Toronto Islands Flood Characterization and Risk Assessment Project

Flood Mitigation Alternatives Report

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Flood Mitigation Alternatives Report

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	2019/02/15	Draft	Client Review	JDW	RBN	RBN
0	2019/04/30	Final	Final Report	JDW	RBN	RBN
1	2019/06/04	Final	Final Report	JDW	RBN	RBN

Executive Summary

Baird & Associates (Baird) was retained by Toronto and Region Conservation Authority (TRCA) to undertake a flood characterization and risk assessment for the Toronto Islands. This third and final report follows the flood characterization report (Baird, 2019a), flood risk assessment report (Baird, 2019b), and flood depth maps prepared by Baird for TRCA.

The City of Toronto, TRCA, and Baird met in December 2018 to discuss flood mitigation alternatives for the Toronto Islands. The brainstorming workshop identified leading alternatives for the areas most affected by the 2017 flood. The alternatives built upon recommendations made by Toronto Island residents (French, 2017) and include protecting low-lying residential areas with a berm or dyke structure, elevating low-lying roads, increasing the crest elevation of shore protection structures, and directing surface drainage to the sumps that were installed in 2018.

The designs were developed using the 500-year stillwater level for Toronto (static lake level plus storm surge) as the design water level. The 500-year flood level has a 6% chance of being equalled or exceeded at least once in a 30 year period and was considered to be a reasonable starting point to develop the conceptual alternatives. The level of acceptable risk, construction costs, and other factors should be evaluated at the next stage of the design. The difference between the 100-year and 500-year flood level is 0.2 m.

This report presents the conceptual designs, estimated quantities, and budgetary cost estimates for the flood mitigation alternatives described below:

- **Ward's Island Promenade:**
  - **Option 1:** a multi-functional flood protection/recreation structure consisting of a berm, pathway, three groynes, three beaches, and small bridge over the Ward's Island cove. The structure extends from the Ward's Island ferry dock to the intersection of First Ave. and Lakeshore Ave. The estimated cost of the works is $2.22M.
  - **Option 2:** Similar concept as above but with a shorter promenade terminating at the intersection of Bayview Ave. and Third Ave. No pedestrian bridge over the Ward's Island cove, and one fewer beach and groyne. The estimated cost of the works is $1.34M.
  - **Option 3:** Similar to Option 2 but with a much shorter promenade, one groyne, and sand fill to enhance the existing beach between the Ward's Island ferry dock and Fifth Ave. The estimated cost of the works is $0.68M.
  - **Option 4:** Berm only option. Berm to follow the shoreline from the Ward's Island ferry dock to the intersection of First Ave. and Lakeshore Ave. The estimated cost of the works is $0.18M.
- **Algonquin Island Berm and Flood Wall:** an approximately 1 m high berm extending from the Queen City Yacht Club to the Algonquin Island Association clubhouse. The berm transitions to a lower height after the clubhouse and continues to the intersection of Wyandot Ave. and Omaha Ave. A concrete flood wall is proposed along the rear property line of the Nottawa Ave. homes that back onto the Queen City Yacht Club. A berm is also proposed at the Queen City Yacht Club to protect four club buildings. The estimated cost of the works is $0.49M.
- **Centreville Flood Protection:** a berm parallel to the Centreville train tracks or raise and reconstruct the trackbed with an impermeable liner. Install four sumps at low spots at Centreville. The estimated cost of the berm is $0.33M. The cost of removing and reinstalling the train track was not estimated.
- **Cibola Ave. Berm:** a berm extending along Cibola Ave. from the Ward's Island ferry dock to the Fire Station. The estimated cost of the works is $0.24M.

- **Island Water Treatment Plant:** a low concrete wall along the existing seawall and a berm along the parking lot. The estimated cost of the works is $0.1M.
- **Elevate Arterial Roads:** approximately 3.8 km of Cibola Ave., Lakeshore Ave., Service Rd., Avenue of the Island, and Beach Rd. are low-lying and should be elevated for safe ingress/egress. The estimated cost of the works is $12.6M.

The estimated total cost of the project varies between $13.9M and $15.9M depending on the flood protection option at Ward's Island. The highest cost is associated with raising low-lying portions of the roads to the 500-year flood level. A phased approach could be considered, elevating the lowest portions of the roads sooner and elevating other sections when they require resurfacing.

Swales and ditches will be required along the roads and berms to direct rainwater towards the lake and existing sumps. New culverts may be required under the roads. Small gaps (1 to 2 m wide) should be made in the berms and flood walls to prevent rainwater ponding in the interior of the structures. The gaps can be closed with sandbags, stoplogs, gates, or other deployable barriers during high lake levels.

Flood mitigation concepts were not developed for private businesses such as the yacht clubs. Temporary flood protection measures, such as water-filled rubber/synthetic barriers, could be installed when needed. Elevating buildings should be considered for some buildings such as the Queen City Yacht Club clubhouse.

Next steps will include determining the level of acceptable risk and priority areas, conducting site investigations and engineering analyses to assess the feasibility of the conceptual designs, confirming the regulatory requirements, and developing preliminary and final designs (including options to naturalize and incorporate habitat features). The estimated cost of the site investigations and future studies is approximately $550,000.

Table of Contents

Tables

Figures

1. Introduction and Study Objectives

Baird & Associates (Baird) was retained by Toronto and Region Conservation Authority (TRCA) to undertake a flood characterization and risk assessment for the Toronto Islands. The overall project objective is to develop conceptual designs, costs, and estimates of annualized reductions in flood damages for various flood mitigation alternatives. The project deliverables will include three reports and one set of emergency response maps. The assessment will consist of the following four main parts:

- **Flood Risk Characterization:** review the conditions that led to the 2017 flooding and re-evaluate return-period extreme lake levels in light of recent data and climate change science.
- **Flood Risk Assessment:** quantify tangible and intangible damages resulting from the return-period flood risk events.
- **Flood Response Plan:** develop emergency mapping based on input from the City of Toronto and TRCA.
- **Flood Mitigation Alternatives:** develop conceptual designs to mitigate the flood risk and quantify annualized expenditures or savings resulting from mitigation works.

This third and final report presents conceptual flood mitigation designs, estimated quantities, and budgetary cost estimates. The flood mitigation alternatives were identified at a workshop attended by the City of Toronto, TRCA, and Baird in December 2018. The alternatives expand upon recommendations made by Toronto Island residents after the 2017 flood (French, 2017).

1.1 Summary of Return Period Water Levels

Return period water levels for Ontario locations on the Great Lakes were developed by the Ontario Ministry of Natural Resources (OMNR, 1989). Baird updated the return period water levels at Toronto for the Flood Characterization Report (Baird, 2019a). The update made use of the additional 31 years of measured data and included an adjustment to account for the change in Lake Ontario regulation plans.

Climate change research was also reviewed to understand how water levels may change in the future. Current research suggests that water levels in the Great Lakes will remain similar or decline slightly due to increased evapotranspiration (see e.g. Baird, 2019a; McDermid et al., 2015). At this time, Baird does not recommend any increase or decrease in the return period water levels due to climate change. The estimated return period stillwater levels (static lake level plus storm surge) for Toronto are summarized in Table 1.1.

Table 1.1: Estimated Toronto Harbour Return Period Stillwater Levels Under 2014 Regulation Plan (Baird, 2019a)

Return Period	2 year	5 year	10 year	25 year	50 year	100 year	200 year	500 year
Stillwater level (m IGLD85)	75.38	75.65	75.80	75.94	76.01	76.05	76.14	76.25

1.2 Summary of Estimated Flood Damages

Financial and non-financial damages for different return period flood levels were estimated in Baird (2019b). The estimated total financial damages to residential and non-residential buildings on Toronto Islands (excluding City of Toronto owned and operated buildings) varies from $0.5M at the 2-year flood to $6.5M for the 500-year flood (see Figure 1.1). The damage estimates consider only buildings that were flooded and do not account for mitigation actions (such as sandbags and pumps). Financial damages for non-residential

buildings (business disruption, lost productivity, etc.) are believed to be underestimated due to limitations inherent to the method. Financial damages incurred by the City of Toronto in 2017 were mostly due to the closure of Toronto Island Park (lost ferry revenues, rent abatements, etc.) and flood mitigation actions (labour, equipment, etc.) rather than damages to flooded City buildings. The estimated financial impact of the 2017 flood on the City was approximately $8M (City of Toronto, 2018). The average annual financial damages[1] for the residential and non-residential buildings on Toronto Islands is estimated to be $387,000 per year. Non-financial damages such as impact of flooding on human health, environment, and the Toronto Islands community is discussed in Baird (2019b).

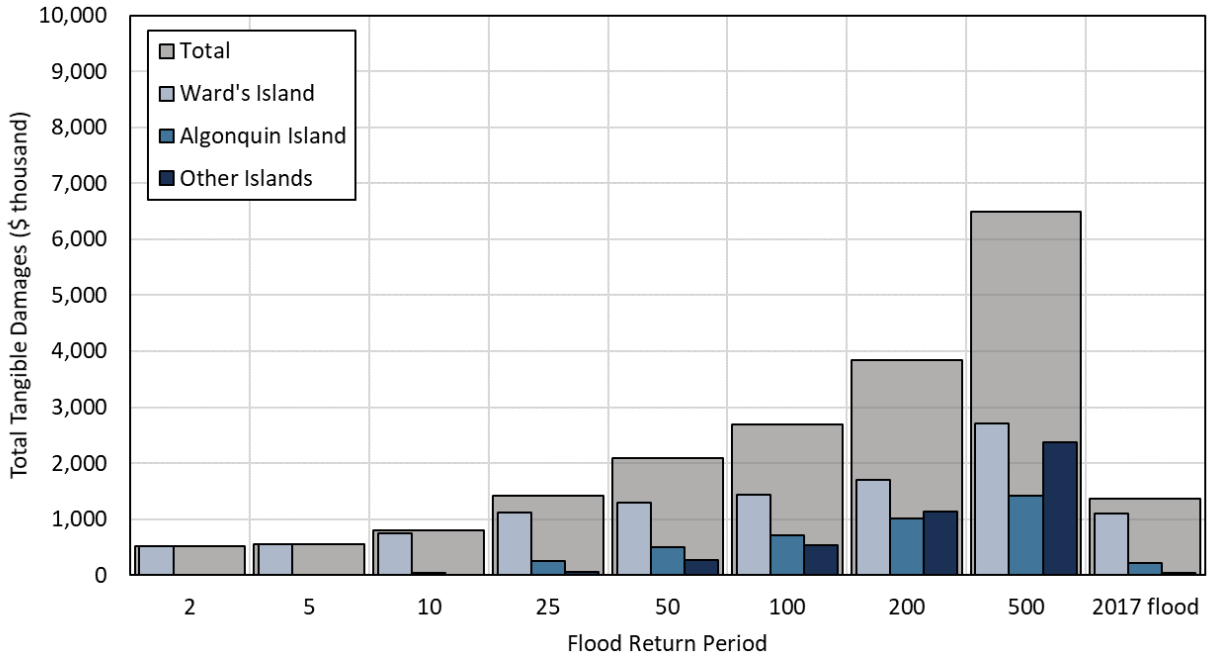

Figure 1.1: Total Tangible Damages for Different Flood Return Periods (from Baird, 2019b)

1.3 Note on Elevations and Datums

Unless otherwise noted, all water levels are reported in International Great Lakes Datum 1985 (IGLD85). IGLD85 is 8.4 cm below Canadian Geodetic Vertical Datum 1928-1978 Ontario Adjusted Version (CGVD 1928:1978), and 49.6 cm below Canadian Geodetic Vertical Datum 2013 (CGVD 2013) at the Canadian Hydrographic Service benchmark 0011959U9526 (also known as 00159U9526, 59U9526, and TORO 1-1959). The benchmark is located at the Toronto Harbour Gaugehouse at the south side of Queen's Quay. The elevation of the benchmark relative to the different datums is shown in Figure 1.2

[1] Average annual financial damages are the sum of all the damages that would occur over many years divided by the number of years

