NATIONAL DISASTER MITIGATION PROGRAM: Risk Assessment Study

Final Report

CBCL LIMITED

Consulting Engineers

Prepared for

WEST HANTS

NOVA SCOTIA

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CBCL LIMITED
Consulting Engineers

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PROVINCE OF NOVA SCOTIA

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1 Introduction

1.1 Purpose of Study

The shores of the Minas Basin and the Avon River run along 13 coastal communities within the Municipality of West Hants. The coastal zone of these communities features agricultural land, residential areas and historic sites, such as the Avondale Wharf. Route 215 is the main road providing these communities with access to the provincial road network that connects this area with the Avon Region and the rest of the Province.

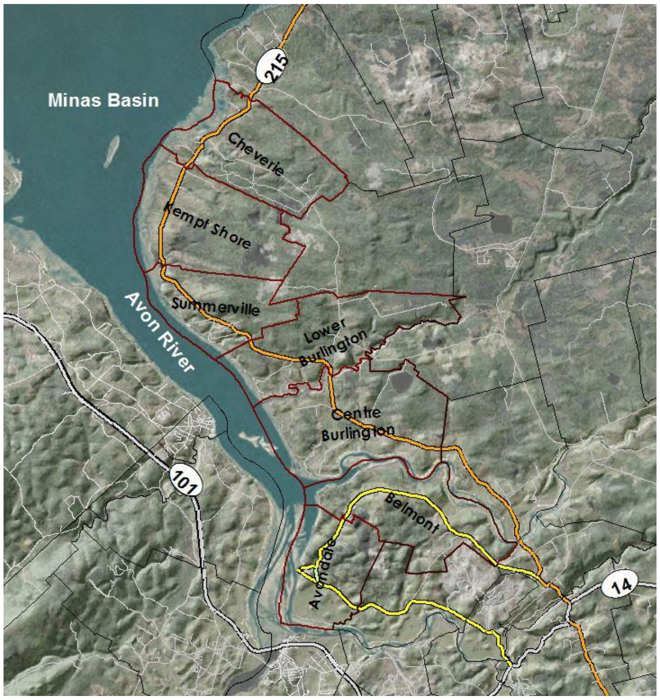


Figure 1.1: Study Area and Road Connectivity

Along the banks of the Kennetcook and the St. Croix Rivers, tributaries to the Avon River, a system of dykes and aboiteaux have historically prevented the high tides of the Bay of Fundy from reaching sections of Route 215 and damaging private and public infrastructure. However, the flooding frequency at Avondale has increased and high coastal water levels have impacted communities between Avondale and Cheverie.

The Municipality of West Hants selected CBCL to evaluate the potential impacts of extreme weather, under current and projected climatic conditions, on the risk of coastal flooding on public infrastructure along the shoreline. This study presents an assessment of potential mitigation measures between Avondale and Cheverie as well as community engagement to assess the priorities and needs of stakeholders and the public at large.

1.2 Study Approach

Flooding hazards along the Avon River and the shores of the Minas Basin are the result of a combination of high tides from the Bay of Fundy, storm surges and waves. Developing an effective flood mitigation plan requires an estimation of potential water levels in the area, which takes into consideration the effect of tidal amplification (i.e., the increase in tidal range and water elevation as the tide enters the Bay of Fundy and its tributaries) and an assessment of the vulnerability of the population and infrastructure at risks. Based on these requirements and the objectives of this assessment, the study was broken down into the following components:

- **Coastal Water Levels Assessment**: Estimation of extreme coastal water levels using historical water level records, tidal predictions from the Canadian Hydrographic Service (CHS) and a 62-year hindcast of offshore wind speeds and wave heights.

- **Hydraulic Model Development and Analysis**: Development of a calibrated coastal model of the Bay of Fundy, the Minas Basin and the Avon River based on historical water levels, estimated extreme water levels and available bathymetric information.
- **Stakeholder Consultation**: Series of meetings and consultations to the public at large and stakeholders including NSDA (Nova Scotia Department of Agriculture) and NSTIR (Nova Scotia Transportation and Infrastructure Renewal).
- **Stormwater Assessment**: Calculation of peak runoff flows in the study area using climate information from Environment Canada and a hydrologic computer model of the watersheds draining into the community. Development of a hydraulic model to assess the hydraulic capacity of dyke-aboiteaux and bridges at risk of being overtopped.
- **Cost-Benefit Assessment of Mitigation Options**: Mapping of areas at risk of flooding, stakeholder engagement to evaluate community needs and priorities, and class D opinion of probable cost to implement the mitigation options under evaluation.
- **Conclusions and Recommendations** for an integrated approach to managing flood risks in the community, based on the findings of this study.

2 Water Level Analysis

2.1 Tides and Storm Surge

Local water levels result from the combined effects of tides, storm surge and sea level rise (SLR). Tides along the Avon River are semi-diurnal in character, with a maximum range of 15.1 m (source: DFO 2018 Canadian Tide and Current Tables). Storm surges are the result of meteorological effects on sea level, such as wind set-up[1] and low atmospheric pressure, and can be defined as the difference between the observed water level during a storm and the predicted astronomical tide. Richards and Daigle (2011) present storm residual estimates for the Port of Saint John. Based on storm surge modelling by Bernier et al. (2006) shown in Figure 2.1, the storm surge residuals at Diligent River and Hantsport were assumed to be similar to those in Saint John. Table 2.1 shows the total extreme still water levels[2] assumed for Diligent River and Hantsport, based on the occurrence of extreme storm surges at higher high water large tide (HHWLT).

Table 2.1: 2018 Tides and Extreme Still Water Levels Estimated for Hantsport (Chart Datum to Canadian Geodetic Vertical Datum Conversion of 7.2 m for Hantsport and 6.375 m at Diligent, as indicated by DFO in per. Comm.)

Extreme Values by Return Period [years]	Hantsport		Diligent River	
	Meters Above Chart Datum (CD)	Meters Above CGVD28	Meters Above Chart Datum (CD)	Meters Above CGVD28
100-yr	16.6	9.4	14.8	8.2
50-yr	16.5	9.3	14.7	8.1
20-year	16.5	9.3	14.7	8.0
10-yr	16.4	9.2	14.6	7.9
5-yr	16.2	9.0	14.4	7.8
1-yr	16.2	9.0	14.4	7.8
2018 Tidal Elevations				
Higher High Water Large Tide (HHWLT)	15.5	8.3	13.7	7.1
Higher High Water Mean Tide (HHWMT)	13.6	6.4	11.9	5.3
Mean Water Level (MWL)	7.5	0.3	6.7	0.1
Lower Low Water Mean Tide (LLWMT)	1.4	-5.8	1.5	-5.1
Lower Low Water Large Tide (LLWLT)	0.2	-7.0	-0.3	-6.9

[1] Wind set-up refers to the increase in mean water level along the coast due to shoreward wind stresses on the water surface.

[2] "Still Water Level" refers to water levels (tidal or extreme storm surge) without wave run-up.

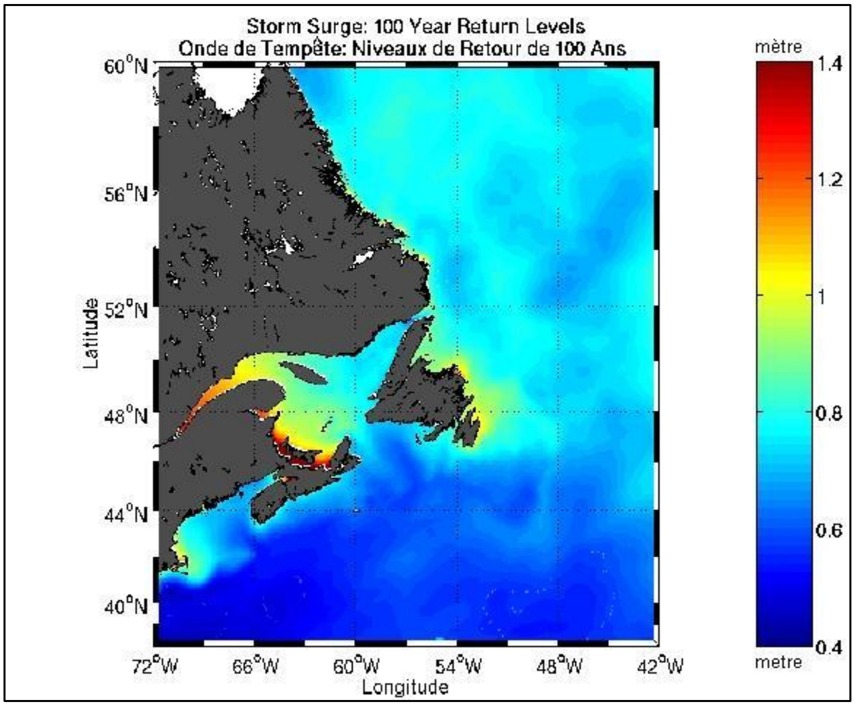


Figure 2.1: Extreme Storm Surge Residual across the Maritimes (Bernier et al. 2006)

2.1.1 Sea Level Rise (SLR)

A typical design life for coastal infrastructure may be close to 75 years with a mid-life refurbishment. For long-term planning purposes, a longer horizon may have to be considered, at least to year 2100. By that time, the site will have experienced significant Sea Level Rise (SLR) caused by climate change and, as a result, extreme water levels with a low return period today will be more common.

The Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5 2013) estimated that the upper-bound Global Mean SLR could be in the order of 1.0 m by year 2100. This upper-bound projection was for Representative Concentration Pathways RCP8.5 scenario, i.e. business-as-usual, high-emission case. At the time there was insufficient evidence to evaluate the probability of specific levels above this 1.0 m projection. DFO then developed the online Canadian Extreme Water Level Adaptation tool, based on the study by Zhai et al. (2014) accounting for local factors. CAN-EWLAT is a science-based planning tool for climate change adaptation of coastal infrastructure related to future water-level extremes. It was developed to provide SLR allowances for DFO harbours across Canada. Allowances are estimates of changes in the elevation of a site that would maintain the same frequency of inundation that the site has experienced historically. CAN-EWLAT was used as a benchmark to forecast relative SLR at Pereaux (Delhaven), in the Minas Basin. For the year 2100, the tool estimates an upper-bound relative SLR of approximately 0.96 m for the IPCC 2013 RCP8.5 scenario, as defined in 2013.

Table 2.2: CAN-EWLAT IPCC 2013 RCP8.5 Scenario – Pereaux, NS

Climate Scenario	CAN-EWLAT, Advocate Harbour, NS – SLR [m]								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
Model RCP8.5	0.04	0.12	0.19	0.29	0.4	0.5	0.63	0.77	0.96

Studies subsequent to the IPCC 2013 and DFO 2014 study suggest that previous Global Mean Sea Level (GMSL) predictions are too modest. These studies updated the scientifically supported upper-end GMSL projections, including recent studies of the potential for rapid ice melt in Greenland and Antarctica. DFO's Han et al. study (2016) revisited projections to include Higher Scenarios. Subsequently, a 2017 NOAA publication (Sweet W. et al., 2017) present a year 2100 GMSL forecast range discretized into six GMSL rise scenarios: a Low (0.3m), Intermediate-Low (0.5m), Intermediate (1.0m), Intermediate-High (1.5m), High (2.0m) and Extreme (2.5m). A key finding was that along regions of the Northeast Atlantic (Virginia coast and northward), regional SLR is projected to be greater than the updated global average for almost all future scenarios (e.g. by 0.3 to 0.5 m under the Intermediate scenario by year 2100). Finally, studies indicate that the human carbon footprint to date has already committed Earth to a long-term GMSL rise of approximately 1.7 m (Clark et al., 2015).

Given these findings, the 2014 DFO estimates based on IPCC AR5 RCP8.5 can now be considered *Intermediate* projections, with *High* and *Extreme* SLR scenarios to range 1.0 to 1.5 m higher than previously anticipated.

In conclusion, a SLR of at least 1.0 m is likely to occur within the coming century, even if the timeline remains uncertain. As a result, maintenance intervals for coastal infrastructure are expected to shorten, and flooding probabilities will significantly increase. The evaluation of options for flood risk mitigation should allow flexibility to accommodate future upgrades for adaptation.

For this study, two time horizons were selected to investigate flooding risks under the effect of sea level rise: year 2050 for medium term planning and 2100 for long term planning. Table 2.3 shows extreme water level projections, a range of extreme events and how water levels considered as the 1 in 100 year event during present conditions increase in frequency by the year 2050 and becomes close to the estimated HHWLT by the year 2100. The water levels are presented for reference as the shape of the bathymetry in the area causes tidal amplification and water surface changes elevation throughout the Avon River and the Minas Basin (Figure 2.2).

Table 2.3: Projected Extreme Water Levels for the Years 2050 and 2100 at Hantsport

Extreme Values by Return Period [years]	Meters above CGVD28		
	2018	2050	2019
100-yr	**9.4**	9.7	10.4
50-yr	9.3	9.6	10.3
20-yr	9.3	9.5	10.1
10-yr	9.2	**9.4**	10.1
5-yr	9.0	9.3	10.0
1-yr	9.0	9.3	9.9
HHWLT	8.3	8.59	**9.26**

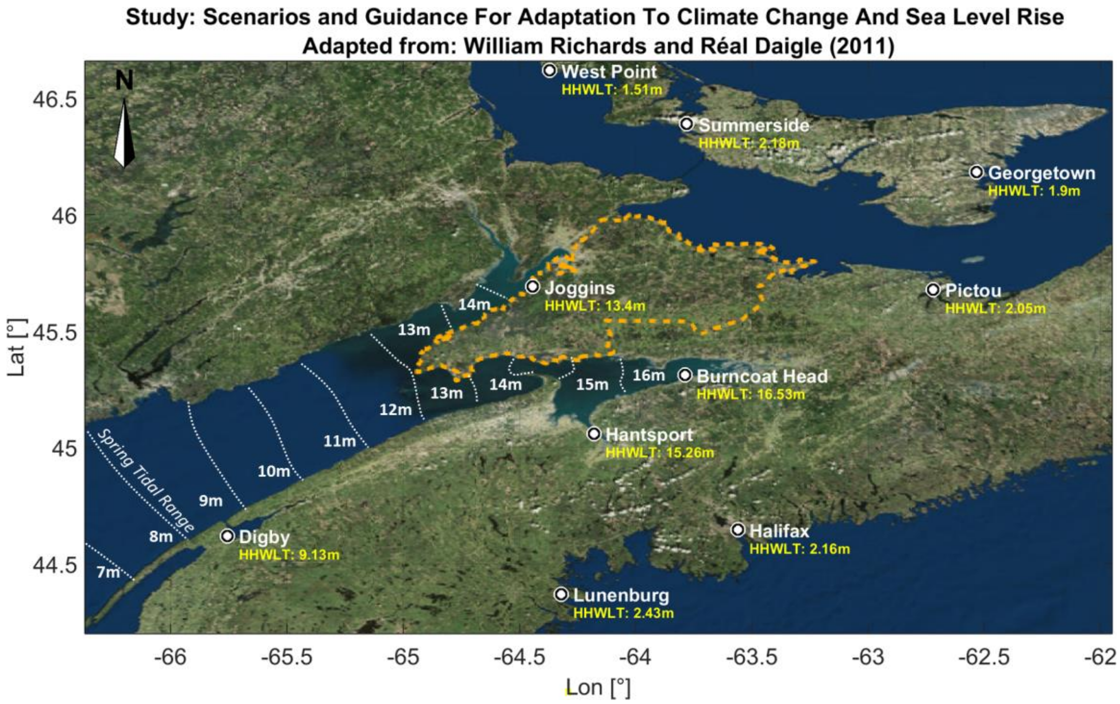


Figure 2.2: Water Levels (Bay of Fundy)

- **HHWLT = Higher High Water Large Tide, i.e. the average of the 19 annual maxima over a 19-year full tidal cycle**

Vertical reference level is Chart Datum, where the zero is typically close to the lowest tide level. Therefore, the HHWLT elevation is a good indication of the total tidal range

2.2 Offshore Wind and Wave Climate

The study area includes communities and infrastructure along the shores of the Minas Basin, which are exposed to the action of strong winds and wave agitation. To evaluate the effect of these processes on the risk of overtopping during a storm event, this assessment combines hydrodynamic modelling with the simulation of extreme waves in the Minas Basin.

2.2.1 Data Source

The MSC50 wind and wave model hindcast from January 1954 to December 2015 contains hourly time series of wind (speed, direction) and wave (height, period, direction) at 45.3N 64.9W, in 46.7 m water depth just offshore of Advocate Harbour. This is the closest location to the study area with sufficient long term wave and wind data to conduct an extreme event analysis. The dataset is a state-of-the art hindcast, i.e., data computed from all existing wind and wave measurements that were re-analysed and input to a 0.1-degree resolution ocean wave growth model that includes the effect of depth and ice cover. The MSC50 hindcast was developed by Oceanweather Inc. and is distributed by Environment Canada (Swail et al., 2006).

2.2.2 Extreme Values

Extreme value analyses were performed on the offshore winds as the shape of Minas Basin does not allow extreme waves from the Bay of Fundy to enter the Minas Basin. Therefore, wave agitation within the study area is the result of strong winds blowing from the north western direction.

Table 2.4 shows wind speeds calculated from the MSC50 data set. These values were input as boundary condition in a numerical model, and transformed into nearshore waves close to the community of Cheverie to evaluate the risks of overtopping existing infrastructure such as the Cheverie Causeway.

Table 2.4: Extreme Return Values for Wind Speed and Offshore Significant Wave Heights with Associated Peak Period at the MSC50 Node (45.3 64.9W) offshore Advocate

Return Period	Wind [m/s]
1 year	15.1
10 year	19.1
20 year	20.3
50 year	21.2
100 year	23.0

These values correspond to deep water conditions. As the wave approaches the shore, changes in depth induce a decrease in wave height. The model allows the calculation of this transformation and the assessment of the risks of overtopping the barrier under a 1 in 100 wave storm event during high water.

2.3 Avon River Morphology

Bottom elevations along the Avon River range between -12 m at the mouth and -6 m at the Windsor Causeway with a mean width of 1.5 Km. Upstream of the causeway, the channel width narrows down to approximately 500 m. Previous studies on the morphology of the Avon River indicate that construction of the Windsor Causeway reduced the tidal prism (the volume of water entering the Avon River between mean high tide and mean low tide) upstream of the mouth of the Avon River by approximately 6.3% (Van Proosdij, et al. 2009). Previous studies of the historical evolution of sedimentation patterns along the Avon River, before and after the construction of the Windsor Causeway, indicate that changes in sediment distribution up to 4 Km downstream of the causeway have resulted in approximately a 10% reduction in the cross sectional area (van Proosdij 2007). The same study indicates that lateral erosion of the marsh banks balances the sediment accretion in intertidal bars between 1.1 and 2.2 Km of the causeway.

A detailed evaluation of the impacts of the Windsor Causeway on flooding risks in the area would require an extensive analysis of the complex currents and sediment transport dynamics along the river including: sediment sampling, 3D hydrodynamic and sediment transport modelling, long term sediment transport simulation, seasonal bathymetric surveying and an assessment of the historical evolution of the geomorphology of the river. Based on the findings of the available studies in the area, it is assumed that the results of such a comprehensive study are unlikely to make a significant difference in the type and location of the potential flooding risk mitigation identified in this assessment. For this reason the water level calculations and the assessment of potential mitigation measures are based on the inflow of tidal currents turning towards the St. Croix River, but flowing upstream of the Windsor Causeway.

2.4 Conclusion

This assessment calculates extreme water levels and wave heights based on previous studies of morphology of the Avon River, storm surge frequencies in Atlantic Canada and historical wave data. In absence of sufficient historical water level records throughout the Minas Basin and along the Avon River, the calculation of extreme water levels assumes concurrence of HHWLT, extreme storm surges and extreme wave heights. These values were used as boundary conditions in a hydrodynamic model of the area to study the variation of water levels along the Avon River, assuming that tidal currents stop at the Windsor Causeway. Based on the findings of previous studies in the morphology of the Avon River, it is assumed that a comprehensive assessment of the impact of the causeway on the water levels along the river is unlikely to result in notable changes to potential flooding mitigation measures presented in this report.

3 Coastal Hydraulic Model Development

3.1 Modeling Approach

Tides entering the Bay of Fundy feature a range of approximately 1 meter and this is amplified across the system including the Minas Basin and the tidal rivers and estuaries connected to the Bay. As discussed by Garret (1974) this process is the result of a combination of the shape of the basin and the tidal period. Therefore, estimating potential flooding extents in the study area requires computer modelling of extreme events governed by the tidal amplification across the Bay of Fundy and wave overtopping. This requires the simulation of the simultaneous occurrence of waves and tidal water levels and currents from the Bay of Fundy. For this type of simulation, the industry standard modelling package MIKE21, available from the Danish Hydraulic Institute (DHI) integrates hydrodynamic calculations in the marine environment with the simulation of waves. The model solves the equations for the conservation of mass and momentum over a 2D domain (or flexible mesh) based on water level boundary conditions as well as bathymetric and topographic information.

Table 3.1 shows a description of the models used for this study and their associated key inputs and outputs.

Table 3.1: Summary of Models Applied in Study

Area of Application	Model	Objective	Main Inputs	Outputs
Regional wave transformation, wind wave growth.	Spectral wave model DHI MIKE21 SW.	Nearshore transformation and wind wave growth up to the mouth of the Avon River.	• MSC50 hindcast. • Bathymetry.	Wave climate and effect on total water levels at the shores of the Minas Basin.
Water levels and tidal currents.	Hydrodynamic model MIKE21 HD coupled with MIK21 SW.	Water levels, flood extents and current speed.	• Tidal predictions, and storm surge estimates. • Bathymetry.	Water levels and currents throughout the model domain.

Figure 3.1 shows the model domain for the hydrodynamic simulation of extreme water levels and waves throughout the Minas Basin and the Avon River. In the absence of long term historical water levels in the Bay of Fundy area, the model domain extends to the Bay of Fundy with boundary conditions at Yarmouth. This allows the model to simulate the tidal amplification throughout the bay and estimate tidal cycles in other locations, based on long term historical data at Yarmouth and Saint John. The model domain consists of a series of meshes of varying element sizes with higher towards the shorelines, the Avon River tributaries, the Cheverie Causeway, and the dykes.

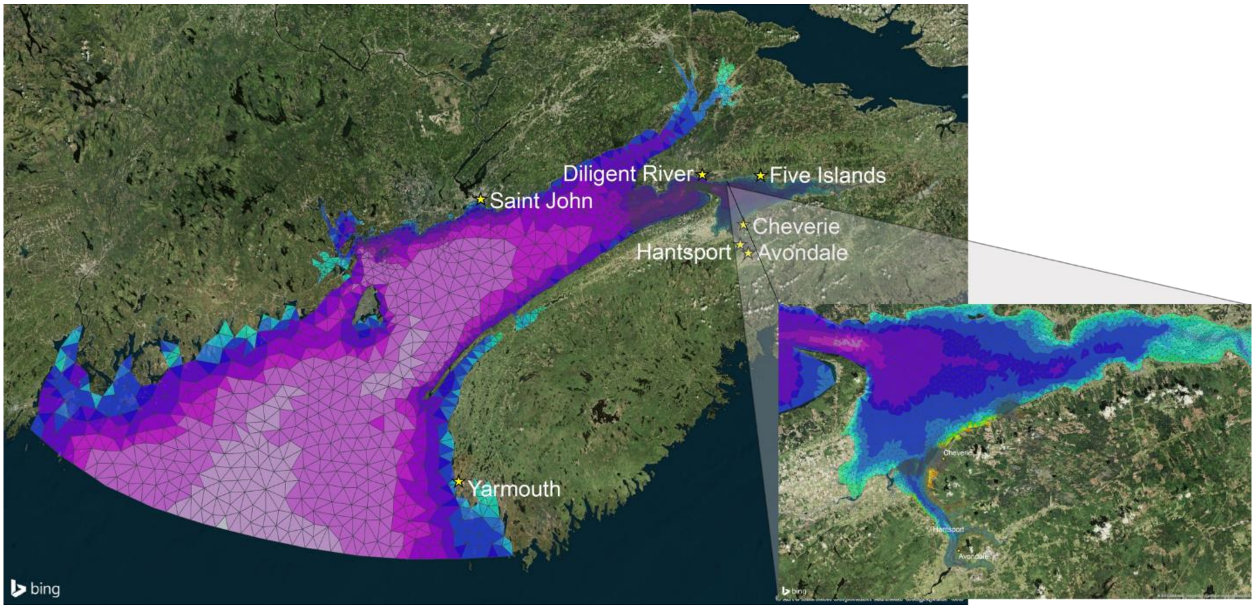


Figure 3.1: Model Domain – Bay of Fundy – Minas Basin – Avon River

3.2 Model Calibration

To validate calculations with the model, historical data available at Yarmouth was used to simulate observed events and replicate observed water levels at Saint John, Diligent River, Five Islands and Hantsport. Discrepancies between the calculations and the observed water levels were addressed by adjusting the model resolution to better simulate the bathymetry of the area. However, one limitation of the process is the sparse availability of long term data across the Bay of Fundy. Historical data from the Environment Canada gauging station is available for the following locations and periods:

Location (see Figure 3.2)	**Period with Data**
Yarmouth	1965-2019
Saint John	1900-2019
Diligent River	August – October 1965
Five Islands	June – October 1965, August 1960 and August 1961
Hantsport	September – 1969

The periods with available data at Diligent River and Hantsport coincided with seasons of calm weather with small influence of local wind storms or storm surges. Therefore, data available at Yarmouth can be used to calibrate the model estimates of the tidal amplification across the Minas Basin and to Hantsport.

Given than the available dataset periods do not overlap throughout the study area the calibration process required splitting in two phases:

- Model calibration up to Diligent River using observed water levels at Yarmouth for the year 1965.
- Model calibration up to Hantsport using observed water levels at Yarmouth for the year 2019.

Figure 3.2 presents the results of the calibration, indicating that the model can simulate the changes in tidal levels across the study area. The calibration process also indicated that the model domain can be split at Diligent and that time series at this location can be used as boundary conditions to calculate water level changes along the Avon River and the Minas Basin.

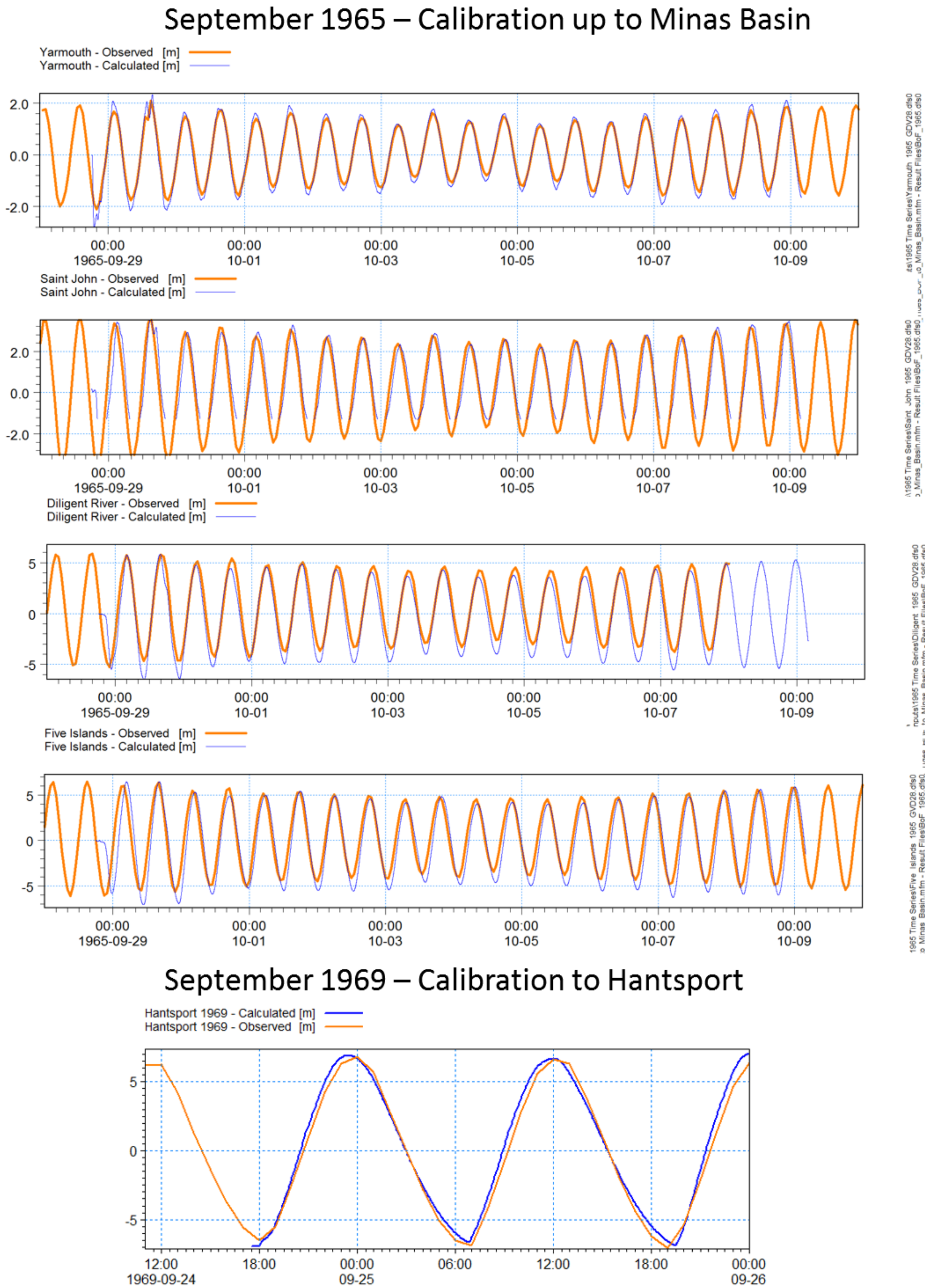


Figure 3.2: Model Calibration across the Bay of Fundy in 1965 and to Hantsport in 1969

3.3 Design Scenarios

Figure 3.3 shows the time series used as boundary conditions in the model at Diligent to simulate the 1 in 1 year, 1 in 20 year and 1 in 100 year flood events in the study area for the years 2018, 2050 and 2100. These time series were calculated by extrapolating the historical water level observations available at Diligent to the extreme water levels discussed in Chapter 0.

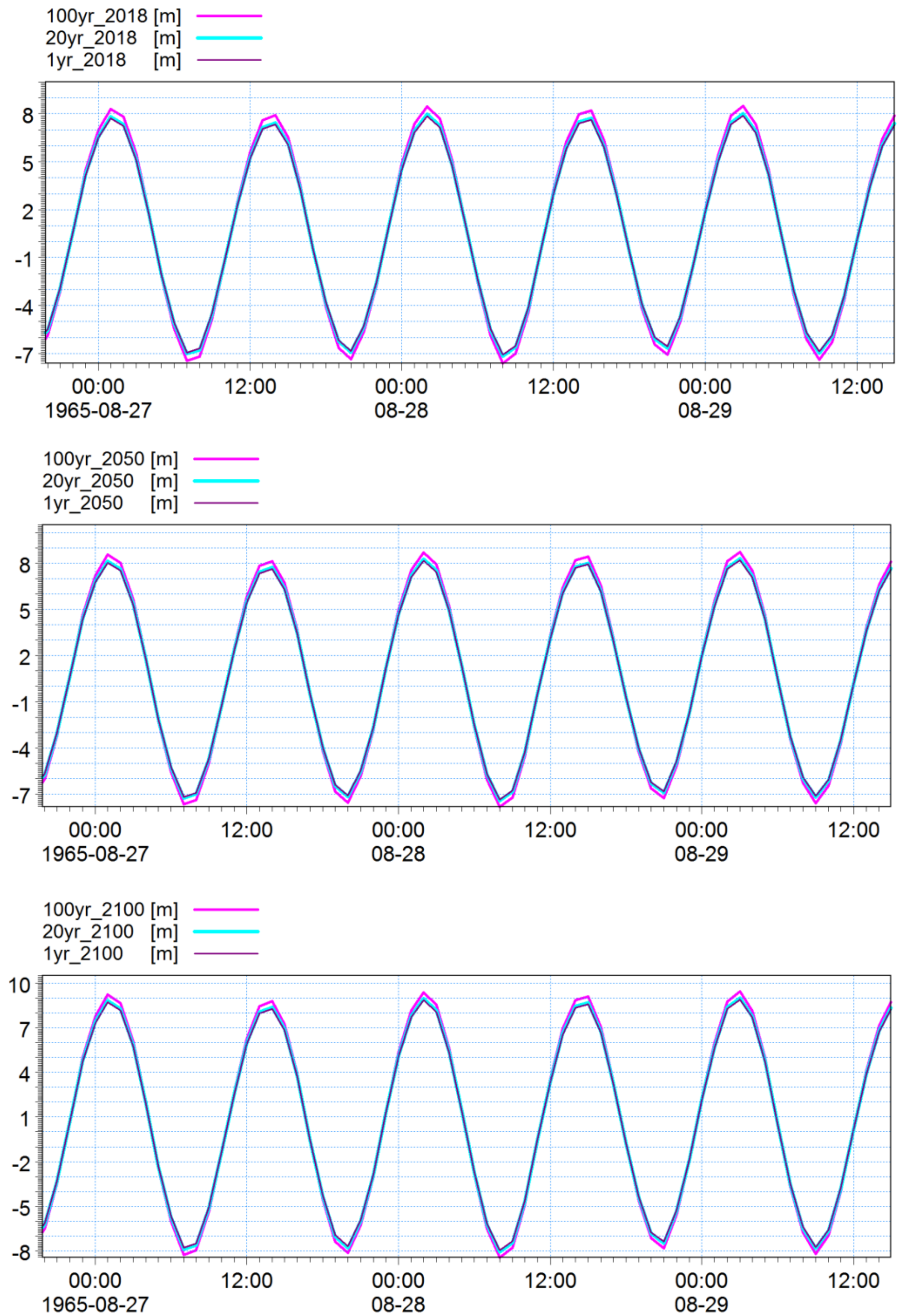


Figure 3.3: Boundary Conditions Time Series at Diligent River

Each return period for the simulations was selected according to the following criteria based on the Municipal Government Act S.N.S. 1998, c. 18 N.S. Reg. 101/2001 (April 1, 1999) N.S. Reg. 272.

