

Table 1.3 - Components of the Existing Drainage Infrastructure That Convey Runoff from the Beach Community Beneath the QEW[a]

Street Name	Pipe Conveying Beach Community Drainage From End-of-Street To Drainage Works In QEW Right-of-Way			Transverse Pipe Conveying Beach Community Drainage Beneath QEW		
	Inlet Characteristics	Characteristics	Modified In 1987[b] (Yes/No)	Characteristics	QEW Station (Approx.)	Dedicated To Beach Community Drainage[c] (Yes/ No)
Dunraven Avenue	600 mm x 600 mm DICB[d]	600 mm ϕ CSP	No	600 mm ϕ CSP	16+015	Yes
Locarno Avenue	600 mm x 600 mm DICB	600 mm ϕ CSP	No	600 mm ϕ CSP	16+080	Yes
Renfrew Avenue	Projecting	300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+130	Yes
North Park Avenue	Projecting	300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+190	Yes
Rembe Avenue	Projecting	300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+265	Yes
Windermere Avenue	Projecting	300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+340	Yes
Knapmans Drive	Projecting	300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+400	Yes
Wickham Avenue	Projecting	300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+455	Yes
Grafton Avenue	Beach Blvd. Municipal Sewer System Projecting	600 mm ϕ Conc. 300 mm ϕ CSP	Yes	600 mm ϕ CSP	16+520	Yes
Comet Avenue	Roadway CBs Projecting	300 mm ϕ Conc. 300 mm ϕ CSP	Yes	600 mm ϕ CSP 300 to 375 mm Conc.	16+600	Yes No
Granville Avenue	600 mm x 600 mm DICB	300 mm ϕ CSP	Yes	300 mm ϕ Conc.	16+675	No
Clare Avenue	Projecting Projecting	300 mm ϕ CSP 300 mm ϕ CSP	Yes	300 mm ϕ Conc. 300 mm ϕ Conc.	16+750	Yes No
Lagoon Avenue	Beach Blvd. Municipal Sewer System 600 mm x 1200 mm DICB	525 mm ϕ Conc. 300 mm ϕ CSP	Yes	600 mm ϕ CSP 300 mm ϕ Conc.	16+820	Yes No
Arden Avenue	Projecting	300 mm ϕ CSP	Yes	300 mm ϕ Conc.	16+900	Yes
Bayside Avenue	600 mm x 600 mm DICB	375 mm ϕ CSP	Yes	450 mm ϕ Conc.	17+480	No

Note:

a) Exhibit 1.3 through Exhibit 1.6 illustrate the existing drainage infrastructure in the Study Area.
b) This column identifies if modifications were made to the Beach Community drainage infrastructure to facilitate the construction of the QEW noise wall and associated berm in 1987 (MTO Detailed Design Contract 86-74).
c) This column identifies whether transverse sewer crossings of the QEW convey runoff from the Beach Community only, or combined drainage from both the Beach Community and the eastern portion of the QEW right-of-way.
d) In addition to intercepting surface runoff at the end of Dunraven Avenue, this DICB receives flows from a 600 mm diameter concrete storm sewer that is part of the Beach Community municipal storm sewer system.

1. Dunraven Avenue

1.1. MRC (2008)

1.3.1.1 Dunraven Avenue

The drainage works at the end of Dunraven Avenue were not impacted by the construction of the QEW noise barrier in 1987. A 600 mm x 600 mm DICB is located at the end of Dunraven Avenue adjacent to a guide rail barrier. A 450 mm diameter PVC pipe conveys runoff from a small ditch aligned along the east side of a concrete retaining wall on MTO property to the backside of the DICB. The DICB is currently full of water and debris. The survey conducted by J.D. Barnes Limited confirmed the presence the 450 mm diameter PVC pipe. It also found a 600 mm diameter concrete storm sewer along Dunraven Avenue that inlets to the DICB.

Photos for Dunraven Avenue

600 mm x 600 mm DICB

450 mm ϕ Pipe Visible in DICB

1.2. Wood (December 2, 2021)

Dunraven Avenue was observed to have pooling on the southside of the street. The 600 mm x 600 mm ditch inlet was not located, only a manhole on the street was noted.

2. Locarno Avenue

2.1. MRC (2008)

1.3.1.2 Locarno Avenue

As with Dunraven Avenue, the drainage works at the end of Locarno Avenue were not impacted by the construction of the QEW noise barrier in 1987. Runoff reaching the roadway flows down street gutters into small swales before reaching a 600 mm x 600 mm DICB located behind the concrete barrier at the end of the street. During the field investigation, a continuous inflow to the DICB was observed. The flow was being contributed from a sump pump serving a nearby residential property. Although the DICB is currently full of water and debris, it appears to be functioning properly. Local residents encountered during the field investigation indicated that flooding on Locarno Avenue is a rare occurrence.