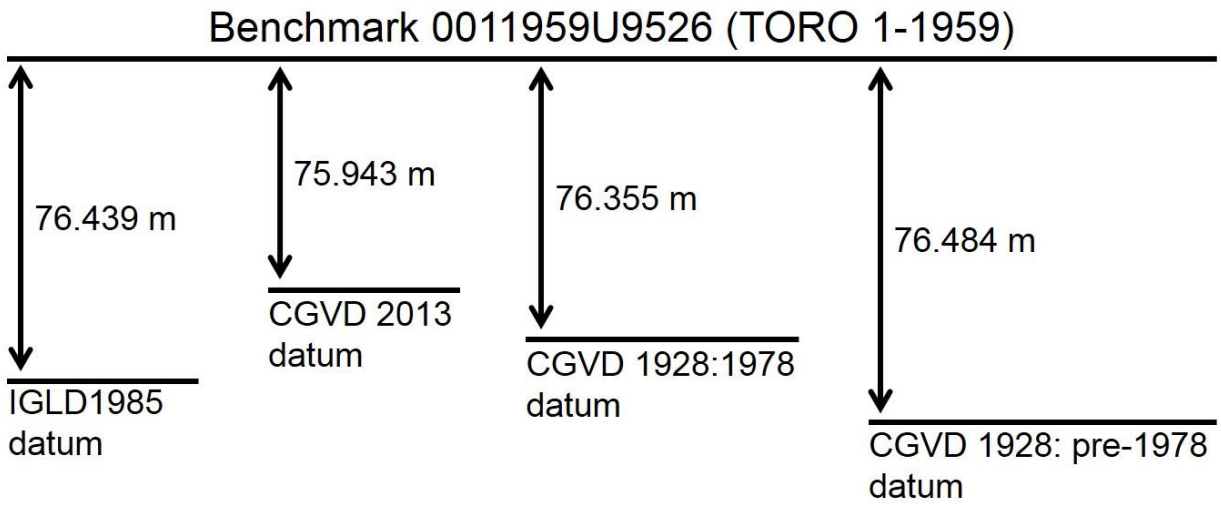

Figure 1.2: Elevation of the Toronto Harbour Gaugehouse Benchmark

2. Initial Flood Mitigation Concepts

The City of Toronto, TRCA, and Baird met on December 14, 2018 to discuss different flood mitigation alternatives for the Toronto Islands. The workshop began with a review of the areas flooded in 2017, the City of Toronto response, and discussion about the impacts on residents, businesses, and City operations. Thereafter, the flood mitigation alternatives proposed by island residents (French, 2017) and other temporary and permanent mitigation alternatives were discussed. By the end of the brainstorming workshop, leading alternatives were identified for the areas most affected in 2017.

The leading alternatives build upon the recommendations made by Toronto Island residents (French, 2017) and include protecting low-lying residential areas with a berm or dyke structure, elevating low-lying roads, increasing the crest elevation of shore protection structures, and directing surface drainage to the sumps that were installed in 2018.

There was broad support at the meeting for multi-benefit solutions that incorporate flood protection with other public amenities such as walking trails. Additionally, many participants reaffirmed that the flood mitigation solutions must respect the nature and function of Toronto Island Park. A list of the leading alternatives is described in Table 2.1.

Table 2.1: Summary of Leading Alternatives from Brainstorming Workshop

Location	Description	Proposed Solution
Northwest corner of Ward's Island	Low-lying residential area was highly impacted in 2017.	Multi-benefit solution or berm
Algonquin Island seawall	Waves overtopped the seawall in 2017 and contributed to localized flooding.	Raise seawall or berm
Algonquin Island, Nottawa Ave. homes backing onto QCYC	Homes on Nottawa Ave. were affected by floodwater originating from Queen City Yacht Club.	Flood wall along property line between homes and QCYC
Algonquin Island, Wyandot Ave. homes	Low-lying residential area was flooded in 2017.	Berm
Island Water Treatment Plant	Some low-lying areas were flooded in 2017. Access road flooded.	Raise seawall and berm and elevate road
Centreville	Some low-lying areas were flooded in 2017. Access road flooded.	Flood protection at Far Enough Farm and elevate road
Cibola Ave. and Lakeshore Ave.	Cibola Ave. and Lakeshore Ave. are the main arteries on the island. Portions of the roads were flooded more than 0.3 m in 2017.	Elevate road or berm depending on location

3. Site Conditions and Constraints

3.1 Ground Elevations

The Toronto Islands are low-lying with ground elevations generally less than 1 m above the annual high water level. Ground elevations and estimated first floor elevations[2] of buildings on Algonquin and Ward's Islands are shown in Figure 3.1. First floor elevations below the 50-year and 500-year stillwater level are coloured in red and pink, respectively.

Figure 3.1: Estimated First Floor Elevation and Ground Elevation on Algonquin and Ward's Islands

[2] First floor elevations were estimated from the number of steps at the front entrance and the ground elevation from the Digital Elevation Model for Toronto Islands.

3.2 Flood Depths

The flood depth maps produced for a lake level of 76.2 m (approximately the 500-year flood event) are included in Appendix A to provide context for the flood mitigation alternatives presented in the report. The maps use one colour scale to show the depth of flooding on land, and another scale to show the depth of flooding on the arterial roads. An example of the flooding that occurred along parts of Cibola Ave. in 2017 is shown in Figure 3.2. The 500-year flood level is approximately 0.3 m higher than the water level in the photograph.

Figure 3.2: Photograph of Cibola Ave. During 2017 Flood (from National Post, 2017)

3.3 Soil Conditions

The subsurface conditions consist of approximately 6 m of medium to fine grained compact sand over shale bedrock (see e.g. Baird and Reinders, 1994). The Toronto Islands Shoreline Management Study (Baird and Reinders, 1994) states that dykes and pumping systems would not be feasible due to the high permeability of the soils.

The study concluded that the only practical alternative is to increase the building and land elevations using fill. The study recommended that all ingress/egress routes be elevated to 76.12 m IGLD85, and that the ten houses on Ward's Island with a first floor elevation below 76.12 m be elevated if the structures are renovated in the future.

Further site investigations and engineering analyses are recommended to confirm the feasibility of the dyke/berm and pumping system alternatives presented in this report.

4. Design Water Level and Level of Risk

The design water level for the flood protection structures needs to consider the project function, human health and safety implications, environmental consequences, capital budget, economic impacts resulting from damage to, or destruction of the structure, ability or willingness to carry out repairs and maintenance, and consequences if an event exceeding the design level were to occur.

The conceptual designs were developed using the 500-year stillwater level for Toronto (static lake level plus storm surge) as the design condition. The 500-year flood event has a 0.2% chance of being equalled or exceeded in a given year, which results in a 6% chance of being equalled or exceeded at least once in a 30 year period (see Figure 4.1). In comparison, there is a 26% chance the 100-year flood level will be equalled or exceeded at least once over a 30 year period. Considering that the risk of the 100-year flood level being equaled or exceeded at least once over a 50 year period is nearly 40%, the 500-year flood level was selected as a reasonable starting point to develop the conceptual alternatives. The level of acceptable risk, construction costs, and other factors should be evaluated at the next stage of the design. The difference between the 100-year and 500-year flood level is 0.2 m.

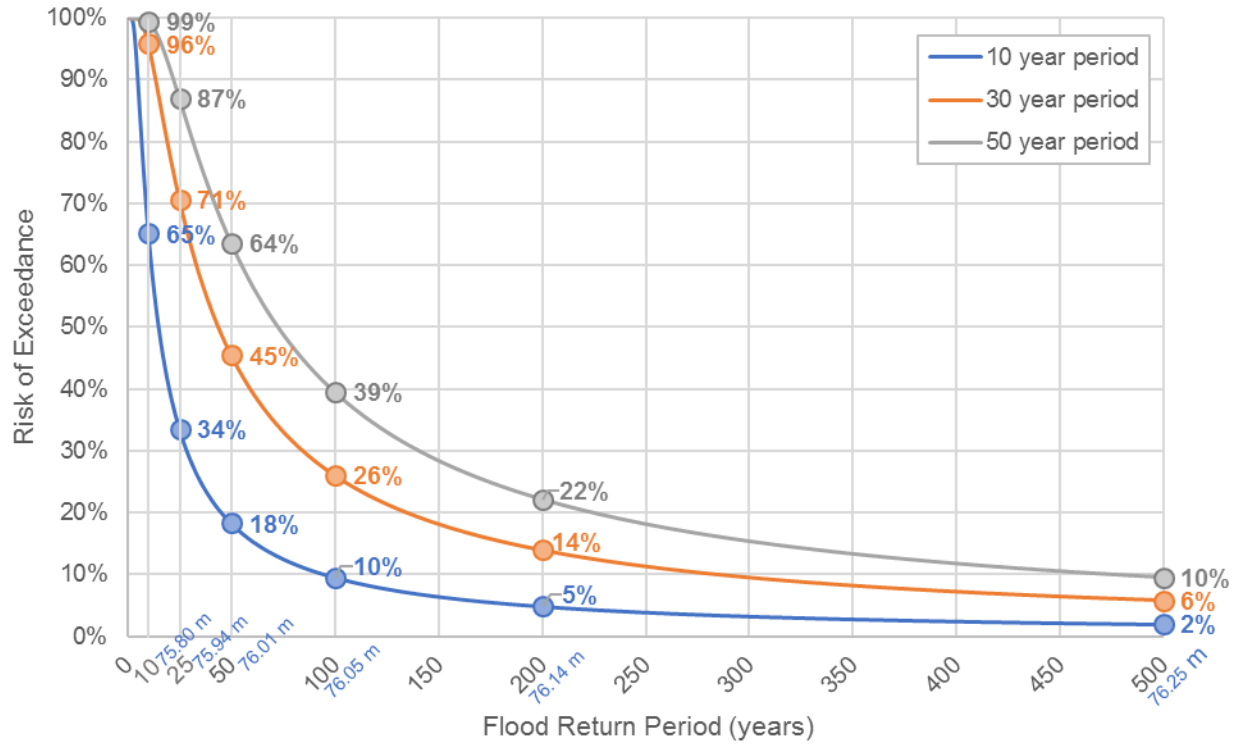

Figure 4.1: Probability of a Specified Flood Event Occurring within a 10, 30, and 50 Year Period (after FEMA, 2014)

5. Proposed Mitigation Alternatives

Berms and other flood protection structures are proposed for the low-lying portions of Ward's and Algonquin Islands, Centreville, the Island Water Treatment Plant, and along Cibola Ave. from the Ward's Island ferry dock to the Fire Station.

Incorporation of terrestrial and aquatic habitat will be implemented where applicable into flood mitigation efforts such as swales, berms, seawalls and groynes. This will significantly enhance the ecological function of the flood protection technique and the overall area. Recreational viewing nodes will also be incorporated into flood mitigation efforts, enhancing the social benefits on the Toronto Islands. Recreational viewing nodes will be integrated into the Ward's Island Promenade.

5.1 Structure Elevations

For inland areas with shallow flooding, the elevation of the berm crest was set to 76.5 m, which is the 500-year stillwater level plus a freeboard allowance of 0.25 m. For the Algonquin Island seawall, the berm crest was increased to 77.0 m (freeboard allowance of 0.75 m) to limit the amount of wave overtopping. The low-lying portions of Cibola Ave., Lakeshore Ave., Beach Ave., Service Rd., and Avenue of the Island that will not be protected by berms were elevated to 76.25 m.

The Ward's Island Promenade Option 1, described below, offers increased protection from wave overtopping compared to the other three options. The crest elevation of the Ward's Island berm should be evaluated at the functional design phase based on the location of the berm and shore protection.

5.2 Surface Drainage

Swales and ditches will be required along the roads and berms to direct rainwater towards the lake and existing sumps. New culverts may be required under the roads. Small gaps (1 to 2 m wide) should be made in the berms and flood walls to prevent rainwater ponding in the interior of the structures. The gaps can be closed with sandbags, stoplogs, gates, or other deployable barriers during high lake levels. One-way valves could also be considered, provided they can be maintained free of debris.

5.3 Ward's Island Promenade

Conceptual designs were developed for a multi-functional flood protection/recreation structure for the northwest corner of Ward's Island. The structure consists of a berm, pathway, groynes, beaches, and a small bridge over the Ward's Island cove. The concepts were developed for the following four options:

- **Option 1:** Promenade extending from the Ward's Island ferry dock to the intersection of First Ave. and Lakeshore Ave. Includes three groynes, three beaches, and a pedestrian bridge over the Ward's Island cove.
- **Option 2:** Shorter promenade extending from the Ward's Island ferry dock to the intersection of Bayview Ave. and Third Ave. Includes two groynes and two beaches.
- **Option 3:** Shorter promenade than Option 2 extending from the Ward's Island ferry dock to the first groyne. Includes one groyne and one beach.
- **Option 4:** Berm only option. Berm follows the shoreline from the Ward's Island ferry dock to the intersection of First Ave. and Lakeshore Ave.