Return Period	Description
1 in 1 year Event	Extreme water levels that are likely to be observed at least once each year.
1 in 20 year Event	Return period of the line generally selected in Nova Scotia to identify areas within which no development is allowed.
1 in 100 year Event	Return period of the line generally selected to delineate areas (between this and the 1 in 20 year line) where flood proofing of private infrastructure is required.

Figure 3.4 shows the tidal amplification calculated for each design scenario for the year 2018. The figure shows up to 0.30 m of water level variation along the river.

To delineate the floodline, these results were converted into a water level surface using ArcMap.

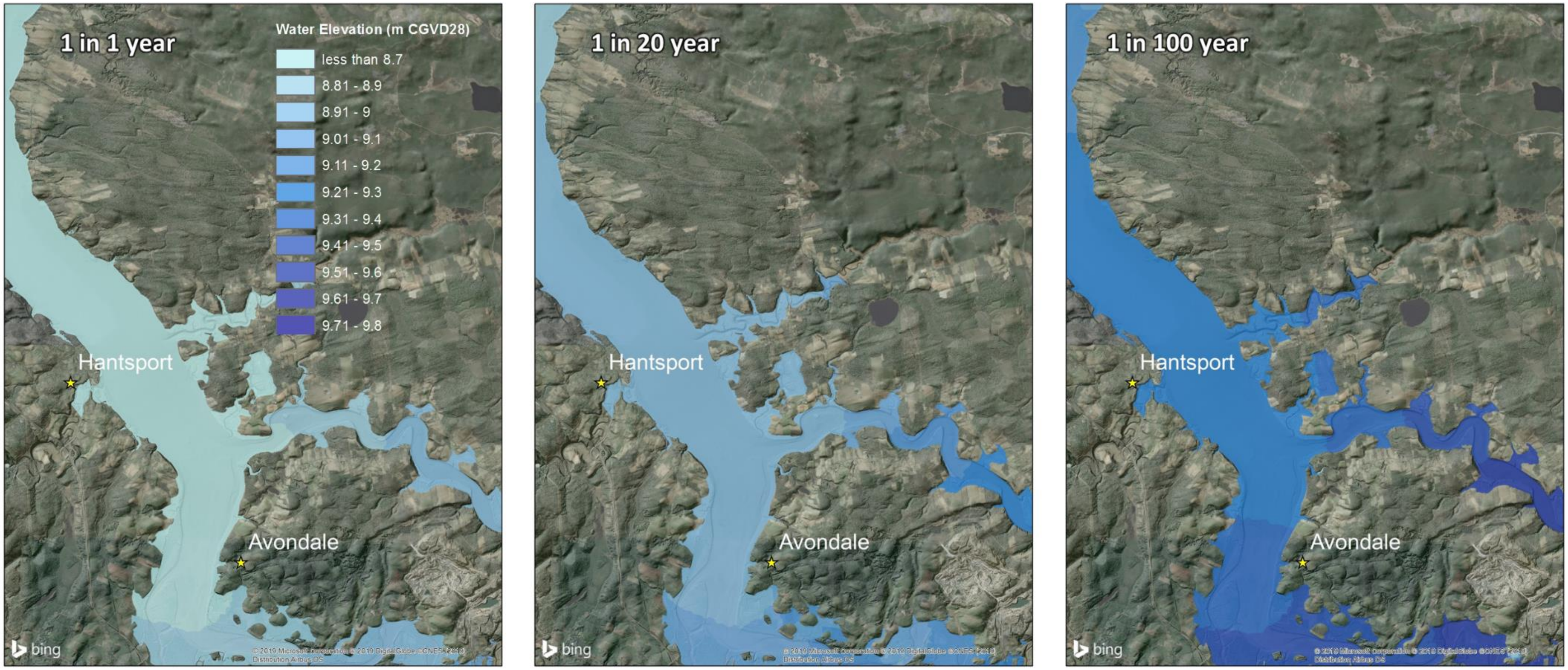


Figure 3.4: **Calculated Tidal Amplification along the Avon River for the 1 in 1, 1 in 20 and 1 in 100 Year Events (Existing Climatic Conditions)**

4 Floodplain and Flooding Risks Analysis

4.1 Floodline Delineation

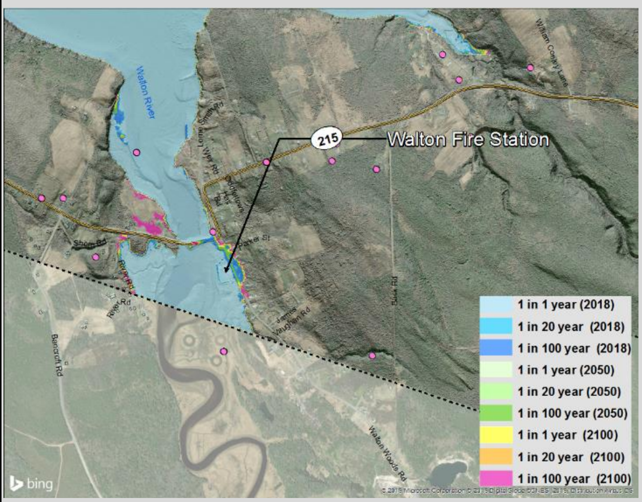
Appendix B presents a floodmap atlas of the study area for the 1 in 1 year, 1 in 20 year and the 1 in 100 year coastal water levels calculated as the combination of HHWL and extreme storm surges. The maps were delineated using 2D results from the coastal hydrodynamic model described in Chapter 3 and the software ArcGIS for the interpolation of a water level surface.

4.2 Infrastructure at Risk

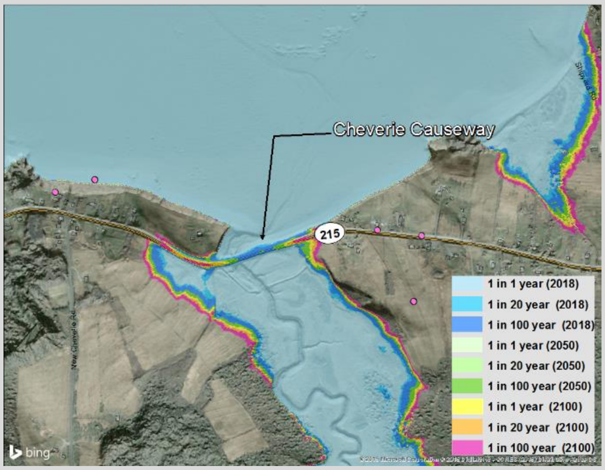
Table 4.1 identifies infrastructure at risk of flooding throughout the study area after an evaluation of the floodmaps presented in Appendix B. The table shows the location of the area, the range of events that could cause flooding in the area, the type of infrastructure and the estimated consequence of damage.

Table 4.1: Infrastructure at Risk

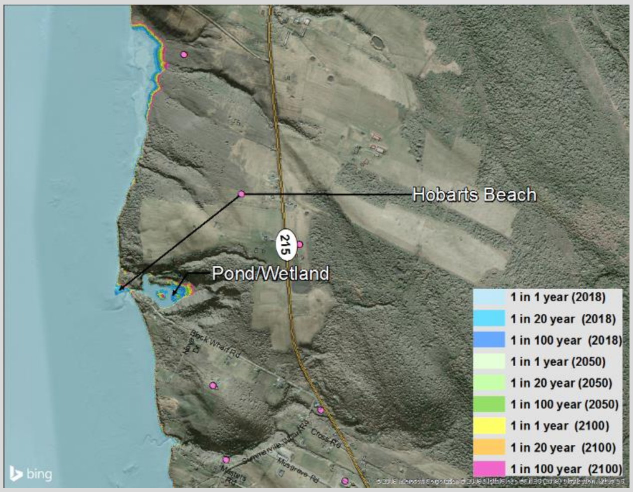
Walton Shore Volunteer Fire Department



Frequency of Flooding:	Very Frequent
Flooding Events:	1 in 1 year (2018) 1 in 20 Year (2018-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Municipal Service
Estimated Consequence of Damage:	High: • Interruption of response to fires.

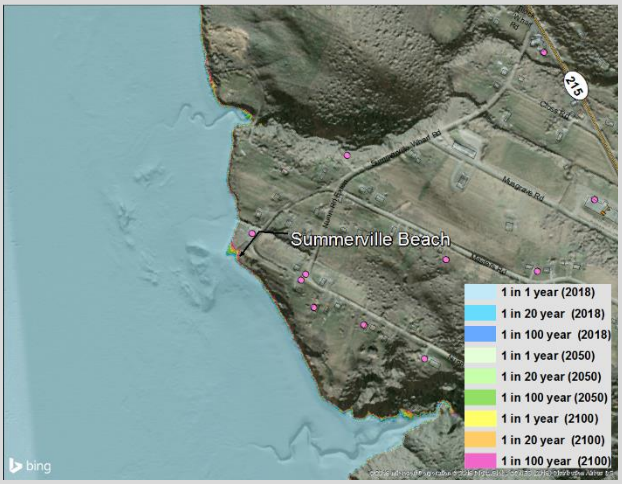
Cheverie Creek Causeway	
	

Frequency of Flooding:	Frequent
Flooding Events:	1 in 1 Year (2100) 1 in 20 Year (2050-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Road Network
Estimated Consequence of Damage:	High : • Interruption of traffic between communities. • Obstructs access to emergency services. • Erosion damage.

Hobart Beach	
	

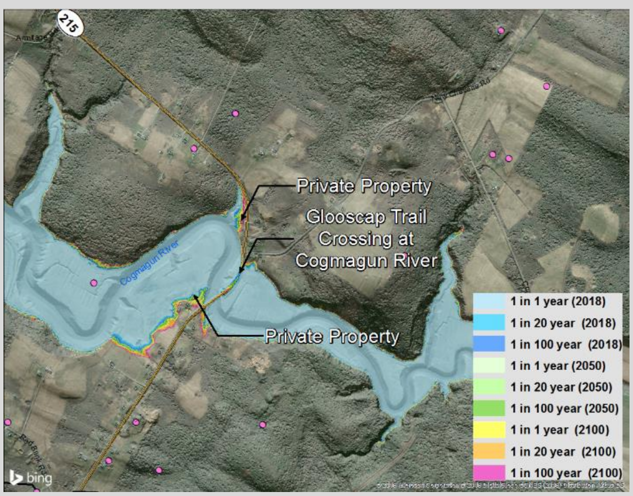
Frequency of Flooding:	Rare
Flooding Events:	1 in 1 year (2100) 1 in 20 Year (2050-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Recreational
Estimated Consequence of Damage:	Low: • Damage to seasonal parking lot and road. • Decrease of recreational visitors.

Summerville Beach



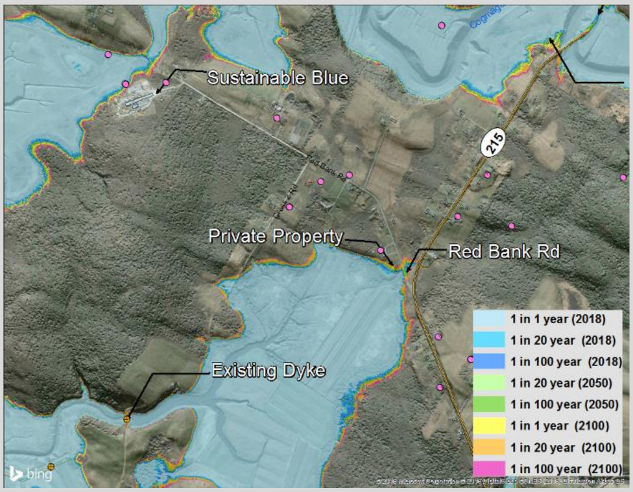
Frequency of Flooding:	Frequent
Flooding Events:	1 in 1 year (2018 -2100) 1 in 20 Year (2018-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Recreational – Residential
Estimated Consequence of Damage:	Low: • Beach erosion. • Decrease of recreational visitors. • Potential threat to residential retention wall.

Glooscap Trail Crossing – Cogmagun River



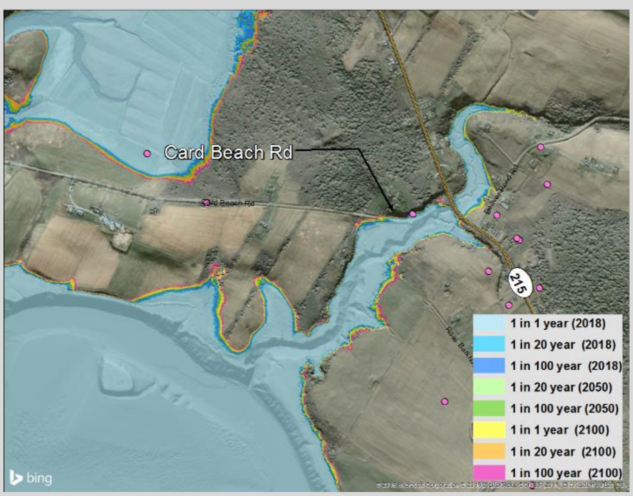
Frequency of Flooding:	Rare
Flooding Events:	1 in 1 year (2100) 1 in 20 Year (2050-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Provincial Road
Estimated Consequence of Damage:	High: • Interruption of traffic between communities. • Obstruction of emergency services.

Red Bank Road



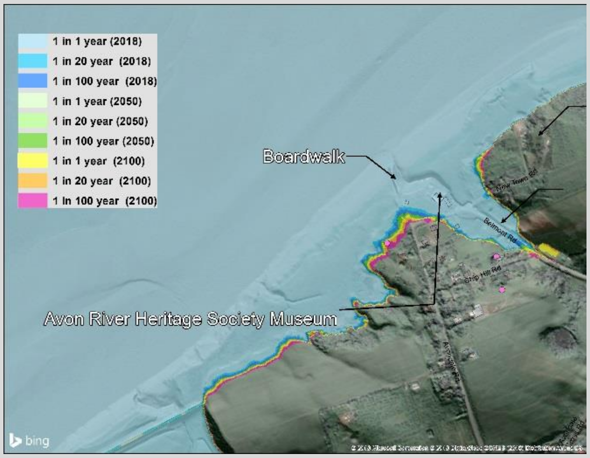
Frequency of Flooding:	Rare
Flooding Events:	1 in 20 Year (2050-2100) 1 in 100 Year (2050-2100)
Type of Infrastructure:	Provincial Road
Estimated Consequence of Damage:	High: • Interruption of access to private residences and industrial property. • Failure of existing dyke may allow flooding of the road and the agricultural land behind the dyke.

Card Beach Road



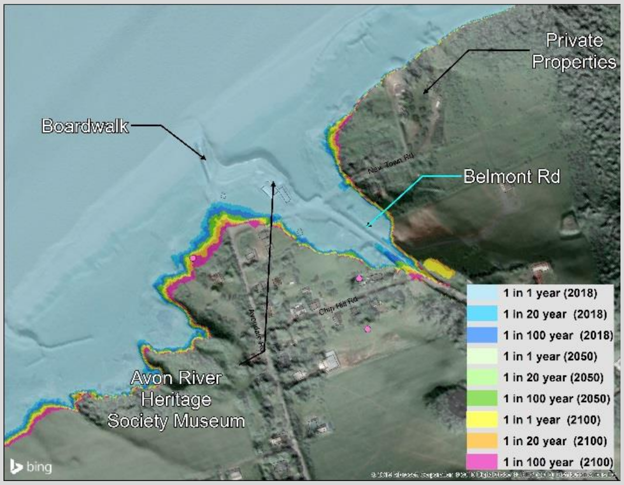
Frequency of Flooding:	Very Frequent
Flooding Events:	1 in 1 year (2018 -2100) 1 in 20 Year (2018-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Provincial Road
Estimated Consequence of Damage:	High: • Interruption of access to private residences as there are not alternative routes available

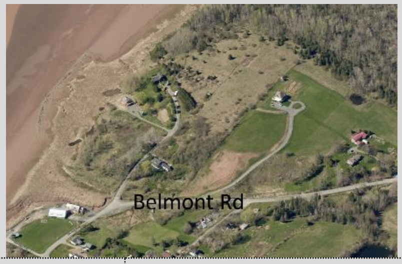
Avon River Heritage Society Museum and Boardwalk



Frequency of Flooding:	Very Frequent
Flooding Events:	1 in 1 year (2018 -2100) 1 in 20 Year (2018-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure	Recreational Services
Estimated Consequence of Damage	High: • Damage to historical assets. • Damage to historical building. • Loss of recreational space.

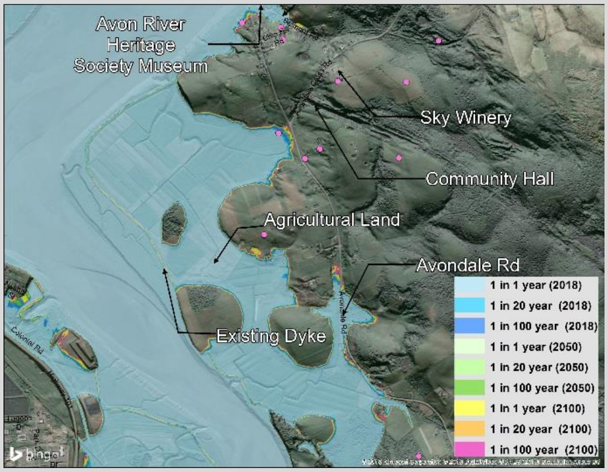
Belmont Road





Frequency of Flooding:	Frequent
Flooding Events:	1 in 1 year (2018 -2100) 1 in 20 Year (2018-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Provincial Road
Estimated Consequence of Damage:	High: • Interruption of access to private residences. • Obstruction of emergency evacuation.

Avondale Road



Frequency of Flooding:	Frequent
Flooding Events:	1 in 1 year (2018 -2100) 1 in 20 Year (2018-2100) 1 in 100 Year (2018-2100)
Type of Infrastructure:	Provincial Road
Estimated Consequence of Damage:	High: • Interruption of access to private residences. • Obstruction of emergency evacuation. • Vulnerable to the failure of existing dyke.

4.3 Vulnerability Assessment

4.3.1 Demographic Characteristics

Census data for the local community for the year 2016 indicates that, excluding the Town of Windsor, West Hants has a population of 15,368 inhabitants, with a study area population of approximately 1,521 with seasonal residents amounting to 10% of this population. Growth in the last 10 years is close to 0.3% with a median age of 46.6 years. Therefore, long term considerations for flood risk management in the area require considering the likelihood of this population growth trend continuing.

As shown in Figure 4.1 settlement in the area follows roads and rivers, with Highway 215 (also known as Glooscap Trail), connecting most of the communities and economic activities in the area. The local economy is tied to tourism, and natural resource based industries, including fishery, forestry and agriculture. According to the 2016 community census, 78 % of the labour force commutes to other locations in the Province of NS. Community assets that may be directly or indirectly vulnerable to floods include important public services such as the Arthur Hines Elementary School and the Walton Shore fire department; economic assets such as agricultural land and aquaculture industries; and touristic attractions such as the Newport Landing Waterfront Park, the Cheverie Salt Marsh Trail, Hobarts Beach and the Avondale Sky Winery, among others. An evaluation of priority areas for flood risk management requires consideration of the potential levels of flooding damage to the health and safety of the population, the economic activities in the area, and the ecosystems.

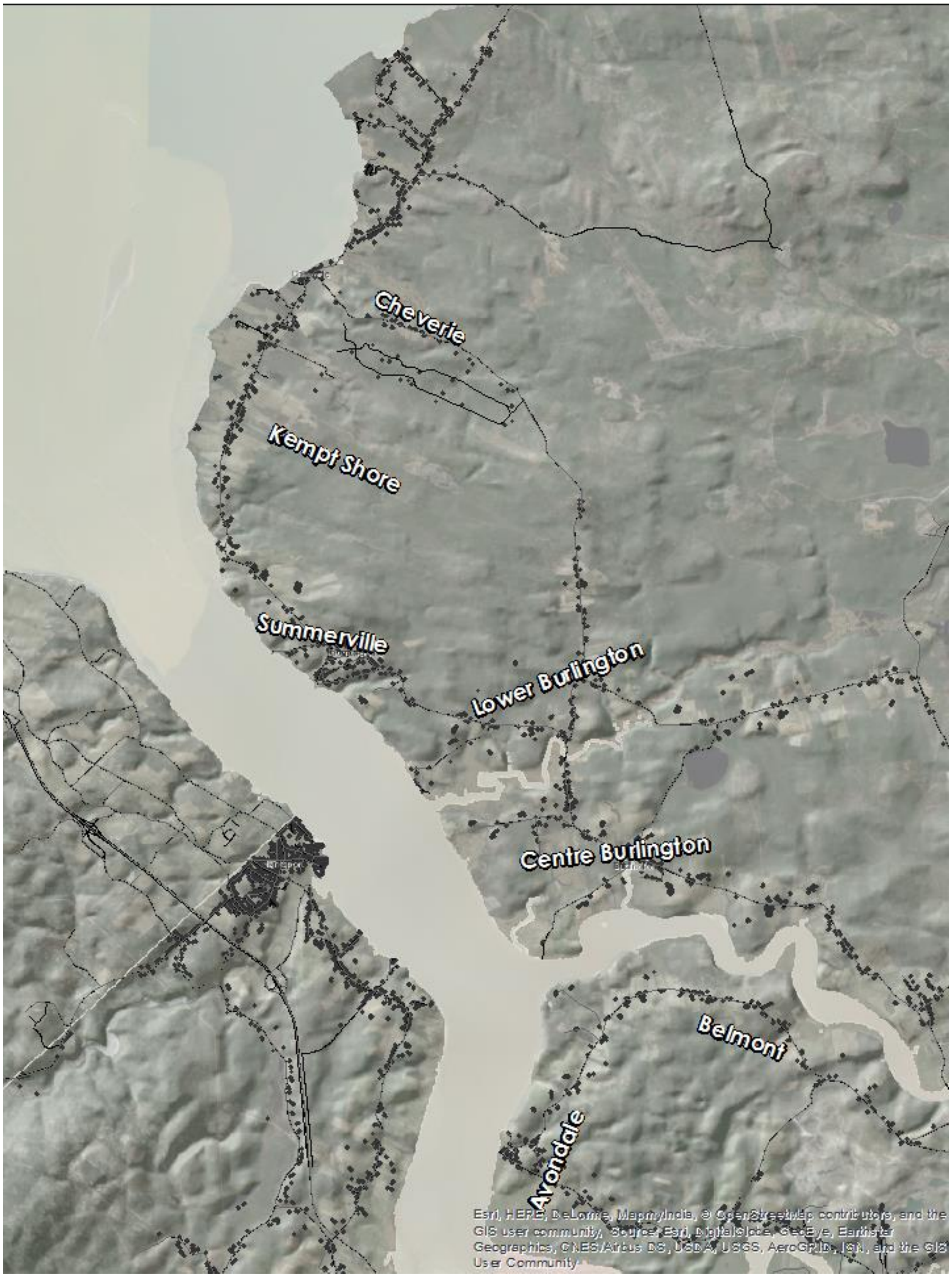


Figure 4.1: Settlement Patterns throughout the Municipality of West Hants

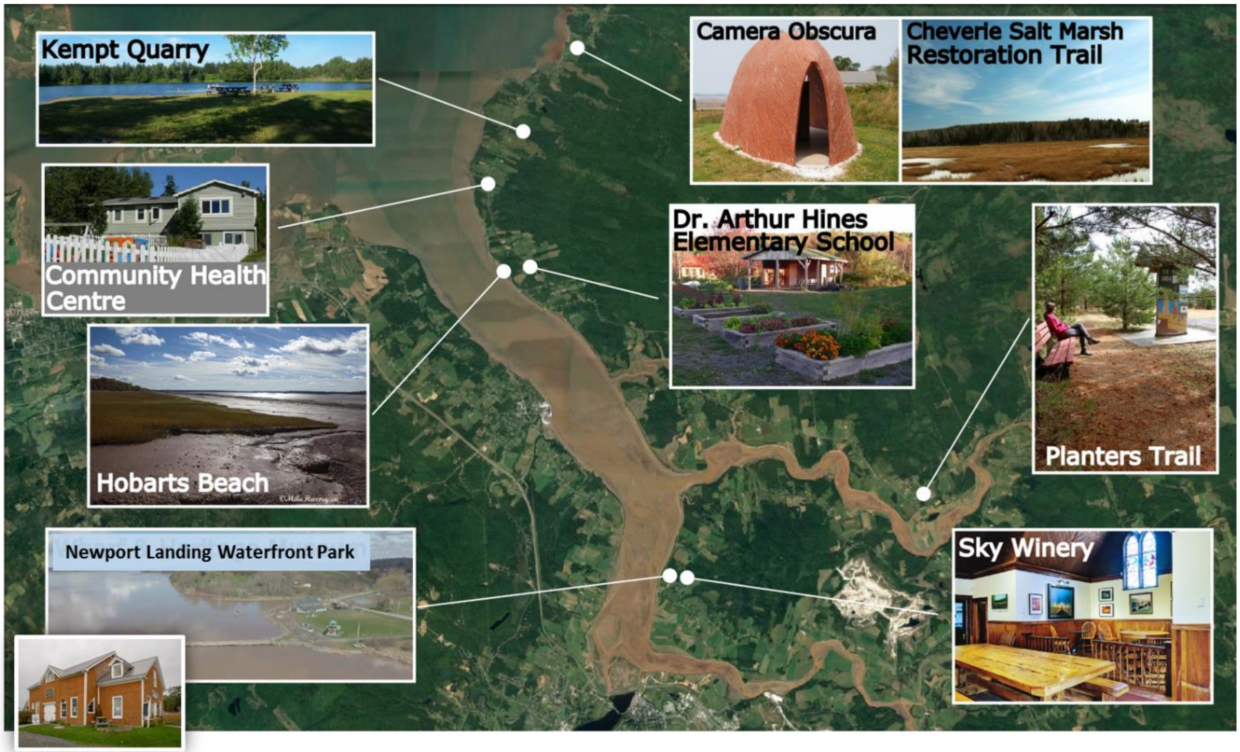


Figure 4.2: Community Assets

4.3.2 Public Concerns

4.3.2.1 Public Meeting

The study team conducted two series of public information sessions on November 24th 2018 and March 25th 2019; in the morning in the community of Summerville and in the afternoon in the community of Belmont. The intention of the meetings was to inform the public about the purpose of the study, gather information about areas of concern for members of the community, and discuss potential flooding mitigation measures. In total, approximately 30 and 35 people attended the meetings held in November and March. Each meeting was two hours in duration, comprised of a presentation followed by a question and answer period, and an open house. During the meeting the study team provided information about the main causes of flooding, described potential mitigation options, and provided participants with flooding maps showing areas under risk of inundation during yearly and extreme events. Attendees at the meetings provided open input that they wished to share, as well as input on specific flood risk areas and potential mitigation solutions.

To gather information about the experiences, concerns and observations among property owners near flood areas, a survey was provided online and in hard copy at the municipal office. A letter was mailed to these property owners to notify them of the survey, as well as the public meetings. The survey was also available at the public meetings. In total, 33 responses were received.

During the first public meeting participants were asked to identify the vulnerable areas they think should be prioritized for flood risk mitigation, by placing a green, yellow and red sticker on a worksheet that listed main public infrastructure in the area as well as private land uses. Each colour corresponded with 1st, 2nd and 3rd priority. Highway 215 received the highest amount of first priority labels with attendees indicating that mitigation options aiming to maintain connectivity of the community via this main transportation road is a priority.

First Public Meeting – Priority Ranking

During the second public meeting, the study team provided information about locations at risk and the potential consequences of damage to specific infrastructure. Similar to the first public meeting, participants were asked to identify the vulnerable areas they thought should be prioritized for flood risk mitigation, by placing a green, yellow and red sticker on a worksheet that listed main public infrastructure in the area as well as private land uses. The Cheverie Causeway and the Avon River Heritage Museum received the highest amount of first priority labels.

<u>Siltation</u>

During the open question and answer period some attendees shared their observations and concerns related to siltation along the Avon River. Although the central topic of the meeting was flood risk, based on their personal experiences, some participants expressed more immediate concern about siltation. Long-time residents have seen a number of changes in siltation over the years, including the formation of mucky bottom and sand bars. For some there is a sense that increased siltation is correlated to the Windsor Causeway construction, and there is worry that the new construction could also have impacts. There is a desire for better information about the extent of the connection between flooding and siltation.

<u>Erosion</u>

Participants described numerous points along the shoreline where erosion is occurring. Some participants qualified the process as severe resulting in loss of use or enjoyment of property. The observed consequences of this process include inability to conduct farming or loss of recreational beach areas. Some participants expressed that this issue affects them frequently and are interested to know more about the association between erosion and flooding. Some participants have noted that along the Avondale shores, erosion has started to undermine the toe of the existing dykes and expressed concerns about the short term integrity of these structures.

4.3.2.2 Survey

Coastal Hazards

Coastal erosion was a main theme throughout the survey, with at least 16 respondents noting loss of shoreline as a threat to their property. Rising tides resulting in loss of land was another major concern. Salt marsh concerns were raised by a few respondents, regarding an increase in size and depth of the marsh. Three respondents had also each noticed loss of wetlands and cloudy water.

As open-ended responses, concerns were raised by three respondents around the potential relation between siltation along the Avon River and the construction of the Windsor causeway, and described these issues in the context of erosion and loss of land.

Three respondents felt that overall, their properties were experiencing little to no effects of flooding or climate related impacts, and had low concern about these issues in the future.

Property and Infrastructure Damage

Out of 24 responses, almost 38% have experienced property damage associated with generalized coastal hazards, while almost 30% noticed loss of wildlife and infrastructure damage. About 25% have noticed loss of plant life and habitat, while 21% noticed a new or invasive plant. Two respondents indicated they had not noticed any adverse effects.

Approximately half of respondents skipped the question concerning flooding impacts, but among those that responded, 50% have noticed flooding over a roadway, and 25% had noticed flood related power outages. Other concerns included failure of flood control devices, damage to agricultural land, flooding into a building and high water within 1 metre of a building. One respondent has witnessed runoff of contaminated water, while no one identified the presence of waterborne diseases. Additional concerns included rising tides and erosion.

Five respondents identified contaminated soils as a concern on their property from salinification, while another five felt that salt water contamination was not an issue.

Level of Concern about Flooding

The levels of concern about these impacts' effects on community access were evenly split, though emergency systems arose as the biggest point of concern. When asked about levels of concerns about how sea-level rise may intensify flooding risks, generally, 45% of respondents responded as "very concerned" and 22% are just "concerned". Of 17 respondents, 42% are very concerned about the impacts of coastal hazards on emergency response systems, and around 30% are very concerned about access to roads, wharves and beaches, property damage and public services. Around 32% are very concerned about access to fire departments and healthcare, while everyday services were less of a concern.

In an emergency situation, the most significant issues or risks that arose were a high number of people who do not possess flood insurance (41%) or an emergency kit (41%), as well as people whose business may be affected (27%) and would have to miss work (27%).

4.3.3 Erosion Vulnerability Assessment

The study team conducted a cursory assessment of potential erosion and deposition patterns in the area after the concerns that the public expressed during the information session and through the surveys. Photographs from 1945 and from the 1970s were georeferenced to examine the shoreline evolution after the construction of the causeway at Windsor in 1970. Changes within the shoreline can be observed throughout the upper reach of the river up to and past the causeway. The primary change is the growth of the salt marshes located along the causeway and banks of the river since the development of the causeway. Some erosion is evident after the construction of the causeway, however changes in the shoreline between the 1970s and the current date do not appear significant. Discrepancies between these evaluation and the observations that the public expressed during the public meeting may be related to the following:

- Coarse resolution and unknown tilt angles of the historical pictures limit accurate orthorectification and georeferencing of the images.
- This method does not account for sediment and currents characteristics.
- The evaluation did not consider potential vertical changes in bathymetry throughout the area.
- Water level elevation at the time of the photograph is unknown.