Photos for Locarno Avenue

600 mm x 600 mm DICB

Local Channelization

Maintained by Residents

2.2. Wood (December 2, 2021)

No visible DICB observed on Locarno Avenue, the inlet was potentially covered by dense vegetation and rip rap or potentially removed. Local channelization remained but did not appear to have been recently maintained.

3. Renfrew and North Park Avenue

3.1. MRC (2008)

1.3.1.3 Renfrew Avenue

Renfrew Avenue is not paved and has very few residential lots fronting on to it. A small ditch conveys runoff from the end of the street to a 300 mm diameter CSP that connects to a 600 mm CSP beneath the QEW. The culvert was dry at the time of the field investigation, and its slope could not be determined. No other drainage works were visible at this location.

Photo for Renfrew Avenue

300 mm ϕ CSP

1.3.1.4 North Park Avenue

A small ditch is located behind debris and sediment trapped by the guide rail barrier. To reach the ditch, runoff from North Park Avenue must follow two small channels created and maintained by local residents on both sides of the roadway. The inlet to the 300 mm diameter CSP that conveys flow beneath the QEW noise berm is elevated slightly above the roadway. As a result, water must pond at the end of the street before it can overflow into the pipe. The 300 mm diameter CSP connects to a 600 mm diameter CSP that conveys runoff beneath the QEW.

Photos for North Park Avenue

Small Channel Maintained by Local Residents

300 mm ϕ CSP

3.2. Wood (December 2, 2021)

Renfrew Ave was not observed during the December 2nd 2021 field visit.

North Park Avenue appeared to have recent road works and small channels toward the ditch that ran under the fence were observed. The 300 mm diameter CSP was not observed but a ditch inlet was noted. Ponding on both North and South of the inlet in the ditch was observed.






4. Rembe Avenue

4.1. MRC (2008)

1.3.1.5 Rembe Avenue

The drainage works at the west end of Rembe Avenue are similar to those found on North Park Avenue. However, the 300 mm diameter CSP is partially buried and obstructed by sediment and leaves. As well, concrete and wood piles placed in front of the guide rail at the end of the street act as barriers to flow.

Photos for Rembe Avenue

Various Obstructions to Flow

300 mm ϕ CSP

4.2. Wood (December 2, 2021)

Rembe Avenue did not have any visible flow obstructions, but the end of the street required roadworks (a breach was found on the road near the manhole on the southside of the street). The 300 mm diameter CSP could not be found but a ditch inlet was noted.

5. Windermere Avenue

5.1. MRC (2008)

1.3.1.6 Windermere Avenue

The condition of the drainage features at the end of Windermere Avenue is similar to the condition of the features found at the end of both North Park Avenue and Rembe Avenue. The inlet to the 300 mm diameter CSP running under the berm towards the QEW is elevated slightly above the roadway. As a result, water must pond at the end of the street before it can overflow into the pipe.

Photos for Windermere Avenue

Build-Up of Debris

Localized Debris

300 mm CSP (dry)

5.2. Wood (December 2, 2021)

Debris was still observed to accumulate at the end of the Windermere Avenue. A catch basin was observed on the north side of street and had water and debris inside of it. The 300 mm diameter CSP was not observed but a ditch inlet was located.

6. Knapmans Drive

6.1. MRC (2008)

1.3.1.7 Knapmans Drive

Photos for Knapmans Drive

The condition of the drainage features at the end of Knapmans Drive is similar to the condition of the features found at the end of North Park Avenue, Rembe Avenue, and Windermere Avenue. A 300 mm diameter CSP runs under the berm towards QEW. Water must also pond at the end of the street to clear a small earth obstruction and reach the culvert. A pipe extends northerly from a catch basin located at the end of the street. The pipe likely connects to a 600 mm diameter CSP beneath the QEW. However, this could not be confirmed in the field.

Debris Blocking Direct Flow

300 mm CSP

6.2. Wood (December 2, 2021)

Knapmans Drive had no visible culvert potentially due to dense vegetation but two catchbasins were observed at the end of the street. Both grates had water and debris inside them.

7. Wickham Avenue

7.1. MRC (2008)

1.3.1.8 Wickham Avenue

As with the previous streets, ponding occurs due to the fact that the inlet to the 300 mm diameter CSP running under the berm towards the QEW is elevated slightly above the roadway. The CSP was partially full of water at the time of the field investigation.