Unmanned Aerial Vehicle photographs of the Ward's Island shoreline from the ferry dock to the cove are shown in Figure 5.1 (photographs provided by TRCA).

Figure 5.1: Photographs of the Ward's Island Shoreline from the Ferry Dock to the Cove

The promenade concept for Ward's Island is similar to a design Baird has used on other projects, including the Rockley Boardwalk in Barbados (see Figure 5.2). A similar design implemented at Ward's Island would offer benefits to residents and visitors including flood protection and recreation. Options 1, 2, and 3 include armourstone groynes and sand or gravel pocket beaches. If desired, the size of the groynes could be increased, making the features into artificial headlands like those along the Rockley Boardwalk. The promenade is intended to draw in visitors disembarking from the ferry and direct them along the shoreline rather than down residential streets. The pathway will run along the back of the beaches and connect with the existing pathway/street network. A seat wall running along the pathway would provide opportunities for residents and visitors to stop to view the City and use the beaches. A berm will be installed on the landward side of the pathway for flood protection. A Geosynthetic Clay Liner, consisting of two geotextile outer layers and a bentonite clay core, would be installed in the berm to reduce seepage through the berm during high lake levels.

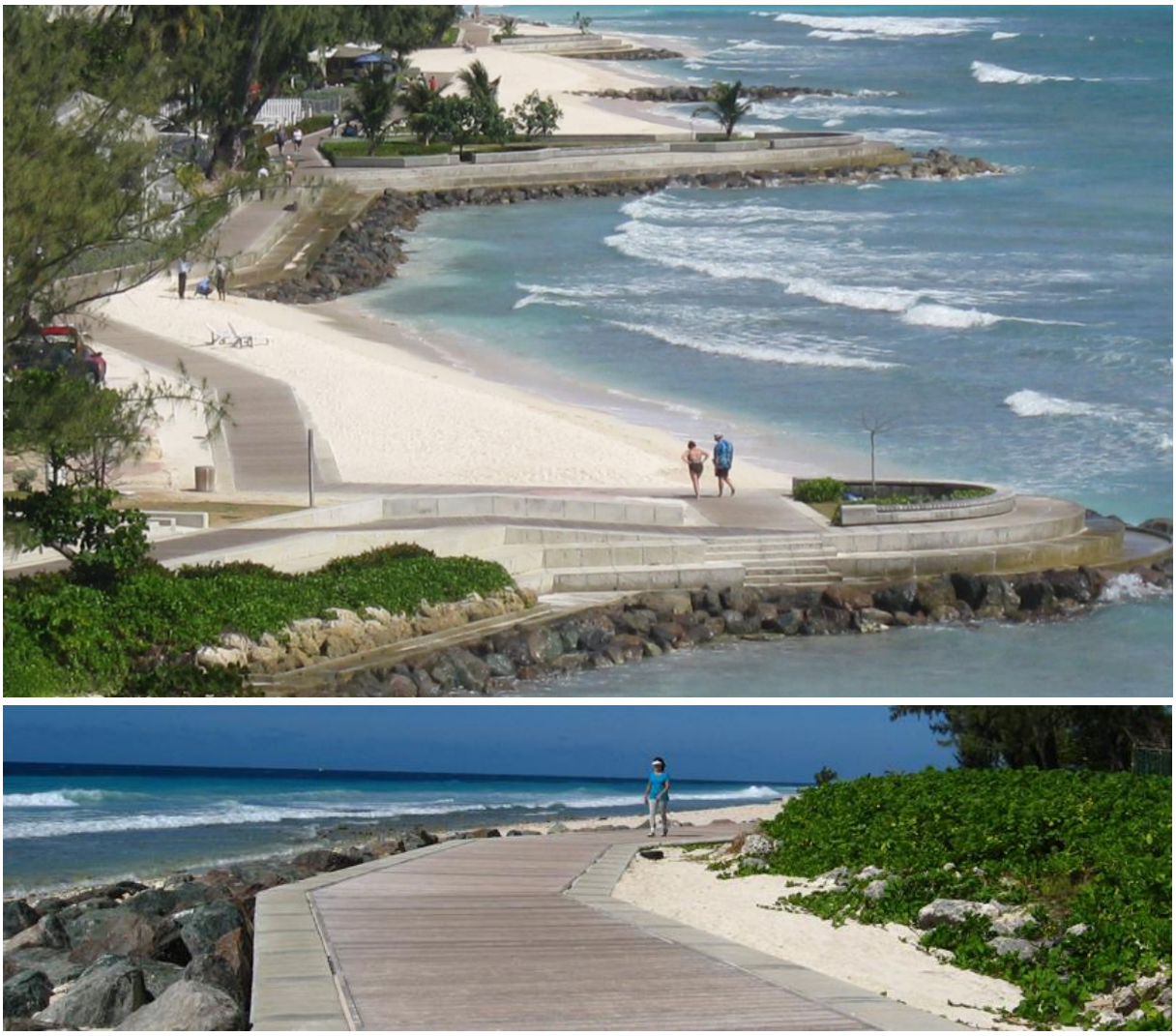

Figure 5.2: Example Similar to the Ward's Island Promenade Concept

The four options for the Ward's Island Promenade are shown on the following pages in plan view (Figure 5.3 to Figure 5.6). Profiles and cross-sections of the promenade, groynes, and berm are provided in Figure 5.7 to Figure 5.11. Larger drawings are provided in Appendix B.