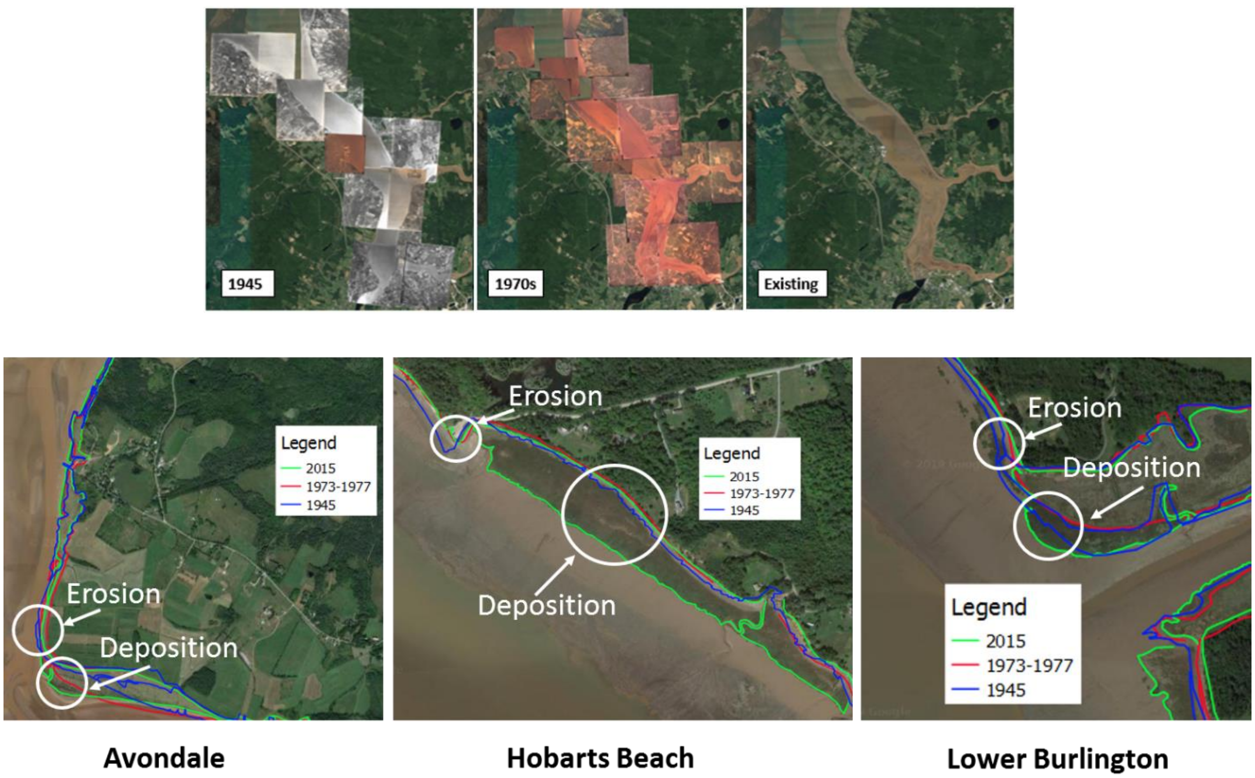


Figure 4.3: Comparison of Avon River Aerial Photography for the Years 1945, 1973-1977 and 2015

A complete and conclusive assessment of vulnerabilities in the area to erosion and siltation requires a thorough assessment including review of previous sediment studies in the area, field data collection of sediments, comparison of detailed historical bathymetric data, computer modelling of currents and sediment transport processes and simulation of different scenarios to evaluate potential effects of the Windsor Causeway in the sedimentation patterns.

4.3.4 Consequence of Damage

The study team conducted a vulnerability assessment meeting with stakeholders from the public agencies that are mainly responsible for managing public infrastructure. These agencies include the following:

Agency	Jurisdiction
Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR)	Provincial roads and building
Nova Scotia Department of Agriculture (NSDA)	Management of dykes and aboiteaux
West Hants Planning and Development Department	Periodic review and update of the planning documents of the Municipality
West Hants Public Works	Potable water, sanitary sewer service and Municipal owned roads within the areas of Falmouth and Three Mile Plains and Hantsport. Also solid waste management, including recycling, for the Municipality of West Hants.

Attendance at the meeting included the following representatives:

Agency	Representative	Position
NSTIR	Gary Rafuse	Region Manager
NSDA	Kevin Bekkers	Director, Resources Sustainability
	Chris Ross	E.I.T, Engineering Support
Municipality of the District of West Hants	Madelyn LeMay	Director of Planning and Development
	Saira Shah	Planner
	Sara Poirier	Planner
	Brad Carrigan	Director of Public Works
	Rupert Jannasch	Council District #1
	Kathy Monroe	Council District #2

During the meetings the study team presented floodmaps showing the 1 in 100 year event for the year 2018, 2050 and 2100. Even though the main focus of this study is public infrastructure, attendants to the meeting discussed with the study team the potential level of damages to the following private and public infrastructure:

- Private properties (residential and commercial).
- Agricultural land.
- Newport Landing Waterfront Park.
- Road Network.

As shown in the potential damages to the population, the local economy and the environment were evaluated according to the degree of their consequences from very low to very high and according to a range of categories including:

- Health and Safety.
- Displacement.

- Loss of livelihood.
- Reputation (as productive, touristic recreational area).
- Financial impact for the public sector.
- Financial impact for the private sector.
- Damages to the quality of the air, water, land or ecosystems.

This evaluation identified that the degree of vulnerability associated with the road network is high as consequences of flooding for health and safety, displacement and potential loss of livelihood in the area are high, especially for the case of the Cheverie Causeway. In general, it was recognized that consequences of simultaneous flooding along Highway 215 would be higher than in areas where other connecting roads may provide alternate access or evacuation routes.

In the case of the Newport Landing Waterfront Park it was recognized that the highest consequence of damage would mostly impact the heritage value of the site for the community and the general perception of the area as a recreational and scenic space. This may cause a high financial impact for the public sector that benefits from the revenues associated with the operation of the museum and the potential loss of livelihood for those individuals with private incomes also associated with the operation of the museum.

The evaluation shown in Figure 4.4 indicates that the degree of vulnerability of private infrastructure, including agricultural land, is also high. However, it was recognized during the stakeholder assessment that a comprehensive evaluation of costs and benefits would be required to evaluate options for flood risk mitigation. Such assessments requires consideration of the size and value of the agricultural land at risk in comparison with the total agricultural land within the study area. Similar considerations would be required for residential and commercial properties.

Consequence

Private Property	People				Economic		Environment			
Degree of Consequence	Health + Safety	Displacement	Loss of Livelihood	Reputation	Financial Impact for public sector	Financial Impact for private sector	Air	Water	Land	Ecosystems
Very Low							✓		✓	✓
Low	✓		✓							
Moderate					✓					
High		✓		✓		✓		✓		
Very High										

Consequence

Agricultural Land	People				Economic		Environment			
Degree of Consequence	Health + Safety	Displacement	Loss of Livelihood	Reputation	Financial Impact for public sector	Financial Impact for private sector	Air	Water	Land	Ecosystems
Very Low	✓	✓			✓ Municipal		✓			✓
Low										
Moderate									✓	
High			✓	✓	✓ Provincial			✓		
Very High						✓				

Museum & Wharf	People				Economic		Environment			
Degree of Consequence	Health + Safety	Displacement	Loss of Livelihood	Reputation	Financial Impact for public sector	Financial Impact for private sector	Air	Water	Land	Ecosystems
Very Low		✓				✓	✓	✓	✓	✓
Low	✓									
Moderate										
High			✓	✓ General	✓					
Very High				✓ Heritage Value						

Road Network	People				Economic		Environment			
Degree of Consequence	Health + Safety	Displacement	Loss of Livelihood	Reputation	Financial Impact for public sector	Financial Impact for private sector	Air	Water	Land	Ecosystems
Very Low					✓ Municipal		✓		✓	✓
Low								✓		
Moderate		✓		✓		✓				
High	✓		✓		✓ Provincial					
Very High										

Figure 4.4: Assessment of Consequences of Damage per Type of Infrastructure

4.4 Flooding Risk Rank

Risk is generally defined as a combination of the probability of occurrence of an unwanted incident and the severity of its consequence. (Engineers Canada 2016). To identify areas of higher, medium and lower risk, this assessment developed the risk matrix presented in Table 4.2. This is a visual representation of the risk profile of each one of the vulnerable locations identified in this assessment. For this assessment the risk profile consists of a series of characteristics at each site that may lead to high-risk interactions:

- **Estimated level of damage and consequences:** An estimate of the possibility of injuries, loss (personal or economical), and loss of function or negative environmental impact associated with damage of infrastructure.
- **Risk timeline**: Estimated time at which a flooding event is likely to occur based on present climatic conditions or projected sea level rise for the years 2050 and 2100.
- **Historical frequency of flooding**: Considerations to how often the infrastructure has flooded in the past.
- **Demographic characteristics of the area**: Estimate of the density and land uses of the area that could be affected by damage of a specific infrastructure.
- **Stakeholder input**: Priorities and needs identified expressed by the stakeholders during consultation.
- **Public input**: Priorities and need identified by the public during the two public consultations conducted during the development of this study.

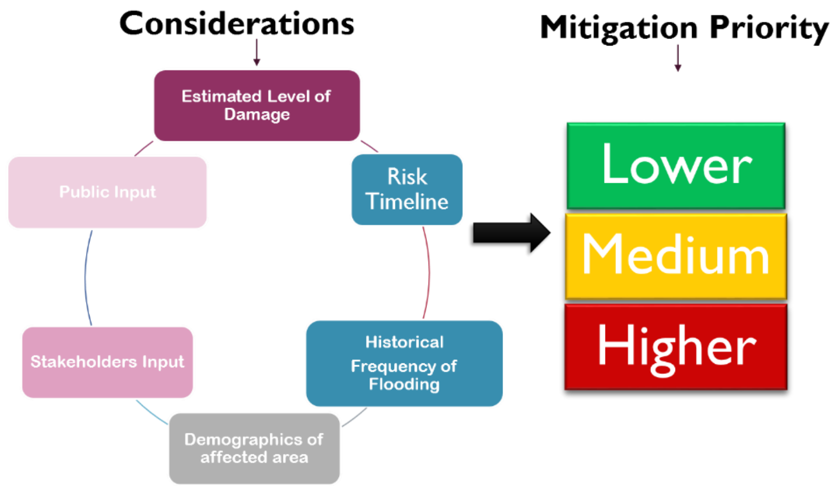


Figure 4.5: Schematic Methodology for Ranking of Priority Areas for Flood Mitigation

Other considerations that may impact the level of risks may include cost estimates of loss revenue as a consequence of downtime due to loss of access during flooding, availability of funding for the implementation of mitigation measures in the short term, capacity of the affected population for recovery after the impact of a flooding event, etc.

Based on the distribution and predominance of colors, the level of risks at each location was interpreted as presented in Table 4.3. **Map1** presents the locations identified as vulnerable thorough the study area, color coded according to the level of risk identified in this assessment. Appendix C presents an atlas of this same map at larger scale according to the tiles shown in Map 1.

The order of implementation of mitigation measures in these areas requires an evaluation of construction costs, funding sources (Federal, Provincial, Municipal), funding availability, as well as infrastructure management jurisdiction (road networks under the jurisdiction of NSTIR, dykes under the jurisdiction of NSDA, other infrastructure under Municipal jurisdiction).

Table 4.2: Mitigation Measures Scores and Ranking

Consideration	Degree of Significance	Score	Walton Fire Station	Cheverie Creek Causeway	Hobarts Beach	Summerville Beach	Cogmagun River Crossing	Red Bank Road	Card Beach	Avondale Road	Newport Landing Boardwalk	Belmont Road	Avon River Society Heritage Museum
Estimated Impact to the Community	Very High												
	High												
	Moderate												
	Low												
	Very Low												
Risk Timeline	2018 – 1 in 1 Year												
	2018 – 1 in 100 Year												
	2050 – 1 in 100 Year												
	2100 – 1 in 100 Year												
Historical Frequency of Flooding Impact	Very Frequent												
	Frequent												
	Rare												
Demographic Characteristics of Affected Area	Municipal Service												
	Medium Density Commercial/Recreational												
	Low Density Commercial/Recreational												
	Medium Density Agricultural												
	Low Density Agricultural												
	Medium Density Residential												
	Low Density Residential/Recreational												
Mitigation Options Implementation Costs	<500,000												
	500-2M												
	2-7M												
Public Meeting 1 Areas of Concern According to Type of Infrastructure	Road Network/Municipal Service												
	Agricultural Land												
	Private Property												
	Museum												
Public Meeting 2 Areas of Concern According to Specific Area	First Priority												
	Second Priority												
	Third Priority												
Stakeholders Areas of Concerns	Agricultural Land												
	Road Network/Municipal Service												
	Private Property												
	Museum/Recreational												

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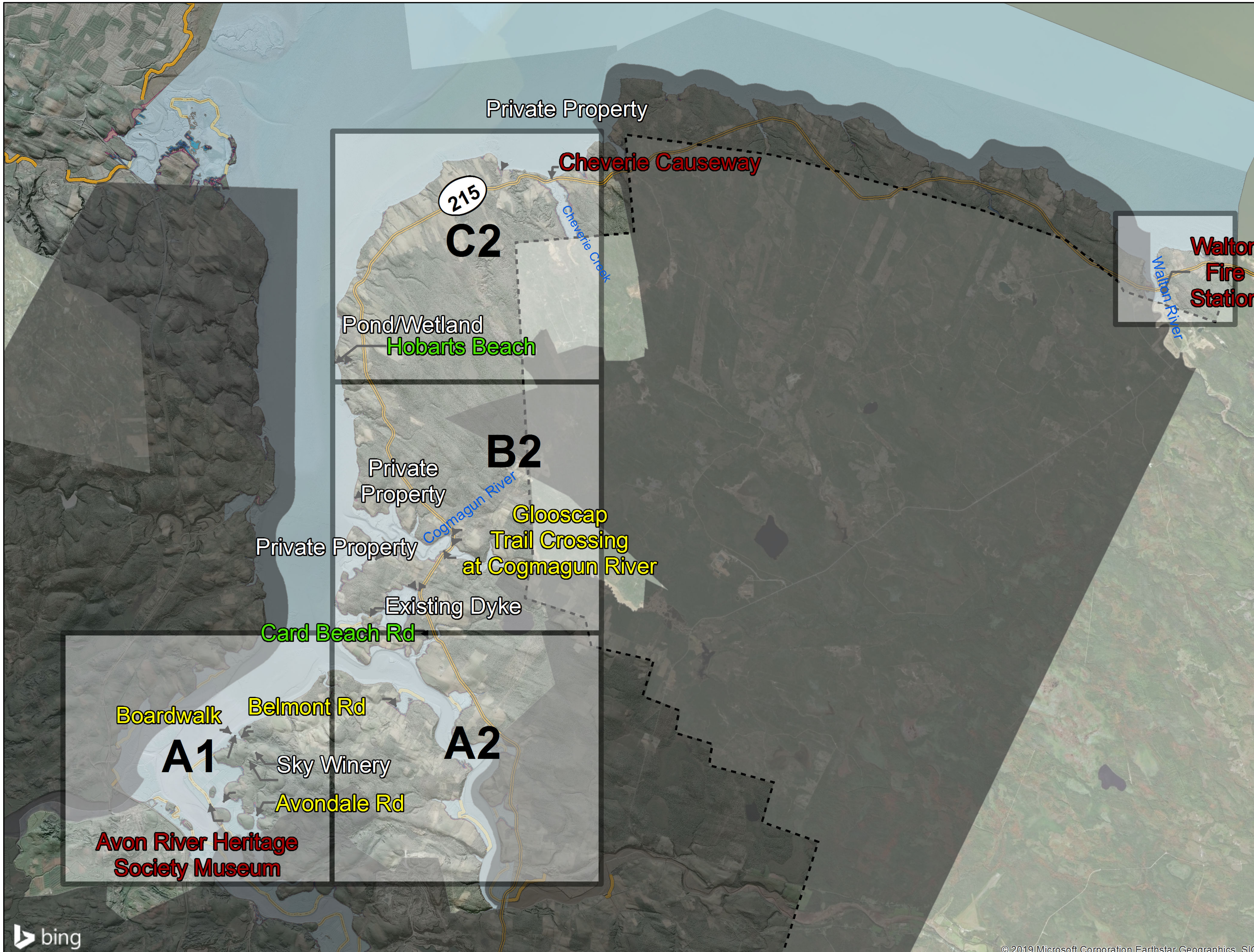


WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Infrastructure at Risk
- Existing Dyke

Floodlines

- Yearly Event (2018)
- Extreme Event (2018)
- Extreme Event (2050)

Map 1
General Map
Level of Flooding Risk

Risk Level	Location Label Color
Higher	Red Labels
Medium	Yellow Labels
Lower	Green Labels

CBCL
CBCL LIMITED
Consulting Engineers

Table 4.3: **Flooding Risk Ranking**

Location	Representation	Risk Level
Cheverie Creek Causeway		Higher
Walton Fire Station		
Avon River Heritage Society Museum		
Cogmagun River Crossing		Medium
Red Bank Road		
Avondale Road		
Belmont Road		
Newport Landing Boardwalk		
Card Beach		Lower
Hobarts Beach		
Summerville Beach		

4.5 Hazard Mapping

Appendix D presents a map atlas of flood severity defined as the combination of flood depth and velocity. Flood severity threshold are considered to determine the impact of flooding on humans, vehicles or buildings and for evaluating evacuation routes during emergency. For this case maps show different zones of low to extreme hazard for the mobilization of adults based on a 1 in 100 year storm surge under present climate conditions. The severity degree is calculated as the product of depth (m) and velocity (m/s). The analysis is based on model results and the methodology described in the FEMA Guidance for Flood Risk Analysis and Mapping and the threshold levels.

5 Stormwater Hydrologic and Hydraulic Assessment

An area of 180 Km^2 drains through the study area into the Avon River through a series of hydraulic openings that include culverts, bridges and aboiteaux. An evaluation of potential flood mitigation measures that may include the upgrade of bridges and dyke requires an assessment of the current capacity of their associated hydraulic openings. Consequently, this assessment includes an estimate of extreme peak runoff discharges, at infrastructure identified as vulnerable, with a hydrologic and hydraulic model of the area using PC-SWMM, a modelling software that uses the SWMM engine developed by the US Environmental Protection Agency to study drainage systems. The model is capable of resolving the effects of water backup, water pooling and culvert hydraulics for dynamically changing flows, which is fundamental in this kind of assessment.

5.1 Rainfall Analysis

Environment Canada (EC) provides Intensity-Duration-Frequency (IDF) curves for 55 locations throughout Atlantic Canada. The IDF curves show extreme rainfall intensities for a range of durations (from 5 minutes to 24 hours) and frequencies (2, 5, 10, 25, 50 and 100 years). These curves are the result of extreme value statistical analysis of 20 years of rainfall intensity records and can be used to calculate synthetic hyetographs (rainfall time series) using methods such as the Chicago Distribution. The closest locations to the study area with available EC IDF curves is Kentville (Figure 5.1). Figure 5.2 shows the 1 in 100-year hyetograph calculated using the Chicago distribution method.

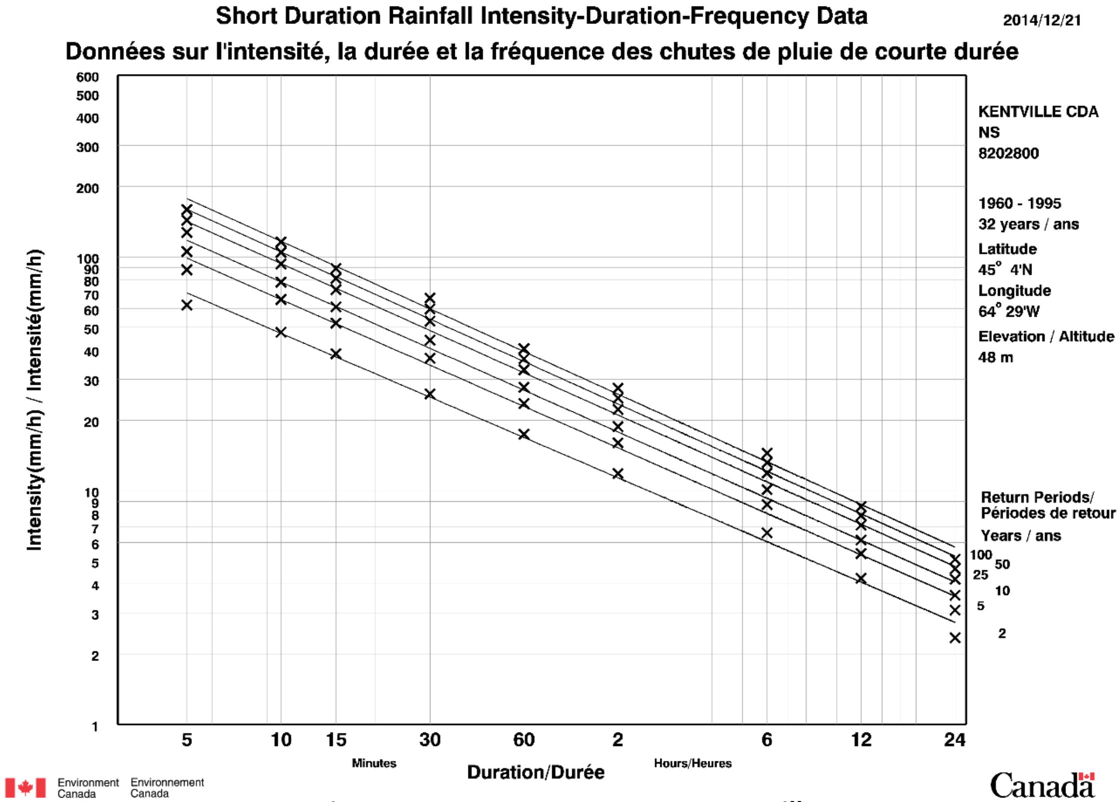


Figure 5.1: EC IDF Curves at Kentville

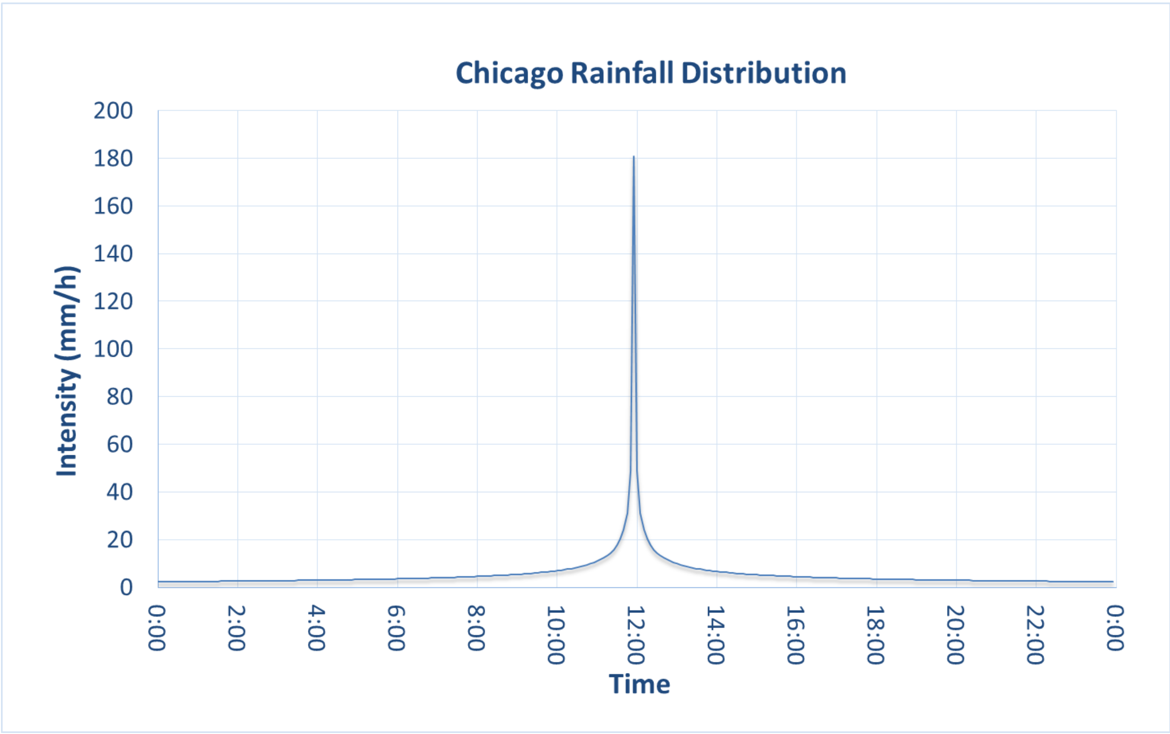


Figure 5.2: Calculated Chicago 1 in 100 year Rainfall Distribution Curve at Kentville (Time step: 5 min)

5.2 Impact of Climate Change on Rainfall

Climate change is expected to severely impact the intensity of rainfall events in the foreseeable future; therefore, increased severity and frequency of flooding can be anticipated. Analysis of flooding risks requires considering the effects of climate change. This assessment calculates the potential effect of climate change on sub-daily (less than 24 hour duration) rainfall intensity using tools that include the Western University IDF_CC tool (Schardong, et al. 2018), Clausius-Clapeyron equation (Westra , et al. 2014), the Cornell Extreme Precipitation in Atlantic Canada tool (Castellano and DeGaetano 2017), and General Circulation models (GCMs). The GCMs are universal climate change estimates used to best represent existing and future climate dynamics within the Earth's atmosphere. These models are based on a 250 km resolution grid.

The Western University Intensity Duration Frequency Climate Change tool (IDF_CC) estimates potential impacts of climate change on IDF curves by downscaling GCMs outputs to current IDF curves (derived either from gauged locations or from interpolation tools). The IDF_CC tool allows to calculate projections from a range of climate models and from average climate scenarios, or ensemble models. For this analysis, calculations with the IDF_CC tool are based on the outcome of a range of climate change scenarios. The tool offers bias corrected GCMs from the Pacific Climate Impacts Consortium (2015), in addition to raw GCMs.

The global climatic models used for estimating climate change impacts in the study area were selected based on location of the station, maximum values, minimum values and ensemble reports to generate a range of climate scenarios. For this study, the worst-case climate change scenario, RCP8.5, as defined in the IPCC 5th Assessment Report (IPCC 2013) was chosen. These estimates indicate that the most extreme future storms could increase rainfall intensity by 136%, whereas the minimum future increase could be as low as 14%. (Westra , et al. 2014). The ensemble RAW GCM model yielded an increase of 22% for 2050 to 2100 whereas the Bias ensemble yielded an increase of 61%. The ensemble model with Canadian and American models show an increase range between 22.5% and 36.2%. Previous assessments in Halifax and Charlottetown found the percent increase in intensity to be between 8.59% and 52%, and between 18.85% and 46.3%, respectively. These estimates are generally close to a 30% increase.

Projected temperature changes in combination with the Clausius-Clapeyron equation (Westra , et al. 2014) allow for the conversion of the temperature output to precipitation due to the tendency of air to hold more water as the temperature increases. The tool is based on the Fifth Assessment Report (IPCC 2013) and uses raw GCMs only. The tool was used with all models and runs to generate extreme ranges for potential temperature increase. This method could result in lower skewed data compared to using the worst case, RCP 8.5. This resulted in a percentage increase ranging from 7% to 78%. The tool was then used to compare the IDF_CC GCMs at RCP 8.5 which resulted in a range of values from 26% to 76% increase in precipitation for the 2070 to 2099 period.

From the above climate analysis, a future generalized precipitation increase of 30% was chosen to evaluate stormwater flooding risks for the 1 in 100 year climate scaled event.

5.3 Watershed Characteristics

Figure 5.3 shows 5 watersheds draining to infrastructure identified in this study as vulnerable to coastal flooding. The hydrologic characteristics of each watershed (area, percent slope, soil conditions, surface roughness and percentage of impervious areas) were extracted using topographical survey data, 1 m LiDAR survey, Nova Scotia 20 m digital elevation models (DEM), aerial photography, satellite images, onsite ground measurements, the NRCAN soil inventory, and local photographs. Appendix A shows the characteristics of each watershed.

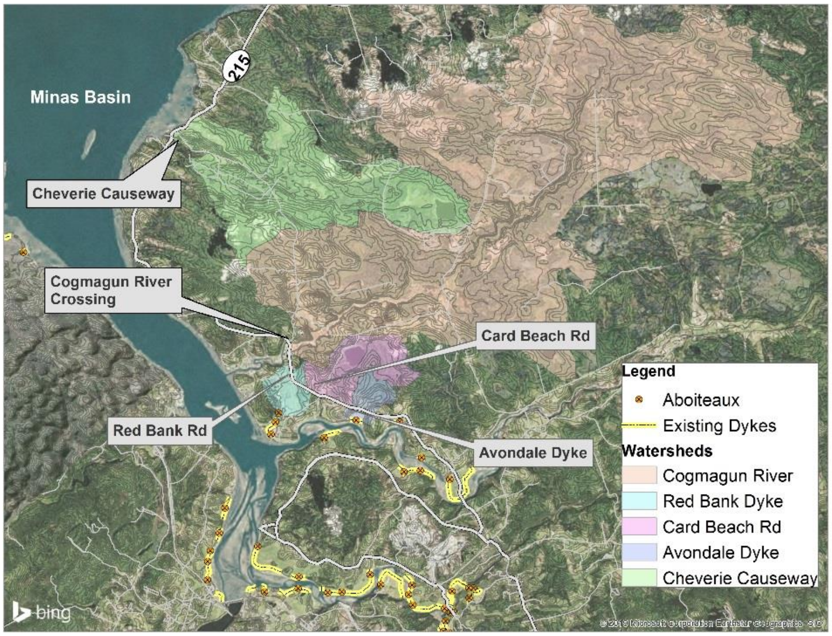


Figure 5.3: Study Area Watersheds

Imperviousness and roughness coefficients were estimated for each land cover type and applied to the watersheds using area-weighted averages. The impervious percentages were estimated by measuring and averaging impervious areas for each land cover type, and roughness coefficients were estimated based on values suggested by McCuen (1996). The capillary suction head and saturated hydraulic conductivity of the soil were estimated for each soil class from the soil mapping based on values suggested by Rawls (1983) and then applied to the watersheds using area-weighted averages. Maximum overland flow lengths were estimated by manually measuring the flow path from the highest point of each sub-watershed to the outlet. Average drainage slopes were estimated using the available DEM and automatic delineation of flow paths.

5.4 Hydrologic Modelling

The hydrologic model of each watershed was developed using PCSWMM, a modelling platform developed by Computational Hydraulics International (CHI) that integrates Version 5 of the Storm Water Management Model (SWMM) with a GIS engine and is capable of performing hydrodynamic simulations. SWMM is a hydrologic and one-dimensional hydraulic model developed by the United Stated Environmental Protection Agency to study semi-urban drainage systems and is capable of performing unsteady flow calculations to simulate water backup, pooling and culvert hydraulics by dynamically solving the continuity and momentum equations with a finite difference scheme. Appendix A shows the peak runoff flows calculated for current and future climate conditions. While local flow measurements were not available to calibrate the model, the results appear to fall within a reasonable bracket based on anecdotal evidence from the community.

5.5 Stormwater Hydraulic Assessment

CBCL developed a computer model of the hydraulic structures present at vulnerable locations to estimate their hydraulic capacity to handle stormwater flows at mean water level. Calculations are based on structure dimensions derived from visual inspection of the site through aerial photography, site visits and the NSDA marshland atlas.