Photos for Wickham Avenue

Typical Flooding

Partially Full CSP

300 mm ϕ CSP

7.2. Wood (December 2, 2021)

Wickham Avenue appeared to have water pooled on the south side of the street. There was no visible 300 mm diameter CSP, however this could be due to overgrown vegetation or the removal of the culvert. Two catchbasins at the end of street on the north and south sides were observed and were noted to be full of water and leaves. The catchbasin on the northside was partially obstructed by leaves and debris.

8. Grafton Avenue

8.1. MRC (2008)

1.3.1.9 Grafton Avenue

As with the previous streets, ponding occurs due to the fact that the inlet to the 300 mm diameter CSP running under the berm towards the QEW is elevated slightly above the roadway. At the time of the field investigation, the CSP was almost completely obstructed by sediment and debris. Although contract drawings identify that a 600 mm diameter concrete storm sewer also enters the QEW right-of-way from Grafton Avenue, it could not be located in the field.

Photo for Grafton Avenue

300 mm ϕ CSP

8.2. Wood (December 2, 2021)

The 300 mm diameter CSP was not visible during the site investigation. A catch basin on the northside of the street was observed to be draining properly but had sediment around it due to recent construction as explained by an owner of a nearby property. The catchbasin on the southside of the street appeared to be draining properly. Both catch basins had water and debris inside of them. The Grafton Pumping station was observed to have a small channel behind and around the property draining to the small ditch/channel toward the QEW. Two ditch inlets were also observed. The second inlet located more to the south appeared to be partially buried.








9. Comet Avenue

9.1. MRC (2008)

1.3.1.10 Comet Avenue

Drainage conditions at the west end of Comet Avenue are similar to those of the preceding streets. The inlet to a 300 mm diameter pipe is located behind a small build-up of debris at the end of the street. The pipe conveys flows beneath the QEW noise berm. As presented in the first two pictures below, two catch basins at the end of the street were full of water and debris at the time of the field investigation. The catchbasins discharge to another 300 mm diameter pipe that also connects to drainage works in the QEW right-of-way.

Photos for Comet Avenue

Typical Flooding

Catch basin Full of Water and Debris

300 mm ϕ CSP (dry)

9.2. Wood (December 2, 2021)

Comet Avenue had two catch basins draining properly and no CSP was observed due to dense vegetation or potential removal.

10. Granville Avenue

10.1. MRC (2008)

1.3.1.11 Granville Avenue

Runoff discharged from the west end of Granville Avenue flows around the SBGR. It is intercepted by a 600 mm x 600 mm DICB. The DICB was full of water and sediment at the time of the field investigation. A 300 mm diameter CSP extends westerly from the Granville Avenue DICB towards a DICB located in the QEW right-of-way west of the noise barrier wall.

Photo for Granville Avenue

600 mm x 600 mm DICB Full of Water

10.2. Wood (December 2, 2021)

Granville Avenue had three catch basins at the end of the road and minor ponding on in the middle of the road on the south side. Each catch basin was partially full of water and sediment. The culvert and ditch inlet could not be observed due to dense vegetation.




11. Clare Avenue

11.1. MRC (2008)

1.3.1.12 Clare Avenue

Drainage works identified for Clare Avenue are the same as those identified for North Park Avenue, with the exception that there is a second 300 mm diameter pipe that is partially buried. Both 300 mm diameter pipes convey flows beneath the noise berm to drainage works in the QEW right-of-way. With reference to the contract drawings compiled for this Study, one of the pipes is connected to a 300 mm diameter storm sewer beneath the QEW, while the other outlets to a catch basin located in the ditch along the outside edge of the QEW eastbound lanes. The pipe outlet locations could not be confirmed in the field.

Photo for Clare Avenue

300 mm ϕ CSP

11.2. Wood (December 2, 2021)

Clare Avenue was observed to have two catch basins, one of which had a basketball net obstructing the flow path. Both catch basins had leaves and debris around them and both of the catch basins were partially full of water. A 600 mm x 1200 mm ditch inlet was found surrounded by rip rap.

 

12. Lagoon Avenue

12.1. MRC (2008)

1.3.1.13 Lagoon Avenue

A 600 mm x 1200 mm DICB is located in a small ditch beyond the guide rail and fence at the west end of Lagoon Avenue. The ditch is aligned along the QEW berm and noise wall. A 300 mm diameter pipe extending westerly toward the QEW is visible when looking into the catch basin. Although contract drawings identify that a 525 mm diameter concrete storm sewer also enters the QEW right-of-way from Lagoon Avenue, it could not be located in the field.