Figure 5.3: Plan View of Ward's Island Promenade Option 1

Figure 5.4: Plan View of Ward's Island Promenade Option 2

Figure 5.5: Plan View of Ward's Island Promenade Option 3

Figure 5.6: Plan View of Ward's Island Promenade Option 4

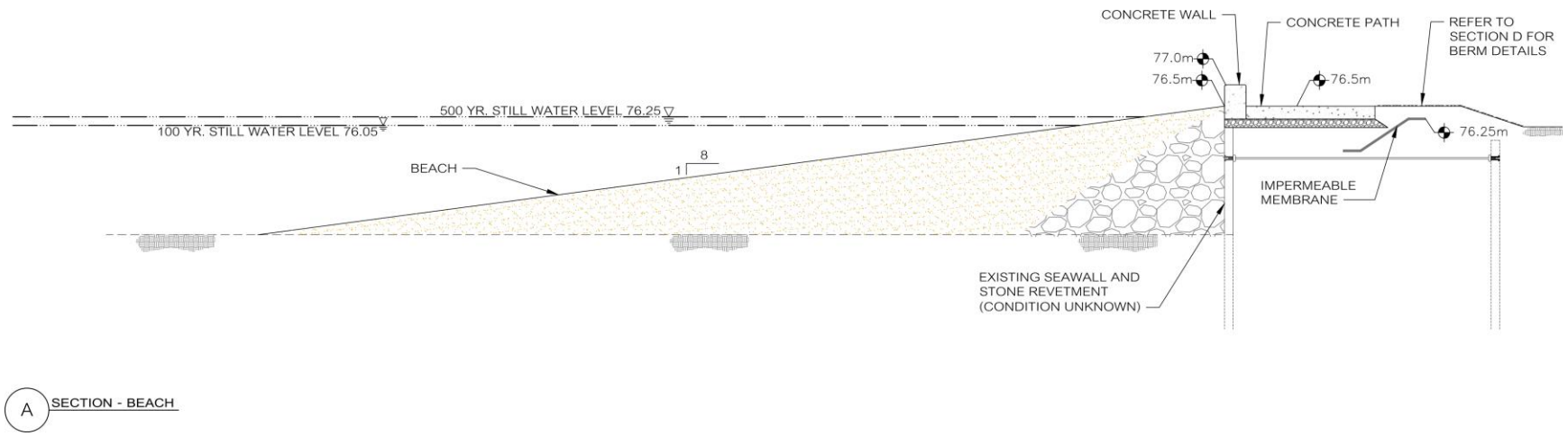

Figure 5.7: Profile of Ward's Island Promenade and Beach

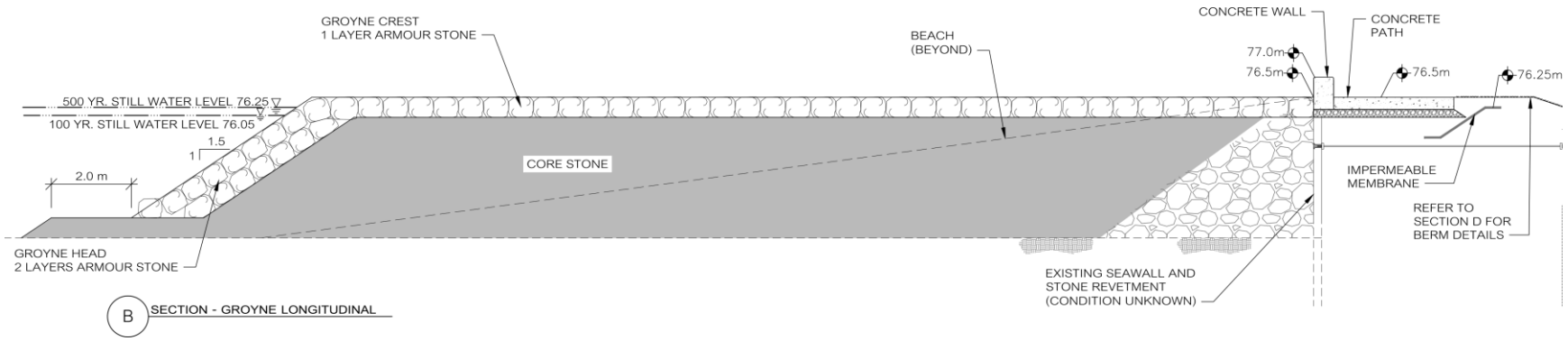

Figure 5.8: Profile of Ward's Island Promenade and Groyne

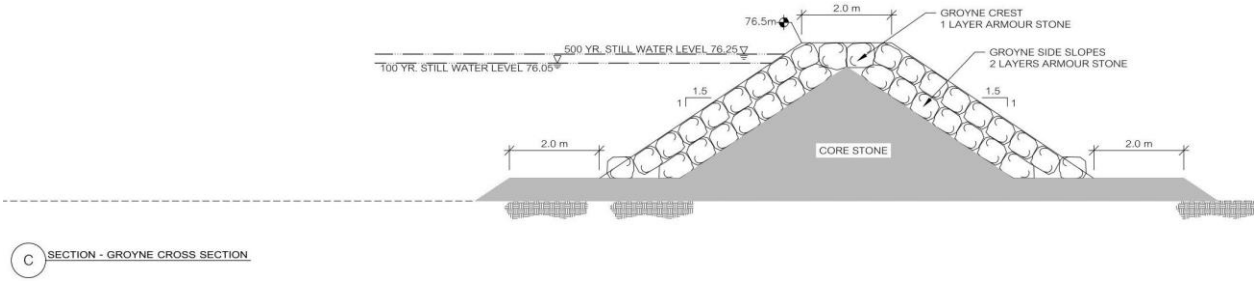

Figure 5.9: Cross-section of Ward's Island Groyne

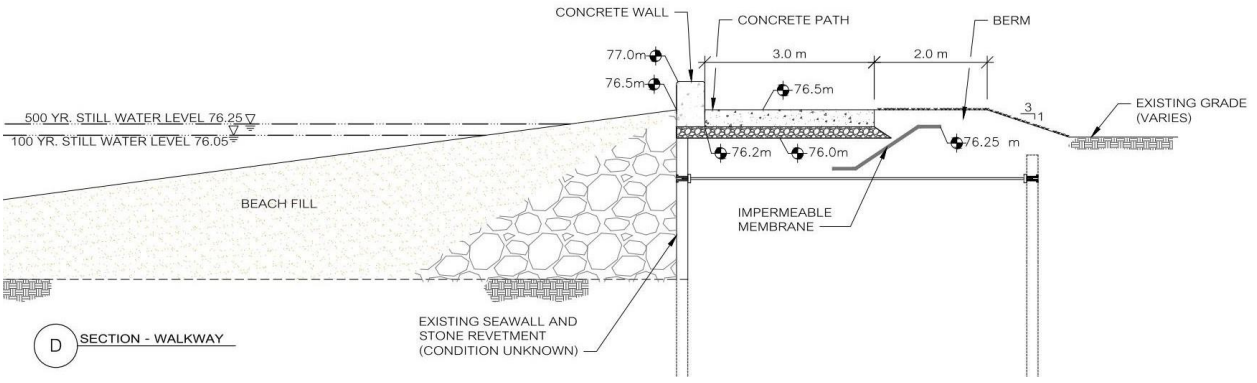

Figure 5.10: Profile of Ward's Island Promenade

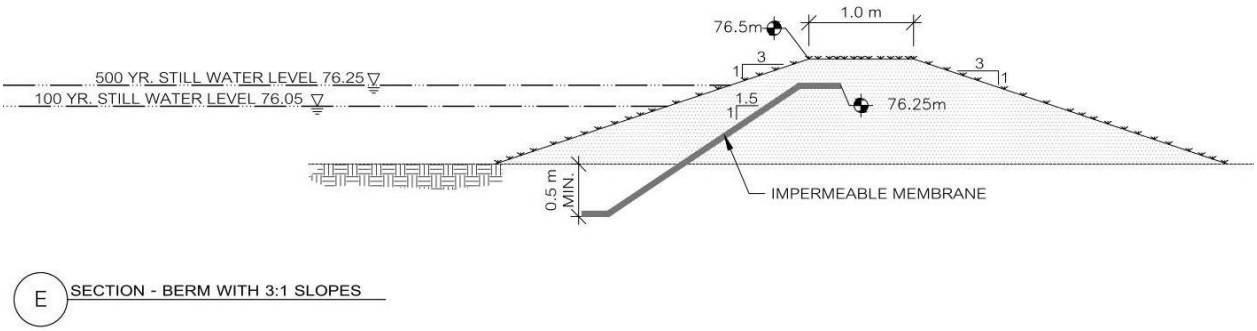

Figure 5.11: Cross-section of Berm

5.4 Algonquin Island Berm and Flood Wall

The Algonquin Island seawall is a steel sheet pile wall with a relatively low crest elevation. A structural assessment of the wall by Baird and Reinders (1994) reported that the wall was in good condition. The current condition of the wall is not known and should be evaluated at the next stage of the design.

An approximately 1 m high berm is proposed along the Algonquin Island seawall to reduce the volume of wave overtopping (see Figure 5.12). The crest of the berm along the seawall is 0.5 m higher than the standard berm elevation due to the greater wave exposure at the seawall (compared to areas further inland). The berm would extend from the Queen City Yacht Club to the Algonquin Island Association clubhouse before transitioning to the standard berm cross-section (76.5 m crest elevation). The berm continues from the clubhouse to the intersection of Wyandot Ave. and Omaha Ave. (see Figure 5.14). The berm will occupy nearly the entire grassy strip between the seawall and Seneca Ave. A walking trail is not proposed on the berm crest due to space limitations. Other configurations, such as a retaining wall or steps on the backslope could be considered in the next phase of the study if a wider crest (and possibly a walking trail) is desired.

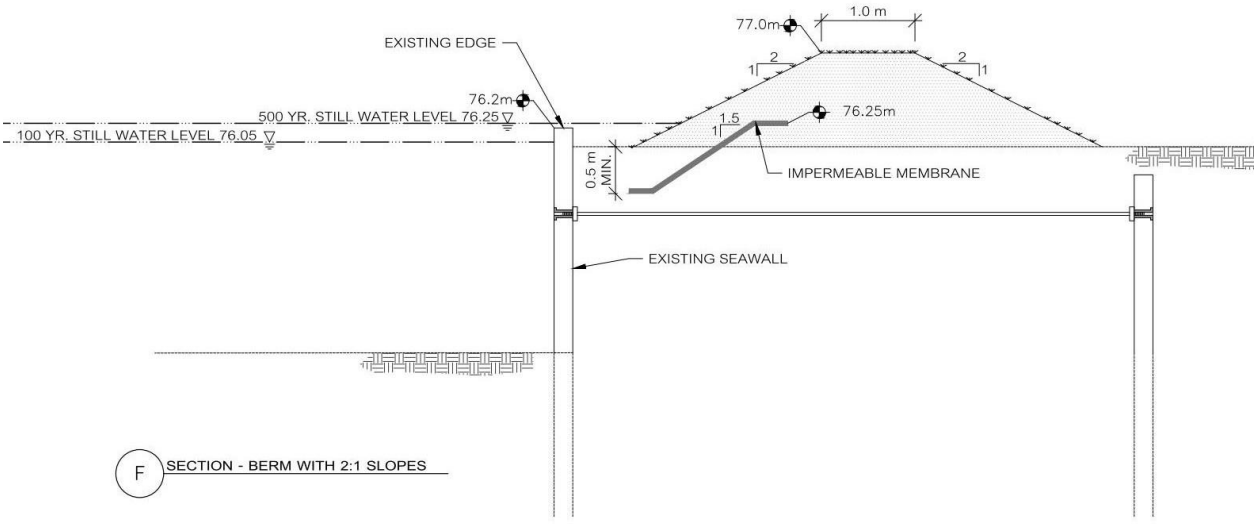

Figure 5.12: Cross-section of Algonquin Island Berm Along Seawall

A concrete flood wall is proposed behind the homes on Nottawa Ave. that back onto the Queen City Yacht Club as there isn't sufficient space for a berm. However, the possibility of using a berm at this location should be discussed with home owners and the yacht club. A conceptual drawing of the flood wall is shown in Figure 5.13. A perforated drain along the interior of the wall is proposed to direct water towards the existing sump on Seneca Ave.

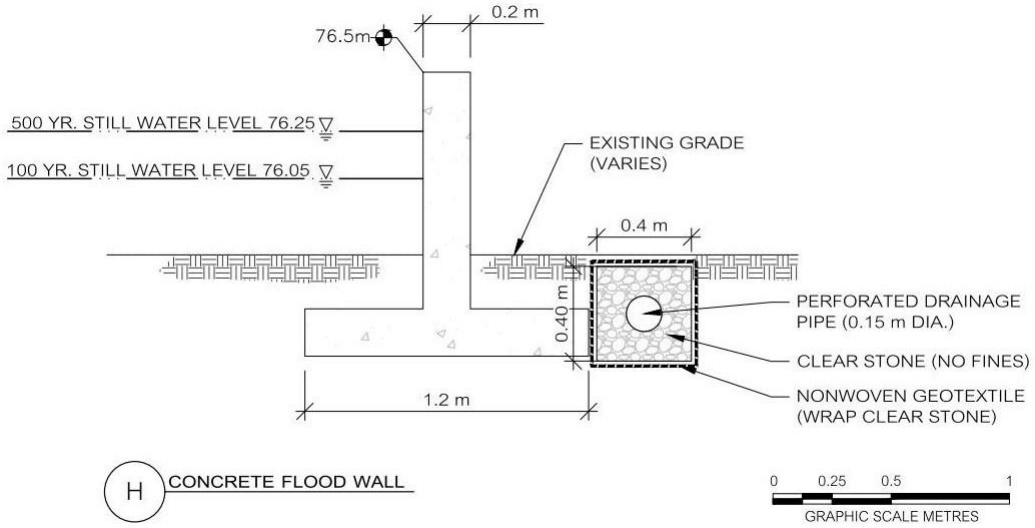

Figure 5.13: Cross-section of Algonquin Island Flood Wall

Two smaller berms are also proposed near the Queen City Yacht Club. The larger of the two berms connects with the concrete flood wall and protects four of the Queen City Yacht Club buildings. The smaller berm connects the east end of the flood wall with Nottawa Ave. The Queen City Yacht Club clubhouse is one of the lowest buildings on the islands. The feasibility and cost of elevating the structure should be investigated.

Figure 5.14: Plan View of Algonquin Island Berm, Algonquin Island Flood wall, and Cibola Ave. Berm

5.5 Cibola Ave. Berm

A berm is proposed along the west side of Cibola Ave. between the Ward's Island ferry dock and the Fire Station. A berm is expected to be substantially less expensive than elevating the road. The location of the berm is shown in Figure 5.14.

5.6 Centreville Flood Protection

The Centreville Amusement Park was highly impacted by the 2017 flooding. Considering that the Centreville train encircles nearly all of the Centreville buildings, an idea was put forth in the meetings to rebuild the trackbed to also function as a flood protection berm. The berm could be built parallel to the trackbed or the trackbed could be raised and reconstructed with an impermeable liner. Similar to the other berm locations, 1 or 2 m wide gaps in the berm or culverts with one-way valves would be required to allow rainwater to drain towards the lake. These gaps would be closed with sandbags, stoplogs, gates, or other deployable barriers during high lake levels. Sumps are also proposed at four low spots within the Centreville property. The location of the berm and sumps are shown in Figure 5.15.

Other flood mitigation concepts were discussed for Centreville including the use of temporary water-filled rubber/synthetic barriers, elevating buildings and land using fill, and installing a water control structure at the entrance to the pond. These options are believed to be less desirable or less effective than the perimeter berm concept.

Figure 5.15: Plan View of Centreville Flood Protection

5.7 Island Water Treatment Plant Flood Protection

The seawall at the Island Water Treatment Plant was partially inundated in 2017. The proposed concept for the seawall is to replace the temporary jersey barriers with a 0.7 m high by 0.5 m wide concrete wall (see Figure 5.16). The wall could be joined/sealed to the existing seawall deck using a rubber or neoprene membrane and dowels. A small berm around the parking area and elevating most of Service Rd. is also recommended (see Figure 5.17).

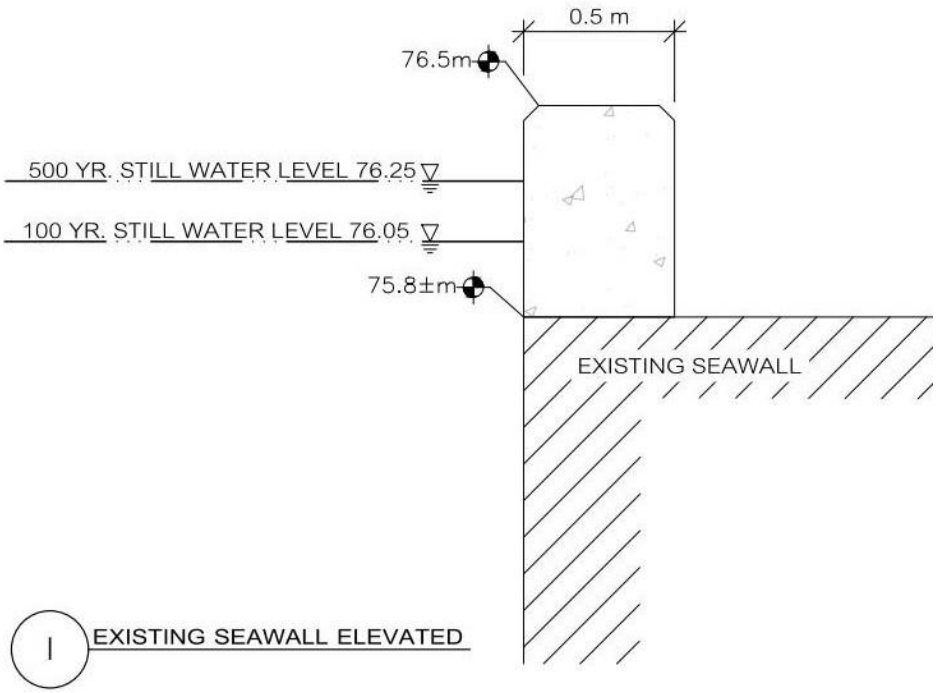

Figure 5.16: Cross-section of Island Water Treatment Plant Concrete Wall on Existing Seawall

Figure 5.17: Plan View of Island Water Treatment Plant Flood Protection

5.8 Road Improvements

Portions of the arterial roads are flooded at moderate flood levels. Low spots should be elevated to 76.25 m to provide safe ingress/egress (see Figure 5.18). The proposed locations of the road improvements are shown in the previous plan view figures and Figure 5.19. The most critical areas are Cibola Ave. south of the Fire Station and Lakeshore Ave. at Gibraltar Point.