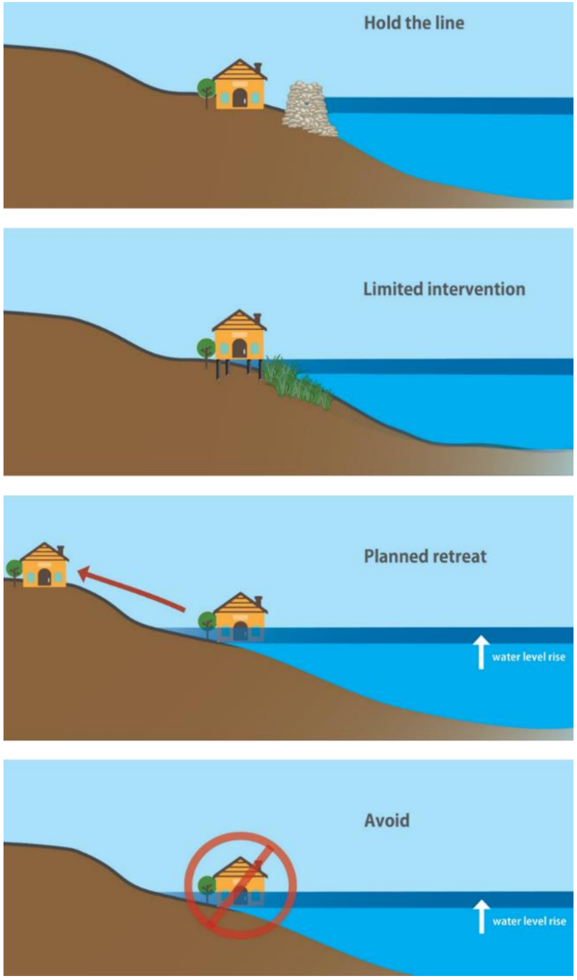
Location	Type of Structure	Estimated Flows (m3/s)		Approximated Current Dimensions	Capacity Evaluation
		Present	Climate Change		
Cheverie Causeway	Bridge	140	200	9.2 m arch	Modelling results do not show bridge overtopping under present and climate change conditions.
Glooscap Trail Crossing at Cogmagun River	Bridge	420	600	52 m span	Modelling results do not show bridge overtopping under present and climate change conditions.
Dyke at Red Bank Road	Aboiteau	31	45	1 circular pipe (900mm) 1 circular pipe (450 mm)	Modelling results do not show dyke overtopping under present and climate change conditions.
Card Beach Road	Culvert with no flap gate	48	70	3.6 m x 2.4 m	Modelling results do not show road overtopping under present and climate change conditions. However, the culvert may be close to surcharging under climate change.
Dyke at Newport Town Marsh (NS027_52)	Aboiteau	16	25	1 circular pipe (900mm)	Modelling results do not show overtopping under present and climate change conditions. However, the culvert may be close to surcharging under current climate conditions.
Dykes at Newport Town Marsh (NS027_20)	Aboiteau	23	31	1 circular pipe (750mm)	Modelling results do not show overtopping under present and climate change conditions. However, the culvert may be close to surcharging under current climate conditions.

5.6 Conclusion

The development of a hydrologic model allows the calculation of the 1 in 100 year peak runoff (under present and projected climatic conditions) discharging towards different hydraulic structures throughout the area. Hydraulic calculations using these flows were conducted to evaluate the hydraulic capacity of aboiteaux and bridges identified as vulnerable within the study area. The assessment indicates that the estimated structure dimension provide enough capacity to convey the calculated runoff flows during low and mean tide. However, conducting a more detailed stormwater assessment based on survey dimensions is recommended prior to the implementation of flooding risks mitigation measures at these locations.

6 Flood Risk Mitigation Options

Generally, effective flood risk management approaches take into consideration the land uses of the vulnerable areas, the environmental impacts of implementing hard protection measures, the effect that both hazards and mitigation measures exert over stakeholders and their properties and the cost-benefit relation between consequences of damage and the benefits of protection. Standard mitigation strategies include:



Holding the Line: This approach maintains land uses and development in the vulnerable areas and relies on the design and maintenance of hard infrastructure to resist extreme events to a set level. However, protected areas are still vulnerable to the occurrence of events larger than those the structure was designed for.

Limited Intervention: This approach involves changing land uses in exposed areas using infrastructure that can tolerate flooding. Examples of this approach include raising or flood proofing vulnerable infrastructure and using floating structures. This option provides additional time for the community and authorities to plan for further adaptation for climatic changes.

Planned Retreat: This approach consists of relocating people and infrastructure away from hazardous coastal areas. Managed retreat involves selecting what to relocate and mitigating the environmental impacts of leaving infrastructure exposed to natural processes. Abandonment is another type of retreat that does not involve planning for relocation or for the impacts that abandonment may cause on the environment. Abandonment is not a beneficial adaptation strategy but may be necessary in cases of emergency.

Avoid: This approach prevents development in hazardous coastal and riparian areas and locates critical infrastructure such as hospitals and emergency services in areas where risks of flooding are negligible.

Procedural: This approach raises awareness and enhances preparedness by generating climate information, producing flood risk maps and disseminating this information to stakeholder and the public. Other measures include detailed hydrodynamic flood forecasting and civil contingency planning.

The assessment of the flooding risks at different locations throughout West Hants and the vulnerability levels of the community brings forth the following options for flood risk mitigation:

- Raising dyke crest elevation (holding the line).
- Raising vulnerable infrastructure (limited intervention).
- Planned relocation.
- Emergency preparedness.

Considerations for the evaluation of each option included:

- Constructability and feasibility.
- Requirements of additional measures in adjacent areas.
- Residual risks (i.e. potential risks after the implementation of a particular mitigation measures).
- Potential for habitat restoration.
- Potential for the implementation of best management practices.
- Maintenance requirements.
- Potential construction costs.

6.1 Mitigation Options Analysis

This section presents a series of tables comparing mitigation options to reduce flooding risks at the public infrastructure identified as vulnerable. Each table presents a risk time line (i.e. estimated year at which a flooding event is likely to occur based on present climatic conditions or projected sea level rise for the years 2050 and 2100), a target upgrade elevation, opinion of probable construction costs, as well as advantages and disadvantages of each option. The atlas map presented in Appendix E shows the locations identified as vulnerable with a list of the mitigation options considered for each site.

It is noted that the costs are intended to provide some guidance in comparing options. However, these estimates are based on a high level analysis of the present topographic elevation and potentially required material quantities. The development of concept and detailed designs would be required to provide a more accurate costs assessment. The selection of a specific option at each location requires other considerations such as funding availability, management jurisdiction of the assets (Provincial: Nova Scotia Department of Agriculture –NSDA and Nova Scotia Department of Transportation and Infrastructure Renewal –NSTIR; or Municipal), concerns about emergency evacuation and considerations of adjacent land uses.

6.1.1 Walton Shore Volunteer Fire Department

A comparison of the mitigation options evaluated at this location indicates that the most economical short-term measure consists of raising the existing dyke to an elevation of 8.40 m to reduce flooding risks during a 1 in 1 year event with a probable construction cost around $470,000. However, after implementation of this measure, the building would remain a risk of flooding under a major event such as a 1 in 100 year storm surge at HHWLT. The cost associated with raising the dyke to higher target elevations increase as a function of the additional quantities and materials associated with the dyke upgrade and other additional requirements including adjustment of the access road elevation, stormwater management infrastructure, staged elevation increase to address potential settlement; and extension of the dyke to raise the elevation along the perimeter. The cost associated with abandonment of the existing infrastructure and reconstruction of the fire station at a suitable location are comparable with those associated with raising the existing dyke to the 1 in 100 year elevation projected for the year 2100. The main advantage of this option is that it removes the structure from a risk area, in the short and the long term, provided that the construction of a new building takes place outside a river flood plain and at an elevation of at least 13 m. Given that the cost of raising the existing concrete building makes this option the least cost-efficient, abandonment and reconstruction of the fire station appears at the most cost effective options to reduce the vulnerability of the fire station operation of flooding risks.

Table 6.1: Walton Volunteer Fire Department - Mitigation Options Comparison

Asset Jurisdiction	Owner is Walton Shore Volunteer Fire Department; within the boundaries of the Municipality of East Hants; the Municipality of West Hants provides some funding			
General Option Description	**Target Elevation (m CGVD28)**	8.4	9.2	10
	Mitigation Timeline	2018	2050	2100
	Residual Risks	1 in 100 year storm (2018)	Sea Level Rise after 2050	Sea Level Rise after 2100
	Additional Requirements of Selected Target Elevation	• Extension of dyke around building. • Emergency management plan for major storms and management of sea level rise. • Evaluation of armour stone or erosion protection measures.	• Raising access road to 9.20 m elevation Stormwater management plan. • Extending dyke length to adjacent areas. • Long term sea level rise adaptation plan. • Geotechnical Investigation.	• Raising access road to 10.40 m elevation. • Stormwater management plan. • Long term sea level rise adaptation plan. • Geotechnical investigation.
Dyke Raising	**Opinion of Probable Construction Costs ($)**	470,000.00	683,800.00	1,750,000.00
	Advantages	Allows the building to remain in its current location		
	Limitations	• The building remains exposed to the occurrence of a 100 year storm surge at HHWLT under existing climate conditions.	• Geotechnical conditions of the substrate may limit the soil capacity to withstand additional weight and may require additional reinforcement of the structure or construction in stages.	• Geotechnical limitations related to the capacity of the soil to withstand additional weight. • Unknown erosion and sedimentation rates. Loss of sediment may affect the integrity of the dyke or limit space available for increasing height.
Raising Building	**Opinion of Probable Construction Costs ($)**	2,000,000		
	Advantages	Allows the building to remain in its current location		
	Limitations	• The building remains exposed to the occurrence of a 100 year storm surge at HHWLT under existing climate conditions. • The costs associated with raising structures built on concrete slabs is significantly higher than those associated with raising wooden structures.	• Geotechnical conditions of the substrate may limit the soil capacity to withstand additional weight and may require additional reinforcement of the structure or construction in stages.	• Geotechnical limitations related to the capacity of the soil to withstand additional weight. • Additional cost associated construction in phases due to settlement. Unknown erosion and sedimentation rates. • Loss of sediment may affect the integrity of the dyke or limit space available for increasing height.

Relocation	Opinion of Probable Construction Costs ($)	750,000.00
	Advantages	Removes the structure from area of flooding risks
	Limitations	• Requires plan for abandonment of existing infrastructure as concrete slab limit the capacity of moving the existing infrastructure. • Requires plan for avoiding down time of the department during relocation. • Requires purchase of new land. • Requires addressing flooding risks in access roads to allow operation during flooding events. • Requires construction of a new building.

6.1.2 Causeway at Cheverie Creek

A comparison of the mitigation options evaluated at this location indicates that the most economical short-term measure consists of raising the existing road to the 9.30 m elevation to reduce flooding risks during a 1 in 100 year event under existing climatic conditions with a probable construction cost of approximately $300,000. However, the road is likely to require periodic maintenance of armour stone protection, as the structure is highly exposed to waves. After implementation of this measure, the road would require further adaptation measures to mitigate flooding risks after the year 2050. Removal of the existing causeway and construction of a bridge would require an investment that may range between 5 million dollars for a 50 m span to 14.50 million for a 200 m span. These options allow improvement of the tidal exchange through the Creek enhancing intertidal habitat conditions. However, building code and structural design requirements add up to minimum deck elevation of 13.70 m which result in significant construction and design costs.

Avoiding flooding risks through a road relocation requires the construction of approximately 1.8 Km of new road with an approximate construction cost of $2,800,000. This option allows the selection of road elevations above the projected water levels beyond 2100. However, this requires further measures to maintain recreational access to Cheverie crossing. This option also increases the travel time between locations at both sides of the Creek, such as the Camera Obscura and Cheverie Food Mart by 5 minutes. This additional time may decrease the affluence of tourists to businesses located east of the Cheverie Crossing, This limitation could be potentially addressed during design with relocation of businesses along the new route, however a socio-economical evaluation of the area and further input from residents and stakeholders, would be required.

Table 6.2: Cheverie Crossing - Mitigation Options Comparison

Asset Jurisdiction	NSTIR		
Option	Target Elevation (m CGVD28)	9.30	10.0
	Mitigation Timeline	2018 – 2050	2100
	Residual Risks	Sea Level Rise after 2050	Sea Level Rise after 2100
	Additional Requirements of Selected Target Elevation	• Long term sea level rise adaptation plan. • Geotechnical Investigation.	• Long term sea level rise adaptation plan. • Geotechnical investigation.
Raising the Road	Opinion of Probable Construction Costs ($)	300,000.00	700,000
	Limitations	• Geotechnical conditions of the substrate may limit the soil capacity to withstand additional weight and may require structural fill. • Exposure to wave action may result in continuous erosion or need of continuous maintenance of armour stone. • Requires a plan for adaptation to future sea level rise. • Requires significant additional costs for the installation of large armour stones to avoid the need of ongoing maintenance.	• Geotechnical limitations related to the capacity of the soil to withstand additional weight. • May require ongoing maintenance of armour stone. • Limited capacity for improving tidal exchange.
	Advantages	• Most economical measure which may facilitate short term implementation. • Allows further restoration of tidal inflow with the installation of additional culverts.	

		• Previous upgrade of the culvert under the causeway improved tidal exchange in the area.
Causeway Removal	**Opinion of Probable Construction Costs (Spans of 50, 120 and 200m)**	5M – 9M – 14.5 M
	Limitations	• Requires significant investment. • Requires adaptation plan. • Minimum required elevation, based on building code requirements is 13.70 m.
	Advantages	• Allows improvement or restoration of tidal exchange and intertidal habitat. • Provides opportunity for enhancing sightseeing and touristic experiences at the Cheverie crossing. • Reduces need of amour stone maintenance.
Relocation of Road	**Costs**	$ 2,800,000
	Advantages	• Allows the implementation of adaptation measures beyond sea level rise projections for the year 2100.
	Limitations	• Requires planning of the new route. • Requires plan of abandonment or removal of the existing causeway. • Requires a strategy for providing touristic and recreational access to the Cheverie crossing, including upgrades of existing infrastructure. • Increases travel time between locations at both sides of Cheverie Creek. • Requires construction of 1.8 Km of new roadways.

6.1.3 Hobarts Beach

The Hobarts Beach Recreation Sites are located at the end of Block Wharf Road, in the community of Summerville. The road embankment separates the shores of the Avon River from a pond-wetland system of lower levels of salinity. During an extreme event under current climatic conditions the road is at risk of overtopping and the wetland is at risk of salt water intrusion. Maintaining the separation between the pond behind the road and the Avon River requires raising the road to at least 9.30 m. This option also maintains access to the beach. However, even if raising the road reduces damage and flooding risk, the potential erosion and loss of sand at the beach may reduce the affluence of recreational visitors. Another option consists of accommodating the floods as they take place and allowing the restoration of intertidal habitat behind the road. Marshlands are valuable areas that allow carbon sequestration with the potential of contributing to the mitigation of climate change.

Table 6.3: Hobarts Beach – Mitigation Options Comparison

Asset Jurisdiction	The Municipality owns the parcels abutting the beach – NSTIR has jurisdiction over Block Wharf Road		
Option	**Target Elevation (m CGVD28)**	9.30	10.10
	Mitigation Timeline	2018 – 2050	2100
	Residual Risks	Sea Level Rise after 2050	Sea Level Rise after 2100
	Additional Requirements of Selected Target Elevation	• Long term sea level rise adaptation plan. • Evaluation of the conditions and uses of the wetland behind the road.	• Long term sea level rise adaptation plan. • Evaluation of the conditions and uses of the wetland behind the road.
Raising the Road	**Opinion of Probable Construction Costs ($)**	150,000	170,000
	Advantages	• Maintains access to the beach. • Maintains separation between Avon River and Pond behind the road.	
	Limitations	• Requires a plan for adaptation to future sea level rise.	

		• Erosion trends in the area may affect life the shoreline and reduce the affluence of recreational visitors despite of the maintenance of the road. • May require ongoing maintenance of armour stone. • Limited capacity for improving tidal exchange.
Accommodate the Floods	Opinion of Probable Construction Costs ($)	50,000
	Advantages	• Short term implementation consists of monitoring. • Allows improvement or restoration of tidal exchange and intertidal habitat. • Reduces need of amour stone maintenance.
	Limitations	• Requires an environmental plan for abandonment. • May limit recreational visitors to the area. • May require plan for re-purposing the area.

6.1.4 Summerville Beach

This recreational area is mainly exposed to flooding during major storm surge events at high tide. In the long term, water levels could potentially impact private infrastructure. Confirming the top elevation of the retention wall located adjacent to be beach will allow the estimation of how vulnerable this private infrastructure is to extreme water levels. In the short term monitoring water levels and creating awareness of the risks in the area are deemed suitable approaches.

Table 6.4: Summerville Beach – Mitigation Options Comparison

Asset Jurisdiction	170 Summerville Wharf Road is owned by the Municipality- NSTIR has jurisdiction over Nunn Road and Summerville Wharf Road – Private ownership abuts the beach		
Option	Target Elevation (m CGVD28)	9.40 – 9.70	10.40
	Mitigation Timeline	2018 – 2050	2100
	Residual Risks	Sea Level Rise after 2050	Sea Level Rise after 2100
	Additional Requirements of Selected Target Elevation	• Long Term Adaptation Plan for sea level rise.	• Long Term Adaptation Plan for sea level rise.
Monitor	Opinion of Probable Construction Costs ($)	N/A	
	Advantages	• Short term implementation. • No additional infrastructure requirement.	
	Limitations	• Geotechnical conditions of the substrate may limit the soil capacity to withstand additional weight and may require structural fill.	

6.1.5 Glooscap Trail Crossing at Cogmagun River

The Glooscap Trail Crossing at the Cogmangun River allows access from the south to Summerville along Highway 215, connecting important touristic centres such as the Summerville Beach and the Flying Apron to the centre of the Province. It also connects the Summerville Volunteer Fire Department with the adjacent communities. The analysis of mitigation measures at this location identified that the construction of flood defenses such as dykes would interrupt the natural tidal inflow through the Cogmagun River and require the installation of an aboiteau to manage stormwater flows. Given the potential environmental impacts and costs associated the construction of a new dyke, this option was not considered for further assessment. Options such as relocating the road or replacing the existing road section with a full bridge to restore tidal inflow require significant cost investments larger than 2 million with limited added benefit. Raising the existing vulnerable section of road up to an elevation of 10.40 m (the 1 in 100 year water level projected for 2100) requires an investment of less than $370,000. Therefore, based on the available information, this is the most feasible measure to address flooding risks at this location.

Table 6.5: Glooscap Trail – Mitigation Options Comparison

Asset Jurisdiction	NSTIR		
Option	**Target Elevation (m CGVD28)**	9.40 – 9.70	10.40
	Mitigation Timeline	2018 – 2050	2100
	Residual Risks	Sea Level Rise after 2050	Sea Level Rise after 2100
	Additional Requirements of Selected Target Elevation	• Long Term Adaptation Plan for sea level rise.	• Long Term Adaptation Plan for sea level rise.
Road Raising	**Opinion of Probable Construction Costs ($)**	175,000	370,000
	Advantages	• Short term implementation. • No additional infrastructure requirement. • Maintain access through existing route.	
	Limitations	• Geotechnical conditions of the substrate may limit the soil capacity to withstand additional weight and may require structural fill.	

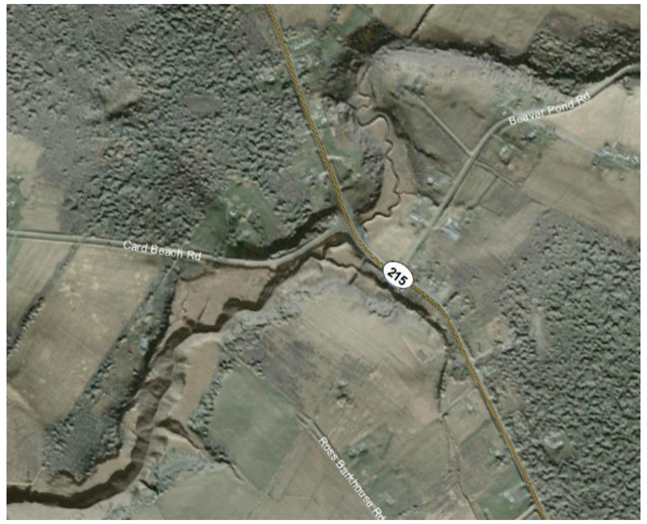
6.1.6 Red Bank Road and Highway 215

Red Bank Road connects Highway 215 to agricultural and industrial centres including Sustainable Blue, a fish farming complex. A dyke and aboiteaux system protects the area enclosed by Red Bank Road, Highway 215 and Card Beach Road from water levels up to an elevation of 9.60 m which corresponds to the 1 in 100 year water levels projected for the year 2050. Therefore, in the short term, if the structural conditions of the dyke do not require upgrades or reinforcement, no additional measures may be required to mitigate the risks at the road. However, it is noted that the existing dyke is at risk of overtopping for a 1 in 1 year storm surge at HHWLT under existing climatic conditions, posing flooding risks for the agricultural land behind the dyke

For long term flood risk management for the road, options include raising the existing dyke and raising the Red Bank Road section at risk. Raising the dyke allows flood risk mitigation for the agricultural land, private properties and local roads located behind the dyke, whereas raising the road addresses flooding risks at the road only. Selection of an option requires further evaluation of the projected land uses in the area. If agricultural and residential land uses in the area are projected to remain active in the area, then raising the dyke may be a suitable measure.

Table 6.6: Red Bank Road – Mitigation Options Comparison

Asset Jurisdiction	NSDA(Dyke)/ NSTIR (Road)	
Option	**Target Elevation (m CGVD28)**	10.20
	Mitigation Timeline	2100
	Residual Risks	Sea level rise after the year 2100
Dyke Raising	**Opinion of Probable Construction Costs ($)**	300,000
	Advantages	• Mitigate risks of local flooding roads, agricultural land private property.
	Limitations	• Interrupts tidal exchange. • Requires upgrade of aboiteaux capacity for runoff flow under climate change conditions. • Mitigating risks behind the dyke requires implementation in the short term, close to the year 2019.
Raising Road	**Opinion of Probable Construction Costs ($)**	172,000
	Advantages	• Allows the road operation during high tides without a dyke and aboiteaux system. • Allows implementation in the long term. • May allow intertidal habitat restoration.
	Limitations	• Require investment in raising adjacent local roads. • If implemented along with dyke realignment or removal, requires repurposing of current agricultural land use. • Requires an evaluation of potential long term land uses in the area and potential losses of active agricultural land.



6.1.7 Card Beach Road

Card Beach Road connects residences along the road with Highway 215. During public consultations residents and farm owners indicated that the road floods frequently with increasing number of events over the year. Options to mitigate risks in this area include raising the road and road relocation. In the short term, raising the road to an elevation of 8.80 m may address short term concerns. However the road would still be exposed to flooding risks during major storm events. Another option includes relocating the road away from an area vulnerable to flooding. This option requires an evaluation of potential routes and acquisition of right of way. The construction costs of this option may be comparable to those associated with raising the road to the 1 in 100 year water level estimated for the year 2100.

Table 6.7: Card Beach Road – Mitigation Options Comparison

Asset Jurisdiction	NSTIR			
Option	**Target Elevation (m CGVD28)**	8.8	9.60	10.20
	Mitigation Timeline	2018	2018-2050	2100
	Residual Risks	1 in 1 year storm event under present climate	Sea level rise after 2050	Sea level rise after 2100
Raising the Road	**Opinion of Probable Construction Costs ($)**	260,000	400,000	500,000
	Advantages	• Maintains access to private residences.		
	Limitations	• Road section is exposed to floods during a 1 in 100 year storm. • Requires erosion protection measures.		
Road Relocation	**Opinion of Probable Construction Costs ($)**	500,000 -900,000		
	Advantages	• Reduces maintenance costs. • Requires an evaluation of long term land uses along Card Beach.		
	Limitations	• Requires procurement of new right of way along private properties.		

6.1.8 Newport Landing Waterfront Complex

The Newport Landing Waterfront Complex combines a series of assets and services that allow access to the site and enjoyment of recreational and cultural activities. This assets include a wooden boardwalk, a gazebo, two buildings constituting the Avon River Heritage Society Museum, a parking lot, a green area used for festivals and concerts and two main access roads. Currently most of the area is exposed to flooding risks. Measures to mitigate the risk include the construction of a dyke around the area or single measures for each assets and potential relocation and redistribution of the uses within the area. The construction of a dyke along the perimeter of the area may reduce flooding risks with the construction of one defense system. However, this option reduces the recreational view to the Avon River, requires additional stormwater management measures and increases the risk of damage under water level elevations above those projected. In addition space and geotechnical limitations and sediment transport processes may challenge the construction of a dyke at elevations exceeding the projected water levels for the year 2100. Given that this is a recreational area where open space and view to the river are valuable for the users, the construction of a dyke may be detrimental for the operation of the site.

Table 6.8: Newport Landing Waterfront Complex – Mitigation Options Comparison

Asset Jurisdiction	Municipality of the District of West Hants			
Option	**Target Elevation (m CGVD28)**	8.8	9.60	10.20
	Mitigation Timeline	2018	2018-2050	2100
	Residual Risks	1 in 1 year storm event under present climate	Sea level rise after 2050	Sea level rise after 2100
	Additional Requirements of Selected Target Elevation	• Flood proofing the building for water levels higher than 8.8 m. • Removing valuable items from elevation lower than 9.6 m.	• Raising access road. • Geotechnical investigation to evaluate the structural capacity of the underlying soils. • Integration with an adaptation plan for the Newport Landing Waterfront Park.	
Construction of Dyke around Entire Area	**Opinion of Probable Construction Costs ($)**	870,000	2,400,000	3,100,000
	Advantages	• Mitigates flooding risks throughout the area with one structure.		
	Limitations	• Creates a low area. • Limits the view to the Avon River. • Requires additional work to integrate Belmont and Avondale Road to the dyke system. • Requires stormwater management measures (aboiteaux or pumping system). • Provides limited adaptation opportunity for extreme water levels above the target elevation and increases the risk of damage during such an event.		

6.1.9 Avon River Heritage Society Museum

The Avon River Heritage Society Museum houses exhibits related to the local history of the area including Acadian and New England settlements, historical architecture, and family histories. The museum also hosts the Avon River Heritage Society and multiple events including the Full Circle Festival and the Honey Harvest Festival. The museum complex includes a larger wooden structure used to host concerts and private events. The museum is located at an approximate elevation of 8.6 m which makes the building vulnerable to flooding under a 1 in 1 year storm surge at HHWLT. This assessment evaluates flooding risks mitigation options that allow to maintain the operation of the museum at its current location including raising the building or the construction of a flood defense around the structure. In the short term the construction of a 0.30 m dyke, with a construction cost of $400,000, would mitigate flooding risks for a 1 in 1 year storm surge at HHWLT. However the building would remain exposed to larger events such as the 1 in 100 year event which would flood the building to a depth of 1 m. This risk could be mitigated with the installation of a pumping system. The evaluation indicates that dykes with a height of 1.0 m would be required to mitigate risks for the 1 in 100 year storm under present climate conditions. A 1.60 m dyke would be required to mitigate risks for the extreme water levels projected for the year 2100. This options require the installation of a pumping system to drain stormwater from the building yards. Another option that allows maintaining operation at the same location involves raising the building. However the characteristics of the main building including a concrete foundation require reconstruction of the structure to allow raising the main floor to a higher elevation. This results in costs closer to $2,0000,000 without including potential raising of the parking lot and Belmont Road to allow access.

Moving the museum to a new location will also require the construction of a new building with an approximate costs of $1,750,000. These costs are comparable to the option of raising the building maintaining its current position. However, relocation allows the reduction of costs associated with raising the ground and raising access roads. Areas along Avondale Cross Road offer potential for maintaining the Museum activities associated with other important touristic centers in the community such as the Avondale Sky Winery. Temporary scenarios are an option to host concerts and festivals in the Newport Landing Waterfront Park.

Table 6.9: Avon River Heritage Society Museum – Mitigation Options Comparison

Asset Jurisdiction	Municipality of the District of West Hants			
Option	**Target Elevation (m CGVD28)**	8.8	9.60	10.20
	Mitigation Timeline	2018	2018-2050	2100
	Residual Risks	1 in 1 year storm event under present climate	Sea level rise after 2050	Sea level rise after 2100
	Additional Requirements of Selected Target Elevation	• Flood proofing the building for water levels higher than 8.8 m. • Removing valuable items from elevation lower than 9.6 m.	• Raising access road. • Geotechnical investigation to evaluate the structural capacity of the underlying soils. • Integration with an adaptation plan for the Newport Landing Waterfront Park.	
Construction of Dyke around Building	**Opinion of Probable Construction Costs ($)**	400,000	700,000	900,000
	Advantages	• Most economical measure. • Allows operation of the museum at its current location.	• Most economical measure. • Allows operation of the museum at its current location.	• Most economical measure. • Allows operation of the museum at its current location.
	Limitations	• The building remains exposed to the occurrence of a 100 year storm surge at HHWLT under existing climate conditions. • Requires stormwater management measures and pumping of tidal water in cases of inundation by water levels larger than 8.8m.	• Requires stormwater management measures (not included in cost estimates). • Dyke would restrict the view of the Avon River from the lower level. • May require slope stabilization to the river bed. • May require raising Belmont Road as part of the dyke.	• Requires stormwater management measures (not included in cost estimates). • Dyke will obstruct view of the Avon River. • May require slope stabilization to the river bed. • Dyke will isolate the museum from the other recreational areas. • May require raising Belmont road as part of the dyke system.
Raising Building	**Opinion of Probable Construction Costs ($)**	1,750,000	1,800,000	1,900,000
	Advantages	• Allows operation of the museum at its current location. • May improve view to the Avon River from the building. • The construction of a new structure may allow for enhancement of the space distribution.	• Allows operation of the museum at its current location. • The construction of a new structure may allow for enhancement of the space distribution.	• Allows operation of the museum at its current location. • The construction of a new structure may allow for enhancement of the space distribution.
	Limitations	• The slab on grade foundation and the geometry of the main building requires reconstruction of the building at a higher elevation. • The building remains exposed to the occurrence of a 100 year storm surge at HHWLT under existing climate conditions. • A large storm event can isolate the building from adjacent areas.	• Geotechnical conditions of the substrate may limit the soil capacity to withstand additional weight and may require additional reinforcement of the structure or construction in stages. • Requires new access ramps to the building. • May require raising of parking lot and Belmont Road (not included in cost estimates).	• Geotechnical limitations related to the capacity of the soil to withstand additional weight. • Additional cost associated construction in phases due to settlement. • Requires raising Belmont Road. • Requires new access ramps to the building. • May require raising of parking lot and Belmont Road (not included in cost estimates).
Relocation	**Opinion of Probable Construction Costs ($)**	250,000 (Museum only) -2,000,000 (Museum and Event Room)		
	Advantages	• May allow long term habitat restoration. • Avoids residual risks. • Addresses long term adaptability to sea level rise.		

		• Selecting only the museum for relocation allows to preserve the structure for a relatively lower costs.
	Limitations	• Removes the museums from its traditional location and may require strategies to facilitate the adaptation of users to the new location. • Requires purchase of land by the Province. • The characteristics of the building does not allow transportation of the existing building and requires the construction of a new structure. • Changes the view to the Avon River. • Separates the building from the open green space used for festivals and concerts. • Relocation of both buildings (museum and concert building) adds a cost of approximately $1,800,000.

6.1.10 Belmont Road

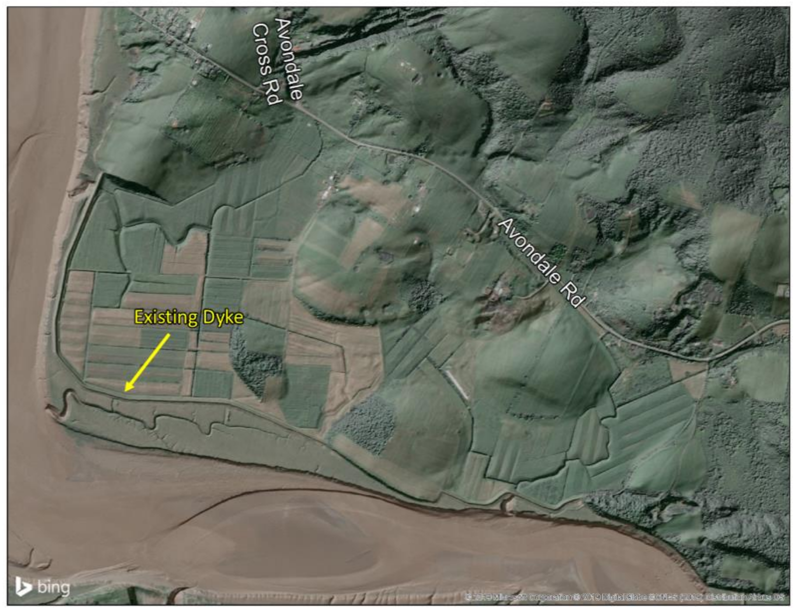
Belmont Road connects the Avon River Heritage Society Museum and private properties along New Town Road with the rest of the community of Avondale and its main roads. The evaluation of options to mitigate flood risks at this location include raising the existing road, and relocating the road. This analysis indicate that raising the road to the projected extreme water levels under current and future climatic conditions is the most economical option. However, additional work would be require to adjust the connection of the road with the New Town Road and the Waterfront park area. Additional costs are potentially required for the construction of stormwater management measures to drain rainfall runoff draining towards the Road. These measures could include installation of an aboiteau or a pumping system. These total additional costs are likely to offset the investment required to relocate the road to an elevation above than the projected extreme water levels. However, road relocation would require procurement of a right of way from private properties in the area. The selection of a specific option requires the development of plan that involves future uses of the Newport Landing Park and the potential future uses of the adjacent private property in the area, considering that sea level rise is likely to reach the private properties currently adjacent to Belmont Road.