Photos for Lagoon Avenue

Typical Ponding

Catch basin Full of Water

600 mm x 1200 mm DICB

12.2. Wood (December 2, 2021)

An undeveloped lot on the northside of Lagoon Avenue at the end of street was observed to have ponding. The two catch basins were observed to be partially full. Riprap and debris were observed at the end of the street obstructing the flow path into the ditch. The ditch channel was partially lined with riprap and the 600 mm x 1200 mm DICB could not be locateddue to the dense vegetation.

13. Arden Avenue

13.1. MRC (2008)

1.3.1.14 Arden Avenue

The drainage collection works at the west end of Arden Avenue are the same as those identified for North Park Avenue, with the exception that the inlet to the 300 mm diameter CSP is located farther back from the SBGR. The pipe connects to a 300 mm diameter storm sewer that conveys flows beneath the QEW.

Photo for Arden Avenue

300 mm ϕ CSP

13.2. Wood (December 2, 2021)

Arden Avenue had no observed catch basins on the road and no 300 mm diameter CSP was observed. Debris and leaves had accumulated at the end of the street. Rip rap was observed in the ditch. There were areas of small ponding on the south and northside of the street.



14. Bayside Avenue

14.1. MRC (2008)

1.3.1.15 Bayside Avenue

A 600 mm x 600 mm DICB is located beyond the guide rail at the end of the street. Two pipes are visible within the DICB. A 300 mm diameter pipe aligned along the QEW berm discharges into the DICB. A 375 mm diameter pipe extending westerly from the DICB conveys flows beneath the QEW berm. Both pipes were submerged at the time of the field investigation. The field observations are consistent with information presented on MTO contract drawings.

Photo for Bayside Avenue

600 mm x 600 mm DICB

14.2. Wood (December 2, 2021)

Bayside Avenue had a temporary concrete jersey barrier wall at the end of the road. The ditch behind it was lined with rip rap and there was a circular (approximately 30 cm in diameter) catch basin inlet partially full of water. No 600 mm x 600 mm was observed but may have been located further south/north along the ditch. The concrete structure may be some type of pumping feature; further confirmation with City staff is required.

15. Between Bayside Avenue and Wark Avenue

15.1. MRC (2008)

1.3.1.16 Between Bayside Avenue and Wark Avenue

A large 600 mm diameter pipe intercepts runoff from lands in the Beach Community between Bayside Avenue and Wark Avenue. It is angled towards the QEW right-of-way and outlets to the ditch along the QEW eastbound lanes. Both ends of the pipe are visible, and the pipe was free of sediment and debris accumulations at the time of the field investigation.

Photo Between Bayside Avenue and Wark Avenue

600 mm ϕ CSP

15.2. Wood (December 2, 2021)

One catch basin was observed to be partially full on the northside of Wark Avenue. The 600 mm diameter pipe was not observed during the field visit on December 2, 2021. It may have been covered by dense vegetation.

16. QEW and Eastport Drive

16.1. MRC (2008)

1.3.2 QEW Drainage Infrastructure

For the most part, the QEW drainage system that intercepts surface runoff from urban lands external to the right-of-way operates independently of the drainage system that serves the highway. Generally, drainage intercepted from the streets in the Beach Community is conveyed under the QEW by 600 mm diameter CSPs installed when the highway was constructed in 1933. The urban drainage is discharged to Hamilton Harbour and the Eastport Drive roadside ditch.

Drainage from the east portion of the QEW right-of-way is collected by a number of surface inlet structures located in ditches and/or swales on the east side of the highway and by catchbasins located in the median. It is conveyed beneath the highway by 300 mm diameter concrete pipes that outlet to Hamilton Harbour and the Eastport Drive roadside ditch. Although most inlet structures on the east side of the QEW are full of water, the overall system seems to be operating as designed. The ditches are free of standing water and debris. Furthermore, the inlet structures are in good physical repair.

1.3.2.1 Outlet Locations

The highway drainage infrastructure serving external urban development and the highway infrastructure serving the highway itself both outlet from the QEW right-of-way to the following two locations:

i) Outlet 1 - Hamilton Harbour: The portion of the QEW drainage infrastructure that serves the highway from Sta. 15+900 to Sta. 16+450 and external contributing areas from Dunraven Avenue to Knapmans Drive outlets to a large diameter storm sewer system that conveys flows northerly along the QEW. Contract drawings identify that pipe diameters along this sewer increase from 900 to 1200 mm along its length. Although the sewer is visible in a number of manholes, its exact outlet location could not be field verified. The Hamilton Harbour Commission indicated they have no records of this sewer outlet. Given the direction the sewer travels along the QEW, it is reasonable to assume that it ultimately outlets deep into Hamilton Harbour. However, neither design nor as-built contract drawings have been found to confirm this. During the field investigations and engineering survey, water elevations in the sewer system were coincident with lake water levels, which confirm that the groundwater table in the study area is directly influenced by the lake water levels.

ii) Outlet 2 – Eastport Ditch to Redhill Creek: The portion of the QEW drainage infrastructure that serves the highway from Sta. 16+450 to Sta. 18+700 and external contributing areas from Wickham Avenue to Kirk Avenue outlets to the Eastport Drive drainage system. Flows in the Eastport Road drainage system are ultimately released to Redhill Creek. Additional details of the Eastport Drive Drainage system are presented in Section 1.3.3.