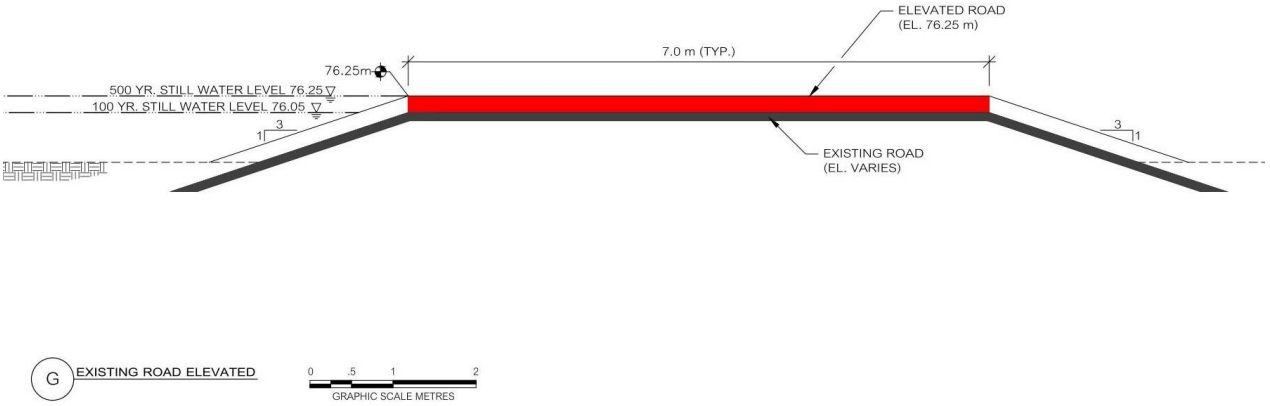

Figure 5.18: Cross-section of Road Improvements

Figure 5.19: Plan View of Cibola Ave. and Lakeshore Ave. Road Improvements

6. Budgetary Cost Estimate

A budgetary cost estimate for the proposed concepts was prepared based on the estimated material quantities and unit rates from previous Baird projects in Ontario. The quantity estimates are subject to uncertainties due to factors unknown to Baird at the time of the study. Additionally, the unit rates are based on past project experience and may not reflect current conditions.

A markup of 10% was applied to the estimates for mobilization, which accounts for some of the challenges with transporting equipment and materials to the islands. An additional 10% markup was applied for landscaping, which is typical for shoreline projects but is likely an overestimate for the road works. Lastly, a 20% contingency was added to the estimates to account for unknowns at this stage of the project.

The estimated construction costs of the flood protection options developed for Ward's Island vary between $180,000 and $2,218,000 (see Table 6.1). Option 4, the berm only option, has the lowest construction cost. The costs associated with Options 1 to 3 depend on the length of the promenade and number of groynes and beaches.

The project has a total estimated cost between $13.9M and $16.0M depending on the flood protection option for Ward's Island. The full promenade concept plus berm (Option 1) has an estimated cost of $2,218,000. Option 2 has an estimated cost of $1,344,000. Option 3 has an estimated cost of $679,000. Option 4, the berm only option, has an estimated cost of $180,000.

The Algonquin Island berm and flood wall has an estimated cost of $487,000. The cost of mobilizing equipment and materials to Algonquin Island may be higher due to fewer access options (e.g. barges may be required).

The Centreville berm has an estimated construction cost of $331,000. This cost assumes that the berm would be built adjacent to the trackbed and does not include removal and reinstatement of the train tracks.

The berm along Cibola Ave. from the ferry dock to the Fire Hall has an estimated cost of $237,000.

The Island Water Treatment Plant seawall modifications and berm have an estimated construction cost of $83,000.

Elevating 3.8 km of Cibola Ave., Lakeshore Ave., Service Rd., Avenue of the Island, and Beach Rd. to the 500-year flood level represents approximately 80% of the total project cost at $12.6M. The road work could possibly be phased such that the roads are raised when they are scheduled for resurfacing.

The materials list, estimated quantities, unit rates, and estimated costs are provided in Table 6.2.

Table 6.1: Budgetary Cost Estimate for Ward's Island Flood Protection Options 1 to 4

Ward's Island Flood Protection Option 1				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	1660	t	$ 40.00	$ 66,400.00
Unreinforced Concrete	270	m^3	$ 600.00	$ 162,000.00
Reinforced Concrete	120	m^3	$ 660.00	$ 79,200.00
Granular B	420	t	$ 30.00	$ 12,587.40
Pre-fab Steel bridge	1	ea.	$ 100,000.00	$ 100,000.00
Terrafix Bentofix GCL	1600	m^2	$ 30.00	$ 48,000.00
Core Stone	2700	t	$ 40.00	$ 108,000.00
Armour Stone	1950	t	$ 130.00	$ 253,500.00
Beach Fill	18500	t	$ 40.00	$ 740,000.00
Excavation	360	m	$ 40.00	$ 14,400.00
Landscaping	1	LS	10%	$ 158,408.74
Contingency	1	LS	20%	$ 316,817.48
Mobilization / Demobilization	1	LS	10%	$ 158,408.74
SUBTOTAL				**$ 2,217,722.36**

Ward's Island Flood Protection Option 2				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	1660	t	$ 40.00	$ 66,400.00
Unreinforced Concrete	140	m^3	$ 600.00	$ 84,000.00
Reinforced Concrete	60	m^3	$ 660.00	$ 39,600.00
Granular B	220	t	$ 30.00	$ 6,600.00
Terrafix Bentofix GCL	1600	m^2	$ 30.00	$ 48,000.00
Core Stone	1800	t	$ 40.00	$ 72,000.00
Armour Stone	1300	t	$ 130.00	$ 169,000.00
Beach Fill	11500	t	$ 40.00	$ 460,000.00
Excavation	360	m	$ 40.00	$ 14,400.00
Landscaping	1	LS	10%	$ 96,000.00
Contingency	1	LS	20%	$ 192,000.00
Mobilization / Demobilization	1	LS	10%	$ 96,000.00
SUBTOTAL				**$ 1,344,000.00**

Ward's Island Flood Protection Option 3				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	1660	t	$ 40.00	$ 66,400.00
Unreinforced Concrete	55	m^3	$ 600.00	$ 33,000.00
Reinforced Concrete	25	m^3	$ 660.00	$ 16,500.00
Granular B	85	t	$ 30.00	$ 2,550.00
Terrafix Bentofix GCL	1600	m^2	$ 30.00	$ 48,000.00
Core Stone	900	t	$ 40.00	$ 36,000.00
Armour Stone	680	t	$ 130.00	$ 88,400.00
Beach Fill	4500	t	$ 40.00	$ 180,000.00
Excavation	360	m	$ 40.00	$ 14,400.00
Landscaping	1	LS	10%	$ 48,525.00
Contingency	1	LS	20%	$ 97,050.00
Mobilization / Demobilization	1	LS	10%	$ 48,525.00
SUBTOTAL				**$ 679,350.00**

Ward's Island Flood Protection Option 4				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	1660	t	$ 40.00	$ 66,400.00
Terrafix Bentofix GCL	1600	m^2	$ 30.00	$ 48,000.00
Excavation	360	m	$ 40.00	$ 14,400.00
Landscaping	1	LS	10%	$ 12,880.00
Contingency	1	LS	20%	$ 25,760.00
Mobilization / Demobilization	1	LS	10%	$ 12,880.00
SUBTOTAL				**$ 180,320.00**

Table 6.2: Budgetary Cost Estimate

1.0 Ward's Island Flood Protection				
				Total
OPTION 1 SUBTOTAL				**$ 2,217,722.36**
OPTION 2 SUBTOTAL				**$ 1,344,000.00**
OPTION 3 SUBTOTAL				**$ 679,350.00**
OPTION 4 SUBTOTAL				**$ 180,320.00**
2.0 Algonquin Island Flood Protection				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	5200	t	$ 40.00	$ 208,000.00
Reinforced Concrete	70	m^3	$ 660.00	$ 46,200.00
Terrafix Bentofix GCL	2750	m^2	$ 30.00	$ 82,500.00
Excavation	280	m	$ 40.00	$ 11,200.00
Landscaping	1	LS	10%	$ 34,790.00
Contingency	1	LS	20%	$ 69,580.00
Mobilization / Demobilization	1	LS	10%	$ 34,790.00
SUBTOTAL				**$ 487,060.00**
3.0 Centreville Flood Protection				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	3500	t	$ 40.00	$ 140,000.00
Terrafix Bentofix GCL	3000	m^2	$ 30.00	$ 90,000.00
Excavation	160	m	$ 40.00	$ 6,400.00
Landscaping	1	LS	10%	$ 23,640.00
Contingency	1	LS	20%	$ 47,280.00
Mobilization / Demobilization	1	LS	10%	$ 23,640.00
SUBTOTAL				**$ 330,960.00**
4.0 Cibola Ave. Flood Protection				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Berm Material	2400	t	$ 40.00	$ 96,000.00
Terrafix Bentofix GCL	2200	m^2	$ 30.00	$ 66,000.00
Excavation	190	m	$ 40.00	$ 7,600.00
Landscaping	1	LS	10%	$ 16,960.00
Contingency	1	LS	20%	$ 33,920.00
Mobilization / Demobilization	1	LS	10%	$ 16,960.00
SUBTOTAL				**$ 237,440.00**
5.0 Island Water Treatment Plant Flood Protection				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Reinforced Concrete	45	m^3	$ 600.00	$ 27,000.00
Berm Material	430	t	$ 40.00	$ 17,200.00
Terrafix Bentofix GCL	380	m^2	$ 30.00	$ 11,400.00
Excavation	95	m	$ 40.00	$ 3,800.00
Landscaping	1	LS	10%	$ 5,940.00
Contingency	1	LS	20%	$ 11,880.00
Mobilization / Demobilization	1	LS	10%	$ 5,940.00
SUBTOTAL				**$ 83,160.00**
6.0 Cibola Ave., Lakeshore Ave., Beach Rd., Avenue of the Island, Service Rd.				
Description	**Qty.**	**Unit**	**Unit Cost**	**Total**
Asphalt	30500	m^2	$ 55.00	$ 1,677,500.00
Asphalt Milling	30500	m^2	$ 140.00	$ 4,270,000.00
Asphalt Base	30500	m^2	$ 45.00	$ 1,372,500.00
Asphalt Ware Course	30500	m^2	$ 55.00	$ 1,677,500.00
Excavation	160	m	$ 40.00	$ 6,400.00
Landscaping	1	LS	10%	$ 900,390.00
Contingency	1	LS	20%	$ 1,800,780.00
Mobilization / Demobilization	1	LS	10%	$ 900,390.00
SUBTOTAL				**$ 12,605,460.00**
TOTAL				**$13,924,400 to $15,961,802**

7. Next Steps and Future Study Requirements

Site investigations and further studies will be required to advance the conceptual designs. Namely, geotechnical investigations will be required to estimate the hydraulic conductivity of the soils, seepage rates at different lake levels, and pumping requirements. The Toronto Islands Shoreline Management Study (Baird and Reinders, 1994) stated that dykes and pumping systems would not be feasible due to the high permeability of the sandy soils. Test pits, boreholes, slug tests, etc. should be conducted within the areas enclosed by the proposed berms to asses the feasibility of the berm concept. Seepage rates (and pumping requirements) will be greater at higher lake levels.