Table 6.10: Belmont Road – Mitigation Options Comparison

Asset Jurisdiction	NSTIR			
Option	**Target Elevation (m CGVD28)**	8.8	9.60	10.20
	Mitigation Timeline	2018	2018-2050	2100
	Residual Risks	1 in 1 year storm event under present climate	Sea level rise after 2050	Sea level rise after 2100
Raising the Road	**Opinion of Probable Construction Costs ($)**	240,000	380,000	430,000
	Advantages	• Maintains access to the current location of Newport Landing Waterfront Park.	• Maintains access to the current location of Newport Landing Waterfront Park.	• Maintains access to the current location of Newport Landing Waterfront Park.
	Limitations	• Requires additional work along New Town Road including the existing bridge. • Road section is exposed to floods during a 1 in 100 year storm. • Requires stormwater management measures to prevent risks of flooding during rainfall events (pumping system, aboiteaux) –not included in cost estimate. • Requires integration to the adaptation plan of the adjacent area. • In combination with potential raising of Avondale Road, and mitigation around the museum, may create a ponding area at the centre of the Newport Landing Waterfront Park.	• Requires additional work along New Town Road including the existing bridge. • Requires stormwater management measures to prevent risks of flooding during rainfall events (pumping system, aboiteaux) in cost estimate. • Requires integration to the adaptation plan of the adjacent area. • In combination with potential raising of Avondale Road, and mitigation around the museum, may	• Requires additional work along New Town Road including the existing bridge. • Requires stormwater management measures to prevent risks of flooding during rainfall events (pumping system, aboiteaux) in cost estimate. • Requires integration to the adaptation plan of the adjacent area. • In combination with potential raising of Avondale Road, and mitigation around the museum, may create a ponding area at the centre of the Newport Landing Waterfront Park.

			create a ponding area at the centre of the Newport Landing Waterfront Park.	
Road Relocation	**Opinion of Probable Construction Costs ($)**	900,000		
		• May allow long term habitat restoration. • Avoids residual risks. • Addresses long term adaptability to sea level rise.		
	Limitations	• Requires procurement of new right of way along private properties.		

6.1.11 Avondale Road



Avondale road is the main route connecting the Avondale community with the rest of the province. An existing dyke has historically protected sections of this road from flooding, however this assessment indicates that the dyke is at risk of overtopping during a 1 in 1 year storm surge at HHWLT. Options to reduce flooding risks in the area include raising the existing dyke and raising the road. Given the number of private, agricultural and commercial properties located along the road, relocation of this asset was not considered as a feasible or practical option.

The cost associated with raising the dyke range between 2.8 and 14 million dollars, offering the advantage of reducing flooding risks along the road and also throughout the agricultural land and the private properties located behind the dyke. Based on the current available information raising the road is the most economical option to maintain access through Avondale Road during extreme water levels. However a selection of the most suitable option for the area requires further evaluation of the land use and the cost of damage to active agricultural land in the area.

Table 6.11: Avondale Road – Mitigation Options Comparison

Asset Jurisdiction	NSTIR (Roads) / NSDA (Dykes)			
Option	**Target Elevation (m CGVD28)**	8.8	9.60	10.20
	Mitigation Timeline	2018	2018-2050	2100
	Residual Risks	1 in 1 year storm event under present climate	Sea level rise after 2050	Sea level rise after 2100
Raising Existing Dykes	**Opinion of Probable Construction Costs ($)**	2,800,000	7,900,000	14,000,000
	Advantages	• Mitigate risks for the Avondale Road and the agricultural land and private property behind the dyke.	• Mitigate risks for the Avondale Road and the agricultural land and private property behind the dyke.	• Mitigate risks for the Avondale Road and the agricultural land and private property behind the dyke.
	Limitations	• Erosion rates on the shore of the Avon River. • May require additional erosion protection measures which may cause erosion at other areas along the river shore. • Vulnerable areas remain exposed to a 1 in 100 year storm surge at HHWLT.	• Erosion rates on the shore of the Avon River. • May require additional erosion protection measures which may cause erosion at other areas along the river shore.	• Erosion rates on the shore of the Avon River. • May require additional erosion protection measures which may cause erosion at other areas along the river shore. • Requires a significant capital investment.

Raising the Road	Opinion of Probable Construction Costs ($)	500,000	650,000	800,000
	Advantages	• Maintains access to Avondale from the east during a 1 in 1 year storm at HHWLT. • Economical option may allow short term implementation.	• Maintains access to Avondale from the east during the projected 1 in 100 year storms surge at HHWLT for the year 2050. • Economical option may allow short term implementation.	• Maintain access to Avondale from the east during the projected 1 in 100 year storms surge at HHWLT for the year 2050. • Economical option may allow short term implementation.
	Limitations	• Agricultural land and private property remains exposed to storm surges.		

6.1.12 Boardwalk at the Newport Landing Waterfront Park

The use of this site to access the water of the Avon River dates back to more than 170 years ago, and it has become an important heritage, cultural and recreational site for the community and the Avon River Heritage Society. The original wharf was constructed close to 1840 and since then several reconstruction and restoration projects have extended its life to the present. However, this study has identified that the structure is exposed to risks of flooding under a 1 in 1 year storm event at HHWLT and features limited adaptability to sea level rise. To address the immediate risks an additional restoration project could allow extending the life of the existing wharf for 20 more years, reducing the frequency of overtopping and speed of deterioration. However, the structure would remain exposed to major storm events such as a 1 in 100 year storm surge at HHWLT. With sea level rise the structure is at risks of remaining under water daily for a period of hours. Addressing long term concerns about sea level rise requires raising the deck elevation of the structure to the projected levels. This is likely to require the construction of a new structure to handle the additional weight. Also, the construction of a taller deck is likely to require driving piles adding complexity and costs to the project. To offset this cost, a shorter structure could be constructed. However, given that recreational uses to the wharf are usually associated with the uses of the Newport Landing Waterfront Park complex, the selection of an option for the wharf requires an evaluation of the overall adaptation plan of the area. If relocation of the adjacent infrastructure is considered, then abandonment of the structure may be a suitable option. Appendix F shows a summary of the structural analysis of options conducted for this study.

Table 6.12: Boardwalk – Mitigation Options Comparison

Asset Jurisdiction	Municipality of the District of West Hants			
Option	Target Elevation (m CGVD28)	8.8	9.60	10.20
	Mitigation Timeline	2018	2018-2050	2100
	Residual Risks	1 in 100 year storm event under present climate	Sea level rise after 2050	Sea level rise after 2100
	Additional Requirements of Selected Target Elevation	• Establish safety measures to prevent access to the structure during storm surges. • Raising a section of the access road or installing stairs or a ramp to access the structure.	• Raising access road. • Geotechnical investigation to evaluate the structural capacity of the underlying soils. • Integration with an adaptation plan for the Newport Landing Waterfront Park.	
Structural Upgrade	Opinion of Probable Construction Costs ($)	125,000	350,000	400,000
	Limitations	• Top of the structure would flood under storms larger than the 1 in 1 year event at HHWLT. • Limited capacity for adaptation to sea level rise without rebuilding the entire structure.	• Requires raising access roads and adjacent land. • Recreational uses may be limited without an adaptation plan for the area. • Complex construction requiring the installation of deep piles. • Significant construction costs. • Will require further upgrades after the year 2050. • Requires removal of the historical structure.	

			• Requires shortening the length of the structure to make it more affordable.
	Advantages	• May extend life of the structure for 20 years. • Allows to continue using the structure as it has been used since last repaired in 2017.	• Maintains recreational access to the water.
Abandonment	**Opinion of Probable Construction Costs ($)**	200,000	
	Limitations	• Requires an environmental assessment and plan for abandonment. • Loss of an important recreational structure in the area. • Requires integration to adaptation plans in the surrounding area.	
		• Cost effective approach to adapting for sea level rise. • Opens opportunity for habitat restoration and development of new recreational and touristic activities.	

6.2 Emergency Management and Public Awareness

Temporary road closures is the most frequent consequence of tidal flooding in roads, causing delays and impacting the transportation of good and obstructing access of emergency services. In the case of the Cheverie causeway, the impact of waves can create unsafe driving conditions even if the road is not completely flooded. A recommended short term measure to mitigate this impacts consists of the implementation of an early warning system or flood forecasting system. The availability of remotely sensed weather prediction, calibrated hydrodynamic models, and platforms for citizen data collection can potentially allow the anticipation of where and when a forecasted weather event is likely to cause more damage. Across Canada flood forecasting systems range from water level and flow monitoring to complex systems involving calibrated computer models. This approach has proven valuable to implement emergency management measures and limit the risk of loss of life.

7 Conclusions and Recommendations

This study evaluates coastal flooding risks for public infrastructure located between the communities of Avondale and Cheverie; and for the Walton Shore Fire Department located in Walton and describe a range of potential mitigation options to identify those risks. The area is exposed to the tides of the Bay of Fundy and the process of tidal amplification along the Avon River. The study area has a population of approximately 1,500 people settled along Highway 215, which is the main road that allows connection between these communities and the rest of the Province. Public infrastructure in the community includes roads, recreational and touristic destinations, schools, fire stations, dykes, community halls, and heritage sites.

7.1 Study Approach Summary

CBCL conducted an assessment of flooding risks in the study area to identify vulnerable infrastructure through the computer simulation of tidal currents, storm surges and waves through the Bay of Fundy, the Minas Basin and the Avon River. The assessment included a review of previous studies conducted in the morphology of the Avon River and the potential effects of the construction of Windsor Causeway. Based on the findings outlined in previous studies, this study assumes that a detailed analysis of the complex sediment transport dynamics in the area would be required to assess the impacts of the Windsor Causeway over flooding risks in the area; and that findings of such assessment are unlikely to result in flooding risks mitigation measures significantly different than those identified in this report.

Modelling results were used to delineate the 1 in 1 year, 1 in 20 year and 1 in a 100 year storm surge at HHWLT floodplains along the Avon River and the Minas Basin under present climatic conditions and for SLR estimates for the years 2050 and 2100. These floodlines are presented in an atlas of maps identifying public and private infrastructure at risks under present and future climate conditions.

7.2 Flooding Risks

The floodmaps presented in this report identify 11 locations at which public and private infrastructure are vulnerable to flooding. Most locations are under risks of flooding under present climatic conditions for a 1 in 100 year storm surge at HHWLT. However other locations such as the Walton Fire Station, sections of Card Beach Road and the Avon River Heritage Society Museum are exposed to flooding under a 1 in 1 year storm surge at HHWLT.

7.3 Vulnerability Assessment

The vulnerability of the communities to flooding of the identified infrastructure was evaluated based on the definition of risk as a combination of the probability of a flooding events and its potential consequences. To assess consequences the study team evaluated land uses connected to the infrastructure at risks and conducted a preliminary assessment of the level of damage associated with flooding throughout the area. In addition the study included one stakeholder consultation meeting, two public information sessions and one online survey for coastal residents. During these consultations the study team collected, from stakeholders and the public at large, information about the frequency of flooding at different locations, the level of impact that a flooding event would have on their community, the level of priority that members of the community assign to each asset at risks, and their level of concern about flooding risks.

With the collected information the study team prepared a color coded representation of the risks based on considerations such as historical frequency of flooding, probability of flooding, potential consequences of damage, priority level for the community and the stakeholders, and probable cost of mitigation options. Based on the visual distribution of the significance of the flooding impact of each category, flooding risks in the area were classified as high, medium and low. Based on the results of this assessment the Cheverie Creek Causeway, the Walton Fire Station and Avon River Heritage Society Museum are the three locations with highest risk of flooding.

7.4 Mitigation Options

This assessment presents a comparison of mitigation options to reduce flooding risks at the public infrastructure identified as vulnerable. Options are compared according to the flooding risk time line (i.e. estimated year at which a flooding event is likely to occur based on present climatic conditions or projected sea level rise for the years 2050 and 2100), a target upgrade elevation, opinion of probable construction costs, as well as constructability limitations, opportunities for habitat restoration, impact on adjacent communities and users of the infrastructure, maintenance requirements, requirements for operation as well as risks after implementation.

7.5 Recommendations

In addition to the implementation of short-term mitigation options, this assessment recommends the following for an integrated approach to flooding risks:

- Limit development in flood prone areas. For example, the Municipal Government Act S.N.S. 1998, c. 18 N.S. Reg. 101/2001 (April 1, 1999) N.S. Reg. 272 defines the 1 in 20 year floodplain as the zone within which no development is allowed.
- Continue to engage NSTIR, NSDA, Nova Scotia Parks, First Nation representatives and property owners throughout the study area and adjacent communities to gather input about the outlook of the community and other socio-economic indicators such as potential value of active agricultural land at risk.
- Include considerations presented in this report as well as socio-economic factors such as the amount of productive agricultural land at risk or the involvement of agencies such as NSTIR and NSDA in the selection and implementation of the presented mitigation measures.
- Implement an early warning system flood forecasting system. The availability of remotely sensed weather prediction, calibrated hydrodynamic models, and platforms for citizen data collection can potentially allow the anticipation of where and when a forecasted weather event is likely to cause more damage. Across Canada, flood forecasting systems range from water level and flow monitoring to complex systems involving calibrated computer models. This approach has proven valuable to implement emergency management measures and limit the risk of loss of life. Implementation costs vary with the study area extent and the level of complexity associated with the system. This can range from simple still water level estimation based on the superimposition of tide predictions and storm surge to more complex models simulating tidal amplification and the effect of forecasted rainfall.

- In the locations considered for potential dyke upgrade and in coordination with NSDA, conduct a dyke safety assessments based on the new NSDA guidelines.
- Include relevant findings of this assessment in the implementation of emergency management measures.
- After managed relocation and construction of infrastructure in new sites, consider the implementation of Low Impact Developments (LID) or Best Management Practices as described in Appendix G.

Please note that the presented hazard mapping is based on uncalibrated velocity calculations and should be used with caution.

7.6 Study Limitations

The findings and recommendations are based on information collected to date at the time of writing, with uncertainties associated with data gaps, notably temporal and spatial gaps in tide gauge information, as well as modeling approximations inherent to this type of desktop study. We recommend that the projected flood elevations be revisited by the Municipality as new information becomes available.

Prepared by:	Reviewed by:
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Water Resources and Coastal Engineer	Practice Lead – Water Resources

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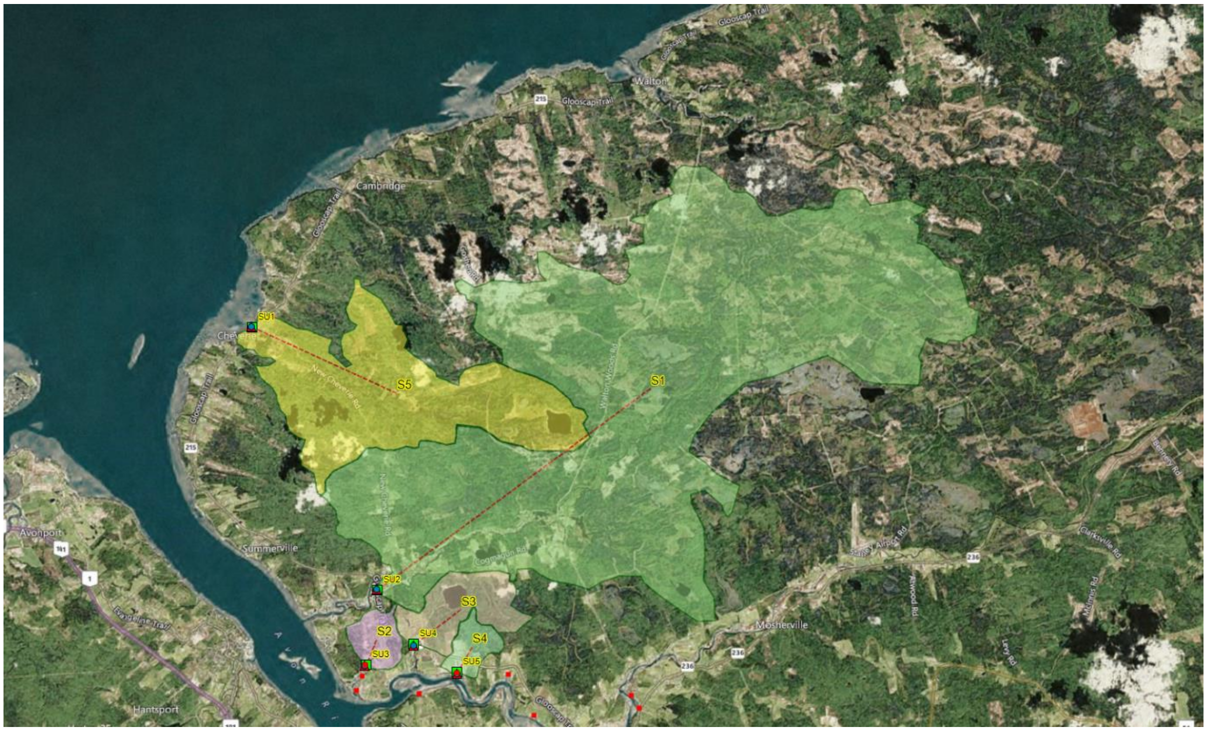
APPENDIX A

Watershed Characteristics



Name	Area	Width	Slope	Impervious Area	Mannings Impervious	Mannings Pervious	Suction Head (mm)	Hydraulic Conductivity (mm/hr)
S1	13517.7	6759	1.7	40	0.013	0.24	225.5	1.6
S2	265.9	1329	4.2	40	0.013	0.24	191.4	4.1
S3	662.8	1657	2.3	40	0.013	0.24	226.2	2.6
S4	228.3	1141	5.2	40	0.013	0.24	211.8	1.0
S5	3203.1	3000	1.9	40	0.013	0.24	226.3	1.5
S6	13517.7	6759	1.7	40	0.013	0.24	225.5	1.6

APPENDIX B

Floodmaps

WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

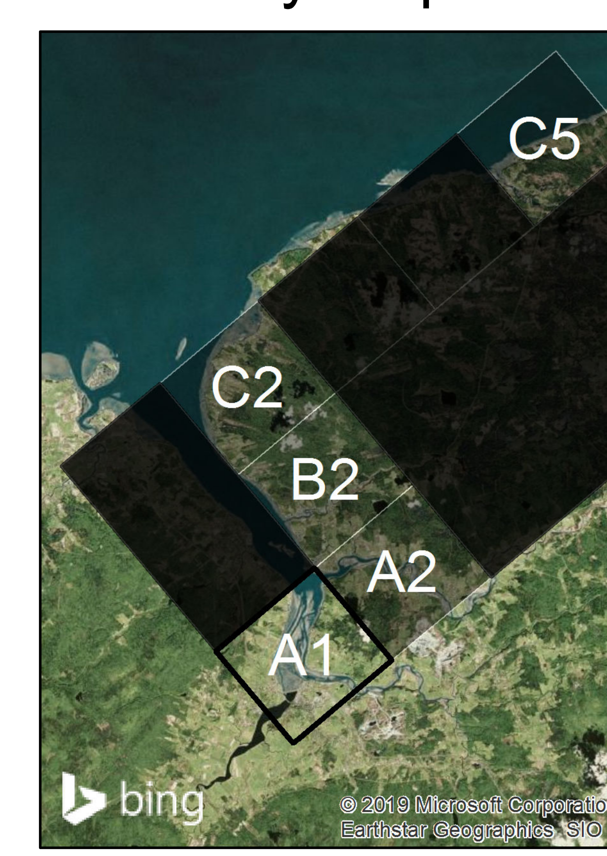
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A1

Present Climatic Conditions

Key Map



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WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

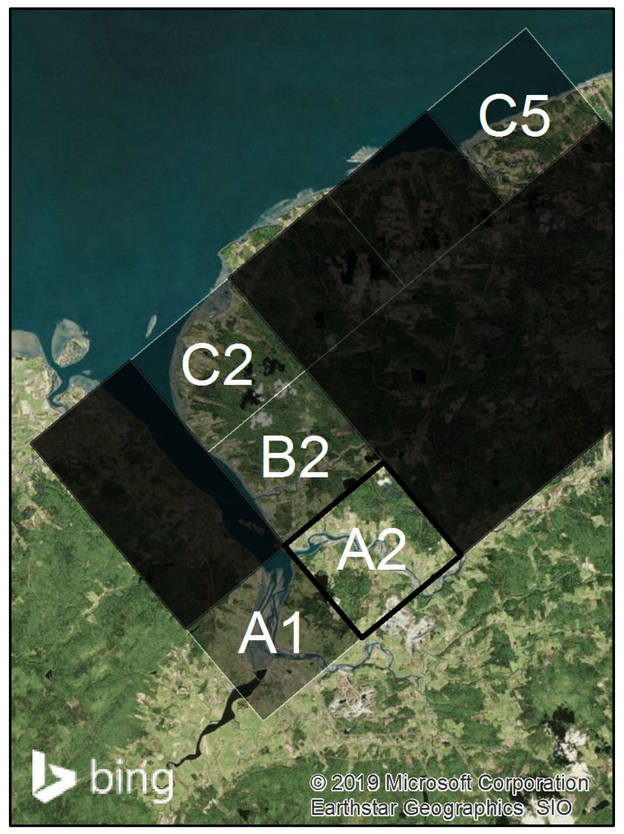
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A2

Present Climatic Conditions

Key Map



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WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program
Flooding Risk Assessment Study

Legend

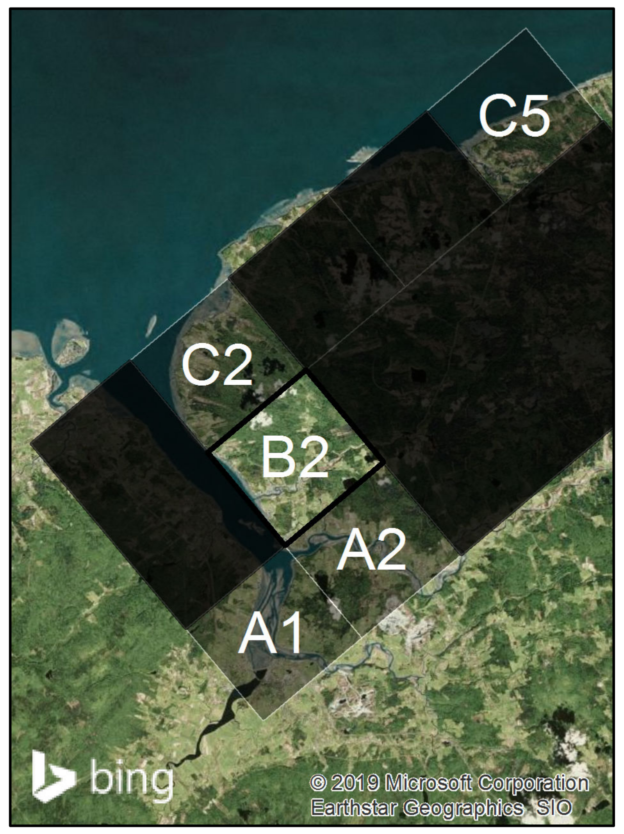
- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding
Tile B2
Present Climatic Conditions

Key Map



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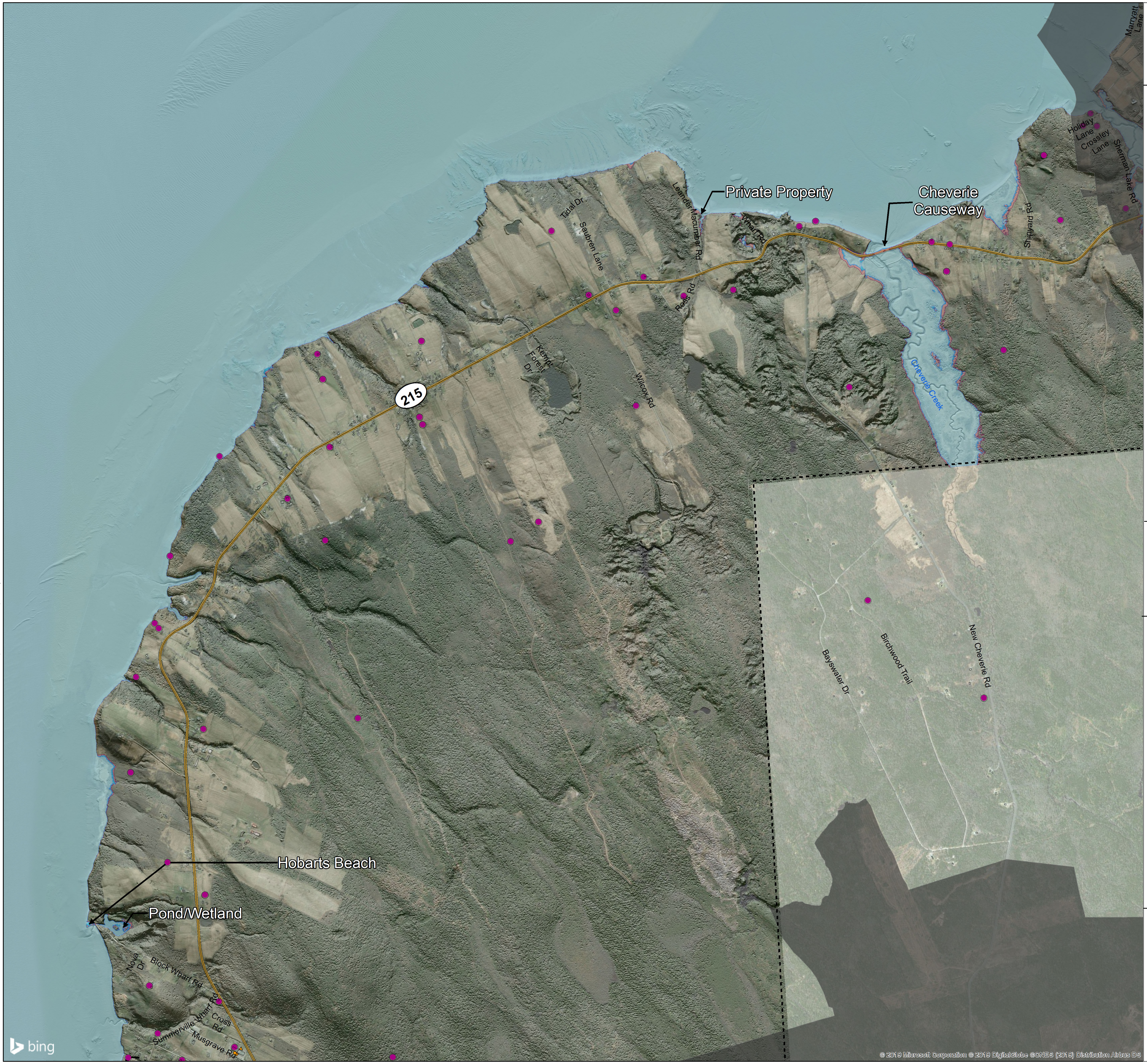


WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

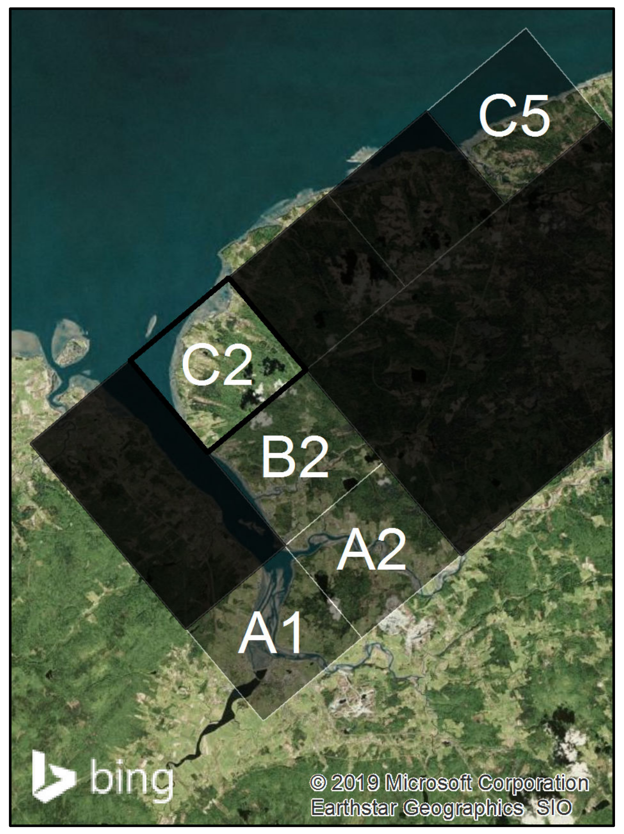
Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile C2
Present Climatic Conditions

Key Map



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NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

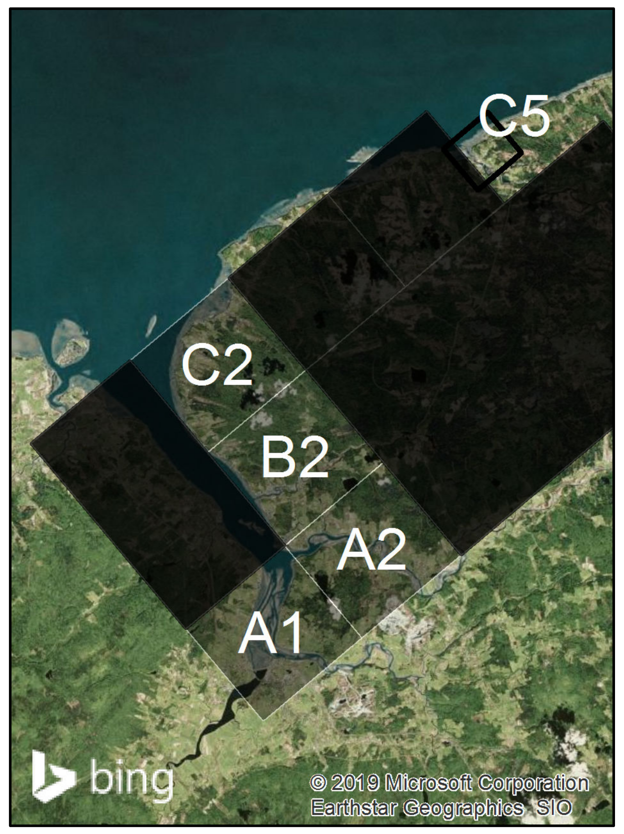
Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile C5
Present Climatic Conditions

Key Map



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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

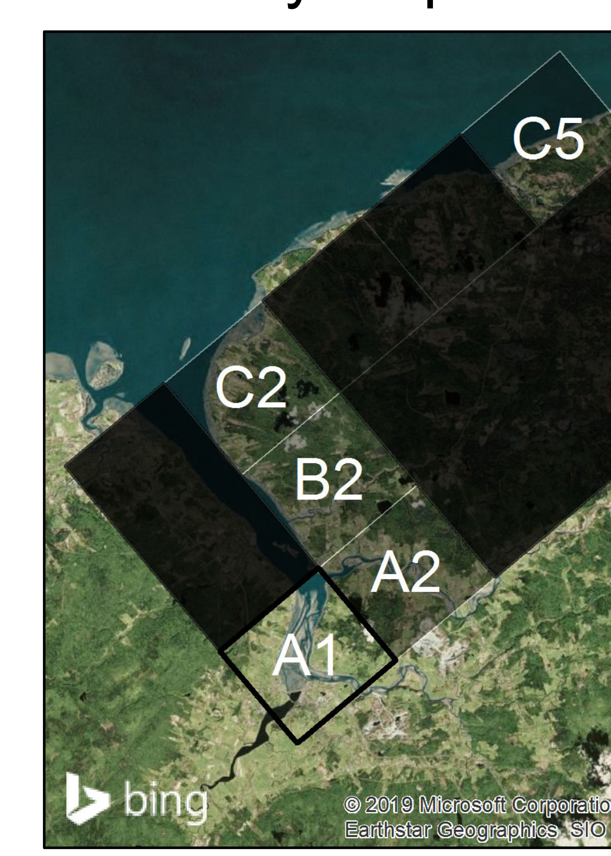
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A1

Future Climate Conditions - 2050

Key Map



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WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