1.3.3 Eastport Drive Drainage System

Eastport Drive was constructed in 1984 as a new four-lane undivided roadway along the Harbour immediately west of the QEW right-of-way. Prior to its construction, the QEW drainage works that that served the QEW as well as the Beach Community east of the QEW both discharged directly to Hamilton Harbour.

At the time that Freeport Drive was constructed, a 2.0 m deep, flat bottomed ditch was graded between Eastport Drive and the QEW. The significant depth and cross-sectional area of the ditch were established to offset the extremely flat longitudinal gradient dictated by the topographic relief along the transportation corridor. Portions of the drainage infrastructure in the QEW right-of-way were modified to outlet to the newly constructed ditch. Pre-construction design Contract 86-74 indicates that several of the 600 mm diameter pipes that convey runoff from the Beach Community beneath the QEW may have been reverse graded (i.e. outlet higher than invert). This could potentially be contributing to flooding experienced at the end of the side streets connecting to Beach Boulevard.

The field survey completed by J.D. Barnes Limited found outlets to the Eastport Ditch from six 600 mm and seven 300 mm diameter pipes. Locations of all outlets to the ditch located in the field are identified on Exhibit 1.3 through 6. Outlets could not be located for pipes conveying runoff from Wickham Avenue, Clare Avenue, Bayside Avenue, and Kirk Avenue. Based on the condition of the ditch observed during field investigations, outlets for these pipes are likely buried beneath sediment or overgrown with dense, weedy vegetation.

Observations made during field investigations and information collected by the topographic survey indicate that water levels in the ditch are coincident with the water levels in Hamilton Harbour. At the time of the engineering survey in the November of 2005, the ditch and Harbour water levels were both at approximately 74.77 m. This corresponds to a 1.5 metre depth of water in the ditch, based on originally constructed elevation.

At a location along the ditch coincident with QEW Sta. 17+900, a 1400 mm diameter CSP was constructed under Eastport Drive to direct ditch flows towards the Windermere Basin. In the late 1990's, fill was placed to create a berm along the west side of Eastport Drive. In addition to creating a barrier between Eastport Drive and the adjacent industrial development, the berm facilitated the placement of a large diameter sewer along the west side of Eastport Drive. The sewer, which consists of pipes ranging in diameter from 1400 to 1600 mm, conveys flows southerly along Eastport Drive for a distance of approximately 520 m. A number of pipes constructed beneath the berm and sewers from the QEW median are connected to this large diameter sewer. Outflows from the sewer are released to a short ditch reach aligned along the west side of Eastport Drive before being discharged to Redhill Creek through a 1600 mm diameter culvert. The location of the outfall to Red Hill Creek from the Eastport Drive drainage system is identified on Exhibit 1.6.

Photos of Eastport Drive Drainage System

Outlet of 1600 mm ϕ Pipe at South End of Berm

Corroded CSP from QEW Median

Outlet of 1600 mm ϕ CSP Into Red Hill Creek

A small man-made earth berm constructed immediately north of the 1400 mm diameter culvert crossing of Eastport Drive prevents water from accessing the 1600 mm diameter sewer directly. Water must accumulate in the ditch until it can overflow across the berm into the sewer. There is no record of construction of this berm.

16.2. Wood (December 2, 2021)

The 1600 mm Culvert that outlets to Red Hill Creek also appears to be in very poor condition.

17. Additional Areas: Beach Blvd 424-466 Beach Townhouses

The Beach Townhouses were noted to only have one outlet to the ditch based on GIS mapping data, however design plans indicated there would be three in total.

The most northern 300 mm diameter pipe outlet may have been partially filled with sediment and debris. No visible water flows was observed due to dense vegetation.

The second 300 mm diameter PVC outlet was noted to be dry and the overflow 100 mm diameter PVC pipe was noted to be partially buried.

The third 300 mm diameter outlet could not be confirmed or observed due to fencing. Sandbags were noted; these may be an attempt to mitigate flooding from the overland flow from the townhouses and ditch to the neighbouring property.