Tasks that may be required to further develop and implement the conceptual designs include:

- Geotechnical investigations and analyses to determine hydraulic conductivity of soils (seepage and pumping requirements), design impermeable barrier system (Geosynthetic Clay Liner, cutoff wall, etc.), determine bearing capacity of soils, etc.
- Structural assessments of Ward's Island revetment and Algonquin Island seawall
- Topographic and bathymetric surveys at locations of proposed structures
- Assessment of land subsidence
- Determination of level of acceptable risk
- Confirmation of environmental design conditions (water levels, waves, ice, freeboard, etc.)
- Confirmation of regulatory requirements
- Evaluation of other alternatives (e.g. elevate buildings using fill)
- Identification of priority areas
- Preliminary designs
- Rainwater drainage plan
- Materials investigation, construction approach, cost estimates
- Landscaping plans (including options to naturalize parts of the shoreline and incorporate habitat into the flood protection features)
- Final designs and tender package

Regulatory requirements may include:

- Fisheries Act (Fisheries and Oceans Canada)
- Navigable Waters Protection Act (Transport Canada)
- Public Lands Act (Ontario Ministry of Natural Resources and Forestry)
- Lakes and Rivers Improvement Act (Ontario Ministry of Natural Resources and Forestry)
- Environmental Assessments Act – Municipal Class Environmental Assessment (Ontario Ministry of the Environment, Conservation and Parks)
- Class Environmental Assessment for Remedial Flood and Erosion Control Projects (Conservation Ontario)
- Harbour Master Authorization (Toronto Port Authority)
- Municipal regulations (City of Toronto)

Study-related costs are typically around 10% of construction costs for complex engineering projects, and are lower for general construction such as road work (1-2%). Based on the estimated construction cost of $3.4M for the flood protection works, and $12.6M for the road works, the total estimated study-related costs are approximately $550,000.

8. Conclusions and Recommendations

The City of Toronto, TRCA, and Baird met in December 2018 to discuss flood mitigation alternatives for the Toronto Islands. The brainstorming workshop identified leading alternatives for the areas most affected by the 2017 flood. The alternatives built upon recommendations made by Toronto Island residents (French, 2017) and include protecting low-lying residential areas with a berm or dyke structure, elevating low-lying roads, increasing the crest elevation of shore protection structures, and directing surface drainage to the sumps that were installed in 2018.

This report presents the conceptual designs, estimated quantities, and budgetary cost estimates for the flood mitigation alternatives described below:

- **Ward's Island Promenade:** a multi-functional flood protection/recreation structure consisting of a berm, pathway, groynes, beaches, and small bridge over the Ward's Island cove. The structure extends from the Ward's Island ferry dock to the intersection of First Ave. and Lakeshore Ave. The estimated cost of the works varies between $0.18M (Option 4) and $2.22M (Option 1).
- **Algonquin Island Berm and Flood Wall:** an approximately 1 m high berm extending from the Queen City Yacht Club to the Algonquin Island Association clubhouse. The berm transitions to a lower height after the clubhouse and continues to the intersection of Wyandot Ave. and Omaha Ave. A concrete flood wall is proposed along the rear property line of the Nottawa Ave. homes that back onto the Queen City Yacht Club. The estimated cost of the works is $0.49M.
- **Centreville Flood Protection:** a berm parallel to the Centreville train tracks or raise and reconstruct the trackbed with an impermeable liner. Install four sumps at low spots at Centreville. The estimated cost of the berm is $0.33M. The cost of removing and reinstalling the train track was not estimated.
- **Cibola Ave. Berm:** a berm extending along Cibola Ave. from the Ward's Island ferry dock to the Fire Station. The estimated cost of the works is $0.24M.
- **Island Water Treatment Plant:** a low concrete wall along the existing seawall and a berm along the parking lot. The estimated cost of the works is $0.1M.
- **Elevate Arterial Roads:** approximately 3.8 km of Cibola Ave., Lakeshore Ave., Service Rd., Avenue of the Island, and Beach Rd. are low-lying and should be elevated for safe ingress/egress. The estimated cost of the works is $12.6M.

The estimated total cost of the project is between $13.9M and $15.9M depending on the flood protection option for Ward's Island. The highest cost is associated with raising low-lying portions of the roads to the 500-year flood level. A phased approach could be considered, elevating the lowest portions of the roads sooner and elevating other sections when they require resurfacing.

Swales and ditches will be required along the roads and berms to direct rainwater towards the lake and existing sumps. New culverts may be required under the roads. Small gaps (1 to 2 m wide) should be made in the berms and flood walls to prevent rainwater ponding in the interior of the structures. The gaps can be closed with sandbags, stoplogs, gates, or other deployable barriers during high lake levels.

Flood mitigation concepts were not developed for private businesses such as the yacht clubs. Temporary flood protection measures, such as water-filled rubber/synthetic barriers, could be installed when needed. Elevating buildings should be considered for some buildings such as the Queen City Yacht Club clubhouse.

The designs were developed using the 500-year stillwater level for Toronto (static lake level plus storm surge) as the design water level. The level of acceptable risk, construction costs, priority areas, and other factors should be evaluated at the next stage of the design. Next steps should include site investigations and engineering analyses to asses the feasibility of the conceptual designs, confirm the regulatory requirements, and develop preliminary and final designs. The estimated cost of the site investigations and future studies is approximately $550,000.

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Appendix A

Flood Depth Maps (76.2m IGLD)

Toronto Islands Flood Depth Map

Water Level = 76.2 m IGLD85

Tile 1: Toronto City Airport

Basemap Layers

- Community/Assembly Hall
- Fire Station
- Restaurant
- Restroom
- School
- Water Treatment Plant
- Yacht Club
- Sumps
- Sewer Pumps
- Sewer Pump Stations
- Sewer Manholes
- Sewer Lines - Forced Main
- Sewer Lines - Gravity Line
- Pedestrian Trail/Boardwalk
- Paved Path (2 m min)
- Road (4 m min)
- Ferry Routes
- Residential Property Boundary (2018)

Road Flood Depth (m)

- Dry
- 0.01 - 0.3
- 0.31 - 0.6
- >0.60

Flood Depth (m)

- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- 0.41 - 0.5
- 0.51 - 0.6
- 0.61 - 0.7
- 0.71 - 0.8
- 0.81 - 0.9
- 0.91 - 1
- > 1

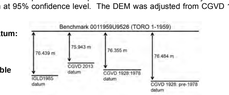
Data Sources

Water depths at Toronto Islands are shown for the specified Lake Ontario water level indicated on this map. Water levels are reported in International Great Lakes Datum 1985 (IGLD85), which is 8.4 cm below Canadian Geodetic Vertical Datum 1928-1978 Ontario Adjusted Version (CGVD 1928:1978), and 49.6 cm below Canadian Geodetic Vertical Datum 2013 (CGVD 2013) at the Canadian Hydrographic Service benchmark 0011959/J9526 (also known as 0015I9J9526, 59J9526, TORO 1-1959). The benchmark is located at the Toronto Harbour Gaugehouse at the south side of Queen's Quay.

Water depths were calculated by subtracting a Digital Elevation Model (DEM) of the land surface from the specified water surface elevation. The DEM was created from LiDAR data flown in April 2014 and April 2015. The vertical accuracy tolerance of the mass point data used to create the DEM is +/- 0.10 m at 95% confidence level. The DEM was adjusted from CGVD 1928:1978 vertical datum to IGLD85 datum by adding 8.4 cm.

To convert between IGLD85 datum and geodetic datum:
IGLD85 = CGVD (1928:1978) + 0.084 m
IGLD85 = CGVD (2013) + 0.496 m

Current water levels for Toronto Harbour are available from Fisheries and Oceans Canada at:
http://www.waterlevels.gc.ca/



Imagery: ESRI Basemap World Imagery. Source: City of Toronto Orthos 2017. Service Layer Credit: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

Other Data Layers: Roads, ferry and property boundary are based on City of Toronto's Open Data Catalogue. Place names are based on Open Steet Map and Google Earth.

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Map Publication Date: April 2019

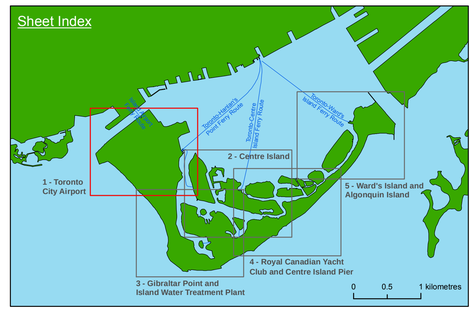
Prepared by:
W.F. Baird & Associates Coastal Engineers, Ltd.

Baird. Innovation Engineered.

Prepared for:
Toronto and Region Conservation Authority

1 cm = 25 m Scale: 1:2,500
0 50 100 metres

Grid Spacing: 50 metres
Coordinate System: Universal Transverse Mercator, Zone 17N, North American Datum 1983



Toronto Islands Flood Depth Map

Water Level = 76.2 m IGLD85

Tile 2: Centre Island

Basemap Layers

- Community/Assembly Hall
- Fire Station
- Restaurant
- Restroom
- School
- Water Treatment Plant
- Yacht Club
- Sumps
- Sewer Pumps
- Sewer Pump Stations
- Sewer Manholes
- Sewer Lines - Forced Main
- Sewer Lines - Gravity Line
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Imagery: ESRI Basemap World Imagery. Source: City of Toronto Orthos 2017, Service Layer Credit: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

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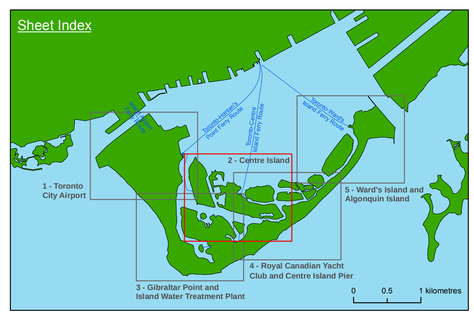
Sheet Index



Toronto Islands Flood Depth Map

Water Level = 76.2 m IGLD85

Tile 3: Gibraltar Point and Island Water Treatment Plant

Basemap Layers

- Community/Assembly Hall
- Fire Station
- Restaurant
- Restroom
- School
- Water Treatment Plant
- Yacht Club
- Sumps
- Sewer Pumps
- Sewer Pump Stations
- Sewer Manholes
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- 0.61 - 0.7
- 0.71 - 0.8
- 0.81 - 0.9
- 0.91 - 1
- > 1

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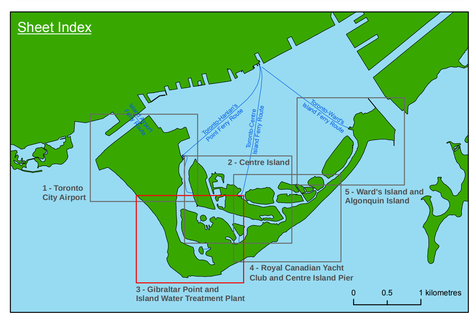
Coordinate System: Universal Transverse Mercator, Zone 17N, North American Datum 1983

Sheet Index



Toronto Islands Flood Depth Map

Water Level = 76.2 m IGLD85

Tile 4: Royal Canadian Yacht Club and Centre Island Pier

Basemap Layers

- Community/Assembly Hall
- Fire Station
- Restaurant
- Restroom
- School
- Water Treatment Plant
- Yacht Club
- Sumps
- Sewer Pumps
- Sewer Pump Stations
- Sewer Manholes
- Sewer Lines - Forced Main
- Sewer Lines - Gravity Line
- Pedestrian Trail/Boardwalk
- Paved Path (2 m min)
- Road (4 m min)
- Ferry Routes
- Residential Property Boundary (2018)

Road Flood Depth (m)

- Dry
- 0.01 - 0.3
- 0.31 - 0.6
- >0.60

Flood Depth (m)

- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- 0.41 - 0.5
- 0.51 - 0.6
- 0.61 - 0.7
- 0.71 - 0.8
- 0.81 - 0.9
- 0.91 - 1
- > 1

Data Sources

Water depths at Toronto Islands are shown for the specified Lake Ontario water level indicated on this map. Water levels are reported in International Great Lakes Datum 1985 (IGLD85), which is 8.4 cm below Canadian Geodetic Vertical Datum 1928-1978 Ontario Adjusted Version (CGVD 1928:1978), and 49.6 cm below Canadian Geodetic Vertical Datum 2013 (CGVD 2013) at the Canadian Hydrographic Service benchmark 0011959U9526 (also known as 00159U9526, 59U9526, TORO 1-1959). The benchmark is located at the Toronto Harbour Gaugehouse at the south side of Queen's Quay.

Water depths were calculated by subtracting a Digital Elevation Model (DEM) of the land surface from the specified water surface elevation. The DEM was created from LiDAR data flown in April 2014 and April 2015. The vertical accuracy tolerance of the mass point data used to create the DEM is +/- 0.10 m at 95% confidence level. The DEM was adjusted from CGVD 1928:1978 vertical datum to IGLD85 datum by adding 8.4 cm.