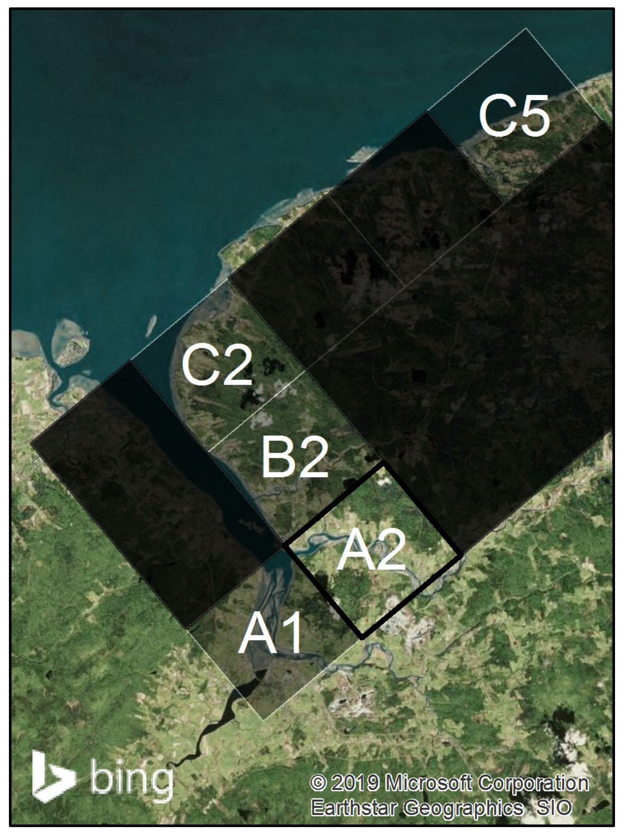
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A2

Future Climate Conditions - 2050

Key Map



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WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

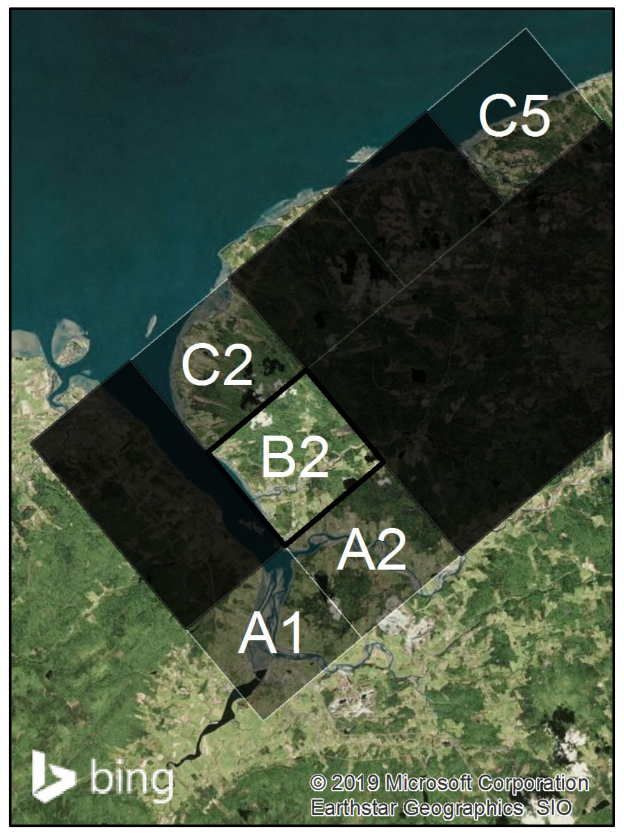
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile B2

Future Climate Conditions - 2050

Key Map



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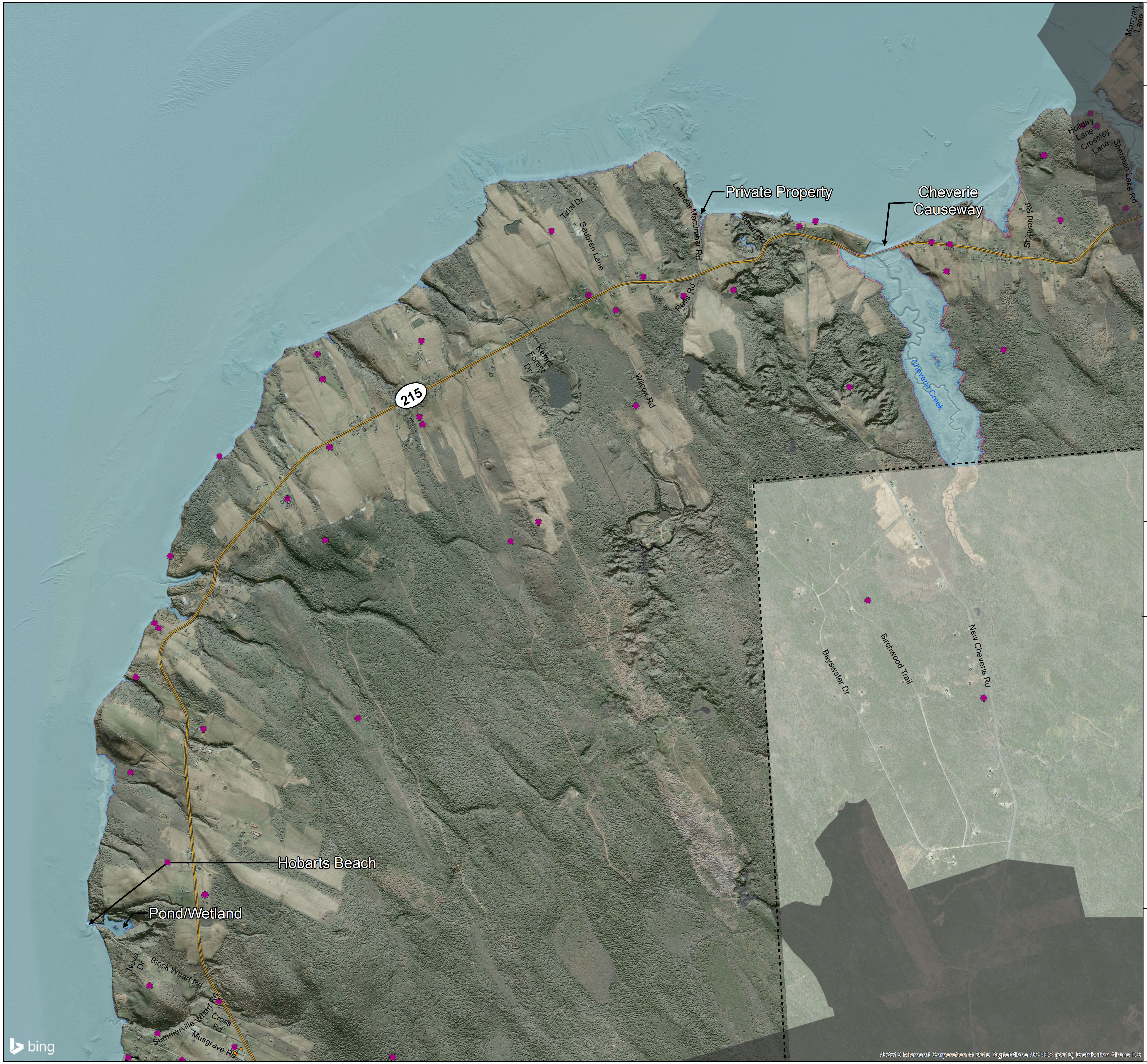


WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

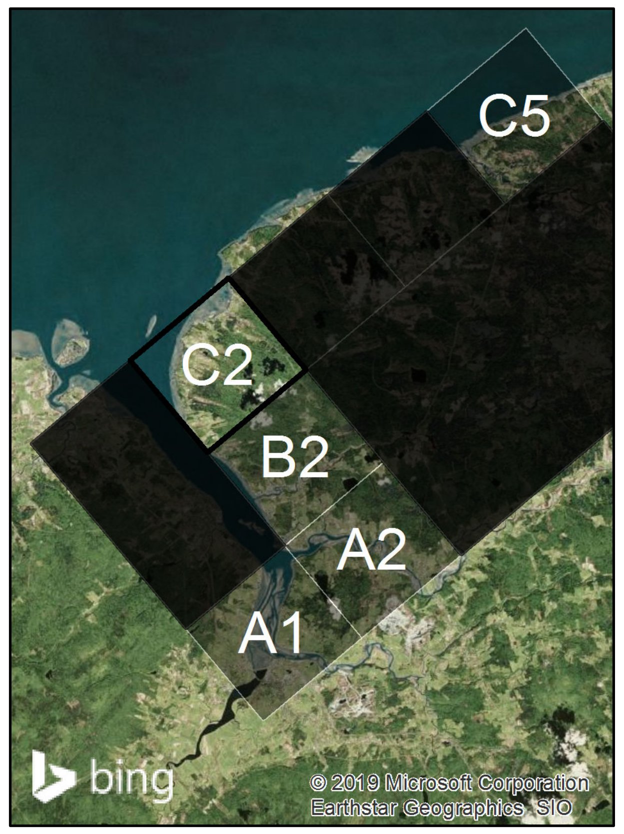
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile C2

Future Climate Conditions - 2050

Key Map



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WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

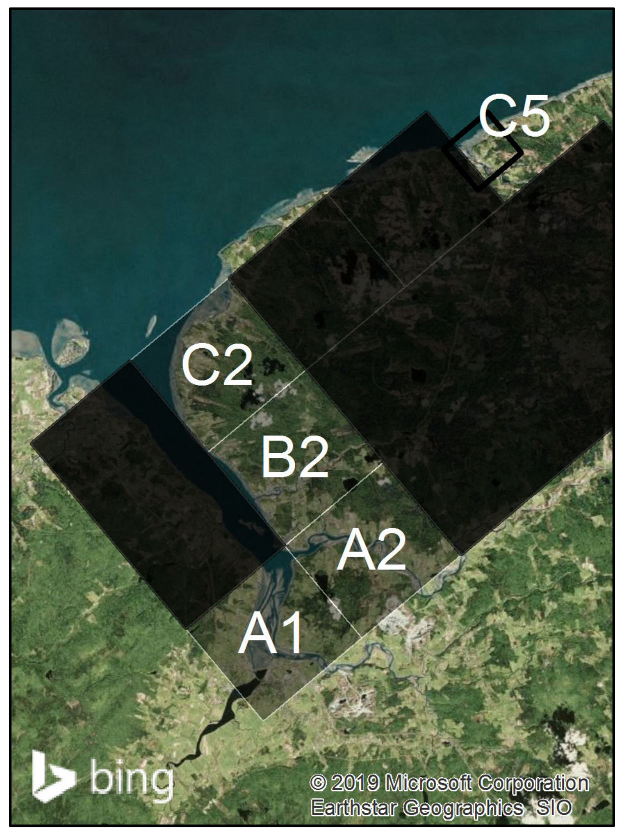
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile C5

Future Climate Conditions - 2050

Key Map



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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

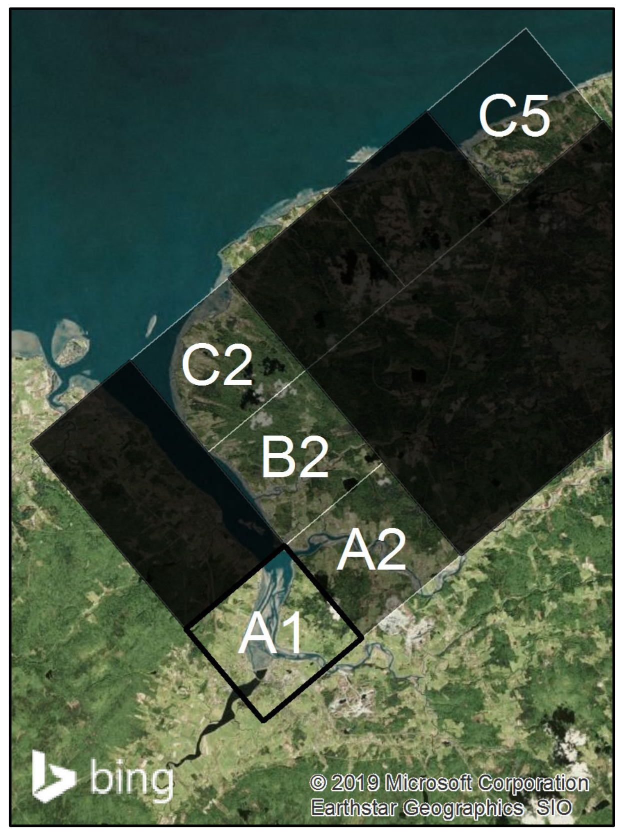
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A1

Future Climate Conditions 2100

Key Map



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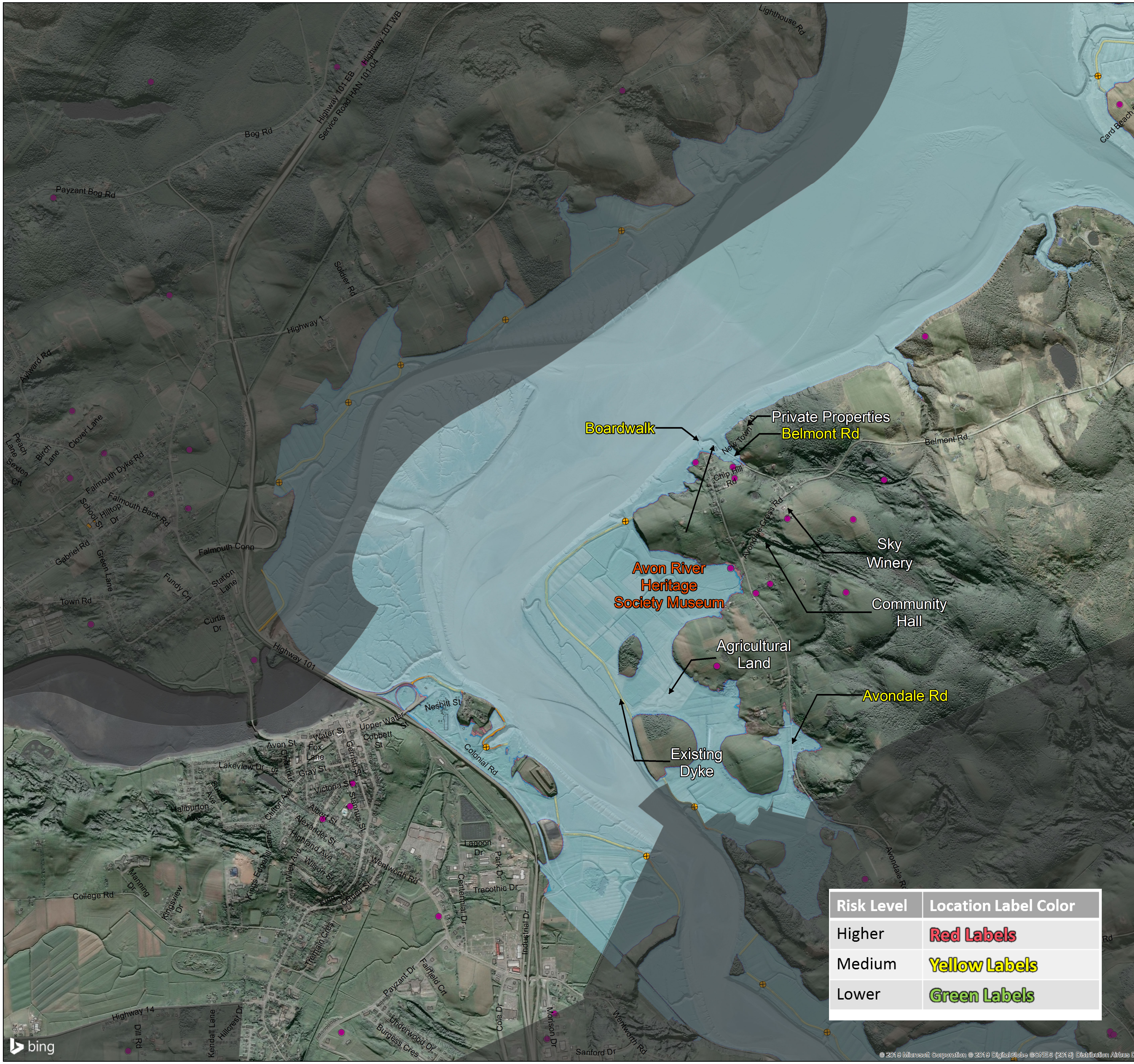
APPENDIX C

Flooding Risk Maps



Risk Level	Location Label Color
Higher	Red Labels
Medium	Yellow Labels
Lower	Green Labels

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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
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- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

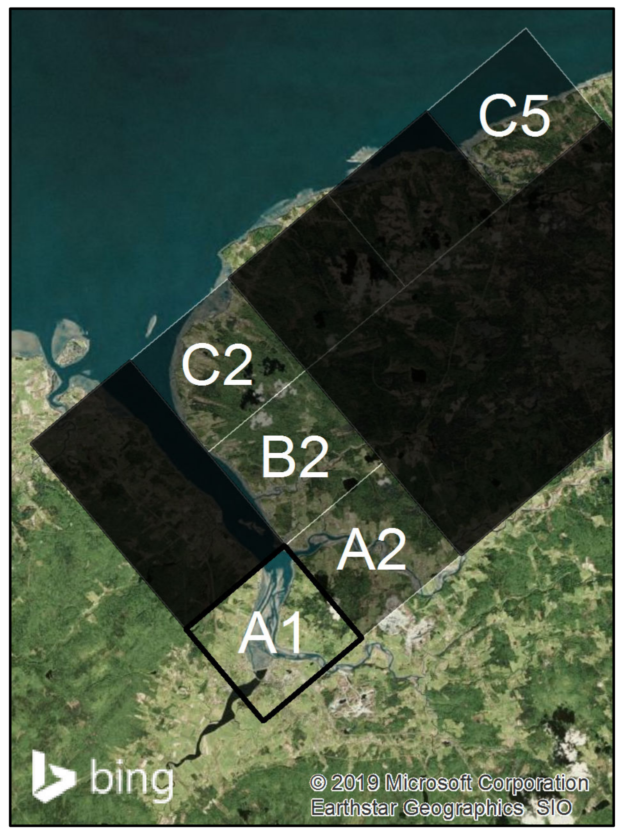
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A1

Present Conditions

Key Map



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Risk Level	Location Label Color
Higher	Red Labels
Medium	Yellow Labels
Lower	Green Labels

WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

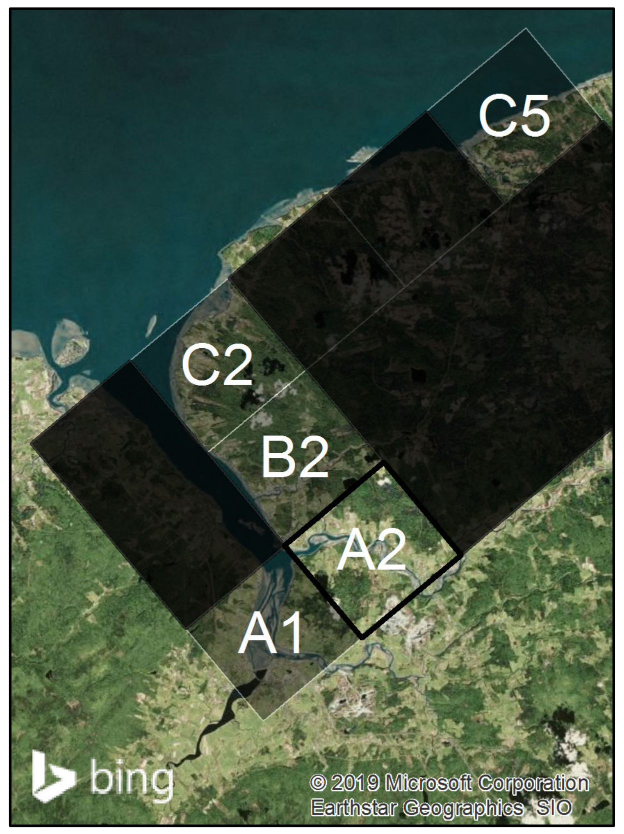
Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile A2 Present Conditions

Key Map



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Risk Level	Location Label Color
Higher	Red Labels
Medium	Yellow Labels
Lower	Green Labels

Document Path: \\HFXDATA4\Data3\181166.00 WEST HANTS NDPR RISK ASSESSMENT\20 CAD\08 GIS\layout\Flooding Risk Levels.mxd

WEST HANTS
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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

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- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

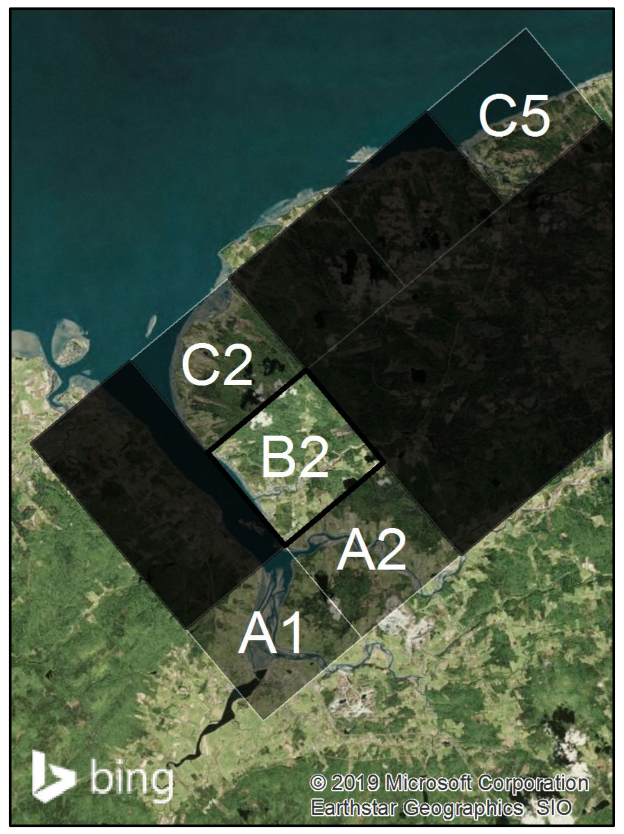
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile B2

Present Conditions

Key Map



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National Disaster Mitigation Program Flooding Risk Assessment Study

Risk Level	Location Label Color
Higher	Red Labels
Medium	Yellow Labels
Lower	Green Labels

Legend

- Limit of Lidar
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- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

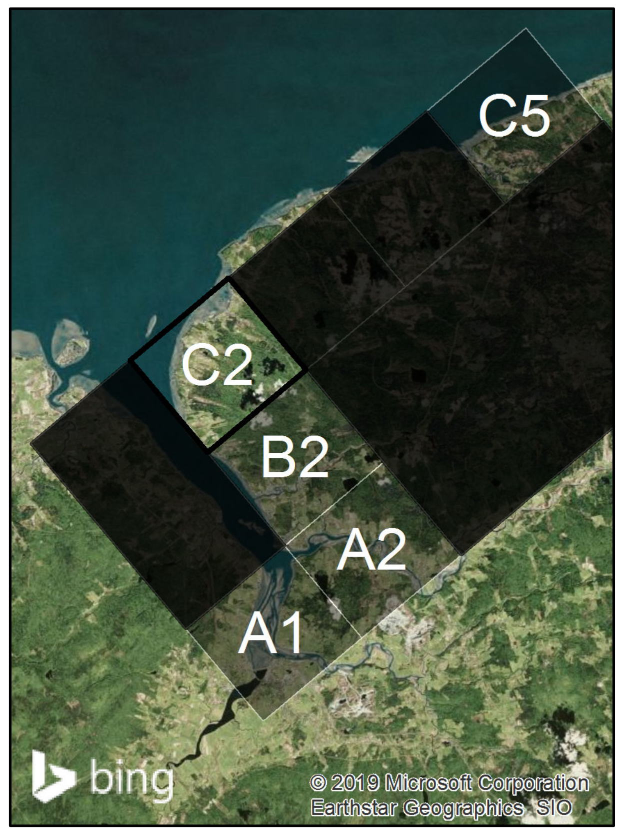
Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Infrastructure at Risk of Flooding

Tile C2
Present Conditions

Key Map



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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

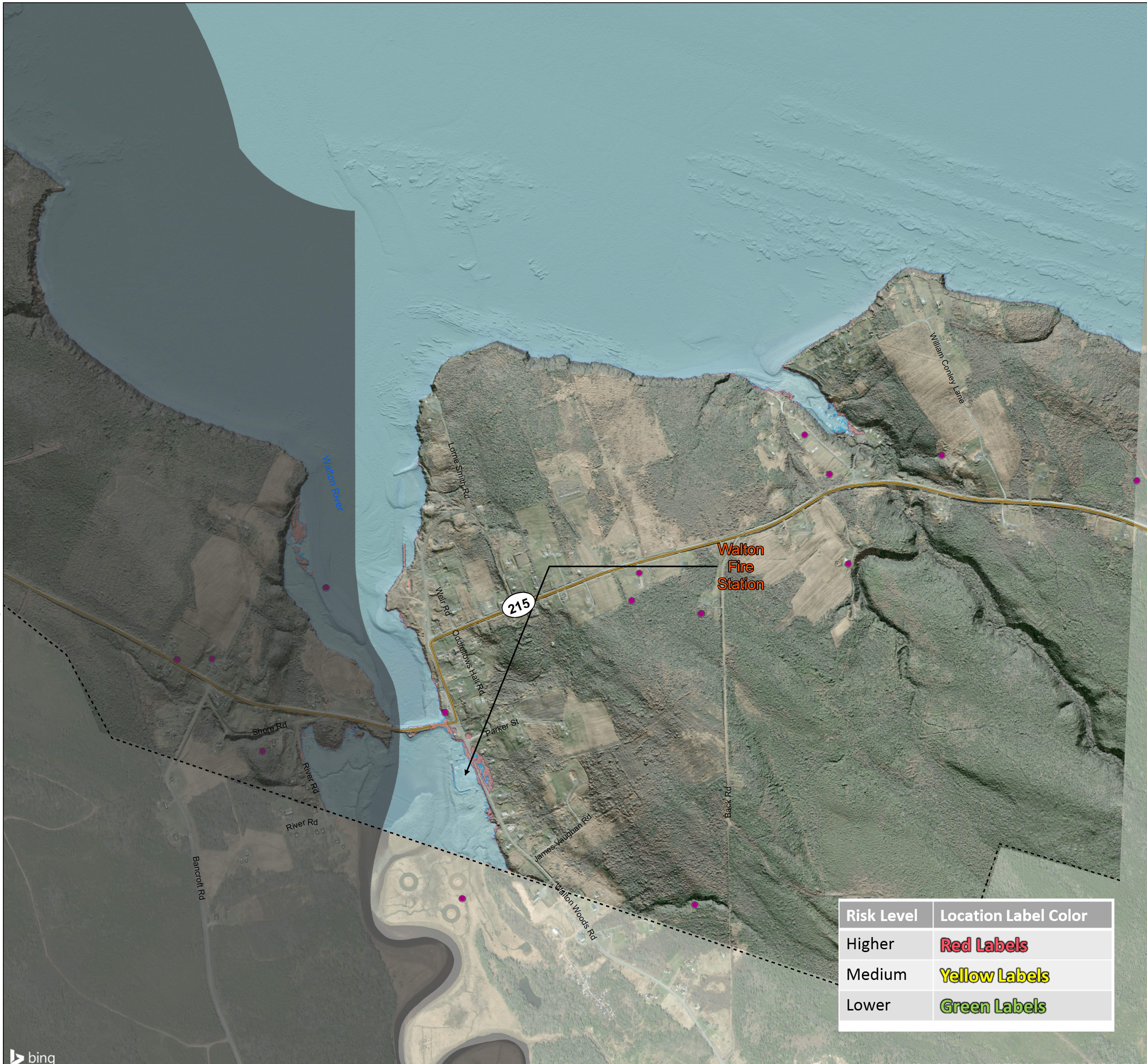
- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

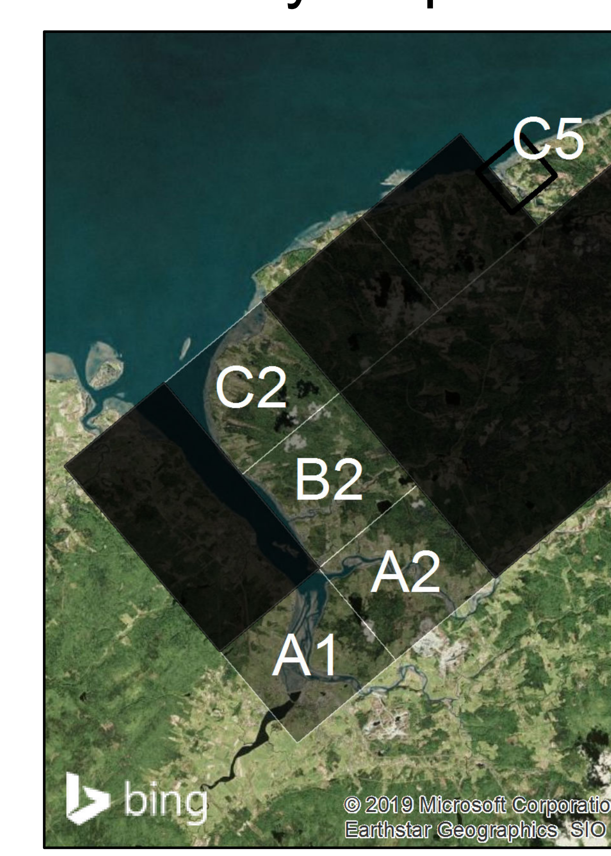
Infrastructure at Risk of Flooding

Tile C5
Present Conditions



Risk Level	Location Label Color
Higher	Red Labels
Medium	Yellow Labels
Lower	Green Labels

Key Map



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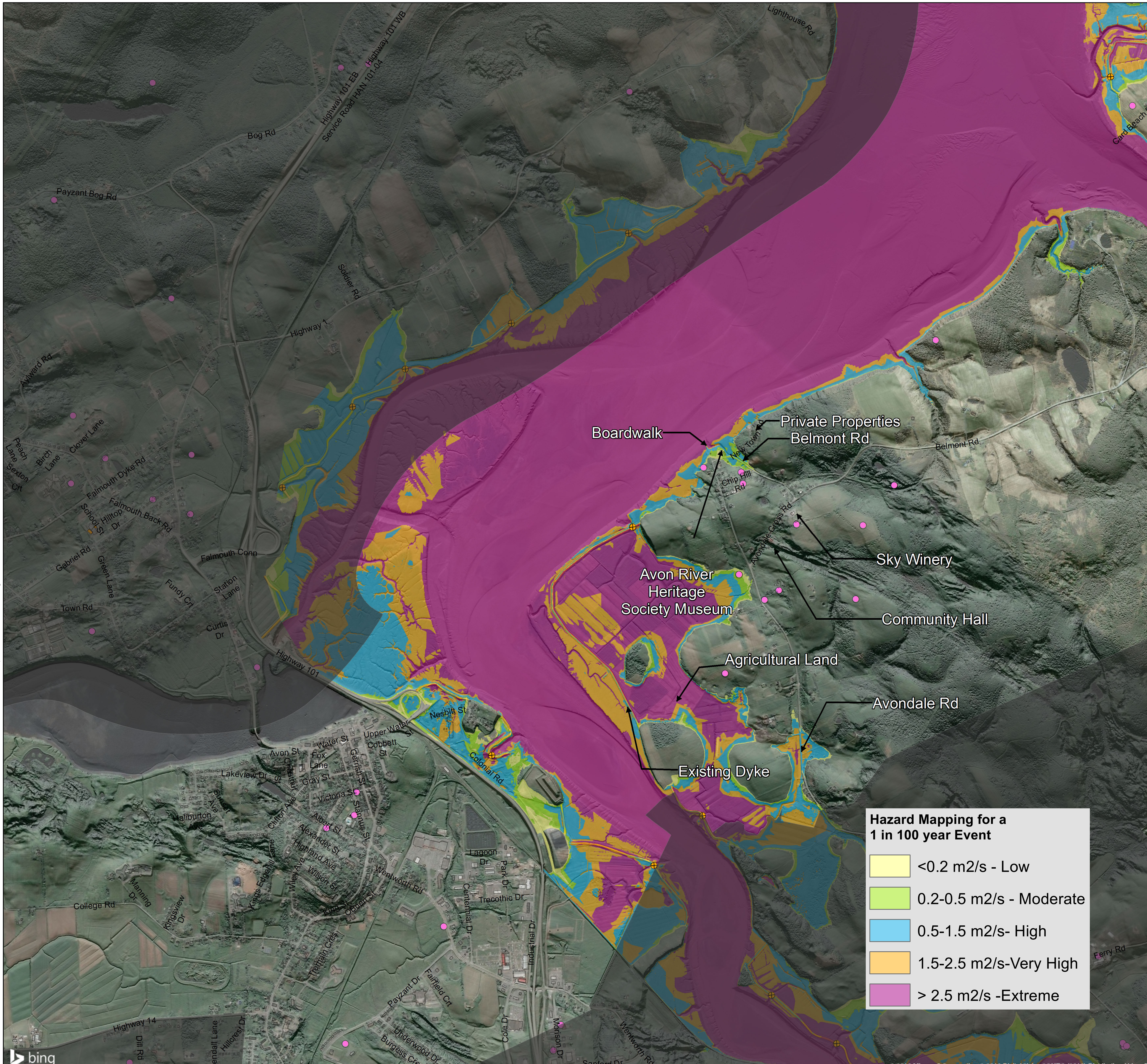
Appendix D

Flood Hazard Maps



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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