To convert between IGLD85 datum and geodetic datum:
IGLD85 = CGVD (1928:1978) + 0.084 m
IGLD85 = CGVD (2013) + 0.496 m

Current water levels for Toronto Harbour are available from Fisheries and Oceans Canada at:
http://www.waterlevels.gc.ca/

Imagery: ESRI Basemap World Imagery. Source: City of Toronto Orthos 2017. Service Layer Credit: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

Other Data Layers: Roads, ferry and property boundary are based on City of Toronto's Open Data Catalogue. Place names are based on Open Steet Map and Google Earth.

Notes: Every reasonable effort has been made to ensure the accuracy of this map. However, neither Toronto and Region Conservation Authority or Baird assume any liability arising from its use. This map is provided without warranty of any kind, either expressed or implied.

Map Publication Date: April 2019

Prepared by:
W.F. Baird & Associates Coastal Engineers, Ltd.

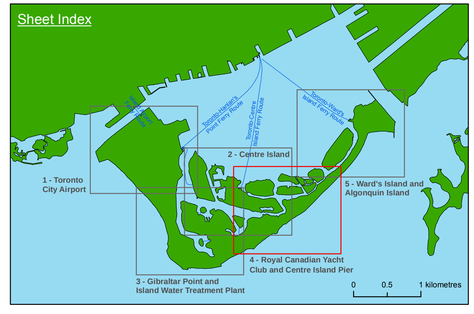
Baird. Innovation Engineered.

Prepared for:
Toronto and Region Conservation Authority

1 cm = 25 m Scale: 1:2,500
0 50 100 metres

Grid Spacing: 50 metres
Coordinate System: Universal Transverse Mercator, Zone 17N, North American Datum 1983

Sheet Index



Toronto Islands Flood Depth Map

Water Level = 76.2 m IGLD85

Tile 5: Ward's Island and Algonquin Island

Basemap Layers

- Community/Assembly Hall
- Fire Station
- Restaurant
- Restroom
- School
- Water Treatment Plant
- Yacht Club
- Sumps
- Sewer Pumps
- Sewer Pump Stations
- Sewer Manholes
- Sewer Lines - Forced Main
- Sewer Lines - Gravity Line
- Pedestrian Trail/Boardwalk
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- 0.31 - 0.6
- >0.60

Flood Depth (m)

- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- 0.41 - 0.5
- 0.51 - 0.6
- 0.61 - 0.7
- 0.71 - 0.8
- 0.81 - 0.9
- 0.91 - 1
- > 1

Data Sources

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Grid Spacing: 50 metres
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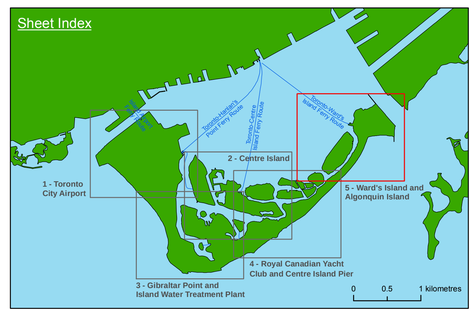

Appendix B

Conceptual Designs of Flood Mitigation Alternatives

LAYOUT PLAN - OVERVIEW

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 150 300 600
GRAPHIC SCALE METRES

NORTH

Project Number: 13017.101

Date: 2019-04-30

Baird.

Toronto and Region Conservation Authority

WARD'S ISLAND - OPTION 1

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 12.5 25 50

GRAPHIC SCALE METRES

NORTH

Project Number: 13017.101

Date: 2019-04-30

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Toronto and Region Conservation Authority

WARD'S ISLAND - OPTION 2

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 12.5 25 50
GRAPHIC SCALE METRES

NORTH

Project Number: 13017.101

Date: 2019-04-30

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BERM TOE (VARIES)

BERM CREST (76.5m)

GROYNE CREST (76.5 m)

GROYNE TOE (VARIES)

CONCRETE WALL

3 m WIDE CONCRETE PATH ON BERM

TIE IN TO EXISTING PATHWAY

SWALE

MINIMIZE DAMAGE TO EXISTING TREES WHERE POSSIBLE

BERM CREST (76.5m)

BERM TOE (VARIES)

BAYVIEW AVE.

CHANNEL AVE.

FIRST ST.

SECOND ST.

THIRD ST.

FOURTH ST.

FIFTH ST.

SIXTH ST.

THIRD ST.

FOURTH ST.

FIFTH ST.

B C D E S

LEGEND

- EXISTING SUMP
- PROPOSED SUMP
- BEACH
- ARMOUR STONE
- CONCRETE PATH
- BERM
- CONCRETE WALL
- PEDESTRIAN BRIDGE
- SWALE
- CONCRETE FLOOD WALL
- ELEVATED SEAWALL
- ELEVATED ROADWAY

WARD'S ISLAND - OPTION 3

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 12.5 25 50

GRAPHIC SCALE METRES

NORTH

Project Number: 13017.101

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WARD'S ISLAND - OPTION 4

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 12.5 25 50
GRAPHIC SCALE METRES

NORTH

Project Number: 13017.101

Date: 2019-04-30

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TRANSITION
BERM CREST (77.0m)
BERM TOE (VARIES)
3 m WIDE CONCRETE PATH ON BERM
CONCRETE FLOOD WALL
MINIMIZE DAMAGE TO EXISTING TREES WHERE POSSIBLE
BERM CREST (76.5 m)
BERM TOE (VARIES)
BERM TOE (VARIES)
BERM CREST (77.0m)
EXISTING ROAD ELEVATED
BERM TOE (VARIES)
BERM CREST (77.0m)
SWALE (TYP.)
BERM CREST (76.5m)
FIRE STATION
SENECA AVE.
WYANDOT AVE.
DACOTAH AVE.
ONEIDA AVE.
OJIBWAY AVE.
NOTTAWA AVE.
OMAHA AVE.
CIBOLA AVE.
E
F
G
H
S

LEGEND
- EXISTING SUMP
- PROPOSED SUMP
- BEACH
- ARMOUR STONE
- CONCRETE PATH
- BERM
- CONCRETE WALL
- PEDESTRIAN BRIDGE
- SWALE
- CONCRETE FLOOD WALL
- ELEVATED SEAWALL
- ELEVATED ROADWAY

ALGONQUIN ISLAND

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 25 50 100
GRAPHIC SCALE METRES

NORTH

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GIBRALTAR POINT & ISLAND FILTRATION PLANT

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 25 50 100
GRAPHIC SCALE METRES

NORTH

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EXISTING ROAD ELEVATED

CENTRE ISLAND DOCK

EXISTING ROAD ELEVATED

AVENUE OF THE ISLAND

EXISTING ROAD ELEVATED

REMOVE AND REPLACE EXISTING TRAIN TRACK ON NEW BERM

PROPOSED SUMP (TYP.)

BERM TOE (VARIES)

BERM CREST (76.5m)

REMOVE AND REPLACE EXISTING TRAIN TRACK ON NEW BERM

LEGEND

- EXISTING SUMP
- PROPOSED SUMP
- BEACH
- ARMOUR STONE
- CONCRETE PATH
- BERM
- CONCRETE WALL
- PEDESTRIAN BRIDGE
- SWALE
- CONCRETE FLOOD WALL
- ELEVATED SEAWALL
- ELEVATED ROADWAY

CENTRE ISLAND

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 25 50 100
GRAPHIC SCALE METRES

NORTH

Project Number: 13017.101

Date: 2019-04-30

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Toronto and Region Conservation Authority

LAKESHORE AVE. & BEACH RD.

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

CIBOLA AVE.

TORONTO ISLANDS FLOOD AND RISK ASSESSMENT

0 40 80 160

GRAPHIC SCALE METRES

Project Number: 13017.101

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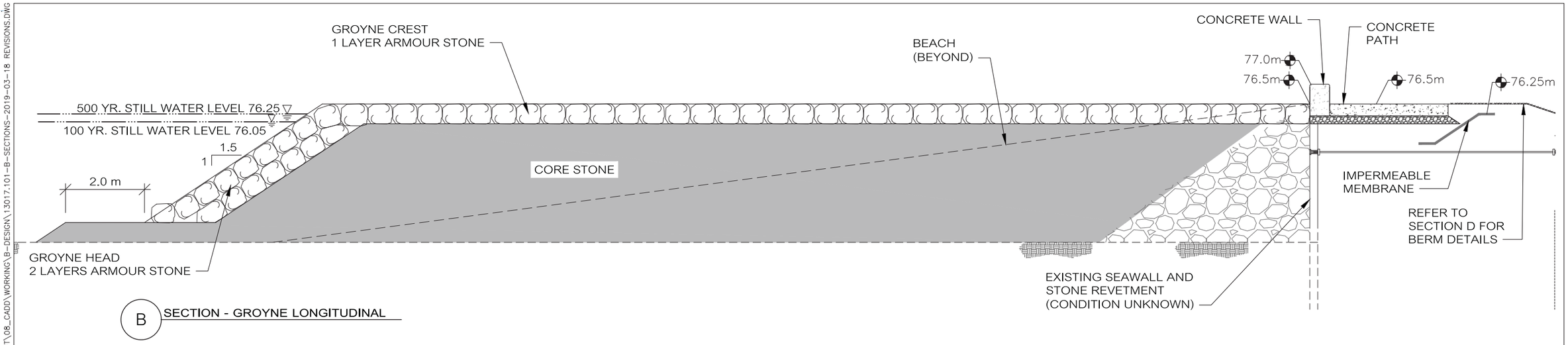

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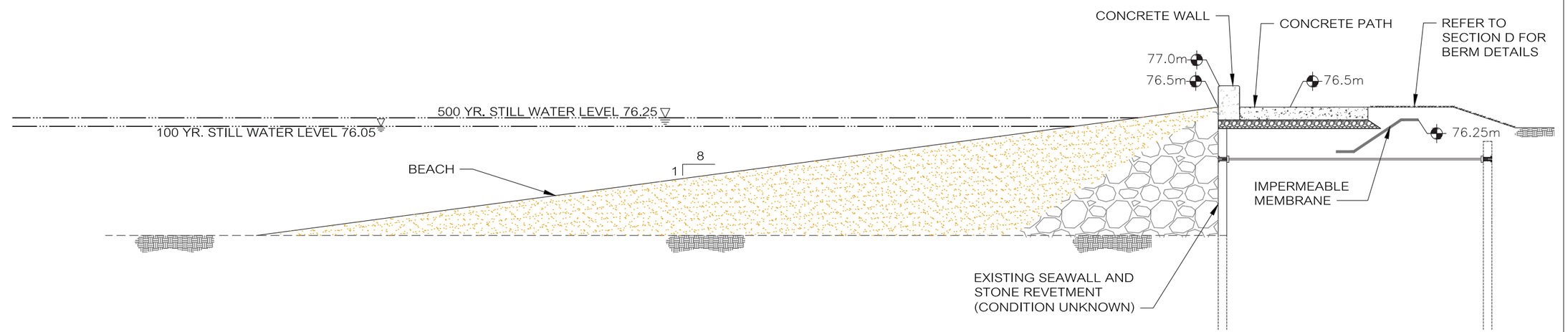