Hazard Mapping for Adult Mobilizaton by Foot

Tile A1
Present Conditions

Key Map

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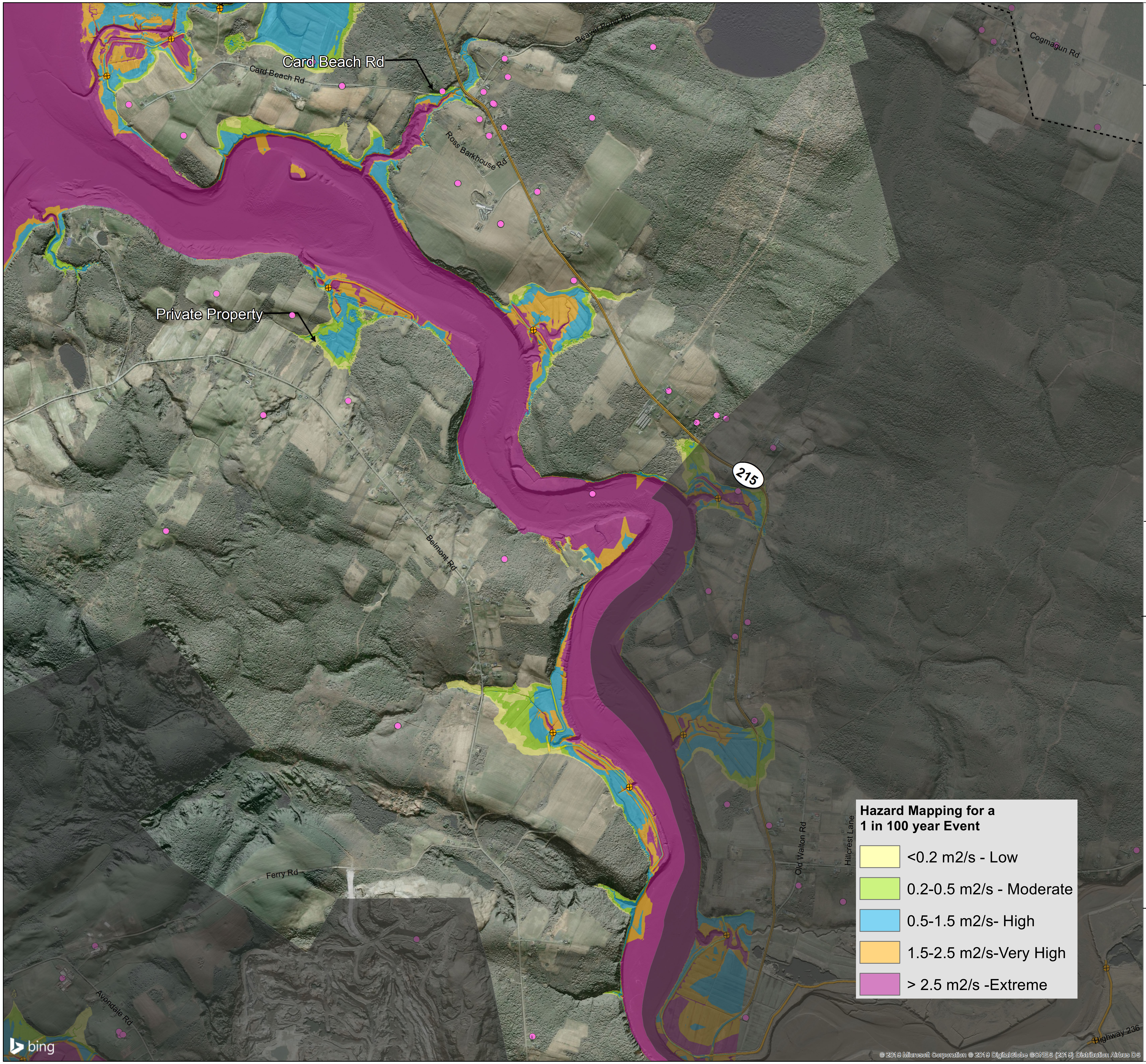

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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

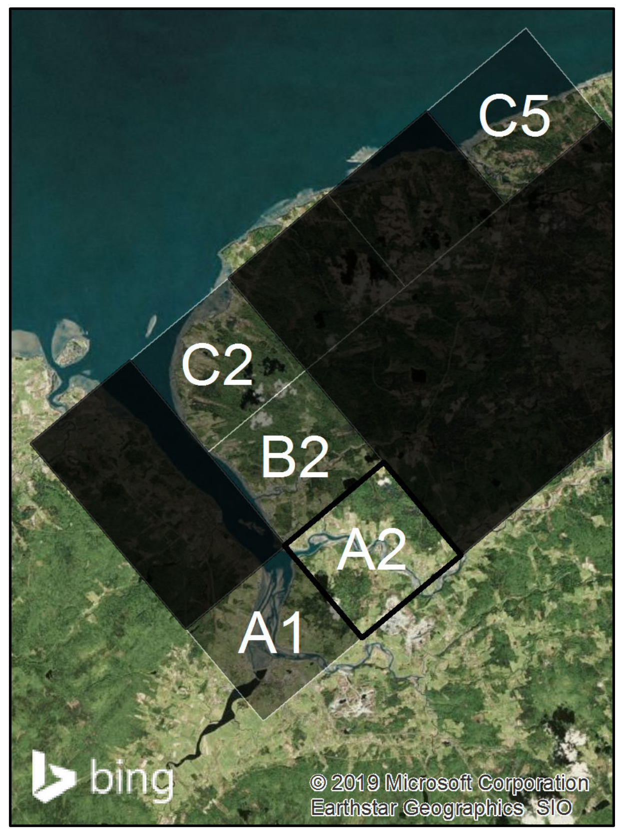
- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

Hazard Mapping for Adult Mobilizaton by Foot

Tile A2
Present Conditions

Key Map



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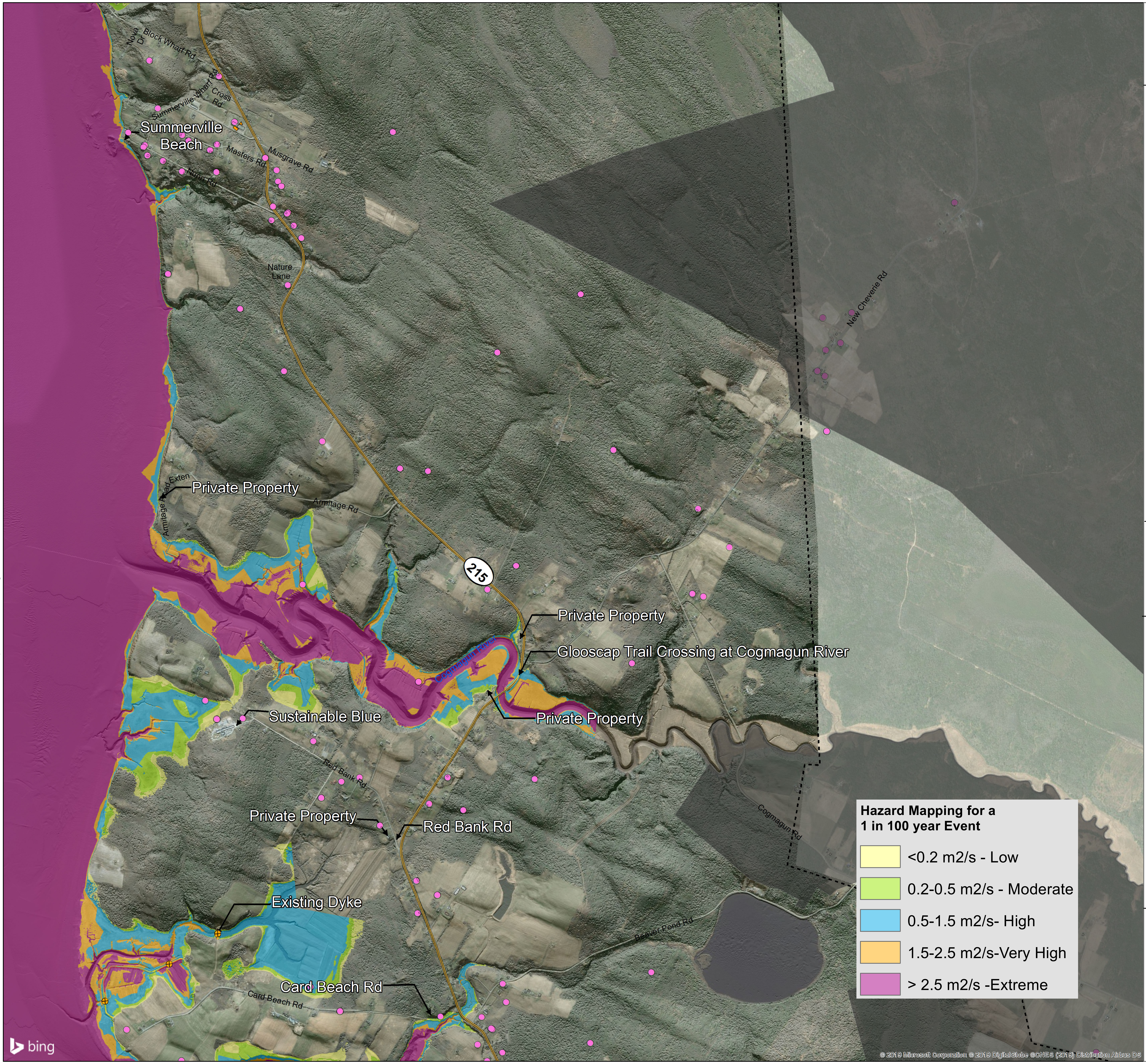

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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

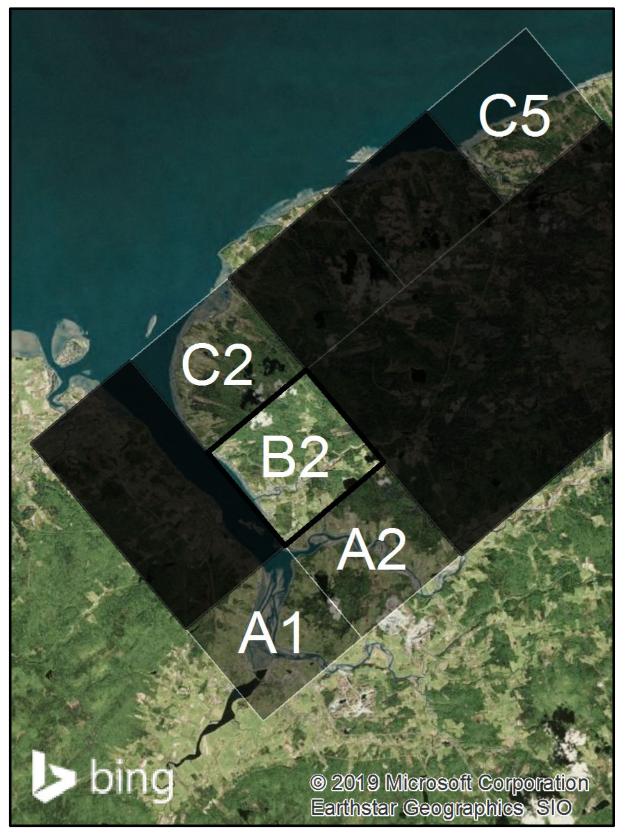
Floodlines

Hazard Mapping for Adult Mobilizaton by Foot

Tile B2

Present Conditions

Key Map



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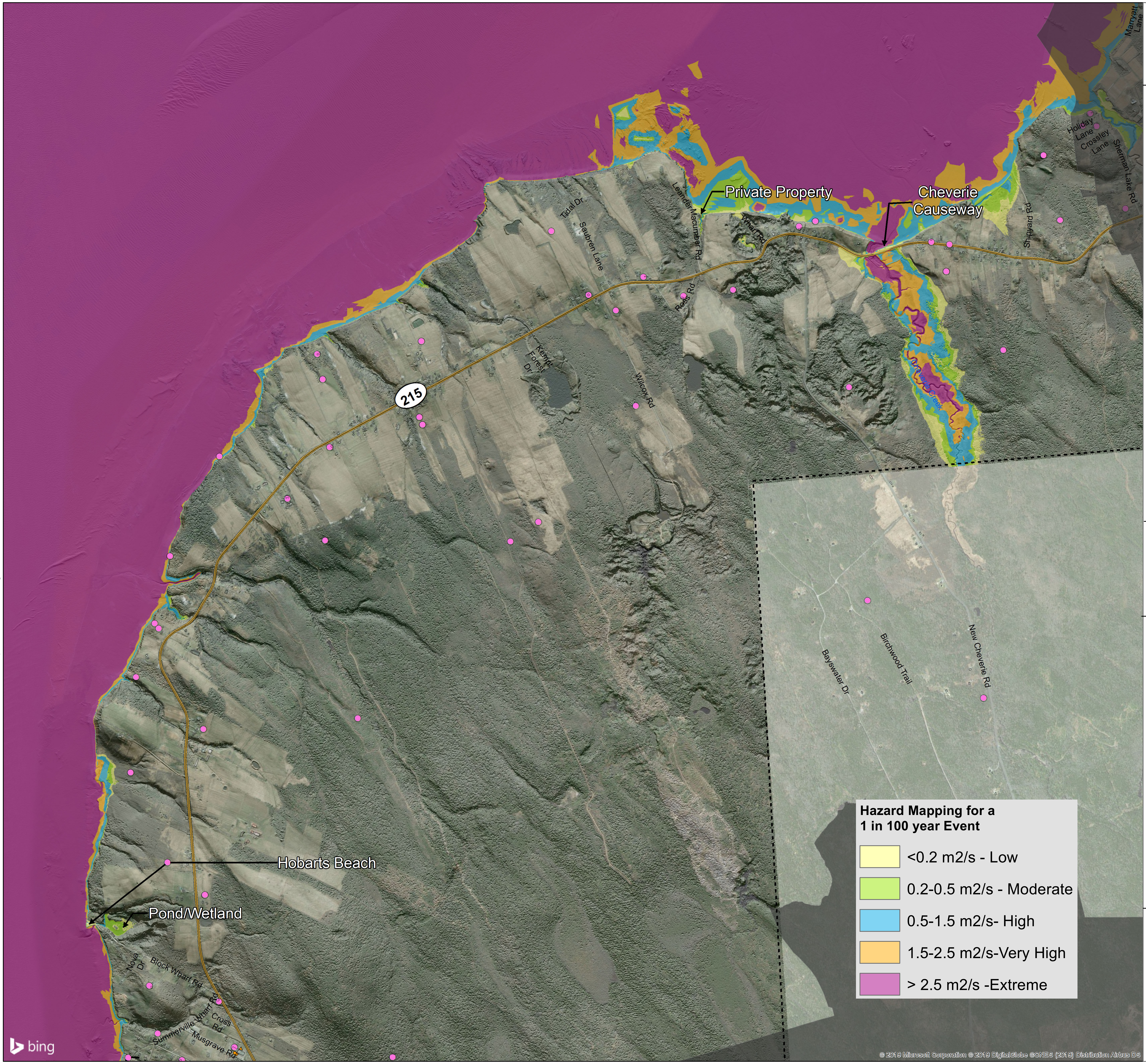

WEST HANTS
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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

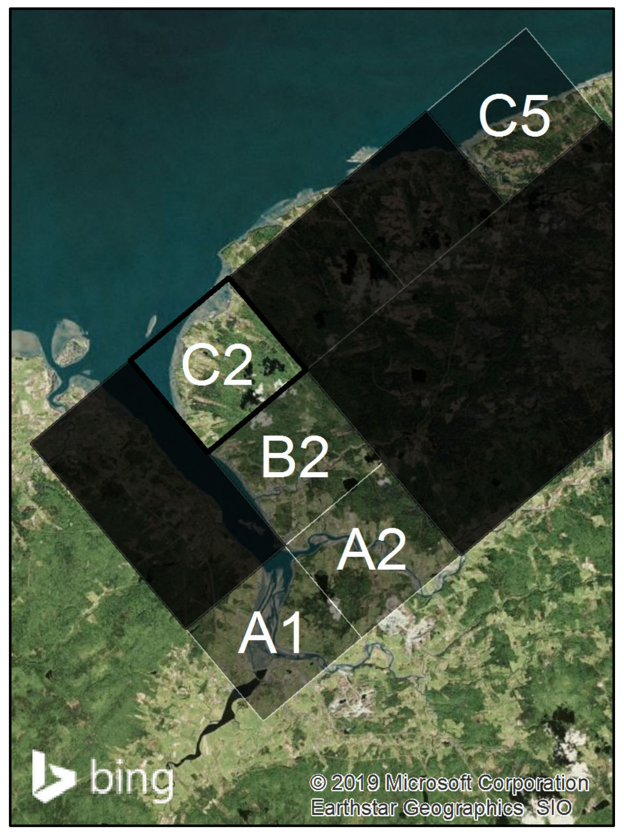
- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

Hazard Mapping for Adult Mobilizaton by Foot

Tile C2
Present Conditions

Key Map



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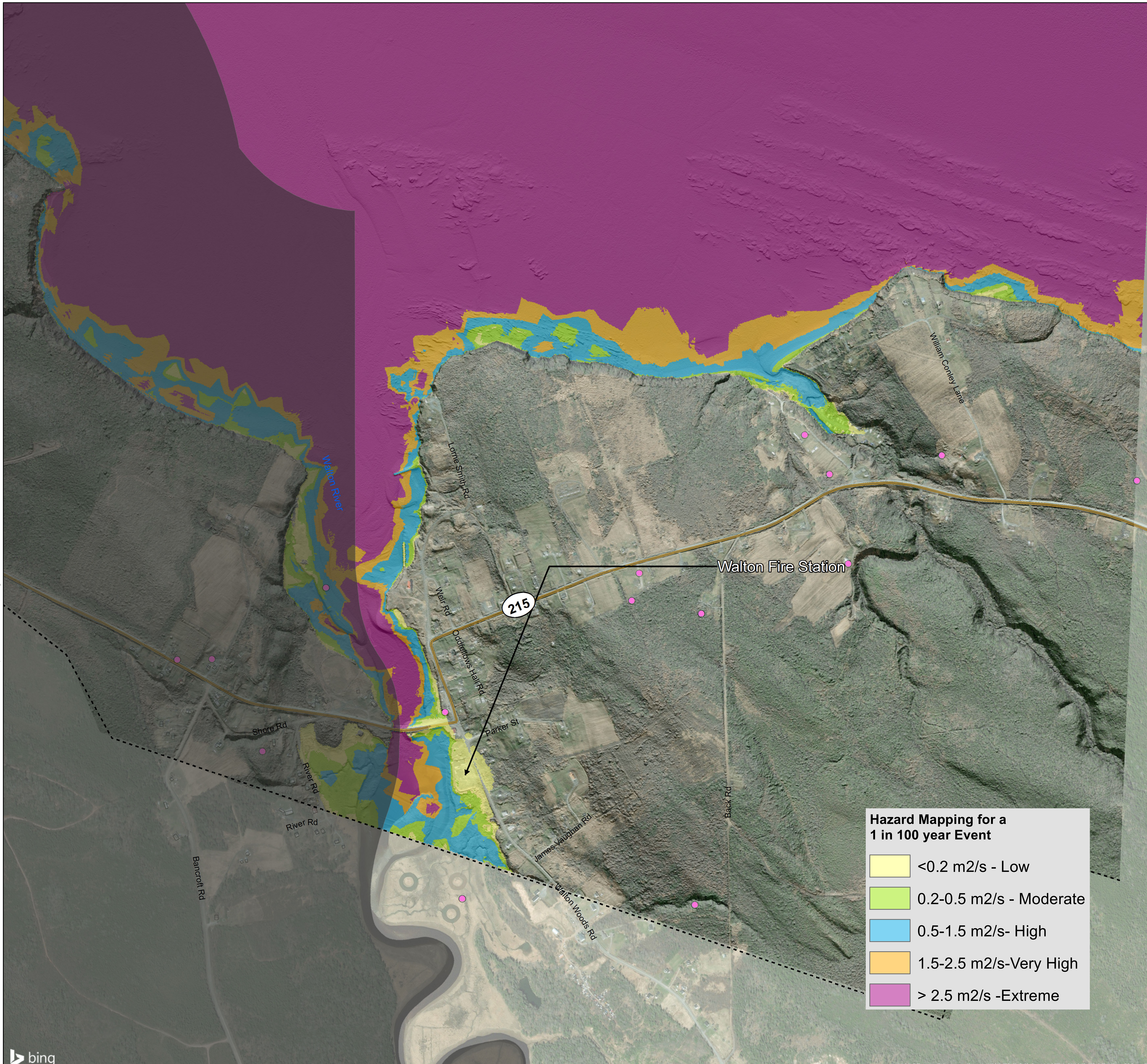

WEST HANTS
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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
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- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

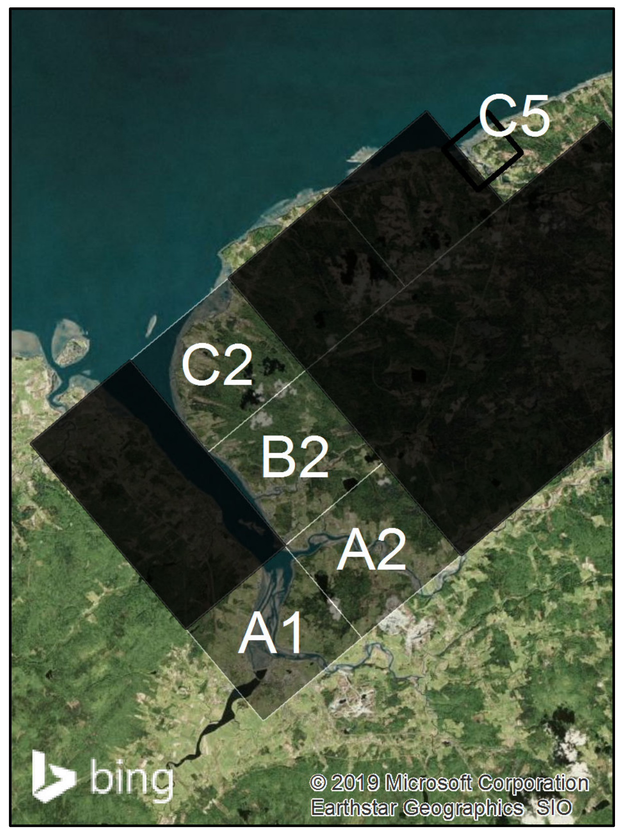
Floodlines

Hazard Mapping for Adult Mobilizaton by Foot

Tile C5

Present Conditions

Key Map



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APPENDIX E

Evaluated Mitigation Measures Maps

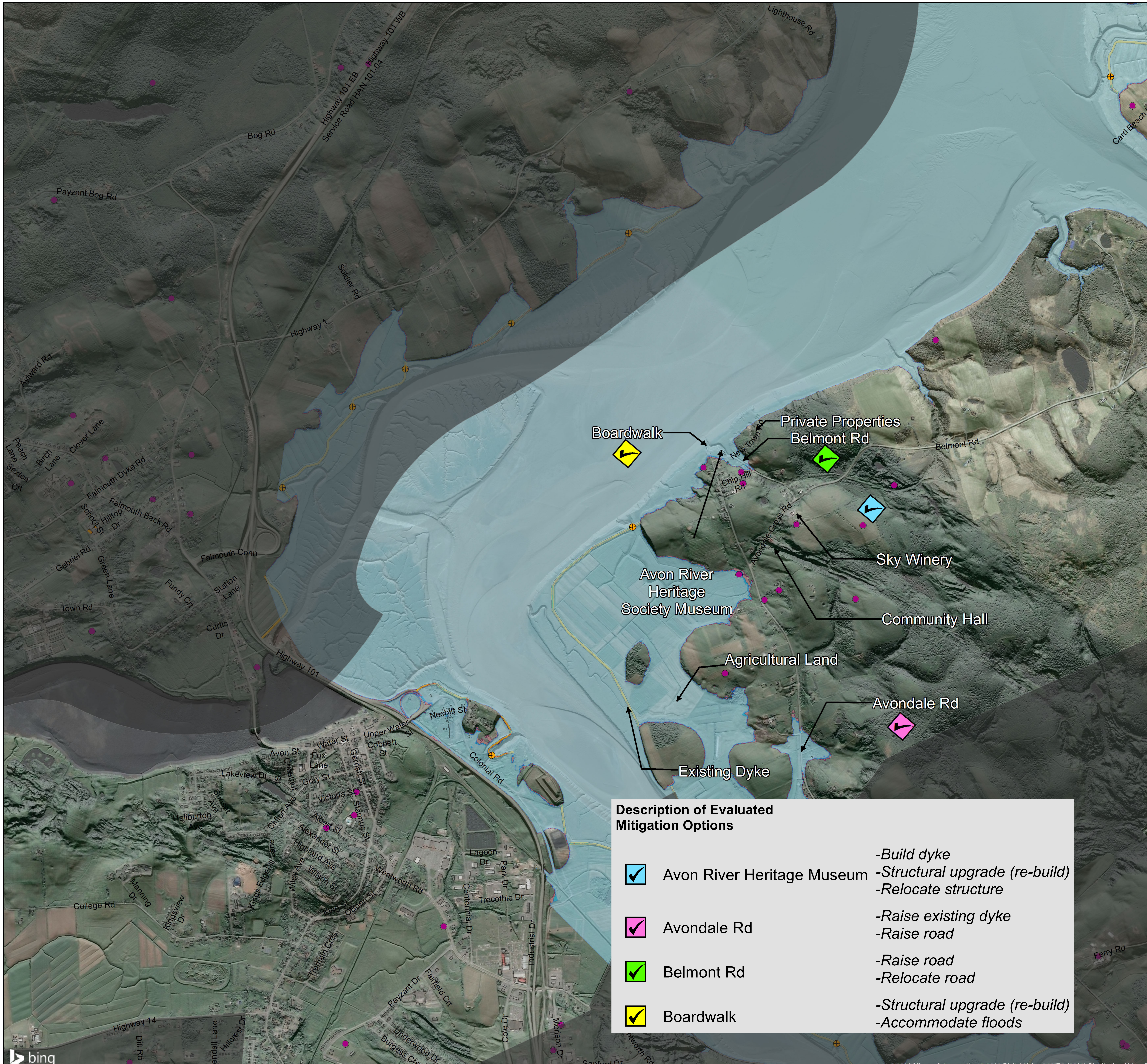
National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year



Description of Evaluated Mitigation Options

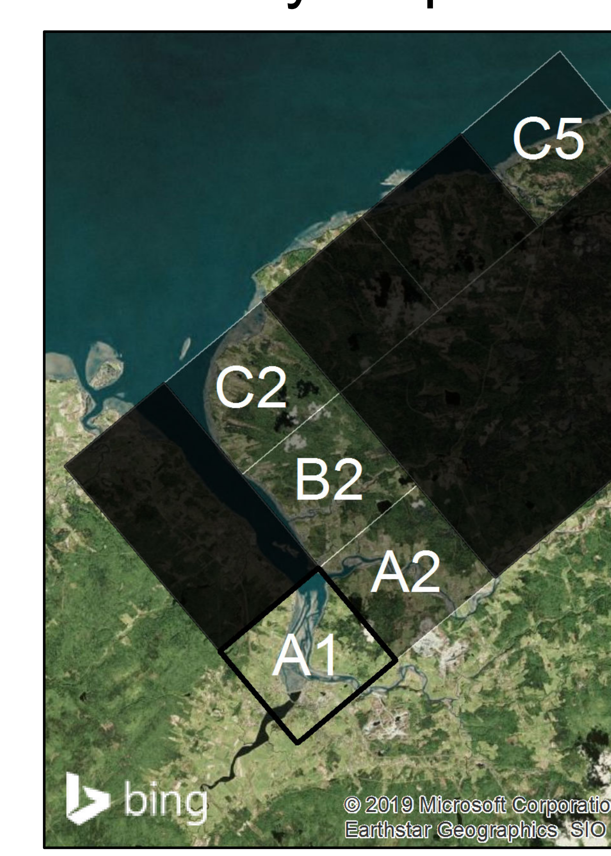
✓	Avon River Heritage Museum	*-Build dyke* *-Structural upgrade (re-build)* *-Relocate structure*
✓	Avondale Rd	*-Raise existing dyke* *-Raise road*
✓	Belmont Rd	*-Raise road* *-Relocate road*
✓	Boardwalk	*-Structural upgrade (re-build)* *-Accommodate floods*

Evaluated Flood Mitigation Measures

Tile A1

Present Conditions

Key Map



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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

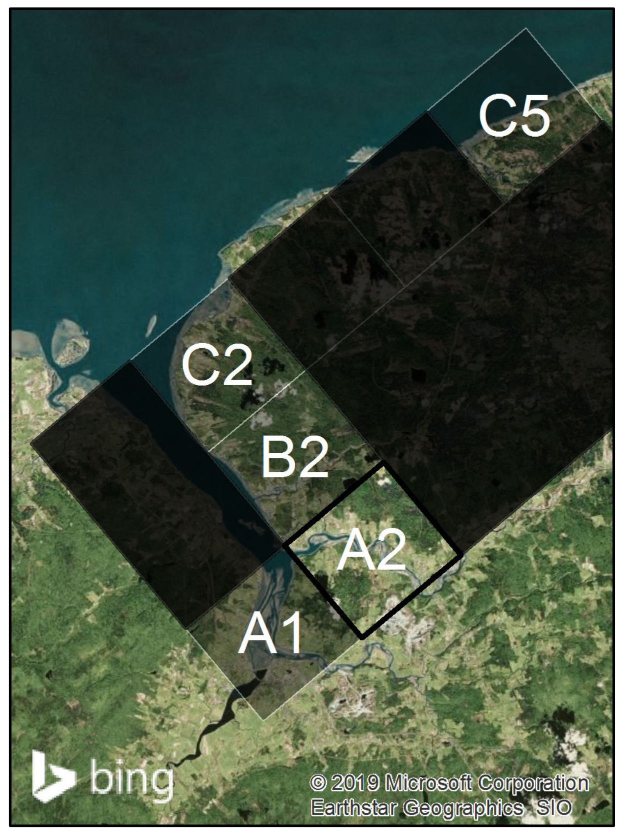
Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Evaluated Flood Mitigation Measures

Tile A2
Present Conditions

Key Map



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WEST HANTS
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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

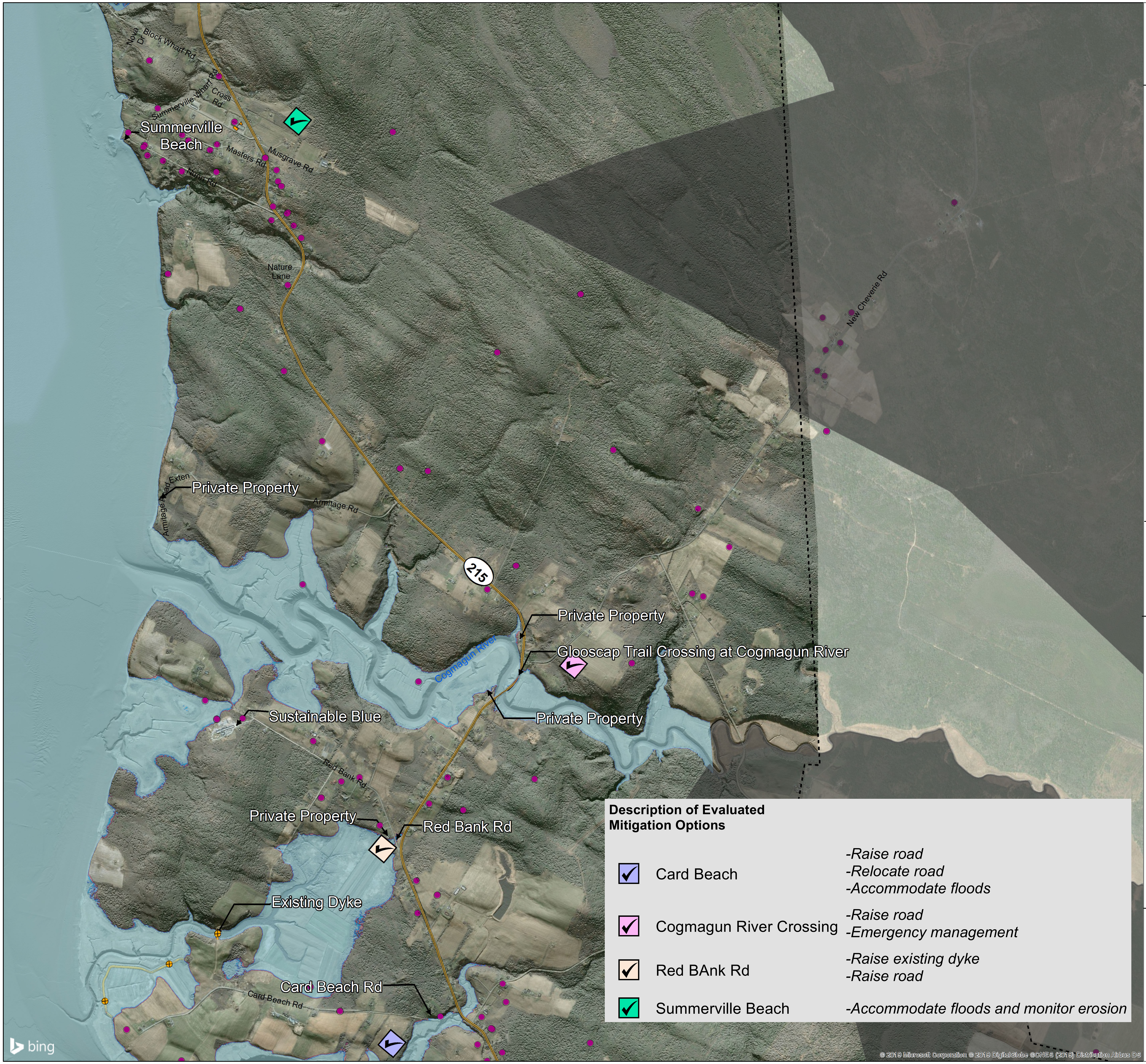
- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Evaluated Flood Mitigation Measures

Tile B2 Present Conditions



Description of Evaluated Mitigation Options

Card Beach	-Raise road -Relocate road -Accommodate floods
Cogmagun River Crossing	-Raise road -Emergency management
Red BAnk Rd	-Raise existing dyke -Raise road
Summerville Beach	-Accommodate floods and monitor erosion

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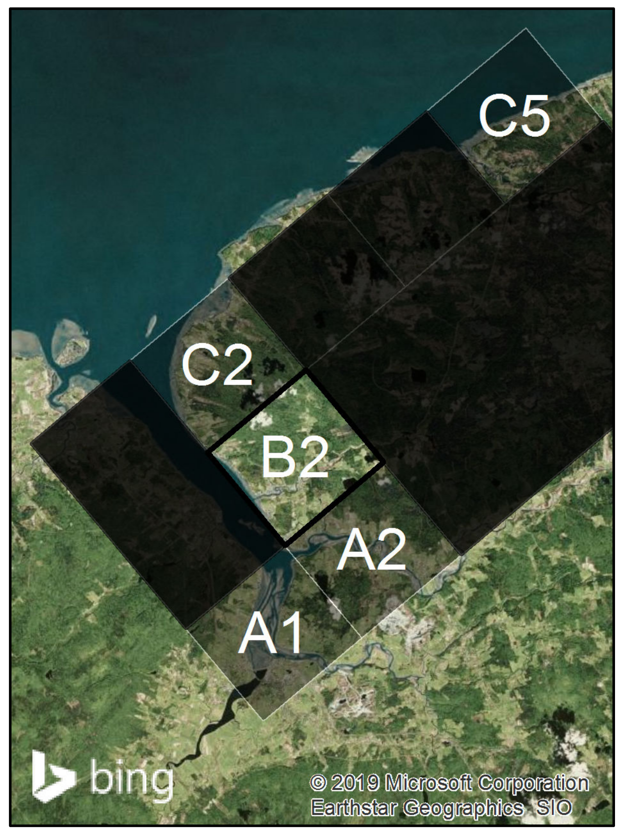
Key Map



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National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

- Limit of Lidar
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

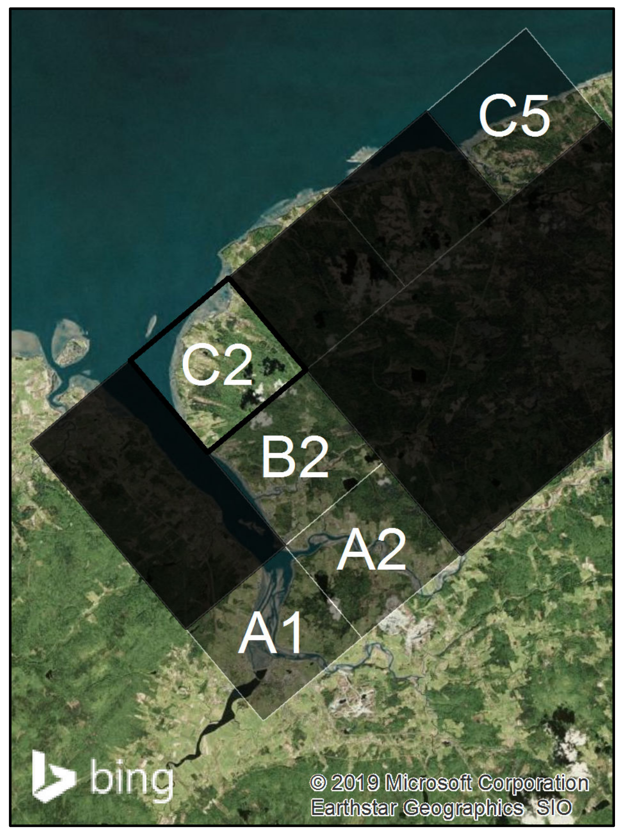
- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Evaluated Flood Mitigation Measures

Tile C2

Present Conditions

Key Map



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WEST HANTS
NOVA SCOTIA

National Disaster Mitigation Program Flooding Risk Assessment Study

Legend

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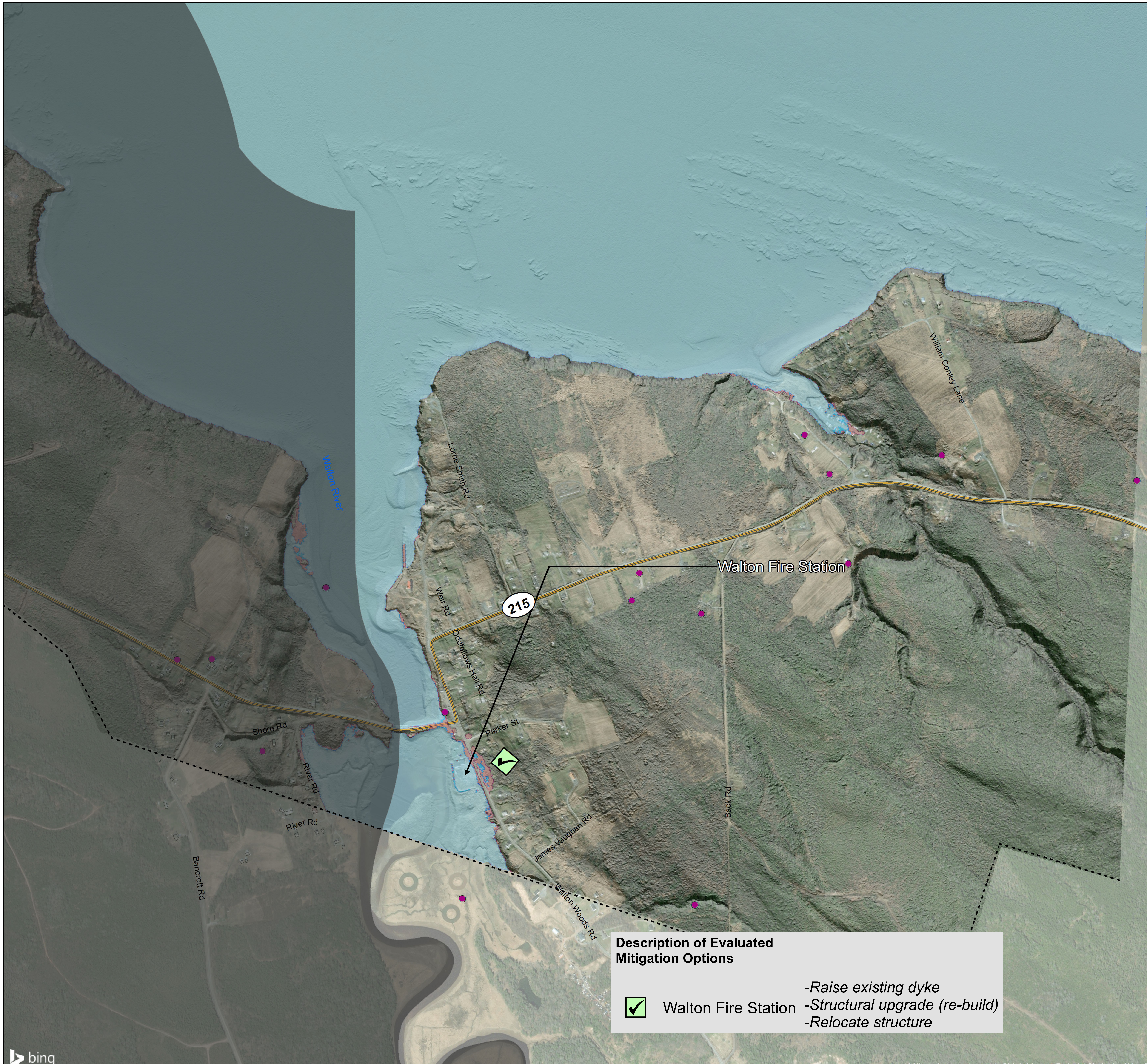
- Outside Study Area
- Aboiteaux
- Groundwater Wells
- Schools
- Infrastructure at Risk
- Existing Dyke
- 2018 Building Footprint

Floodlines

- 1 in 1 year
- 1 in 20 year
- 1 in 100 year

Evaluated Flood Mitigation Measures

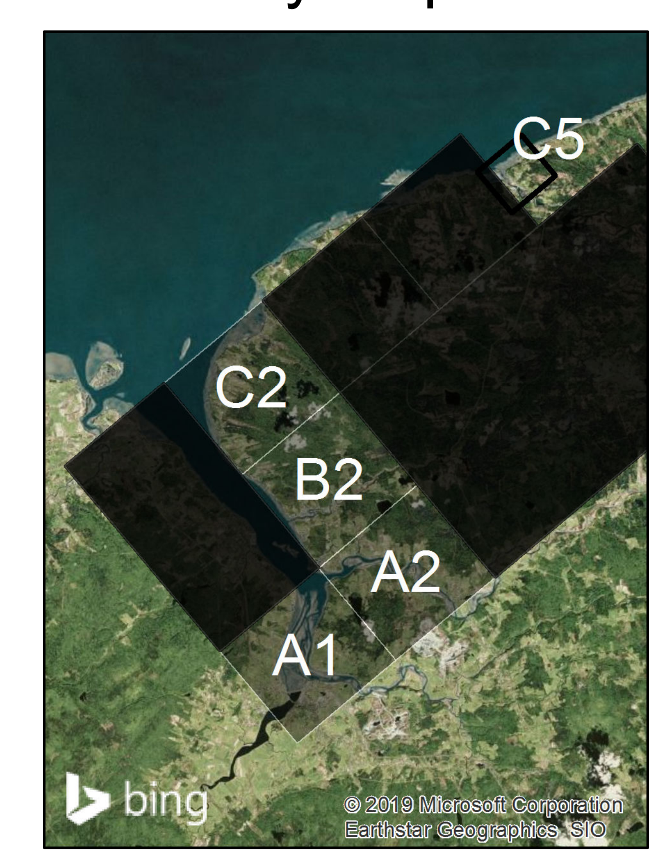
Tile C5
Present Conditions



Description of Evaluated Mitigation Options

✓	Walton Fire Station	*-Raise existing dyke* *-Structural upgrade (re-build)* *-Relocate structure*

Key Map



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APPENDIX F

Review of Stormwater Best Management Practices in Canada

Description of LID

Many municipalities throughout the USA and the rest of Canada are no longer accepting the use of conventional stormwater management practices (simple water detention) that solely aim at maintaining pre-development peak flow rates, as they do not address the fundamental role of rainfall in the natural water balance and sustainability of ecosystems. Conventional stormwater infrastructure such as retention ponds are known to negatively impact water quality, create additional flooding issues further downstream and reduce groundwater recharge. In lieu of ponds, the current shift towards sustainable development has instead promoted stormwater management approaches that aim to mimic the natural hydrologic processes of the land, treat stormwater runoff at its source and provide aesthetic, ecologic and social benefits to the development. This design approach to development is commonly referred to in Canada and the USA as Low Impact Development (LID) or stormwater Best Management Practices (BMPs), and their design features are often referred to as Green Infrastructure (GI) or source controls.

To understand how LID can be implemented for a site, the natural hydrologic processes of the site must first be understood. On undeveloped land, rainwater is initially intercepted by trees or absorbed by plants and soils. Some of the water will then infiltrate into the ground, replenishing the groundwater table below or providing slow freshwater release to rivers, streams, lakes and wetlands. Rainwater that is not able to be absorbed by the ground or by vegetation then runs off overland towards downstream watercourses, slowed down by rough natural terrain and evapotranspired by the plants and small natural pools. LID attempts to mimic these natural processes using design features such as bioswales, rain gardens, permeable pavements, perforated pipe networks and green roofs that allow for stormwater to infiltrate into the ground and be treated by vegetation and soils. Increase in biodiversity, and carbon sequestration are goals that are currently also sought after, which LID systems can achieve. In addition to environmental benefits, LID also improves the aesthetics of the urban design and can therefore increase property value and community liveability. Finally, LID also minimizes the area needed for retention ponds or can eliminate them altogether, resulting in more space for development and recreational areas.

LID in the USA and Canada

In the USA, the Clean Water Act prevents the discharge of any pollutant from a point source into surface waters without obtaining a permit through the Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System. The EPA recognizes that conventional peak flow reduction approaches to stormwater management generally do not achieve water quality objectives and negatively impact watershed hydrology and stream hydraulics, through increased erosion and flooding risks. As a result, the EPA highly promotes the use of LID for stormwater management to comply with the Clean Water Act, and municipalities throughout the USA have been adapting these LID approaches over the past few decades to manage their stormwater runoff.

In Canada, the federal government has recognized for more than a decade that conventional practices in stormwater management using detention systems often do not successfully reduce flood risks, can exacerbate low baseflows, can increase habitat degradation and can create large maintenance and safety burdens for municipalities. While no top-down regulatory approach has been implemented in Canada, the federal government promotes and provides guidance for carrying out “integrated stormwater management plans”, which are multi-disciplinary planning approaches to stormwater management involving land-use planners, engineers, landscape architects and environmental scientists. This guidance is found in Stormwater Management Planning: A Best Practice by the National Guide to Sustainable Municipal Infrastructure (Federation of Canadian Municipalities and National Research Council, 2004). Many Canadian municipalities have therefore adopted the integrated stormwater management planning framework to ensure that future development will use more sustainable stormwater practices such as LID that minimize impact on natural watershed hydrology and surface water quality. This practice has been particularly prominent in British Columbia over the past two decades, and the province developed a guidebook for developing and implementing integrated stormwater management plans in 2002 (Stormwater Planning: A Guidebook for British Columbia).

All provincial stormwater management guidelines from British Columbia to Quebec include guidance for implementing stormwater infiltration systems or LID. Individual municipalities have then developed integrated stormwater management plans, regulations and guidelines to further improve stormwater management locally, and have implemented funding strategies that promote the use of LID. Financial incentives not only promote more sustainable development and increase public education, but also reduce economic burdens on municipal infrastructure such as culverts, ponds, CSO chambers and wastewater treatment plants for combined sewers. An overview of stormwater management plans, strategies, LID financial incentives and LID guidelines that have been implemented in select municipalities throughout the Canadian provinces is presented in Table 1 (attached). As shown in Table 1, common goals of the various master plans and strategies include:

1. Capture and treat a percentage of the average annual runoff using LID.
2. Encourage or require LID for all new development or redevelopment.
3. Revise street design and maintenance standards to include LID in the right-of-way.
4. Develop financial incentive programs to promote LID.
5. Provide public and professional education and guidance on LID.

Common LID Approaches in Canada

Most types of LID features that are used in the USA are also used throughout the Canadian provinces. These include the following:

- Rainwater Harvesting (rain barrels or cisterns).
- Vegetated Filter Strips.
- Green Roofs.
- Infiltration Trenches.
- Rain Gardens.
- Permeable Pavements.
- Perforated Pipe Systems.
- Constructed Wetlands.
- Bioswales (grass-lined or with plants).
- Tree Planter Systems.

Some municipalities have also focused on promoting specific types of LID features. For example, the City of Victoria provides rebates for rain barrels, rain gardens, bioswales and permeable pavements; the City of Toronto has mandated that all new buildings have a green roof and that all downspouts be disconnected; the City of Guelph has developed a financial incentive program to promote installations of private rain barrels and cisterns; and the City of Calgary has developed a Complete Streets Policy (also currently being discussed in HRM), which aims to create multi-modal streets that integrate walking, cycling, transit and LID stormwater infrastructure (similar to the Toronto Green Streets strategy that is currently in development). These strategies allow for municipalities to become familiar with the implementation of specific approaches, while also allowing for all other types of LID features.

Similar to the northern states of the USA, winter operation practices are accounted for when implementing LID, such as avoiding road sand, minimizing road salt usage, snow storage planning and designing infiltration media to the depth of frost. In locations such as the prairies where the land is flat and the soils have high clay content, engineered subgrades and underdrains are designed to prevent ponding and to infiltrate only what is needed to preserve site hydrology and provide water quality benefits.

Applicable Stormwater Management Features for West Hants

Below is a description of LID features applicable to the West Hants based on the review of stormwater practices in the USA and Canada presented above. These features have all been shown to function in both summer and winter climates, and are expected to also function in the Nova Scotia region if designed and maintained properly for the local winter climate. Best practices for LID design in winter climates that should be followed include:

- Locating LID features with infiltration media away from fine materials that can cause clogging;
- Avoiding road sands for roads that drain to LID features.
- Performing regular street sweeping practices to prevent fine particles from entering into infiltration systems.
- Providing snow storage locations to avoid snow being stored on LID features, or specifically designing and maintaining LID features such as roadway bioswales for temporary snow storage.
- Considering the depth of frost in conjunction with the underlying soils in the design.
- Design underdrains for infiltration layers located in soils with lower permeability.
- Selecting native plants that are flood, drought and salt resistant for roadside LID features that involve bioretention such as rain gardens and bioswales.

Phosphorous Removal

With respect to phosphorous removal, the LID features presented below (with the exception of rainwater harvesting) achieve moderate to high phosphorous removal through processes that primarily include:

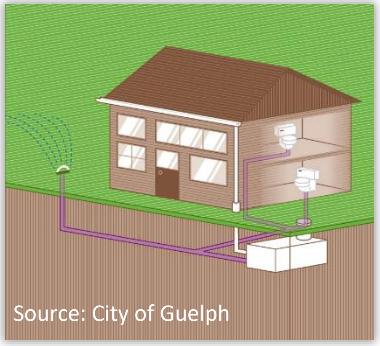
- Plant uptake.
- Adsorption by soils, organic matter and infiltration gravels.
- Chemical precipitation with aluminium or iron.

However, since a full reduction of phosphorous may not be able to be achieved using conventional LID features alone, the following additional measures are encouraged to help meet the "no net export of phosphorous" requirement:

- Add iron to the infiltration gravels to adsorb phosphorous.
- Use engineered aggregates for infiltration gravels that are treated with sorbtive admixtures.
- Introduce regulations that minimize or eliminate the use of fertilizer containing phosphorous.

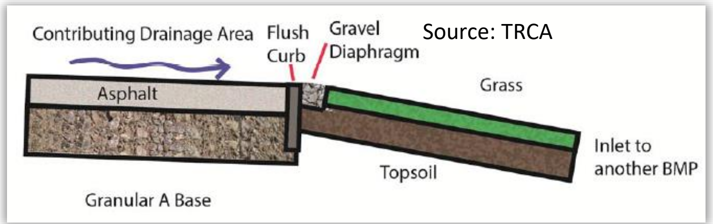
The following sections describe a range of LID features that are applicable to the development to help achieve the stormwater volume and quality control requirements.

Rainwater Harvesting



Rainwater harvesting refers to the use of rain barrels and rain cisterns to collect rainfall for future water usage or for slow release between storm events. Rainwater harvesting systems can be either seasonal (disconnected during the winter) or year-round. Seasonal systems typically store rainfall in outdoor tanks during the warmer months and are mostly used for irrigation, whereas year-round systems are installed either indoors or buried below the frost line and are connected to plumbing fixtures such as toilets. Rainwater harvesting therefore has the advantage of reducing both stormwater runoff and water usage. Underground cisterns should be installed below the depth of frost to avoid freezing.

Vegetated Filter Strips



Vegetated filter strips are bands of dense vegetation planted downstream of a sheet flow runoff source that slow down, treat, absorb and infiltrate the runoff. Filter strips are well suited for treating runoff from roads and highways, roof downspouts, small parking lots, and other small or linear impervious surfaces. They are also ideal components for the fringe of a stream buffer, as pre-treatment for a structural practice and as pre-treatment for other LID features to reduce sediment loads.

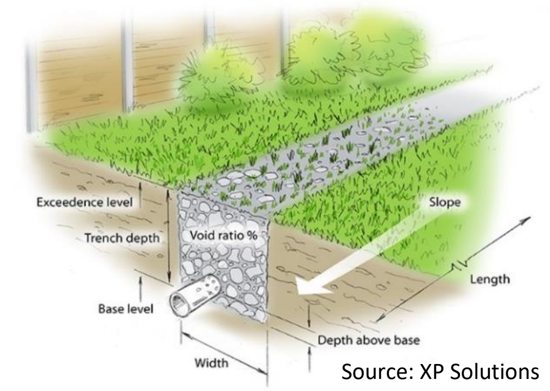
Green Roofs

A green roof is a roof that includes a waterproof membrane and is covered or partially covered by a vegetative growing medium. From a stormwater management perspective, green roofs are able to reduce runoff volumes and provide flow attenuation for smaller storm events. Other benefits include air filtration, heat insulation, sound insulation, carbon capture and biodiversity. Green roofs must be structurally designed to saturated conditions, and lightweight composites are typically used for drainage

materials. Plant selection should be limited to plants that can withstand local extreme weather conditions, including high winds. Green roofs are significantly less susceptible to clogging by fine materials found in runoff, and maintenance activities primarily consist of maintaining the plants.

Infiltration Trenches

Infiltration trenches are gravel-filled ditches with either no outlet or a low flow underdrain. The gravel layer collects, filters and stores runoff during a storm event, and then releases it into the soil below by infiltration. Infiltration trenches are often used in conjunction with other LID features such as a rain gardens, bioswales or permeable pavements to provide additional water quality, aesthetic and/or practical benefits.



Source: XP Solutions

Permeable Pavements

Permeable pavements allow stormwater to drain through a porous or permeable surface into a gravel infiltration layer below, and are installed as an alternative to conventional asphalt or concrete pavements. “Permeable pavements” is an umbrella term for all pavements techniques that allow for infiltration, including porous asphalt, pervious concrete, permeable pavers, concrete grid pavers and plastic grid pavers:

- Porous asphalt or pervious concrete are similar to conventional asphalt or concrete pavements, except that fines are not included in the mix, providing a high void ratio that allows for water to infiltrate.
- Permeable pavers are modular systems typically made of impervious concrete, but have spaces between their joints filled with gravel that allow for water to pass through.
- Concrete grid pavers and plastic grid pavers consist of load bearing matrices with large voids filled with gravel or soil.

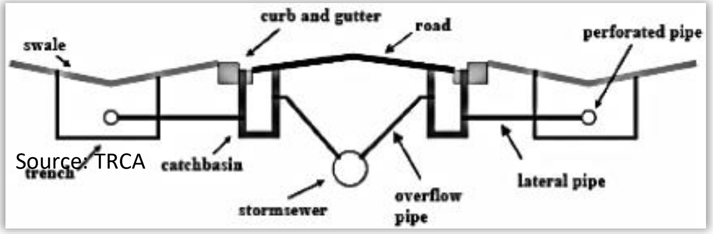
Permeable pavements are most suitable for applications with low to medium traffic areas. These include residential roads, alleys, driveways, walkways, plazas, low traffic parking lots and other locations with low levels of contaminants. When compared to conventional pavements, the amount of de-icing agents used in the winter for permeable pavements can be significantly reduced (studies have shown up to 75% reduction) or eliminated altogether, as snow collected on these pavements melts rapidly and the surface helps to reduce the occurrence of black ice and frozen puddles. For snow removal on permeable pavers, rollers should be attached to snow plow blades to prevent catching on the edge of the pavers.


Source: Yarmouth Hawthorne St. Design by CBCL Limited

Maintenance for permeable pavements primarily consists of vacuum sweeping, which the industry recommends to be carried out once or twice per year. Additional measures such as pressure washing or vibration loosening can be carried out prior to vacuum sweeping to improve sediment removal.

It is noted since pervious concrete takes a longer time to cure, is more prone to weakening from road salt application and can leach phosphorous during the first years of installation, special design considerations and construction methods need to be taken into account if applied in West Hants. For these reasons, pervious concrete is not recommended for the constructions in West Hants.

Perforated Pipe Systems

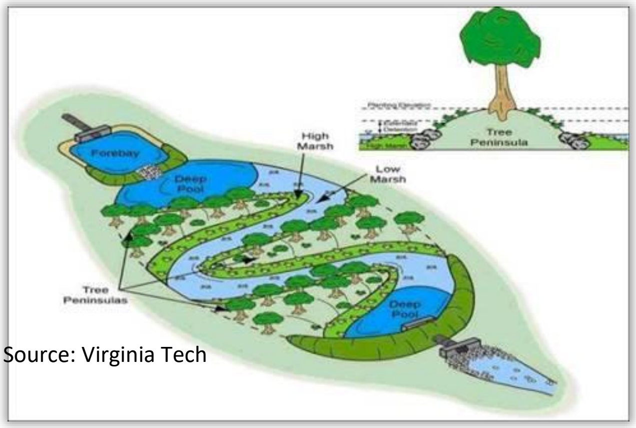


Source: TRCA

Perforated pipe systems are designed both for the conveyance and infiltration of stormwater. The design is similar to traditional stormwater pipe systems; however, holes are made in the pipe and the infrastructure is bedded in graded gravel. Perforations within the pipe allow water to flow downwards out of the pipe, infiltrating through the gravel bedding and into the ground. Infiltration from the pipe can decrease flows discharged at the pipe outlet, allowing for smaller pipes to be used. The pipe and gravel bedding should be installed below the frost line to avoid freezing during winter. Perforated pipe systems may also contain pervious catch basins, which are normal catch basins with larger sumps that are physically connected to an exfiltration storage zone made up of gravel or other porous material. The storage media is typically located beneath or beside the catch basin.

To minimize clogging of the perforated pipe system, it is necessary to pre-treat runoff that carries a high sediment load. This can be achieved by conveying the runoff over vegetated filter strips, or installing in-ground devices such as oil and grit separators or sedimentation chambers. Maintenance for perforated pipe systems primarily consists of standard catch basin cleaning practices and cleaning of any pre-treatment devices.

Constructed Wetlands



Source: Virginia Tech

Constructed wetlands are shallow pools developed for stormwater treatment and flow control that create growing conditions suitable for wetland plants. While still end-of-pipe systems, constructed wetlands provide additional water quality benefits compared to conventional stormwater retention ponds.

Alternatively, regenerative stormwater conveyance systems can be implemented, which consist of a series of shallow constructed wetlands and riffles. These systems provide similar stormwater treatment and flow control of constructed wetlands, but are constructed along a drainage path instead of at a single end-of-pipe location.

Enhanced Grass Swales

Enhanced grass swales are vegetated swales with check dams that are designed to maximum infiltration, filtration and evapotranspiration. Gravel infiltration layers are typically installed below the soil layer to further increase storage and infiltration. Maintenance of enhanced grass swales is similar to standard ditches, consisting of debris removal, weed removal and light mowing.

Source: Larry Uteck Interchange Design by CBCL Limited

Rain Gardens

Rain gardens are bioretention cells that reside in a shallow depression to collect, filter and infiltrate stormwater runoff. During a storm, the depression fills up with water, which is then filtered through the soil and plant layer into the ground below. Rain gardens often have a gravel infiltration layer installed below the soil layer to store additional runoff and increase filtration and infiltration. Basic gardening practices are carried out to maintain rain gardens such as debris removal, weed removal, repairs to eroded soils/mulch, pruning and removal and replacement of dead or diseased plants.

Source: City of Arden Hills (similar latitude to HRM)

Bioswales

Bioswales combine the bioretention of rain gardens with the conveyance of swales, providing additional water quality benefits of additional plant vegetation than enhanced grass swales. Bioswales consist of a vegetated bioretention layer above a gravel infiltration layer, and include check dams along its drainage path. Maintenance of bioswales is similar to rain gardens, consisting of debris removal, weed removal, repairs to eroded soils/mulch, pruning and removal and replacement of dead or diseased plants.

Source: City of Kingston

Tree Planter Systems


Source: GreenBlue Urban

Tree planter systems consist of enhanced urban tree pits that allow for roots to expand beyond conventional planter boxes, while also providing underground stormwater storage. These systems allow for trees to survive in urban areas for significantly longer periods of time and to grow to significantly larger sizes. Trees provide interception of rainfall and significant water uptake through root systems. The additional underground storage area and root system provided with tree planter systems allow for higher runoff volume reductions and water quality benefits. In addition to stormwater benefits, they also provide cooling for urban heat island, carbon sequestration and improve air quality.

APPENDIX G

Analysis of Options for Boardwalk

CBCL LIMITED
Consulting Engineers

MEMORANDUM

DATE: 03/21/19

PROJECT NO: 181166.00

MEMO TO	Victoria Fernandez
PROJECT NAME	West Hants Flood Study
SUBJECT	Wharf (Boardwalk) Repairs
FROM	Bruce Higgins
COPIES TO	Kevin Bezanson, Greg Peters

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BACKGROUND

The history of the wharf site goes back to the Harvie and Mosher shipyard in the 1860's. The footprint of the existing wharf structure is 5m x 45m, and occupies only a portion of the former wharf. Remnants of the 10m x 60m previous structure can be seen at low tide. The present wharf is understood to have been repaired in 1991, when the funds allocated for demolition of the wharf were instead used to repair the structure. An engineering report in 2010 estimated that approximately $80,000 of maintenance work was required. An engineering report in 2016 indicated that the wharf had numerous structural deficiencies, and significant repairs were required to accommodate pedestrian live loading. Limited upgrading was carried out, and the subsequent engineering report in 2017 noted that the live load capacity of the wharf still did not meet pedestrian loading requirements.

ALTERNATIVES

Three alternatives were examined for comparison. They are designed to satisfy pedestrian loading, and briefly described as follows

- **Option 1** is meant to salvage the existing structure with repairs as necessary to achieve live load capacity suitable for pedestrian use. The usable life span of this type of repair would be governed by the integrity of the existing log crib structure, which is estimated to be in the range of 5-10 years.
- **Option 2** is reconstruction of the facility with a service life consistent with new construction, which would be in the order of 50 years for marine structure at this site. The top of deck elevation is proposed to be 9.6 m.
- **Option 3** is essentially the same as Option 2, but with the deck elevation raised to elevation 10.4 m.

Option 1 – Upgrade Existing Wharf (Top of Existing Deck Elevation ~8.8 m)

- Pinto in 2016 deemed the live load capacity of the deck was inadequate. The deck was determined to be OK, but stringers, cross beams, posts and connections are deficient.
- Subsequent repairs were carried out by July 2017, and the deck structure was raised. Stringers are still undersized. The first five bents have 4 x 8 cross beams, with 5 posts. However, remaining ~10 bents have three posts per bent, and the cross beams are undersized. Additional deficiencies with connections, bracing and foundation.
- Assuming same footprint (4.9m x 46 m), required upgrading is still significant. Based on 2017 Pinto report, quantities required for upgrading include:
  - Additional cross beams plus additional posts – 8 cu. m. say.
  - Foundations - 30 concrete post foundations.
  - Miscellaneous repairs including missing transverse timber bracing, inadequate connections (bolts or spikes), and poor connection and bearing details.
- While the Pinto report noted missing and undersized members, it did not identify the extent of deteriorated condition of timbers in the existing crib structure. This would include selected (i) longitudinals on the face are untreated logs which are over 25 years old (ii) cross-ties (horizontal crib members perpendicular to the length of the wharf), which are believed to be even older, and (iii) remnants of vertical piles/posts at the face of wharf. An approximate allowance has been made for repairs to compensate for obvious crib deterioration.
- **Estimated cost $125,000 (Class D).**

Option 2 – New Wharf at Top of Deck Elevation ~9.6 m

- Say wharf footprint is reduced to 4.0 m wide x 30 m long.
- Demolish existing wharf. Salvage rock fill ballast where practical, but most of existing crib ballast would get used as "mattress" for new structure.
- Assume "block and span" construction, i.e. using timber cribs (blocks) and timber stringers (spans). Timber cribs assumed with open face construction.
- **Estimated cost $350,000 (Class D).**

Option 3 – New Wharf at Top of Deck Elevation ~10.4 m

- Say wharf footprint is reduced to 4.0 m wide x 30 m long.
- Demolish existing wharf, use base as "mattress for new crib structure".
- Assume "block and span" construction, i.e. using timber cribs (blocks) and timber stringers (spans). Timber cribs assumed with open face construction.
- **Estimated cost $400,000 (Class D).**

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