A SECTION - BEACH

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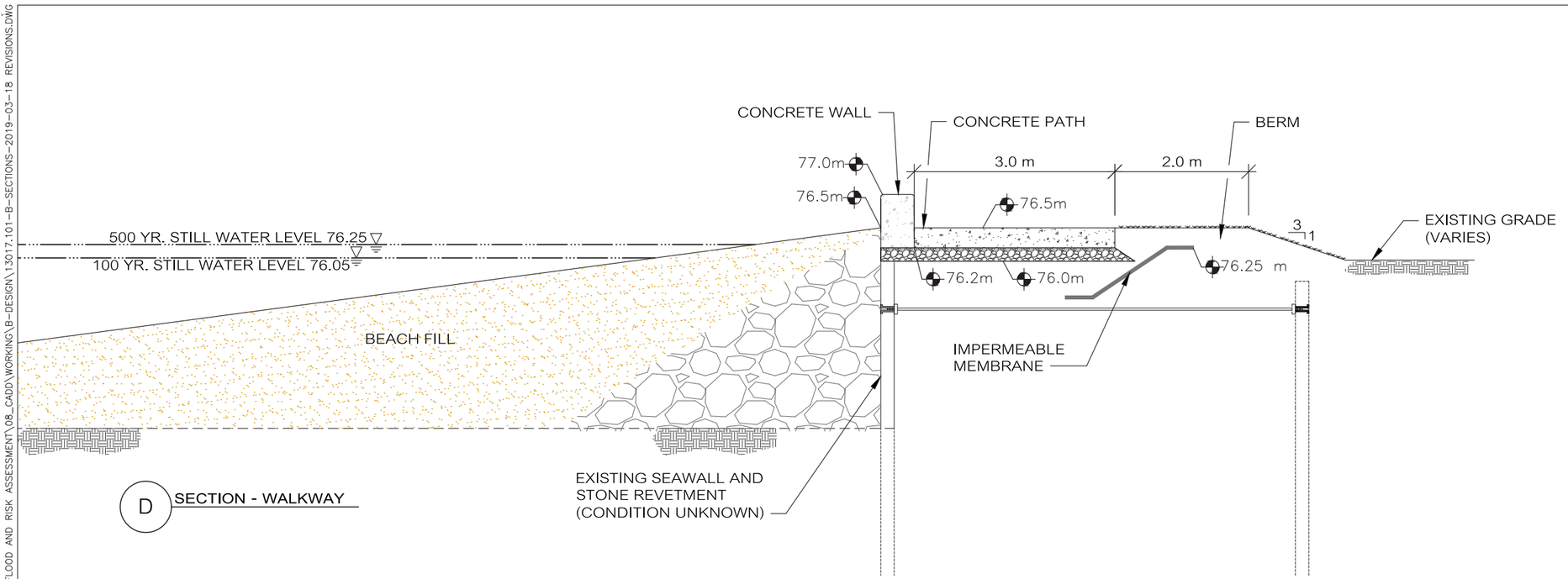

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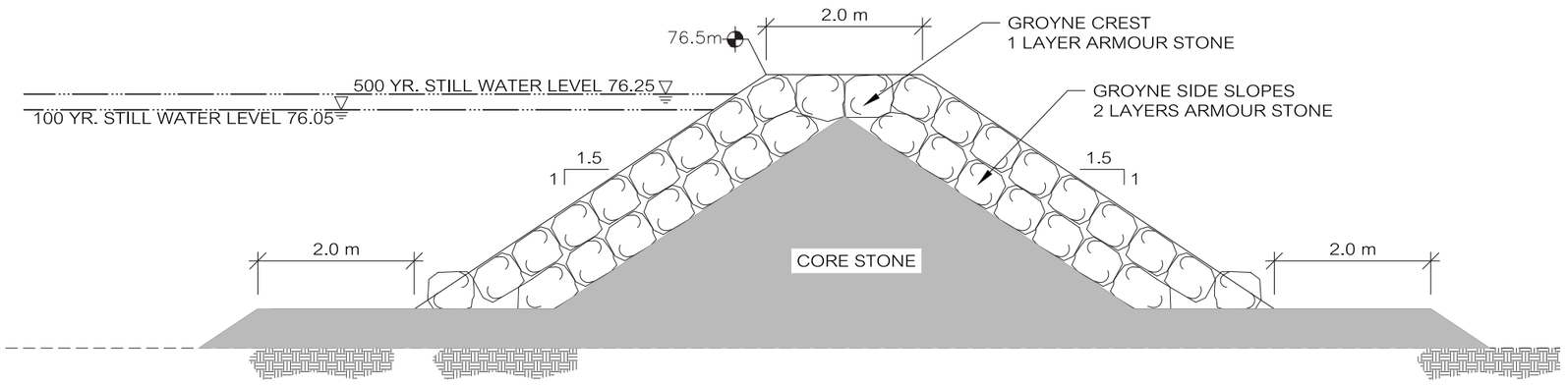

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TYPICAL SECTIONS

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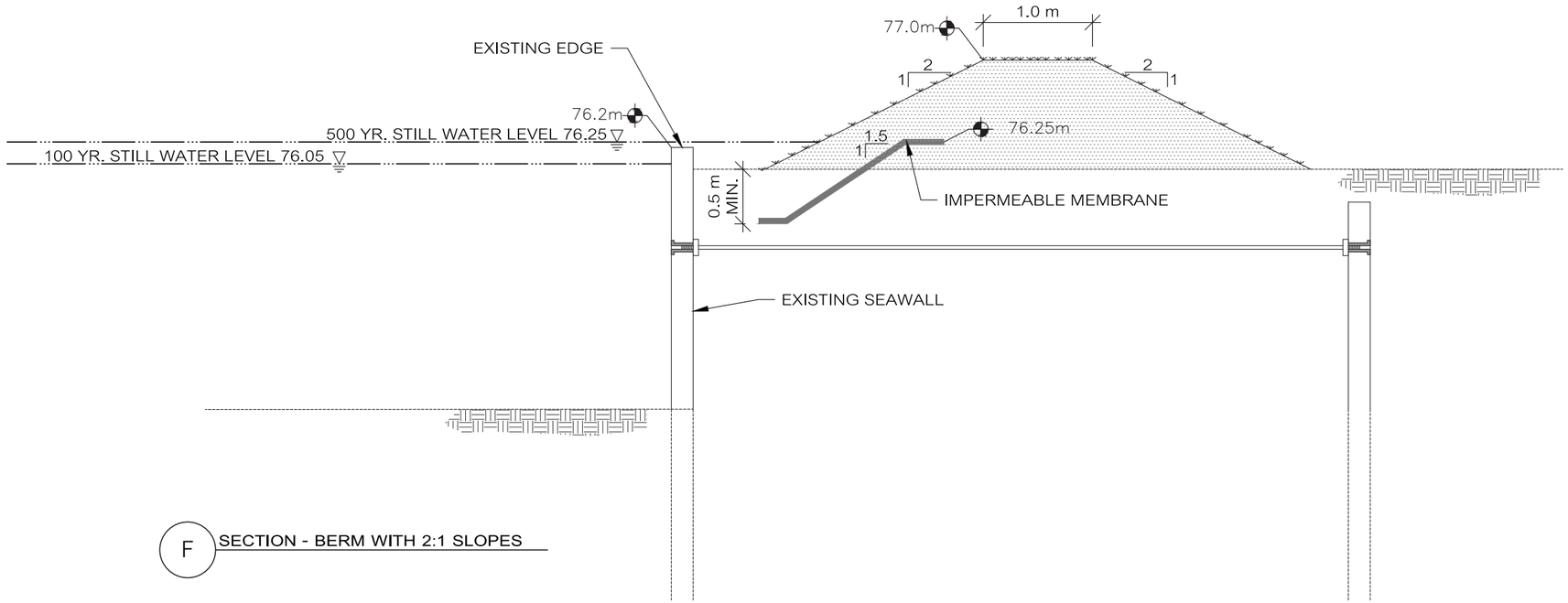

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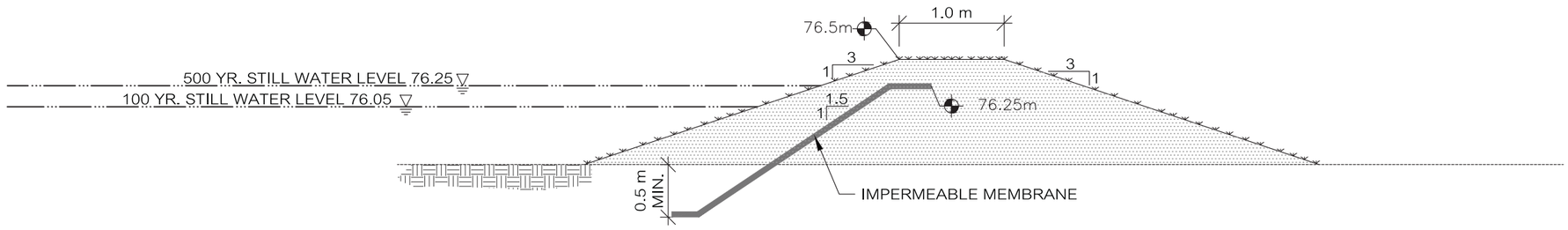

E SECTION - BERM WITH 3:1 SLOPES

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TYPICAL SECTIONS

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Project Number: 13017.101

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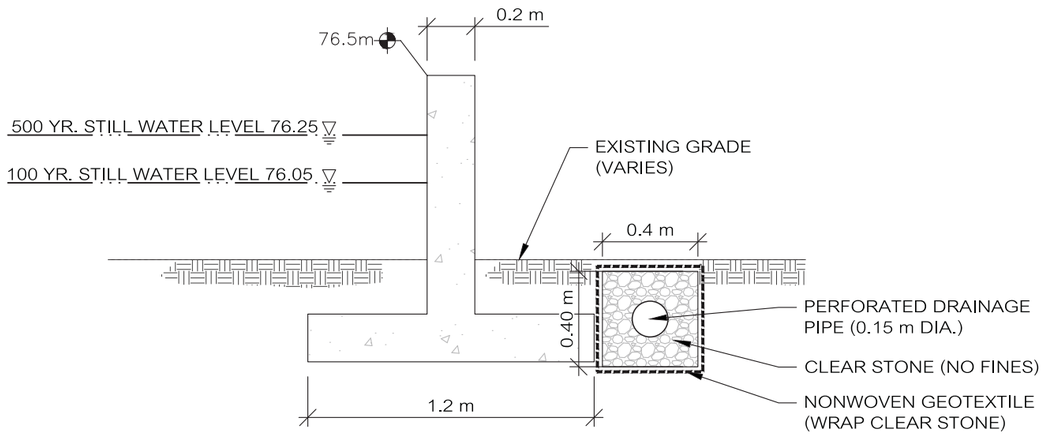
Toronto and Region Conservation Authority



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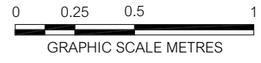

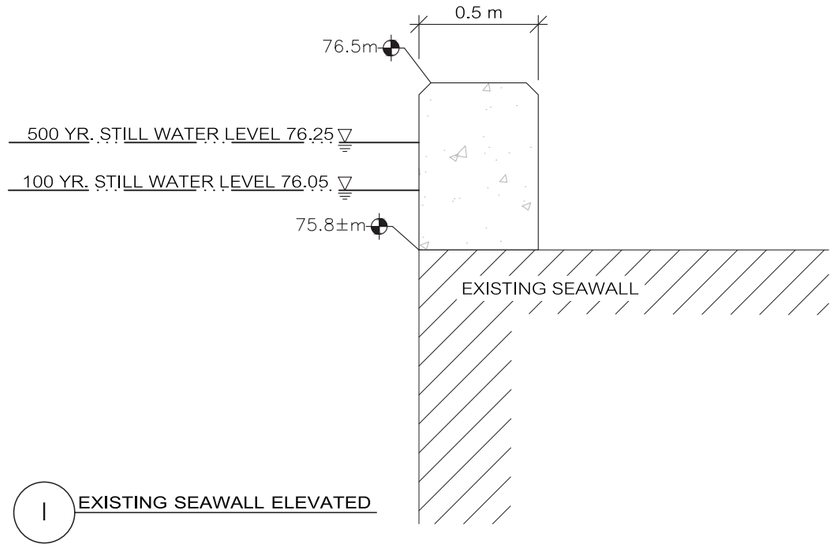

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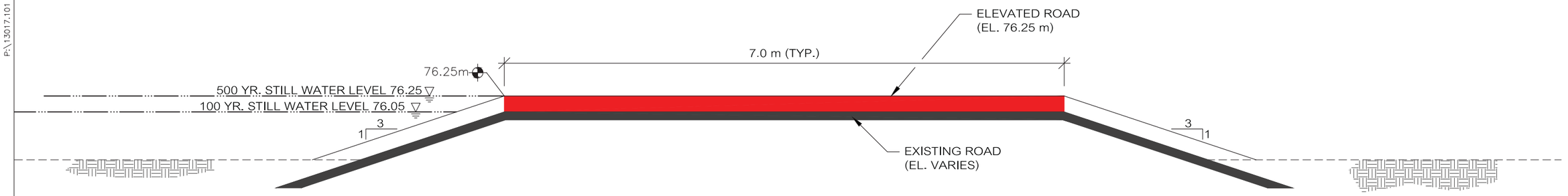
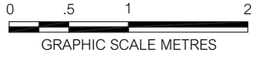


G EXISTING ROAD ELEVATED



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TYPICAL SECTIONS

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